HANDBOOK

ON

Radio Frequency Interference

VOLUME 4

UTILIZATION OF THE ELECTROMAGNETIC SPECTRUM

ERRATA

Two errors have been found in the Volumes of this Handbook. The following corrections should be made:

Volume 1, page 2-41, last paragraph should be changed to read:

"In obtaining the census of equipments, it is important to include not only those in operation but those planned for future installation. This information may not necessarily be available from the Area Frequency Coordinators, and it may be necessary to contact other installations to obtain this information. For the Air Force, GEEIA (Ground Electronic Equipment Installation Agency) is responsible for the installation of radars. Its headquarters is at Griffiss Air Force Base (Rome, New York), but it also maintains regional offices in the United States and overseas. The regional offices in the United States are located at Brookley Air Force Base, Mobile, Alabama (Eastern GEEIA); Tinker Air Force Base, Oklahoma City, Oklahoma (Central GEEIA); and McClellan Air Force Base, Sacramento, California (Western GEEIA). These offices have information pertinent to radars installed, being installed, and planned for installation. This data will, in general, augment data furnished by Area Frequency Coordinators. Similarly, Naval Districts and Army Districts will also serve to provide additional information as to equipments that are being considered for installation."

Volume 2, page 5-3, second equation should be changed to read:

"$A(db) = 3.34\sqrt{\mu f g}\,(d)$"

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PREFACE

This is the fourth in our series of volumes on Radio Frequency Interference. In this volume we discuss the general considerations and current practices in the utilization and conservation of the radio spectrum. These considerations and practices are the fundamentals upon which must be based our efforts to obtain system and equipment compatibility, and freedom from interference.

For maximum compatibility we must consider several basic aspects of spectrum utilization:

A. Over-all determination of occupancy of the spectrum for maximum benefit of the general populace of the United States and the world.

B. Detailed allocation of spectrum space for maximum effectiveness of usage in accordance with services to be provided.

C. Design and production of equipment with known spectrum characteristics appropriate to the frequency allocation for maximum compatibility and minimum interference.

D. Control of spectrum usage through appropriate regulations, standards, monitoring systems, and legal procedures.

As has been previously pointed out in these volumes, the studies and technical developments required to obtain interference-free spectrum usage are complex and time-consuming. They require a high order of technical competence if satisfactory results are to be obtained. And it follows, therefore, that considerable funds are required.

In the past few years our advances in missile and space electronics have brought home to both engineers and administrators the vital role of proper spectrum management in exploiting electromagnetic waves for military and civilian purposes. More funds are now becoming available for the growing emphasis on developing programs which will provide guides to the design, production and operation of electromagnetic systems for maximum compatibility. Additionally, it is to be expected that there will be greater control of spectrum usage through better defined specifications and standards with tightening of tolerances and limits.

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Through the years, the United States has given strong support to such international organizations as the International Telecommunications Union and the International Radio Consultative Committee. Today, these groups are, more than ever, the key to interference-free radio operations as they coordinate requirements and allocations for space and satellite communications. The advent of the Telstar satellite relay foretells a new era in long-range, global mass communications which, to be effective, will require complete cooperation from all nations to attain interference-free operation.

Material for Volume 4 has been obtained from many sources and appropriate credit has been given in the references at the end of each Chapter. I am particularly indebted to McGraw-Hill Publishing Company for permission to reproduce material on spectrum utilization from Chapter 4 of the book Radio Spectrum Conservation. I also wish to express my thanks to SIGNAL, the magazine of the Armed Forces Communications Electronics Association, and to Brig. Gen. Pochyla for allowing the use of the chart in Figure 4 - 1 showing the national communications - electronics community.

Chapters 1 through 5 of this Volume have been prepared by Mr. A. H. Sullivan, Jr., the Editor of the RFI Handbook. Mr. J. A. Hopkins (with the assistance of Mr. D. M. Agee) was primarily responsible for arrangement of Appendices I through V and for Chapter 6. Mr. H. M. Humbertson handled the production matters and together with Mr. Hopkins was generally responsible for organizing the Volume 4 material for the press.

Contained in the Appendices of this Volume are selected Government standards, specifications, and regulations which pertain to radio frequency interference, electronic compatibility, and spectrum signatures. These documents have been included as a handy reference for design engineers who may have difficulty in obtaining copies when urgently needed to resolve design or testing problems.

It is the hope of all of us at Frederick Research Corporation that Volume 4 (and the other Volumes of the Handbook) will indeed prove useful to those engaged in planning and engineering work for communication-electronic compatibility and utilization of the radio spectrum.

Carl L. Frederick, Sr.
Wheaton, Maryland
10 September 1962

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HANDBOOK

ON

RADIO FREQUENCY INTERFERENCE

Volume 4

UTILIZATION OF THE ELECTROMAGNETIC SPECTRUM

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THE ELECTROMAGNETIC SPECTRUM–A NATURAL RESOURCE

CHAPTER 1

1. INTRODUCTION

The radio frequency spectrum is a natural resource. It is a limited resource, however, and differs in many ways from material commodities. Its optimum utilization requires careful management and there are many technical, political, and economic difficulties in the solution of management problems. It is clear, however, that the radio spectrum is a public domain which must be as carefully conserved as forests, water, land, and minerals.

Radio communication was first used in a practical manner in about 1898 when lifeboats participated off the coast of England in a marine disaster which had been reported by wireless telegraphy. In 1903, the first international radio conference was held in Berlin to establish certain operating rules and tariffs. Another and larger conference was held in Berlin in 1906 and from this meeting came a convention and regulations dealing with ship-to-shore service. By 1907, long distance point to point service had been started and in 1912 a radio telegraph conference was held in London to set up international regulations for radio frequency utilization. At an inter-Allied radio conference in 1919, the needs of services other than maritime mobile were considered for the first time and because of the rapid growth in utilization of spectrum, the United States held four domestic conferences during the years between 1922 and 1925. In 1927 the Federal Radio Commission was created and in the same year an international radio telegraph conference was held in Washington. This Washington conference dealt with ship-to-shore and broadcasting services.

During the next ten years the use of the spectrum continued to grow and various meetings were held to advance world wide technical coordination. At the Cairo conference in 1938, consideration was given to some of the expanding uses of the spectrum and for the first time aviation communication needs along international routes were recognized. In the United States, the Communications Act of 1934 gave greater regulatory powers to the Federal Communications Commission which had superseded the older Federal Radio Commission.

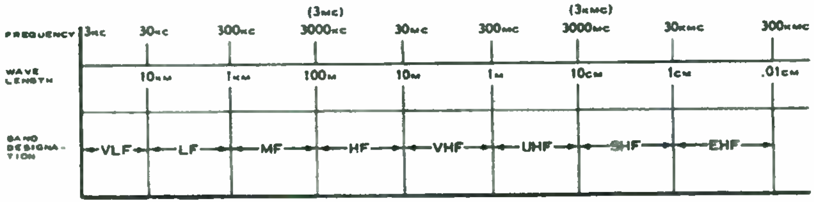
During the following years the spectrum continued to expand with the development of the higher frequencies and the VHF and UHF regions began to open up. Because of the rapidly increasing requirements for frequency usage in an already overcrowded spectrum, several international conferences have been held in the years since 1938, the most recent of which was the Geneva Administrative Radio Conference held in 1959. Preparations are now being made for the forthcoming Extraordinary Administrative Radio Conference proposed by the International Telecommunication Union for 1963. The explicit purpose of this meeting is to re-evaluate rapidly changing requirements for radio frequencies in relation to earth space operations.

Since the time of the Berlin radio conference in 1906 when the usable radio spectrum was only about 500 kc wide, the spectrum has broadened to include about 40 million kc or about 80 thousand times as much as originally used. About 15 million kc of this spectrum is used so extensively that it has become close to impossible to satisfy new requirements. These requirements are greater by nearly two hundred times than those at the beginning of World War II. There has been a four fold increase since the Korean War.

2. THE RADIO FREQUENCY SPECTRUM

For practical purposes the radio frequency spectrum can be said to extend from about ten kilocycles per second (kc/s) to about 40,000 megacycles per second (mc/s). For working convenience the radio frequency spectrum has been divided into parts which are related in multiples of ten. Current band and frequency designation used in the United States are shown in Figure 1-1. If the entire spectrum were completely usable, there would be several million channels available. In addition, in many parts of the spectrum, multiple use can be made of each channel based on geographical and time-sharing assignments. Thus, there would appear to be ample room in the spectrum for all users. Unfortunately, there are many other factors to be considered and a discussion of these factors is indicative of the problems involved in optimum spectrum utilization.

The whole range of frequencies in the spectrum from 3 kc to 40,000 mc is not all usable. Natural phenomena and the state of the art somewhat limit the use of the spectrum above 3,000 megacycles. Although there are some electronic and communication systems in use above 3,000 megacycles, approximately 90% of the spectrum between 3,000 mc and 40,000 mc is relatively unused compared to the 10% of the spectrum below 3,000 mc. Below 3,000 mc there are other problems in spectrum use because some portions are extremely overcrowded and other parts do



Wave length in kilometers, meters, and centimeters
Frequency in kilocycles, megacycles, and kilomegacycles
Band designations as shown below:

VLF -	Very Low Frequency	VHF -	Very High Frequency
LF -	Low Frequency	UHF -	Ultra High Frequency
MF -	Medium Frequency	SHF -	Super High Frequency
HF -	High Frequency	EHF -	Extremely High Frequency

Figure 1-1. The Radio Frequency Spectrum

not have the necessary technical characteristics for some types of communications.

In practice, use of specific frequencies is influenced by a number of technical factors:

(1) Propagation characteristics vary throughout the spectrum. For example, at some frequencies, radiation may be reflected by upper layers of the atmosphere over long distances, whereas at other frequencies, radiation can be transmitted only at line-of-sight distances.

(2) Propagation characteristics of the upper atmosphere are erratic and irregular. Diurnal and seasonal variations are displayed as well as a considerable responsiveness to solar sun spots and flares.

(3) Interference from both man-made and natural sources varies throughout the spectrum.

(4) Antenna size varies with frequency and type of service. For example, mobile stations obviously can only accommodate compact arrays. Only certain types of communication traffic economically justify large investments for massive arrays required for low frequencies.

(5) Transmitter power used for mobile stations is usually lower than that at fixed stations.

(6) The feasibility of channel sharing varies considerably, depending upon practical communication needs and variations in propagation conditions.

(7) Radio technology is continually advancing, adding new channels through the use of new techniques and opening up new regions of the spectrum, particularly at higher frequencies.

Single radio channels are normally referred to in terms of single frequencies, giving rise to the assumption that millions of channels are available. In fact, each radio channel occupies not only its assigned frequency but also occupies a number of frequencies in the neighborhood of its basic frequency assignment. Depending upon the information being carried, a channel may be from a few cycles to several million cycles wide. In double sideband emission as generally used in broadcast transmission, the channel width is twice the departure (tolerance) of the actual operating frequency from the assigned frequency plus twice the band width required to convey the particular intelligence desired. The frequency tolerance is usually specified as a number of cycles which are a percentage of the assigned frequency. Thus the tolerance increases with increase in assigned frequency. The tolerance usually is that which is the best that can be met by the industry in the design of equipment. For example, a broadcast transmitter in the 535 to 1605 kc region may not deviate more than a fixed value or tolerance of plus of minus 20 cycles. At higher frequencies, broadcast frequency tolerance is expressed in percentage of the operating frequency. Thus, a broadcast transmitter assigned a frequency of 6,000 kc must maintain a carrier tolerance of 0.003 percent. The maximum carrier variation must therefore be within 180 cycles of the assigned frequency. Allowable frequency tolerances are shown in Figure 1-2.

Although all parts of the spectrum are not equally useful for all purposes, each is in sufficient demand to give rise to allocation and assignment problems. For example, the high-frequency portion of the radio spectrum (3 mc to 30 mc) presents a serious allocation problem because of its desirability in providing for medium-distance and long-distance communications, tropical and long-distance broadcasting, and other services; because of its international aspects; and because frequencies outside these limits are, in general, not suitable substitutes. The capabilities of the high-frequency portion of the spectrum must be measured in terms of possible circuits rather than frequencies due to the fact that more than one assigned frequency is generally required for each circuit. The number of possible circuits in the spectrum depends upon:

(1) Geographical location of the terminals.

(2) Time of day, season, and phase of the sunspot cycle.

(3) Amount of power used.

(4) Type of antennas used.

(5) Correct use of propagation characteristics.

(6) Circuit made (radiotelephone, radiotelegraph, etc.).

(7) Man-made and natural interference.

(8) Efficiency and effectiveness of equipment and operator.

Frequency Bands and Categories of Stations				Tolerance (in percent)
A.	From 10 to 535 kc			2
	1. Fixed Stations			
		-from 10 to 50 kc		0.1
		-from 50 kc to end of band		0.02
	2. Land Stations			
		(a) Coast Stations		
			-power above 200 watts	0.02
			-power below 200 watts	0.05
		(b) Aeronautical Stations		0.02
	3. Mobile Stations			
		Ship Stations		0.1
		Aircraft Stations		0.05
		Emergency (reserve) ship transmitters, and lifeboat, lifecraft and survival craft transmitters		0.5
	4. Radio-Navigation Stations			0.02
	5. Broadcasting Stations			20 cycles per second
B.	From 535 to 1605 kc			
	Broadcasting Stations			20 cycles per second
C.	From 1605 to 4000 kc			
	1. Fixed Stations			
		-power above 200 watts		0.005
		-power below 200 watts		0.01
	2. Land Stations			
		(a) Coast Stations		
			-power above 200 watts	0.005
			-power below 200 watts	0.01

Figure 1-2. Table of Frequency Tolerances

Frequency Bands and Categories of Stations	Tolerance (in percent)
(b) Aeronautical Stations	
-power above 200 watts	0.005
-power below 200 watts	0.01
(c) Base Stations	
-power above 200 watts	0.005
-power below 200 watts	0.01
3. Mobile Stations	
Ship Stations	0.02
Aircraft Stations	0.02
Land Mobile Stations	0.02
4. Radio Navigation Stations	
-power above 200 watts	0.005
-power below 200 watts	0.01
5. Broadcasting Stations	0.005
D. From 4000 to 30000 kc	
1. Fixed Stations	
-power above 500 watts	0.003
-power below 500 watts	0.01
2. (a) Coast Stations	0.005
(b) Aeronautical Stations	
-power above 500 watts	0.005
-power below 500 watts	0.01
(c) Base Stations	
-power above 500 watts	0.005
-power below 500 watts	0.01
3. Mobile Stations	
Ship Stations	0.02
Aircraft Stations	0.02

Figure 1-2 (cont.). Table of Frequency Tolerances

Frequency Bands and Categories of Stations		Tolerance (in percent)
	Land Mobile Stations	0.02
	Transmitters in lifeboats and survival craft	0.02
	4. Broadcasting Stations	0.003
E.	From 30 to 100 mc	
	1. Fixed Stations	0.02
	2. Land Stations	0.02
	3. Mobile Stations	0.02
	4. Radio-Navigation Stations	0.02
	5. Broadcasting Stations	0.003
F.	From 100 to 500 mc	
	1. Fixed Stations	0.01
	2. Land Stations	0.01
	3. Mobile Stations	0.01
	4. Radio Navigation Stations	0.02
	5. Broadcasting Stations	0.003
G.	From 500 to 10500 mc	0.75

Figure 1-2 (cont.). Table of Frequency Tolerances

The impact of some of these factors can be illustrated by examining the frequency assignment requirements for a long-distance high frequency radio circuit:

(1) Frequencies must be assigned in the 3 mc to 30 mc region of the spectrum.

(2) Most long-distance circuits are operated duplex, thus doubling the number of frequencies required.

(3) The average long-distance circuit requires three frequency assignments of, for example, 6, 10, and 14 mc, for night-time, transition, and daytime operation respectively.

(4) To insure operation over the entire sunspot cycle (11 years) as many as five additional frequencies may be required.

(5) The path or great circle route between the transmitter and receiver further determines the part of the high frequency band to be used. Because of this, several megacycles on either end of the band may be removed from consideration.

(6) In practice, because of the greater requirements for frequencies below 8 mc, the supply of channels between 6 and 8 mc (taking into account possible multiple use of each frequency) determines the maximum possible number of 24 hour long-distance circuits.

The actual number of channels available within any particular portion of the spectrum is continually changing with improvements in equipment, operating techniques, circuit discipline, and availability and proper use of propagational data, and with the necessity and capability of accepting a poorer grade of circuit. Necessary separation between channels has been continually decreasing because of improvements in the stability and selectivity of equipment.

In practice, the manner of utilization of the radio spectrum and the choice of frequency depends upon a full understanding of the relation of band width, power requirement, and the basic aspects of information to be transmitted.

As mentioned before, transmissions are not made on discrete frequencies but rather on bands of frequencies. Obviously the wider the band the more space is occupied in the radio spectrum. There is thus considerable pressure for maintaining these bandwidths as narrow as is consistent with the service intended.

Consideration of bandwidth requirements shows a direct relationship between quantity of information to be transmitted per unit of time, and both power and bandwidth. Greater bandwidth is required for the communication of voice signals than for telegraphy, greater for high fidelity music programs than for voice, and greater for rapid facsimile or television programs than for high fidelity sound.

To communicate by electrical means, some form of modulation must be used. The different types of modulation require various bandwidths and powers, and have various advantages depending upon the signal characteristics and system requirements. Using the symbols shown in Figure 1-3 it is possible to describe the emission of any radio frequency transmitter by means of a combination of symbols. A listing of these types of emission is shown in Figure 1-4. In determining the type of modulation required for a specific communication use, practical balance must be achieved between bandwidth, power, and reliability of communication. The design engineer will find his task simplified if he can trade power for bandwidth. On the other hand, spectrum conservation depends upon use of minimum bandwidth for each communication channel. Investigations and studies of the use of communication channels have resulted in considerable advances in our knowledge of the relations of the various factors involved in performing a communication function. These advances are based upon so-called "communication" and "information" theory.

3. ELEMENTS OF INFORMATION THEORY

The substantive material of "communication" is "information". To perform a mathematical or statistical study of information processes, it is desirable to consider small quantities of the information as the pieces which make up the total information. These small quantities are generally referred to as "bits", derived from the term "binary digits". The total information transmitted requires a certain minimum number of binary digits to express the information message so as to distinguish it from all other possible messages. The rate of transmission of information (measured in bits per second) is a function of bandwidth and of the power ratio of the average signal to average noise (commonly known as "signal-to-noise" ratio). We can exchange power for bandwidth but it should be recognized that under the present state-of-the-art, the amount of power available for some purposes, as for example, satellite-to-earth transmission is limited. In addition, it is generally undesirable to indulge in a power race among competing channels in the same part of the

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A. Types of Modulation

Type	Symbol
(1) Amplitude	A
(2) Frequency	F
(3) Pulse	P

(NOTE: Damped waves are symbolized by the letter B.)

Figure 1-3. Symbols for Modulation and Transmission Characteristics

B. Types of Transmission

Type	Symbol
(1) Absence of any modulation intended to carry information	0
(2) Telegraphy without the use of modulating audio frequency	1
(3) Telegraphy by the keying of a modulating audio frequency or audio frequencies or by keying of the modulated emission. (Special case: an unkeyed modulated emission.)	2
(4) Telephony	3
(5) Facsimile	4
(6) Television	5
(7) Composite transmissions and cases not covered by the above	9

C. Supplementary Characteristics

(1) Double sideband, full carrier	(none)
(2) Single sideband, reduced carrier	a
(3) Two independent sidebands, reduced carriers	b
(4) Other emissions, reduced carrier	c
(5) Pulse, amplitude modulated	d
(6) Pulse, width modulated	e
(7) Pulse, phase (or position) modulated	f

Figure 1-3 (cont.). Symbols for Modulation and Transmission Characteristics

Type of Modulation or Emission	Type of Transmission	Supplementary Characteristics	Symbol
Amplitude	Absence of any modulation		A0
	Telegraphy without the use of modulating audio frequency (on-off keying)	. . . .	A1
	Telegraphy by the keying of a modulating audio frequency or audio frequencies or by keying of the modulated emission. (Special case: an unkeyed modulation emission.)	. . . .	A2
	Telephony	Double sideband, full carrier	A3
		Single sideband, reduced carrier	A3a
		Two independent sidebands, reduced carrier	A3b
	Facsimile		A4
	Television		A5
	Composite transmission and cases not covered by above	. . . .	A9
	Composite transmissions	Reduced carrier	A9c
Frequency (or phase)	Absence of any modulation	. . . .	F0
	Telegraphy without the use of modulating audio frequency (frequency shift keying)		F1
	Telegraphy by the keying of a modulating audio frequency or audio frequencies, or by keying of the modulated emission. (Special cases: an unkeying emission modulated by audio frequency.)		F2

Figure 1-4. Types of Emission

Type of Modulation or Emission	Type of Transmission	Supplementary Characteristics	Symbol
	Telephony	. . . .	F3
	Facsimile		F4
	Television		F5
Frequency (or phase)	Composite transmission and cases not covered by the above	. . . .	F9
Pulse	Absence of any modulation intended to carry information		P0
	Telegraphy without the use of modulating audio frequency	. . . .	P1
	Telegraphy by the keying of a modulated audio frequency or audio frequencies, or by the keying of the modulated pulse. (Special case: an unkeyed modulated pulse.)	Audio frequency or audio frequencies modulating the pulse in amplitude	P2d
		Audio frequency or audio frequencies modulating the width of the pulse	P2e
		Audio frequency or audio frequencies modulating the phase (or position) of the pulse	P2f
	Telephony	Amplitude modulated	P3d
		Width modulated	P3e
		Phase (or position) modulated	P3f
	Composite transmission and cases not covered by the above		P9

Figure 1-4 (cont.). Types of Emission

spectrum. Such a race will eventually be reflected in even less effective use of the spectrum due to increased interference.

Any form of intelligence may be transmitted as bits. The more complex the intelligence and the faster the transmission desired, the more bits must be transmitted in any given time interval. All communication systems operate in the presence of unwanted background noise, which may be considered as a set of random bits, rather than bits organized in a discrete pattern as in the case of the desired communications signal. In order that the communication signal be recognized, the receiver must discriminate between signal and noise. This requires that the power of the signal be above the background. The more bits that are transmitted in a given time, and the shorter the time interval there is between them, the greater resemblance there is between bits of noise and bits of signal. Thus, as the speed of transmission rises, so must the power of the signal rise.

If the transmitted power is very high then only relatively narrow bands are necessary for communication. For lower transmitted power, it might be necessary to substitute two or more transmitters with separate operating frequencies. The number of simultaneous transmissions required will depend on the power level of each transmission and the amount of information to be communicated per unit time. Thus power has been traded for bandwidth. As an example, a facsimile picture transmission by scanning the image along closely spaced lines may take minutes with wide band and one hour with narrow. If a number of such pictures are to be transmitted, such as from a meteorological satellite, reflecting transient processes in the atmosphere, they would lose their value unless the transmissions were sufficiently rapid. Thus wide band transmission would be essential, particularly in view of the low power of the satellite transmissions.

In view of the difficulties in the way of using either greater bandwidth or greater power, it is desirable to consider means of improving the information content of a transmission.

Sophisticated communication methods can be used to materially reduce bandwidth requirements for all types of complex signals including speech, telemetry, television, and facsimile. (Note, however, that equipment cost and complexity increase rapidly with the degree of communication sophistication.) In one method of transmitting speech, the amount of speech energy falling into a selected number of frequency bands is measured and transmitted together with information concerning pitch. With some loss of naturalness, speech can be transmitted by this means over bandwidths of a few hundred cycles, an improvement of the order of ten fold over conventional practice.

In the transmission of data, such as that pertaining to temperature, pressure, air density, radioactivity, and magnetic fields, it is found that such information can generally be described by smooth curves. Points on the curves can be predicted with reasonable accuracy through extrapolation or interpolation of the curve shape. Thus it is possible to generate a predicted value from previous information and to transmit only the error. If this is done at both terminals, the original characteristic of the information can be reproduced at the receiver. A certain amount of redundancy should remain as a check on errors in transmission.

Many of our present forms of information transfer are quite redundant insofar as the use of power and spectrum space is concerned. Speech, for example, requires far greater bandwidths and a greater amount of time (and thus power) than several other forms of communication. If the text of speech were to be transmitted by teletypewriter, a considerable saving in bandwidth and power would be obtained. Teletype transmissions generally require about five bits per character, including spaces. Pierce and Cutler[1] have pointed out that the known probability of letter sequences allows transmission to be accomplished using only four bits per character. If the text is encoded word by word, it may require only 2.14 bits per character and can theoretically be reduced to only one bit per character.

4. SOME GENERAL REMARKS CONCERNING SPECTRUM UTILIZATION

In this Chapter, we have discussed the overall aspects of spectrum utilization and succeeding chapters will contain more detailed information on spectrum utilization problems as well as the specific mechanisms by which domestic and international frequency allocations are made. Since the rise of the radio spectrum has grown in advance of adequate knowledge of the behavior of the various bands of radio frequencies, we have developed a world-wide situation in which allocations are not always ideal from a technical standpoint. Unfortunately, the cost of drastic changes in the allocations as well as the political connotations of such changes present problems which are particularly difficult of solution.

In an effort to determine what steps could be taken to better the use of the radio spectrum, a study (published in 1952) was made by the

Joint Technical Advisory Committee. The JTAC was formed in 1948 and was sponsored by the Institute of Radio Engineers and the Radio-Television Manufacturers Association (now the Electronics Industries Association). The study, entitled Radio Spectrum Conservation (see reference 2), was a thorough and detailed consideration of the many factors bearing on the utilization of the spectrum. It asked for an overall recognition of the fact that the spectrum is a limited resource and recommended a policy of "dynamic conservation", which would take advantage of technical advances and at the same time would allow for spectrum management such that changing requirements of spectrum users would be met to the best advantage of the world's population.

Carrying out a "dynamic conservation" policy for the radio spectrum spectrum is a formidable project. The influence of the various factors which have been discussed in this Chapter tends to reduce the flexibility of approaches to the problem. Nevertheless, as the importance of the spectrum conservation program becomes better understood, more study and effort is being put into the attempts to solve the problems and a greater degree of cooperation and coordination is being attained among all the nations of the world. As time goes on, it is probable that better management of the spectrum will result.

REFERENCES

1. Pierce, J. R., Cutler, C. C.: Interplanetary Communications from Advances in Space Science, Academic Press, New York, Volume I, 1959.

2. IRE-RTMA Joint Technical Advisory Committee: Radio Spectrum Conservation, McGraw-Hill, New York, 1952.

3. Policy Planning for Space Telecommunications, a Staff Report prepared for the Committee on Aeronautical and Space Sciences, U. S. Senate, Government Printing Office, 4 December 1960.

CONSIDERATIONS AND PROBLEMS IN SPECTRUM UTILIZATION

CHAPTER 2

1. SYSTEM AND EQUIPMENT DESIGN

In Chapter 1 of this Volume, we pointed out some of the overall factors pertaining to spectrum utilization. From the standpoint of the engineer, consideration of these factors must result in system and equipment designs which accomplish the required communication function yet which make optimum use of the spectrum. From the standpoint of the communication system manager, the design must be economically feasible in operation. Here the engineering and economic aspects are directly related, and it would appear that, in general, engineering design which makes better use of the spectrum also improves system economy. For example, the use of interference-free communications techniques may actually allow the transmission of a much greater amount of information for the same power and bandwidth more economically than a system designed without attention to those state-of-the-art techniques known to mitigate interference.

Designing systems for optimum use of the radio spectrum requires consideration of many factors other than those which are a part of the electrical and mechanical design of components and equipments. It is of basic importance that consideration be given to the interaction between systems. Such interaction may result because of choice of frequency, amount of power radiated, type of modulation, or internal characteristics of transmitter and/or receiver. The system or equipment being designed must operate to fit its radio spectrum environment, without radiating interference, or being susceptible to radiations outside its assigned portion of the spectrum.

As has been discussed in Chapter 1, the use of modulation and information techniques should be given special consideration so that the greatest possible effectiveness can be attained in spectrum usage. Regardless of the type of information which is communicated in the system, the parameters of time, bandwidth, power, and type of data being transmitted can all be balanced for most effective spectrum use.

For proper use of the spectrum, it is absolutely essential that the designer as well as the operator be fully informed as to the spectrum characteristics of both transmitter and receiver. While frequently difficult and complex to measure, these characteristics are the very key to the type of design and spectrum use which we are discussing here. These characteristics are commonly known as "spectrum signatures." So important are spectrum signatures now considered by the Department of Defense that a military standard (MIL STANDARD 449A) has been promulgated explaining in exact detail the data required for spectrum signatures. (Information concerning methods of obtaining spectrum signatures may be found in Volume III of this Handbook, and the specification itself is reproduced in this Volume as a convenience to the reader.) It is important to be aware that the optimum use of the spectrum depends not only on the transmitter and the transmitted signal, but upon the characteristics of the receiver as well. By having a high susceptibility to the reception of signals other than those for which it was designed, a receiver may vastly aggravate the spectrum utilization problem. Knowing the spectrum characteristics of transmitters and receivers can allow the system manager to determine the best method of use for his equipment, or can serve as a basis for additional requirements for design improvement.

In order to further improve the use of the spectrum, various agencies have established rules and regulations concerning the use of the spectrum and the design of systems and equipments. The International Telecommunications Union is the focal point for coordination on such matters on an international basis. Within the United States, the Federal Communications Commission issues rules and regulations pertaining to the operation of nongovernmental systems and equipments. The Department of Defense has established rules, regulations, specifications, and standards pertaining to military systems and equipments. From the standpoint of the designer, these published requirements must be viewed in the light of their meaning with respect to system design. In particular, the designer should be concerned with meeting specifications which have been established for the purpose of insuring that transmitters and receivers are interference-free insofar as it is possible to make them interference-free at the present state-of-the-art. Specifications and standards pertaining to radio interference are included in Appendices IV and V of this Volume.

2. CURRENT USE OF THE SPECTRUM *

2.1 GENERAL

Despite the shortcomings in the frequency allocations now in effect, radio is performing all over the world in effective fashion, and a better situation exists than might have resulted in view of the many

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difficulties. The present state in radio has been reached in spite of frequent revolutionary discoveries and changes in the basic factors. Consequently, it has not been possible to set up an allocation plan which would be satisfactory for more than a few years. Only within the last decade has sufficient information been available to permit a comprehensive view of the entire spectrum. Quantitative and reasonably exact knowledge is available about all parts of the spectrum except the extreme upper end.

The high degree of accomplishment in frequency allocation has been attained in large part by international cooperation, which has continued steadily since its early beginnings in 1903 through such agencies as the International Telecommunications Union (ITU), the International Frequency Registration Board (IFRB), the International Radio Consultative Committee (IRCC), the International Scientific Radio Union (URSI), and the Department of National Defense (DND) (Canada). In this country, the FCC, CRPL, IRE and other organizations have made major contributions. Even with such cooperation, present allocations have been largely the result of unplanned growth, with expediency often dictating decisions and assignments. Especially in the region above 30 mc, assignments have been made in advance of certain knowledge of their suitabilities, some cases turning out well and others unfortunately. Furthermore, this region was "staked out" at a time when its technical characteristics were little known and when government and military services headed the list of priorities because of war or approaching war.

Introduction of changes in allocation resulting from technological progress must necessarily lag behind new developments and new possibilities in use of the spectrum. The introduction of these changes must be timed nicely; herein is one of the great problems of allocation. If changes are made too soon, mistakes may be made or development penalized; if too late, implementation and operational introduction become more difficult and more costly. Nevertheless, the application of wisdom and good judgment can bring about realization of the benefits of technological progress.

It would help enormously if adequate propagation research were conducted in advance of service use. Usually, propagation research programs are not sufficiently extensive to produce adequate results, because both government agencies and industry are handicapped in financing such activity. Adequate propagation studies usually are made only after a new service has provided convenient technical facilities, and even then the studies are too often conducted as a by-product in the regular operation of the new service.

The problem is complicated by the fact that knowledge of the propagation laws is often acquired simultaneously with the development of new services. The desire to introduce a new radio service has almost always appeared before full knowledge was available concerning the behavior of the spectrum segment involved. Under these conditions, it is inevitable that misfits should occur.

A limitation on improvement in allocations exists in the reluctance of some users to adopt technological improvements because of the consequent expense of replacing old equipment with new. For example, in spite of the demonstrated practicability of ship-to-shore communication for over ten years beginning in 1900, it was not until after the "Titanic" disaster in 1912 that large passenger vessels were equipped with radio and manned throughout the day.

Later, in spite of the readily demonstrated superiority and greater efficiency of continuous-wave systems over the early spark method, displacement of the latter was not accomplished until it was compelled.

The reluctance to install a new service is usually accompanied by continued resistance against replacing equipment with improved types, even after a reasonable period of use and obsolescence. This tendency arises largely from the circumstance that amortization of most equipment other than radio is based on a rather long useful life. Radio, being in a state of rapid and continuous technical development, frequently makes available improvements and refinements which represent a considerable change in a period of less than ten years. Such a length of time often seems to operating managements to be too short a period to justify replacement of apparatus with improved types. When the improved equipment would permit beneficial allocation changes, such changes are delayed.

2.2 THE SPECTRUM FROM 10 TO 200 KC

This frequency range is useful for long-distance transmission by ground waves and sky waves. It is allocated primarily to the fixed, mobile, radio navigation and (in Europe) broadcasting services. The first uses were for transoceanic fixed communication and long-distance maritime mobile communication. After the development of HF techniques and their utilization in the fixed service, LF facilities were maintained for stand-by use during the ionospheric conditions when high frequencies were erratic.

The use of this range for fixed service is limited by the small amount of frequency space available, the noise level in certain regions, and the large, expensive, and difficult-to-maintain antenna structures required for effective radiation. Its use for mobile communication is limited by the same considerations plus the fact that highly efficient radiating systems on board ships and aircraft are impracticable.

One characteristic of propagation in this range is particularly advantageous in navigation aids and long-range communications: namely, waves at these frequencies travel over land with only slightly more absorption than over sea water. This makes it possible for one navigational aid system to serve both surface craft and aircraft and gives greater freedom in locating the stations.

In the European region, the range 160 to 200 kc is used for broadcasting. Since these frequencies have low ground absorption and are effective for relatively long distances over land, they are well suited to the requirements of broadcasting to rural areas. Unfortunately, the number of channels possible in the range is very small, so that this service, in a realistic allocation, must extend into the region of the spectrum considerably above 200 kc.

2.3 THE SPECTRUM FROM 200 TO 2,000 KC

Most of the frequency range 200 to 2,000 kc is used for broadcasting throughout the world. The international allocation for broadcasting is 535 to 1605 kc, and in the European region the ranges 150 to 255 kc and, to a lesser extent, 255 to 405 kc also are used for broadcasting. Frequencies above 535 kc were allocated to broadcasting, not because the band is most suitable from a propagation standpoint, but because it was the only available band at the time broadcasting began. The location of this service would be better if it were somewhat lower, because greater area coverage would be provided.

However, the space allocated to sound broadcasting served the basic requirements of this service sufficiently well to enable it to continue its rapid growth into even wider use. These basic requirements are:

a. High-grade signals day and night over short distances (approximately 50 miles).

b. Moderately good signals at night over distances up to a few hundred miles.

An unfortunate condition of propagation in this band is the discontinuous nature of the nighttime service area from the station to the limit of the range. The coverage area is broken into inner and outer zones, separated by a fading zone extending about 50 to 75 miles in radius. This phenomenon is caused by interference between the ground and sky waves, which have about equal strengths in this critical zone. Beyond this zone, the ground wave disappears and such fading as is present is comparatively free of distortion.

In spite of the reasonably satisfactory allocation to aural broadcasting in this band, the service actually rendered has become degraded seriously throughout the world by the assignment and operation of a technically excessive number of stations. Some duplication of stations on a channel is permissible, with appropriate attention to geographical separation, but the interfering range of stations is so much greater than the service range that duplication cannot be carried very far in any one area. Duplication has, in fact, been carried too far in many areas, with the result that good sound broadcasting service outside cities and suburbs has largely disappeared. Even urban-area service has been degraded; many stations which give good service in the daytime to a radius of 50 miles or more find their service range reduced at night to 5 or 10 miles.

Under the existing crowded condition of the spectrum, it is difficult to effect a major improvement in aural broadcasting allocation. Studies of the subject should differentiate clearly between local and distant service areas, because an improvement in one may degrade the other. An expansion of VHF broadcasting will improve local broadcasting but cannot affect rural service if the nearest stations are a few hundred miles distant. Lowering the allocation from 535 to about 200 kc would greatly improve the rural service, provided assignments were made properly and appropriate power were used. In fact, considerable technical improvement over the present situation is possible without changing the allocation, merely by limiting the number of stations on the same channel and increasing power to appropriate levels.

Aeronautical, maritime, and land mobile services throughout the world occupy portions of this frequency range. The band from 400 to 550 kc has been used for many years for maritime mobile service and to some extent for aeronautical service. The frequency 500 kc is established by international agreements for distress and emergency traffic. This allocation was made before there was very extensive knowledge of propagation or equipment. Although attempts are now being made to transfer these mobile services to more suitable ranges, the large amount of equipment and the consistent use of this band over many years continue to impede the transfer to other frequency ranges.

Radio navigation services, primarily aeronautical but including maritime radio direction finding, occupy frequencies between 200 and 415 kc. In the American region extensive use is made of this band for aeronautical radio ranges. These ranges are now being replaced in some countries with VHF ranges. Maritime radio beacons used for direction finding are still in extensive use after many years of service. The maritime field is noted for its reluctance to adopt new radio methods and equipment, but it seems certain that the present beacons will eventually be replaced by newer navigation aids.

Above 1,600 kc the band is used throughout the world for fixed and mobile services, primarily for coastal shipping in the European region and land mobile services in the American region. These frequencies are well suited to medium-distance maritime mobile communication, and antennas of reasonable efficiency are practicable on most ships. They are not well suited to land mobile service except in areas where the ground conductivity is exceptionally high. The land mobile services in this range are seriously limited at night by sky-wave interference. As a result, the short-distance land mobile users are rapidly converting to VHF and microwave systems, and it is probable that in a reasonably short time this frequency range can be allocated to medium-distance maritime mobile services and other services for which it is best suited.

The band 1,800 to 2,000 kc is allocated to the loran system of navigational aid which is operated extensively in the North Atlantic and Pacific Oceans. The principles of operation of this system and the service range desired require that it operate either in this part of the frequency spectrum, where certain sky-wave reflections are sufficiently stable for the purpose, or in a much lower part of the spectrum, where ground-wave absorption is sufficiently low so that ground waves can be used to the necessary distance, which may be more than 2,000 miles. The present system was largely installed during World War II by the United States.

2.4 PRESENT USE OF THE SPECTRUM FROM 2 TO 30 MC

First operations in the frequency spectrum above 2 mc began at about the time of World War I. A few naval systems were operated during that war on frequencies near 3 mc. Strange to say, in the light of present-day knowledge of propagation, the naval equipment was intended for very short range, communicating over a few miles only. That its range was limited to a few miles was the result of very low power rather than of propagation limitations as was thought at the time. In the years immediately following World War I, knowledge of the propagation characteristics of this part of the spectrum increased rapidly, and the theory and practice of long-distance radio communication was revolutionized.

The range 4 to 30 mc was found to be well suited to long-distance transmission, both day and night, although subject to variations and peculiarities because the transmission was entirely by sky-wave reflections. Study of these variations has been conducted intensively for the past 35 years, and now they are understood sufficiently well so that advance prediction is feasible. The operation of long-distance commercial communication circuits can now be conducted with efficiency under all but rare and most extreme conditions.

Because of the effectiveness of this band in long-distance communication, many services desire to use it. These include transoceanic telegraphy, telephony, and broadcasting; maritime telegraphy and telephony; aeronautical and amateur communication; and navigational and meteorological aids. In consequence, this band has become the most congested part of the spectrum.

There is considerable difference in performance between the two ends of this band of the spectrum. The low end of the band is more useful during the low part of the sunspot activity cycle, while the upper part of the range (above 21 mc) is more useful during the highly active part of the cycle. Most of the long-distance services do not require frequencies below 3.5 mc, and therefore the range of 2 to 3.5 mc is devoted throughout the world to short-range mobile services, including maritime mobile telephone and aeronautical. Some short-distance fixed circuits are operated below 3.5 mc, and some frequencies have been allocated to tropical broadcasting. These services are moving gradually to VHF, where they can obtain equivalent performance and where they will cause less interference to other services at greater distances.

The fixed stations in this region are generally of low power and operate intermittently; while the frequency range is not particularly appropriate, many of them will continue for a number of years. Broadcasting in tropical zones was established on the assumption that the signal-to-noise ratio in tropical regions would be more satisfactory at frequencies between 2 and 4 mc. Subsequently it has been found, for areas of average or even high ground conductivity, that the ground-wave signal at these frequencies decreases so rapidly that the signal-to-noise ratio is not so good at distances of 10 to 30 miles as it would be at a lower frequency. The existence of receivers in the hands of the public will require maintenance of a "tropical broadcasting" allocation for some time, although it is certain that better service generally can be provided below 1,500 kc and a much better service above 50 mc.

The frequency range above 3.5 mc is devoted to long-distance service, including maritime and aeronautical mobile, fixed, broadcasting, and amateur. Each of these services has a series of bands throughout this range to permit selection of optimum frequency, which depends upon the distance involved, the time of day, and the solar activity. Because of these variables, several frequencies are required for each station. During low sunspot activity, all the services in the HF bands except amateur and other intermittent operations must have frequencies between 3 and 7 mc in order to maintain communication. During high sunspot activity higher frequencies can be used, since the total amount of frequency space available is then greater and the range of frequency which can be used to maintain a given circuit is greater. As a result, during periods of high sunspot activity, operation of the various services is fairly satisfactory. During low sunspot activity, on the other hand, congestion and resultant interference are great.

During the high-activity portion of the solar cycle, these services must have frequencies above 7 mc. Since more channels are available above 7 mc than below it, the congestion and interference problem is not so serious above 7 mc as it is below it. Below 7 mc the problem is extremely difficult and there appears to be no wholly satisfactory solution at present. Future improvement in techniques may permit reduction in bandwidth with consequent increase in number of channels available or allow some users to move to other parts of the spectrum.

In maritime coastal and inland waters telephony, allocations are in the MF-HF and VHF regions of the spectrum, but most of the present use is in the band 2 to 3 mc. The number of users has increased enormously during the past few years, so that congestion, interference, and traffic delay are excessive. The use of this band is increasing steadily, and this trend promises to continue for several years.

In HF international broadcasting, bands are distributed through the range 6 to 25 mc to provide for service under the wide variety of propagation conditions. However, the bands are greatly overcrowded with transmitters. Congestion is especially severe in the lower bands (6 to 9 mc) during the evening hours in the three principal reception areas (Europe, the Americas, the Far East). In the 6-mc band, at 1,800 to 2,200 GMT, transmitting stations are operating in or near Europe on nearly every 5-kc channel, and in some cases two or three transmitters operate on the same channel. Other transmitters operate above and below the allocated limits of the band.

Even in the absence of interference, the quality of reception in HF international broadcasting is not good because of the propagation vagaries of high frequencies and the relative inefficiency of receiving antennas in home installations. Consequently there has been a trend away from HF broadcasting in areas where other broadcast services render good service. For example, in the United States, the public generally has lost interest in HF broadcast reception, and as a result very few receivers with provisions for the reception of HF bands are now marketed. Contributing to this condition is the fact that especially noteworthy international events are picked up by the various networks, using special equipment and antenna systems, and rebroadcast on the standard broadcast frequencies, with consequent better quality than direct reception in the home could achieve.

The present situation in HF broadcasting is that more and more transmitters are being used, creating additional interference, while there is generally less and less listening to HF broadcasts. The public interest would appear to require a reduction in the total frequency utilization. The transmitters which can be justified should operate at still higher power with selective programming directed to the best listening hours in the area to be served.

The worldwide interference capability of HF transmission, the heavy pressure for space in this part of the spectrum by governments and private services, and the uncertainty of the degree of future growth of all these users make the problem of allocation exceedingly difficult to solve.

2.5 PRESENT USE OF THE SPECTRUM FROM 30 TO 3,000 MC

The 30- to 3,000-mc range is well suited to short-distance communication of all kinds, except that the low portion of the range (below about 50 mc) can produce serious interference at long distances under some conditions of the ionosphere. Since the band is effective for short-distance communication, it is used extensively by the fixed, mobile, broadcasting, navigation, and amateur services. In the aeronautical mobile service, the utility of this frequency range is affected adversely by the long distances at which interference can be caused by transmissions from high-flying aircraft.

The most extensive use of the range is found in the American region, particularly in the United States, where VHF sound broadcasting and television broadcasting have built up large new services. Mobile communications in this range have been adopted by many new users.

The frequencies in this range of the spectrum are high enough to permit efficient wide-band modulation of transmitter carrier frequencies. Therefore such wide-band applications as television and FM telephony can utilize this range, whereas they cannot modulate efficiently in the lower frequency ranges. Since this range of the spectrum does not provide reliable long-distance transmission, these applications must be built up commercially and economically on a short-distance basis.

The availability of techniques and equipment suitable for commercial operation in this range burst upon the radio world rather suddenly (about the year 1935), and various services were introduced and accompanying frequency allocations set up before the propagation behavior of this range of the spectrum was thoroughly understood.

The band 30 to 60 mc has effective ground-wave transmission considerably better than that of slightly higher frequencies. Therefore this portion of the range is more efficient for vehicle-to-vehicle operation in the mobile service, where low-power transmitters and low antennas must be used. However, the transmissions are subject to shielding by obstructions such as buildings and rough terrain. The greatest disadvantage of the 30-to 60-mc range is sporadic transmission to great distances, which causes serious interference to other transmissions. It appears advisable, from the international allocation standpoint, not to establish critical or high-power services below about 50 mc, because serious interference can be expected during at least the high part of the solar cycle.

According to presently available data, the aeronautical mobile service is not adversely affected by propagation conditions in its air-to-ground communication anywhere in the range up to 3,000 mc. This service has numerous allocated bands from 100 to 3,000 mc, allocated originally on a basis of equipment availability.

The allocations to aeronautical navigation service are somewhat unwieldy because many of them were set up individually as the requirements appeared. The requirements arose sequentially during the period when propagation in the HF, VHF, and UHF regions was little understood. Simplification of the allocations is desirable. In the United States a plan (known as "RTCA SC-31") has been developed and a transition program under the plan is being implemented. It is intended to complete the ultimate program by 1963.

The heart of the SC-31 system is the band 960 to 1,215 mc. Since these higher frequencies are usable in air-to-ground service and have the advantage of small antennas particularly suitable for aircraft, the relinquishment by aeronautical services of frequency space now occupied elsewhere is a future possibility.

The land mobile services have allocations in the neighborhoods of 40 to 60, 150 and 450 mc. The 60-mc band is subject to shielding by obstacles such as buildings and mountains and to sporadic interference. The 150-mc band is excellent in practically every respect for land mobile communications. While this band is closely limited to "line-of-sight" operation, reflections from obstacles fill in the "shadows" behind other obstacles. The 150-mc band covers less distance than the 60-mc band under conditions of smooth terrain or under other circumstances where advantage cannot be taken of the multiple reflections from intervening obstacles. Consequently, the 150-mc band is preferred for urban and metropolitan mobile services. It should be noted that the property of "filling-in" shadows, which is prominent at 150 mc and above, is not wholly effective in any system which must transmit information at a high time rate as, for instance, television. In such systems, the reception of multiple reflections from which the property is derived results in distortion, multiple images, etc. In telegraphy and telephony other than high-fidelity sound broadcasting, the distortions are not serious enough to outweigh the advantages.

The 450-mc band, for lack of equipment, has not been used extensively as yet in the mobile services. It promises to be effective for urban and metropolitan services. The degree of utility will depend upon the adequacy of the engineering standards set up to control assignments to particular users. The matters of channel width, frequency stability, receiver design, and various other system standards, if correctly determined initially, will assure most effective use of the band. Sound engineering standards in allocation and assignment of both the 450- and 150-mc bands are necessary if the very rapid growth of mobile systems is not to result in intolerable congestion and interference in the near future.

Very-high-frequency aural broadcasting as assigned at present in the United States can be said to have adequate space and a satisfactory location in the spectrum.

In the future, when the relationships of urban and rural listening, and the relationship between aural and visual broadcasting have become more definitely established, some other region of the spectrum may be more advantageous for aural broadcasting, either higher or lower in frequency. Higher regions could utilize either FM or AM. Lower regions (LF) would necessarily use AM. Studies of VHF broadcasting should take account of the fact that it cannot give, in large countries such as the United States, the extent of nationwide coverage which is given by stations in the MF part of the spectrum without an uneconomic number of stations. Medium-frequency (standard broadcast) stations can serve an urban area and a large rural area simultaneously. This fact made possible the rapid and wide use of sound broadcasting, even in areas unable to support a station because of sparse population.

Television broadcasting has worldwide allocations, varying somewhat in the several regions, as follows: 54 to 72 mc, 76 to 88 mc, 174 to 216 mc, 470 to 960 mc. In the United States the allocations are 54 to 72 mc, 76 to 88 mc, 174 to 216 mc, 470 to 890 mc.

Present American television operations are of large magnitude. The channel width assigned is 6 mc, which has proved satisfactory for current black-and-white techniques. After considerable testing experience, this channel width has been found to be sufficient to accommodate foreseeable future developments, including color television. The basic requirement of television broadcasting is the same as that of sound broadcasting, namely, to reach all people in a given area requiring service regardless of their particular locations, with stations so located that the service area of each includes enough listeners to support it. Television unfortunately cannot use that part of the frequency spectrum which made it easy for sound broadcasting to serve both short and long distances with one station, because its channel-width requirement is too great. Television must operate in the VHF region or higher, with resulting limitation in range and area which each station can serve. Consequently it appears that special attention must be given to the problem of certain areas having sparse population, insufficient to justify erection and operation of television stations, which cannot have television broadcast service except perhaps by some special arrangements such as community distribution by wire or relay transmitters.

The minimum bandwidth of a channel is 6 mc. Several scores of channels are necessary for good service in a large country, so that the space in the spectrum required for television broadcasting totals many hundreds of megacycles. The present allocation provides this amount of space, but it is broken up into the four bands of contiguous channels listed above, some of which are widely separated. This arrangement imposes considerable penalty on apparatus design and performance, especially receivers. Apparatus can always be simpler and less costly if the frequency bands it uses are contiguous. In addition, system-operating problems are simplified if the frequency range is not so great that dissimilar behavior among stations is produced by different propagation characteristics. The present allocation, extending from 54 to 960 mc, covers the tremendous range of 906 mc, yet only 572 mc of this space is allocated to television. The maximum and minimum frequencies are in the ratio of over 16 to 1, a serious handicap in the design and performance of apparatus. If the same amount of spectrum space were made continuous, as from 54 to 626 mc, the ratio of the limiting frequencies would be only about 11 to 1.

The present situation resulted from an insufficient allocation made at a time when knowledge was limited as to the eventual needs of the service and when knowledge of propagation characteristics was meager.

In the United States, the current service reaches a large part of the population and is established in the 54- to 72-, 76- to 88-, and 174- to 216-mc bands. Future expansion is contemplated for the 470- to 890-mc band. This choice seems unfortunate in that operation would be much more efficient in the region immediately above 216 mc. This region is now occupied by services which could operate effectively in a higher part of the spectrum.

Most of the bands allocated to industrial, scientific, medical, and miscellaneous noncommunication devices are in the region above 30 mc. Allocations were made to these devices because it appeared to be impracticable to construct them in such manner that they would not radiate sufficiently to cause interference to radio communication services. Minimum interference is caused if they are assigned specific bands and required to operate within those bands. This condition still exists but has lessened since allocations were made originally. There is now general agreement among manufacturers of these devices, based on experience, that it is frequently more practicable to provide shielding of the devices sufficient to prevent troublesome radiation than to provide means for holding frequencies sufficiently constant to stay within the allocated bands. Consequently, manufacture is tending in this direction and successful shielding is being achieved. It should be emphasized that radiation from industrial devices, like smoke abatement and the prevention of the pollution of water supplies, is a matter which is best checked at its inception.

It is likely that many existing and new devices will have to be frequency-controlled within allocated bands until sufficient knowledge of shielding methods is acquired to control radiation under all circumstances. It may well be that certain devices, because of their very close proximity to receivers with which they may interfere, will never be adequately shielded and must always operate in allocated bands.

Medical diathermy equipment is especially difficult to control, and present practice utilizes both shielding and frequency control methods. However, good results have been obtained.

It appears that the present frequency allocations in this field meet adequately the needs of the industry and of the radio communication services and that the allocations will continue to be required for some time, although there is hope that eventually they may be eliminated.

2.6 PRESENT USE OF THE SPECTRUM FROM 3,000 TO 300,000 MC

This region of the spectrum is still largely experimental in nature, since established commercial services have had experience only with frequencies near the lower limit. The first utilization of this region was by military radar, which began operational use in 1943. Since then military radar has expanded greatly in this region. Commercial uses have included maritime radar and microwave communication relays.

Another interesting possibility of the extremely high frequencies arises from the fact that the physical dimensions of associated radiating elements are so small that very high directivity of the radiation is feasible. With wavelengths of the order of 1 mm (300,000 mc), concentration of high power in very small area beams becomes possible. Such concentration of electric power in high-energy density beams has other applications than communication, as, for example, the drilling of holes or other mechanical operations.

Maritime radar has present allocations as follows:

3,000 - 3,246 mc
5,460 - 5,650 mc
9,320 - 9,500 mc

The second of these is used little at present. The first and third are widely used, and opinion is divided as to their merits. The 9,000-mc band is preferable with respect to resolution, minimum range, and antenna size, and the 3,000-mc band is preferable with respect to stability and ease of manufacture. Operation on the 9,000-mc band is affected by heavy rainfall, if this covers a considerable part of the path between instrument and target, but this condition occurs so rarely that it is outweighed by the advantages mentioned. Use of the 9,000-mc band is increasing rapidly as installation of radar extends to smaller ships and boats. British ships are required by law to use this band.

Interference is not a problem in maritime radar at present and probably will not become one until the number of installations in use is very much larger than at present. In general, the allocation situation in maritime radar is satisfactory.

It is important to note that, while the absorption caused by rain in the transmission path begins to be appreciable at frequencies in the vicinity of 5,000 mc in radar operation, it is not equally appreciable in radio communication operation until frequencies of 20,000 mc or higher are reached. This is because radar utilizes very weak reflected signals.

Relaying and point-to-point transmission of wide bands of communications, as in television and multiplex telephony and telegraphy, have reached a stage of rather general use, especially in the regions of 4,000 and 7,500 mc, and higher frequencies are coming into general use.

Certain properties of frequencies in this region make them especially well adapted for use in long-distance relaying. The feasibility of highly directive antenna systems and the property of high attenuation beyond the horizon, with consequent freedom from interference beyond the intended receiving point, make feasible relaying without the use of much frequency spectrum space. A chain of relay stations can repeat the same frequency with only moderate distance separation, especially if zigzagging of station locations is employed.

A highly developed form of relay system is now being operated in the United States by the Bell System. This is capable of transmitting television and telephone traffic across the country. Comparable relay facilities in private service are being installed extensively throughout the United States and abroad.

Tests indicate that there is no substantial degradation in signal quality. The wide band of frequencies employed, the high antenna directivity, and the low power of transmitters combine to make such use of this region of the spectrum advantageous.

A second network operating in this band of frequencies is being installed in the United States by the Western Union Telegraph Company. It is reasonable to expect that these systems are the beginnings of extensive networks which ultimately will cover most of North America as well as other large continental areas. It is clear that, as systems of this kind develop and expand, allocation problems will increase also and there will be need for substantial frequency space.

In addition to the telephone and telegraph radio networks open to public correspondence in the United States, there is now an increasing number of private operators of radio relay systems for particular purposes. For example, pipe-line companies transporting oil or gas are large users of microwave relays.

3. THE FUTURE OF THE HIGH FREQUENCY SPECTRUM

One of the most crowded portions of the spectrum is that between 3 and 30 mc, the so-called high frequency portion of the spectrum. As previously pointed out, this part of the spectrum has many users because of its desirable characteristics. Data published by the International Telecommunication Union indicates that the use of high frequencies are increasing at a high rate of 15 percent a year world-wide. As one source[1] has pointed out, this means that the increase in the demand for high frequency channels by 1965 will be about double the 1958 level of use. Since conditions from an interference standpoint are already extremely bad in the channels of the high frequency spectrum, it can be expected that these conditions will become considerably worse as the years go on.

Coupled with the expectations for additional channel demands in the HF spectrum is another related problem. This is the problem of decreasing spectrum space for long-distance radio communication in the HF region because of the downward trend in the sunspot cycle. By 1965 it is expected that the HF region will be useful for long-distance radio communications only between 3 and 15 mc rather than from 3 to 30 mc.

This is a reduction in the usable channels about 50 percent. We have, therefore, approximately a 400 percent expected increase in level of long-distance traffic in the usable part of the HF region.[1]

Because of the tremendous amount of capital plant existing in the high frequency communications systems today, the future appears to be very grim indeed for some of the most important communication channels that we have. There are indications that this relatively low sunspot activity and thus the reduction in long-distance HF frequencies will be with us almost until the year 2000.

This example of the special problems existing in the high frequency spectrum has been chosen to illustrate the difficulties in relieving spectrum congestion. Each region of the spectrum has its individual problems. Even in the VHF and UHF parts of the spectrum which have been relatively uncrowded until recent years, we now find ionospheric and tropospheric scatter systems with global ranges. In addition, there are increasing requirements for frequencies for use in space communications.

4. SPACE COMMUNICATIONS

Of increasing importance in any consideration of spectrum utilization are the fast-growing problems of space communications. At the present time, the basic design parameters pertaining to space communications are:

a. Very sensitive ground-based receivers equipped with large aperture antennas.

b. High power ground-based transmitters.

c. Receivers and transmitters of relatively low power for use in satellites and space vehicles.

While it is not the purpose of this Chapter to present an analysis of the capabilities or characteristics of satellite and space communications, nevertheless it must be pointed out that the use of satellites for communications purposes represents many possible advantages in extending the use of the VHF, UHF, and microwave spectrum regions for long-distance channels.

At the 1959 Geneva Meeting of the International Telecommunications Union, it was agreed that various frequency bands would be set aside on a shared basis for research and one frequency band exclusively for radio astronomy. These allocations are shown in Table 2-1.[3] An Extraordinary Session of the ITU is planned for 1963 at which new research data and operational needs for space use will be considered, and the 1959 agreements will be reviewed and modified, if necessary.

Table 2-1 has a column for "status" remarks. The notes in this refer to "recommendations," "footnotes," and "allocations" contained in the ITU regulations. These various actions differ in the degree of protection from interference which the conference is willing to give to the service. "Allocation" is the strongest protection. "Footnote" indicates treaty status with strength depending on the words contained in the footnote. "Recommendation" expresses concurrence that planning should take place for future action.

On November 9, 1960, the Staff Director, Mr. Kenneth E. BeLieu, of the Senate Committee on Aeronautical and Space Science transmitted a report to the Committee Chairman. This report was entitled "Policy Planning for Space Telecommunications." It dealt largely with allocation of frequencies for space use and effectively summarized the principal aspects of space telecommunications. The conclusions of the staff as presented in the report were as follows (in part):[3]

a. Reliable communication between space vehicles and ground stations is critically necessary to the success of exploration and use of outer space.

b. Protection against harmful interference appears best guaranteed by existing processes of administrative control over the radio spectrum through the international allocation and domestic assignment of frequencies.

c. Most authorities state that under current technology, the only positive assurance of immediate progress in space research lies in the allocation of exclusive, unshared radio channels for earth-space service and for radio astronomy observation.

d. Steps taken through the International Telecommunication Union at its 1959 Administrative Radio Conference represent an important first step toward this goal.

e. Rapid advancements in space research point to very early practical applications in the form of artificial satellites for global communication, devices to improve weather forecasting through observation of

Frequency for space use	ITU regulation page	Status	Parent band	Primary use	Secondary use	Region
2500 kc/s	42, 607	Recommendation 31 and footnote 201.	2498-2502 kc/s	Standard frequency	RAS	Worldwide
5000 kc/s	47, 605	do.	4995-5005 kc/s	do	RAS	Do.
10,000 kc/s	50, 608	do.	9995-10,005 kc/s	do	RAS	Do.
10,003-10,005 kc/s	50, 607	Recommendation 31 and footnote 213.	9995-10,005 kc/s	do	Service for space research	Do.
15,000 kc/s	52, 607	do.	14,990-15,010 kc/s	do	RAS	Do.
20,000 kc/s	53, 608	do.	19,990-20,010 kc/s	do	RAS	Do.
[illegible]-20,010 kc/s	53	Footnote 221	19,990-20,010 kc/s	do	Space and Earth-space services for research purposes	Do.
25 Mc/s	54, 608	Recommendation 31 and footnote 209.	24,990-25,010 Mc/s	do	RAS	Do.
[illegible] Mc/s and 23 Mc/s	609	Recommendation 32	29.7-41.0 Mc/s	Fixed, mobile		Do.
[illegible] Mc/s	56, 57	Footnote 235	29.7-41 Mc/s	Fixed, mobile	Space, Earth space	Do.
[illegible] Mc/s and 35 Mc/s	609	Recommendation 33.	29.7-41.0 Mc/s	do.		Do.
[illegible] Mc/s	60, 61	Footnote 253	68-74.6 Mc/s	Fixed, mobile, broadcasting	RAS	Region 2 only
[illegible] Mc/s	62, 63	Footnote 261	75.2-87.5 Mc/s	Fixed, mobile, and broadcasting	RAS	Regions 1 and 3 (except Korea, India or Japan)
136-137 Mc/s	66, 68	Allocation	136-137 Mc/s	Space, fixed, and mobile. Earth-space.		Worldwide
150-153 Mc/s	67, 68	Footnote 296	150-154 Mc/s	Fixed and mobile	RAS	Region 1 only
[illegible] Mc/s	69, 70	Footnote 2[illegible]	174-216 Mc/s	Fixed, mobile, broadcasting	Space, Earth space	Worldwide
322-329 Mc/s	72	Footnote 310	322-328.6 Mc/s	do.	RAS	Do.
			328.6-335.4 Mc/s	Aeronautical radionavigation.		
400-401 Mc/s	72	Allocation	400-401 Mc/s	Meteorological aids, space, Earth-space.		Do.
401-410 Mc/s	73	Footnote 317	401-406 Mc/s	Meteorological, fixed and mobile	RAS	[illegible], (?).
			[illegible] Mc/s	Fixed and mobile		
606-614 Mc/s	76, 77	Footnote 332	[illegible] Mc/s	Broadcasting in regions 1 and 2		
			585-610 Mc/s	Radionavigation; fixed, mobile, and broadcasting in region 3	RAS	Regions 1 and 3
606-614 Mc/s	610	Recommendation 32	606-790 Mc/s	Broadcasting in regions 1 and 2		
			585-610 Mc/s	Radionavigation, fixed, mobile, and broadcasting in region 3.	RAS	(?).
1400-1427 Mc/s	80	Allocation	1400-1427 Mc/s	RAS		Worldwide except [illegible]
1427-1429 Mc/s	80	do.	1427-1429 Mc/s	Space, fixed and mobile except aeronautical mobile, Earth space.		Worldwide

[illegible] Mc/s	[illegible]	Footnote 334	[illegible]-1700 Mc/s	Meteorological aids, fixed and mobile, except aeronautical mobile.	R.A.S, Soviet bloc only	([illegible]).
1700-1710 Mc/s	[illegible]	Allocation	1700-1710 Mc/s	Fixed, region 1	Space,[illegible] mobile, Earth-space	Region 1.[illegible]
			1700-1710 Mc/s	Fixed, and mobile in regions 2 and 3	Space,[illegible] Earth-space [illegible]	Region 2, 3.
2290-2300 Mc/s	[illegible]	do	2290-2300 Mc/s	Fixed, region 1	Space,[illegible] mobile, Earth-space[illegible].	Region 1.[illegible]
			2290-2300 Mc/s	Fixed and mobile, regions 2 and 3	Space,[illegible] Earth-space [illegible]	2, 3.
[illegible]-2700 Mc/s	[illegible]	Footnote 365	2550-2700 Mc/s	Fixed and mobile	R.A.S.	Worldwide.[illegible]
[illegible] Mc/s	[illegible]	Footnote 334	3100-3300 Mc/s	Radio location and merchant ship radar.	R.A.S, Soviet bloc only	([illegible]).
[illegible] Mc/s	[illegible]	do	4400-5000 Mc/s	Fixed and mobile	do	([illegible]).
[illegible] Mc/s	[illegible]	Footnote 365	4400-5000 Mc/s	do	R.A.S.	Worldwide.[illegible]
[illegible] Mc/s	[illegible]	Allocation	[illegible] Mc/s	Radiolocation	Space,[illegible] Earth-space [illegible]	Do.
[illegible] Mc/s	[illegible]	Footnote 334	[illegible] Mc/s	Radiolocation and amateur, also industrial, scientific, medical at [illegible] Mc/s	R.A.S, Soviet bloc only	([illegible]).
[illegible] Mc/s	[illegible]	Allocation	[illegible]-8500 Mc/s	Fixed, and mobile	Space,[illegible] Earth-space [illegible]	Worldwide [illegible]
[illegible] Mc/s	[illegible]	Footnote 334	[illegible]-8700 Mc/s	Radiolocation	R.A.S, Soviet bloc only	([illegible]).
[illegible]-10.7 Gc/s	[illegible]	Footnote 405	10.55-10.7 Gc/s	Fixed, and mobile	Radiolocation (R.A.S)	Worldwide.[illegible]
15.15-15.25 Gc/s	[illegible]	Allocation	15.15-15.25 Gc/s	Space,[illegible] Earth-space [illegible]	Fixed, and mobile	Do.
[illegible]-15.4 Gc/s	[illegible]	Footnote [illegible]	15.25-15.4 Gc/s	Fixed, mobile	R.A.S.	([illegible]).
19.3-19.4 Gc/s	[illegible]	do	17.7-21.0 Gc/s	do	R.A.S.	([illegible]).
31.3-31.5 Gc/s	[illegible]	do	25.25-31.5 Gc/s	do	R.A.S.	([illegible]).
31.5-31.8 Gc/s	[illegible]	Allocation	31.5-31.8 Gc/s	Space,[illegible] Earth-space [illegible]	Fixed, and mobile	Worldwide.

[1] It is recommended that administrations take all practicable measures to safeguard the standard frequency bands from harmful interference.

[2] It is recommended that a firm allocation for R.A.S be considered and that in the meanwhile, administrations should avoid these bands for other services.

[3] In making assignments to stations of other services to which this band is allocated, administrations are urged to take all practicable steps to protect radio astronomy observations from harmful interference. The radio astronomy service shall be protected from harmful interference from services operating in other bands in accordance with the provisions of these regulations, only to the extent that these services are protected from each other.

[4] For research purposes.

[5] Aeronautical mobile (OR) service will be the primary service for as long as it continues to operate in this band. On discontinuation of this service, the space and Earth-space services will be the primary services.

[6] R.A.S observations on deuterium line (327.4 Mc/s) are carried out in a number of countries on a national arrangement. Administrations should bear in mind needs of R.A.S in their future planning of this band.

[7] In Greece, Yugoslavia, Albania, Bulgaria, Hungary, Poland, Rumania, Czechoslovakia, U.S.S.R., and Sweden, the band [illegible] Mc/s is also allocated to fixed and mobile services.

[8] The band [illegible] Mc/s in regions 2 and 3 and the band [illegible] Mc/s in region 1 are also allocated to R.A.S. An appropriate continuous band within these limits shall be determined on a national or area basis.

[9] In regions 1 and 3, the band may be used for R.A.S until such time as it is required for use by other services to which this band is allocated. During this period, administrations should take all practicable measures to avoid harmful interference to R.A.S observations.

[10] Administrations, when drawing up frequency assignment plans, should leave as far as practicable this band free for R.A.S, or should assign frequencies to stations of other services in this band, in such a way as to afford the maximum practicable protection for the radioastronomy service.

[11] In Albania, Bulgaria, Hungary, Poland, Rumania, Czechoslovakia and U.S.S.R., band is also allocated to fixed and to mobile, except aeronautical mobile, services.

[12] In Bulgaria, Hungary, Poland, Rumania, Czechoslovakia, and U.S.S.R., this band is allocated also to R.A.S observations.

[13] Bands are allocated on a secondary basis to the space and the Earth-space services, subject to causing no harmful interference with the other services to which these bands are allocated.

[14] In Albania, Austria, Bulgaria, Hungary, Poland, Rumania, Sweden, Switzerland, Czechoslovakia and U.S.S.R., the band [illegible] Mc/s is also allocated to radionavigation service.

[15] In Australia and the United Kingdom, the band [illegible] Mc/s is allocated to the radio location service, the band [illegible] Mc/s is also allocated on a secondary basis, to the space and earth-space services for research purposes.

[16] Allocation to space and earth-space services, for research purposes, subject to causing no harmful interference.

[17] Stations of a secondary service shall not cause harmful interference to stations of primary services and cannot claim protection from harmful interference of a primary service. They can claim protection from the same service (art. [illegible], Geneva, 1959, Radio Regulations).

[18] See app. D.

[19] See app. E.

[20] R.A.S is abbreviation for "radio astronomy service".

(SPECIAL NOTE: SEE SECTION 4 OF THIS CHAPTER FOR DISCUSSION OF THE ABOVE TABLE.)

Table 2-1. Allocation of Radio Spectrum for Space Communication and Radio Astronomy, Administrative Radio Conference, Geneva, December 1959 metereological factors, for navigation and for surveillance. By virtue of the technology involved, virtually all of these services require wide bands of frequencies in order that they may transmit or relay to the ground messages, speech, facsimile, or televisual images.

f. Space relay stations appear to hold unusual promise for reliable long-distance communication, thus to supplement existing long-distance radio circuits that are disrupted by sun spots and submarine cables which are vulnerable to cutting by fishing trawlers. Moreover, studies indicate that space relay stations will be economically competitive.

g. In the use of artificial satellites for space relays, the case for exclusive frequencies without sharing is more controversial, and authorities do not agree on the degree of channel sharing possible without mutual interference. While sharing provides one means of accommodating all applicants for radio spectrum, the potential of space relays could conceivably be inhibited by premature assignment to other services of channels most suitable for space use. Immediate research is needed to resolve this problem.

h. The implications of the recent FCC decisions on availability of frequencies for space telecommunications should be immediately examined.

i. The study and development of communication satellites would not only serve to meet the increasing demand for overseas traffic and to provide an important redundancy of U. S. military standby circuits for overseas commitments, but might also serve to foster the technological growth of those new nations whose need for both domestic and international communication is unprecedented.

j. Thus, both to improve the protection of space experiments against harmful interference and to provide wider bands for practicable application, leadership should be exercised by the United States in negotiating additional frequency channels for space service at the Extraordinary Administrative Radio Conference of the ITU proposed for 1963.

k. The general problem of world-wide communications involves a complex and interrelated set of economic and political as well as technical considerations. Thus, any plans for such an important step as space service requires reevaluation of broad national policies in the field of communications.

5. FUTURE DEVELOPMENTS

As in the past, it can be expected that continuing pressure for more communication channels and facilities will result in opening up new approaches to the overall communication problem. The expanding use of microwave relays, the use of tropospheric and ionospheric scatter techniques, the development of sophisticated communication techniques, the approaching use of satellite communication relays, and similar developments are tending to show us directions in which we can proceed to reduce spectrum congestion.

Among the more recent developments is the consideration of the optical maser (laser) for communication purposes. The optical maser has the property of producing a powerful, very sharply defined beam of light. With ruby lasers, pulses of the order of 10 kw can be obtained with a pulse duration of the order of one millisecond. Total energy per pulse, therefore, may be on the order of 10 joules. With the high intensity of the light and the extremely small beam due to the coherent properties of the light emanation, power can be transmitted over considerable distances with very little loss.

The problem with the laser is not one of spectrum congestion, but rather the capability to modulate the laser output. Lasers have been modulated at frequencies up to 10,000 megacycles, but this has required very large modulating powers. Much work remains to be done in this area. In the part of the light spectrum where the ruby laser operates, the frequency of light is approximately 4×10^{14} cps. A one percent band of the spectrum at this frequency has a bandwidth of four million megacycles which would make possible a billion telephone conversations at the same time.[4] The basic formula for transmission loss in the optical region is the same as in the radio region:

$$\frac{P_r}{P_t} = \frac{A_t A_r}{\lambda^2 D^2}$$

where: P_t = Transmitted power

P_r = Received power

A_t = Area of transmitting antenna

A_r = Area of receiving antenna

λ = Wavelength

D = Distance between antennas

Oliver[4] has shown that a laser with a 10 joule pulse could provide a 60 db signal-to-noise ratio circuit between earth and moon without any associated optics. A three-inch optical objective would be sufficient to provide a 40 db SNR channel to Mars, and a ten-inch objective would provide a 30 db SNR across the solar system.

With the huge channel capacity at optical frequencies, the high directivity, and the long-range capability, it may be that the laser will provide material assistance in improving our utilization of the electromagnetic spectrum.

References

1. Jacobs, G.: Radio Interference - Suicide or Challenge, IRE Transactions on Radio Frequency Interference, Vol. RFI-4, No. 2, May 1962.

2. A Report of the IRE-RTMA Joint Technical Advisory Committee: Radio Spectrum Conservation, published by McGraw-Hill, 1952.

3. Policy Planning for Space Telecommunications, A Staff Report prepared for the Committee on Aeronautical and Space Sciences, U. S. Senate, Government Printing Office, December 4, 1960.

4. Oliver, B. M.: Some Potentialities of Optical Lasers, Proc. IRE, Vol. 50, No. 2, p. 135, February 1962.

5. Hacke, J. E., Jr.: The Future Natural, Technological, and Social Environment of Global Communications, 2nd Annual Symposium on Global Communications, St. Petersburg, Florida, December 3, 1958.

6. W. L. Firestone, S. G. Lutz, and J. Smith: Control of Interference Between Surface Microwave and Satellite Communication Systems, IRE Transactions on Radio Frequency Interference, Vol. RFI-4, No. 2, May 1962.

INTERNATIONAL FREQUENCY ALLOCATION PROCEDURES

CHAPTER 3

1. INTERNATIONAL ASPECTS OF RADIO SPECTRUM UTILIZATION

Because of electromagnetic wave propagation characteristics and because of the use of many parts of the radio spectrum in shared and common services throughout the world, it is necessary to consider spectrum utilization on an international basis. Thus, since the early recognition of the necessity of world-wide cooperation in the use of the radio spectrum, international radio conferences have been held frequently for more than 50 years.

In earlier years, these conferences concerned themselves largely with agreements as to frequencies for common usage. For example, it was recognized at an early date that it was important that there be internationally-agreed channels for ship-to-shore communications.

In more recent times, there has been a growing recognition that more thorough and deeper studies of spectrum usage must be made. We have become aware that effective use of the radio spectrum requires a dynamic rather than a passive management approach. Consideration must be given to new techniques of spectrum utilization and to new equipment design features which allow more channels in the same bandwidth. Because of the range of radio propagation and because each radio channel may not be used full time by an individual station, the definitive usage of the spectrum, and consequently management of the spectrum, must cover frequency, time, and geographic location.

Two additional factors must receive consideration as well. One of these factors is the future availability of channels so as to allow new services to be developed. The other factor is the problem of obsolescence and research in opening new parts of the spectrum or in reallocating existing services from one part of the spectrum to another.

Planning for future availability of spectrum space is important if maximum benefits are to be gained from the use of radio. If the radio spectrum becomes so completely utilized that no channels are available in the future for new services, not only is the general public not being benefitted but individual potential users are being discriminated against. For example, if all available channels for taxicab communications are assigned and in use in a certain area, then new taxicab companies are being prevented from going into business since, in many cities, a radio dispatch service is an economic necessity to taxicab companies if they are to be competitive. Internationally, a station may transmit information over a high frequency channel for a relatively small part of the day and preempt the channel by transmission of test signals or other non-informative signals during the rest of the day. Thus, in this case, other countries may be prevented from adding services even on a shared frequency basis.

In addition to managing the spectrum so that there are maximum benefits and minimum discrimination in frequency allocations, it is necessary to consider the economics of equipment development and obsolescence as a consequence of improved planning for spectrum utilization and extension of the spectrum through research and study. Ideally, it is desirable that each type of radio service occupy a part of the spectrum suited to the service. For example, from a technical standpoint it might be desirable that very short range, point-to-point radio communications be confined to the microwave frequency bands. On the other hand, those organizations with a substantial capital investment in equipment operating on the VHF and UHF bands might find it economically unfeasible to replace their equipment with microwave devices except on a long-term basis as the equipment becomes obsolescent.

Although technical considerations may indicate that changes in spectrum allocations are desirable, such changes are dependent also upon economic and political considerations. Thus, management of the radio spectrum on a global basis requires cooperation and coordination internationally.

2. THE INTERNATIONAL TELECOMMUNICATIONS UNION

The International Telecommunications Union (originally known as the International Telegraph Union) was founded in 1865 to coordinate communications matters between the European Countries. Through the years, it has been effective in obtaining cooperation between nations in matters of mutual concern pertaining to telegraph, telephone, and radio communications. In 1947, the ITU became a specialized agency of the United Nations and now has a recognized responsibility for coordination of the use of all forms of telecommunications by landline, submarine cable, or radio means. The ITU is advised by two technical committees, the International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR). An 11-member International Frequency Registration Board (IFRB) handles the details of radio frequency registrations which are published in the Table of Frequency Allocations. The IFRB also provides advice concerning general utilization of the radio spectrum for frequency allocations.

The ITU has approximately 100 full and associate members representing most of the major powers, geographic, and political subdivisions. Permanent headquarters are located in Geneva, Switzerland. A Secretary-General (with a full-time General Secretariat) is responsible for administrative operations. Policy guidance is provided by an Administrative Council with representatives from 25 nations. The Administrative Council meets for approximately a month each year.

Frequent international conferences are convened by the ITU to revise and up-date the International Radio Regulations including the Table of Frequency Allocations, and to agree on recommendations for technical standards. The basic purposes of the ITU are defined as follows:

> "To maintain and extend international cooperation for the improvement and rational use of telecommunications of all kinds;
>
> "To promote the development of technical facilities and their most efficient operation with a view to improving the efficiency of telecommunication services, increasing their usefulness and making them, so far as possible, generally available to the public;
>
> "To harmonize the actions of nations in the attainment of these common ends."

It is important to note that the 1959 ITU Radio Regulations defines "telecommunications" as "any transmission, emission or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, visual, or other electromagnetic systems." Thus the word "telecommunications" in this context covers broadcasting, radar, radionavigation, and most other uses of radio emissions.

An ITU Conference on Space Telecommunications is scheduled for late 1963 and a Plenipotentiary Conference is scheduled for Geneva in 1965. A table showing previous ITU Conferences is shown in Figure 3 - 1.

YEAR	MEETING	RADIO SPECTRUM COVERAGE
1906	Berlin Radio Conference	500 kc/s - 1,000 kc/s
1912	London Radio Conference	150 kc/s - 1,000 kc/s
1927	Washington Radio Conference	10 kc/s - 23,000 kc/s
1932	Madrid Radio Conference	10 kc/s - 60,000 kc/s
1938	Cairo Radio Conference	10 kc/s - 200 mc/s
1947	Atlantic City Radio Conference	10 kc/s - 10,500 mc/s
1959	Geneva Radio Conference	10 kc/s - 40,000 mc/s

Figure 3-1 Meetings of the ITU 1906-1959

At the ITU Radio Conferences, delegates of member nations submit their proposals for frequency usage. Meetings are then held to discuss the technical implications of such usage and to resolve conflicts in requirements for frequencies. Generally, proposals for changes in frequency allocations are circulated for review by all members of the conference. Occasionally proposals are also made from the floor. Final recommendations are made to the plenary body for formal vote after negotiation in subworking groups.

Although the Radio Conferences allocate various bands of frequencies for use by different types of services, they do not assign frequencies to particular users. Licensing or authorization of transmissions by individual users is the responsibility of each member nation in accordance with the Tables of Frequency Allocation that represent the instrument of international agreement on frequencies within the ITU.

When agreement is reached on any matter at an ITU Radio Conference, the decision is embodied in ITU Radio Regulations. These Radio Regulations are then submitted to the ITU member nations for ratification as a multilateral treaty.

3. THE INTERNATIONAL RADIO CONSULTATIVE COMMITTEE (CCIR)*

The International Radio Consultative Committee (CCIR) is an official advisory organization of ITU which is empowered to study and make recommendations on technical radio questions and operating procedures. The Study Groups of CCIR and CCITT (International Telephone and Telegraph Consultative Committee) have over 300 telecommunications problems presently under study. There are fourteen CCIR Study Groups as follows:

I	Transmitters
II	Receivers
III	Fixed Systems
IV	Space Systems
V	Wave Propagation
VI	Ionospheric Propagation
VII	Standard Frequencies and Time Signals
VIII	International Monitoring
IX	Radio Relay Systems
X	Broadcasting
XI	Television

*The initials CCIR are derived from the French title of the Committee.

XII Tropical Broadcasting
XIII Mobile Services
XIV Vocabulary

The CCIR was founded in the late 1920's to provide an international meeting place for the exchange of technical information on radio matters. As an advisory group to ITU, its duties are stated as:

> "The duties of the International Radio Consultative Committee (CCIR) shall be to study technical and operating questions relating specifically to radio communication and to issue recommendations on them."

Each of the fourteen Study Groups of the CCIR is a self-contained organization. Each Group is composed of individuals who are generally internationally recognized experts in the field of interest of the Group. A large amount of the Study Group business is conducted by correspondence and an international meeting of each Group is usually held once each year. The CCIR meets in plenary assembly approximately every 3 years to consider the recommendations of the Study Groups and to transmit approved recommendations to the appropriate ITU Radio Conference. A formal CCIR meeting is scheduled for early 1963 in New Delhi.

4. THE INTERNATIONAL FREQUENCY REGISTRATION BOARD (IFRB)

The 11-member International Frequency Registration Board (IFRB) was established in 1947. Its powers were considerably strengthened at the Geneva Radio Conference in 1959. It presently is responsible for the orderly recording of frequency assignments made by the various countries to individual stations, and acts as a clearing house for the reporting of interference. The International Monitoring System (established as a result of the ITU Atlantic City Meeting in 1947) assists the IFRB by detection and identification of interfering signals, and by observations of radio spectrum occupancy. The IFRB recommends frequency assignments, indicates incompatibilities in assignments, and coordinates adjustment of assignments and schedules for optimum international use of the spectrum.

5. OTHER INTERNATIONAL ORGANIZATIONS

Although the ITU is the international organization primarily concerned with frequency allocation matters, various other groups have an interest and a voice in allocation policies and frequency assignments. These include such organizations as the International Scientific Radio Union (URSI), the International Astronomical Union (IAU), and International Geophysical Year (IGY). There is a particular interest internationally in space telecommunications and the use of communications satellites. These matters have been discussed in the United Nations Assembly. Other organizations with a specific interest in spectrum utilization and frequency allocation include the International Civil Aviation Organization (ICAO), the World Meteorological Organization (WMO), and the Inter-Governmental Maritime Consultative Organization (IMCO).

6. THE U.S. STATE DEPARTMENT IN INTERNATIONAL TELECOMMUNICATIONS PLANNING

The State Department is the focal point of United States cooperation in international telecommunications planning. It coordinates with other U. S. agencies to obtain agreed U. S. positions for international conferences. The process of registering frequencies and liaison with the International Frequency Registration Board has been delegated to the Federal Communications Commission. To carry out U. S. responsibilities for participation in the CCIR, the Department of State has sponsored the United States National CCIR Organization. This consists of an Executive Committee, responsible for National Coordination of U. S. CCIR papers, and 14 Study Group Committees corresponding to the 14 international Study Groups. Each of the Study Group Committees studies and makes recommendations concerning problems assigned by the ITU to its corresponding CCIR Study Group. Papers prepared by the National Study Group Committees and approved by the Executive Committee are transmitted through the Department of State to the Director of the CCIR at Geneva.

U. S. participation in the other international organizations mentioned in Section 5 above is also under the general sponsorship of the State Department.

REFERENCES

1. Mapes, C. M.: A Need for International Cooperation, Signal, Volume XVI, Number 7, March 1962.

2. Policy Planning for Space Telecommunications, A Staff Report prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate. Published by the Government Printing Office, 4 December 1960.

3. Raish, L. R.: International Agreement: Key to Military Global Telecommunications, Signal, Volume XVI, Number 7, March 1962.

4. Loeber, C. W.: The CCIR and International Telecommunications Developments, Signal, Volume XVI, Number 7, March 1962.

FREQUENCY ALLOCATION IN THE UNITED STATES

CHAPTER 4

1. THE GENERAL PROBLEM OF FREQUENCY ALLOCATION IN THE UNITED STATES

One of the vital problems in the management of our national affairs is that of determining policies for telecommunications planning and operations. The importance of telecommunications was emphasized in a study by the President's Communications Policy Board "Telecommunications — A Program for Progress", March 1951. In the preface of this study, the essence of the importance of telecommunications is presented:

> "One of the bulwarks of a free society is freedom of communications. Its commerce, its education, its policies, its spiritual integrity, and its security depend upon an unimpeded and unsubservient exchange of information and ideas.
>
> "One of the hopes for a peaceful world rests upon the ultimate possibility of extending this same freedom of communications beyond all barriers. War begins in the minds of men, and in the minds of men must be engendered the will for peace. We must, therefore, strive to facilitate a meeting of the minds of men everywhere, and through the liberating arts of communication to create the attitudes favorable to peace."

The Communications Policy Board listed eight concepts relative to the formulation and foundation of a national policy on telecommunications. Four of these concepts bear upon the utilization and conservation of the radio spectrum and are listed below:

> "(1) Radio frequency spectrum is a world resource in the public domain and measures to conserve and utilize the resource must be undertaken in the best interest both of this Nation and with due regard to the needs and rights of other nations.

"(2) The U.S. telecommunication system is essential to national security, to international relations, and to the business, social, educational, and political life in the country. Hence, the Government must remain alert to the problems of the system and be prepared to support measures necessary to insure the continued strength of the telecommunication system as a whole.

"(3) The U.S. considers the International Telecommunication Union to be the competent and appropriate international forum for negotiating worldwide agreements.

"(4) Specifically with regard to radio communication, the Board identified a set of more detailed policy actions:

(a) Radio frequencies assigned for transmission purposes with a view toward avoidance of harmful interference.

(b) Long-range radio frequencies for other than overseas circuits, normally shall be used only when other forms of communication, notably wire communication, are not adequate. Priorities in normal peacetime assignment shall be as follows, in the order named:

i. Frequencies predominantly, primarily, and directly for national security and defense

ii. Frequencies to safeguard life and property in conditions of distress

iii. Frequencies used in services that have no other adequate means of rapid communication when such communication is in the national interest and the frequencies for all other purposes, judged upon the merits of individual need."

It is obvious from the above that the President's Communications Policy Board felt strongly that emphasis must be placed on the conservation and good management of radio spectrum resources. It also noted the priority requirements for long-range radio frequencies for national security and defense purposes.

With a large population, a large geographical area, a large industry, and a large military organization, the United States is faced with a complex situation in the utilization of the radio spectrum for minimum interference and optimum benefit in broadcasting, point-to-point services, national defense communications, and public and private services. To carry out planning and coordination for the use of the spectrum, principal responsibility falls on the State Department, the Interdepartment Radio Advisory Committee and the Federal Communications Commission. However, these three organizations are but part of the national "communications - electronics community." Almost all of the government agencies (representing various types of C-E users) have a strong concern with spectrum utilization. Since the spectrum has definite technical limitations, each of the government agencies has at least a minimum individual interest as a user. Some agencies have other interests, as, for example, the State Department, which is concerned with the overall international use of the spectrum and the representation of the United States interests in this regard.

With a heavy program in air navigation devices, a military C-E activity using thousands upon thousands of equipments, and a public and private service requirement for large numbers of channels over large areas, the United States has a very basic and strong interest in ascertaining that the most beneficial use is made of the spectrum on an international basis.

2. THE COMMUNICATIONS-ELECTRONICS COMMUNITY

Since many government agencies are interested in and concerned with communications and electronics matters, it follows that the national "communications - electronics community" is large and has many members. Most of these members are concerned in one way or another with radio frequency allocation and management. Figure 4-1 shows the government agencies which are part of the "C-E Community." Some agencies, such as the Bureau of the Budget, have a basic interest in the "C-E Community" from an overall national interest standpoint. Likewise, note the various Congressional committees which have held hearings related to C-E affairs.

FRC

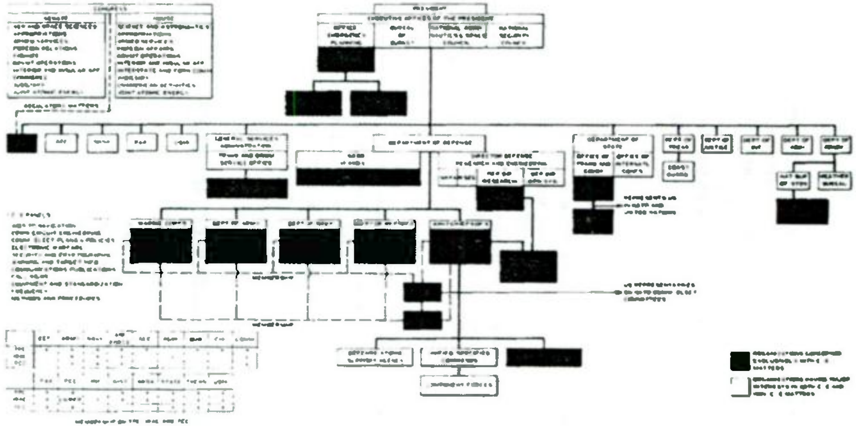

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Figure 4-1. U. S. Government Communications-Electronics (C-E) Community

The heavy use of C-E systems and equipment by the military organizations is reflected in the large number of military agencies shown in Figure 4-1.

As previously mentioned, three of the most important groups from a spectrum utilization standpoint are the State Department, the Interdepartment Radio Advisory Committee, and the Federal Communications Commission. Each of the groups has a basic frequency allocation responsibility in which it is often assisted or advised by other agencies.

3. THE STATE DEPARTMENT

The position of the State Department as the U.S. focal point for coordination of spectrum utilization internationally has been previously pointed out. Within the United States, the State Department, through its Telecommunications Division, serves to guide U.S. Agencies in establishing national positions with respect to various aspects of telecommunications. It also acts as the agency which represents United States interests in cooperative approaches to the international use of the spectrum and the resolution of interference cases. In this work the State Department is assisted by the Interdepartment Radio Advisory Committee, the Federal Communications Commission, and government-industry advisory committees. The State Department is advised by the Telecommunications Coordinating Committee which is made up of high level representatives of major government agencies, including the military.

As an example of coordinated activities, since the 1959 Geneva Radio Conference the United States has been carefully preparing for the special Space Conference to be held in 1963. The military services, the Federal Communications Commission, and other government agencies, together with the communication industry, made a study of frequency requirements for space communications. The National Aeronautics and Space Administration, the Federal Aviation Agency, the U.S. Information Agency, the Weather Bureau, the Department of Defense, and other government agencies, then supplied to the Interdepartment Radio Advisory Committee (IRAC) all available data and information. At the same time, the Federal Communications Commission (FCC) conducted formal proceedings and obtained technical material bearing on the problem from industrial organizations. The IRAC and FCC together arrived at preliminary conclusions for space frequency allocations to be proposed by the United States at the 1963 Space Conference. The FCC then asked, in the spring of 1961, for public comment on the proposals. These proposals were then revised and the final proposal document was transmitted to the State Department, where it was formally cleared on 7 September 1961. It has now been transmitted to the member nations of ITU for review. The title of the final document is Preliminary Views of the United States of America - Frequency Allocations for Space Radiocommunications.

4. THE INTERDEPARTMENT RADIO ADVISORY COMMITTEE (IRAC)

The Interdepartment Radio Advisory Committee (IRAC) has a membership consisting of representatives from the three military services, FAA, USIA, NASA, Department of Agriculture, Department of Commerce, Department of the Interior, Department of Justice, Department of State, and the Treasury. FCC furnishes a liaison representative.

IRAC has in the past acted as an advisory group to the Director of OCDM and later to the Director of the Office of Emergency Planning (OEP). Since the establishment of the position of Director of Telecommunications Management on 17 February 1962 within OEM, IRAC now provides advice to the new Director at his request.

In the past, acting for the President, or for the Director of OCDM or OEP, IRAC has coordinated frequency usage for and has assigned frequencies to government agencies subject to Presidential approval. It has coordinated and cooperated with the Federal Communications Commission, which has the responsibility and authority for licensing and assignment of frequencies for non-Federal U.S. users of the radio spectrum.

5. THE FEDERAL COMMUNICATIONS COMMISSION (FCC)

The Federal Communications Commission (FCC) was established under the Communications Act of 1934. It has statutory authority to regulate the interstate and foreign commerce in communications by wire and radio. Included in this jurisdiction is radio broadcasting, television, and communication activities of State and local governments. Licensing of satellites as relays for broadcasting, for private service, or for common carriers would thus fall under FCC jurisdiction. Rules and Regulations of the FCC are available through the Government Printing Office. They spell out specific requirements to be met by all classes of non-Federal telecommunications services. Basic to these regulations is the interference-free operation of equipments and systems by licensees, and the observance of frequency, power, propagation, and operating procedures as established by the FCC in granting each license.

Some devices radiate electromagnetic energy but do not fall under the six criteria for licensing of Section 301 of the Communications Act of 1934. For such devices, the FCC has promulgated Part 15 (Incidental and Restricted Radiation Devices) and Part 18 (Industrial, Scientific, and Medical Service) of its rules. The FCC has taken the position that operation of equipments covered by Parts 15 and 18 will not have interstate effects as long as they are kept within specified limitations and do not cause specific interference. Part 15 includes the requirement that devices causing harmful interference must be shut down or modified. In general, the devices covered under Part 15 include electric shavers, auto ignition systems, fluorescent lights, radio receivers, carrier current systems, wireless microphones, garage door openers and similar items.

Part 18 of the FCC Rules covering Industrial, Scientific and Medical equipment applies to such devices as industrial heaters, medical diathermy machines, ultrasonic equipment, RF stabilized arc welders, electronic ovens and RF excited neon signs.

Garlan and Whipple[4] have summarized radiation limits of devices covered under Parts 15 and 18 of the FCC Rules. These limits are shown in Tables I through X.

Further details concerning FCC Rules and Regulations, as well as FCC policies and procedures, are contained in Chapter 6 of this Volume. Appendix IV contains complete copies of Parts 15 and 18 of the FCC Rules.

6. THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT

By Executive Order of the President there was established on February 17 the new position of Director of Telecommunications Management in the Office of Emergency Planning. In the preamble of the Executive Order, emphasis is placed on several points--that "telecommunications is vital to the security and welfare of the nation", that "the radio spectrum is a critical national resource which requires effective, efficient and prudent administration", and that "there is an immediate and urgent

TABLE I

PART 15 --- RADIO RECEIVERS			
FREQUENCY (Mc)	INTERFERENCE LIMIT		
	TV	ALL OTHERS	
0.45 - 9	100	100	CONDUCTED (uv)
9 - 10	100	100 - 1000 *	
10 - 25	100	1000	
25 - 70	32		RADIATED (uv/m at 100 ft.)
70 - 130	50		
130 - 174	50 - 150 *		
174 - 260	150		
260 - 470	150 - 500 *		
470 - 1000	500 **		

* Linear interpolation
** Temporarily increased to 1000 uv/m for UHF TV receivers

TABLE II

PART 15 --- COMMUNITY ANTENNA TV SYSTEM	
FREQUENCY	RADIATED LIMIT
UP TO 54 Mc	15 uv/m at 100 feet
54 - 132 Mc	*20 uv/m at 10 feet
132 - 216 Mc	**50 uv/m at 10 feet
ABOVE 216 Mc	15 uv/m at 100 feet

* 400 uv/m
** 1000 uv/m
in sparsely inhabited area

(TABLES FROM GARLAN-WHIPPLE "CONTROL OF RADIO FREQUENCY INTERFERENCE FROM NONLICENSED APPARATUS" - SEE REFERENCE 4)

TABLE III

PART 15 --- LOW POWER COMMUNICATION DEVICES			
FREQUENCY	RADIATED LIMIT		OTHER LIMIT
10 - 160 Kc	$\frac{2400}{F}$ uv/m at 1000 ft.		
160 - 190 Kc	$\frac{2400}{F}$ uv/m at 1000 ft.	OR	1 WATT INPUT 50 FOOT ANTENNA
190 - 490 Kc	$\frac{2400}{F}$ uv/m at 1000 ft.		
510 - 1600 Kc	$\frac{24000}{F}$ uv/m at 100 ft.	OR	100 MILLIWATTS INPUT 10 FOOT ANTENNA
26.97 - 27.27 Mc			100 MILLIWATTS INPUT 5 FOOT ANTENNA
ABOVE 70 Mc	RADIATED LIMIT FOR RECEIVERS	AND	1 SECOND ON ONCE IN 30 SECONDS

TABLE IV

PART 15 --- GENERAL REQUIREMENT
RADIATED LIMIT (at all frequencies) = 15 uv/m at $\frac{\lambda}{2\pi}$ meters
$\frac{\lambda}{2\pi}$ meters = $\frac{157,000}{f_{kc}}$ feet

(TABLES FROM GARLAN-WHIPPLE, "CONTROL OF RADIO FREQUENCY INTERFERENCE FROM NONLICENSED APPARATUS" - SEE REFERENCE 4)

TABLE V

PART 18 --- ISM FREQUENCIES		
CENTER FREQUENCY	TOLERANCE	BAND
13560 Kc	6.78 Kc	13553.22 - 13566.78 Kc
27120 Kc	160 Kc	26960 - 27280 Kc
40680 Kc	20 Kc	40660 - 40700 Kc
915 Mc	25 Mc	890 - 940 Mc
2450 Mc	50 Mc	2400 - 2500 Mc
5850 Mc	75 Mc	5775 - 5925 Mc
18000 Mc	150 Mc	17850 - 18150 Mc
UNLIMITED RADIATION PERMITTED IN ISM BANDS		

TABLE VI

PART 18 --- MEDICAL DIATHERMY	
OPERATING FREQUENCY	OUT-OF-BAND RADIATION
13.56 Mc 27.12 40.68	25 uv/m at 1000 feet
ANY OTHER UP TO 915 Mc	15 uv/m at 1000 feet
915 Mc and above	TO GREATEST EXTENT PRACTICAL WITHIN STATE OF ART

(TABLES FROM GARLAN-WHIPPLE, "CONTROL OF RADIO FREQUENCY INTERFERENCE FROM NONLICENSED APPARATUS" - SEE REFERENCE 4)

TABLE VII

PART 18 --- INDUSTRIAL HEATERS (INCLUDES INDUCTION AND DIELECTRIC)	
OPERATING FREQUENCY	OUT-OF-BAND RADIATION
UP TO 5775 Mc	10 uv/m at 1 mile
ABOVE 5775 Mc	TO GREATEST EXTENT PRACTICAL WITHIN STATE OF ART

TABLE VIII

PART 18 --- ULTRASONIC EQUIPMENT			
FREQUENCY OF RADIATION	POWER (Watts)	RADIATED LIMIT	
		FIELD STRENGTH (uv/m)	DISTANCE (Feet)
UP TO 490 Kc	UP TO 500	$\frac{2400}{F}$	1000
	ABOVE 500	$\frac{2400}{F}\sqrt{\frac{\text{GEN. POWER}^*}{500}}$	1000
490 - 1600 Kc	ANY	$\frac{24000}{F}$	100
ABOVE 1600 Kc	ANY	15	100
*NOT TO EXCEED 10 uv/m at 1 mile			

(TABLES FROM GARLAN-WHIPPLE, "CONTROL OF RADIO FREQUENCY INTERFERENCE FROM NONLICENSED APPARATUS" - SEE REFERENCE 4)

TABLE IX

PART 18 --- R.F. STABILIZED ARC WELDERS	
OPERATING FREQUENCY	OUT-OF-BAND RADIATION
UP TO 5775 Mc	10 uv/m at 1 mile

TABLE X

PART 18 --- MISCELLANEOUS EQUIPMENT		
OPERATING FREQUENCY	POWER (Watts)	OUT-OF-BAND RADIATION (uv/m at 1000 feet)
13.56 Mc 27.12 40.68	UP TO 500	25
	OVER 500	$25\sqrt{\frac{\text{GEN. POWER}^{*}}{500}}$
ANY OTHER UP TO 915 Mc	UP TO 500	15
	OVER 500	$15\sqrt{\frac{\text{GEN. POWER}^{*}}{500}}$
915 Mc and above	ANY	TO GREATEST EXTENT PRACTICAL WITHIN STATE OF ART

* NOT TO EXCEED 10 uv/m at 1 mile

(TABLES FROM GARLAN-WHIPPLE, "CONTROL OF RADIO FREQUENCY INTERFERENCE FROM NONLICENSED APPARATUS" - SEE REFERENCE [illegible]) need for an examination of ways and means of improving the administration and utilization of the radio spectrum as a whole." The Executive Order states that the Director of Telecommunications Management shall:

"(a) Coordinate telecommunications activities of the executive branch of the Government and be responsible for the formulation, after consultation with appropriate agencies, of over-all policies and standards therefor. He shall promote and encourage the adoption of uniform policies and standards by agencies authorized to operate telecommunications systems. Agencies shall consult with the Director of Telecommunications Management in the development of policies and standards for the conduct of their telecommunications activities within the over-all policies of the executive branch.

"(b) Develop data with regard to United States Government frequency requirements.

"(c) Encourage such research and development activities as he shall deem necessary and desirable for the attainment of the objectives set forth in section 6 below.

"(d) Contract for studies and reports related to any aspect of his responsibilities."

Sections 3 through 10 of the Executive Order further define the responsibilities of the Director of Telecommunications Management.

"Section 3. The authority to assign radio frequencies to Government agencies, vested in the President by section 305 of the Communications Act of 1934, as amended (47 U.S.C. 305), including all functions heretofore vested in the Interdepartment Radio Advisory Committee, is hereby delegated to the Director of the Office of Emergency Planning, who may redelegate such authority to the Director of Telecommunications Management. Such authority shall include the power to amend, modify, or revoke frequency assignments.

"Section 4. The functions and responsibilities vested in the Director of the Office of Emergency Planning by Executive Order No. 10705 of April 17, 1957, as amended, may be redelegated to the Director of Telecommunications Management. Executive Orders No. 10695A of January 16, 1957, and No. 10705, as amended, are hereby further amended insofar as they are inconsistent with the present order. Executive Order No. 10460 of June 16, 1953, is hereby revoked.

"Section 5. The Director of Telecommunications Management shall establish such interagency advisory committees and working groups composed of representatives of interested agencies and consult with such departments and agencies as may be necessary for the most effective performance of his functions. To the extent that he deems it necessary or advisable to continue the Interdepartment Radio Advisory Committee, it shall serve in an advisory capacity to the Director of Telecommunications Management.

"Section 6. In carrying out functions under this order, the Director of Telecommunications Management shall consider the following objectives:

(a) Full and efficient employment of telecommunications resources in carrying out national policies;

(b) Development of telecommunications plans, policies, and programs under which full advantage of technological development will accrue to the Nation and the users of telecommunications; and which will satisfactorily serve the national security; sustain and contribute to the full development of world trade and commerce; strengthen the position and serve the best interests of the United States in negotiations with foreign nations; and permit maximum use of resources through better frequency management;

(c) Utilization of the radio spectrum by the Federal Government in a manner which permits and encourages the most beneficial use thereof in the public interest;

(d) Implementation of the national policy of development and effective use of space satellites for international telecommunications services.

"Section 7. Nothing contained in this order shall be deemed to impair any existing authority or jurisdiction of the Federal Communications Commission.

"Section 8. The Director of Telecommunications Management and the Federal Communications Commission shall assist and give policy advice to the Department of State in the discharge of its functions in the field of international telecommunications policies, positions and negotiations.

"Section 9. The Director of Telecommunications Management shall issue such rules and regulations as may be necessary to carry out the duties and responsibilities vested in him by this order or delegated to him under this order.

"Section 10. All executive departments and agencies of the Federal Government are authorized and directed to cooperate with the Director of Telecommunications Management and to furnish him such information, support and assistance, not inconsistent with the law, as he may require in the performance of his duties."

The position of Director of Telecommunications Management was filled by the appointment of Dr. Irvin Stewart, who headed the President's Communications Policy Board in 1950-51 and who also served on the Special Advisory Committee on Telecommunications in 1958.

7. OTHER AGENCIES

As shown in Figure 4-1, many other agencies play a part in the "communications - electronics community." Their responsibilities and functions extend from policy preparation to frequency assignment. For example, each of the military services has an office responsible for assignment of operating frequencies for electromagnetic emitters. These assignments are coordinated through the Director, J-6, Communications - Electronics of the Joint Chiefs of Staff. In turn, IRAC exercises over-all coordination to include the Department of Defense as well as other government agencies.

Such groups as the Joint Frequency Panel of Military Communications - Electronics Board, the Telecommunications Planning Committee, the Telecommunications Coordination Committee, and the various other panels of the Military C-E Board all serve to provide coordination, cooperation and liaison in the utilization of the radio spectrum.

REFERENCES

1. Raish, L. R.: International Agreement: Key to Military Global Telecommunications, Signal, Vol. XVI, No. 7, March 1962.

2. Pochyla, B. H.: The National Communications - Electronics Community (including Chart showing National Communications - Electronics (C-E) Community, Signal, Vol. XVI, No. 9, May 1962.

3. Policy Planning for Space Telecommunications, Staff Report prepared for the Committee on Aeronautical and Space Sciences, U. S. Senate, Government Printing Office, 4 December 1960.

4. Garlan, H., and Whipple, L. G.: Control of Radio Frequency Interference from Nonlicensed Apparatus, Report No. TR-6104, Federal Communications Commission, Office of the Chief Engineer, 1 September 1961, Washington 25, D. C.

GOVERNMENT PROGRAMS FOR INTERFERENCE-FREE SPECTRUM UTILIZATION

CHAPTER 5

1. REQUIREMENTS FOR SPECIAL PROGRAMS FOR OPTIMUM SPECTRUM UTILIZATION

Although the allocation and assignment of frequencies is a basic approach to effective spectrum utilization, it is nevertheless necessary that other steps be taken if the spectrum is to be properly managed. The large number of emitters and their power and proximity to each other requires that careful studies be made of their relationships and that these relationships be carefully controlled. There are six types of action which are desirable to accomplish this:

A. Determination of spectrum signatures of all equipments--this includes power and frequency characteristics of emissions of all devices, susceptibility characteristics of all receivers, and radiation patterns and propagation characteristics of all antennas.

B. Prediction of inter-system and inter-equipment effects based on A. above. By appropriate prediction methods and use of mathematical models and computers, the effects of large numbers of equipments on each other can be determined.

C. Establishment of system and equipment spectrum data files to which reference can be made by designers and system planners for effective planning of spectrum usage.

D. Coordination of system planning and operation through conferences and meetings of spectrum users.

E. Establishment of standards, specifications, rules, and regulations regarding design and operation of radio equipment and systems for interference-free operation.

F. Monitoring and measurement programs to ascertain that design and operation of equipment is carried out in accordance with specifications and regulations.

In order to accomplish the six actions discussed above, the Government has established a number of programs which are briefly described in this Chapter.

2. MONITORING BY THE FEDERAL COMMUNICATIONS COMMISSION

To ascertain that licensed stations are operating on frequency and in accordance with the Rules of the FCC and that unlicensed emitters are not causing interference, the FCC operates a group of 18 monitoring stations. The stations are equipped with direction finding facilities so that unknown interference sources can be located by triangulation. When FCC measurement of frequency or other characteristics of a licensed transmitter shows that the station is operating in an unauthorized manner, the owner is notified to correct the condition.

In addition to domestic monitoring, the FCC monitor stations, plus 15 monitor stations owned by private companies such as RCA, Mackay, AT&T, Tropical Radio, Press Wireless, and Globe Wireless, participate in the International Monitoring Service (see Chapter 3 of this Volume). The International Monitoring Service operates under Article 13 of the Geneva, 1959, Radio Regulations of the ITU. The State Department has designated the Field Engineering and Monitoring Bureau of the FCC as the U.S. Centralizing Office for International Monitoring. This agency gathers spectrum occupancy data from the 33 U.S. monitoring stations and sends it to the International Frequency Registration Board of the ITU for use in frequency allocation studies.

3. RADIO INTERFERENCE AND TELEVISION INTERFERENCE COMMITTEES

In order to encourage the voluntary participation of users of the radio spectrum in self-regulation, the FCC has worked with the local industry and other groups in various localities to establish Radio Interference Committees. These Committees seek methods to prevent and eliminate interference among the radio spectrum users. They maintain an effective liaison among themselves and meet regularly to discuss interference conditions. The FCC assists in solution of the more difficult interference situations.

In various areas of the country where interference has become an especially difficult problem, informal liaison is conducted and conferences are held from time to time to discuss specific interference cases. For example, the Regional Office of the Federal Aviation Agency in Los Angeles has held several meetings to resolve interference conditions between the user agencies in the Los Angeles-San Diego area where there is a particularly heavy concentration of X, S, and L band pulse transmitters. Such meetings are particularly effective in finding solutions to interference problems which are or could become very troublesome.

5. AREA FREQUENCY COORDINATORS

Because of the critical spectrum utilization problems existing in the area of certain military establishments, Area Frequency Coordinators perform joint radio frequency coordination in these particular areas. At the present time such Area Coordinators have been established at the Air Force Missile Test Center at Patrick Air Force Base in Florida (Cape Canaveral); at the U.S. Army Electronic Proving Ground at Fort Huachuca, Arizona; at the White Sands Missile Range, Las Cruces, New Mexico; and at the Naval Air Missile Test Center at Point Mugu, California.

The Area Frequency Coordinator in Florida accomplishes interservice frequency coordination within a 200-mile radius of Patrick Air Force Base and within a 200-mile radius of Eglin Air Force Base. The Fort Huachuca Frequency Coordinator accomplishes the frequency coordination for the entire state of Arizona. The White Sands Area Frequency Coordinator accomplishes frequency coordination for the entire state of New Mexico and other areas within a 150-mile radius of the White Sands Missile Range. The Area Frequency Coordinator at Point Mugu accomplishes frequency coordination within a 200-mile radius of Point Mugu including frequency coordination for the Naval Ordnance Test Station at China Lake, California, and Edwards Air Force Base, California.

The Area Frequency Coordinators maintain current records of frequencies which have been coordinated for use in their areas of cognizance. They also provide advice as to probability of harmful interference which might be caused to or from proposed operations. The Area Frequency Coordinators frequently arrange for time sharing and technical adjustments to minimize interference.

6. THE DEPARTMENT OF DEFENSE COMPATIBILITY PROGRAM

On 19 July 1960, the Secretary of Defense approved a major program for electromagnetic compatibility in the military electronic systems and their environments. This program seeks to attain a high level of compatibility among the many thousands of military equipments which are required in modern military operations.

A continuing enlargement and extension of military electronics programs means that not only are the numbers of equipments and systems in operation increasing but also there is a continuing increase in types of modulation and sophisticated signal propagation methods. All of these things mean further pressure on spectrum utilization and a continuing enlargement of the problem of obtaining compatibility among the equipments. Since the primary requirement of military systems in comparison to civilian commercial systems is the operational effectiveness under combat conditions, economic factors which normally call for obsolescence and depreciation over a relatively long period of time play very little part.

The objective of the electromagnetic compatibility program is to insure that each electronic system operates at design levels of performance without causing or receiving unacceptable degradation in its operational environment. Equipments and systems which are degraded to the point of rendering weapons systems inaccurate or ineffective through incompatibility are wasted and might as well not have been procured.

One of the principal accomplishments of the compatibility program to date has been the preparation and publication of MIL-STD-449A, which was issued on 24 October 1961, entitled "Military Standard Radio Frequency Spectrum Characteristics, Measurement of." This Standard clearly defines the requirements for minimum spectrum signature characteristics and their measurement. Additional manuals and standards will probably be issued under this same program.

Of primary importance in the compatibility program is the buildup of a library of spectrum signatures. The collection plan was approved for this purpose on October 28, 1960, and implementation by the military departments is now under way. In the Army, the work of collecting spectrum signatures has been assigned to the Army Electronic Proving Ground at Fort Huachuca, Arizona, as a task for the Electronic Environment Test Facility. In the Navy, the Bureau of Ships is currently updating a spectrum signature collection program under the auspices of the

Bureau of Ships. The Air Force program is being conducted by the Rome Air Development Center. All of these collection programs are attempting to build a complete library of radio frequency spectrum characteristics of military electronic equipment. This library will be maintained at the Electromagnetic Compatibility Analysis Center operated by the Department of Defense at Annapolis, Maryland. When complete it will allow a more thorough approach to the problem of planning compatible electromagnetic systems for the future.

Additional parts of the program include research into measurement techniques and test procedures. Much remains to be done in the study of measurement methods and procedures which will produce reliable and repeatable results. In addition, considerable work is required to produce components and equipment which radiate less interference and have a lower susceptibility to interfering signals.

Related to the compatibility program is the work in the preparation of military standards and specifications concerning the design of equipment and systems. These specifications can be expected to be tightened and more thoroughly enforced as time goes on. The most widely used military standards and specifications pertaining to radio frequency interference are contained in Appendix 5 of this Volume.

As might be expected, the compatibility program of the Department of Defense has resulted in other similar programs being established within government agencies and even within industrial organizations. Toler and Norton[4] have described the establishment of such a program at the George C. Marshall Space Flight Center at Huntsville, Alabama. This program is oriented toward space vehicles and space vehicle checkout facilities. At Huntsville the compatibility program has been initiated and is being implemented by the Electromagnetic Interference Unit of the Quality Assurance Division. The specifications of the over-all interference control program have been divided into five different major tasks:

1) Establishment of philosophy;
2) Education;
3) Prediction;
4) Testing suppression and reporting; and
5) Specification development.

It is to be expected that the compatibility and spectrum signature programs will have a considerable impact on equipment and test instrument design. Test instruments currently available are relatively unsatisfactory for the acquisition and recording of the large quantities of measurement data required by the compatibility programs. The electronics equipments and systems themselves have, for the most part, been designed with built-in compatibility problems, particularly with respect to system interfaces. Standardization of design methods for compatibility of equipments and systems will require continuing attention to design details which in the past have been ignored due to lack of specification requirements for minimum interference.

7. THE EETF PROGRAM AT FORT HUACHUCA, ARIZONA

The U.S. Army Electronic Proving Ground at Fort Huachuca has the responsibility for operating an Electromagnetic Environmental Test Facility (EETF) Program. This program concerns itself principally with interference problems encountered by tactically deployed units. The Facility is capable of detecting the presence of interference, determining the amount of degradation caused, determining the source, and making recommendations for reduction. The environment of the Facility allows these determinations to be made under the same conditions as in a combat situation. The objectives of the EETF[8] are:

> "a. To reveal and determine the incompatibilities of existing Army equipment and systems.
>
> "b. To suggest modifications to existing Army equipment to reduce interference.
>
> "c. To provide a firm basis for the establishment of realistic standards for new Army Equipment.
>
> "d. To test Army methods of frequency assignment.
>
> "e. To test newly developed Army equipment prior to its acceptance by the Army."

In meeting the above objectives, the following functions are performed:

> "(1) Generation of an environment equivalent to that which the equipment tested would experience if that equipment were deployed under battlefield conditions.

"(2) Control of the environment to facilitate rapid testing as well as the provision of a frequency monitoring capability to insure accurate results without interfering with electromagnetic activity outside the test area.

"(3) Testing of communication links in such a manner that the existence, extent, and cause of interference may be determined objectively.

"(4) Evaluation of test results to enable accurate analysis of the situation as well as provide the basis for corrective recommendation."

8. FUTURE PROGRAMS

It is to be expected that the increasing emphasis on compatibility in communications-electronics systems will result in expanded programs in many areas. Manufacturing and production requirements will become more severe and, as is the case with reliability and quality control programs, assurance of compatibility will be sought by increased testing activities, including enlarged spectrum signature measurements by manufacturers as well as in the field. A continued upgrading and improvement of specifications, standards, and test procedures will be emphasized. Last but not least, an increased effort will take place to produce test instruments and techniques better adapted to solving the massive problems of data acquisition, recording, and processing.

Professional and technical organizations will provide increasing assistance to the government and to industry in studying and resolving compatibility and RFI problems. Prominent among such organizations are the Institute of Radio Engineers and the Electronic Industries Association. Each of these has committees and special groups which are concerned with RFI problems.

In the Institute of Radio Engineers, the Professional Group on Radio Frequency Interference sponsors annual symposiums and publishes its Transactions several times each year. IRE also has a Technical Committee on Radio Frequency Interference with several subcommittees dealing with RFI as it is related to basic measurements, radio and TV receivers, radio transmitters, industrial electronics, and mobile communications equipment.

Within the Electronic Industries Association, Committee M-5 (Military Electronic Systems) has a Committee M-5.8 which is concerned with RFI. In general, the M-5.8 Committee studies and develops technical criteria and procedures which will guide electronic systems designers to insure electromagnetic compatibility of new systems and equipment. Electronic compatibility, as used here, means the compatibility of electronic components or systems to be operated in the intended operational environment at designed levels of efficiency without degradation due to unintentional interference. The group also studies and coordinates comments on existing and proposed Military Specifications and other documents concerned with electromagnetic interference reduction and control. Electromagnetic interference specification documents are proposed to the Military where deemed required. Educational activity regarding electromagnetic interference is promoted by the dissemination of information to industry through reports and papers. A system designers' guide for system compatibility is being developed. The group also fosters industry-DOD cooperation with respect to the data collection and implementation of the electromagnetic compatibility plan.

Future years should see an expanding program of cooperation between the government, industrial groups, and professional organizations in working toward a goal of complete communication-electronic system compatibility.

REFERENCES

1. Turner, G. S.: The International Monitoring System and the Work of CCIR Study Group VIII, Signal, Volume 16, No. 7, March 1962.

2. ARDC Frequency Management Procedures, ARDC Manual 100-1, 2 May 1960, HQ Air Research and Development Command (now HQ Air Systems Command), U.S. Air Force.

3. Brady, R. F.; Dean, W., Jr.; Randall, H.; Schulte, O. J.: The Progress of the Department of Defense Electromagnetic Compatibility Program, Conference Proceedings, 5th National Convention on Military Electronics, June 26, 27, 28, 1961, Washington, D.C., page 191.

4. Toler, J. C., and Norton, C. M.: Establishment of an Electromagnetic Compatibility Program, Symposium Digest, Fourth National Symposium on Radio Frequency Interference, June 28-29, 1962, San Francisco.

5. Sullivan, A. H., Jr.; Zink, H. D.; Dozier, J. J.: The Impact of Spectrum Signature Programs on Equipment and Test Instrument Design, op. cit.

6. Brosius, G. D.: The Army's Electromagnetic Environmental Test Facility, op. cit.

7. Hoehn, A. J., and Michalk, E. R.: Use of the EMETF Field Facility for Validation of Interference Prediction Model, op. cit.

8. Woolwine, C. C.: The Mission and Operating Philosophy of the Analysis Center, Proceedings of the 7th Conference on Radio Interference Reduction and Electronic Compatibility sponsored by the Army, Navy and Air Force, conducted by Armour Research Foundation, Chicago, Illinois, 7, 8, 9 November 1961.

9. Cohn, S. I.: The Technical Program of the Analysis Center, op. cit.

10. Babcock, L. F.: A Facility for the Investigation of Radio-Interference Problems, op. cit.

1. THE NEED FOR STANDARDIZATION OF INTERFERENCE MEASUREMENT

In order to obtain realistic results in interference measurement and suppression, to allow exchange of ideas and information among interested parties, and to achieve results which give significant information concerning the ultimate effect of the interference, standard methods of measuring interference must be established. To meet this requirement, the military services have set forth a number of military specifications establishing standard test equipment and test procedures, with the ultimate end of realizing interference-free performance of all military electric and electronic installations.

This achievement can be considered only as an ultimate goal at present due to the obvious fact that the problem is far from eliminated; however, RFI is being reduced significantly by new suppression technology which is developing at an impressive rate. The result is that any specification dealing in a quantitative way with the measurement of RFI can reflect only the state-of-the-art on its issue date.

In any event, RFI test procedures must continue to be stipulated, even though their expected period of usefulness may be short. Simultaneously, these procedures need to be continuously reviewed in the light of new developments. The need for this two-fold approach is best explained by considering the problems of RFI measurement inherent in those techniques, generally accepted and in development.

In an inexact science such as RFI control, measurement techniques developed by independent agents must be constantly compared to previously accepted criteria and at the same time be evaluated with a view toward expanding their limited application to the forming of new or revised criteria. Effective standardization, preferably in the form of government specifications, can accomplish this. The measurement of the interfering signals themselves is the level at which standardization is best applied. Consideration of the various types of signals will help define the problem and suggest the need for establishing standards.

In general, the nature of an interfering signal is such that no single parameter completely describes it. A comprehensive description can be given in either one of two equivalent forms: (1) a plot of signal amplitude as a function of time; or, (2) a plot of signal power density as a function of frequency. The first is well known by the term wave form, the second, the term frequency distribution. For interference of a random, intermittent or impulsive nature, neither of these forms is suitable for the quick and easy determination of interference characteristics, since each requires a very large number (theoretically an infinite number) of individual measurements. If the interfering signal consists of a single transient, there is, indeed, no simple method available of obtaining significant information about it by means of a single or a very small number of measurements. Most interfering signals encountered in practice are either roughly periodic, or such that the small differences between samples of the signal taken at different times is not significant (that is, their statistical description is stationary). In either case, information about the signal at all times is not required, and attention may be focused on just a short space of time, either a cycle or an arbitrary interval. Furthermore, properties may be defined which can be measured by means of a single measurement, and these properties may be used to characterize the signal. The properties most commonly used are the true average, (rarely used because it is usually zero); the half-cycle average, usually simply called "average"; the root-mean-square; and the peak values of the interfering current or voltage taken either over a period or over an arbitrary time interval.

For purposes of analysis, all interfering signals may be said to consist of a series of pulses. In practice, many signals may be classified as one of two types: the impulsive type, in which the individual pulses are very short as compared to their average repetition rate, so that a comparatively long period of silence exists between successive pulses; and the random type, often called "white noise," in which the pulses follow one another so closely that the character of the individual pulse is completely lost. There is no sharp boundary between the two, and all intermediate stages are possible. Yet, a large group of interfering signals encountered in practice can definitely be placed in one or the other.

Interference of the impulsive type will show very high peak values and very low average or root-mean-square values. In fact, on some types of meters reading average or root-mean-square values, an impulsive type of interference may indicate near zero and yet the interference may be seriously degrading system performance. Random interference, on the other hand, is best measured by its average or root-mean-square value, while its peak value, which may be only slightly larger than the average and may be subject to considerable random variation, is of no great significance. Thus, it is seen that a meter, or its mode of operation, must be chosen intelligently according to the type of interference to be measured.

Just as the type of meter to be used in measuring generated interference must be chosen according to the type of interference to be measured, so the generator used in susceptibility tests must be chosen according to the type of response of the receiver. Since any type of interference may be present, the susceptibility of a receiver should be tested with a signal of the type which causes the greatest response.

Since all receivers terminate in some kind of output device capable of responding to interference, the simplest and most direct means of detecting the presence of interference is by using the output equipment normally installed.

If all the electrical components of a system are of proper design and have been correctly installed, inter-system interference should be below an acceptable level for all susceptible components. The "General Acceptance Tests" set forth in military specifications cover much of this area. Equipments which do not meet these requirements must go back for re-work and then be subjected to detailed tests of a quantitative nature. The general acceptance tests have the additional advantage of testing both the efficacy of the sources and the susceptibility of the receivers during the same measuring process.

The procedures just described are of little help to the manufacturer who wants information about a single component before it is installed. Hence, test instruments have been constructed and procedures have been set up to enable the manufacturer to evaluate his product in a way which, as much as possible, insures satisfactory performance. The best guarantee is for those in charge of design to become familiar with the latest issues of military specifications.

2. THE ROLE OF SPECIFICATIONS AND STANDARDS IN RFI REDUCTION

The basic objective of all RFI specifications and standards of the military services is to insure the operational compatibility of components, communications systems, weapons systems, etc., through measurement and control.

The introduction of military specification MIL-I-26600 and others dealing with acceptable levels of conducted interference, radiation, and susceptibility, has done much to make systems engineers and design engineers aware of the consequences of RFI. Unfortunately, in many instances, the system is designed and constructed without any thought being given to the applicable RFI specification until after the system is completed and its functional requirements have been met. Usually when the finalized equipment is tested, it fails to meet the RFI specification, and subsequently requires expensive modification.

The design engineer must keep in mind that the limits set by the military specifications are reasonable and necessary. In all cases, actual limits were imposed only after careful study and the accumulation of a vast amount of experience. It is usually found that, as soon as deviations are granted, the final product is again unsatisfactory, and much time and money is again wasted in order to make the necessary "fixes." Frequently, it is found that more time is lost by this procedure than was gained by granting the deviations; and the final product is never as satisfactory as a design that met the specifications from the beginning.

The most complicated problem in carrying out an effective interference control program is making the various echelons of subcontractors and suppliers aware of interference problems and their governing specifications. Strict and persevering control must be exercised in procurement of subassemblies and components which, when mated into the assembly, can give rise to sometimes unpredictable sources of interference. The prime contractor has the dual task of orienting his suppliers toward RFI-proof design and fabrication practices, and of becoming thoroughly cognizant himself of the relationship of interference arising in the basic subassemblies and the subsequent propagation of this interference through his equipment. He should give as much attention to specifications stating limits of RFI as he does to those setting forth restrictions on other interconnecting factors such as reliability, temperature, and vibration.

2.1 MILITARY SPECIFICATIONS

Along with the expanding scope of RFI control technology over the past decade has come a corresponding increase in military specifications on RFI. Where early specifications concerned themselves only with outgoing interference from an equipment, currently released specifications include restrictions in regard to other aspects of RFI, such as susceptibility of equipment, antenna-conducted interference, and intermodulation. Even present day regulations lean much more heavily on the outgoing aspects of RFI than on susceptibility. This is because the state-of-the-art in radiation measurements is more advanced than that of susceptibility measurements.

Additionally, military specifications have sought to keep pace with the "spectrum explosion" and therefore have embraced the wider frequency spectrum now in use. This has produced a ten-fold increase in the high end of the frequency bands from that heretofore encompassed by military specifications.

2.2 FEDERAL COMMUNICATIONS COMMISSION REGULATIONS

The Federal Communications Commission Regulations differ from military specifications in many areas. Most important of these is that the FCC has enforcing power, to the extent that cases of RFI in excess of FCC stated restrictions can result in the shut-down of the offending source. It has the legal responsibility for RFI control. Additional power is granted in that it is able to step in for regulatory action in those areas where specific FCC rules have not yet been evolved, and it enjoys discretional capability in all areas of interest with respect to RFI control.

Unlike the control effect of military specifications, the FCC rarely has power over a manufacturer who is developing what may result in a potential source of RFI; but rather its rules apply only to the user. Therefore, in military equipment, the use of RFI-free techniques for development and fabrication is required by the military specification, but when the equipment is in operation, the FCC is primarily responsible for the perpetuation of interference-free practices through its monitoring and enforcing functions.

It can be seen that the control of the commercial manufacturer is quite different from the military one. Other than following FCC recommendations concerning RFI-proof design, he is subject to no RFI control requirements. Only when the individual user violates good interference control practice can the FCC utilize its regulatory powers.

Finally, FCC control cannot, by nature, extend into the aspects of equipment susceptibility; rather its regulations cover outgoing radiation only. This, when coupled with the presently incomplete control over equipment susceptibility in the design phase by military specification, causes a lack of effective control which places a significant obstacle in the road to obtaining electromagnetic compatibility.

The comprehensiveness of the FCC's role in RFI control is best demonstrated by citing some examples of the area in which it performs its functions. Besides its routine control over licensed operations, the

FCC takes measurements and sets limits in three general categories: incidental radiation devices, restricted radiation devices, and ISM (Industrial, Scientific and Medical) equipment.

Control over incidental radiation devices, that is, those whose RF radiation is unintentional, varies, necessarily, from case to case. Such mechanisms as electric motors, auto ignition systems, fluorescent lights, and electric razors can be regulated only on a complaint basis, and the FCC has the right to enforce modification or shut-down when their RFI problem is serious.

Restricted radiation devices are those unlicensed sources that make use of RF energy intentionally but which may permit its escape through radiation or conduction along wires. Radio receivers, carrier current systems (such as community TV antennas and campus radio), and low power communications (like garage door openers) are examples of this category. More strict regulation is possible here; all three types are subject to stringent output limitations. In addition, TV and FM receivers are being provided with FCC certifying seals to help the public avoid receivers that are apt to have an RFI problem. Overriding these regulations is the general requirement that output from devices of this type shall not exceed 15 microvolts per meter at a distance of $\lambda/2\pi$ meters.

The operation of ISM equipment, which is defined as any device that uses electromagnetic waves for industrial, scientific, or medical purposes, is also unlicensed but closely controlled by the FCC. There are general conditions of operation for all ISM-type gear and additional restrictions on individual source types. The four major devices under this heading are diathermy equipment, induction and dielectric heaters, ultrasonic apparatus, and RF stabilized arc welders.

The general regulations allocate specific frequency bands for ISM use with no radiation limits; additionally, radiation is permitted outside these bands, but with strictly regulated limitations.

Control over diathermy, industrial heaters, and ultrasonic apparatus have been specified and in operation for many years, but the problems of regulating RF stabilized arc welding are still unresolved by the FCC. This energy is broadband and subject to wide fluctuations in load conditions. The wide use of portable arc welders adds the variable of operating environment, and makes standardization difficult.

Pending the adoption of permanent rules governing this type of radiation, arc welders are temporarily subject to the limits now applied to industrial heating equipment.

3. DEFICIENCIES IN MILITARY SPECIFICATIONS AND STANDARDS

3.1 MILITARY SPECIFICATION MIL-I- 26600

Deficiencies in specifications dealing with the measurement of both radiation and susceptibility may be a source of difficulty to the system engineer seriously interested in preventing RFI by proper original design, rather than by remedial measures.

As an indication of the extent of the problem, consider the following two paragraphs from MIL-I-26600.

The first paragraph is (4. 3. 2) Radiated Interference; it states:

"Radiated interference fields in excess of the values given in figures 6, 7, 8 and 9 shall not radiate from any unit, cable (including control, pulse, IF, video, antenna transmission and power cables) or interconnecting wiring over the frequency range of 0. 15 to 10, 000 mc for CW and pulsed CW interference and 0. 15 to 400 mc for broadband impulsive interference. This requirement includes the transmitter fundamental, spurious radiation, oscillator radiation, other spurious emanations and broadband interference. This does not include radiation from antennas."

Paragraph (4. 3. 4. 2) on Radiated Susceptibility states:

"No change in indications, malfunctions or degradations of performance shall be produced when the equipment is subjected to a radio frequency field. This field shall be established with a signal generator driving the antenna listed below. Care shall be taken to use matching networks when required. The voltages specified are those calculated to exist across the antenna terminals. The test setup is shown in Figure 26 for the rod antenna and is similar to Figures 16 and 17 for the other antennas, with the signal source replacing the interference meter.

Frequency	Microvolts	Antenna
0. 10 to 25 mc	100, 000	41 inch rod
25 to 35 mc	100, 000	35 mc dipole
35 to 1000 mc	100, 000	tuned dipole
1000 to 10, 000 mc	100, 000	non-directive antennas"

First, consider the implications of the paragraph on radiated interference, (4. 3. 2) which, incidentally, uses the same antenna setup as required by paragraph (4. 3. 4. 2). It should be noted that the drawings which show how these radiated fields are to be measured indicate a standardized arrangement which is used regardless of the configuration being tested. No consideration is given to the fact that the RFI polarization might be different from the antenna polarization for some equipments but not for others. This means there could exist two equipments that both meet the specification and yet one of them could radiate much more energy than the other. A careful examination of all the conditions for the measurement of radiated interference shows additional cases where similar situations could result. This is not to be construed as a condemnation of the specification, however. The problem of spurious and leakage radiations from all classes of equipments is a very complex one and to be solved exactly would require a different measurement setup for each different type of equipment, which, of course, would be undesirable. The present specification has evolved as a means of standardizing all radiated interference measurements so that measurements made on an equipment at one facility can be compared with those made at another. Admittedly, there is a certain degree of arbitrariness inherent in these setups, but until a better arrangement can be established, this method of measurement must be employed. An intensified study into economical means by which measurements can be carried out without these limitations would yield great benefit.

The fact that standardization is yet to be applied to the susceptibility aspect of RFI control, especially in its broadband aspect, is itself complicated by these same arguments. It should be noted that this situation is due less to any oversight than to a definite limitation in the state-of-the-art of acceptable signal generators. High-powered, broadband noise or impulse generators do not exist which have the precision requisite for repeatable, standardized measurements. The only possible way to test susceptibility at the present time is to apply the highest practical CW signal to the antennas specified and noting any degradation in performance. The adaptation of high-powered noise and pulse generators for incorporation into a military specification to allow broadband susceptibility measurement would be an important step in filling this lack.

The lack of any definition in MIL-I-26600 of the relationship between the amount of radiated interference that one equipment generates and the susceptibility of another equipment to this same radiation is the result of many other factors in addition to those noted above. Among them are the following:

a. a lack of knowledge of the incident field strength on the susceptible equipment, since the specification defines only the voltage that should exist across the antenna terminals.

b. the lack of knowledge of the exact part of the susceptible equipment that responds to the incident energy.

c. the lack of knowledge of the mechanism and location of the radiated interfering energy.

Because of these factors, it is necessary, when designing a system that will not interfere with itself, to make more specific tests than are outlined in the specification. For any specific equipment, all these factors are determinable, but they require measurements far beyond MIL-I-26600.

3.2 MILITARY SPECIFICATIONS IN GENERAL

Recent detailed analyses of the military specification aspect of RFI control have yielded a wide spectrum of constructive criticisms and suggestions in addition to those already noted concerning amplification of susceptibility measurement and control. The following four ideas stand out as most important:

a. Augmenting of Test Procedures

Existing specifications on RFI suppression are based on the point-by-point method of measurement, which involves nothing more than searching and measuring, incrementally, the frequencies and modulations of interest. This method is valuable for measuring CW interference and also, but to a lesser degree, for measuring broadband interference, provided that each frequency is analyzed separately. The advantages in augmenting this approach with the use of a broadband VTVM peak-type detector circuit are worth attention; a single readout such as this would be an instantaneous check-out of an applied RFI reduction method. Another addition to the current procedure could make use of a frequency sweep presentation; this would obviate the large number of point-by-point measurements now required over an extensive frequency range.

b. Classification of Test Equipment and Procedures

Presently, military specifications are not detailed enough to clarify which test equipment is the most effective for measuring which source of RFI. Thus, systems requiring high reliability are tested in the same manner as low-reliability commercial items not involved in very strict RFI control environments. One of two possibilities exist in these cases: expensive over-design if the tolerances are strict, or malfunctions, if they are not.

c. Compliance Criteria

There is, at present, a distinct gray area between absolute acceptance of an item and absolute rejection, based on existing RFI specification limits. Into this region fall many systems and components which, in general, meet the requirements but which exceed interference tolerances at isolated spots by a small value. Under the existing specifications they should be rejected entirely; however, in practice waivers of the specifications are granted because of urgency or the estimated added expense of further RFI suppression measures. Criteria are required which would establish general, as well as specific, guide-lines by which systems or components could be accepted or rejected depending on the relative importance of the offending parameter.

d. Field Measurements

A de-emphasis on RFI measurements in the field, with an emphasis on making these same measurements in a shielded room, is a current trend. It is true that many equipments do not lend themselves to shielded-room measurement; for example, those which are very large or whose operational characteristics dictate a certain field environment. However, the blanket specification requiring field measurements can be supplanted, in a great many cases, by a clarification of the exact needs of the operational and testing environment. If this were done, the great advantages inherent in shielded enclosures could be realized. The two most important factors are: (1) that the screen room provides, in many cases, a more realistic physical environment; e.g., the metal structure to be expected in missiles and aircraft, and (2) that the enclosure serves to confine the area of measurement, both physical and electrical, and excludes outside interference, thus yielding a quicker and more positive identification of the RFI source.

4. INTERFERENCE SPECIFICATION COMPARISON

4.1 GENERAL

In this section a brief discussion is presented of the specifications that are in effect for controlling the measurement and suppression of interference in communications-electronics (C-E) equipments from other C-E equipments and electrical equipments. Special emphasis is given to the more comprehensive specifications utilized by the military services and the FCC. (See Appendix V for a reprint of all specifications and standards discussed in this section).

Figure 4-1 is a listing in tabular form of the specifications that cover measurements, suppression, and shielded enclosures. This figure is intended to provide a quick comparison of the specifications that a contractor may be required to meet when manufacturing a component or system for the government. The measurements required by each specification were generalized for inclusion on the chart.

4.2 MIL-I-6181D

MIL-I-6181D (which superseded MIL-I-006181C) was originated in November 1959. This specification is mandatory for use by the Department of the Army, Navy, and Air Force; the Signal Corps is custodian of the specification. The specification covers the design requirements, test procedures, and limits of interference for electrical and electronic equipment to be installed or closely associated with aeronautical equipment in the frequency range of 150 kc to 10,000 mc.

Four categories of military test equipments and their commercial equivalents are included in the specification. Test setups are shown in pictorial form for each general measurement to be performed and the acceptance limits are included in graphical form. The specification does not include the suppression procedures to be undertaken if the equipment(s) under test fails to meet the acceptable limits. In addition, a sample outline is included for preparing a test plan and test report.

The measurements to be performed under this specification include conducted, radiated, antenna conducted, and susceptibility measurements. The conducted interference measurements are performed in the frequency range of 150 kc to 25 mc. The conducted interference level is measured on all power leads and any other connecting leads between equipments under test.

Radiated interference measurements are made in the frequency range of 150 kc to 10,000 mc for CW and pulsed CW interference, and from 150 kc to 400 mc for broadband interference. Measurements are made at all cables, antenna leads, power cords, cases, etc. The measurements must include radiations at the fundamental and harmonic frequencies, oscillator frequencies, and other spurious frequencies that may be encountered.

Antenna conducted interference is any interfering signal that can be measured at the antenna terminal. Transmitter key-up and receiver measurements are conducted in the frequency range 150 kc to 10,000 mc. Measurements are usually made up to the 20th harmonic or 1000 mc, whichever is higher, but not above 10,000 mc. These measurements include both receiver local oscillator radiations and other transmitter radiations under key-up conditions.

Transmitter key-down measurements are conducted under normal operations except the transmitter is operated into a dummy load. These measurements are made in the frequency range of 150 kc to 10,000 mc and include checking oscillator fundamental and harmonic frequencies, frequency multiplier outputs, BFO outputs, crystal saver circuits, etc. Normal measurements are made through the 10th harmonic or 1000 mc, whichever is higher, but not to exceed 10,000 mc. The second and third harmonics must be 60 db below the fundamental output power, and all other harmonics and spurious outputs 80 db below fundamental power output.

Interference susceptibility measurements are performed on equipments under this specification. RF conducted susceptibility is measured in the frequency range of 150 kc to 10,000 mc; no degradation in performance may be noted when a 100,000 μv signal is applied to the test sample over the entire frequency range. AF conducted susceptibility is measured in the frequency range of 50 to 15,000 cps; no degradation in performance may be noted when a 3-volt rms signal is applied to the test sample over the frequency range. No degradation in performance is permitted when a 100,000 μv RF signal is radiated over the frequency range of 150 kc to 10,000 mc from a signal generator; the input and output of the equipment under the test are shielded.

Receiver intermodulation tests are performed over the entire frequency range. Two signal generators are used that have a dynamic range of 100 db (1μv into 50Ω) and separated by a frequency that corresponds to the test frequency. Receiver front end rejection measurements are made by tuning a signal generator set at 80 db above mds over the frequency range of 150 kc to 10,000 mc and monitoring the output for any undesirable response.

4.3 MIL-I-26600

MIL-I-26600 was originated in June 1958 and the latest amendment is dated 9 May 1960; this specification is used by the Department of the Air Force. The specification covers the design requirements, interference test procedures, and limits for electrical and electronic aeronautical equipment including ignition systems, to be installed in or associated with weapon systems or support systems. The amendments to the specification include limits and requirements for machine tools and electrically powered portable hand tools. This specification contains the same limits, measurements, equipment layout, etc. as discussed under MIL-I-6181D, with the exception that no military measuring equipments are specified for performing the tests.

4.4 MIL-I-16910A

MIL-I-16910A was originated in August 1954 and the latest amendment is dated November 1957. This specification is used by the Department of the Navy and covers methods for use in the measurement of interference produced by electrical, electronic, and mechanical equipment in the frequency range of 14 kc to 1000 mc. The specification includes the maximum allowable limits that may be conducted, radiated, or antenna conducted from C-E equipments and radiated and conducted interference levels from engines and other rotating machinery.

The radiated, conducted, and antenna conducted measurements are similar to the measurements that were discussed under MIL-I-6181D. Interference must be measured on the inside and outside of vehicles to determine the radiated and conducted interference levels. Engines and rotating machinery included in this specification are tanks, armored cars, half-track vehicles, tractors, motor transport vehicles, and motorcycles.

The interference levels are specified in levels of μv/m/kc of bandwidth. The measurement setups are shown in pictorial form for each general measurement. Military interference measuring equipment is specified and the performance characteristics of the measuring equipment are included.

Amendment 2, the most recent supplement of MIL-I-16910A, requires measurements on the equipment spectrum signature. The test must be performed for all equipment operating functions over the frequency range of 14 kc to 1000 mc.

4.5 MIL-I-11748B

MIL-I-11748B was originated in November 1958 and amended in June 1959; this specification is used by the Department of the Army.

This specification covers the interference limits, tests, and design requirements for the reduction of interference emanation, and susceptibility to such emanation, over the frequency range of 14 kc to 36,000 mc, for all electrical and electronic systems of ground vehicles, engines, engine driven equipments, railroad rolling stock, water craft, and air vehicles.

The specification delineates acceptance limits of the interference levels, and general test hookups are shown in block diagrams. Interference tests conducted under control of this specification include: case radiated, conducted for power source and load lines, antenna terminal conducted, powerline conducted susceptibility, receiver front end rejection, susceptibility to case radiation, harmonic and spurious outputs of transmitter, transmitter sideband splatter, transmitter key-up radiations, radiated and conducted interference from equipments not designed to radiate power, and the necessary suppression items that may be used to eliminate interference. Measuring equipments are specified, and a general discussion is included for the general equipment specified. The selection of test frequencies is discussed, and additional data is included on the general test conditions.

4.6 MIL-E-4957A

MIL-E-4957A (which supersedes MIL-E-4957 and MIL-E-8669) was originated in November 1954 and amended in February 1956. This specification has been approved by the Department of the Air Force and the former Naval Bureau of Aeronautics. The specification covers shielding enclosures (screen rooms) which are to provide a minimum of 100 db of attenuation to electromagnetic fields within the frequency range of 100 kc to 10,000 mc.

The specification describes the materials, parts design, and construction required of the screen room. Detailed requirements are included for inspecting and testing and screened enclosure. Pictorial diagrams are included that show the test setups with respect to the screened enclosure. Additional data is provided to enable the contractor to build power sources required to test the screened enclosure.

The shielded enclosure provided by this specification is intended to provide an interference-free enclosure for the operation, testing, and alignment of electronic equipment. The completed assembled enclosure is intended to attenuate electromagnetic fields from internal or external sources that cause undesirable interference with the test and alignment or operation of all types of electronic equipment.

4.7 MIL-STD-285

MIL-STD-285 (which supersedes MIL-A-18123) was originated in June 1956. This standard is mandatory for use by the Departments of the Army, Navy, and Air Force. This standard covers a method of measuring the attenuation characteristics of electromagnetic shielding enclosures used for electronic test purposes over the frequency range 100 kilocycles to 10,000 megacycles. This standard covers the same tests and limits as discussed under MIL-E-4957A, with the exception of construction details which are not specified.

4.8 MIL-STD-449A

MIL-STD-449A (which supersedes MIL-STD-449 and MIL-STD-752) was originated in October 1961. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, Navy, and Air Force. This technical standard establishes uniform measurement techniques that are applicable to the determination of the spectral characteristics of radio-frequency transmitters and receivers. The utlimate goal is to insure the compatibility of present and future systems. The data obtained from the measurements described in the standard will be utilized to predict the performance of equipment and systems in an operational electromagnetic environment and the effect of a particular equipment or system on the electromagnetic environment of other equipments and systems. This standard applies to equipment and systems designed to either emit or respond to electromagnetic energy from 0.01 to 12,000 mc.

The general spectrum characteristics measurements specified in this standard are: (1) Radio frequency output at equipment terminals, (2) Antenna radiated RF output, (3) Receiver susceptibility, and (4) The environmental operational level.

The standard specifies characteristics and accuracies of the equipments to be used in testing. Block diagrams are included for the various test setups. The standard requires that the following data be obtained on transmitters: power output, spurious emissions, emission spectrum, modulation characteristics, intermodulation, modulator bandwidth, and carrier frequency stability. The data to be obtained on receivers includes the following: sensitivity, selectivity, spurious responses, overall susceptibility, intermodulation, adjacent signal interference, pulse desensitization, CW desensitization, dynamic range, and oscillator radiation. In addition to the transmitter and receiver tests, the antenna patterns must be obtained at the fundamental and all harmonic frequencies (up to 12 gc) of the antenna in the azimuthal and vertical planes.

4.9 MIL-S-5786

MIL-S-5786 (which supersedes USAF No. 32331-A) was originated in June 1950. This specification is used by the Department of the Air Force and describes the requirements for one type of radio frequency noise suppressor, designed to provide a minimum of 40 db of voltage attenuation from 200 kc to 20 mc. The specification describes the mechanical and electrical test limits that the suppressor will be required to meet.

The suppressor covered by this specification is intended for use in aircraft to attenuate the radio frequency noise influence voltage throughout the electrical system.

4.10 MIL-I-9622

MIL-I-9622 was originated in February 1958 and is used by the Department of the Air Force. This specification covers one type of mutual radar interference blanker, designed as Interference Blanker Group AN/GPA-28( ). The AN/GPA-28 Blanker Group is used with normal and MTI radar sets to eliminate radar interference from one radar set to another by blanking out the interfered-with set during the time interference would be received.

This specification is essentially a design spec for the blanker, and operating requirements are detailed for the various subassemblies. Also included in the specification are the system operational tests, environmental tests, and mechanical tests required for inspection and acceptance of the end item.

4.11 MIL-S-10379A

MIL-S-10379A (which supersedes MIL-S-10379) was originated in July 1951 and amended in July 1952. This specification was approved by the Departments of the Army, Navy, and Air Force for use of the procurement services of the respective departments. This specification covers the requirements for radio interference suppression within the frequency range of 0.15 to 1000 mc, for all internal combustion engine-driven vehicles, tactical and nontactical procured by the Ordnance Corps for all the services to permit satisfactory reception of intelligence with high sensitivity C-E equipment installed in or adjacent to a vehicle.

The following types of vehicles shall conform to this specification: self-propelled vehicles which receive C-E equipment, tanks, armored cars, self-propelled cannons, half-tracks, motor transport vehicles, high-speed tractors, and motorcycles. Additional vehicles may be required to meet the specification if required by the contract. These vehicles include excavators, road graders, fork-lift trucks, slow-speed tractors, railroad equipment, etc.

Radiated measurements (inside and outside the vehicle) are required under this specification. In addition, interference levels that may be measured between any pair of terminals supplying power to C-E equipment are specified. Interference limits are given in tabular form for each frequency range covered by the specified military sets of RFI measuring equipment. Test setups are shown in pictorial views for various vehicles. This specification discusses the various suppression methods that must be followed in reducing the interference to the specified levels.

The contractor is required to submit a pilot model of each vehicle for inspection and test of the suppression system to the procuring activity.

4.12 MIL-I-11683B

MIL-I-11683B (which supersedes MIL-I-11683A) was originated in January 1956 as a Limited Coordination Military Specification by the Department of the Army (Sig C). The specification covers the requirement for radio interference reduction in the frequency range of 0.15 to 1000 mc for all internal combustion engine-driven generators, and all miscellaneous internal combustion engine-driven equipment (except equipments covered by Military Specification MIL-S-10379A) to permit satisfactory reception of intelligence with high sensitivity C-E equipment located adjacent thereto or electrically powered thereby.

Radiated and conducted interference measurements must be performed on the following equipments: All engine-driven generators and associated electrical equipment and all types of engines used to power or drive such miscellaneous equipments as bulldozers, cranes, graders, rollers, fork-lift trucks, compressors, laundry unit pumps, etc., including the electrical equipment associated with these units.

Interference limits and measurements vary for the various types of equipment. The RFI measuring equipments are specified, and sketches show the required antenna location and position for the various tests. The types of suppression that may be utilized to reduce the interference levels are also included in the specification. The manufacturer of the equipment is required to submit pilot models to the government for testing. Typical suppression systems are shown that may be used to reduce the interference levels on various types of engines.

4.13 MIL-E-6051C

MIL-E-6051C (which supersedes MIL-I-006051B) was originated in June 1960 and has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, Navy, and Air Force. This specification outlines design requirements and test procedures necessary to control the electronic interference environment of weapon systems, associated electronic and electrical subsystems, and aircraft.

Interference produced by the weapons system shall be controlled to eliminate undesired interaction and malfunctioning of all electronic and electrical subsystems regardless whether the ultimate output of the subsystem is electrical, aural, video, or mechanical. This requirement applies to the entire frequency range of the installed subsystem and those for which complete installation provisions have been made.

The contractor is required to submit, within 90 days after approval of the weapons system by the procuring activity, a detailed plan outlining his interference control program, the engineering design procedures, and techniques that will be used in complying with this specification. All support systems and subsystems shall incorporate interference control requirements in accordance with the applicable sections of either MIL-I-6181D or MIL-I-26600.

This specification includes requirements for bonding, shielding, and interference control components. Test locations and measuring equipment requirements are specified. Additional details include data on the electrical-electronic compatibility test of the system, specification compliance test system, general acceptance test, and levels of unacceptable response.

4.14 MIL-F-15733D

MIL-F-15733D (which supersedes MIL-F-15733C and MIL-F-18344A) was originated in March 1960 and amended in April 1961.

The specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, Navy, and Air Force. The specification covers the general requirements for current-carrying filter (ac and dc), for use primarily in the reduction of broad-band radio interference.

The specification contains design and construction details, qualification inspection requirements, acceptance inspection requirements, test methods, and delivery instructions. The detailed test required for qualification and acceptance inspection include the following: flashpoint of impregnant, visual and mechanical examination, seal, capacitance to ground, temperature rise, dielectric breakdown, insulation resistance, voltage drop, insertion loss, overload, terminal strength, vibration, moisture resistance, life, effect of soldering, salt spray, and temperature and immersion cycling.

Supplement 1 to MIL-F-15733D was dated March 1960 and contains detailed design and construction data on 8 styles of filters.

4.15 MIL-I-16165D

MIL-I-16165D (which supersedes MIL-R-16165C) was originated in August 1961. This specification is used by the Department of the Navy, Bureau of Ships. The specification covers requirements for interference shielding items and shielded harnesses for engine electrical systems aboard Naval vessels, at advanced bases, and in the vicinity of electronic installations. It includes the allowable interference limits for such items and the permissible limits for auxiliary devices normally installed on electrical wiring systems associated with these engines.

Interference shielding items furnished under this specification have passed the following qualification tests: torque, vibration, interference, temperature tests, corrosion resistance, salt spray, interference check, cable terminal assembly temperature test, and interference tests at the plant of the equipment builder. Interference tests are performed in accordance with the applicable sections of MIL-I-16910A, and the limits of the interference check test are also referenced to MIL-I-16910A. Information is included on requirements of the individual items comprising the shielded items and harnesses including cables, connectors, gaskets, fittings, fastening devices, etc.

4.16 MIL-I-17623

This specification was originated in September 1953, with the latest amendment dated July 1957, and was adapted for use by all interested Bureaus of the Navy Department and the Marine Corps. This specification covers the radio interference requirements associated with electric office machines, printing, and lithographic equipment.

Conducted interference measurements are required over the frequency range of 150 kc to 20 mc, and radiated interference measurements are required over the frequency range of 14 kc to 1000 mc. Conducted interference limits are specified for any radio interference voltage appearing on the external power conductors or on any external system connection. Interference radiated from any unit, cable (including control and input power cables) or interconnecting wiring of the equipment shall not exceed the specified limits.

The operating conditions that must be in effect when the measurements are conducted are specified. The equipment interconnections are shown in pictorial form for various tests. Equipments and antenna orientation and positioning are also specified. The following is a partial list of equipments that are covered by this specification:

accounting machines	postage meters
adding machines	dictating machines
calculating machines	stapling machines
cash registers	time recorders
folding machines	typewriters
multilith equipment	varitypes

4.17 MIL-I-25171

MIL-I-25171 was originated in March 1955 and is used by the Department of the Air Force. This specification covers interference limits applicable to aircraft being modified or reconditioned. The specification requires that there shall be no undesired response from electronic receivers above the area noise level, or malfunctioning of other electronic equipment, due to radio interference produced by any or all electrical, electronic, and other equipment of the aircraft, when tested as specified. This requirement applies to the entire frequency range of all installed electronic equipment and to the entire frequency range of all electronic equipment for which complete installation provisions have been made.

The measuring equipment is the same as the equipment in use in the aircraft, or its equivalent. Methods and materials are specified for suppressing or eliminating the interference. The test conditions and procedures that must be followed while performing the test are specified.

4.18 MIL-STD-220A

MIL-STD-220A (which supersedes MIL-STD-220) was originated in December 1959. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, Navy, and Air Force. The standard describes a method of measuring, in a 50-ohm system, the insertion loss of feed-through suppression capacitors, and of single- and multiple-circuit, radio-frequency filters at frequencies up to 1,000 mc.

The test circuit required for measuring the insertion loss is specified, also, the RF-dc-insertion-loss-measuring equipment is shown in detailed plans. All test equipment must be well shielded and filtered to the extent that leakage, either conducted or radiated, from the signal generator or any portion of the signal source circuitry shall not affect the output of the receiver when operating at the output level and sensitivity needed to make the measurement.

4.19 MIL-B-5087A

MIL-B-5087A (which supersedes MIL-B-5087) was originated in July 1954 and amended in January 1958. This specification has been approved by the Department of the Air Force and the former Naval Bureau of Aeronautics. This specification provides requirements for the application and testing of electrical bonding on all-metal aircraft. For aircraft which are not of all-metal construction, the bonding requirement will be determined by the procuring activity.

The specification specifies the material and parts required to provide a satisfactory bond. The purposes of bonding, the application of bonding, and the extent of bonding required in particular applications are discussed. Detailed requirements are specified for bonding in the following applications: Bonding for lightning protection, bonding to provide power-current return paths, bonding of antenna installations, bonding to prevent the development of RF potentials, bonding to prevent shock hazards resulting from equipment internally power faulted, and bonding to prevent the accumulation of static charge. Examples are given for objects that require bonding; the requirement and reason for the bond is also specified.

4.20 FCC PART 15

FCC Part 15 governs the restricted and incidental radiation devices that emit RF energy on frequencies within the radio spectrum and constitute a source of harmful interference to authorized communications services. This part contains rules that specify under which conditions the operation of incidental and restricted devices may operate without a license. No incidental or restricted radiation device that fails to conform to FCC Part 15 or which causes harmful interference may be operated without a station license. This part defines the radio spectrum as existing between 10 kc and 3,000,000 mc. Items governed by this rule include incidental radiation devices (a device not intentionally designed to generate RF energy), radio receivers, community antenna television systems, and low power communication devices such as wireless microphones, phonograph oscillators, radio controlled garage door openers and models. Measurement procedures and interference limits are specified for the various items governed by this specification.

4.21 FCC PART 18

FCC Part 18 contains the requirements whereby any medical diathermy equipment, industrial heating equipment, or miscellaneous equipment may operate without a license. Medical diathermy equipments include any apparatus which transmits RF energy for use as therapeutic purposes, and industrial heating equipment includes any apparatus which transmits RF energy for use in industrial heating operations utilized in a manufacturing or production process. Miscellaneous equipments include those equipments where RF energy is applied to materials to produce physical, biological, or chemical effects such as heating ionization of gases, mechanical vibrations, and hair removal. Additional equipments governed by this rule include, electronic ovens, RF neon signs, ultrasonic equipment, arc welders, epilators, etc.

Detailed measurement requirements are specified for the various equipment categories, including operating condition of the equipment while the tests are being conducted. The interference levels that determine whether or not a station license is required are also included. The frequency range governed by this rule extends from 10 kc to 30,000 mc. Although a station license is not normally required under all circumstances, a certificate of compliance may be required by the Commission.

COMPARISON OF RFI SPECIFICATIONS

MILITARY SPECIFICATION NUMBER	TITLE	ORIGINATING DATE	CURRENT AMENDMENT DATE	SUPERSEDED MIL SPEC NUMBER	USING SERVICE	FREQUENCY RANGE	REQUIRED MEASUREMENTS: C-E EQUIPMENTS		
							CONDUCTED	RADIATED	ANTENNA CONDUCTED
MIL-E-4957A	Enclosure, Electromagnetic Shielding, Demountable, Prefabricated for Electronic Test Purposes	17 Nov. 1956	3 Feb. 1958	MIL-E-4957 MIL-E-4669	USAF and USN (BuWeps)	100 kc to 10,000 mc		YES	
MIL-B-5087A	Bonding, Electrical (for Aircraft)	10 July 1954	19 Jan. 1958	MIL-B-5087	USAF and USN (BuWeps)	Not applicable			
MIL-S-5706	Suppressor, Electrical Noise, Radio Frequency	22 June 1950	None	USAF No. 32131-A	USAF	200 kc to 20 mc			
MIL-E-6051C	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft	17 June 1960	None	MIL-I-006051B	USA, USN and USAF	Same as the installed and planned subsystems on the vehicle	YES	YES	YES
MIL-I-6181D	Interference Control Requirements, Aircraft Equipment	25 Nov. 1959	None	MIL-I-006181C MIL-I-6181B	USA, USN and USAF	0.15 to 10,000 mc	YES	YES	YES
MIL-I-9622	Interference Blanker Group AN/GPA-30( )	26 Feb. 1958	None	None	USAF	Not applicable			
MIL-S-10379A	Suppression, Radio Interference General Requirements for Vehicles (and Vehicular Subassemblies)	6 July 1951	21 July 1954	MIL-S-10379	USA, USN and USAF	0.15 to 1,000 mc			
MIL-I-11683B	Interference Suppression, Radio, Requirements for Engine Generators and Miscellaneous Engines	3 Jan. 1956	None	MIL-I-11683A	USA(SigC)	0.15 to 1,000 mc			
MIL-I-11748B	Interference Reduction for Electrical and Electronic Equipment	4 Nov. 1958	5 June 1959	MIL-I-11748A	USA(SigC)	14 kc to 26,000 mc	YES	YES	YES
MIL-F-15733D	Filters, Radio Interference, General Specifications for	22 March 1960	10 April 1961	MIL-F-15733C MIL-F-18349A	USA, USN, and USAF	Not applicable			
MIL-I-16165D	Interference Shielding, Engine Electrical Systems	24 Aug. 1961	None	MIL-S-16165C	USN(BuShips)	14 kc to 1,000 mc			

Figure 6-1. Comparison of RFI Specifications

REQUIRED MEASUREMENTS				ARE SUPPRESSION TECHNIQUES SPECIFIED	ARE ACCEPTANCE LIMITS SPECIFIED	ARE TEST SETUPS SPECIFIED	ARE MEASURING EQUIPMENTS SPECIFIED	REMARKS
ENGINES AND ROTATING MACHINERY		MISCELLANEOUS EQUIPMENTS						
CONDUCTED	RADIATED	CONDUCTED	RADIATED					
			YES	NO (General construction details)	YES	YES (Sketches)	NO (Specifies types)	This specification details tests required to determine the shielding effectiveness of a screen room.
				Not applicable	Not applicable	Not applicable	Not applicable	This specification provides requirements for the application and testing of electrical bonding on all metal aircraft.
				Not applicable	YES	YES (Sketch)	YES (To test insertion loss)	This specification covers one type of a radio frequency noise suppressor.
YES	YES	YES	YES	YES	YES	Normal system operation	YES (Equipments utilized in the systems)	This specification outlines design requirements and test procedures necessary to control the electronic interference environment.
YES	YES			NO	YES (Graphs)	YES (Sketches)	YES (Commercial and military)	This specification covers design requirements, interference test procedures, and limits for electrical and electronic aeronautical equipment to be installed in, or closely associated with, aircraft.
				Not applicable	YES (As operating requirements)	Not applicable	Not applicable	This specification covers one type of a mutual radar interference blanker - AN/CPA-20( ).
YES	YES	YES	YES	YES	YES	YES (Sketches)	YES (Military versions of RFI equipment)	This specification covers the requirements for radio interference suppression of all internal combustion engine driven vehicles, tactical and non-tactical.
YES	YES	YES	YES	YES	YES (Tables)	YES (Sketches)	YES (Commercial and military)	This specification covers the requirements for radio interference reduction for all internal combustion engine driven generators, and all miscellaneous internal combustion engine driven equipment to permit satisfactory reception of intelligence.
YES	YES	YES	YES	YES	YES (Tables)	YES (Sketches)	YES (Commercial and military)	This specification covers the radio frequency limits, tests, and design requirements for RFI emanation and susceptibility to such emanations for all electrical and electronic equipment and systems.
				Not applicable	Not applicable	Not applicable	Not applicable	This specification covers the general requirements for current-carrying filters for use primarily in the reduction of broadband radio interference.
				YES (To meet limits of MIL-I-16910)	YES (To meet limits of MIL-I-16910)	Not applicable	Not applicable	This specification covers requirements for interference shielding items and shielded harnesses for engine electrical systems.

MILITARY SPECIFICATION NUMBER	TITLE	ORIGINATING DATE	CURRENT AMENDMENT DATE	SUPERSEDES MIL SPEC NUMBER	USING SERVICE	FREQUENCY RANGE	REQUIRED MEASUREMENTS C-E EQUIPMENTS: CONDUCTED	RADIATED	ANTENNA CONDUCTED
MIL-I-16910A	Interference Measurement, Radio, Methods and Limits; 14 Kilocycles to 1,000 Megacycles	[illegible] Aug. 195[illegible]	1 Nov. 195[illegible]	MIL-I-16910	USN (Ships)	14 kc to 1,000 mc	YES	YES	YES
MIL-I-17623	Interference, Radio; Requirements, Methods and Limits (14 kc to 1,000 mc) for Electric Office Machinery, Printing and Lithographic Equipment	[illegible] Sept. 195[illegible]	[illegible] July 195[illegible]	None	USN	14 kc to 1,000 mc			
MIL-I-[illegible]	Interference Limits and Tests for [illegible] and [illegible] Aircraft	[illegible] March 195[illegible]	None	None	USAF	Same as equipment [illegible] in aircraft	YES	YES	YES
MIL-I-26600	Interference Control Requirements, Aeronautical Equipment	2 June 195[illegible]	9 May 1960	MIL-I-[illegible]	USAF	[illegible] kc to [illegible] mc	YES	YES	YES
MIL-STD-220A	Method of Insertion-Loss Measurements	15 Dec. 195[illegible]	None	MIL-STD-220	USA, USN, and USAF	Up to [illegible] mc			
MIL-STD-285	Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of	25 June 1956	None	MIL-A-18123?	USA, USN, and USAF	[illegible] to 10,000 mc		YES	
MIL-STD-449A	Radio Frequency Spectrum Characteristics, Measurement of	24 Oct. 1961	None	MIL-STD-449, MIL-STD-[illegible]	USA, USN, and USAF	10 [illegible] to [illegible] mc		YES	YES
FCC PART 15	Incidental and Restricted Radiation Devices	April 195[illegible]	None	None	FCC	[illegible]	YES	YES	YES
FCC PART 18	Industrial, Scientific, and Medical Services	April 195[illegible]	4 March 1961?	None	FCC	[illegible]			

Figure 6-1. Comparison of RFI Specifications (Cont.)

REQUIRED MEASUREMENTS: ENGINES AND ROTATING MACHINERY — CONDUCTED	ENGINES AND ROTATING MACHINERY — RADIATED	MISCELLANEOUS EQUIPMENTS — CONDUCTED	MISCELLANEOUS EQUIPMENTS — RADIATED	ARE SUPPRESSION TECHNIQUES SPECIFIED	ARE ACCEPTANCE LIMITS SPECIFIED	ARE TEST SETUPS SPECIFIED	ARE MEASURING EQUIPMENTS SPECIFIED	REMARKS
YES	YES			NO	YES (Graphs)	YES (Sketches)	YES (Military versions of RFI meters)	This specification covers methods for use in the measurement of radio interference produced by electrical, electronic, and mechanical equipment and provides means whereby significant and uniform measurements may be made.
YES		YES	YES	NO	YES (Graphs)	YES (Sketches)	YES (Military and Commercial)	This specification covers the radio interference requirements associated with electric office machines, printing and lithographic equipment.
YES	YES	YES	YES	YES (Filters)	NO	YES (General)	YES (Stock equipment in aircraft)	This specification covers interference limits applicable to aircraft being modified or reconditioned.
YES	YES	YES	YES	YES	YES (Graphs)	YES (Sketches)	YES (Commercial)	This specification covers design requirements, interference test procedures, and limits for electrical and electronic aeronautical equipment, including ignition systems, to be installed or associated with aircraft systems or support systems.
				Not applicable	Not applicable	YES	YES (General requirements)	This standard covers a method of measuring, in a 50-ohm system, the insertion loss of feed-through suppression capacitors, and of single- and multi-circuit, radio-frequency (RF) filters at frequencies up to 1,000 mc.
			YES	NO	YES	YES (Sketches)	YES (Commercial and Military)	This standard covers a method of measuring the attenuation characteristics of electromagnetic shielding enclosures used for electronic test purposes.
				Not applicable	Not applicable	YES (Block diagrams)	YES (Specific accuracies of equipments)	This technical standard establishes uniform measurement techniques that are applicable to the determination of the spectral characteristics of RF transmitters and receivers.
				NO	NO	YES	NO (General requirements only)	This part contains rules that set forth the conditions under which the operation of incidental and restricted radiation devices is considered to fall outside the purview of Section 301 of the Communications Act which specifies that a station license is required as a condition for lawful operation.
		YES	YES	NO	NO	YES	NO (General requirements only)	This part contains rules that set forth the conditions for the operation of ISM equipment that uses electromagnetic waves (for industrial, scientific, medical, or other purposes) not intended to be used for radio communication.

APPENDICES AND INDEX

A	Amplifier gain
A	Effective area
A	Emissive surface
A	Propagation factor for other than free space line-of-sight
A	Penetration or absorption loss in db inside the barrier
A_e	Effective aperture of antenna
A_f	Amplification occurring between the point where the interference is introduced and the output, with feedback
A(f)	Receiver response function
A_o	Amplification occurring between the point where the interference is introduced and the output, with no feedback
A_p	Aperture physical size
$A\beta$	Feedback factor
AGC	Automatic gain control
AM	Amplitude modulation
AVNL	Automatic video noise limiting
AZ	Azimuth
A_A	Antenna effective aperture
a	Average coil diameter
a_l	Aperture dimension in wavelengths
B	Beam area in (radians)^2 at half-power points
B	Magnetic flux density
B	Positive or negative correction term which need not be taken into account when penetration loss (A) is more than 15 db
BB	Broadband
BFO	Beat frequency oscillator
BTU/hr	British thermal units per hour
BW	Beamwidth
B_r	Receiver bandwidth
b	Core width in inches
b	Length of coil winding
bw	Bandwidth
C	Constant dependent upon material
C	Thermal capacity of the active element
C	Capacitance

C-E	Communication electronic
Co	Distributed capacitance of a single layer coil
CRT	Cathode ray tube
CW	Continuous wave
C_c	Coupling reactance to mixer grid
C_{gp}	Mixer grid plate capacitance
C_{in}	Input capacitance of mixer
C_o	Mixer output capacitance
°C	Degrees centigrade
cm	Centimeters
cos	Cosine
cps	Cycles per second
cu. ft.	Cubic feet
D	Divergence factor
D	Maximum dimensions of largest antenna aperture
D	Distance in meters
D	Maximum antenna dimension
D	Amplifier output distortion
D^2	Distance from origin in miles
D^2/λ	Far field
d	Length of waveguide
d	Differential element of solid angle
d	Distortion generated in the amplifier
dA	Elemental aperture area
db	Decibels
dbm	Decibels above a milliwatt
d Ep	Differential electric field at point "p"
d_1	Distance from antenna in wavelengths
d_L	Line-of-sight distance between antennas
$d\omega$	Distance between Rx and Tx in miles
$\frac{d}{dt}$	Operator for differentiation with respect to time
$\frac{da}{du}$	riation in the amplitude of transmission expressed in decibels ange in transmission for an octave change in frequency
E	Electromotive force
E	Energy
E	Generator voltage (dc)

EBW	Exploding bridge wire
EED	Electroexplosive devices
EL	Elevation
ERP	Effective radiated power
E_1	Field intensity after passing through a shield
E_2	Field intensity before passing through a shield
E_{max}	Maximum safe field strength
E_o	Maximum field intensity at the aperture
E_p	Total electric field at point "p"
E_x	Electric field intensity
e	Absolute charge on an electron
e	Dielectric constant of a coaxial transmission line
e	2.718
e_{lo}	Open circuit local oscillator voltage
e_s	Supplied signal
F	Characteristic constant of the emissive surface
F	Electric or magnetic field intensity at a known distance from surface
F	Force
FI	Field intensity
FIM	Field intensity meter
FM	Frequency modulation
F(ρ)	Field distribution over the aperture surface
FSK	Frequency shift keying
FST	Fast time constant
F_H	Correction factor depending on "h" direction aperture illumination
F_h	Correction factor (illumination in horizontal direction)
F_{if}	Intermediate frequency
F_{Lo}	Local oscillator frequency
F_m	Frequency in megacycles per second
F_o	Electric or magnetic field intensity at the surface
F_{sp}	Spurious frequency
F_t	Transmission factor
F_v	Correction factor (illumination in vertical direction)

F_v	Correction factor depending on "V" direction aperture illumination
f	Radiation frequency
f_c	Carrier frequency
f_c	Cutoff frequency
f_o	Receiver tuned frequency
f_∞	Frequency of infinite attenuation
G	Power gain (isotropic source)
GCA	Ground control approach
$G(\theta, \phi)$	Gain function of the antenna relative to an isotropic radiator
G_c	Composite antenna gain
G_n	Transmitter gain at frequency fn
G_o	Maximum gain
G_R	Gain of RX antenna
G_{ro}	Far-field gain of receiver
G_T	Gain of TX antenna
G_t	Antenna gain
G_{to}	Far-field gain of transmitter
g	Conductivity
gal/hr	Gallons per hour
gcs	Gigacycles per second
h	Departure in feet from a level tangent
h	Height
h	Plank's constant
H	Horizontal dimension of rectangular aperture
H	Magnetization
$H(F, \theta, \phi)$	Spectrum signature of the transmitter
H_0) H_0) H_1) H_1)	Hankel functions of first and second order and of the first and second kind. The subscripts refer to the order of the Hankel function; the unprimed symbols are Hankel functions of the first kind, and the primed symbols are Hankel functions of the second kind.
$H_r(\theta, \phi, f)$	Transfer function of receiver section
H_Z	Magnetic field intensity

I	Current (dc)
I	External interfering signal
$\bar{I}$	Mean current
I	Total flux for a unit length of wire
IAGC	Instantaneous automatic gain control
IF	Intermediate frequency
I_{nf}	Maximum no-fire value
i	Current
j	$\sqrt{-1}$
K	Efficiency
K	Number of coil turns per inch
°K	Degrees Kelvin
k	Boltzmann constant
kΩ	Kilohm
k & T_o	Empirical constants for each window
kva	Kilovoltampe
kw	Kilowatt
L	Inductance
L	Distance between maxima and minima in the cyclic variations in field intensity along a radial line from the antenna aperture
L	Total length of test cable
L_R	Receiver line loss in db
L_T	Transmitter line loss in db
l	Effective length of conductor perpendicular to field
l	Largest linear dimension of antenna
l	Length of bridge wire
lbs.	Pounds
l_g	Inductive internal impedance of the generator
l_n	Log_e
l_p	Insertion loss of filter

M	Mass
MDS	Minimum discernible signal
MPMVS	Mid-pulse minimum visible signal
MSL	Mean sea level
N	Number of turns in the loop
N	Radar system noise
N_{db}	Number of decibels
n	Number
P	Power
P	Pressure
$\bar{P}$	Mean power
PD	Pulse duration
P_D	Power density at distance D from transmitter
P(f)	Spectral density power
P_R	Power received
P_{RR}	Power density due to reflection
P_T	Power peak
P_{TR}	Power within the RX bandwidth
P_t	Transmitter power
PPI	Planned position indicator
PRF	Pulse repetition frequency
P_{TN}	Power at the harmonic
P_{TN}	Actual power fed to antenna from the transmitter
P_{dn}	Power density
P_{tn}	Transmitted power at frequency F_n fed to the antenna
p	Multiple positive integer of the LO frequency
p	Polarization mismatch in db
Q	Ratio of the inductive reactance to the resistance
Q	Quantity of electricity
q	Order of the input signal

R	Resistance
R	Total reflection loss in db from both surfaces of the shelf
R_b	Bridge wire resistance
R_g	Internal resistance of the generator
R_{in}	Input resistance of mixer circuit and tube
R_{lo}	External damping on local oscillator
R_0	Resistive part of intrinsic medium
R_1	Fresnel region
RF	Radio frequency
RFI	Radio frequency interference
RX	Receiver
RLOS	Radio line-of-sight
RMS	Root mean square
r	Radius
r_m	Mean radius
rpm	Revolutions per minute
S	Shielding effectiveness in db
S	Switch
S	Target signal
S_d	Depth of penetration
$S(f)$	Power spectral density
(S/I)	Signal-to-interference
S/N	Signal-to-noise
S_{RN}	Power level received through test antenna
SSB	Single sideband
STC	Sensitivity time control
S_{tn}	Signal generator power fed to the antenna
s	Surface density
s	Surface density of charge
T	Average transmission of a window
T	Pulse width at 50% points
T_a	Antenna temperature presented by the source
T_r	Radiator temperature
T_{sn}	Effective temperature of a source emitting energy to the nth lobe

T_{so}	Effective noise temperature of the sky
TASO	Television Allocations Study Organization
TSI	Threshold signal-to-interference ratio
TV	Television
TX	Transmitter
tr	0-100% rise and fall time
UHF	Ultrahigh frequency
V	Peripheral velocity
V	Vertical dimension of rectangular aperture
VHF	Very high frequency
VSWR	Voltage standing wave ratio
VTVM	Vacuum tube voltmeter
v_{oc}	Open circuit voltage
W	Weight
W	Water vapor concentration of the transmission data
W_{max}	Maximum allowable power density at the EED circuitry
W_o	Power density at the aperture
W_p	Power density at point "p"
X_L	Inductive reactance
X_o	Reactive part of intrinsic medium
x	Distance along a radial line from antenna aperture
y	Admittance
y	Desired signal
Z	Impedance
z_a	Antenna impedance
z_o	Intrinsic impedance of the medium
z_r	Impedance of the load
z_s	Impedance of the source

α — Attenuation constant of the medium

β — Phase constant of the medium

β circuit — Feedback circuit

βE — Fractional part of the output voltage which is added to the external input signal

$-\Delta f$ — Difference between generator frequency and receiver frequency

ϵ — Permittivity of air

η — Intrinsic impedance of the medium

φ — Elevation angle to receiver site

ϕ — Phase of surface reflection coefficient

ϕ_1 — Vertical beamwidth in radians at the half-power point

γ — Propagation constant of the medium

γ — Propagation loss that provides loss in excess of the free-space loss

λ — Wavelength

λ_c — Cutoff wavelength

λ_c — Cutoff wavelength of the waveguide

μ — Permeability

$\mu\mu$ — Micromicro (10^{-12})

μ_d — Average incremental permeability

μh — Microhenry (10^{-6})

μ_i — Given mean

μv — Microvolt (10^{-6})

ω — Angular frequency in radians per second

Ω — Ohm

Ω_a — Solid angle representing effective antenna beam

π — 3.142

ρ	Magnitude of surface reflection coefficient
ρ	Resistivity of the material
σ	Stefan-Boltzman constant
σ	Conductivity
σ_μ	Relative conductivity
σ_o	Scattering cross section of the obstacle
σ^2	Variance
τ	Mean carrier lifetime
θ_1	Horizontal beamwidth in radians at half-power point
θ radians	Electrical length of transmission line
θ	Azimuth angle to receiver site
θ	The plane of the loop
θ	Phase lag due to path length difference
ζ	Output of detection system

DEFINITION OF TERMS — APPENDIX II

Ambient Interference - The background level of electromagnetic energy resulting from atmospheric noise, internal noise of the equipment, and inescapable man-made noise.

Antenna - A device employed as a means for radiating or receiving radio frequency energy.

ARC - Low voltage, high current discharge; as in contrast to a spark.

Atmospheric Noise - Electromagnetic energy caused by the natural disturbances in the atmosphere.

Attenuation - The process of decreasing the power level of RF and audio frequency energy. The change in power level is expressed in db.

Break Transient - Transients produced by the opening of a switch.

Broadband Radiated Interference (microvolts per meter per kilocycle of bandwidth)- Interference having a spectrum broad compared with the nominal bandwidth of the receiver; for example, interference from a fluorescent lamp.

By-Passing - The technique of providing low shunt impedance for RF and AF current in electronic circuits by means of a capacitor.

Calibration - The process by which measuring equipment indication is adjusted for optimum conformance with that of standard.

Case Penetration - Radiated RF energy which enters electronic equipment through discontinuities in its enclosure.

Characteristic Impedance - The natural or surge impedance of a circuit or transmission line, determined by its physical dimensions and the properties of the medium surrounding the conductors.

Conducted Interference - Any interference transmitted through metallic leads.

Corona Discharge - The discharge brought about by the ionization of gas surrounding a conductor. It occurs when the potential gradient exceeds a certain value but is not sufficient to cause sparking. It is evident as a bluish glow and, in air, produces ozone.

Coupling Factor (referring to receivers) - The ratio of antenna input voltage to the voltage input required at the various coupling paths to produce the same output.

Cross Modulation - Modulation of a desired signal by an undesired signal.

Cycle - One complete sequence of a regularly recurring event.

Decibel - A measure of the ratio of two powers. Power ratio (decibels) is equal to $10 \log_{10} P_1/P_2$.

dbm (decibels relative to 1 milliwatt) - Decibels relative to 1 milliwatt $= 10 \log_{10} P$, where P is the power in milliwatts.

dbm/m² (decibels relative to 1 milliwatt per square meter) - Decibels relative to 1.0 milliwatt/meter² $= 10 \log_{10} \frac{P}{A}$, where P is the power in milliwatts and A is the effective area in square meters over which P is measured.

dbm/m²/mc or dbm/m²/kc (decibels relative to 1 milliwatt per square meter per megacycle or per kilocycle bandwidth) - Decibels relative to 1.0 milliwatt/meter²/mc or 1.0 milliwatt/meter²/kc $= 10 \log_{10} \frac{P}{A\beta}$, where P is the power in milliwatts and A is the effective area in square meters over which P is measured, and β is the measurement system bandwidth in megacycles or kilocycles, respectively.

Decoupling - Re-routing of unwanted energy to less harmful paths; usually ground.

Depth of Penetration - The distance from the surface of a metal at which an electromagnetic wave or current has decreased to 1/e times its value at the surface.

Desensitization - CW desensitization is that change in sensitivity of a receiver in the presence of on-frequency CW interference signals. It is caused by an adverse change in the bias levels of the receiver's amplifier stages due to the presence of the interfering CW signal. Pulse desensitization is the transient change in the receiver characteristics due to an interrupted interfering signal. It is usually measured as a function of sensitivity versus delay time between the desired and undesired pulse.

Dielectric Strength - The ratio of breakdown voltage to the thickness of the dielectric between contacts.

Dynamic Range - The response difference between the standard response level and the output limiting level. The AGC system, if one exists, is in full operating condition.

Effective Bandwidth - The frequency difference between the two points 6 db down on the response curve of an amplifier or receiver.

Effective Height - This is a measure of effective length of the antenna. It is determined by dividing the voltage delivered from the antenna by the known field strength intercepted by the antenna.

Electrostatic (Faraday) Shield - A device to reduce capacitive coupling between circuits.

Elevatable Antennas - Antennas designed to elevate through an angle of 80° or greater, and which can be fixed at any desired elevation angle. (The intention of this definition is to preclude the requirement of more than routine efforts to provide maneuverability in the vertical plane. If a servo mechanism or manual drive are available to provide this capability, for example, the antenna is said to be elevatable. If the antenna configuration requires adjustment by removal and replacement of bolts, for example, it is said to have fixed elevation capabilities.)

Emission Spectrum - The power versus frequency distribution of a signal about its fundamental frequency which includes the fundamental frequency, the associated modulation sidebands, as well as non-harmonic and harmonic spurious emissions and their associated sidebands.

Far-Field Distance - That distance between two antennas equal to D^2/λ, where D is the maximum aperture dimension of the largest antenna, and λ is the wavelength of measurement. In no case shall this distance be less than 3λ.

Ferrites (Ferrospinels) - Mixtures of crystalline iron oxides of ceramic-like structure.

Field Fixes - The modification of existing equipment and installations to insure comparative freedom from radio interference.

Field Intensity - The magnitude of an electromagnetic field, usually expressed in terms of microvolts per meter.

Field Tests - Tests conducted in an "open space" under actual operating and load conditions. Tests of conducted interference performed at the actual site of permanent installation meet the requirements of Field Tests.

Filter - A network designed to either pass or attenuate energy within a specific frequency or band of frequencies.

Floating Ground - The common return conductor is an electronic chassis from which electric measurements are referenced.

Frequency Coverage - That range (or those ranges) of frequencies over which the equipment is designed to operate, e.g., the frequency coverage of the AN/URM-XX may be 0.15 to 0.4 mc and 1.5 to 1000 mc, etc.

Frequency-Selective Voltmeter - A frequency-selective radio receiver as a two terminal voltmeter, for example, a field-intensity meter.

Frequency Translation - The production of new frequencies in a nonlinear element.

Fundamental - The lowest component frequency in a complex wave or vibration.

Ground -

1. Earth - Some plane or volume within the surface of the earth, used as a reference plane or point.
2. System - A specially constructed pattern of conductors which is buried under the surface of the earth. The ground bus connects electrical or electronic equipment to the center of the system.
3. Bus - A conductor by which electronic systems are connected to earth.
4. Chassis or Frame - The common reference return point in electronic circuits. A point of "zero" or "reference" electrical potential, often used in the following sense: (1) to connect to the aircraft structure through a low impedance path, and (2) to make equipotential with all other "ground points" in the system.

Harmonic - An integral multiple of a fundamental frequency.

Impedance (referring to networks) - The ratio of voltage to current.

Impedance (referring to media) - The ratio of electric to the magnetic field intensity.

Impedance Concept - Consideration of impedance as the ratio of cause to effect leads to the idea which regards the entire system as a single network.

Improvement Threshold - The minimum signal-to-interference ratio necessary at the input to produce an intelligible signal at the output.

Impulsive Bandwidth - That bandwidth which is a function of the pulse repetition rate, pulse width, charge time of weighting circuits, and the overload factor. No definite conversion factor to the normal concept of bandwidth can be given in general.

Impulsive Radiated Interference - Interference characterized by non-overlapping transient disturbances, for example, pulse energy from a radar.

Indicated Microvolts - A measurement in microvolts indicate by the "interference" measuring equipment before conversion to standard units.

Insertion Loss - The attenuation introduced by a device inserted into an electrical circuit usually expressed in db.

Isolation - Physical and electrical separation of circuit elements to avoid undesired transfers of energy.

Insulator - A nonconductor of electrical current used to separate or support conductors without providing a conducting path through itself.

Interference - Interference is the product of undesired conducted or radiated electrical disturbances, with desired conducted or radiated energy which results in degraded intelligibility.

Interference-Free Measurement Area - An area sufficiently free from interference and site reflections so that measurement results are not adversely affected.

Interference Voltage Reduction Factor - The ratio of the signal-to-interference ratio at the output to that at the input of a receiver.

Internal Noise - Electromagnetic disturbances originating in the circuitry of electronic equipment, i.e., shot noise, thermal agitation, and hum.

Intrinsic Impedance - The ratio of electric to magnetic field intensity in a medium in which no reflected wave is present.

Laboratory Test - Radiated or conducted measurements of a test item in a screened enclosure or other area of low ambient level under controlled conditions.

Line Impedance Stabilization Network - A network which provides a standard impedance across which conducted interference is measured. Abbreviated LISN.

Major Unit - An assembly of parts, connected mechanically or electrically such as a radar transmitter or a power pack, to perform a specific function.

Microvolts per kc - Interference intensity in microvolts per kc is equal to the number of rms sine wave microvolts (unmodulated), applied to the input of the measuring circuit at its center frequency, which will result in peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the effective bandwidth of the circuit in kilocycles. The effective bandwidth is the area divided by the height, of the voltage-response-versus- radio-frequency selectivity curve, from antenna to peak detector.

Microvolts per Meter - The standard unit of intensity of an electromagnetic field.

Microvolt per Meter per Kilocycle - Same as microvolts per meter except correct to one kilocycle bandwidth; microvolts per meter divided by the bandwidth of the measuring instrument in kilocycles.

Mid-Pulse-Minimum Visible Signal (MPMVS) - The minimum input pulse signal power level which permits visibility of the center of the output pulse. This level is obtained in the same manner as the MVS level, with the center of the pulse being the point of reference.

Minimum Visible Signal (MVS) - The minimum input pulse signal power level which permits visibility of any portion of the output signal. This level is obtained by initially setting the input signal above the detection threshold, and then slowly decreasing the amplitude.

Mismatch Ratio - The ratio of impedances looking to the right and to the left of a pair of terminals.

Mutual Interference - That condition which exists when operation of one electronics equipment produces a malfunctioning in another and vice versa.

Narrow Band Radiated Interference - Interference having a spectrum exhibiting one or more sharp peaks narrow in width compared to the nominal bandwidth of the receiver, for example a CW signal.

Necessary Bandwidth - For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission or reception of intelligence at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.

Nonlinear Impedance - An impedance that varies with the voltage or current applied.

Occupied Bandwidth - The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5% of the total mean power radiated by a given emission. In some cases, for example multichannel frequency division systems, the percentage of 0.5% may lead to certain difficulties in the practical application of the definitions of occupied and necessary bandwidth, in such cases a different percentage may prove useful.

Octave - The range from a particular frequency to twice that frequency: f to 2 f, 2f to 4f, 4f to 8f.

Open Space - A site on flat terrain with no physical obstructions within 100 feet, and having low ambient level of radiation within the testing spectrum.

Orient - To turn or place in a certain position relative to a direction or point of reference.

Oscillator Interference - Spurious energy from a local oscillator, also called "receiver oscillator interference."

Parasitic Oscillations - Undesired self-sustained oscillations produced by an electronic circuit, at other than the operating frequency or its harmonics.

Plane of Reference - An arbitrary reference point in a transmission line or waveguide between an antenna and its associated transmitter or receiver such that the portion of the equipment on the antenna and the portion of the equipment on the other side of the plane is appropriately designated either the transmitter or receiver. It is at this reference plane that equipment separation takes place when necessary for measurements.

Precipitation Static - Noise produced by electrically charged atmospheric particles; rain static.

Propagation - The continuing generation of electromagnetic waves passing through a medium.

Quasi-Peak Measurement (QP) - A voltage proportional to the type of signal measured, obtained through the use of an arbitrarily weighted detector circuit having a charging time of 1 ± 0.5 milliseconds and a discharging time of 600 ± 120 milliseconds. A sine wave signal is indicated at its appropriate FI value, while that of an impulse signal may be indicated as nearly to peak value. When the QP indication is equal to 2 x FI or greater, it is regarded as broadband.

Radiation - The phenomenon of electromagnetic waves spreading out in space from a source according to the laws of wave propagation.

Radiator - An antenna or conductor used for propagation or reception of radio signals and spurious energy.

Radiated Interference - Propagated energy which produces malfunctioning of electronic equipment

Radio Interference - Any electrical disturbance which causes an undesirable response or malfunctioning in any electronic equipment.

Random Interference - An electrical disturbance without regularity of occurrence, which causes malfunctioning of electronic equipment.

Random Noise - An electrical disturbance that is completely without regularity in its detailed properties.

Receiver - Any electronic equipment in which unwanted signals may cause an undesirable response.

Receiver Input Coupler - A shielded network whose insertion loss is known at the measurement frequency and whose input properly terminates the signal source.

Rectification - The process of changing alternating current into pulsating direct current.

Rotatable Antennas - Antennas designed to rotate through 360°.

Selectivity - A measure of a receiver's ability to discriminate against off-channel radiations; that is, a measure of the receiver's band-pass characteristics. The selectivity is adequately defined by a few measurements, for example, the 3, 6, 20, 40, and 60 db response frequencies.

Semi-elevatable Antennas - Antennas designed to elevate through an angle less than 80°, or stepped in increments in the elevation plane.

Shield - A partition between two regions of space such that the electric and magnetic fields of interest are attenuated in passing from one region to the other.

Shielded Enclosures - An area enclosed by metallic panels or screening to act as a barrier to electromagnetic radiations.

Shock Excitation - The phenomena which occurs when a complex waveform is impressed upon a resonant circuit. If the complex waveform contains components at the center frequency of the resonant circuit, ringing (damped oscillations) will occur.

Shot Effect - The irregularity of plate current in a vacuum tube due to variations in cathode emission.

Sideband Splatter - Those emissions that appear outside of the necessary bandwidth and which are a result of intermodulation products of the modulation spectrum.

Skin Effect - The crowding of current toward the surface, or skin, of a conductor.

Spectrum Analyzer - A narrow band superheterodyne receiver which is repeatedly swept in frequency over a selected portion of the radio frequency band. At the same time, the horizontal deflection of the spot on a cathode ray tube moves in synchronism with the sweep. The vertical deflection of the spot is proportional to the output voltage of the receiver. The resultant display is a plot of amplitude versus frequency.

Spectrum Signature - The package of data which describes the electromagnetic radiating and receiving characteristics of the equipment.

Spurious Emissions - Emission on a frequency or frequencies which are outside the necessary bandwidth, and the level of which may be reduced without affecting the corresponding transmission of intelligence. Spurious emissions include harmonics, parasitic emissions, and intermodulation products, but exclude unnecessary modulation sidebands of the fundamental frequency.

Spurious Response - The response of a receiver due to its circuitry and construction which causes it to react to off-frequency signals. Spurious responses are often functions of the internal frequencies inherent within the receiver combining with an external signal to produce an undesired response.

Standard Response - A response observed at a selected point in a receiver where normal operation will be observed. The input signal to the receiver is adjusted so that the ratio of the output signal plus noise to noise is 6 db when communication receivers are used. The standard response for radar receivers is when the input required to give the minimum visible signal is present.

Standard Test Frequencies - That group of frequencies to which transmitters or receivers are tuned during the test procedure. Three such frequencies exist in each equipment tuning band, located at approximately the 5%, 50%, and 95% points in each band, and called the low, mean, and high test frequencies respectively. In some transmitters, frequency is selected by employing one of a series of output tubes. For this type of equipment tests shall be run with lowest, mean, and highest frequency tubes installed.

Surface Contact Transients - Transients resulting from the variation in contact resistances across sliding surfaces of rotating electrical machines.

Surface Transfer Impedance - The ratio of longitudinal voltage drop along the outside of a tubular shield to the current carried by the shield.

Susceptibility - That sensitivity of electronic equipment to electromagnetic energy not required for its normal operation.

System - Contains two or more sets or major units located at different points but accomplishing their objective through interdependent or interrelated operations, as for example a Propeller Control System.

Test Antenna - The antenna associated with the measurement equipment.

Thermal Agitation - The thermal motion of the conduction electrons in a resistor causing minute interfering currents.

To Bond - To connect between two points through a low impedance path.

Transmission Factor (referring to networks) - The ratio of the voltage in the transmitted wave to that in the incident wave at a point of discontinuity.

Transmission Factor (referring to media) - The ratio of the electric field intensity in the transmitted wave to that of the incident wave at a surface of discontinuity.

Transmit-Receive (TR) Box - A device used in radar sets to prevent the transmitted pulse from entering the receiver.

Transmitter - An equipment or system which generates radio frequency energy whether by design or not.

Transmitter Signal Sampling Device - A device to measure the output level of each frequency emitted. This device may be a voltage divider, power attenuator, directional coupler, probe, or a suitable band rejection filter. Its coupling loss should be known to within 1 db at each measurement frequency.

Tuning Band - That partial range of the tuning frequency range over which a particular configuration of equipment operates with a given bandswitch setting, e.g., one head of the AN/URM-XX may have the following tuning bands:

Band 1:	0.15	to	0.4	mc
Band 2:	0.35	to	0.92	mc
Band 3:	0.9	to	2.45	mc
Band 4:	2.4	to	6.3	mc
Band 5:	6.0	to	15.4	mc
Band 6:	15.0	to	30.0	mc

Tuning Frequency Range - That partial range of the frequency coverage over which a particular configuration of equipment operates, e.g., the AN/URM-XX may have the following tuning frequency range:

0.15 to 30	mc with head T-1 Installed
20 to 220	mc with head T-2 Installed
200 to 410	mc with head T-3 Installed
400 to 1000	mc with head T-4 Installed

Undesirable Response - Any audible, visible, or otherwise measurable response of a receiver not produced by a desired signal provided that either its duration is longer than one second or its highest recurrence rate during normal operation of the system is greater than once every three minutes.

Unnecessary Modulation Sidebands - Modulation sidebands refer to the spectral distribution of energy about the fundamental frequency which are a result of the modulation process for the transmission of intelligence. Unnecessary modulation sidebands are the sidebands which fall outside of the necessary bandwidth.

Wave Trap - A circuit designed to attenuate a selected frequency while passing, without appreciable attenuation, other frequencies. A band rejection filter.

White Noise - Random noise such as shot noise and thermal noise, which has constant energy per unit bandwidth.

SELECTED REFERENCES — APPENDIX III

The references in this Appendix are for use with all four Volumes of the RFI Handbook. Each reference will be found in one or more sections in the Appendix in accordance with its subject matter.

ANTENNAS AND PROPAGATION

1. Naval Research Laboratory: Spurious Radiation from Radio Transmitters and Receivers via Antenna Paths, BuAer Problem A276R-U, Electronics, NRL Letter 3920 168/48, October 11, 1948.

2. Lightning and Transients Institute, Quarterly Progress Report No. 21693-16, June 16, 1950, p. 5 ff.

3. Chapman, L. A.: Anti-Interference Aerials, Wireless World 38, Vol. 15, p. 3, January, 1936.

4. Crossley, A.: Interference Reducing Antenna Systems, QST No. 26, p. 25-26, May, 1942.

5. Sandretto: Principles of Aeronautical Radio Engineering, McGraw-Hill, p. 114 ff.

6. Starr, E. C.: Precipitation - Static Radio Interference Phenomena on Aircraft, Bull. 10, 1939, Engineering Experiment Station, Oregon State College.

7. Bartelt, Carl A.: Preliminary Investigation, WADC Technical Report No. 52-34, Part 1, Autogenous Electrification of a B 45A Aircraft.

8. Silver, S.: Microwave Antenna Theory and Design, First Edition, McGraw-Hill Book Co., Inc., 1949, p. 180.

9. Jasik, H.: Antenna Engineering Handbook, First Edition, McGraw-Hill Book Co., Inc., 1961.

10. Radio Research Laboratory Staff: Very High-Frequency Techniques, First Edition, McGraw-Hill Book Co., Inc., 1947.

11. Rhodes, D. R.: An Experimental Investigation of the Radiation Patterns of Electromagnetic Horn Antennas, Proc. IRE, Vol. 36, pp. 1101-1105, September, 1948.

12. Pullara, J. C., and Jones, J. P.: Radiation Characteristics of Antennas at Other Than Design Frequencies, 1961 International Convention Record, Part 8, p. 330.

13. Jacobs, E., and Salati, O. M.: The Gain of Aperture Antennas at Spurious Frequencies, Fifth Conference on Radio Interference Reduction and Electronic Compatibility (Proceedings), October, 1959, p. 492.

14. Polk, C.: Propagation and Antenna Considerations in the Prediction of Man-Made Interference, Proceedings of Conference on Radio Frequency Interference Reduction, Armour Research Foundation, December, 1954, p. 330.

15. Terman, F. E.: Radio Engineers' Handbook, First Edition, McGraw-Hill Book Co., Inc., 1943, p. 697.

16. Lindeman, Benjamin: Interference Aspects of Fresnel Region Phenomena, RADC-TN-60-214, December, 1960.

17. Jacobs, E.: Fresnel Region Patterns and Gain Corrections of Large Rectangular Antennas, Unclassified Proceeding of the Fifth Conference on Radio Interference Reduction and Electronic Compatibility, October, 1959.

APPLICATION OF FOURIER INTEGRAL ANALYSIS TO SIMPLE TRAPEZOIDAL PULSES

1. Campbell, G. A., and Foster, R. M.: Fourier Integrals for Practical Applications, Bell System, B-584, 1931.

ARCING

1. Lightning and Transients Research Laboratory: Radio Interference Transients Investigation II, filed in Lightning and Transients Res. Lab. Report No. 3.

2. Hernz, Fisher, and Peger: Time Function of the Radiation of Short Spark Discharges, ATI, Vol. 13, No. 13.

3. Kleis, J. D.: How Contact Arcing Can Be Minimized, Electrical Manufacturing, January, 1945.

4. Matson, Randolph: Aircraft Electrical Engineering, p. 222, McGraw-Hill, 1943.

5. War Dept.: Suppression of Radio Noises. TM 11-483, November, 1944.

BANDWIDTH CONSIDERATIONS

1. Proc. I. R. E.: Relations Between Speed of Indication, Bandwidth & S/N in Radio Navigation and Direction Finding. IRE, May, 1949.

BONDING

1. Signal Corps.: Radio Interference Suppression System for 100 kw Engine-Generator Unit, Manufactured by Cummins Engine Co., Inc., Columbus, Indiana, Hall Tech., Memo No. M-1301, SCP No. 4114B - 1085, June 27, 1950.

2. Cook Research Laboratories: Low Impedance Path Bonding Jumpers, Report No. FPRI-1-E.O., No. 112-133, p. 343, June, 1951.

CONSIDERATION OF THE ENTIRE AIRCRAFT AS A SINGLE NETWORK

1. Navaer: Elimination of Radio Interference in Aircraft, Report No. 16-5Q-517.

2. Shea, T. A.: Transmission Networks and Wave Filters, D. Van Nostrand Co., 1929.

CONTACT IMPEDANCE

1. Curtis, A. M.: Contact Phenomena in Telephone Switching Circuits, Bell System Technical Journal, Vol. 19, No. 1, p. 40-62, January, 1940.

2. Hunt, L. B.: Electrical Contacts, Johnson, Mathey & Co., Ltd., & Mallory Metallurgical Prod., Ltd., London, 1946.

CORROSION

1. Germer, L. M., Haworth, F. E.: Erosion of Electrical Contacts on Make, Journal of Applied Physics, Vol. 20, p. 1058-1109, November, Bell Telephone System Monograph No. 1710.

DECIBEL EQUIVALENTS TO CURRENT, VOLTAGE, AND POWER RATIOS

1. Vogelman, J. H.: The Derivation and Application of the Decibel, Eng. Div. Watson Labs., Report No. LESV-2-092447, April 24, 1947.

DIGITAL SYSTEMS

1. Wier: Digital Data Communication Techniques, Proceedings of the IRE, January, 1961, p. 196.

DISCHARGERS

1. National Advisory Committee for Aeronautics, Technical Note No. 1001, 1946.

2. Handbook, Static Discharger AN/ASA-3.

3. Naval Research Laboratory: Installation of Dry Wick Type Electrostatic Dischargers, NRL Report No. A903A.

4. Army-Navy Precipitation Static Report No. A1043A.

EFFECTS OF DIFFERENT TYPES OF MODULATION

1. OSRD: Studies on the Effect of Noise on Speech Communications, OSRD - 2038, November 25, 1943, PB 22907.

2. OSRD: Speech in Noise: A Study of the Factors Determining its Intelligibility, OSRD - 4023, September 1, 1944. PB 19805.

3. OSRD: Effects of Amplitude Distortion Upon the Intelligibility of Speech, OSRD - 4217, November 15, 1944, PB 19775.

4. OSRD: The Masking of Signals by Noise, OSRD - 5387, October 1, 1945.

5. Goldman, Stanford: Frequency Analysis, Modulation, and Noise, McGraw-Hill, 1948.

ELECTRICAL OSCILLATIONS IN STATIONARY CIRCUITS

1. Carson, J. R., Zobel, O. J.: Transient Oscillations in Wave Filters, Bell System Technical Journal, July, 1923.

2. Eastman, A. V.: Fundamentals of Vacuum Tubes, McGraw-Hill, Chap. XI, 1941.

3. Glasgow, R. S.: Principles of Radio Engineering, McGraw-Hill, Chap. V., 1936.

FILTERING AND SUPPRESSION NETWORKS

1. Mason, Warren P.: Electromechanical Transducers and Wave Filters, D. Van Nostrand Co., 1946.

2. Corby, R. E.: The Theory of a Three-Terminal Capacitor, Proc. IRE, June, 1950, Vol. 38, No. 6, p. 635-6.

3. Frick & Zimmerman: Aircraft Radio Noise Filters, Aircraft Communications 23, 32, 42, July, 1943.

4. Rollin Company: Development of High Efficiency Low Pressure Radio Filters, Lab. Report, Contract W33-038-AC-17991, December 15, 1947.

5. AEEL: Design Details of a 500 amp. 50 volt Line Filter Suitable for Use in Naval Aircraft, Report No. 75-48, September 7, 1948.

6. Edwards, Jonathan: An Electronic Power Supply Filter, IRE Fall Convention, San Francisco, 1949.

7. Linder, L.: The Effect of Self-Inductance of Rolled Paper Capacitors on Their Impedance, Elektrotech, Zeit, Vol. 60, pp. 793-798, AF Translation dtd. August, 1946.

8. Mason, M. P.: Filters & Transformers Using Coaxial & Balanced Transmission Lines, Bell System Technical Journal, Monograph B-1003.

9. Sprague Electric Co.: Small Size Feed-Through Capacitors, Oct. 18, 1948.

10. Carson, J.R.: Selective Circuits and Static Interference, Trans. AIEE, Vol. 43, p. 789, 1924.

11. Shea, T. E.: Transmission Networks and Wave Filters, D. Van Nostrand Co., Inc., 1951.

12. Haviland, R.P.: Simple Noise Limiter, Radio & Television News 44, August, 1950.

13. Maguire Industries: Noise Limiting Circuits.

14. Markus, John, and Zeluff, Vin: Handbook of Industrial Electronic Circuits, Chapter on Limiter Circuits, p. 85, McGraw-Hill, 1948.

15. Terman, F.E.: Radio Engineers Handbook, Sec. 9., Par. 6-8, McGraw-Hill, 1943.

16. U. Radio: Noise Limiters (Manual & Automatic Types for UHF and BC Receivers), No. 268, p. 26-28, May, 1942.

FLUORESCENT LAMPS

1. Young, C.S.: Radio Noise from Fluorescent Lamps, EEI Bull., Vol. 12, p. 59, February 2, 1944.

GENERAL DESIGN CONSIDERATIONS FOR INTERFERENCE-FREE OPERATION

1. Frick, C.: How to Minimize the Radio Influence of Electric Devices, Electrical Mfg., March, 1939.

2. Gill, A.J., Whitehead, S.: Electrical Interference with Radio Reception, JIEE, p. 345-386, 1938, Vol. 83.

3. Kogel, K.: Methods of H. F. Interference Suppression for Machines & Appliances up to 500 Watts, AEG Mitteilunger, pp. W238, September/October, 1941.

4. Majumdar & Khastgir: Studies of Electrical Interference to Radio Reception, Ind. J. Phys., Vol. 17, p. 271-282, October, 1943.

5. Busignies, H.: Some Relations Between Speed of Indication Bandwidth and Signal-to-Random Noise Ratio in Radio Navigation and Direction Finding, Proc. IRE, Vol. 37, p. 478-488, May, 1949, Electrical Communication, Vol. 26, p. 228-242, September, 1949.

6. Goldman, Stanford: Some Fundamental Considerations Concerning Noise Reduction and Range in Radar and Communication, Tech. Report No. 32, Res. Lab. of Electronics, MIT, December 15, 1947.

7. OSRD: Auditory Tests of the Ability to Hear Speech in Noise, OSRD-3516, September 1, 1944.

8. Curtiss-Wright Corp.: Investigation of Radio Interference Analysis in a Type B-17 Aircraft, Report TE-49-12-E, Part 3, July, 1950.

9. General Lab. Associates: Factors Influencing Generation of and Susceptibility to Interference Voltages by Electronic Equipment, 1949.

10. OSRD: A. F. Factors in Portable Radio Equipment - Redesign of SCR-274N and ATA Modulators - Performance of Eaves Sound Projector, OSRD-1528, June 28, 1943.

11. Royal Aircraft Establishment: Mutual Interference Between Radio Communications and Radar Equipments, Section 4.

12. ATSC: Coupling of Airplane Antennas with the Aircraft Wiring System & the Effect of the Aircraft Wiring System, AAF Trans. PB-25227.

13. Burgess, R. E.: Noise in Receiving Aerial Systems, Proc. Physical Society, Vol. 53, p. 293-304, 1941.

14. Post Office Engineering Dept.: London, England, Radio Report No. 2009-1950.

15. Aggers, C. V.: Methods of Controlling Radio Interference, Electrical Engineering.

16. Mallory, P. R. & Co.: Practical Radio Noise Suppression, MYE Technical Manual, p. 309-324, Sec. 10, 1942.

17. Pyle, H.: Eliminating Noise in Aircraft Radio Receivers, Aero Eng. Rev. 4; 87, April, 1945.

18. St. Dallas, G.: New Methods for the Reduction of Interference in Receivers, Funktech Monatshefte, No. 5, pp. 69-75, May, 1941.

19. O'Neil: Radio Interference Suppression - Investigation of 24-volt Waterproof Electrical System, Tech. Memo No. M-1261, SCP No. 4114A-1145, March 10, 1950.

20. McClennon, D.: Spurious Radiation from Radio Transmitters and Receivers via Antenna Paths, Final Report, Naval Research Lab.

21. War Dept.: Elimination of Radio Noise in Aircraft, (I) Int. to aircraft radio noise (II) Detecting, localizing and measuring radio noise; (III) Application of suppression techniques, June 25, 1945.

GROUNDING

1. A. H. Sullivan, Jr.: Why R. F. Grounds, Electrical Design News, September 1960.

GUN-LAYING RADAR SYSTEM

1. ATSC: Notes on Design of Radar Systems Which Do Not Cause Radio Interference, Tech. Note TN-TSERP2-1, February 20, 1945.

2. Cady, Karelitz, and Turner: Radar Scanners and Radomes, MIT Series, Vol. 26.

3. MIT: Interference Between SCR-584's Tracking APN-19 Beacon, MIT 816.

IGNITION SYSTEMS

1. AAF: Radio Shielding of Aircraft Engine Ignition Systems, Army Air Force Materiel Command, Serial TN-92-1, p. Xi-Xii, May, 1944.

2. Bendix-Scintilla: Development of Lightweight Magnetos, 3rd Quarterly Report, SCL-3071, March 15, 1948.

3. Curtis, L. F.: Ignition Disturbances, Proceedings of the Radio Club of America, October, 1936.

4. Nethercot, W.: The Relation Between the Sparking Plug Current and the Short Wave Radiation Produced by Ignition Systems, ERA Report M/T 53, 1937.

5. Pender, Harold, and DelMar, W. A.: Electrical Engineers Handbook, Sec. 17, p. 137, 138, John Wiley & Sons.

6. Purdy, R. M.: Development of Lightweight Magnetos, Second Quarterly Report.

7. Sprague Electric Co.: Radio Interference Suppressors, Contract AF 33(038)0353, February-April, 1950.

8. War Dept.: Radio Interference Suppression System for International Harvester Co. Model UD-16 Engine (Magneto Ignition, TM No. M-1279.

9. AAF: Radio Shielding of Aircraft Engine Ignition Systems, TN-92-1, May 26, 1944 and July 1, 1946.

10. AMC: Ignition System Exciter, September 29, 1944, 92-885.

11. Inst. of Aero Sc.: Radio Noise in Aircraft Engines, Rev. 4, Aero Eng. 13-32, August, 1945.

12. Nethercot, W.: Car Ignition Interference, Wireless Engineer, Vol. 26, No. 311, p. 251-255, August, 1949.

13. Pierce, R. H.: Radio Interference Suppression System for Cushman Models M6, M7-2, M7-3, and M8 Gasoline Engines, Signal Corps Labs., SCP 4114C-2171, May 8, 1950.

14. Wolcott, L. C.: Airplane Motor Radio Shielding, Aviation Engineering, June, 1931.

IMPEDANCE CONCEPT

1. AMC: Impedance of Aircraft Electrical Systems at Radio Frequencies, Engineering Division, Technical Note Serial TN-TSELS6-8, June, 1946.

LORAN SYSTEM

1. AMC: Interference Rejection Antenna System for Loran AN/APN-4 and Equipments, Memo TSELR-66.

2. Pierce, McKenzie, and Woodward: Loran, MIT Series, Vol. IV.

MEASUREMENT OF INSERTION LOSS OF FILTERS

1. Armed Services Electrical Standards Agency: Method of Insertion-Loss Measurement for Radio-Frequency Filters, Project 116A, Proposed MIL-STD., October, 1951.

2. MIT, Radiation Lab.: A Method of Shielding for Filter Insertion Loss Measurement, Rad. Lab. Report No. 786, PB 2784.

3. Signal Corps: Measurement of Filter Insertion Loss at High and Ultra-High Frequencies, Eng. Lab., Tech. Memo M-1328, September 22, 1950.

4. USNEL: Discussion of Problems Relating to Insertion Loss Measurement and Standardization, Report No. 84, September 21, 1948.

MEASUREMENT OF INTERFERING SIGNALS

1. Bond, F. E.: Measurements of Noise, Crosstalk, Volume and Related Quantities in Communication Systems, AMC, USAF, Wright Field, Signal Corps Proj. No. 2051-18, February 24, 1949.

2. ENT., Measurements of High Frequency Interference, Vol. 18, No. 6, pp. 126-133, June, 1941.

3. Evans, J.: Measurement and Suppression of Radio Interference, British Institution of Radio Engineers, February, 1949.

4. Fletcher, H.: Noise Measurements, Elec. Engineering, v. 52, p. 744, November, 1933.

5. Franke, C. J.: The Measurement of Radio Noise Interference, RMA Engr., Vol. 3, p. 7-10, November, 1938.

6. Hamburger, B. L.: Interference Measurement, Wireless Engineer, v. 25, 293 and 294, p. 44-54 and 89-97, February and March, 1948.

7. Kaye, G. W. C.: Measurement of Noise, Phys. Soc. Reports, v. 3, p. 130 (1936).

8. Naday, G.: Noise Measurements in High Frequency Receivers, Annales de Radioelectricite, July, 1949, pp. 257-260.

9. OSRD: Investigations of the Measurements of Noise, Final report, PB 19657, 10/31/45, OSRD-6358.

10. Dean: Measurements of the Subjective Effects of Interference in TV Reception, Proceedings of the IRE, June, 1960, p. 1035.

11. Dozier, J. J., Jr., Sullivan, A. H., Jr., and Savage, J. W.: Notes on Spectrum Signature Measurement Problems, Washington Chapter PGRFI, October 17, 1961.

12. Aggers, C. V., Foster, D. E., and Young, C. S.: Instruments and Methods of Measuring Radio Noise, AIEE Transactions, Vol. 59, pp. 178-192, March, 1940.

13. Burrill, C. M.: New Equipment to Measure Intensity of Radio Noise, Broadcast News No. 32, pp. 6-7, March, 1940.

14. Daniel, L. H.: Apparatus for the Measurement of Interference at UHF, ERA Report M/T 64, 1939. Also, IEE Journal, Vol. 88, Part III, pp. 41-49, March, 1941.

15. Davis, A. H.: An Objective Noise Meter for the Measurement of Moderate and Loud, Steady and Impulsive Noises, Journal IEE, Vol. 83, pp. 249-260, August, 1938.

16. OSRD: Standard Radio Noise Signal Generator, OSRD-5284.

17. Frederick Research Corporation: Test Equipment Data Handbook, Vol. No. 5.

MODULATORS

1. Claview, A. G.: Signal-To-Noise Radio Improvement in a Pulse-Count-Modulation System, FTL, Elec. Communication, pp. 257-262, September, 1949.

2. DeLoraine, E. M.: Pulse Modulation, Electrical Communication 26, pp. 222-227, September, 1949.

3. Mallach, L. W.: Reduction of Radar-Radio Interference from Modulators, Radiation Labs., MIT, August 3, 1943.

MUTUAL INDUCTANCE BETWEEN TWO SETS OF INFINITELY LONG PARALLEL PAIRS OF STRAIGHT WIRES

1. Grover, F. W.: Inductance Calculations, D. Van Nostrand & Co., 1946.

NATIONAL COMMUNICATIONS

1. Pochyla, B. H.: The National Communications - Electronics Community (including Chart showing National Communications - Electronics (C-E) Community, Signal, Vol. XVI, No. 9, May 1962.

NATURE OF INTERFERENCE

1. Brooks, Harvey: Theory of Random and Modulated Noise, NDRC 147.

2. Franz, K.: Amplitude of Noise Voltages, Wireless Eng., v. 20, p. 397 (1943).

3. Freberg, C. R.: Noise, Its Character and Measurement, Refrig. Eng., v. 53, p. 119 (1947).

4. Gardner, M. F., and Barnes, J. L.: Transients in Linear Systems, John Wiley & Sons, (1942).

5. Johnson, Walter C.: Transmission Lines and Networks, McGraw-Hill, 1950.

6. Landon, V. D.: A Study of the Characteristics of Noise, Proc. Inst. Radio Engineers, (1936), 24, 1514 - 1521.

7. Ritz, W. A.: Analysis of Radio Interference Sources, Electron 5:1-13, October, (1949).

8. Surdin, M.: Distribution in Time of Spontaneous Fluctuations Voltage, Phil. Mag., 1943, 34 - 716 - 722.

9. Gerson, N. C.: Noise Levels in the American Sub-Arctic, Proc. IRE, August, 1950.

10. Crichlow, W. Q.: Noise Investigations at VLF by the National Bureau of Standards, Proc. IRE, June, 1957.

11. Ko, H. C.: Amplitude Scintillation of Extraterrestrial Radio Waves at Ultra High Frequencies, Proc. IRE, November, 1958.

12. Watt, A. D., Coon, R. M., Maxwell, E. L., and Plush, R. W.: Performance of Some Radio Systems in the Presence of Thermal and Atmospheric Noise, Proc. IRE, December, 1958.

13. Bullington, Kenneth: Radio Propagation at Frequencies Above 30 Megacycles, Proc. IRE, October, 1947.

14. Air Forces Manual: No. 40, p. 6, December, 1944.

15. George, R. H.: Tech. Report C. A. A., No. 29, April, 1940, p. 2.

16. Gunn, R.: Proc. IRE, p. 177, April, 1946.

17. Gott, J. P.: Charge on Water Drops Falling Through a Cloud of Charged Particles in a Vertical Field, Proc. Royal Soc., Vol. 151, p. 665-684, 1935.

18. Nukiyama, D.: On the Accumulation of Electric Charges on Thunderclouds, Japanese Jour. Astron. and Geophysics, Vol. VI, No. 1, 1928.

19. Nukiyama, D., and Noto, H.: On the Electrification of Water Drops, Japanese Jour. Astron. and Geophysics, Vol. VI, No. 1, 1928.

20. Zeleny, John: Current-Voltage Characteristics of High-Potential, Direct Current Brush and Glow Discharges in Air at Atmospheric Pressure, Jour. Franklin Institute, p. 685-699, 1934.

21. Humphreys, W. J., and Lippincott: Physics of the Air, p. 314.

22. Morgan, H. K.: Rain Static, Proc. IRE, Vol. 25, p. 959-963, 1936.

23. Swarup, G., Maxwell, A., and Thompson, A. R.: The Radio Spectrum of Solar Activity, Proc. IRE, January, 1958.

24. Reed and Russell: Ultra High Frequency Propagation, p. 95, Curves of Reflection Coefficients and Phase Shifts Versus Angles of Incidence, John Wiley & Sons, Inc.

25. Appleton, E. V., Watson-Watt, R. A., and Herd, J. F.: On the Nature of Atmospherics, II and III, Proc. Royal Soc., 1926, p. 615-77.

26. Appleton, E. V., and Chapman, F. W.: On the Nature of Atmospherics, IV, Proc. Royal Soc., v. 158, p. 1-22, 1937.

27. Gunn, R., and Parker, J. P.: The High-Voltage Characteristics of Aircraft in Flight, Proc. IRE, Vol. 34, No. 5, p. 241-247, May, 1946.

28. Lutkin, F. E.: The Nature of Atmospherics VI, Proc. Royal Soc., Vol. 171, p. 285-313, 1939.

29. Morgan: Proc. IRE, p. 969, 1936.

30. Munro, G. H., and Webster, H. C.: Nature of Atmospherics, Proc. Royal Soc., v. 134, p. 850 and 987, 1934.

31. OSRD: Precipitation Static Research, OSRD-1807, August 31, 1943.

32. ATSC: Radio Interferences by Electrical Charges and Their Removal, AAF Trans., PB27606.

33. OSRD: Precipitation Static Exploration C-70, OSRD-3595, February 15, 1944.

34. Malan, D. J., and Schonland, B.. The Distribution of Electricity in Thunderclouds, Proc. Royal Soc. A, p. 158-177, 1951.

35. Schonland, B.: The Flight of Thunderbolts, Clarendon Press, Oxford, 1950.

36. Simpson, G. C.: The Electricity of Atmospheric Precipitation, Phil. Mag. v. 30, p. 1-12, 1951.

37. Stimmel, R. G., Rogers, E. H., Waterfall, F. E., and Gunn, R.: Electrification of Aircraft Flying in Precipitation Areas, Proc. IRE, Vol. 34, No. 4, p. 167P-177P, April, 1946.

38. Farrel, O. P.: New Concepts on the Causes of Radio Interference, Radio 29; 27-28 Dec., 1945, Radio 30; 25 Jan., 1946, Radio 30; 23-24; Feb., 1946.

NAVIGATIONAL RADAR SET

1. Roberts, A.: Radar Beacons, Chapter 4, Vol. 3, Rad. Lab. Series, McGraw-Hill, 1947.

NON-LINEAR IMPEDANCE

1. Bunimovich, V. I.: Effect of the Fluctuations and Signal Voltages on a Non-Linear System, J. Phy., USSR v. 10, n 1, p. 35-48 (1946).

2. Everitt, W. L.: Communication Engineering, McGraw-Hill, 1937.

3. Middleton, D.: Some General Results in the Theory of Noise Through Non-Linear Devices, Quart. of Appl. Math., 5, 4, 1948, p. 445.

NUISANCE VALUE OF INTERFERING SIGNALS

1. Goldman, Stanford: Frequency Analysis, Modulation, and Noise, McGraw-Hill, 1948

OPTICAL LASERS

1. Oliver, B. M.: Some Potentialities of Optical Lasers, Proc. IRE, Vol. 50, No. 2, p. 135, February 1962.

PARASITIC OSCILLATIONS

1. Hultbert, C. A.: Neutralization of Screen Grid Tubes to Improve the Stability of Intermediate-Frequency Amplifiers, Proc. IRE, Vol. 31, pp. 663-665, December, 1943.

PRECIPITATION STATIC

1. AN: Aircraft Treatment for the Elimination of Precipitation Static, AN-P Stat. Proj., Report A955A.

2. OSRD: Precipitation Static Reduction C-21, OSRD-1907, March 31, 1943.

3. Kinser, G. D.: Investigations of Methods for Reducing Precipitation Static Radio Interference, Proc. IRE, Vol. 34, No. 5, p. 234-240, May, 1946.

PROPAGATION - See ANTENNAS AND PROPAGATION

RADAR RECEIVERS

1. ATSC: Notes on Design of Radar Systems Which Do Not Cause Radio Interference, April 25, 1945.

2. Beard, E. G.: Reduction of Noise at U. H. F. in Triode Valves and Grounded Grid Amplifiers, Philips Tech. Commun., p. 20-3, March, 1947.

3. Bell System Technical Journal: Radar Systems and Components, p. 364-740, Van Nostrand, 1947.

4. Goldman, Stanford: Reduction Radar Noise, Proc. IRE 36, p. 584-594, 1950.

5. Levy, M.: Signal/Noise Ratio in Radar, Wireless Engineer, Vol. 24, n. 291, p. 349-52, December, 1947, Wireless Engineer, Vol. 25, n. 298, p. 236-7, July, 1948.

6. MIT: Principles of Radar, Radar School Staff, 2nd Edition, McGraw-Hill Book Company.

7. Pollard, Ernest, and Sturtevant, Julian: Microwaves and Radar Electronics, Chapter 5 - Circuit Bandwidth, Chapter 8 - I-F Amplifiers, Receiving Gating, Anti-Jamming, and Anti-Clutter Circuits, Chapter 10 - Receiver Gating, Wiley - 1948.

8. Ridenour: Radar Systems Engineering, MIT Series, Vol. I.

9. Royal Aircraft Establishment: Interference in Communication Receivers from Radar D.C. Pulses, I - Outline of Fourier Analysis, II - Application of Theory of Part I, III - Relationship between Spectral Density Curves and the Interference Curves, IV - Experiment Which Verifies the Experimental Result, December, 1945.

10. Wireless Engineer: Signal-Noise Ratio in Radar, p. 399-352, December, 1947.

11. Garner, W. R., and Hamburger, F.: Detectability and Discriminability of Targets on a Remote Projection Plan-Position Indicator, Proceedings of the IRE, November, 1947, p. 1221.

12. Haeff, A. V.: Minimum Detectable Radar Signal and Its Dependence Upon Parameters of Radar Systems, Proceedings of the IRE, November, 1946, p. 857

RADIATION

1. Air Technical Services Command: Direction of Currents on an Airplane Excited by Radiation, AAF Translation.

2. Chatterjee, S. K.: Absorption and Reflection of U. H. F. Waves (300-500 mc/s) by Seawater, Ind. Journal of Phys., June, 1949 (23-6 monthly), pp. 273-279.

3. Jordan, E. C.: Electromagnetic Waves and Radiating Systems, Prentice-Hall, 1950

RADIATION HAZARDS

1. Mumford, W. W.: Radiation Hazards, Proc. IRE, February 1961.

2. Midwest Research Institute, Summary Report: Survey of Radio Frequency Radiation Hazards, June 14, 1960.

3. Mumford, W. W.: Some Technical Aspects of Microwave Radiation Hazards, Proc. IRE, Vol. 49, p. 427, February, 1961.

4. Schwan, H. P., and Li, K.: Hazards Due to Total Body Irradiation by Radar, Proc. IRE, Vol. 44, p. 1572, 1956.

5. Weinbaum, B.: Susceptibility of Pyrotechnic Devices to Electromagnetic Energy, Fifth Conference on RFI Reduction and Electromagnetic Compatibility (Proceedings), October, 1959, p. 43.

6. Knapp, K. W., and Lambdin, W. S.: An Instrument for Measurement of High RF Power Density, Sixth Conference on RFI Reduction and Electromagnetic Compatibility (Proceedings), October, 1960, p. 406.

RADIO FREQUENCY INTERFERENCE

1. Bibliography on Radio Frequency Interference, IRE Transactions on Radio Frequency Interference, Vol. RFI-4, No. 1, February, 1962.

2. Jacobs, G.: Radio Interference - Suicide or Challenge, IRE Transactions on Radio Frequency Interference, Vol. RFI-4, No. 2, May 1962.

3. Garlan, H., and Whipple, L. G.: Control of Radio Frequency Interference from Nonlicensed Apparatus, Report No. TR-6104, Federal Communications Commission, Office of the Chief Engineer, 1 September 1961, Washington 25, D. C.

4. Brady, R. F.; Dean, W., Jr.; Randall, H.; Schulte, O. J.: The Progress of the Department of Defense Electromagnetic Compatibility Program, Conference Proceedings, 5th National Convention on Military Electronics, June 26, 27, 28, 1961, Washington, D. C., page 191.

5. Toler, J. C., and Norton, C. M.: Establishment of an Electromagnetic Compatibility Program, Symposium Digest, Fourth National Symposium on Radio Frequency Interference, June 28-29, 1962, San Francisco.

6. Brosius, G. D.: The Army's Electromagnetic Environmental Test Facility, op. cit.

7. Hoehn, A. J., and Michalk, E. R.: Use of the EMETF Field Facility for Validation of Interference Prediction Model, op. cit.

8. Woolwine, C. C.: The Mission and Operating Philosophy of the Analysis Center, Proceedings of the 7th Conference on Radio Interference Reduction and Electronic Compatibility sponsored by the Army, Navy and Air Force, conducted by Armour Research Foundation, Chicago, Illinois, 7, 8, 9 November 1961.

9. Cohn, S. I.: The Technical Program of the Analysis Center, op. cit.

10. Babcock, L. F.: A Facility for the Investigation of Radio-Interference Problems, op. cit.

RADIO RECEIVERS

1. Admiralty Signal Establishment: Interference-Free Transmitters and Interference Immune Receivers, Section B, July, 1945.

2. Burgess, R. E.: Receiver Input Circuits, Design Considerations for Optimum Signal/Noise Ratio, Wireless Engineer, v. 20, p. 66, 1943.

3. Friis: Noise Figures of Radio Receivers, Proc. IRE, p. 419, July, 1944.

4. Fubini and Johnson: Signal to Noise Ratio in A. M. Receivers. Proc. IRE, p. 1461, December, 1948.

5. Goldman, Stanford: Some Final Consideration Concerning Noise Reduction and Range in Radar and Communication, Proc. IRE, p. 554-594, May, 1948.

6. Millman, Jacob, and Seeley, Samuel: Chapter XIX, Sec. 19-10, Electronics, McGraw-Hill.

7. Reich, H. J.: Interference Suppression in AM and FM, Communications, vol. 22, No. 8, p. 7, 16, 19-20, August, 1942.

8. Rogers, D. C.: Suppressing Impulse Noise, Wireless World 55: 489-492, December, 1949.

9. Zinn, M. K.: Transient Response of an F-M Receiver, Bell System Technical Journal, Vol. 27, p. 714-731, October, 1948.

10. A. H. Sullivan, Jr.: Problems in Aircraft Radio, IAS, Dayton, Ohio, 1950.

RELAYS

1. Dallas, J. P., and McCully, T. M.: Sensitive Relay Contact Protection, Trans. AIEE, p. 1204-7, 1948.

2. Lightning & Transients Research Lab.: Radio Interference Transients Investigation, Technical Report No. 2, p. 1-32, March 15, 1946.

3. Lightning & Transients Research Lab: Radio Interference Transients in Aircraft - I, Technical Report, 1949.

4. Packard, Charles A.: Relay Engineering, Struthers-Dunn, Inc., Philadelphia, 1945.

ROTATING MACHINERY

1. Motter, D. P.: Commutation of DC Machines and Its Influence on Radio-Interference Voltage Generation, Trans. AIEE, p. 491-5 and 495, 1949.

2. Hoyes, Pitman: Current-Collecting Brushes in Electrical Machines, Sir Isaac Pitman, London, 1947.

3. Kloeffler, R.G., Kerchner, R.M., Brenneman, J.L.: Direct Current Machinery, The Macmillan Company, 1948.

4. Langsdorf, A.L.: Theory of Alternating Current Machinery, McGraw-Hill, 1947.

5. Frick & Motter: Investigation of Radio Noise Generation in Aircraft Electrical Machinery, G.E. Terminal Report, Contract W28-099-ac-83.

6. Signal Corps.: Suppression of Radio Interference Created by Engine-Generator Units, Manual SIG-461-1, August, 1945.

7. Naval Air Material Center, Philadelphia, Pa., Radio Interference Correctives for 800-1 Series Motor Alternators, Project TED NAM EL-406, Report No. ARRL 511-47.

8. Hoyes, and Pitman: Current-Collecting Brushes in Electrical Machines, Sir Isaac Pitman, London, 1947.

9. Kloeffler, R.G., Kerchner, R.M., and Brenneman, J.L. Direct Current Machinery, The Macmillan Company, 1948.

10. Langsdorf, A.L.: Theory of Alternating Current Machinery, McGraw-Hill, 1947.

SENSORY COMMUNICATION

1. Rosenblith, W.A.: Sensory Communication, MIT Press and John Wiley & Sons, Inc., Interactive Processes in Visual Perception, by D. M. MacKay, p. 339.

SHIELDING

1. Air Technical Services Command: Shielding Effect of Interference, Eliminating Flexible Tubes, AAF Translation, April 1946.

2. Air Technical Services Command: Examination of Lines Variously Shielded to Avoid Radio Interference, AAF Translation.

3. Breeze Corporation: Investigation of Shielding Efficiency Theoretical and Practical Investigation of Shielding Efficiency with Separate Measurements of E and A, Terminal Report.

4. Levy, S.: Electromagnetic Shielding Effect, Proc. I. R. E., v. 24, No. 6:923 - 941, June, 1936.

5. Naval Research Lab.: Shielding Efficiency of Shielded Enclosures, January 10, 1951.

6. Schelkunoff, S. E.: Electromagnetic Waves, D. Van Nostrand Co., Inc., 1943, p. 303 - 315.

7. AMC.: Radio Shielding of Aircraft Engine Ignition Systems, A. A. F., Engineering Division, Technical Note TN-92-1.

8. Anderson, Alton R.: Cylindrical Shielding and Its Measurement at Radio Frequencies, Proceed. of the IRE and Waves and Electronics, Vol. 34, No. 5, May, 1946.

9. ATSC: Shielding Effect of Interference Eliminating Flexible Tubes, A. A. F. Translation No. 518, April 22, 1946.

10. Lightning & Transients Lab.: Aircraft Interference Fields, Report No. 174, January, 1951, p. 11-12-17-23-24.

11. Roston, B.: Shielding at VHF, Wireless Engineer, July, 1948, Vol. 25, No. 298, p. 221-230.

12. Schaefer: The Effect of Different Types of Electromagnetic Shields, Translation by Univ. of Cincinnati, Edited by Leibiger Research Lab., Inc., August 27, 1947.

13. Technicraft Lab.: Study of Tubular Shielding, Final Report Vol. I, June 28, 1948; Vol. II, June 29, 1949.

14. Zepler, E. E.: The Technique of Radio Design, John Wiley and Sons, Inc., Chap. 8, The Principles of Screening, 1943.

15. Diamond, H., and Gardner, F. G.: Engine-Ignition Shielding for Radio Reception in Aircraft, Proc. IRE, v. 18, No. 5, 840-861, May, 1930.

16. Schelkunoff, S. A.: A Theory of Shielding, Bell Lab. Record 14, p. 229-232, March, 1936.

17. Lyons: Electromagnetic Shielding, Proc. IRE.

18. Coles Signal Lab.: Development of Magnetic Field Probe, Tech. Memo M-1082, June 10, 1947.

19. Coles Signal Lab.: Development of Procedure for Testing R-F Leakage in Shielding Conduit, (0.15-156 mc), October 21, 1946.

20. Schelkunoff, S. A.: The Impedance Concept and Its Application to Problems of Reflection, Refraction, Shielding, and Power Absorption, Bell System Technical Journal, Vol. 17, January, 1938.

21. Signal Corps: Development of Procedure for Testing R-F Leakage in Shielding Conduit (0.15-156 mc), Tech. Memo No. M-1019, October, 1946, Sig. Corps Engineering Laboratories.

SIGNAL ACCEPTABILITY CRITERIA

1. Schwartz, R. F.: Signal Acceptability Criteria, IRE Transactions, Professional Group on RFI, May, 1961, p. 11.

2. Pearlston: Interference Acceptance Ratios in Electronic Communication Equipments, Fourth Conference on Radio Interference Reduction, Armour Research Foundation, Illinois Institute of Technology, Chicago, Illinois, 1958.

SPACE COMMUNICATIONS

1. Pierce, J. R., Cutler, C. C.: Interplanetary Communications from Advances in Space Science, Academic Press, New York, Volume I, 1959.

2. IRE-RTMA Joint Technical Advisory Committee: Radio Spectrum Conservation, McGraw-Hill, New York, 1952.

3. Policy Planning for Space Telecommunications, a Staff Report prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, Government Printing Office, 4 December 1960.

4. Hacke, J. E., Jr.: The Future Natural, Technological, and Social Environment of Global Communications, 2nd Annual Symposium on Global Communications, St. Petersburg, Florida, December 3, 1958.

5. Firestone, W. L.; Lutz, S. G.; and Smith, J.: Control of Interference Between Surface Microwave and Satellite Communication Systems, IRE Transactions on Radio Frequency Interference, Vol. RFI-4, No. 2, May 1962.

6. Mapes, C. M.: A Need for International Cooperation, Signal, Volume XIV, No. 7, March 1962.

7. Raish, L. R.: International Agreement: Key to Military Global Telecommunications, Signal, Vol. XVI, No. 7, March 1962.

8. Loeber, C. W.: The CCIR and International Telecommunications Developments, Signal, Vol. XVI, No. 7, March 1962.

SPECTRUM SIGNATURES

1. J. J. Dozier, A. H. Sullivan, Jr., H. D. Zink: The Impact of Spectrum Signature Programs on Equipment and Test Instrument Design, 4th Symposium on Radio Frequency Interference, San Francisco, 28-29 June 1962.

2. H. D. Zink, A. H. Sullivan, Jr.: Spectrum Signatures and RFI Prediction, paper presented at Wright Patterson Air Force Base, Dayton, Ohio, November, 1961.

STATISTICAL ANALYSIS

1. Ballantine, S.: Shot Effect in High-Frequency Circuits, JFI, v.206, p. 159-167 (1928).

2. Bell, D. A.: Shot Noise and Valve Equivalent Circuits, Wireless Eng. v. 20, p. 538 (1943).

3. Carson, J. R.: The Statistical Energy-Frequency Spectrum of Random Disturbances, Bell System Technical Journal, Vol. 10, pp. 374-381, July, 1931.

4. Glas, E. T.: Frequency Analysis in the Investigation of Radio Interference, Teknisk Tidskrift, Vol. 66 No. 10, Sup. p. 41-46, March, 1936.

5. Goldman, Stanford: Frequency Analysis, Modulation, and Noise, McGraw-Hill, 1948.

6. Lawson and Uhlenbeck: Threshold Signals, MIT-Radiation Laboratory Series, Vol. 24, McGraw-Hill, 1950.

7. Lee and Stutt: Statistical Prediction of Noise, TR 129, MIT July 12, 1949.

8. MacDonald, D. K. C.: Some Statistical Properties of Random Noise, Proc. Cambridge Philo. Soc., pp. 369 - 372, July, 1949.

9. Radio News: Analysis of Radio Interference Phenomena, Vol. 35, p. 54, June, 1946.

10. Rice, S. I.: Mathematical Analysis of Random Noise, Bell System Technical Journal, 23 - 282 - 232 (July, 1944), 24 - 47 - 156 (Jan., 1945), 621 - 35: 530, 162.

SWITCHING AND COMMUTATION

1. Pfann, W. G.: Bridge Erosion in Electrical Contacts and Its Prevention, Trans. AIEE, p. 1528-33, Bell Telephone System Monograph B-1621.

2. Foerlag, Gebers: Electrical Contacts, Ragnar Holm, Stockholm, Sweden, 1946.

3. P. R. Mallory & Co., Mallory Electrical Contacts Data Book, Indianapolis, 1945.

4. Olney, F. D.: Resistance Commutation, Trans. AIEE, 1950.

TELEVISION SYSTEMS

1. Fink, D.: Television Engineering Handbook, First Edition, McGraw-Hill Book Co., Inc., 1957, pp. 3-16, 3-17.

2. Frendendall: Picture Quality - Procedures for Evaluating Subjective Effects of Interference, Proceedings of the IRE, June, 1960, p. 1030.

THUNDERSTORMS AND LIGHTNING

1. Banerji, S. K.: The Electric Field of Overhead Thunderclouds, Royal Meteorological Society, J. Vol. 56, p. 305, 1930.

2. Baumler, M.: The Simultaneous Appearance of Atmospheric Disturbances, Jb. Drahtl. Telegr., Vol. 22, p. 2-8, 1923.

3. Bellaschi, P. L.: Lightning Strokes in Field and Laboratory, Trans. A. I. E. E., August, 1941.

4. Chapman, F. W.: Atmospheric Disturbances Due to Thundercloud Discharges, Part I, Proc. Phys. Soc., London, Vol. 51, p. 876-894, 1939.

5. deBallore, R.: The Relation Between Storms and Atmospherics, Onde Elect., Vol. 8, p. 463-464, 1929.

6. Gould, K. E.: Fields Caused by Remote Thunderstorms, Elect. Eng., Vol. 55, p. 575-582, 1937.

7. Halliday, E. C.: The Polarity of Thunderclouds, Proc. Royal Soc. A, p. 205-228, 1932.

8. Jensen, J. C.: The Branching of Lightning and the Polarity of Thunderclouds, J. Franklin Institute, Vol. 216, p. 707-748, 1933.

9. Morganrath, O.: In Atmospheric Storms, Funktech M., Vol. 3, p. 70-74, 1939.

10. Simpson, G. C.: The Mechanism of a Thunderstorm, Proc. Royal Soc., Vol. 114, pp. 376-401, 1927.

11. Gen. Elec. Rev.: p. 414-418, September, 1936.

12. Terres. Magnetism and Atmospheric Electricity, p. 93, March, 1935.

13. Byers: Misc. Report No. 3, Univ. of Chicago, Institute of Meteor.

14. Malan, D., and Schonland, B.: The Electrical Processes in the Intervals Between the Strokes of a Lightning Discharge, Proc. Soc. A, p. 145-163, 1951.

15. McEachron, K. B., and Patrick, K. G.: Playing with Lightning, Random House, New York, 1940.

16. Norinder, H.: Rapid Variations in the Magnetic Field Produced by Lightning Discharges, Proc. Phys. Soc., London, Vol. 49, p. 364-375, 1937.

17. Schonland, B.: The Polarity of Thunderclouds, Proc. Royal Soc., Vol. 118, p. 233-251.

18. Simpson, G., and Robinson, O.: The Distribution of Electricity in Thunderclouds II, Proc. Royal Soc., Vol. 177, p. 281-329, 1941.

19. Wilson, C. T. R.: Investigation of Lightning Discharge and on the Electric Field of Thunderstorms, Philos. Trans. (A), Vol. 221, p. 73-115, 1921.

20. Allbright, J. G.: A Lightning Flash and Its Component Strokes, Journal Applied Physics, Vol. 8, p. 313-318, 1937.

21. Allibone, T. E.: The Mechanism of the Long Spark, Jour. Inst. Elect. Engineers, London, p. 513-521, May, 1938.

22. Bruce, C. E. R., and Golde, R. H.: The Lightning Discharge, J. Inst. Elec. Engrs., Vol. 88 (2), p. 487-505, 1941.

23. Evans, E. A., and McEachron, K. B.: The Thunderstorm, Gen. Elect. Rev., p. 413-425, 1936.

24. George, R. H.: C. A. A. Technical Report No. 9, p. 2, April, 1940.

25. Goodlet, B. L.: Lightning, Journ. Inst. Elec. Engrs., Vol. 81, p. 1-26, 1937. Completed form, Vol. 82, p. 1-55, 1938.

26. Meek, J. M.: The Mechanism of the Lightning Discharge, Vol. 55, p. 972-977, 1939.

27. Simpson, G. C.: Lightning, Jour. Inst. Elec. Engrs., Vol. 67, p. 1269-1283, 1929.

TRANSFORMERS

1. Legg, V. E.: Magnetic Material and Method of Treatment Thereof, U. S. Patent No. 1,998,840.

TRANSIENTS IN RESONANT CIRCUITS

1. Cruft Elec. Staff, Harvard University: Electronic Circuits and Tubes, Chap. VII, Sec. 4, McGraw-Hill, 1947.

2. Kallman, H. E., Spencer, R. E., and Singer, C. P.: Transient Response, Proc. IRE, Vol. 33, pp. 169-195, March, 1945.

TRANSMISSION METHODS

1. Kimbark, E. W.: Electrical Transmission of Power and Signals, John Wiley & Sons, 1949

TRANSMITTERS

1. Black, H. S.: Stabilized Feedback Amplifiers, Bell System Technical Journal, 13, p. 1, January, 1934.

2. Cunningham, W. J., Gofford, S. J., and Licklider, J. C. R.: The Influence of Amplitude Limiting and Frequency Selectivity Upon the Performance of Radio Receivers in Noise, Proc. IRE, v. 35, p. 1021, October, 1947.

3. Freeman, R. L.: Use of Feedback to Compensate for Vacuum-Tube Input-Capacitance with Grid Bias, Proc. IRE, Vol. 26, pp. 1360-1366, November, 1936.

4. Terman, F. E.: Radio Engineering, McGraw-Hill, Chap. VI., 1947.

VIBRATORS

1. ASTM: Bibliography and Abstracts on Electrical Contacts, 1944.

SELECTED FCC REGULATIONS

(PARTS 15 AND 18)

APPENDIX IV

The Federal Communications Rules and Regulations included in this Appendix were current at the time this Appendix was prepared for printing. However, the FCC from time to time issues changes to its Rules and Regulations. If the reader has a requirement for the most current and up-to-date version of Part 15 or Part 18, he should direct his inquiry for current information to the FCC.

RULES AND REGULATIONS

Part 15 — *Incidental and Restricted Radiation Devices*

DECEMBER 1961

FEDERAL COMMUNICATIONS COMMISSION

[illegible]

Contents

SUBPART A—GENERAL

§ 15.1 Basis of This Part.

Section 301 of the Communications Act of 1934, as amended, provides for the control by the Federal Government over all the channels of interstate and foreign radio communication and further provides, in part, that no person shall use or operate apparatus for the transmission of energy, communications or signals by radio when the effects of such operation extend beyond state lines or cause interference with the transmission or reception of energy, communications, or signals, of any interstate or foreign character by radio, except under and in accordance with the Communications Act and a license granted under the provisions of that act. Restricted and incidental radiation devices emit radio frequency energy on frequencies within the radio spectrum and constitute a source of harmful interference to authorized radio communication services operating upon the channels of interstate and foreign communication unless precautions are taken which will prevent the creation of any substantial amount of such interference.

§ 15.2 Scope of This Part.

(a) This part contains rules that set forth the conditions under which the operation of incidental and restricted radiation devices is considered to fall outside the purview of section 301 of the Communications Act which specifies when a station license is required as a condition for lawful operation.

(b) No incidental or restricted radiation device which fails to conform to the provisions of this part, or which causes harmful interference, may be operated without a station license. Unless such devices may be operated in accordance with the provisions of some other part of this chapter (see particularly Part 19, Citizens Radio Service), persons wishing to operate such devices in a manner inconsistent with this part will be required to first secure an amendment of the Commission's rules to establish a licensed service providing for such operation and setting forth the technical and other limitations thereof; *Provided*, That in appropriate circumstances, when such a petition for rule making has been filed, the Commission may consider, prior to final action thereon, applications for Special Temporary Authorizations to operate stations on a developmental basis where it can be shown that such temporary operation would be in aid of a final determination as to whether the proposed rule should be adopted, and that such temporary operation would otherwise be in the public interest; and *Provided further*, That the Commission will, in exceptional situations, consider individual applications for licenses to operate incidental or restricted radiation devices, not conforming to the provisions of this part, where it can be shown that the proposed operation would be in the public interest, that it is for a unique type of station or for a type of operation which is incapable of establishment as a regular service, and that the proposed operation cannot feasibly be conducted under this part.

§ 15.3 General Condition of Operation.

Persons operating restricted or incidental radiation devices shall not be deemed to have any vested or recognizable right to the continued use of any given frequency, by virtue of prior registration or certification of equipment. Operation of these devices is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by other incidental or restricted radiation devices, industrial, scientific or medical equipment, or from any authorized radio service.

§ 15.4 General Definitions.

(a) *Radio frequency energy.* Electromagnetic energy at any frequency in the radio spectrum between 10 kc/s and 3,000,000 Mc/s.

(b) *Harmful interference.* Any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this chapter.

(c) *Incidental radiation device.* A device that radiates radio frequency energy during the course of its operation although the device is not intentionally designed to generate radio frequency energy.

(d) *Restricted radiation device.* A device in which the generation of radio frequency energy is intentionally incorporated into the design and in which the radio frequency energy is conducted along wires or is radiated, exclusive of transmitters which require licensing under other parts of this chapter and exclusive of devices in which the radio frequency energy is used to produce physical chemical or biological effects in materials and which are regulated under the provisions of Part 18 of this chapter.

(e) *Community antenna television system.* A restricted radiation device designed and used for the purpose of distributing television signals by means of conducted or guided radio frequency currents to a multiplicity of receivers outside the confines of a single building.

NOTE: The television signals that are distributed are modulated radio frequency signals and may be:

(a) Broadcast signals that have been received and amplified.

(b) Broadcast signals that have been received and converted to another frequency.

(c Any other modulated radio frequency signals fed into the system.

(f) *Low power communication device.* A low power communication device is a restricted radiation device, exclusive of those employing conducted or guided radio frequency techniques, used for the transmission of signs, signals (including control signals), writing, images and sounds or intelligence of any nature by radiation of electromagnetic energy.

EXAMPLES: Wireless microphone, phonograph oscillator, radio controlled garage door opener and radio controlled models.

§ 15.5 Equipment Available for Inspection.

Any equipment or device subject to the provisions of this part together with any license, certificate, notice of registration or any technical data required to be kept on file by the operator of the device shall be made available for inspection by Commission representatives upon reasonable request.

§ 15.6 Information Required by the Commission.

The owner or operator of any device subject to this part shall promptly furnish to the Commission or its representative such information as may be requested concerning the operation of the device including a copy of any field strength measurements made by or for the operator of the device.

§ 15.7 General Requirement for Restricted Radiation Devices.

Unless regulated under some other subpart of this part, any apparatus which generates a radio frequency electromagnetic field functionally utilizing a small part of such field in the operation of associated apparatus not physically connected thereto and at a distance not greater than $\frac{157{,}000}{F(kc/s)}$ feet $\left(\text{equivalent to } \frac{\lambda}{2\pi}\right)$ need not be licensed provided:

(a) That such apparatus shall be operated with the minimum power possible to accomplish the desired purpose.

(b) That the best engineering principles shall be utilized in the generation of radio frequency currents so as to guard against interference to established radio services, particularly on the fundamental and harmonic frequencies.

(c) That in any event the total electromagnetic field produced at any point a distance of $\frac{157{,}000}{F(kc/s)}$ feet $\left(\text{equivalent to } \frac{\lambda}{2\pi}\right)$ from the apparatus shall not exceed 15 microvolts per meter.

(d) That the apparatus shall conform to such engineering standards as may from time to time be promulgated by the Commission.

(e) That in the event harmful interference is caused, the operator of the apparatus shall promptly take steps to eliminate the harmful interference.

SUBPART B—INCIDENTAL RADIATION DEVICES

§ 15.31 Operating Requirements.

An incidental radiation device shall be operated so that the radio frequency energy that is radiated does not cause harmful interference. In the event that harmful interference is caused, the operator of the device shall promptly take steps to eliminate the harmful interference.

(Ed. 12/61)

SUBPART C—RADIO RECEIVERS

§ 15.61 Scope of This Subpart.

Radio receivers come within the scope of this subpart insofar as they are restricted radiation devices and generate and radiate radio frequency energy. Typically, these rules apply to superheterodyne receivers in which the oscillator may produce harmful interference. As another example, these rules also regulate television broadcast receivers with respect to the radio frequency energy which is generated by the horizontal sweep circuits and which may cause interference.

§ 15.62 Radiation Interference Limits.

(a) The radiation from all radio receivers that operate (tune) in the range 30 to 890 Mc/s, including frequency modulation broadcast receivers and television broadcast receivers, manufacturered after the effective date specified in § 15.66 shall not exceed the following field strength limits at a distance of 100 feet or more from the receiver:

Frequency of radiation (Mc/s)	Field strength (uv/m)
0.45 up to and including 25	See paragraph (b).
Over 25 up to and including 70	32
Over 70 up to and including 130	50.
130–174	50–150 (linear interpolation).
174–260	150
260–470	150–500 (linear interpolation).
470–1000	500.

(b) Pending the development of suitable measurement techniques for measuring the actual radiation in the band 0.45 to 25 Mc/s, the interference capabilities of a receiver in this band will be determined by the measurement of radio frequency voltage between each power line and ground at the power terminals of the receiver. This requirement applies only to radio receivers intended to be connected to power lines of public utility systems. For television broadcast receivers the voltage so measured shall not exceed 100 uv at any frequency between 450 kc/s and 25 Mc/s inclusive. For all other receivers the voltage shall not exceed 100 uv at any frequency between 450 kc/s and 9 Mc/s inclusive, 1000 uv for frequencies between 10 Mc/s and 25 Mc/s and linear increase from 100 uv to 1000 uv for frequencies between 9 Mc/s and 10 Mc/s.

§ 15.63 Measurement Procedure.

(a) Any measurement procedure acceptable to the Commission may be used to show compliance with the requirements of this subpart. A detailed description of the proposed measurement procedure, including a list of the test equipment to be used, shall be submitted to the Commission when requesting a determination regarding the acceptability of the proposed measurement procedure.

(b) The following methods of measurement are considered acceptable procedures for certification of receivers pursuant to § 15.64:

(1) Institute of Radio Engineers Standard 61 IRE 17S1 for radiation measurements.

(2) Institute of Radio Engineers Standard 61 IRE 27S1 for conducted interference measurements from frequency modulated and television broadcast receivers in the range 300 kc/s to 25 Mc/s.

(c) In the case of measurements in the field, radiation in excess of 15 uv/m at any frequency between 450 kc/s and 25 Mc/s at the border of the property and more than 15 feet from any power line crossing this border under the control and exclusive use of the person operating or authorizing the operation of the receiver will be considered an indication of noncompliance with the radiation requirements of this subpart.

§ 15.64 Certification of Radio Receivers.

(a) No radio receiver manufactured after the effective dates of this subpart that operates in the range 30 to 890 Mc/s, including frequency modulation broadcast receivers and television broadcast receivers, shall be operated without a station license unless it has been certificated to demonstrate compliance with the radiation interference limits in this subpart.

(b) The owner or operator need not certificate his own receiver, if it has been certificated by the manufacturer or the distributor.

(c) Certification made by a manufacturer or the distributor shall be based on tests made on receivers actually produced for sale. Tests shall be performed on a sufficient number of production units to assure that all production units comply with the radiation limitations of this subpart.

(d) The certificate may be executed by an engineer skilled in making and interpreting field strength measurements.

(e) The certificate shall contain the following information:

(1) Name of manufacturer or distributor of receiver,

(2) Model number,

(3) Brief description of receiver, including tuning range, type of circuit, purpose for which used (as broadcast, aircraft, etc.),

(4) Brief statement of the measurement procedure used,

(5) Date the measurements were made,

(6) A summary of the date obtained,

(7) A statement certifying that on the basis of measurements made, the radio receiver is capable of complying with the requirements of this part under normal operation with the usual maintenance,

(8) The name and address of the certifying engineer, and name and address of his employer, if any, and

(9) Date of the certificate.

(f) The certificate shall be retained by the owner, manufacturer or the distributor for a period of five years, and shall be made available, upon reasonable request, to an authorized Commission representative, or photostat furnished by mail. (See § 15.65 for filing requirement with FCC).

§ 15.65 Information To Be Filed With Commission.

(a) Each manufacturer, distributor or other certifying agency that issues certifications pursuant to this subpart shall file with the Commission a description of its measurement facilities used for certification.

(b) A copy of each certificate prepared by a manufacturer, distributor or certifying agency shall be filed with the Commission at the time the certificate is prepared.

§ 15.66 Identification of Certificated Receivers.

Each certificated receiver shall be identified by a distinctive seal or label, which may be a part of the name plate and which shall state that the receiver has been certificated for compliance with the requirements of this subpart. The seal or label shall be permanently attached to the receiver and shall be readily visible for inspection by prospective purchasers.

§ 15.67 Operation of Radio Receivers Aboard a Ship.

In addition to meeting the requirements of this part, a radio receiver operated aboard a ship shall also meet the requirements of Part 8 of this chapter.

§ 15.68 Date When Certification Is Required.

VHF television broadcast receivers manufactured after May 1, 1956, shall comply with the certification requirements of this subpart, except that compliance with the power line interference limits for frequencies between 3 Mc/s and 25 Mc/s is required for such receivers manufactured after December 31, 1957. All other radio receivers that operate (tune) in the range 30 to 890 Mc/s manufactured after October 1, 1956, shall comply with the certification requirements of this subpart, except as follows:

(a) FM broadcast receivers manufactured after December 31, 1956, shall comply with the certification requirements with respect to frequencies above 25 Mc. All such receivers manufactured after December 31, 1957, shall comply with the certification requirements with respect to all frequencies.

(b) UHF television broadcast receivers manufactured after December 1957 shall comply with the certification requirements of this subpart: *Provided, however,* That the limit of 500 uv/m appearing in the table contained in § 15.62 is temporarily increased to 1,000 uv/m for all UHF television receivers until December 31, 1962.

(c) The radiation interference limits and the certification requirement with respect thereto shall be met by all pocket type super-regenerative receivers used in the one-way signalling services as defined in Part 6 of this chapter which are manufactured after December 31, 1956.

(d) Super-regenerative receivers manufactured after October 1, 1956, for use by Class B stations in the Citizens Radio Service shall comply with the certification requirements of this subpart; except that, until November 1, 1963, radiation need not be limited within the band 462.525–467.475 Mc/s.

§ 15.69 Interference From a Radio Receiver.

The operator of a radio receiver, regardless of tuning range, date of manufacture, or of certification, which causes harmful interference shall promptly take steps to eliminate the harmful interference.

SUBPART D—COMMUNITY ANTENNA TELEVISION SYSTEMS

§ 15.161 Radiation From a Community Antenna Television System.

Radiation from a community antenna television system shall be limited as follows:

Frequencies (Mc/s)	Distance (ft.)	Radiation limits (µv/m)	
		General requirement	Sparsely inhabited areas [1]
Up to and including 54	100	15	15
Over 54 up to and including 132	10	20	400
Over 132 up to and including 216	10	50	1,000
Over 216	100	15	15

[1] For the purpose of this section, a sparsely inhabited area is that area within 1,000 feet of a community antenna television system where television broadcast signals are, in fact, not being received directly from a television broadcast station.

§ 15.162 Demonstration of Compliance.

The operator of each CATV system shall be responsible for insuring that each such system is designed, installed and operated in a manner which fully complies with the provisions of this subpart. Each system operator shall be prepared to show, upon reasonable demand by an authorized representative of the Commission, that the system does, in fact, comply with the rules.

§ 15.163 Interference From a Community Antenna Television System.

In the event that the operation of a community antenna television system causes harmful interference to reception of authorized radio stations the operator of the system shall immediately take whatever steps are necessary to remedy the interference.

§ 15.164 Responsibility for Receiver Generated Interference.

Interference originating in a radio receiver shall be the responsibility of the receiver operator in accordance with the provisions of Subpart C of this part: *Provided, however,* That the operator of the community antenna television system to which the receiver is connected shall be responsible for the suppression of receiver generated interference that is distributed by the system when this interference is conducted into the system at the receiver.

§ 15.165 Measurement of Field Strength.

Measurements to determine the field strength of radio frequency energy generated by community antenna television systems shall be made in accordance with standard engineering procedures. Measurements made above 25 megacycles shall include the following:

(a) A field strength meter using a horizontal dipole antenna shall be employed.

(b) Field strength shall be expressed in terms of the RMS value of synchronizing peak.

(c) The dipole antenna shall be placed 12 feet above the ground and positioned directly below the system components. Where such placement results in a separation of less than 10 feet between the center of the dipole antenna and the system components, the dipole shall be repositioned to provide a separation of 10 feet.

(d) The horizontal dipole antenna shall be rotated about a vertical axis and the maximum meter reading shall be used.

(e) Measurements shall be made where other conductors are 10 or more feet away from the measuring antenna.

§ 15.166 Effective Date of Radiation Limits in This Subpart.

(a) The radiation limits for community antenna television systems shall be met by all new systems whose construction began on or after October 1, 1966, and by all new sections added to existing systems whose construction begins on or after October 1, 1966.

(b) Community antenna television systems in existence on September 30, 1966, shall comply with the radiation limits in this subpart not later than December 31, 1969: *Provided,* That any harmful interference to the reception of authorized radio stations caused by such systems shall be promptly remedied during this period by the operator of the CATV system.

SUBPART E—LOW POWER COMMUNICATION DEVICES

§ 15.201 Frequencies of Operation.

(a) A low power communication device may be operated on any frequency in the bands 10–490 kc/s, 510–1600 kc/s and 26.97–27.27 Mc/s.

(b) Other frequencies above 70 Mc/s may be used for operations of short duration in accordance with the requirements set forth in § 15.206.

§ 15.202 Radiation Limitation Below 1600 kc/s.

A low power communication device which operates on any frequency between 10 and 490 kc/s or between 510 and 1600 kc/s shall limit the radiation so that the field strength does not exceed the value specified in the following table:

(Ed. 12/66)

Frequency (kc/s)	Distance (feet)	Field strength (uv/m)
10–490	1,000	$\frac{2400}{F(kc/s)}$
510–1600	100	$\frac{24000}{F(kc/s)}$

§ 15.203 Alternative Requirement for Operation on Frequencies Between 160 kc/s and 190 kc/s.

In lieu of meeting the radiation limitation, stated in § 15.202, a low power communication device operating on a frequency between 160 and 190 kc/s need only meet the following requirements:

(a) The power input to the final radio frequency stage (exclusive of filament or heater power) does not exceed one watt.

(b) All emissions below 160 kc/s or above 190 kc/s are suppressed 20 db or more below the unmodulated carrier.

(c) The total length of the transmission line plus the antenna does not exceed 50 feet.

§ 15.204 Alternative Requirement for Operation on Frequencies Between 510 and 1600 kc/s.

In lieu of meeting the radiation limitation stated in § 15.202, a low power communication device operating on a frequency between 510 and 1600 kc/s inclusive need only meet the following requirements:

(a) The power input to the final radio stage (exclusive of filament or heater power) does not exceed 100 milliwatts.

(b) The emissions below 510 kc/s or above 1600 kc/s are suppressed 20 db or more below the unmodulated carrier.

(c) The total length of the transmission line plus the antenna does not exceed 10 feet.

(d) Low power communication devices obtaining their power from the lines of public utility systems shall limit the radio frequency voltage appearing on each power line to 200 microvolts or less on any frequency from 510 kc/s to 1600 kc/s. Measurements shall be made from each power line to ground both with the equipment grounded and with the equipment ungrounded.

NOTE: One method of determining radio frequency voltage on the power line is described in "Military Specification for Interference Measurement" MIL–I–16910 (SHIPS) dated January 14, 1952, available from the Commanding Officer, Naval Supply Depot, Scotia 2, New York. Note that this procedure calls for grounding the equipment under test, whereas the Commission's rules call for measurements both with the equipment grounded and with the equipment ungrounded.

§ 15.205 Operation Within the Frequency Band 26.97–27.27 Mc/s.

A low power communication device may operate within the band 26.97–27.27 Mc/s (27.12 Mc/s ± 150 kc/s) provided it complies with all of the following requirements:

(a) The carrier of the device shall be maintained within the band 26.97–27.27 Mc/s.

(b) All emissions, including modulation products, below 26.97 Mc/s or above 27.27 Mc/s shall be suppressed 20 db or more below the unmodulated carrier.

(c) The power input to the final radio stage (exclusive of filament or heater power) shall not exceed 100 milliwatts.

(d) The antenna shall consist of a single element that does not exceed 5 feet in length.

§ 15.206 Operation Above 70 Mc/s.

A low power communication device may be operated on any frequency above 70 Mc/s, provided it complies with all of the following conditions:

(a) Operation is limited to one second duration and to occur not more than once in 30 seconds.

(b) The radiated field on any frequency from 70 Mc/s to 1000 Mc/s does not exceed the limits specified for receivers in § 15.62.

(c) The radiated field on any frequency above 1000 Mc/s does not exceed 500 microvolts per meter at a distance of 100 feet.

(d) The device is provided with means for automatically limiting operation within the time restrictions specified in this section.

§ 15.207 Class B Emission Prohibited.

Operation of low power communication devices that produce Class B emissions (damped waves) is prohibited.

§ 15.208 Certification Requirements.

(a) No low power communication device manufactured after the dates set forth in § 15.211 shall be operated without a station license unless it has been certificated to demonstrate compliance with the requirements in this part.

(b) The owner or operator need not certificate his own low power communication device, if it has been certificated by the manufacturer or distributor.

(c) Where certification is based on measurement of a prototype, a sufficient number of units shall be tested to assure that all production units comply with the technical requirements of this subpart.

(d) The certificate may be executed by a technician skilled in making and interpreting the measurements that are required to assure compliance with the requirements of this part.

(e) The certificate shall contain the following information:

(1) The operating conditions under which the device is intended to be used.

(2) The antenna to be used with the device.

(3) A statement certifying that the device can be expected to comply with the requirements of this subpart under the operating conditions specified in the certificate.

(4) The month and year in which the device was manufactured.

§ 15.209 Location of Certificate.

The certificate shall be permanently attached to the device and shall be readily visible for inspection.

§ 15.210 Interference From Low Power Communication Devices.

Notwithstanding the other requirements of this part, the operator of a low power communication device, regardless of date of manufacture, which causes harmful interference to an authorized radio service, shall promptly stop operating the device until the harmful interference has been eliminated.

§ 15.211 Date When Certification Is Required.

All low power communication devices which operate on frequencies of 70 Mc/s or above, manufactured after June 30, 1958, shall comply with the certification requirements of this subpart. All low power communication devices which operate on frequencies below 70 Mc/s, manufactured after December 31, 1957, shall comply with the certification requirements of this subpart.

RULES AND REGULATIONS

Part 18 — *Industrial, Scientific, and Medical Equipment*

DECEMBER 1961

FEDERAL COMMUNICATIONS COMMISSION

Contents

(Ed. 12/61)

SUBPART A—GENERAL

§ 18.1 Statement of Basis and Purpose.

(a) Section 301 of the Communications Act of 1934, as amended, provides for the control by the Federal Government over all the channels of interstate and foreign radio communication and further provides, in part, that no person shall use or operate apparatus for the transmission of energy, communications, or signals by radio when the effects of such operation extend beyond state lines or cause interference with the transmission or reception of energy, communications or signals, of any interstate or foreign character by radio, except under and in accordance with the Communications Act and a license granted under the provisions of that act. The operation in the industrial, scientific and medical service of medical diathermy equipment, industrial heating equipment and miscellaneous equipment of a type which emits radio frequency energy upon frequencies within the radio spectrum constitutes a serious source of interference to authorized radio communication services operating upon the channels of interstate and foreign communication unless precautions are taken which will prevent the creation of any substantial amount of such interference.

(b) The following rules and regulations are designed to have a twofold effect:

(1) They set forth the conditions under which the operation of the equipment in question is not regarded as a cause of interference to the authorized radio communication services and is therefore not required to be operated pursuant to license under the Communications Act.

(2) They provide a procedure for the licensing of medical diathermy, industrial heating and miscellaneous equipment which in operation constitute a source of interference to authorized communication services, directly affect the control of the Federal Government over the channels of interstate and foreign radio communication, and are therefore required to be licensed.

§ 18.2 Definitions.

For purposes of the provisions of this part the following definitions in the industrial, scientific, and medical service shall be applicable:

(a) "Radio frequency energy" shall include electromagnetic energy generated at any frequency in the radio spectrum between 10 kilocycles and 30,000 megacycles.

(b) "Medical diathermy equipment" shall include any apparatus (other than surgical diathermy apparatus designed for intermittent operation with low power) which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for therapeutic purposes.

(c) "Industrial heating equipment" shall include any apparatus which utilizes a radio frequency oscillator or any other type of radio frequency generator and transmits radio frequency energy used for or in connection with industrial heating operations utilized in a manufacturing or production process.

(d) Miscellaneous equipment shall include apparatus other than that defined in or excepted by paragraphs (b) and (c) of this section in which radio frequency energy is applied to materials to produce physical, biological, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal and acceleration of charged particles, which do not involve communications or the use of radio receiving equipment.

(e) Ultrasonic equipment is a special type of miscellaneous equipment which includes any apparatus which generates radio frequency energy on frequencies above 20 kc/s and utilizes that energy to excite or drive an electro-mechanical transducer for the production and transmission of ultrasonic energy for industrial, scientific, medical or other purposes.

(f) "Industrial, scientific and medical equipment" (ISM equipment). Devices which use radio waves for industrial, scientific, medical or any other purposes including the transfer of energy by radio and which are neither used nor intended to be used for radiocommunication.

(g) "Harmful interference." Any emission, radiation or induction which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with this chapter.

(h) "ISM frequency." A frequency assigned by this part for the use of ISM equipment. A specified tolerance is associated with each ISM frequency. (See § 18.6.)

§ 18.3 When License Is Required.

Any medical diathermy equipment, industrial heating equipment or miscellaneous equipment which complies with the provisions of this part may be operated without a station license. A license is required for any such equipment operated otherwise.

§ 18.4 Full Information; Inspection by Commission Representatives.

Upon request by the Commission the owner or operator of any medical diathermy equipment, industrial heating equipment, or miscellaneous equipment shall promptly furnish the Commission with such information as may be requested concerning the operation of such equipment. The premises in which medical diathermy, industrial heating, or miscellaneous equipment are operated, and any license or certification required hereby, shall be available for inspection by representatives of the Commission at all reasonable hours.

§ 18.5 Radio Frequency Stabilized Arc Welders.

(a) The requirements of this part with respect to electric arc welding devices using radio frequency energy is suspended until action is completed in the

Docket No. 11467 proceeding with respect to these devices: *Provided*, That, in the event of interference from electric arc welding devices using radio frequency energy to any authorized radio service, steps to remedy such interference shall promptly be taken (except that, in case of interference to receivers arising from direct intermediate frequency pickup by such receivers of the fundamental frequency emissions of certified electric arc welding equipment using radio frequency energy, this provision with respect to interference shall not apply): *And further provided, however*, That equipment manufactured after September 1, 1962 shall be subject to the same technical limitations and standards as set forth for industrial heating equipment in §§ 18.101 to 18.106, inclusive, except that such equipment need not be operated within a shielded room or space but in lieu thereof shall be operated with sufficient shielding to limit the radiation to the value prescribed in § 18.102: *And further provided*, That radio frequency stabilized electric arc welding equipment designed for operation on ISM frequencies may be type approved and operated in accordance with the provisions of § 18.31(c): *And further provided*, That broad band type of emissions from arc welding equipment shall be measured by an instrument having performance characteristics similar to the "Proposed American Standards Specification for a Radio Noise Meter—0.15 to 25 Megacycles/second" dated March 1960, published by the American Standards Association Committee on Radio Electrical Coordination C63. Quasi-peak values of field strength shall be measured and used in determining compliance with § 18.102. Instruments not having characteristics similar to the above-mentioned standards may be used provided suitable correlation factors are used to adjust the field strength readings to values which would be obtained with an instrument having the desired characteristics.

(b) The certification required by § 18.101 may be based upon field strength measurements made by the manufacturer of the equipment at locations other than the one where the equipment is in use provided such certification includes a statement by the operator of the equipment that the equipment covered thereby has been installed and is being operated in conformity to the instructions issued by the manufacturer.

(c) The certificate required for rf stabilized arc welders shall be executed by an engineer skilled in making and interpreting field strength measurements. The Commission may require such engineer to provide proof of his qualifications.

(d) The certificate for an rf stabilized arc welder measured at the location where it is in use shall contain the following information:

(1) Type and serial number, or other positive identification, of the welder being certificated.

(2) Conditions under which the welder shall be operated and maintained.

(3) Brief description of the engineering tests and a summary of the measured data upon which the certificate is based.

(4) Date the measurements were made.

(5) A statement certifying that the welder does meet and may reasonably be expected to continue to meet the requirements of this part.

(6) Date of certification.

(7) Signature of certifying engineer.

(8) Name and address of employer of certifying engineer, if any.

(9) If the certificate is based on measurement of a prototype at some other location:

(i) Detailed installation instructions which will insure that the welder may reasonably be expected to comply with the radiation limits in § 18.102, and

(ii) A statement signed by the person responsible for the operation of the welder, attesting that it has been installed in accordance with the installation instructions attached to this certificate.

(e) In general the certificate shall be attached to the equipment. Alternatively the certificate may be placed at any location where it will be conveniently available for inspection by authorized representatives of the Commission, provided there is attached to the equipment a notice stating where the certificate is located.

§ 18.6 ISM Frequencies and Frequency Tolerances.

The following frequencies are allocated for use by ISM equipment with the tolerance limits specified:

ISM frequency:	Frequency tolerance
13,560 kc/s	±6.78 kc/s
27,120 kc/s	±160.0 kc/s
40,680 kc/s	±20.0 kc/s
915 Mc/s [1]	±25.0 Mc/s
2,450 Mc/s [1]	±50.0 Mc/s
5,800 Mc/s [1]	±75.0 Mc/s
22,125 Mc/s [1]	±125.0 Mc/s

[1] The use of this frequency is subject to the conditions in § 18.7.

§ 18.7 Operation on Microwave Frequencies.

Except for industrial heating equipment which is regulated by §§ 18.101 through 18.122, inclusive, ISM equipment may be operated on the microwave ISM frequencies (915 Mc/s, 2450 Mc/s, 5800 Mc/s and 22,125 Mc/s) subject to the following conditions:

(a) The emission of radio frequency energy resulting from such operation shall be on the particular frequency and must not exceed tolerance limits associated with each such frequency as set forth in § 18.6.

(b) The energy radiated and the bandwidth of emissions shall be reduced to the greatest extent practicable.

(c) No harmful interference shall be caused to authorized communication services from spurious or harmonic radiation. In the event of such harmful interference, operation of the ISM equipment causing such harmful interference shall cease and shall not be resumed until steps necessary to eliminate such interference have been taken.

§ 18.8 Interference From ISM Equipment.

(a) Subject to the exceptions in paragraphs (b) and (c) of this section and irrespective of whether the equipment otherwise complies with the rules in this part, the operator of ISM equipment that causes harmful interference to any authorized radio service shall promptly take steps as may be necessary to remedy the interference.

(b) The provisions of paragraph (a) of this section shall not apply in the case of interference to an authorized radio station operating on an ISM frequency (including tolerance).

(c) The provisions of paragraph (a) of this section shall not apply in the case of interference to a receiver arising from direct intermediate frequency pickup by the receiver of the fundamental frequency emissions of ISM equipment operating on an ISM frequency (including tolerance) and otherwise complying with the requirements of this part.

SUBPART B—MEDICAL DIATHERMY EQUIPMENT

§ 18.11 Operation on Assigned Frequencies.

A station license is not required for the operation of medical diathermy equipment on assigned frequencies provided such operation meets the following conditions:

(a) Such operation must conform to the general condition set out in the guarantee or certificate required by paragraphs (c) and (d) of this section. Operation must be confined to one or more of the frequencies:

ISM frequency:	*Frequency tolerance*
13,560 kc/s	±6.78 kc/s
27,120 kc/s	±160.0 kc/s
40,680 kc/s	±20.0 kc/s
915 Mc/s [1]	±25.0 Mc/s
2,450 Mc/s [1]	±50.0 Mc/s
5,800 Mc/s [1]	±75.0 Mc/s
22,125 Mc/s [1]	±125.0 Mc/s

[1] The use of this frequency is subject to the conditions in § 18.7.

(b) Such operation may be without regard to the type or power of emissions being radiated. Spurious and harmonic radiations on frequencies other than those specified above shall be suppressed so that such radiations do not exceed a strength of 25 microvolts per meter at a distance of 1,000 feet or more from the medical diathermy equipment causing such radiations.

(c) With respect to equipment for which type approval has been received from the Commission in accordance with §§ 18.14 to 18.16, inclusive, there shall be affixed to each unit of equipment operated in accordance with paragraphs (a) and (b) of this section, or posted in the room in which such operation occurs, a dated certificate of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment, setting forth the F.C.C. type approval number for such equipment, the general conditions under which such equipment should be operated, and certifying that the equipment involved may reasonably be expected to meet the requirements of this section under the described conditions of operation for a period of at least three years. The certification required in this section shall describe with certainty the apparatus covered thereby.

(d) The owners or operators of equipment which has not received type approval but which is manufactured for operation without a license and designed to meet the technical requirements set forth under paragraphs (a) and (b) of this section shall have posted in the room in which such equipment is operated a dated certificate of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment, setting forth the general conditions under which such equipment should be operated and certifying that the equipment involved may reasonably be expected to meet the requirements of this section for a period of at least three years under the described conditions of operation. The certification required by this section shall describe with certainty the apparatus covered thereby, and shall include a brief statement of the engineering tests upon which such certification is based and the results thereof. Field intensity measurements in such tests shall be made in accordance with § 18.13.

(e) No regular renewal of certification is required for equipment covered in paragraph (c) of this section. The certification required in paragraph (d) of this section shall be renewed at intervals of three years. Notwithstanding the above provisions with respect to renewal of certification, the certification required by paragraph (c) or (d) of this section shall be renewed for particular equipment by such date as the Commission may specify if the Commission has reason to believe that the operation of such equipment may be inconsistent with provisions of this part or the source of interference to radio communication.

§ 18.12 Operation on Unassigned Frequencies.

A station license is not required for the operation of medical diathermy equipment on frequencies other than those specified in § 18.11 (a) provided such operation is in accordance with the general conditions of operation set out in the certification required in paragraph (b) of this section, and meets the following conditions:

(a) The equipment used in such operation shall be provided with a rectified and filtered plate power supply, power line filters and shall be provided with sufficient shielding so that the emission of radio frequency energy generated by such operation, including spurious and harmonic emissions, shall not exceed a strength of fifteen microvolts per meter at a distance of 1,000 feet or more from the medical diathermy equipment on frequencies other than those specified in § 18.11(a) under any conditions of operation.

(b) There shall be affixed to each unit of equipment so operated, or posted in the room in which such operation occurs, a dated certification of a competent engineer, or a dated certificate or name plate of the manufacturer of the equipment setting forth the general conditions under which such equipment should be operated and certifying that under the described conditions of operation the requirements of this section may reasonably be expected to be met for a period of at least three years. The certification required by this section shall describe with certainty the equipment covered thereby, and shall include a brief statement of the engineering tests upon which the certification is based and the results thereof. Field intensity measurements in such tests shall be made in accordance with the provisions of § 18.13.

(c) The certification required in paragraph (b) of this section shall be renewed every three years: *Provided*, That such certification shall be renewed for particular equipment by such earlier date as the Commission may specify if the Commission has reason to believe that the operation of such equipment may be inconsistent with the provisions of this part or a source of interference to radio communication.

§ 18.13 Measurement of Field Intensity.

Measurements to determine the field intensity of radio frequency energy generated by medical diathermy equipment shall be made in accordance with standard engineering procedures and shall include the following:

(a) An approved type of field intensity meter using loop pickup shall be used for measurements on frequencies below and including 18 Mc/s, and such a meter with a doublet antenna shall be used for measurements for frequencies above 18 Mc/s. Appropriate techniques shall be resorted to for measurements in the microwave region of the spectrum

(b) The field intensity at 1,000 feet from the medical diathermy equipment, or at any other point at which it becomes necessary to determine such intensity shall be determined by measurements at approximately 100-foot intervals along 5 radials approximately 72° apart, provided that additional measurements shall be taken when necessary in particular cases. An average curve shall be drawn through the points obtained for each radial and then either (1) the field intensity at 1,000 feet taken from the curve or (2) the curve extended to the 1,000-foot point to obtain the field intensity at that point. If points of measurement along a radial are such that marked changes of field intensity over short distances are noted because of standing waves, multipaths, etc., continuous measurements shall be made along any such radial at points 100 feet apart in order to obtain average values for such points.

(c) The field intensities specified in this section refer to the maximum field intensity regardless of polarization, measured at a height of 12 feet above the immediate terrain or at such lower height at which the field intensity may exeed that at 12 feet.

(d) If due to the location of equipment in a large city, or for some other reason, measurements as outlined above are impractical because of shadows or shielding of large buildings or other objects, every effort should be made to obtain necessary measurements at clear locations such as atop adjacent buildings, etc., with the measurements corrected to the height specified in paragraph (c) of this section in accordance with best available engineering information.

§ 18.14 Procedure for Type Approval.

(a) Manufacturers of medical diathermy equipment designed to operate on the frequencies specified in § 18.11(a) may submit units of such equipment to this Commission for type approval upon the grant of request therefor made in writing by the manufacturer to the Secretary of the Commission. Such a request will not be granted unless at least 5 units of the model to be submitted are scheduled for manufacture and the manufacturer agrees to bear all forwarding and return charges in connection with the shipment of the unit to be tested between the Federal Communications Commission, Laboratory Division, Laurel, Maryland, and the manufacturer.

(b) Any such equipment which is submitted will be tested and a certificate of type approval will be issued to the manufacturer for each type of equipment which meets the following tests:

(1) The frequency at all times during the tests below shall be maintained within 70% of the tolerance specified in § 18.11(a).

(i) From a cold start the machine will be operated continuously at full load for 6 hours, except that machines classified as portable will be subject to a 2 hour test.

(ii) From a cold start the machine will be operated at no load for 5 minutes and then the frequency deviation determined over a normal treatment cycle. A treatment cycle will be simulated by artificial varying loads and varying settings of the resonance and other operating controls. Similar treatment cycle tests will be conducted after periods of continuous full load operations up to six hours (2 hours for portable operation) to determine the maximum deviation. The number of such tests normally will be determined by the results of test (i): *Provided, however*, That equipment designed to operate on the frequencies set forth in § 18.11(a) may be granted type approval regardless of frequency stability, provided such equipment meets the other requirements hereof and contains a power cut-off mechanism which is effective in rendering the machine inoperative when the deviation from the assigned frequency exceeds 70 percent of the tolerance provided for.

(2) The equipment must be designed to prevent the emission of spurious and harmonic radiations to the extent required in § 18.11(b).

(3) The electrical and mechanical components of the machine and their installation must be such as to give reasonable assurance of compliance with the requirements of permissible frequency tolerance for at least 5 years

NOTE: Medical diathermy equipment operated on 915 Mc/s, 2450 Mc/s, 5800 Mc/s or 22,125 Mc/s will be eligible for type approval upon a determination by the Chief Engineer of compliance with the requirements of the Commission's public notice and order of December 28, 1946, which requirements are set forth in § 18.7.

§ 18.15 Effect of Certificate of Type Approval.

A certificate of type approval constitutes a recognition that on the basis of the tests made the equipment appears to have the capability of functioning in accordance with the provisions of § 18.11 (a) and (b) provided such equipment is properly constructed, maintained and operated, and no change whatsoever is made in the construction of equipment sold under the Certificate of Type Approval issued by the Commission except on specific approval by the Commission to any changes made.

§ 18.16 Withdrawal of Certificate of Type Approval.

(a) A certificate of type approval may be withdrawn if the type of equipment for which it was issued proves defective in service and under usual conditions of maintenance and operation such equipment cannot be relied on to meet the conditions set forth in this part for the operation of the type of equipment involved, or if any change whatsoever is made in the construction of equipment sold under the certificate of type approval issued by the Commission, without the specific prior approval of the Commission.

(b) The procedure for withdrawal of a certificate of type approval shall be the same as that prescribed for revocation of a radio station license pursuant to the provisions of the Communications Act of 1934, as amended.

(c) In the case of withdrawal of a certificate of type approval the manufacturer shall make no further sale of equipment under such certificate.

(d) When a certificate of type approval has been withdrawn for unauthorized changes or for failure to comply with technical requirements, the Commission will consider that fact in determining whether the manufacturer in question is eligible to receive any new certificate of type approval.

SUBPART C—MISCELLANEOUS EQUIPMENT

§ 18.31 Miscellaneous Equipment.

(a) The operation without a license of miscellaneous equipment, as defined in § 18.2(d), generating radio-frequency power of 500 watts or less, shall be in compliance with the provisions of this part for medical diathermy apparatus.

(b) Operation of such equipment generating radio-frequency power in excess of 500 watts shall be in compliance with the requirements for medical diathermy apparatus except that the maximum radiated field permitted shall be increased as the square root of the ratio of the generated power to 500 watts: *Provided*, That the radiated field shall in no case exceed the fields permitted industrial heating apparatus: *And provided further*, That equipment used in predominantly residential areas and operating on frequencies below 1,000 Mc/s shall not be permitted the increase in field with power as indicated in this paragraph, but shall be subject to the restrictions contained in this paragraph for diathermy equipment.

(c) Miscellaneous equipment, as defined in § 18.2(d), may be type approved under procedures similar to that for diathermy equipment with such changes in the above procedure as may be required because of the nature of the particular equipment involved.

(d) For the purpose of field intensity measurements, the location of the miscellaneous equipment may be considered to be the actual physical location of such equipment or, where several such units are grouped within a circle of 200 feet radius or less, the several units may, at the election of the certifying engineer, be considered as a single unit, the location of which will be the center of the smallest enclosing circle: *Provided, however*, That if the certification includes more than one unit, the distance of 1,000 feet at which the maximum permissible radiation is determined shall be decreased by an amount equivalent to the radius of the circle encompassing the several units.

(e) It shall be the responsibility of the operator to have the equipment recertified when changes have been made that might increase the radiation beyond the specified limits.

SUBPART D—OPERATION FOR WHICH A LICENSE IS REQUIRED

§ 18.41 When a License Is Required.

(a) No medical diathermy equipment, industrial heating equipment or miscellaneous equipment which does not comply with this part shall be operated except pursuant to a station license issued by the Commission authorizing such operation.

(b) Whenever the Commission on complaint or on its own motion determines that medical diathermy equipment, industrial heating equipment or miscellaneous equipment is not in fact operating in compliance with the provisions of this part and so advises the operator of such equipment, further operation of such equipment without a station license shall be unlawful unless within 10 days of the receipt of such notice, or within such further time as the Commission may for good cause allow, the operator of such equipment shall file with the Commission a certificate of a competent engineer stating that the equipment is now capable of complying with the requirements of the rules.

§ 18.42 Showing Required.

A station license for the operation of medical diathermy equipment, industrial heating equipment or miscellaneous equipment will be granted upon proper application therefor in accordance with the provisions of this part and a showing that in the light of the following considerations the public interest, convenience, and necessity would be served by such a grant: (a) The purpose for which the equipment sought to be licensed will be used; (b) the reasons why the equipment involved may not be operated in compliance with the provisions of this part for the operation of such equipment without a license; and (c) the nature and extent of interference that may be caused to authorized communication services by the operation of such equipment.

§ 18.43 Applications for Station Licenses.

Each applicant for a station license authorizing the operation of medical diathermy, industrial heating equipment, or miscellaneous equipment, or requesting the modification or renewal of such a license, shall file with the Commission in Washington, D.C., three copies of each application on the appropriate form designated by the Commission and a like number of any exhibits and other papers incorporated therein and made a part thereof. Only the original copy need be sworn to. Application for a license shall be made up on the appropriate form prescribed by the Commission, and separate application should be made for each unit of equipment for which a license is sought. Application for modification or renewal of a license shall also be upon appropriate form prescribed by the Commission.

§ 18.44 Full Information.

Each application for a license authorizing the operation of medical diathermy, industrial heating equipment or miscellaneous equipment shall contain full and complete information concerning all matters and things required to be disclosed by the application form.

§ 18.45 License Period.

Each station license authorizing the operation of medical diathermy, industrial equipment or miscellaneous equipment will expire at the hour of 3 a.m. and will be issued for a normal license period of five years or such other period as the Commission may specify upon consideration of the facts in a particular case. Each such license shall be nontransferable.

§ 18.46 Renewal of License.

Unless otherwise directed or permitted by the Commission, applications for renewal of a station license for the operation of medical diathermy, industrial heating equipment or miscellaneous equipment shall be filed with the Commission upon prescribed forms at least 60 days prior to the expiration date of such license.

§ 18.47 Station License, Posting of.

The original of each station license shall be posted in the room in which the equipment is operated. Licenses covering equipment not used in a fixed place shall be attached to the equipment itself.

§ 18.48 Operator Requirements.

Equipment for which a station license is issued pursuant to the provisions of this part may be operated by persons who do not hold an operator license or permit issued by this agency.

§ 18.49 Cessation of Operation Pursuant to License.

If any equipment for which a license has been issued hereunder shall cease to be operated pursuant to such license, or is transferred, sold, assigned, leased, loaned, stolen, destroyed, or otherwise removed from the possession of the licensee, the licensee shall within five days of such occurrence notify the Commission thereof and, where possible, include in such notification the name and address of the recipient of such equipment.

§ 18.51 Existing Equipment.

The provisions of this part shall not be applicable until June 30, 1954 to epilation equipment, which uses radio frequency energy, manufactured before December 31, 1950, and shall not be applicable until December 31, 1955 for such equipment manufactured between December 31, 1950 and June 30, 1953: *Provided*, That the foregoing provisions of this section shall be applicable only if such steps as may be necessary are promptly taken to eliminate interference to authorized radio services resulting from the operation of equipment manufactured prior to the respective dates set forth in this section.

SUBPART E—ULTRASONIC EQUIPMENT

§ 18.70 Operation Without a License.

Ultrasonic equipment may be operated without a license: *Provided*, The design and operation complies with the technical limitations for such equipment: *And provided further*, That the equipment has been type approved by the Commission or has been certified pursuant to the requirements of §§ 18.70 to 18.84 and the certificate is attached to the equipment or is prominently posted in the room in which the equipment is being operated; except that ultrasonic equipment operating on frequencies below 90 kc/s and generating less than 500 watts of radio frequency power may be operated without license, type approval or certification, if such equipment complies with all other applicable provisions of §§ 18.70 to 18.84.

§ 18.71 Technical Limitations.

(a) Ultrasonic equipment shall be designed and constructed in accordance with good engineering practice with sufficient shielding and filtering to provide adequate suppression of emissions on frequencies outside the ISM frequency bands.

(b) Except for ultrasonic measurement equipment that operates over a continuous band of frequencies, the fundamental frequency of operation shall fall outside the frequency bands 490–510 kc/s, 2170–2194 kc/s, and 8354–8374 kc/s.

(c) The varying conditions under which Ultrasonic equipment is operated shall not result in radiation exceeding the following limits:

Frequency	Distance *Feet*	Field *µv/m*
Up to and including 490 kc/s......	1,000	2400 / Frequency in kc/s
Over 490 kc/s up to and including 1600 kc/s.	100	24000 / Frequency in kc/s
Over 1600 kc/s exclusive of frequencies in the ISM frequency bands.	100	15.

(d) The operation of ultrasonic equipment on frequencies below 490 kc/s using radio frequency power in excess of 500 watts shall be in compliance with the requirements of this section except that the maximum radiated field permitted may be increased as the square root of the ratio of the generated radio frequency power to 500 watts: *Provided*, That the radiated field shall in no case exceed the field permitted industrial heating equipment: *And provided further*, That equipment used in predominantly residential areas shall not be permitted the increase in field with power as indicated in this paragraph.

(e) On any frequency above 490 kc/s, the radio frequency voltage appearing on each power line shall not exceed 200 microvolts. On any frequency below 490 kc/s, the radio frequency voltage appearing on each power line shall not exceed 1000 microvolts. Measurement shall be made from each power line to ground with the equipment itself both grounded and ungrounded.

NOTE: One method of making conducted interference measurements is described in "Military Specification for Interference Measurement" MIL–I–16910 (SHIPS) dated January 14, 1952, available from the Commanding Officer, Naval Supply Depot, Scotia 2, New York. Note that this procedure calls for grounding the equipment under test, whereas these rules call for measurements with the equipment both grounded and ungrounded.

§ 18.72 Type Approval.

(a) Manufacturers of ultrasonic equipment desiring to obtain type approval for their equipment may request permission to submit such equipment to the Commission for testing by following the procedure set out in Part 2 of this chapter. The request shall include a statement that at least 5 units of the model to be submitted are scheduled for manufacture.

(b) To be acceptable for type approval, ultrasonic equipment must meet the following requirements:

(1) The equipment must comply with the technical limitations for ultrasonic equipment.

(2) The design and construction of the equipment must give reasonable assurance of compliance with the rules in this part for at least 5 years under normal operation and with average maintenance.

(c) Additional rules relative to type approval will be found in Part 2 of this chapter.

§ 18.73 Identification of Type Approved Equipment.

(a) Equipment for which a certificate of type approval has been issued shall be identified by the insertion of the FCC Type Approval Number on the nameplate of the equipment.

(b) In addition to the nameplate, the manufacturer shall furnish each user of type approved equipment a certificate setting forth the conditions under which such equipment shall be operated.

§ 18.74 Effect of Certificate of Type Approval.

A certificate of type approval issued by the Commission constitutes a recognition that, on the basis of the tests made, the equipment appears to be capable of complying with the technical limitations in the rules in this part, provided such equipment is properly installed, maintained and operated, and no change whatsoever is made in the construction of equipment sold under the certificate of type approval except on specific prior approval by the Commission to any changes made.

§ 18.75 Changes in Type Approved Equipment.

No changes whatsoever may be made in ultrasonic equipment for which a certificate of type approval has been issued except on specific prior approval by the Commission.

§ 18.76 Withdrawal of Certificate of Type Approval.

(a) A certificate of type approval may be withdrawn if the type of equipment for which it was issued proves defective in service and under usual conditions of maintenance and operation such equipment cannot be relied on to meet the conditions set forth in this part for the operation of the type of equipment involved, or if any change whatsoever is made in the construction of equipment sold under the certificate of type approval issued by the Commission, without the specific prior approval of the Commission.

(b) The procedure for withdrawal of the certificate of type approval shall be the same as that prescribed for revocation of a radio station license pursuant to the provisions of the Communications Act of 1934, as amended.

(c) In the case of withdrawal of a certificate of type approval the manufacturer shall make no further sale of equipment under such certificate.

(d) When a certificate of type approval has been withdrawn for unauthorized changes or for failure to comply with technical requirements, the Commission will consider that fact in determining whether the manufacturer in question is eligible to receive any new certificate of type approval.

§ 18.77 Measurement of Field Intensity.

Measurements to determine the field intensity of radio frequency energy including both fundamental and spurious (including harmonic) emissions, generated by the ultrasonic equipment shall be made in accordance with standard engineering procedures and shall include the following:

(Ed. 12/61)

(a) A field intensity meter using loop pickup shall be used for measurements on frequencies up to and including 18 Mc/s, and such a meter with a doublet antenna shall be used for measurements on frequencies above 18 Mc/s.

(b) The radiation shall be determined along at least 5 radials approximately 72° apart. A smooth curve shall be drawn through the measurements when plotted and the value of field intensity determined from these curves.

§ 18.78 Location of Equipment.

For the purpose of measurements required in order to execute a certification of compliance, the location of the ultrasonic equipment may be considered to be the actual physical location of the equipment, or, where several such units are grouped within a circle of 200 feet radius or less, the several units may at the election of the certifying engineer be considered as a single unit, located at the center of the smallest enclosing circle. If the certification includes several units treated as one equipment, the distance of 1,000 feet at which the maximum permissible radiation is determined shall be decreased by the radius of the smallest circle that encloses the several units.

§ 18.79 [Reserved]

§ 18.80 Certification Attesting Compliance With Rules.

(a) A certification attesting compliance with the rules in this part may be affixed or posted for any ultrasonic equipment.

(b) The certification shall be based on an inspection of the equipment and measurements taken at the place of use after the ultrasonic equipment has been assembled and is ready for operation: *Provided however*, That the certifying engineer may, in lieu of measuring the radio frequency voltage on the power lines, base the certification on specifications for the power line filter and test data regarding the radio frequency voltage on the power lines furnished by the manufacturer of the ultrasonic equipment.

(c) The certification may be executed by any engineer skilled in making and interpreting field intensity measurements. The Commission may require such engineer to present proof of his qualifications to make such measurements.

(d) The certification shall contain the following information:

(1) Type and serial number, or other positive identification of the ultrasonic equipment being certificated.

(2) Conditions under which the certificated equipment shall be operated.

(3) Brief description of the engineering tests and a summary of the measured data upon which the certification is based.

(4) If the radio frequency voltage on the power line is not measured, a statement that, based on an inspection of the equipment and study of such test data and specifications as may be furnished by the manufacturer, the equipment can reasonably be expected to meet the requirements for radio frequency voltage on the power lines.

(5) A statement certifying that under the described condition of operation, the certificated equipment may reasonably be expected to meet the requirements of the rules in this part. This statement shall include the period of time over which the equipment may reasonably be expected to comply with the rules in this part.

(6) Date the measurements were made.

(7) Date of certification.

(8) Signature of certifying engineer.

(9) Name and address of employer of certifying engineer, if any.

§ 18.81 Renewal of Certification.

The certification required by §§ 18.70 to 18.84 does not require renewal. However, when the Commission has reason to believe that operation of the equipment concerned may be inconsistent with §§ 18.70 to 18.84, it may require a new certification based on a new set of measurements.

§ 18.82 Certification After Maintenance Work.

It shall be the responsibility of the operator of the ultrasonic equipment to have such equipment recertificated when changes have been made that might increase the radiated or conducted interference beyond the limits specified in §§ 18.70 to 18.84

§ 18.84 Effective Date.

(a) All ultrasonic equipment manufactured on or after July 1, 1955, must comply with the rules in §§ 18.70 to 18.84.

(b) Ultrasonic equipment manufactured prior to July 1, 1955, may be utilized until July 1, 1965, providing it complies either with the rules in §§ 18.70 to 18.84 or with the rules for miscellaneous equipment in § 18.31. After July 1, 1965, all such equipment must comply with the rules in §§ 18.70 to 18.84.

SUBPART F—INDUSTRIAL HEATING EQUIPMENT

§ 18.101 Operation Without a License.

Industrial heating equipment may be operated without a license: *Provided*, The design and operation of the equipment complies with the technical limitations in this part for such equipment: *And provided further*, That the equipment has been certificated pursuant to the requirements of this part.

§ 18.102 Technical Limitations.

(a) Industrial heating equipment shall be designed and constructed in accordance with good engineering practice with sufficient shielding and filtering to meet the requirements of this part.

(b) Industrial heating equipment may be operated on any frequency except frequencies in the bands 490-510 kc/s, 2170-2194 kc/s, and 8354-8374 kc/s. Equipment operating on an ISM frequency may be operated with unlimited radiation on that frequency. Equipment operated on other frequencies must suppress radiation on the fundamental carrier frequency as well as other frequencies as required by this part.

(c) Industrial heating equipment designed for operation on an ISM frequency shall be adjusted to operate as close to that ISM frequency as practicable.

(d) Radiation of radio frequency energy from any industrial heating equipment on any frequency below 5725 Mc/s, except ISM frequencies, shall be suppressed so that the radiated field strength does not exceed 10 microvolts per meter at a distance of one mile or more from the equipment.

(e) Radiation of radio frequency energy from any industrial heating equipment on any frequency above 5725 Mc/s, except ISM frequencies, shall be reduced to the greatest extent practicable.

NOTE: The Commission will establish definite radiation limits for these frequencies as soon as information regarding equipment operating on these frequencies becomes available.

(f) Filtering between the industrial heating equipment and power lines must be provided to the extent necessary to prevent the radiation of energy from power lines on frequencies other than ISM frequencies with a field strength in excess of 10 microvolts per meter at a distance of one mile or more from the industrial heating equipment and at a distance of 50 feet from the power line.

§ 18.103 [Reserved]

§ 18.104 [Reserved]

§ 18.105 Inspection of Industrial Heating Equipment.

(a) Industrial heating equipment shall be periodically inspected in order to reaffirm the validity of the certificate required by this part.

(b) Inspection shall be made at sufficiently frequent intervals to insure that each industrial heating equipment is installed, maintained, and operated in a manner that provides compliance with the provisions of this part.

(c) A log shall be maintained of the inspections made. The inspector shall enter a brief note of his findings and shall date and sign each entry.

(d) The log shall be maintained at the same location as the certificate.

(e) The inspector shall require the equipment to be recertificated pursuant to the requirements of this part if he determines, as a result of his inspection, that such action is necessary in order to assure compliance with this part.

§ 18.106 Renewal of Certificate.

(a) The certificate required to be exhibited by this part shall be renewed:

(1) When changes have been made that might increase the radiated interference beyond the limits specified in this part.

(2) When the inspector has determined that such action is necessary to assure compliance with the requirements of this part.

(3) When required by the Commission because it has reason to believe that operation of the equipment concerned may be inconsistent with the requirements of this part.

(b) The renewal of the certificate shall be based on measurements made at the point of installation.

(c) After April 30, 1961, the renewal certificate shall be executed on FCC Form 724.

§ 18.107 Measurement of Field Strength.

Measurements to determine the field strength of radio frequency energy generated by industrial heating equipment shall be made in accordance with standard engineering procedures and shall include the following:

(a) A loop antenna shall be used for measurements on frequencies below 18 Mc/s, and a doublet antenna shall be used for measurements on frequencies above 30 Mc/s. Either a loop or doublet antenna shall be used on frequencies between 18 Mc/s and 30 Mc/s. Appropriate techniques shall be resorted to for measurements in the microwave region of the spectrum.

(b) Prior to the determination of the maximum field strength at one mile, a sufficient number of measurements shall be made in the vicinity of the industrial heating equipment to enable plotting of the polar radiation pattern and to assure the correct determination of the major lobes. Where conditions permit, these measurements shall be made at intervals of not more than 20 degrees in azimuth directions and at distances not exceeding 1,000 feet from the location of the equipment. The measurements so obtained shall be reduced to equivalent field strength at 1,000 feet.

(c) The field strength measurements for the maximum field strength at one mile shall be made along the radial corresponding to the lobe of maximum radiation as determined from the polar radiation pattern. Sufficient measurements shall be made along radials extending through all lobes which are within 15 db of the apparent maximum lobe, as determined in paragraph (b) of this section to assure that the assumed lobe of greatest field strength is in fact the maximum lobe. If two or more lobes of radiation of approximately the same strength are present, measurements to determine field strength shall be made along the several radials for such lobes. Where possible, field strength measurements shall be made along each radial at intervals of not greater than 500 feet and an average curve drawn for measured field strength in microvolts per meter versus distance in feet. Where necessary, the average curve shall be extended to show the extrapolated field strength at one mile. In those cases where it is impractical to conduct measurements along the radial of maximum radiation a sufficient number of field strength measurements shall be made to clearly indicate the magnitude of the radiation field in the sector containing the lobe of maximum radiation.

(d) Where there is evidence of radiation from power lines, field strength measurements shall be made at not less than three points along the power line located approximately 1 mile from the location of the industrial heating equipment causing such radiation and to include a length of power line not less than 500 feet. One point of measurement shall lie within the 1-mile distance and the others beyond. At each of these points at least three measurements of field strength shall be made along a line normal to the power line and out to a distance from the power line not exceeding 50 feet measured horizontally along the ground from a point directly below the outermost conductor.

(e) The field strengths specified herein refer to the maximum field strengths, regardless of polarization, measured at a height of 12 feet above the immediate terrain or at such lower height at which the field strengths may exceed that at 12 feet. Measurements made at frequencies below 18 Mc/s may be made at any convenient height.

(f) The spectrum shall be investigated from the lowest frequency generated in the equipment up to the tenth harmonic of the fundamental frequency or to 5725 Mc/s whichever is lower.

§ 18.108 Location of Equipment.

For the purpose of measurements required in order to execute a certification of compliance, the location of the industrial heating equipment may be considered to be the actual physical location of the equipment, or, where several such units are grouped within a circle of 500 feet radius or less, the several units may, at the election of the certifying engineer, be considered as a single unit, located at the center of the smallest enclosing circle. If the certification includes several units treated as one equipment, the distance of one mile at which the maximum permissible radiation is determined shall be reduced by the radius of the smallest circle that encloses the several units.

§ 18.109 Report of radiation measurements.

The report of radiation measurements shall contain the following information:

(a) A description of the equipment that was measured for radiation, including: manufacturer, type number, nominal operating frequency, and nominal power rating.

(b) A listing of the measuring equipment used, including the serial numbers.

(c) A statement of the date when the measuring equipment was last calibrated.

(d) The date the measurements were made.

(e) The frequency range that was investigated.

(f) A list of all frequencies at which measurements were made and the magnitude of the field that was measured.

(g) If the required range of investigation includes the following frequencies, indicate the magnitude of the field measured on these frequencies or in these frequency bands:

Mc/s
74.6 to 75.4
108.0 to 118.0
121.5
156.8
243.0
328.6 to 335.4
420.0 to 460.0

(h) A plot of field strength vs. frequency showing the level of all signals measured. The plot shall also show the ambient noise level.

(i) A plot of the polar radiation pattern as required by § 18.107(b).

(j) A plot of field strength vs. distance along the radial of maximum radiation in the polar plot as required by § 18.107(c).

(k) A statement of the operating conditions that must be observed to ensure that radiation during routine operation does not exceed, within reasonable limits, the radiation that was measured and is reported herein.

§ 18.110 [Reserved]

§ 18.111 Form of certificate.

(a) Certificates issued after April 30, 1961, for industrial heating equipment shall be executed on FCC Form 724 except as provided in paragraph (b) of this section.

(b) Where the industrial heating equipment is identical to a prototype which had been tested for radiation prior to April 30, 1961, the manufacturer's certification manual heretofore issued for such equipment may be substituted for Part III of FCC Form 724.

§ 18.112 Certification regarding operation.

The certification required in Part I of FCC Form 724 shall be executed by the owner or lessee of the equipment, in the case of proprietorship; by one of the partners, in the case of a partnership; or by an officer or authorized employee in the case of a corporation. If Part I is signed by an authorized employee, an officer shall execute Part II of the certificate.

§ 18.113 Certification regarding radiation.

The certification required in Part III of FCC Form 724 shall be executed by an engineer skilled in making and interpreting field strength measurements. The Commission may require such engineer to furnish proof of his qualifications.

§ 18.114 Prototype certification permitted.

The certification required in Part III of FCC Form 724 may be issued on the basis of field strength measurements made at the place where the industrial heating equipment has been installed for operation or on the basis of field strength measurements made on a prototype.

§ 18.115 Compliance with installation instructions.

Where the certification regarding radiation (Part III of FCC Form 724) is based on measurements of a prototype, the equipment shall be installed in accordance with the instructions which the engineer certifying to Part III of FCC Form 724 has certified as being adequate to ensure reasonable expectation of compliance with the radiation limits in § 18.102

§ 18.116 Certificate to be filed with Commission.

The certificate required by §§ 18.101 and 18.111 shall be filed with the Secretary, Federal Communications Commission, Washington 25, D.C. The copy of FCC Form 724 filed with the Commission shall include:

(a) The original of Part I properly completed and signed;

(b) When required, the original of Part II properly signed;

(c) The original or a facsimile copy of Part III properly completed and signed: *Provided*, That the manufacturer's certification manual may be substituted for Part III as provided by § 18.111(b).

§ 18.117 Copy of certificate with equipment.

A copy of the certificate filed with the Commission pursuant to § 18.116 shall be retained by the operator and shall be attached to the equipment. Alternatively, the copy of the certificate may be placed at any location where it will be conveniently available for inspection by authorized representatives of the Commission, provided there is attached to the equipment a notice stating where the copy of the certificate is located.

§ 18.118 Rejection of certificate.

(a) A certificate that is incomplete or otherwise does not meet the requirements of Subpart F of this part may be rejected.

(b) The certificate shall be considered accepted unless rejected in writing within 60 days of receipt by the Commission.

(c) In the event a certificate is rejected but with no harmful interference involved, the equipment may be operated for a period of 30 days from the date of the rejection notice pending the submission of an acceptable certificate.

(d) If the certificate is rejected after the second submission thereof, the equipment may not be operated until a certificate has been filed with and accepted by the Commission.

§ 18.119 Procedure in the event of harmful interference.

(a) The operator of industrial heating equipment that causes harmful interference to radio communications shall take prompt steps to eliminate the harmful interference (see §§ 18.2(g) and 18.8) and shall make an adequate investigation in the vicinity of the industrial heating equipment to ensure that the harmful interference has been eliminated.

(b) The investigation shall be made by an engineer skilled in interference control techniques. The Commission may require such engineer to furnish proof of his qualifications.

§ 18.120 Interference to a radionavigation or safety service.

If the operator is notified by the Commission that the harmful interference is endangering the functioning of a radionavigation or a safety service, he shall immediately cease operating the equipment. Operation on a temporary basis may be resumed, with the permission of the Commission's Engineer in Charge, for the purpose of eliminating the harmful interference and obtaining certification. Operation on a regular basis may be resumed after the harmful interference has been eliminated, the equipment has been properly certificated, and the final interference report required by § 18.122 has been submitted.

§ 18.121 Interference to other radio services.

If the operator is notified by the Commission that the harmful interference is obstructing or repeatedly interrupting an authorized radio service other than a radionavigation or safety service, he shall take prompt steps to eliminate the interference. He need not cease operation unless specifically ordered to do so by the Commission. If ordered to cease operation, he may resume operation on a temporary basis with the permission of the Commission's Engineer in Charge for the purpose of eliminating the harmful interference and obtaining certification. Operation on a regular basis may be resumed after the harmful interference has been eliminated, the equipment has been properly certificated, and the final interference report required by § 18.122 has been submitted.

§ 18.122 Report of interference investigation.

(a) An interim report on the investigation and of the corrective measures that were taken shall be filed with the Engineer in Charge of the local FCC office within 30 days of notification of harmful interference. The final report shall be filed with the Engineer in Charge within 60 days of notification.

(b) The date for filing the final report may be extended for 30 days by the Engineer in Charge when the operator has shown that he has been diligent in his efforts and that additional time is required to put into effect the corrective measures or to complete the investigation. The request for extension of time shall be accompanied by a progress report showing what has been accomplished to date.

(c) The final report of the interference investigation shall list the location of each receiver that was checked and the name(s) of the receiver owner(s), shall describe the steps taken to eliminate the harmful interference, and shall specify the date and time the receiver(s) was rechecked to ensure that the harmful interference has been eliminated.

(Ed. 12/61)

U.S. GOVERNMENT PRINTING OFFICE 1961 O—[illegible]

SELECTED MILITARY STANDARDS AND SPECIFICATIONS PERTAINING TO RADIO FREQUENCY INTERFERENCE — APPENDIX V

This Appendix contains selected military standards and specifications pertaining to radio frequency interference, compatibility, and spectrum signatures. Each group is arranged in numerical order.

Military specifications and standards are subject to amendment and revision to meet changing needs of the military departments brought on by an advancing technology. The military specifications and standards, included in this Appendix, were current at the time this Appendix was prepared for printing. However, changes and modifications may be made to these documents from time to time by the Government. Therefore, if it is required to know the exact technical requirements of a military specification or standard contained in the Appendix, the most recent issue of the document should be obtained from the appropriate Department of Defense activity.

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

MILITARY STANDARDS

FRC

MIL-STD-220A
15 December 1959

SUPERSEDING
MIL-STD-220
25 June 1952

MILITARY STANDARD

METHOD OF INSERTION-LOSS MEASUREMENT.

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1960

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. — Price [illegible] cents

ARMED FORCES SUPPLY SUPPORT CENTER

WASHINGTON 25, D. C.

Method of Insertion-
Loss Measurement
MIL-STD-220A

15 December 1959

1. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force, effective (date).

2. In accordance with established procedure, the Signal Corps, Bureau of Ships, and Air Force have been designated as Army-Navy-Air Force custodians of this standard.

3. Recommended corrections, additions, or deletions should be addressed to the Standardization Division, Armed Forces Supply Support Center, TEMPOX, Washington 25, D.C.

CONTENTS

FIGURES

1. SCOPE

1.1 This standard covers a method of measuring, in a 50-ohm system, the insertion loss of feed-through suppression capacitors, and of single- and multiple-circuit, radio-frequency (RF) filters at frequencies up to 1,000 megacycles (mc).

2. REFERENCED DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this standard:

SPECIFICATIONS

FEDERAL

QQ-S-571 — Solder: Lead Alloy; Tin Lead Alloy, and Tin Alloy; Flux Cored Ribbon and Wire, and Solid Form.

MILITARY

MIL-C-17 — Cables, Radio Frequency; Coaxial, Dual Coaxial, Twin-Conductor, and Twin Lead.

MIL-C-71 — Connectors, "N", for Radio Frequency Cables.

MIL-I-631 — Insulation, Electrical, Synthetic - Resin Composition, Nonrigid.

MIL-C-11693 — Capacitors, Feed Through, Radio-Interference Reduction, Paper Dielectric, AC and DC (Hermetically Sealed in Metallic Cases).

STANDARDS

MILITARY

MS35140 — Strap, Retaining, Single Hole, Open End Type.

MS35229 — Screw, Machine, Pan Head, Slotted, Brass, Plain Finish, NC-2A and UNC-2A.

MS35271 — Screw, Machine, Drilled, Fillister-Head, Slotted, Brass, Plain Finish, NC-2A and UNC-2A.

MS35289 — Screw, Cap, Hexagon Head (Finished Hexagon Bolt), Low Carbon Steel, Plain Finish, UNC-2A.

MS35333 — Washer, Lock, Flat, Internal Tooth.

MS35337 — Washer, Lock, Split, Helical, Light Series.

MS35446 — Terminal, Lug Solder Type, Copper Tubing, One Hole.

AIR FORCE-NAVY AERONAUTICAL

AN931 — Grommet—Elastic.

AN3102 — Connectors — Electrical, Receptacles, Box Mounting.

AN3106 — Connectors — Electrical, Plugs, Straight.

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. DEFINITIONS

3.1 **Insertion loss.** At a given frequency, the insertion loss of a feed-through suppression capacitor or a filter connected into a given transmission system is defined as the ratio of voltages appearing across the line immediately beyond the point of insertion, before and after insertion. As measured herein, insertion loss is represented as the ratio of input voltage required to obtain constant output voltage, with and without the component, in the specified 50-ohm system. This ratio is expressed in decibles (db) as follows:

$$\text{Insertion loss} = 20 \log \frac{E_1}{E_2}$$

Where:

E_1 = The output voltage of the signal generator with the component in the circuit.

E_2 = The output voltage of the signal generator with the component not in the circuit.

4. GENERAL REQUIREMENTS

4.1 **Test setup.** The test circuit shall be arranged as shown on figure 1, 2, 3, 4, 5, or 6. Using the RF-dc-insertion-loss-measuring-equipment assembly shown on figure 7, the test setup shall be capable of indicating a constant value of insertion loss within ±1.0 db over the required frequency range, when the standard attenuator (see 4.2.6) is measured by the method specified in 5.2.2. All test equipment shall be well shielded, and shall be filtered to the extent that leakage, either conducted or radiated, from the signal generator or any portion of the signal-source circuitry shall not affect the output of the receiver when the generator and receiver are operating at the output level and sensitivity, respectively, needed to make the required maximum insertion-loss measurement. The test setup shall be in accordance with 4.1.1 for each frequency at which an insertion-loss measurement is to be made.

Caution: The direct-current (dc) source used in making insertion-loss measurements with full load applied shall be a floating dc source and shall not be connected to ground.

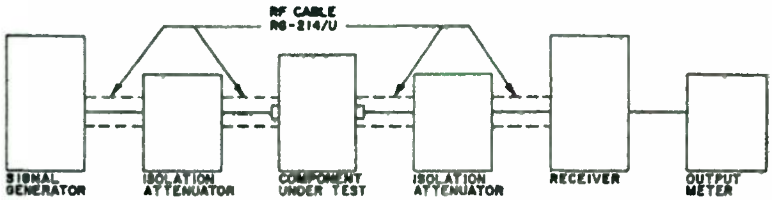


Figure 1. Basic test circuit.

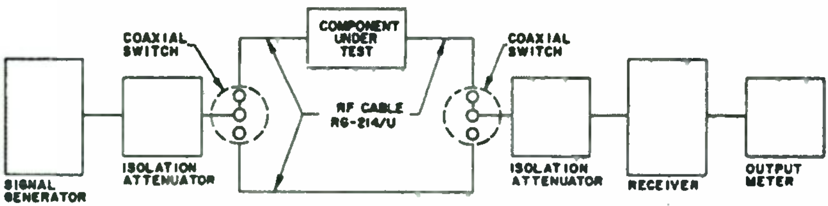


Figure 2. Test circuit for rapid measurement.

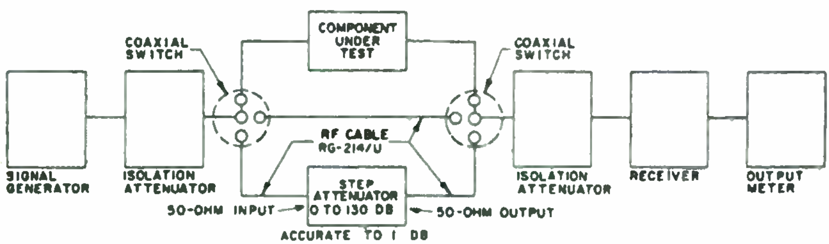


Figure 3. Alternate test circuit for rapid measurement.

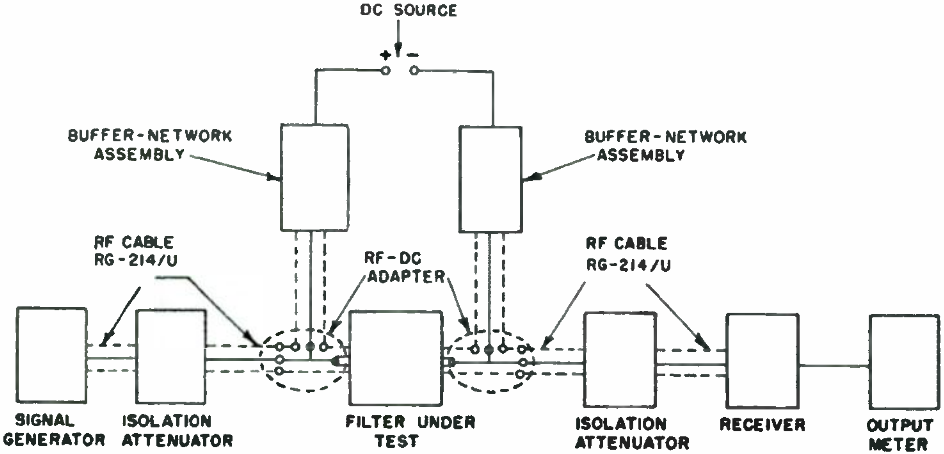


Figure 4. Basic test circuit for measurement with full load applied.

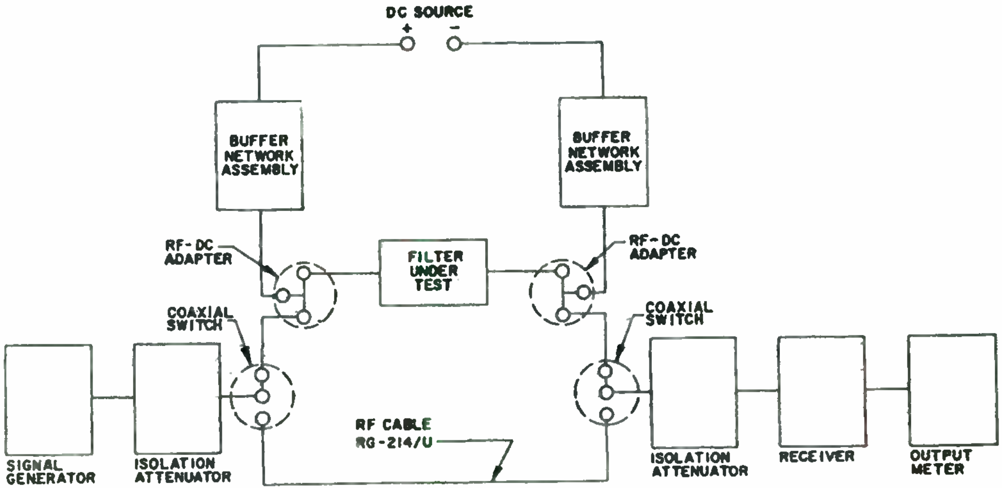


Figure 5. Test circuit for rapid measurement with full load applied.

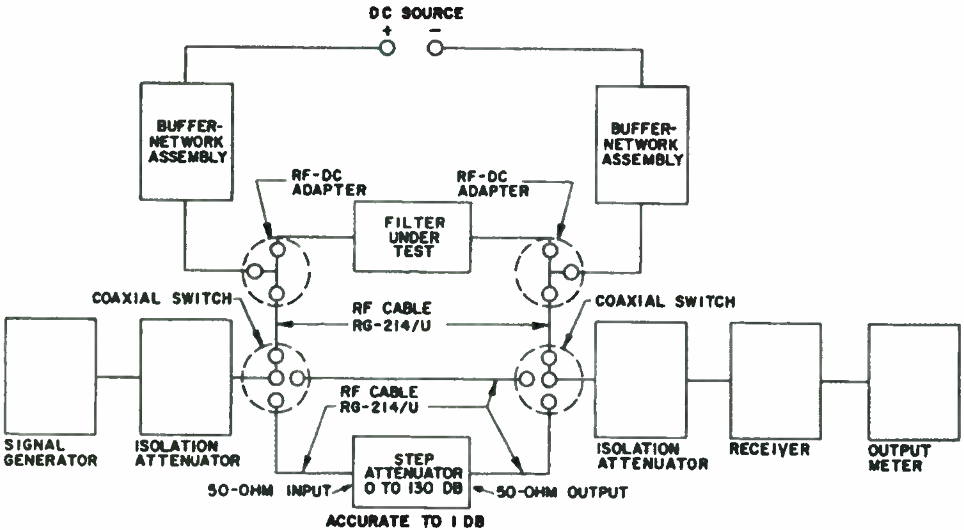


FIGURE 6. Alternate test circuit for rapid measurement with full load applied.

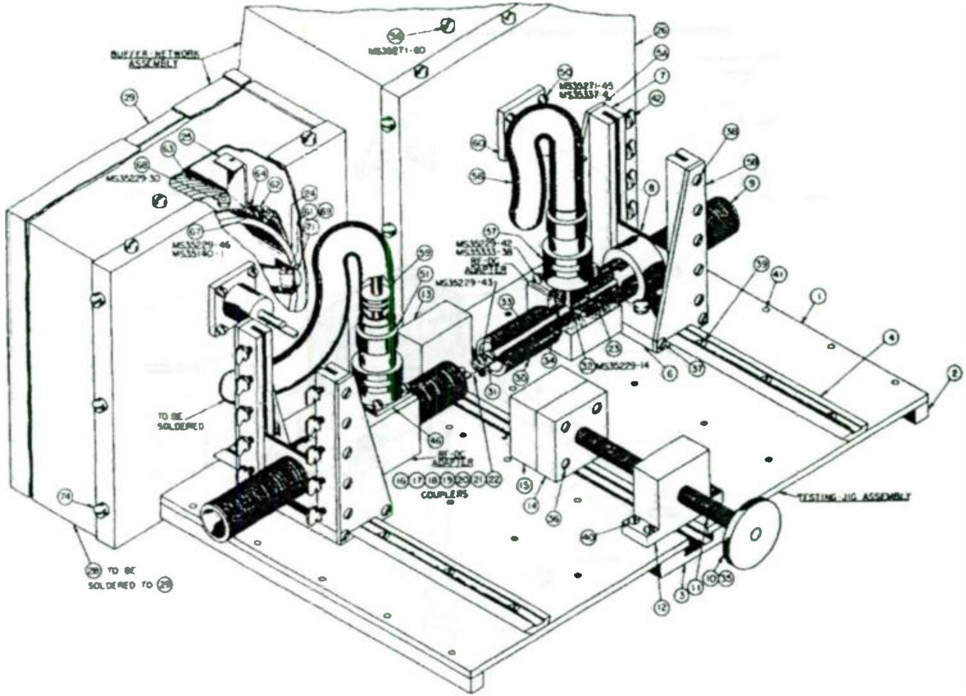


Figure 7. RF-De-insertion — loss-measuring-equipment assembly.

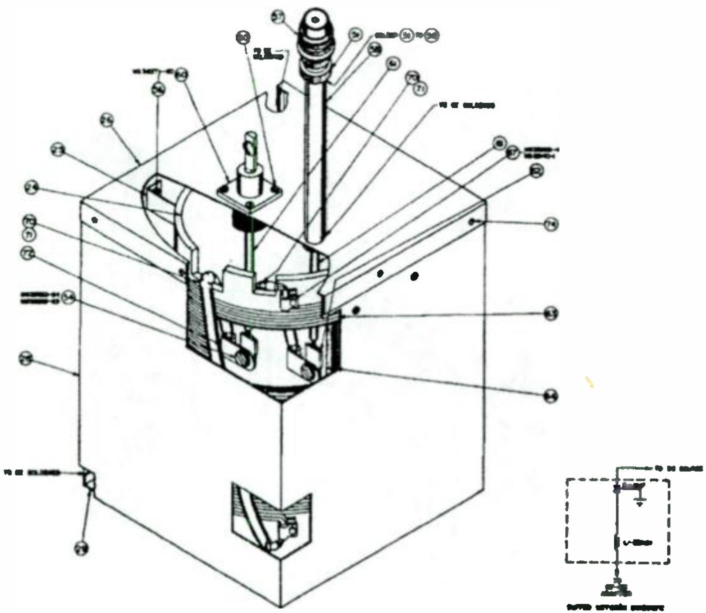


FIGURE 7. RF-Dc-insertion — loss-measuring-equipment assembly—Continued

Item No. or MS part No.	Description	Material	Quantity
1	Plate		2
2	Bar		2
3	Channel		1
4	Track		2
5A	Right plate		2
5B	Left plate	Brass (chrome plated)	2
6	Runner		2
7	Bar		4
8	Eye		2
9	Tube		2
10	Knob		1
11	Shaft	Steel (chrome plated)	1
12	Front block		1
13	Rear block		1
14	Block		1
15	Block		1
16	Coupler		2
17	Coupler		2
18	Coupler	Brass (chrome plated)	2
19	Coupler		2
20	Coupler		2
21	Coupler		2
22	Coupler		2
23	Connector		2
24	Coil form	Plastic	2
25	Bracket	Brass	8
26	Cover		2
27	Case	Copper (1 side tinned)	2
29	Bottom panel		2
30	Adapter body	Brass (chrome plated)	2

FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued

Item No. or MS part No.	Description	Material	Quantity
31	Conductor	Copper (silver plated)	2
32	Conductor		2
33	Insulator	Acrylic plastic	2
34	Insulator		2
35	Set screw, cup point No. 8–32 NC–2A, ⅜ lg.	Steel	1
36	Screw, RHMS, No. 10–32 NF–2A, 1¼ lg.	Brass (zinc or cadmium plated)	4
37	Screw, FHMS, No. 8–32 NC–2A, ½ lg.	Brass (zinc or cadmium plated)	8
38	Screw, FHMS, No. 10–32 NF–2A, 9/16 lg.		20
39	Screw, FHMS, No. 10–32 NF–2A, ⅜ lg.		10
40	Screw, FIL H MS, No. 10–32 NF–2A, ⅜ lg.		6
41	Screw, FHMS, No. 10–32 NF–2A, ¾ lg.		20
42	Screw, thumb shoulder, No. 10–24 NC–2A, ½ lg.		24
46	Receptacle, per AN3102A–18–6S.		2
50	Hex nut, No. 8–32 NC–2B		8
51	Nut, per U–4864–3B Titeflex Metal Hose Co., or equiv.		2
54	Hex nut, No. 18 UNC–2B	Steel	4
56	Hex nut, No. 10–24 NC–2B	Brass	16
57	Connector, per AN3106A–18–6S.	. . . . . .	2
58	Conduit shielding, per No. 152–48 Titeflex Metal Hose Co., or equiv. 8⅜ lg.		2

FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued

Item No. or MS part No.	Description	Material	Quantity
59	Grommet, per AN931B5-9		8
60	Capacitor, feed through, CZ 34 per Spec. MIL-C-11693.		2
61	Cable, 6 tw, 600 volt		As reqd
62	Terminal, per MS35446-5		4
63	Coil, No. 6 rectangular form-ex wire(wound 2 layers for total of 48 turns.	... ...	As reqd
64	Kraft paper		As reqd (use optional)
67	Hex nut, No. 8-32 NC-2B	Brass	8
68	Hex nut, No. 6-32 NC-2B		16
69	Terminal, per No. 5040 Patton-MacGuyer Co., or equiv.	Copper (hot-tin dipped)	2
70	Cable, ⅜ braided, 2 pc 5½ lg, 2 pc 16½ lg.	Copper	
71	Insulation, per Spec. MIL-I-631, 2 pc 5½ lg, 2 pc 16½ lg.	Vinyl	
72	Terminal, per No. 3007 Patton-MacGuyer Co., or equiv.	Copper	4
74	Screw, self tapping, FIL H, No. 6 type B, ⅜ lg.	Steel	24
MS35140-1	Strap, retaining		8
MS35229-14	Screw		1
MS35229-30	Screw		16
MS35229-42	Screw		8
MS35229-43	Screw		2
MS35229-46	Screw	Brass	4
MS35271-45	Screw		4
MS35271-60	Screw		16
MS36289-29	Screw		4
MS35333-24	Lockwasher		4
MS35333-38	Lockwasher	Steel	8
MS35337-4	Lockwasher		8

FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued

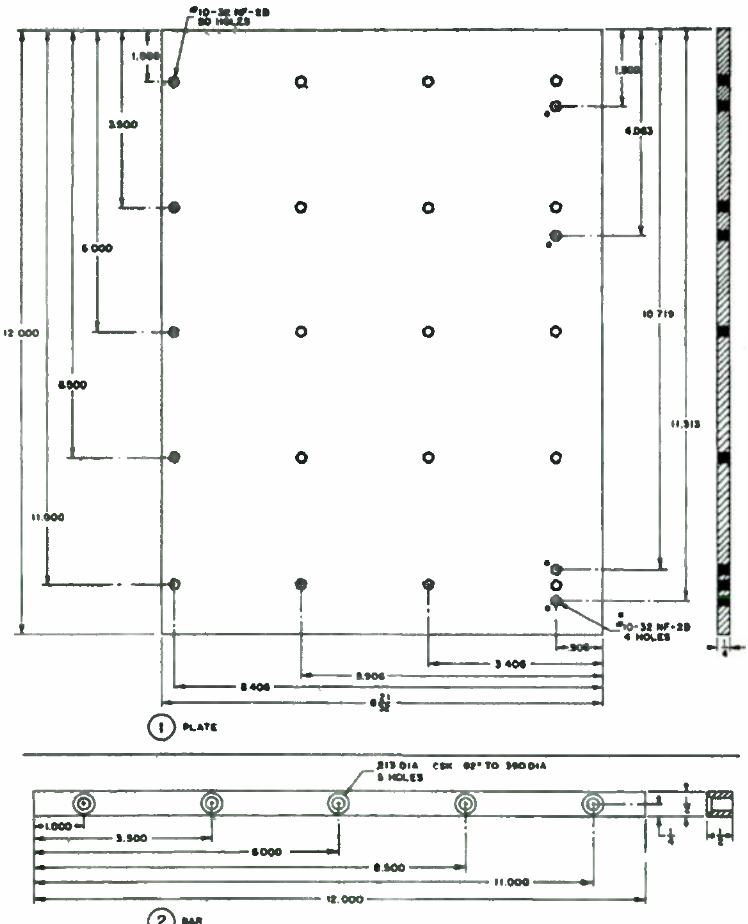


FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued

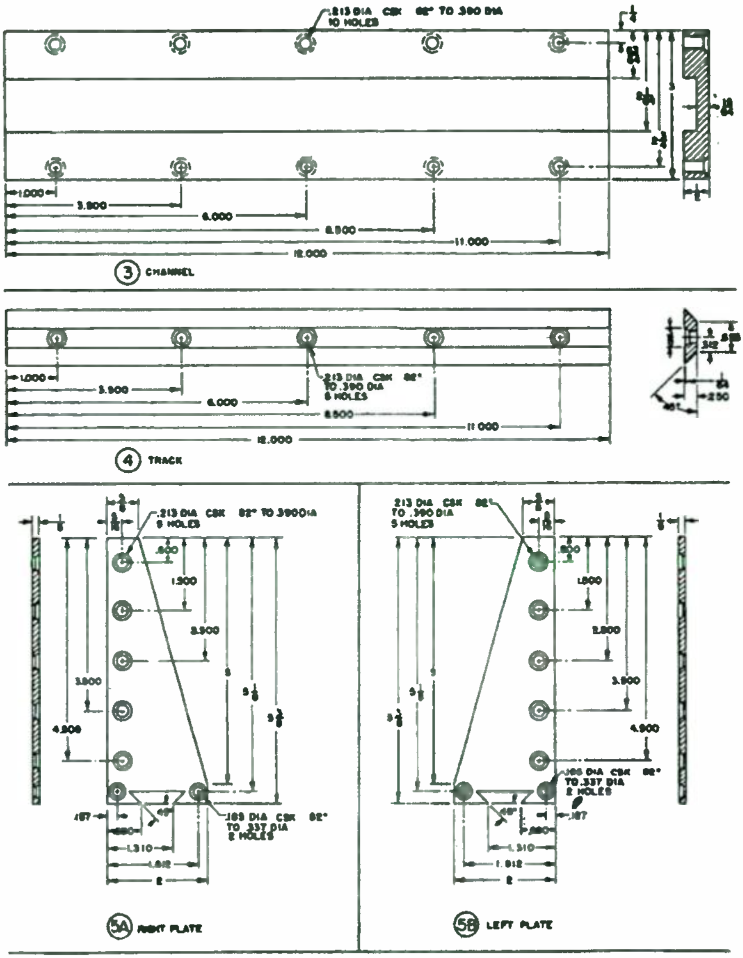


FIGURE 7. RF-Dc-insertion — loss-measuring-equipment assembly.—Continued

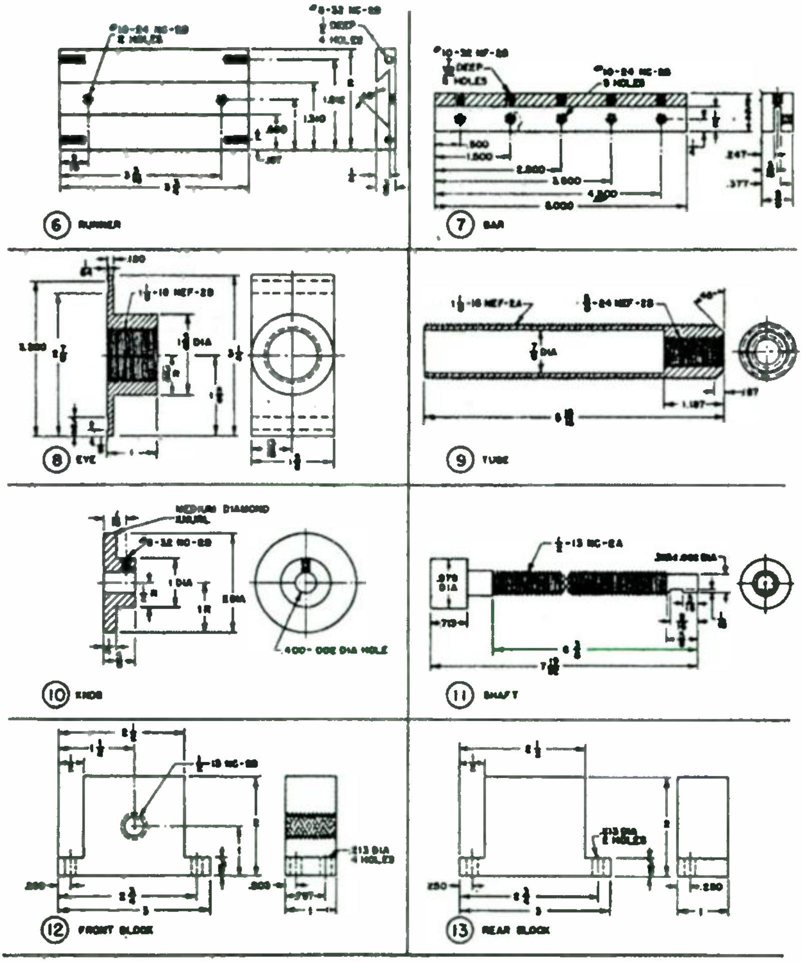


FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly*—Continued

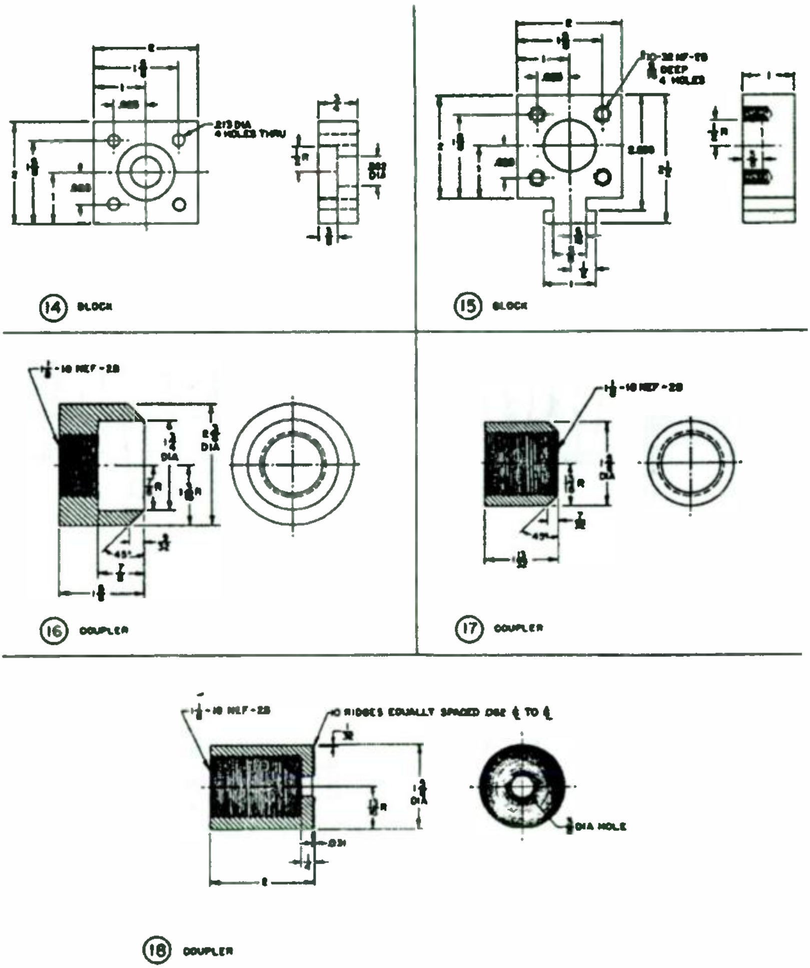
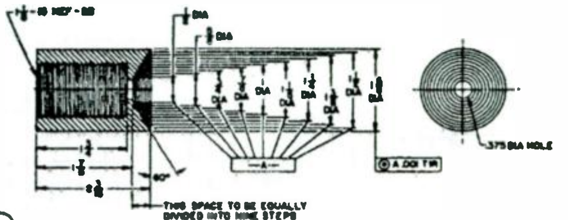
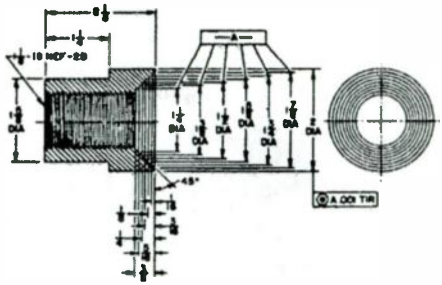


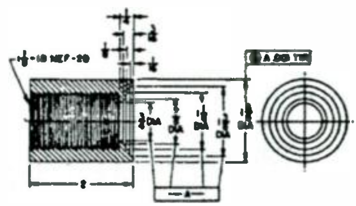
FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued



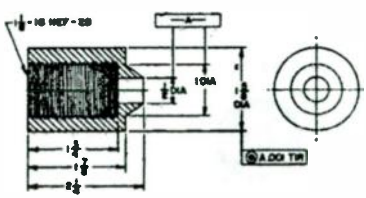
(19) COUPLER



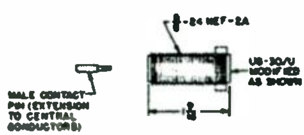
(20) COUPLER



(21) COUPLER



(22) COUPLER



(23) CONNECTOR

FIGURE 7. RF-De-insertion — loss-measuring-equipment assembly.—Continued

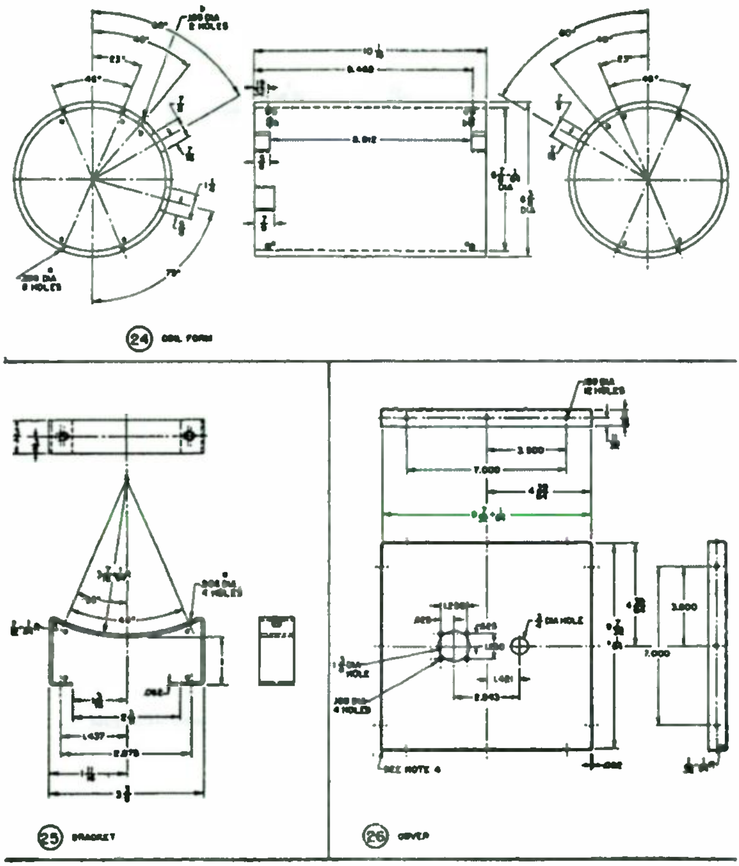
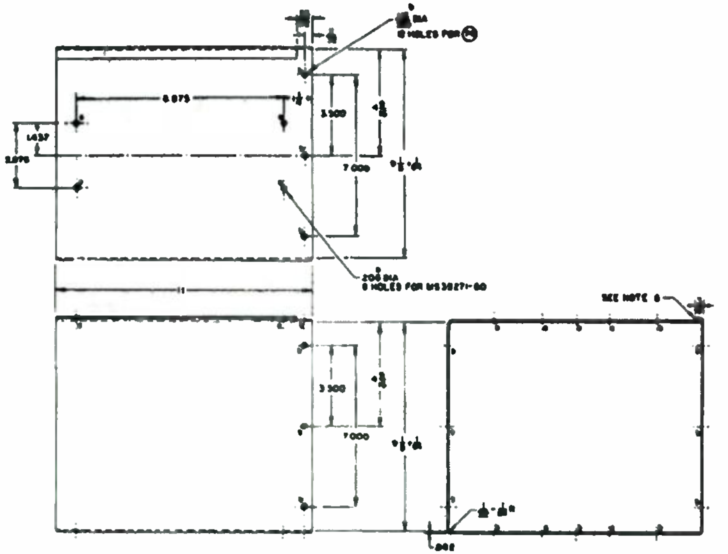
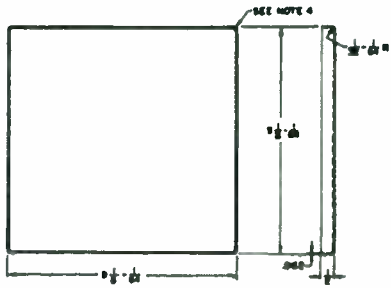


FIGURE 7. RF-De-insertion — loss-measuring-equipment assembly.—Continued

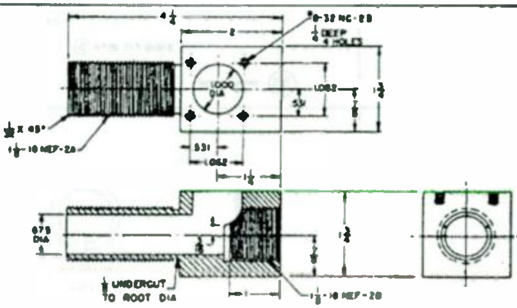


(28) CASE

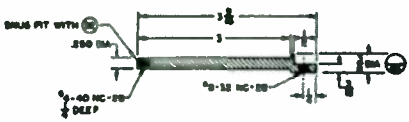
FIGURE 7. RF-De-insertion — loss-measuring-equipment assembly.—Continued



(29) BOTTOM PANEL

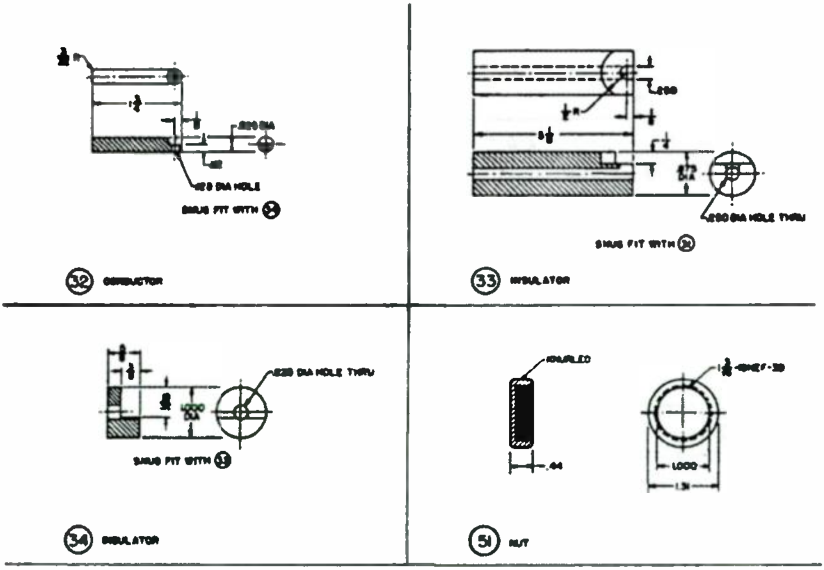


(30) ADAPTER BODY



(31) CONDUCTOR

FIGURE 7. *RF-De-insertion — loss-measuring-equipment assembly.*—Continued



NOTES:

1. ALL DIMENSIONS IN INCHES.
2. UNLESS OTHERWISE SPECIFIED, TOLERANCES ARE ± 1/64 ON FRACTIONS, ±.005 ON DECIMALS, AND ±1° ON ANGLES.
3. SOLDER USED SHALL BE COMPOSITION Sn40 PER SPECIFICATION QQ-S-571.
4. CORNERS SHALL BE SOLDERED AND THEN ROUNDED OFF.
5. THE EDGE SHALL BE SECURELY SOLDERED

FIGURE 7. *RF-Dc-insertion — loss-measuring-equipment assembly.*—Continued

4.1.1 *Shielding test*. With the equipment completely set up for the filter-out condition of insertion-loss measurement (see 5.2.2), the signal generator shall be disconnected from the powerline, and the receiver gain shall be adjusted to provide a convenient output indication of receiver fluctuation noise. The generator shall then be connected to the powerline, and its output voltage (E_7) shall be adjusted to provide a receiver output indication of 1.0 db above that obtained for receiver fluctuation noise. The receiver output indication shall be capable of being adjusted completely down to fluctuation noise by means of the generator output control, that is, in decreasing the generator output, a point shall not be reached at which lowering the output has no further effect on receiver indication while the receiver indication is perceptibly above fluctuation noise. Using the RF-dc-insertion-loss-measuring-equipment assembly specified in 4.2.5 with the coupler as shown on figure 7 (see detail drawings 16 to 22, inclusive), the test setup shall then be connected for the filter-in condition by substituting for the component a solid brass or copper plate at least ¼ inch thick with plane faces at least 2⅝ inches wide in all directions. This plate shall be placed across the coupler and center conductor of the RF-dc-insertion-loss-measuring-equipment assembly so that the signal source and load are completely short circuited by the faces of the plate. The output of the generator shall then be raised to the voltage (E_1) which causes a receiver-output indication of 1 db above receiver fluctuation noise. The insertion loss then obtained from the formula "Insertion loss = $20 \log \frac{E_1}{E_7}$" shall be at least 10 db greater than the insertion loss to be measured.

4.2 Test equipment.

4.2.1 *Signal generator*. After a 30-minute warmup period, the signal generator shall be capable of maintaining, within ±1.0 percent, any frequency to which it may be set, and the output voltage of the generator shall remain constant over any 2-minute test period within ±1.0 percent of any value to which it may be set. The generator shall be equipped, either internaly or externally, with an attenuator calibrated in terms of output-voltage increments and continuously variable from minimum to maximum; calibration shall be accurate within ± 5.0 percent in db when the geneartor is terminated with an impedance of 50 ohms. The output of the generator shall be fitted with or adapted to a coaxial connector in accordance with 4.2.3. When two or more generators are required to cover the specified frequency range, a coaxial switch in accordance with 4.2.3 may be used on the generator side of the isolation attenuator to facilitate changing of generators.

4.2.2 *Receiver*. After a 30-minute warmup period, the receiver shall be capable of maintaining, within ±1.0 percent, any frequency to which it may be tuned, and the overall gain of the receiver shall remain constant over any 2-minute test perior, maintaining an output voltage within ±1.0 percent of any value to which it may be set. The sensitivity shall be great enough and the level of circuit noise low enough to allow clear reception of the signal required for the measurement. The receiver automatic gain-control circuit shall be disabled during measurements, and an output meter shall be used to indicate relative voltage. The input to the receiver shall be fitted with or adapted to a coaxial connector in accordance with 4.2.3. When two or more receivers are required to cover the specified frequency range, a coaxial switch in accordance with 4.2.3 may be used on the receiver side of the isolation attenuator to facilitate changing of receivers.

4.2.3 *Coaxial lines, connectors, and switches*. All coaxial lines shall be Radio Frequency Cable RG-214/U, or equal, and shall conform to Specification MIL-C-17. It is essential that cable with the characteristic impedance of type RG-214/U be used to connect the isolation attenuators together for the filter-out condition and to connect the component to the isolation attenuators for the filter-in condition. The length of cable connecting the isolation attenuators for the filter-out condition shall be within ±6 inches of the combined length of the two cables connecting the component to the isolation attenuators for the filter-in condition. Type N 50-ohm coaxial connectors conforming to Specification MIL-C-71 shall be used where applicable. When coaxial switches are used, they shall have a 50-ohm characteristic impedance, and a maximum voltage standing wave ratio (VSWR) of 1.1 to 1 at the frequency of measurement.

4.2.4 *Isolation attenuators.* The isolation attenuators shall be appropriate resistive networks having 50-ohm-input and 50-ohm-output impedances. The attenuators shall have a minimum insertion loss of 10 db measured in a 50-ohm system. Looking into either end of each attenuator with the other end terminated in 50 ohms, the VSWR shall be a maximum of 1.1 to 1 up to 400 mc, and a maximum of 1.2 to 1 from 400 to 1,000 mc, inclusive. The characteristics of the attenuators shall show no significant change when the system is subjected to the maximum signal-generator power required for measurement. The input and output of each attenuator shall be fitted with coaxial connectors in accordance with 4.2.3. These attenuators are for the purpose of obtaining a standard 50-ohm termination for all attenuation measurements.

4.2.5 *RF - Dc-insertion-loss-measuring-equipment assembly.* When the component under test has no provision for coaxial connections, the RF-dc-insertion-loss-measuring-equipment assembly shown on figure 7 shall be used to insert the component into the line, unless otherwise specified in the individual component specification. When a component has such a shape that it cannot be satisfactorily clamped in this assembly, other adequate clamping means shall be used.

4.2.5.1 *Buffer-network assembly and RF-dc adapter.*

4.2.5.1.1 *Full-load insertion-loss measurements.* The buffer-network assembly and RF-dc adapter shown on figure 7 shall be used for providing coaxial connections when performing insertion-loss measurements with rated current (dc ratings or equivalent) applied. The complete RF-dc-insertion-loss-measuring-equipment assembly shall be used for test measurements over the frequency range of 100 kilocycles (kc) to 20 mc, inclusive. The buffer network shown on figure 7 is suitable for continuous use with currents up to 100 amperes.

4.2.5.1.2 *No-load insertion-loss measurements.* The buffer-network assembly shown on figure 7 shall not be used when performing no-load insertion-loss measurements. The RF-dc adapter shown on figure 7 may be used at all frequencies for providing coaxial connections during no-load insertion-loss measurements.

4.2.6 *Standard attenuator.* A standard attenuator shall be provided with the following characteristics:

(a) Attenuation of 50 ± 0.5 db over the frequency range of 150 kc to 1,000 mc, inclusive.
(b) Maximum VSWR of 1.2 to 1 over the frequency range of 150 kc to 1,000 mc, inclusive.
(c) Input and output impedance of 50 ohms.

The standard attenuator shall be inserted into the system in place of a component, to test for proper operation as specified in 4.1.

4.2.7 *Output meter*. An output meter, or similar indicating device, which will provide a readable indication of the magnitude of signal shall be used. The indicating device may be a part of the receiver or may be a separate instrument connected to the receiver.

5. METHOD OF TEST

5.1 Test conditions. Unless otherwise specified in the individual component specification, all measurements shall be made at room ambient temperature, atmospheric pressure, and relative humidity.

5.2 Test procedure.

5.2.1 *Preliminary operation.* To insure stability, each signal generator and receiver shall be operated for a period of at least 30 minutes immediately before measurement.

5.2.2 *Method of measurement.* The test equipment shall be set up as shown on figure 1, 2, 3, 4, 5, or 6, except that a cable of the type and length specified in 4.2.3 for the filter-out condition shall be inserted between the attenuators to replace the component and its connecting cables. The signal generator shall be adjusted to the desired frequency, with the attenuator set for the lowest convenient value of output voltage. The receiver shall be tuned to resonance at the frequency of the generator, and the gain controls shall be set so that the sensitivity will be great enough and the level of circuit noise low enough to allow clear reception of the signal required for the measurements. The output of the generator (E_2) shall be adjusted to give the lowest possible stable and readable indication on the output meter, care being taken not to saturate or overload the receiver. The cable used for the filter-out condition shall then be removed, and the component and its connecting cables shall be inserted between the isolation attenuators, with the component connected to the cables as specified in 4.2.5. The receiver shall be returned to resonance, and the output of the generator (E_1) adjusted until the output meter gives the same indication as that obtained for the filter-out condition. The insertion loss of the component under the specified conditions and at the frequency of measurement may then be expressed in db

as $20 \log \frac{E_1}{E_2}$ (see 3.1).

5.2.2.1 *Multiple-circuit components.* The insertion loss of each circuit of a multiple-circuit component shall be measured with each of the other circuits open and also with each of the other circuits short circuited; the short-circuit connections shall be as short and direct as possible. The insertion loss of the circuit at the frequency of the test shall be considered to be equal to the lesser of the two measurements.

5.2.2.2 *Test circuit for rapid measurement.* The test circuit for rapid measurement as shown on figure 2, 3, 5, or 6 may be used to facilitate the change from the filter-out condition to the filter-in condition. The coaxial switches shall be in accordance with 4.2.3.

5.2.2.3 *Full-load insertion-loss measurements.* Full-load insertion-loss measurements shall be performed as shown on figure 4, 5, or 6 over the frequency range of 100 kc to 20 mc, inclusive. The equipment specified in 4.2.5.1.1 shall be used for coaxial connections. The nominal dc rated current of dc components, or the dc equivalent of the peak alternating-current (ac) rated current of ac components shall be applied during these tests.

5.2.2.4 *No-load insertion-loss measurements.* No-load insertion-loss measurements shall be performed as shown on figure 1, 2, or 3. The equipment specified in 4.2.5.1.2 shall be used for coaxial connections.

Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.

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MILITARY STANDARD
ATTENUATION MEASUREMENTS FOR ENCLOSURES, ELECTROMAGNETIC SHIELDING, FOR ELECTRONIC TEST PURPOSES, METHOD OF

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WASHINGTON 25, D. C.

25 June 1956

Supply and Logistics

ATTENUATION MEASUREMENTS FOR ENCLOSURES, ELECTROMAGNETIC SHIELDING, FOR ELECTRONIC TEST PURPOSES, METHOD OF

MIL-STD-285

1. This standard has been approved by the Department of Defense and is mandatory for use of the Departments of the Army, the Navy, and the Air Force.

2. In accordance with established procedure, the Standardization Division has designated the Signal Corps, the Bureau of Ships, and the Air Force, respectively, as Army-Navy-Air Force custodians of this standard.

3. This standard is mandatory for use effective 25 June 1956 by the Departments of the Army, the Navy, and the Air Force.

4. Recommended corrections, additions, or deletions should be addressed to the Standardization Division, Office of the Assistant Secretary of Defense (Supply and Logistics), Washington 25, D. C.

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ATTENUATION MEASUREMENTS FOR ENCLOSURES, ELECTROMAGNETIC SHIELDING, FOR ELECTRONIC TEST PURPOSES, METHOD OF

1. SCOPE

1.1 This standard covers a method of measuring the attenuation characteristics of electromagnetic shielding enclosures used for electronic test purposes over the frequency range 100 kilocycles to 10,000 megacycles.

2. APPLICABLE DOCUMENTS

3. DEFINITIONS

3.1 Attenuation.—Attenuation is the ratio, expressed in decibels (db), of the received powers on opposite sides of a shield when the shield is illuminated by electromagnetic radiation; and as used in this standard, is the figure of merit to designate the shielding effectiveness of electromagnetic enclosures.

3.2 Voltage versus power ratio.—In accordance with 3.1, measurement should be made of powers associated with the incident wave, and the ratio of these measurements should be expressed in decibels. It is acceptable instead, when the wave impedance is identical for E_1 and E_2 to measure only the electric field intensities, E_1 and E_2 and to use the expression:

$$\text{Attenuation (db)} = 20 \log \frac{E_1}{E_2}$$

It is assumed that the wave impedance will be identical and that this method is used for the sake of convenience.

4. REQUIREMENTS

4.1 Test set-up.—The arrangement of signal sources, measuring equipments, pick-up devices, and shielded enclosures shall be in accordance with the following paragraphs and figures 1 through 6. All power lines, RF cables, and other utilities entering the shielded enclosure shall be in place when tests are conducted. Special care shall be taken to make measurements in the vicinity of utility entrances, doors, and access panels.

4.1.1 *Measurement of attenuation low impedance (magnetic) fields.*

4.1.1.1 *Attenuator.*—When an attenuator, the calibration of which is used as a basis for the desired measurements, is employed between either the receiver or the transmitter and its antenna, the antenna shall "look back" into an impedance which is independent of the setting of the attenuator. The attenuator A may be a 50 or 72 ohm transmission line, low input impedance, step attenuator. A signal generator shall be used to calibrate the attenuator. The attenuator shall be capable of measuring an insertion loss of over 70 db.

4.1.1.2 *Detector.*—The detector may be any receiver such as the DZ-2 or the BC-348-Q or a field strength meter provided with a low impedance input such as the Radio Test Set AN/PRM-1, AN/PRM-14, and Empire Devices, Incorporated, NF-114. A matching device may be used with high input impedance receivers or field strength meters.

4.1.1.3 *Signal source.*

4.1.1.3.1 Signal source S may be a signal generator or power oscillator of sufficient CW, MCW or Pulsed CW output. In case loop L_1 is connected to the output of a signal generator or power oscillator, a tuning capacitor may be connected in series with L_1 to obtain resonance at the test frequency used.

4.1.1.3.2 If the signal generator has a reliable output attenuator, it may be used, instead of the attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the attenuation of the shielding enclosure by using the detector D at the same reference level when the shielding enclosure wall is removed. In this case, no precaution has to be taken to guard against case leakage at the detector.

4.1.1.3.3 A signal source shall be constructed as shown on figure 2.

4.1.1.4 *Measurement of db attenuation.*—Measurement of db attenuation to low impedance magnetic fields shall be performed in accordance with figure 1.

4.1.1.4.1 The attenuation of the enclosure is the increase in the db setting of the attenuator A necessary to obtain the same reference reading level in detector D, when the shielding enclosure wall, S_1 S_2 is removed, without changing the relative positions of L_1 and L_2. (The attenuation in db is also essentially equal to 20 log E_1/E_2, where E_2 and E_1 are the voltages induced in the receiving loop, with the enclosure wall in and with the enclosure wall removed, respectively, without changing the relative positions of L_1 and L_2.) The equipment as a whole shall be capable of measuring a shielded enclosure attenuation of at least 100 db.

4.1.1.4.2 The position of L_1 with respect to the enclosure shall be anywhere around the enclosure and in any orientation to the section seams and access panel seams. A reading shall be taken on all four sides of the enclosure, and the minimum attenuation recorded. This shall be a minimum of 70 db.

4.1.1.4.3 When it becomes impractical to remove the shielding enclosure wall S_1, S_2, the loops L_1 and L_2 shall be set outside the enclosure in an exactly similar position with no obstruction. Because the strong magnetic field generated by L_1 can penetrate the metal case of detector D and attenuator A, these two equipments shall be left inside the enclosure and the loop L_2 brought out of the enclosure through a transmission line connector. The connector shall be grounded circumferentially where it passes through each wall of the shielded enclosure. Shielded enclosure doors shall be closed during tests.

4.1.1.4.4 A test shall be made to insure that no case leakage exists at D and A. The detector should show no indication whatever above the inherent background when cable C_2 or C_3 is disconnected.

4.1.2 *Measurement of attenuation to high impedance (electric) fields (see figure 3).*

4.1.2.1 *Attenuator.*—The attenuator used may be a high impedance capacity type attenuator, similar to the external attenuator used with the Ferris Model 32A(TS-432/U) or constructed similarly to the one used internally on the AN/PRM-1. A signal generator shall be used to calibrate this attenuator. The attenuator shall be able to measure an insertion loss of over 100 db.

4.1.2.2 *Detector.*—The detector may be a field strength meter such as the Ferris 32A(TS-432/U), the AN/PRM-1, the AN/PRM-14, and Empire Devices, Incorporated, NF-114. In this case, attenuator A may be deleted as these instruments can measure induced voltages in the receiving antenna R_2, and are able to record levels 100 db apart. The readings obtained on these instruments shall be checked against a signal generator.

4.1.2.2.1 When the receiver is used as other than a fixed reference level indicator, and the signal source is a broadband device such as described on figures 2 and 4, the output indication of the receiver shall drop at least 30 db: (a) when the local oscillator is disabled, (b) while in the strongest field, and (c) at the highest input level to the first tube to be used during the test of the shielded enclosure. Also, the image rejection shall be at least 30 db, and the IF rejection shall be at least 40 db, when broadband signals are used. The case leakage and power-line filtering of the receiver-attenuator combination shall be such that when operating in the strongest field required to be measured, removing the antenna and substituting a shielded dummy antenna simulating the actual antenna impedance will result in at least a 30 db reduction of output indication.

4.1.2.3 A receiver such as the BC-348-Q may be used. In this case, they are used only as reference level indicators. The attenuation may be read on attenuator A. The equal reference level chosen shall be low enough as not to represent any overloading or saturation of the receiver. If necessary, a matching device may be used with low input impedance receivers.

4.1.2.4 *Signal source.*

4.1.2.4.1 Signal source S may be a signal generator or power oscillator of sufficient CW, MCW or pulsed CW output. The termination of cable C_1 may be matched to the signal source S if desired.

4.1.2.4.2 If the signal generator has a reliable output attenuator, it may be used instead of the attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the db attenuation of the enclosure by operating the detector D at the same reference level when the shielding enclosure wall is removed. In this case, no precaution has to be taken to guard against case leakage at the detector.

4.1.2.4.3 If a large output signal generator or power oscillator is not available, a pulse signal source may be easily constructed as shown on the three set-ups on figure 4.

4.1.2.5 *Measurement of db attenuation, (see figure 3).*

4.1.2.5.1 The attenuation of the enclosure is the increase in the db setting of the attenuator A necessary to obtain the same reference reading level in detector D when the shielding enclosure wall S_1 and S_2 is removed, without changing the relative position of R_1 and R_2. The attenuation in db is also essentially equal to 20 log 10 E_1/E_2, where E_2 and E_1 are the voltages induced in receiving rod with the enclosure wall in and with the enclosure wall removed, respectively.

4.1.2.5.2 The positioning of R_1 with respect to the shielding enclosure walls shall be anywhere around the enclosure, in any orientation to the section seams and access-panel seams. A reading shall be taken at each side of the shielding enclosure and the minimum attenuation recorded. This minimum shall be over 100 db.

4.1.2.5.3 When it becomes impractical to remove the shielding enclosure walls, S_1 and S_2, both rods R_1 and R_2 shall be set outside the enclosure in the exact similar position, with no obstruction. Because the strong electric fields generated by R_1 can penetrate the metal case of detector D and attenuator A, these two equipments shall be left inside the enclosure and the rod R_2 brought out of the enclosure through a transmission line connector. The cable used shall be as short as possible. The connector shall be grounded circumferentially where it passes through each wall of the shielded enclosure. Shielded enclosure doors shall be closed during the test.

4.1.2.5.4 A test shall be made to insure that no case leakage exists at D or A. The detector should show no indication whatsoever above inherent background when cable C_2 or C_3 is disconnected.

4.1.3 *Measurement of attenuation to plane waves (see figure 5).*

4.1.3.1 *Attenuator.*—The attenuator shall be as specified in 4.1.1.1.

4.1.3.2 *Detector.*—The detector may be a receiver such as Receiving Equipment AN/APR-4, RF Interference Test Set AN/URM-28, RF Interference Test Set AN/URM-29, Radio Set AN/ARC-27, or a field strength meter such as the Noise Field Intensity Meter TS-587/U, Radio Test Set AN/URM-17, AN/URM-7 or Empire Devices, Incorporated, NF-105. Detectors which cannot readily give peak indications may be used with an oscilloscope connected to their output.

4.1.3.3 *Signal source.*

4.1.3.3.1 Signal source S may be a signal generator or power oscillator of sufficient CW, MCW, or pulsed CW output. The terminal of cable C_1 may be matched to the signal source when necessary.

4.1.3.3.2 If the signal generator has a reliable output attenuator, it may be used instead of attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the attenuation of the enclosure by using the detector D at the same reference level. In this case, no precaution may have to be taken to guard against leakage at the detector.

4.1.3.3.3 The signal source may be an AN/ARC-27 transmitter, a high frequency Rollin Signal generator Model 30(TS608/U), or equal, or Radar Set AN/APT-5 radar transmitter. An oscillator, tuned to the frequency of test may be constructed, using a high voltage plate supply and then pulsed, to obtain high peak power. A signal source may be constructed as shown on figure 6.

4.1.3.4 *Measurement of db attenuation (see figure 5).*

4.1.3.4.1 The attenuation of the enclosure in db is equal to the increase in the db setting of attenuator A necessary to obtain the same reference reading level in detector D when the receiving antenna is switched from position R_1 to R_2, without changing the position of R_1. (The attenuation in db is also essentially equal to 20 log 10 E_1/E_2, where E_1/E_2 are the voltages induced in R_1 and R_2, respectively.)

4.1.3.4.2 The position of R_2 with respect to the shielding enclosure walls shall be anywhere around the enclosure in any orientation with respect to the section seams and access-panel seams. Several readings shall be taken, and the minimum attenuation recorded. This minimum shall be over 100 db.

4.1.3.4.3 A test shall be made to insure that no case leakage exists at D or A. The detector D should show no indication whatsoever above inherent background when cable C_1 or C_2 is disconnected.

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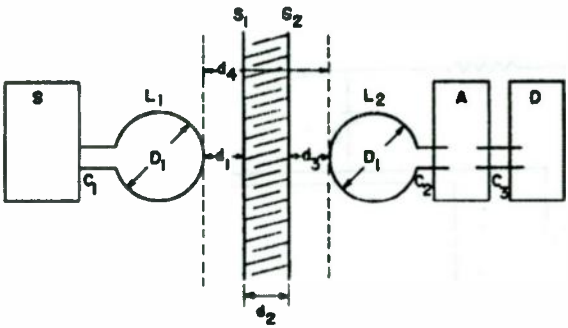

FIGURE 1.—*Attenuation measurement low impedance magnetic field.*

d_1 = 12 inches.
d_2 = separation between inner and outer shields.
d_3 = 12 inches.
d_4 = 25 inches—($d_1 + d_2 + d_3 = d_4$).
S_1 = Outer screen.
S_2 = Inner screen.
S = Low impedance signal source to obtain adequate output at the frequency of test.
D_1 = 12 inches.
Frequency of test = One frequency in the 150 to 200 kc. range.
L_1 = Transmitting loop radiator; low impedance. One turn of No. 6 AWG copper wire. Oriented at any angle in a plane perpendicular to the shielding enclosure wall.
D = Detector of adequate sensitivity tuned to frequency of test. Used only as a reference level indicator.
L_2 = Receiving loop antenna, positioned in the same plane as L_1.
A = DB attenuator of low impedance input, calibrated at the frequency of test.
C_1, C_2, C_3 = Shielded transmission line cables. As short as possible and used only if necessary.

Note.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL-STD-16).

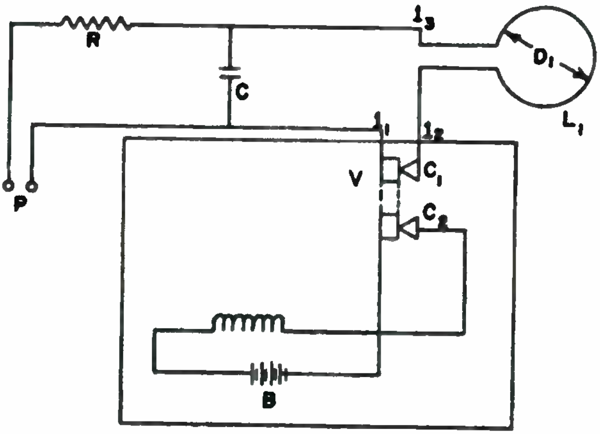

FIGURE 2.—*Source of intense peak power magnetic field.*

L_1, D_1 = See figure 1.
C = 1.0 mfd. paper, 600 volts.
R = 10,000 ohms, 5 watts.
B = Dry cell, 3 to 45 volts.
P = 300 volts d. c. Battery or rectifier power supply.
C_1 = Contact interruptor shorting out capacitor C at a rate of 20 to 100 pulses per second. Operated by C_2 but not electrically connected to it.
V = Vibrator.
l_1, l_2, l_3 = Leads; shall be as short as possible.

NOTE.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL–STD–16).

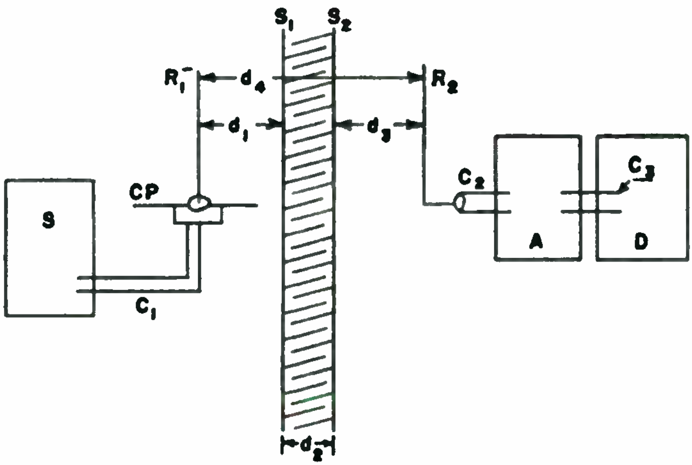

FIGURE 3.—*Attenuation measurement high impedance electric field.*

d_1 = 12 inches.
d_2 = Separation between inner and outer shields.
S_1 = Outer screen.
S_2 = Inner screen.
S = High impedance signal source to obtain adequate output at the frequency of test.
Frequencies of test = 200 kc., 1.0 mc. and 18.0 mc.
R_1 = Transmitting rod radiator, 41 inches long. High impedance oriented in any position parallel to the shielding enclosure wall.
C_1, C_2 and C_3 = Shielded transmission line cables. As short as possible and used only if necessary.
A = Capacity type db attenuator. High input impedance.
CP = Counterpoise.
R_2 = Receiving rod antenna, 41 inches long. High impedance, positioned parallel to R_1 and in the same plane.
D = Detector of adequate sensitivity. Tuned to frequency of test. Used only as an equal reference level indicator.

d_3 = 12 inches.
d_4 = 25 inches = (d_1 + d_2 + d_3 = d_4).

Note.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL–STD–16).

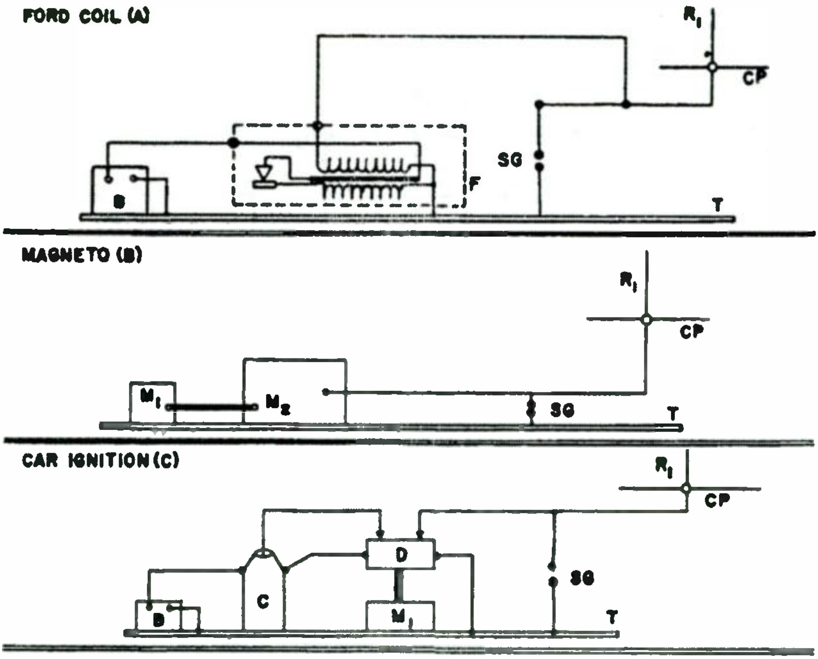

FIGURE 4.—*Source for intense peak power electric field.*

R_1 = Radiator (fig. 3).
M_1 = Motor drive.
C = Ignition coil.
CP = Counterpoise.
T = Ground metal table.
F = Ford coil (ignition).
M_2 = Magneto.
B = Battery.
D = Ignition distributor.
SG = Spark gap.

Note.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL-STD-16).

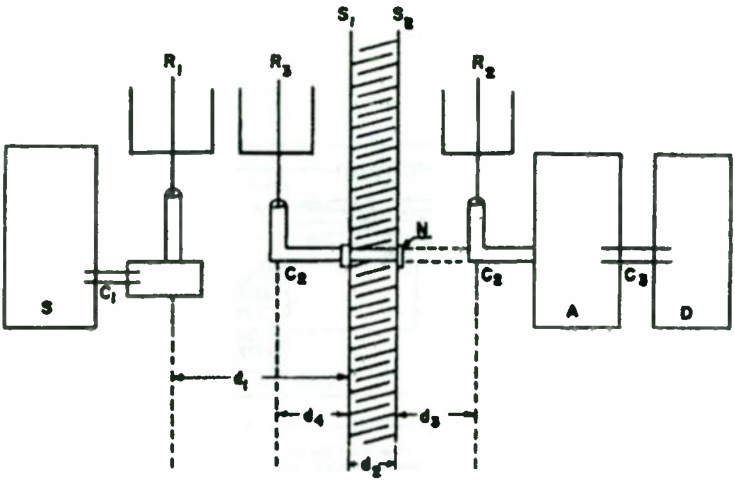

FIGURE 5.—Attenuation test for plane waves (wave impedance = 377 ohms).

d_1 = 72 inches minimum. Distance shall be as great as possible and limited only by the output of S. However, always hold more than two times the wave length from S_1, S_2.

d_2 = Distance between shields.

d_3 = 2 inches. Two inches is the minimum value. R_2 is positioned anywhere inside the enclosure and oriented for maximum indication on detector D, in order to minimize the effect of reflections.

d_4 = Not less than 2 inches, and not more than 24 inches—R_3 is positioned anywhere outside the enclosure and oriented for maximum indication on detector D, in order to minimize the effect of reflections. The entire region, from 2 to 8 inches shall be explored for maximum indication. R_3 shall never be closer than 2 inches to S_1 or S_2, in order to prevent capacity coupling.

S_1, S_2 = Outer and inner shields, respectively.

N = Transmission line connector.

S = Signal source, to obtain adequate output at the test frequency.

Frequency of test = 400 megacycles.

R_1 = Transmitting radiator. Dipole, tuned to 400 mc. If a tuned dipole is used with a single coaxial line, it shall be a balanced dipole, similar to the Antenna AT-275/URM-28. Other suitable antenna types are: Antenna AT-141A/ARC, used with the Radio Set AN/ARC-27, Antenna AT-292/URM-29 used with Radio Interference Measurement Equipment AN/URM-29, and Antenna AT-90/AP used with Radar Set AN/APT-5. The radiator shall be positioned to obtain maximum field intensity at the shielding enclosure.

R_2 = R_3 = Receiving antenna. May be similar to R_1.

C_1, C_2, C_3 = Shielded transmission line cables. As short as possible, and used only if necessary.

A = Attenuator, calibrated at the frequency of test.

D = Detector of adequate sensitivity, tuned to the frequency of test. Used only as an equal reference level indicator.

Note.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL-STD-16).

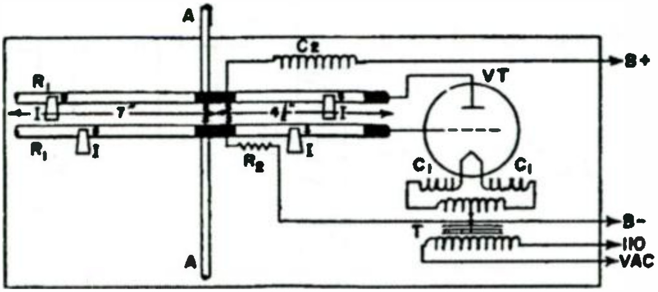

Figure 6.—Signal source for plane waves at 400 mc.

A – Dipole antenna. Each rod ½ inch diameter, 7 inches long, horizontal.
R_1 – ¼ inch solid copper rods, ¼ inch apart, 2 inches from insulating board.
I – Porcelain insulators, 2 inches high.
C_1 – Chokes, 30 turns No. 18 wire, ¼ inch diameter, suspended in air.
C_2 – Choke, 40 turns No. 28 wire, ¼ inch diameter, suspended in air.
R_2 – 15,000 ohms, 10 watt S – Fuse clips B – Insulating board.
T – Filament transformer, 2½ volt secondary, center tapped, or two 1½ volt dry cells with proper limiting resistor.
V.T. – Vacuum tube W.E. 316A, Ep = 450 volt, Ip = 80 MA, Ef = 2.0 volt, If = 3.65 amperes, Ig = 12 MA, output = 7.5 watts.
B + – Plate voltage, 450 volts direct current from any dry cells or rectified alternating current power supply; or 1000 volts alternating current r.m.s., 60-cycle from high voltage transformer.

Note.—Similar circuits may be used using an RCA 8012A or 8025A tube or equivalent.

Note.—The code letters used on this figure should not be confused with electrical and electronic reference designations (see MIL-STD-16).

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ARMED FORCES SUPPLY SUPPORT CENTER

WASHINGTON 25, D.C.

Radio Frequency Spectrum
Characteristics, Measurement Of

MIL-STD-449A

1. This standard has been approved by the Department of Defense and is mandatory for use by the Departments of the Army the Navy, and the Air Force, effective 24 October 1961.

2. Recommended corrections, additions, or deletions should be addressed to the Standardization Division, Armed Forces Supply Support Center or Chief, Bureau of Ships, Department of the Navy (Preparing Activity), Washington 25, D.C.

FOREWORD

The successful operation of most military systems depends upon the use of information received through electromagnetic radiations. Such operation is degraded if the equipment is interfered with by the presence of the almost innumerable radiations that will exist in every normal environment. In order to predict the mutual interference effects of electronic equipment—both in existence and planned—more quantitative information is needed than now exists. The entire transmitter emission spectra needs to be known as well as the susceptibility of receivers to the various frequencies, powers, and modulations that may occur in their operational environments.

Spectrum characteristics are needed both for existing transmitters and receivers and for developmental and planned equipments.

The purpose of this standard is to provide standard techniques for the measurement of radio-frequency-spectrum characteristics of military electronic equipment to ensure the usefulness of all such data collected. These data will be used to assist in determining whether equipment, subsystems, and systems will be compatible with their electromagnetic environments. The data will also permit improvements in the methods of assigning frequencies and in the design of new electronic devices.

The measurement techniques outlined in this standard are in conformance to the existing state of the art. As the state of the art advances, improvements in the testing methods and techniques will be presented in revised standards.

Suggestions as to improvement of the methods of collection of spectrum characteristics should be directed to Chief, Bureau of Ships, Department of the Navy, Washington 25, D. C.

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FIGURES

EQUIPMENT SPECTRUM SIGNATURES, COLLECTION STANDARD FOR

1. SCOPE

1.1 PURPOSE. - This technical standard establishes uniform measurement techniques that are applicable to the determination of the spectral characteristics of radio-frequency transmitters and receivers. The ultimate goal is to ensure the compatibility of present and future systems.

1.1.1 The data obtained from the measurements described in this standard will comprise one of the principal aids for (a) predicting the performance of equipment and systems in an operational electromagnetic environment, and (b) predicting the effect of a particular equipment or system on the electromagnetic environment of other equipments or systems. These data will also be used as aids for establishing the characteristics required of new equipment for compatible operation in present and future electromagnetic environments.

1.1.2 The measurement standards have been selected on the basis of their practicability and applicability. Insofar as possible, all measurements will be stated in absolute rather than in relative terms. The units of measurement should require little mathematical manipulation. The description of the measurement should be in sufficient detail, however, to permit the use of the data in any pertinent application.

1.2 APPLICATION. - This radio-frequency-measurement standard shall apply to all equipments and systems that are designed to emit or will respond to electromagnetic energy in the radio-frequency range of from 0.01 to 12,000 megacycles.

1.3 CLASSIFICATION. -

1.3.1 The general spectrum characteristics measurements specified in this standard are:

1.3.1.1 Radio-frequency output at equipment terminals (closed-system). - These measurements are intended to disclose the radiation spectrum characteristics at the antenna terminals of equipments designed either to transmit or receive radio-frequency energy.

1.3.1.2 Antenna-radiated radio-frequency output (open-field). - These measurements are intended to disclose the radio-frequency spectrum characteristics of a complete equipment, including the effects of the transmission line and antenna.

1.3.1.3 Receiver susceptibility. - These measurements are designed to determine the susceptibility of receiving equipment to radiation at other than the desired operating frequency. Such measurements are currently employed to determine the spurious-response characteristics of receivers and are referred to in such terms as "unwanted response," "receiver susceptibility," "receiver vulnerability," "image rejection," "spurious-response rejection ratio," "intermediate-frequency rejection ratio," and "off-frequency sensitivity." A knowledge of these effects is necessary to all interference control activity.

1.3.2 Environmental operational level. - These measurements are designed to determine the effects of the electromagnetic environment upon the electronic equipment in terms of degradation and failure as the electronic environment becomes more severe.

2. REFERENCED DOCUMENTS

2.1 Not applicable.

3. DEFINITIONS

3.1 Frequency coverage. - That range (or those ranges) of frequencies over which the equipment is designed to operate; for example, the frequency coverage of the AN/URM-XX may be 0.15 to 0.4 mc and 1.5 to 1000 mc.

3.1.1 Tuning band. - That partial range of the tuning frequency range over which a particular configuration of equipment operates with a given band-switch setting; for example, one head of the AN/URM-XX may have the following tuning bands:

Band 1:	0.15	to	0.4	mc
Band 2:	0.35	to	0.92	mc
Band 3:	0.9	to	2.45	mc
Band 4:	2.4	to	6.3	mc
Band 5:	6.0	to	15.4	mc
Band 6:	15.0	to	30.0	mc

3.1.2 Tuning frequency range. - That partial range of the frequency coverage over which a particular configuration of equipment operates; for example, the AN/URM-XX may have the following tuning frequency range:

0.15	to	30	mc with head T-1 installed
20	to	220	mc with head T-2 installed
200	to	410	mc with head T-3 installed
400	to	1000	mc with head T-4 installed

3.2 Standard test frequencies. - That group of frequencies to which transmitters or receivers are tuned during the test procedure. Three such frequencies exist in each equipment tuning band, located at approximately the 5 percent, 50 percent and 95 percent points in each band, and called the low, mean, and high test frequencies respectively. In some transmitters, frequency is selected by employing one of a series of output tubes. For this type of equipment tests shall be run with lowest, mean, and highest frequency tubes installed.

3.3 Receiver. - An equipment or system specifically designed to respond selectively to radio-frequency energy.

3.4 Transmitter. - An equipment or system specifically designed to generate radio-frequency energy.

3.5 Antenna. - A device employed as a means for radiating or receiving radio-frequency energy.

3.6 Emission spectrum. - The power versus frequency distribution of a signal about its fundamental frequency which includes the fundamental frequency, the associated modulation sidebands, as well as non-harmonic and harmonic spurious emissions and their associated sidebands.

3.6.1 Spurious emissions. - Emission on a frequency or frequencies which are outside the necessary bandwidth, and the level of which may be reduced without affecting the corresponding transmission of intelligence. Spurious emissions include harmonics, parasitic emissions, and intermodulation products, but exclude unnecessary modulation sidebands of the fundamental frequency.

3.6.2 Necessary bandwidth. - For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission or reception of intelligence at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in the necessary bandwidth.

3.6.3 Occupied bandwidth. - The frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission. In some cases, for example multichannel frequency-division systems, the percentage of 0.5 percent may lead to certain difficulties in the practical application of the definitions of occupied and necessary bandwidth; in such cases a different percentage may prove useful.

3.6.4 Unnecessary modulation sidebands. - Modulation sidebands refer to the spectral distribution of energy about the fundamental frequency which are a result of the modulation process for the transmission of intelligence. Unnecessary modulation sidebands are the sidebands which fall outside of the necessary bandwidth.

3.6.5 Sideband splatter. - Those emissions that appear outside of the necessary bandwidth and which are a result of intermodulation products of the modulation spectrum.

3.7 Spurious responses. - Any response of a receiver to energy outside the receiver necessary bandwidth.

3.8 Power levels. -

3.8.1 db (Decibels). - db = $10 \log_{10} \frac{P_1}{P_2}$, where P_1 and P_2 are the powers compared.

3.8.2 dbm (Decibels relative to 1 milliwatt). - Decibels relative to 1 milliwatt = $10 \log_{10} P$, where P is the power in milliwatts.

3.8.3 dbm/m^2 (Decibels relative to 1 milliwatt per Square Meter). - Decibels relative to 1.0 milliwatt/meter^2 = $10 \log_{10} \frac{P}{A}$, where P is as defined in 3.8.2 and A is the effective area in square meters over which P is measured.

3.8.4 dbm/m^2/mc or dbm/m^2/kc (Decibels relative to 1 milliwatt per square meter per megacycle or per kilocycle bandwidth). - Decibels relative to 1.0 milliwatt/meter^2/mc or 1.0 milliwatt/meter^2/kc = $10 \log_{10} \frac{P}{A\beta}$, where P and A are as defined in 3.8.2 and 3.8.3, and β is the measurement system bandwidth in megacycles or kilocycles, respectively.

3.9 Frequency-selective voltmeter. - A frequency-selective radio receiver calibrated as a two terminal voltmeter; for example, a field-intensity meter.

3.10 Minimum visible signal (MVS). - The minimum input pulse signal power level which permits visibility of any portion of the output signal. This level is obtained by initially setting the input signal above the detection threshold, and then slowly decreasing the amplitude.

3.11 Mid-pulse-minimum visible signal (MPMVS). - The minimum input pulse signal power level which permits visibility of the center of the output pulse. This level is obtained in the same manner as the MVS level, with the center of the pulse being the point of reference.

3.12 Far-field distance. - That distance between two antennas equal to D^2/λ, where D is the maximum aperture dimension of the largest antenna, and λ is the wavelength of measurement. In no case shall this distance be less than 3 λ

3.13 System antenna. - The antenna whose characteristics are being measured.

3.14 Test antenna. - The antenna associated with the measurement equipment.

3.15 Rotatable antennas. - Antennas designed to rotate through 360°.

3.16 Elevatable antennas. - Antennas designed to elevate through an angle of 80° or greater, and which can be fixed at any desired elevation angle. (The intention of this definition is to preclude the requirement of more than routine efforts to provide maneuverability in the vertical plane. If a servo mechanism or manual drive are available to provide this capability, for example, the antenna is said to be elevatable. If the antenna configuration requires adjustment by removal and replacement of bolts, for example, it is said to have fixed elevation capabilities.)

3.17 Semi-elevatable antennas. - Antennas designed to elevate through an angle less than 80°, or stepped in increments in the elevation plane.

3.18 Reference is made to the IRE standard definitions for all definitions not included in this document.

4. GENERAL REQUIREMENTS

4.1 Measurement setup. - The equipment to be measured shall, in general, be set up so that it closely approximates the intended operating electrical condition and physical configuration.

4.2 Primary power-supply voltages. - The primary power-supply voltage shall be maintained within 5 percent of the mean of the rated operating voltage range of the equipment being tested.

4.3 Interference-free measurement areas. - All field measurements shall be conducted, insofar as practicable, in areas sufficiently free from interference and reflections, and under conditions that will not adversely affect the results.

4.4 Preparation of equipment. - Before any measurements are performed, the equipment shall be in proper operating condition. The steps specified in the operation and maintenance sections of the pertinent instruction manual shall be performed, and any operating discrepancies shall be corrected before measuring is started. The equipment shall be aligned, if necessary, as specified in the pertinent operating instructions to ensure that, insofar as possible, it represents an average equipment in normal operating condition. Under no circumstances will the equipment be optimized with regard to alignment at the test frequencies. It is important that the readings represent field conditions of operation.

4.5 Modulation. - The modulation used in the measurements shall be as specified in the individual procedures described in Section 5.

4.6 Physical distinction between receiver, transmitter, and antenna. - When tests are to be performed on a receiver or transmitter with an integrated antenna system, it will be necessary to establish a "plane of reference" such that the portion of the equipment on the antenna structure side of the plane is designated the antenna, and that portion of the equipment on the other side of the plane is appropriately designated either the transmitter or receiver. It is at this reference plane that equipment separation will take place, when necessary. The plane of reference shall remain fixed for an entire series of equipment tests. In the process of establishing the reference plane, no portion of the system under test shall be electrically removed from the system, nor shall extra electrical circuitry be added except as indicated in the measurement procedure.

4.7 Equipment terminations. -

4.7.1 Transmitter dummy loads. - Dummy loads shall be of adequate power handling capacity to terminate the transmitters (for detailed requirements for dummy loads, see 5.1.2.1).

4.7.1.1 For unbalanced systems with operating frequencies above 20 mc, the resistance of the dummy load shall be 50 ohms, resistive.

4.7.1.2 For unbalanced systems with operating frequencies of 20 mc and below, the load shall be either 50 or 300 ohms, resistive, to whichever load the transmitter is capable of delivering greater power when it is adjusted as prescribed in 4.4.

4.7.1.3 For balanced systems, the loads shall be as in 4.7.1.1 or 4.7.1.2, except that one dummy load shall be applied from each output line to the ground.

4.7.2 Receiver input coupler. - The receiver input coupler shall be a shielded network whose insertion loss is known at the measurement frequency and whose input properly terminates the signal source (see 5.1.2.2).

4.7.2.1 Output impedance. -

4.7.2.1.1 For unbalanced systems with fundamental above 20 mc: 50 ohm, resistive.

4.7.2.1.2 For unbalanced systems with fundamental frequencies of 20 mc and below: 50 or 300 ohms, resistive, whichever more closely matches the nominal impedance of the receiver input.

4.7.2.1.3 For balanced systems as in 4.7.2.1.1 or 4.7.2.1.2, except that the source resistance shall be that specified in 4.7.2.1.1 or 4.7.2.1.2 from each line to ground.

4.8 Measurement equipment. - All measured quantities in this procedure shall be referred to the frequency, voltage, and power indications of (1) laboratory-type signal generators, and (2) calibrated attenuators.

4.9 Other measurement variables. - Initial testing conditions other than those indicated in this plan may be specified. These variations might include reruns of specific tests following selected equipment detuning and retuning operations, test reruns following replacement of selected system components.

4.10 Reported data. - Reported information is not to be restricted to the data specified for each test in Section 5. Additional information must be provided in order that measurement results can be effectively evaluated.

4.10.1 General data. -

4.10.1.1 Detailed identification of measurement and calibration instruments, and pertinent auxiliary equipment used in the performance of these tests.

4.10.1.2 Descriptions of all laboratory test layouts, and all field test deployments, including plans, drawings, and photographs, where applicable. Dimensions not conveniently obtainable shall be estimated.

4.10.1.3 Description of measurement location terrain, with emphasis on any features (mountains, buildings, etc.) which may influence the measured data, and the geographical location of the measurement site.

4.10.1.4 All initially recorded test data, plus sample calculations to show how derived data was obtained.

4.10.1.5 A list of all failures that occurred to the equipment involved in the measurement program during the test period, and a description of checks made to determine the condition of equipment performance following repairs.

4.10.1.6 A list of interference reduction features associated with the equipment under test, such as noise suppression circuitry, modulation discrimination capabilities.

4.10.1.7 Other information relevant to the test program, such as peculiarities encountered in equipment performance, difficulties in performing tests, meteorological characteristics, description of measurement procedures (if at variance with those procedures outlined herein).

4.10.2 General system information. - (For transmitters, receivers, and antennas).

4.10.2.1 Equipment. - Model and serial number.

4.10.2.2 Bands. - Initial and final frequencies.

4.10.2.3 Month and year of measurement. -

4.10.2.4 Source and observer. -

4.10.2.5 Plane of reference. - Defined in 3.6.

4.10.3 Specific transmitter information. -

4.10.3.1 Function. - Communications, navigational aids, air search, surface search and fire control.

4.10.3.2 Other operational characteristics. - Frequency diversity and chirp.

4.10.3.3 Emission type and bandwidth. - 6A3, 0.1A1, 30F9 and P0.

4.10.3.4 Pulse repetition rates. -

4.10.3.5 Pulse widths. -

4.10.3.6 Power. - Both nominal peak power (KW) and nominal average power (KW).

4.10.4 Specific receiver information. -

4.10.4.1 Function. - Communications, navigational aid, air search, surface search and fire control.

4.10.4.2 Other operational characteristics. - Monopulse, doppler, frequency and diversity.

4.10.4.3 Types of signals designed to receive. - AM, FM, SSB and pulse.

4.10.4.4 Type receiver. - Crystal video, TRF, single superheterodyne and double super-heterodyne.

4.10.4.5 Nominal sensitivity. -

4.10.4.6 Nominal receiver bandwidth. - (3 db)

4.10.4.7 IF frequencies. -

4.10.4.8 Local oscillator frequencies. - Also, note if the local oscillator is tunable above or below the signal or both.

4.10.5 Specific antenna information. -

4.10.5.1 Polarization. -

4.10.5.2 Nominal gain (db). -

4.10.5.3 Scan characteristics. - For example, rotation rates, nodding rates, scan limitations, provision for sector scan, conical or rotating scan details.

4.10.5.4 Number of beams and description. - This should include nomenclature of beams, tilt angles, 3 db beamwidths, frequency range per beam if applicable.

5. DETAILED REQUIREMENTS

5.1 Instrumentation. -

5.1.1 Signal generators. -

5.1.1.1 Frequency accuracy. - The frequency accuracy of signal generators shall be within 1 percent. The signal generator frequency shall be measured before and during the procedures with a frequency meter or counter capable of assuring the desired degree of accuracy.

5.1.1.2 Output accuracy. - The overall output calibration of the signal generator shall be correct to within 2 db at any attenuator setting. Where greater accuracy is required, the output should be calibrated with an external device of the required accuracy.

5.1.1.3 Output impedance. - The signal generator output impedance shall be unbalanced 50 ohms, resistive, with a VSWR not to exceed 1.3:1. For this purpose, the generator may be adjusted with a matching network of known loss at the measurement frequency.

5.1.1.4 Modulation and deviation. - For measurements where modulation is required, all quantities shall be within 5 percent, unless otherwise specified for the individual test.

5.1.1.5 Harmonic content. - Signal-generator outputs contain harmonics of the fundamental frequency. Care should be taken that these harmonic outputs are attenuated sufficiently in order that false receiver responses will not be produced. In particular, low-pass or band-pass filters of known insertion loss at the fundamental frequency should be used when spurious responses are being measured at frequencies well below the receiver-tuned frequency. This technique is used to attenuate all generator harmonics to levels below the receiver's threshold sensitivity.

5.1.1.6 Leakage. - Most signal-generators exhibit some leakage that is particularly noticeable when the attenuator is near its maximum attenuation setting. Low-leakage signal generators shall be used to perform the measurement under this procedure; adequate shielding, separation, and power line filtering shall be employed to eliminate the possibility of erroneous results caused by improper coupling of the signal generator to the receiver.

5.1.2 Equipment terminations. - The requirements for equipment termination are given in 4.7.

5.1.2.1 Dummy loads. - The dummy loads specified in 4.7.1 shall have a low VSWR not to exceed 1.5:1 at any test frequency.

5.1.2.2 Receiver-input coupler. - The receiver-input coupler described in 4.7.2 shall have an input impedance of 50 ohms (VSWR less than 1.3:1) when its output is terminated by a VSWR greater than 3:1. The impedance, looking into the output terminals of the receiver-input coupler, shall be the specified nominal value (VSWR less than 1.5:1). The insertion loss shall be known to within 1 db over the frequency range of the device when it is terminated in the nominal impedance.

5.1.3 Frequency-selective voltmeters. -

5.1.3.1 Calibration. - Frequency-selective voltmeters shall be calibrated as two-terminal voltmeters at all frequencies with an accuracy of 2 db of the indicated value. These values are to be maintained throughout the measurements by reference to standard signal generators.

5.1.3.2 Indications. - Frequency-selective voltmeters used in these measurements shall be monitored by aural as well as visual indicators.

5.1.3.3 Bandwidth. - When making measurements requiring recovery of the pulse envelope, the instrumentation 3 db bandwidth shall be sufficient to permit a low distortion recovery. For example, for a fixed frequency pulse the bandwidth in megacycles shall be at least 2/W where W is the nominal pulse width, in microseconds. For a pulse compression system, this bandwidth should be at least 2d/W where d is the pulse compression ratio. If the instrumentation is to be used to obtain fine grain spectrum details such as determining the shape of the main lobe or peaks of the side lobes, it should have a bandwidth of less than $\frac{1}{10W}$.

5.1.4 Attenuators. - The calibration of attenuators shall be known within 1 db at each measuring frequency.

5.1.5 Transmitter signal sampling device. - For transmitter testing, a sampling device shall be used, where needed, to measure the output level of each frequency emitted. This device may be a voltage divider, power attenuator, directional coupler, probe, or a suitable band-rejection filter, or combination thereof. The choice of sampling device is to be determined by its availability, the frequency of the transmitter, the power-output level, the minimum level at which spurious responses can be detected, and knowledge of the impedance characteristics of the transmitter output termination. The coupling loss of the device shall be known within 1 db at each measurement frequency.

5.1.6 Spectrum analyzers. - The spectrum analyzer shall be used with a signal generator for calibration purposes, and the resultant amplitude accuracy shall be within 3 db. For bandwidth considerations refer to 5.1.3.3.

5.1.7 Frequency accuracy. - When a frequency is stated in a test, test tabulation, test report, etc., it shall be taken to mean the stated frequency with an accuracy of 1 part in 1000 except where otherwise noted with the statement of the frequency accuracy; for example, 10 mc ± 50 cycles; 4.5 ± 0.1 mc and 156 mc ± 2 percent.

5.2 Transmitter measurements. - The following measurements shall be performed on all transmitters, unless otherwise indicated.

(a) Power output
(b) Spurious emissions
(c) Emission spectrum
(d) Modulation characteristics
(e) Intermodulation
(f) Modulator bandwidth
(g) Carrier frequency stability

Since this measurement procedure is dedicated to an absolute rather than a relative system of measurement, use of uniform units of measurements becomes obligatory. In this procedure all data taken on transmitter emission are to be in dbm wherever practicable. Voltage measurements alone provide inadequate information for the establishment of mutual interference relationships between different equipments. Where ratios are required, they shall be expressed in db. During each test, transmitter power output shall be monitored, and the range of variation recorded and presented with the test data. Where a system is designed to operate into one or two specific antennas, and only such antennas, those antennas shall be employed in lieu of any other output termination.

5.2.1 Modulation. -

5.2.1.1 AM and FM transmitters. - The output of AM and FM transmitters for (a) and (b) of 5.2 shall be A0 or F0. For (c), (d), (e) and (f) of 5.2, the modulation shall be as specified in the individual procedures.

5.2.1.2 Single-sideband transmitters. - For single sideband transmitters, the modulation frequency for tests (a) and (b) of 5.2 shall be two tones of 400 and 2500 cycles per second at the level required to give the transmitter-rated output. For test (c), (d), (e) and (f), the modulation shall be as specified in the individual tests.

5.2.1.3 Pulsed transmitters. - Tests (a), (b), (c), (d) and (g) shall be performed under conditions of minimum and maximum duty cycle at each standard test frequency. Additionally, these same tests shall be performed at the mean standard test frequency using the mean pulse width and repetition rate of the system under test.

5.2.2 Power-output. -

5.2.2.1 General requirement. - Since the fundamental power output of a transmitter may vary considerably over the frequency coverage and, in multiband transmitters, may also vary from tuning band to tuning band, the power output should be measured at several frequencies spaced throughout the frequency coverage, for example, at least the standard test frequencies of each tuning band.

5.2.2.2 Measurement setup. - The setup shall be as shown in Figure 1 except the fundamental frequency rejection network is not required for the power output test. Measuring equipment shall be adequately shielded for protection from transmitter leakage.

5.2.2.3 Procedure for power output measurement. - (For power measurement in single-sideband transmitters, refer to 5.2.2.3.1): The procedure for power output measurement shall be as follows:

(a) Tune the transmitter to be measured to a standard test frequency. With the coaxial switch in position one, tune the frequency-selective voltmeter to the transmitter-output frequency. Adjust the output of the sampled signal to provide a convenient reading by varying the signal-sampling-network-attenuation, the adjustable-attenuator-loss, or the frequency selective voltmeter controls; the meter must not be in overload. With the coaxial switch in position 2, tune the signal generator to the same test frequency, adjust the output attenuator of the generator (unmodulated) to give the same reading on the frequency-selective voltmeter, and record the generator-output reading in dbm.
(b) Alternatively, thermal type power indicators may be used in place of the frequency-selective voltmeter for measurement of average power.
(c) Repeat this test for each standard test frequency.

5.2.2.3.1 Measurement of peak envelope power (PEP). - (This paragraph applies to single-sideband transmitters only.) The PEP is determined by the measurement on an oscilloscope of waveform amplitude obtained from a pickup situated adjacent to the transmitter feeder. With the carrier suppressed, the transmitter is set up with a 400 cycle tone input such that the power output approximates the designed CW level. Two equal tones (400 and 2500 cycles) are then applied to the transmitter. The tone levels are increased simultaneously until the transmitter is emitting its full power output as indicated by the third order intermodulation products being 25 db below the two tones. The amplitude of the waveform shown on the oscilloscope is recorded. The 2500 cycle tone is then removed and the 400 cycle tone amplitude is noted on the oscilloscope and recorded. The CW power into the load is measured and recorded. The power rating is then given by:

PEP = continuous CW power x $(A/B)^2$ where B = waveform amplitude under CW conditions and A = waveform amplitude under 2 tone conditions.

The test is repeated for each standard test frequency.

5.2.2.3.2 Balanced system- If the transmitter has a balanced-output system, repeat these steps with the signal-sampling network in the other line.

5.2.2.3.3 Frequency-selective voltmeter function. - For pulsed transmitters, the meter shall read the peak function. For non-pulsed transmitters the meter shall measure the average or CW function.

5.2.2.4 Data to be recorded. -

5.2.2.4.1 Power output determination. - If the transmitter has a balanced output, convert the two power readings at each frequency to watts, add the two values thus obtained and convert the sum to dbm, then proceed with the steps described in 5.2.2.4.1.1. If the transmitter does not have a balanced output, proceed directly with the steps described in 5.2.2.4.1.1.

5.2.2.4.1.1 To the signal-generator output reading in dbm (or the corrected output of 5.2.2.4.1) at each frequency, add:

(a) The adjustable-attenuator attenuation in db, and,
(b) The insertion loss of the signal-sampling network, in db, at the test frequency.

The sum is the power output, in dbm, at the measured frequency.

5.2.2.4.2 Presentation of test data. - Transmitter data shall be presented by frequency and power output, under the following headings:

Tuning Band________

Frequency (Mc/s)	Power Output (dbm)

In the power output column, show whether the output is peak, average, or peak envelope. For pulsed transmitters, record the pulse width and repetition rate at each measured frequency.

5.2.3 Spurious emission. - The purpose of the tests is to scan the spectrum, locate, measure, and record the spurious outputs of the transmitters under test. Two types of tests, involving different test methods, are required to evaluate the spurious emissions of the large variety of transmitter types. One method, exemplified by Figure 1, is a closed-system method and the other, exemplified by Figure 2 involves an open-field method of measurement. Each type of transmitter under test shall be evaluated by the method specified for it in 5.2.3.1. Care must be taken in these tests to avoid recording measurement equipment spurious responses as transmitter outputs. Fundamental frequency rejection networks or filters will probably be required to enable the frequency-selective voltmeter to measure small spurious outputs in the presence of the larger fundamental. The insertion loss of this network shall be known at the frequencies of the spurious outputs being measured to ± 1 db.

5.2.3.1 Types. - Transmitters with one or more of the following characteristics shall be tested by the open-field method exemplified by Figure 2. All other transmitters shall be tested by the closed-system method as illustrated by Figure 1.

(a) Equipment designed to operate into no more than two specific antennas. A test shall be performed utilizing each antenna.
(b) Equipment whose antenna to transmitter transmission system employs waveguide or coaxial cable that can support multiple-mode propagation below 12 kmc.

5.2.3.2 Closed-system measurement setup. - The closed-system measurement setup is illustrated by Figure 1.

5.2.3.3 Procedure for spurious emission measurement (closed system). - The procedure for the spurious emission measurement (closed system) shall be as follows:

(a) Tune the transmitter to a standard test frequency. With the coaxial switch of Figure 1 in position 1, and the fundamental-frequency rejection network bypassed, tune the frequency-selective voltmeter to the transmitter frequency. Adjust the signal-sampling-network attenuation, the adjustable attenuator and the voltmeter controls for a convenient reading on the meter. Record all settings.
(b) Using the transmitter settings of 5.2.3.3(a) insert the fundamental-frequency rejection network, and tune it to reject the transmitter fundamental frequency. With minimum system attenuation and maximum instrument sensitivity, tune the frequency-selective voltmeter through the frequency spectrum to detect all responses. The frequency range shall be 10 kilocycles to 12 kilomegacycles, unless otherwise specified.
(c) Each time a spurious transmitter output is found, adjust the voltmeter sensitivity to give a convenient reading. Set the coaxial switch to position 2 and determine the signal level of the response as described in 5.2.2.3. Record these values. When determining the level of the responses, the attenuation of the signal-sampling network at the spurious frequency shall be known.
(d) Repeat the foregoing steps at each transmitter standard test frequency.

5.2.3.4 Data presentation. - The data on the spurious and harmonic emissions test shall be presented in the following tabular form:

Transmitter		Spurious Frequency		
Fundamental (mc)	Tuning Band	Frequency (mc)	Origin	Power Output (dbm)

In the "Power Output" column, indicate whether the output is "peak" or "average". Under the "origin" column, indicate the suspected source of the spurious frequency, if possible, for example, "3rd harmonic of fundamental". For pulsed transmitters, record the pulse width and repetition rate at each measured frequency.

5.2.3.5 Open-field measurement setup. - The open-field measurement setup is illustrated by Figure 2. The separation between transmitter antenna and the test antenna shall be approximately the far-field distance at the test transmitter fundamental frequency of test, unless otherwise indicated.

5.2.3.5.1 Antenna positioning. - The following sequence shall be used for the orientation of the transmitter and test antennas.

(a) For transmitters with scanning antennas, the scanning elements shall be in such a position that the radiated energy will be maximized as close to the geometric axis of the antenna as is practical.
(b) Where azimuth and elevation of the system antenna can be varied, this shall be done to produce the maximum signal at each test frequency at the test antenna. The test antenna shall be positioned for maximum received energy at each frequency at which a spurious emission is detected. The azimuth (θ) and elevation (∅) angles between the antenna boresight axis of the system and the test antenna shall be recorded after the signal is maximized.
(c) The test antenna shall be rotated to find the polarization of maximum response at each frequency at which a spurious emission is detected.

All positioning information shall be recorded together with the test results.

5.2.3.5.2 Measurement sensitivity. - The measurement system shall have a calibrated sensitivity better than

(a) at frequency up to 300 mc- -90 dbm/m^2
(b) above 300 to 1000 mc- -80 dbm/m^2
(c) above 1000 to 3000 mc- -70 dbm/m^2
(d) above 3000 to 10,000 mc- -60 dbm/m^2
(e) above 10,000 mc- -50 dbm/m^2

5.2.3.5.3 Procedure for spurious emission measurement (open-field). - The procedure for the open field spurious emission measurement shall be as follows:

(a) Tune the transmitter to a standard test frequency with the fundamental rejection network by-passed; tune the frequency-selective voltmeter to this frequency. Position the antennas as outlined in 5.2.3.5.1. Determine the power density of the fundamental frequency signal in accordance with the procedures of the frequency-selective voltmeter instruction manual.
(b) With the fundamental frequency rejection network tuned to reject the transmitter fundamental frequency and the test equipment at maximum sensitivity, tune the frequency-selective voltmeter through the spectrum and note all responses. Determine and discard those responses that are test equipment spurious responses.
(c) At each transmitter spurious output, determine the received power density.
(d) Repeat the foregoing steps at each transmitter standard test frequency.

5.2.3.6 Data presentation. - The data on the spurious and harmonic emissions test shall be presented in the following tabular form:

Transmitter		Antenna Orientation		Spurious Frequency		
Fundamental (mc)	Tuning Band	θ	∅	Frequency	Origin	Power Density (dbm/m^2)

In the "Power Density" column, indicate whether the output is "peak" or "average". If the output is "peak", record the bandwidth of the measuring instrument. Under the "Origin" column, indicate the suspected source of the spurious frequency, if possible. For pulsed transmitters, record the pulse width and repetition rate at each measured frequency.

5.2.4 Emission spectrum measurement. - Emission spectra measurements fall into two classes. The sideband-splatter test shall be used on non-pulsed equipment such as AM, FM, and suppressed-carrier transmitters. The power vs frequency test shall be used on pulsed transmitters.

5.2.4.1 Sideband-splatter test. -

5.2.4.1.1 General requirement. - The sideband splatter measurement consists of a two-tone test and a dynamic noise-loaded test. The measurement setup shall be as shown in Figure 3. In the dynamic noise-loaded test, however, the two audio signal generators of the figure are replaced by a random noise generator whose bandwidth is equal to or greater than the transmitter modulator bandwidth.

5.2.4.1.2 Procedure. - The procedure for the sideband-splatter test shall be as follows:

(a) Tune the transmitter to a frequency near the center of the lowest operating band, and adjust the output to provide a useable deflection on a spectrum analyzer. Adjust the spectrum analyzer to position the carrier in mid-position on a narrow sweep presentation (approximately 10 kc).
(b) Tune one audio signal generator to 400 cycles and the other to 2500 cycles and connect the outputs to the transmitter-modulator input. Maintain the output levels equal and adjust them to obtain successively a 30-, 60-, and 90-percent modulation or deviation (for SSB adjust the input to produce 1/2, 1, and 1-1/2 times rated power output). In each case, photograph the spectrum analyzer presentation and record the test details. Adjust the camera so that the exposure time will include at least three sweeps.
(c) Repeat (a) and (b) for wider sweep widths if necessary to give a clearer indication of out-of-band characteristics.

(d) Disconnect the audio signal generator and connect the noise generator. Adjust the RMS output of the noise generator to the same RMS voltages as that of the two tones in (b) and photograph the resultant presentations on the spectrum analyzer.
(e) Repeat the foregoing procedure in each transmitter operating band.

5.2.4.1.3 Presentation of test data. - The data to be presented for the sideband-splatter test will include the photographs taken in the procedure described in 5.2.4.1.2(b) as well as the following data obtained from the photographs:

Fundamental Frequency (mc)	Tuning Band No.	Sweep Width (kc)	Power Output (dbm)

5.2.4.2 Power vs frequency test. -

5.2.4.2.1 General requirement. - The sepctrum of a pulse signal is the power versus frequency distribution of a pulse about some nominal frequency. For the purpose of this document, the nominal frequency is intended to mean the fundamental or spurious frequencies of the transmitter. The measurement technique consists of measuring the general amplitude distribution of the spectral components of the signal. As a minimum requirement, the envelope of the peaks of the lobe structure of the signal shall be determined. Figure 4 shows a typical pulse signal spectral distribution, and illustrates this minimum requirement. A system capable of providing a minimum of 80 db range of measurement shall be employed. The measurement system sensitivity shall be at least -80 dbm/kc/m^2. The measurement setup shall be as shown in Figure 2 except that a spectrum analyzer shall be used in place of the frequency-selective voltmeter.

5.2.4.2.2 Procedure for emission spectra measurement. - The open-field measurement setup in paragraphs 5.2.3.5 and 5.2.3.5.1 form the basis for this test. The procedure for emission spectra measurement shall be as follows:

(a) Tune the transmitter to be measured to a standard test frequency. Remove or bypass the fundamental frequency rejection network. With the coaxial switch in position 1, tune the spectrum analyzer to the transmitter output frequency. Adjust the output of the sampled signal by varying the signal coupling network attenuation, the variable attenuator, and the spectrum analyzer gain so that no overload condition exists, and a convenient amplitude reference is established.
(b) With the coaxial switch in position 2, tune the signal generator to the same frequency as that at which the reference amplitude was established, and adjust the generator output attenuator to give the same reference amplitude on the spectrum analyzer. Record the generator output in dbm. Tune the spectrum analyzer successively to other frequencies throughout the fundamental emission spectrum and repeat the above procedure.
(c) Repeat this test with the spectrum analyzer tuned successively across each of the spurious signals recorded under 5.2.3 and with the fundamental frequency rejection network inserted and tuned to reject the transmitter fundamental frequency.

5.2.4.2.3 Data to be recorded. -

(a) If spectral data are obtained by the above point-by-point process, the previous procedure shall be repeated at sufficient frequency increments to define adequately the region of the main energy lobe, and the envelope of the sidelobes. To the signal generator output reading in dbm at each frequency, add the variable attenuator attenuation in db and the insertion loss of the signal-sampling network in db, at the test frequency.
(b) If spectral data is obtained initially by photographic means, select points suitable for describing the desired envelope, and tabulate in the format shown below. Submit photographs.

5.2.4.2.4 Presentation of test data. - Transmitter data shall be presented under the following headings:

Transmitter Tuned Frequency (mc)	Band	Fundamental or Spurious Signal being Analyzed (mc)	Δf (mc)	Spectral Power Density (dbm/kc/m^2)

The sign of the terms under the "Δf" heading shall indicate whether the measured frequency is above or below the transmitter fundamental or spurious frequency. Record the pulse width and repetition rate at each measured frequency.

5.2.5 Modulation characteristics. - Modulation characteristics measurements fall into two classes, non-pulsed and pulsed.

5.2.5.1 Non-pulsed. -

5.2.5.1.1 General requirement. - This test is a check of the modulator power supply capability for AM transmitters and SSB transmitters, and the deviation linearity for FM transmitters, as well as the intermodulation characteristics of these transmitters with respect to the modulator. If the modulator input voltage versus the percentage modulation (frequency deviation for FM, or peak-envelope-power for SSB) is not linear, the output of the transmitter will be degraded. The desired modulation will be distorted and unwanted adjacent channel emission will probably occur (modulation splatter).

5.2.5.1.2 Measurement setup. - The setup shall be as shown in Figure 1, except that no rejection network is used, and a modulation or deviation monitor is used for AM and FM equipments.

5.2.5.1.3 Procedure. - The procedure for measuring non-pulsed modulation characteristics shall be as follows:

(a) Tune the transmitter for AM, FM, or SSB operation at a test frequency near the center of the lowest operating band, in accordance with the tuning procedure outlined in the Equipment Technical Manual. Tune the monitor to the transmitter frequency. Set the audio generator frequency to 1000 cps (for SSB, use two generators adjusted to 400 and 2500 cps), and with the output control set to minimum, connect the audio generator to the modulator input. Slowly increase the audio signal generator output and observe the monitor. Record sufficient values of audio voltage input and percentage modulation (or deviation) to plot a smooth curve.
(b) Repeat the test in each operating band of the transmitter.

5.2.5.1.4 Presentation of test data. - These data will be presented in tabular form:

Fundamental Frequency (mc)	Deviation in Percent; or Modulation in Percent; or Peak Envelope Power in dbm	(Audio Input) (dbm)

5.2.5.2 Pulsed. -

5.2.5.2.1 General requirements. - The purpose of this test is to recover information on the amplitude versus time characteristics of system radiated output.

5.2.5.2.2 Measurement setup. - The setup shall be as shown in Figure 2, except that an oscilloscope shall be connected to the second detector output of the frequency-selective voltmeter. The signal generator shown in the figure is not required for this test.

5.2.5.2.3 Procedure. - The open-field measurement setup in 5.2.3.5 and 5.2.3.5.1 form the basis for this test. The procedure for measuring pulsed modulation characteristics shall be as follows:

(a) Tune the transmitter and frequency-selective voltmeter to be measured to a standard test frequency. Remove or bypass the fundamental frequency rejection network. Photograph this display, recording oscilloscope sweep calibration.
(b) Repeat this test with the frequency-selective voltmeter to each of the spurious signals recorded under 5.2.3 and with the fundamental frequency rejection network inserted and tuned to the transmitter fundamental frequency.
(c) Repeat the above series of tests at each standard test frequency.

5.2.5.2.4 Presentation of test data. - These data will consist of the photographed waveforms and calibration data. Record the transmitter pulse width and pulse repetition rate used for this test.

5.2.6 Intermodulation (Non-pulse transmitter). -

5.2.6.1 General requirement. - This test evaluates the intermodulation-generating properties of the output stage of a transmitter. The level of intermodulation products obtained when an external signal is coupled into a transmitter output circuit depends on the selectivity of the coupling circuit, level of interfering signal, and the nonlinearity of the output stage. Spurious frequencies may be generated in accordance with the equation: $f_s = nf_o \pm mf_1$ where f_s = spurious frequency generated; f_o = frequency of transmitter under test; f_1 = frequency of interfering signal; and m, n = 0, 1, 2, 3, . . .

5.2.6.2 Measurement. - The setup shall be as shown in Figure 5.

5.2.6.3 Intermodulation test procedure. - The procedure for intermodulation test shall be as follows:

(a) Tune the interfering transmitter to a frequency f_1, approximately one percent higher than f_o. With the switch in position 1, note the frequency selective voltmeter reading. Put the switch in position 2 to measure the signal generator output. Adjust the signal generator frequency and output level to duplicate the reading obtained with the transmitter. Record the generator frequency and output in dbm.
(b) Add the attenuation in decibels of the attenuator to the signal generator output reading in dbm to obtain the power output at f_1. Insert an attenuator in the coupling unit so that the ratio of the power coupled from the output at f_1 to the output at f_o is approximately 20 decibels. Tune the frequency-selective voltmeter in steps of Δf above f_1 and in steps of Δf below f_o. Repeat the above steps for couplings of 40 and 60 db.
(c) Repeat for f_1 approximately 5 and 10 percent of f_o.

5.2.6.4 Presentation of test data. - These data will be presented in the following form:

Frequency (mc)	Output (dbm)	Frequency Identification	Coupling (db)	Δf Spacing (mc)

5.2.7 Modulator Bandwidth (Non-pulse transmitters). -

5.2.7.1 General requirement. - This test is designed to determine whether the modulator has excessive bandwidth which can cause sidebands outside the assigned channel. This type of interference is usually adjacent-channel in nature and drops off rapidly with Δf. Because of this, the bandwidth of the modulator should be no greater than one-half of the channel spacings, and at the frequency equal to one-half of the channel spacing the response should be down at least 20 decibels.

5.2.7.2 Test setup. - See Figure 6.

5.2.7.3 Test procedure. - The procedure for modulator band width (non-pulsed transmitters) shall be as follows:

(a) Adjust the audio signal generator output to obtain 30 percent modulation or 30 percent of rated deviation or one-half the rated peak-envelope-power. Increase the output of the audio signal generator by three decibels. Increase the signal generator frequency until the percentage modulation or deviation decreases to 30 percent or the peak-envelope-power decreases to one-half rated. Record this frequency. Decrease the signal generator until the percentage modulation or percentage of rated deviation decreases to 30 percent or peak-envelope-power decreases to one-half rated.
(b) Repeat for audio increases of 6, 12, 18 and 24 decibels.

5.2.7.4 Presentation of test data. - These data will be presented in the following tabular form:

Modulation Frequency (mc)	Response (db relative to maximum)

5.2.8 Carrier frequency stability test. -

5.2.8.1 General requirement. - The purpose of this test is to determine transmitter frequency stability.

5.2.8.2 Measurement setup. - Equipment configuration shall be as shown in Figure 7. The transmitter shall be tuned to the mean frequency in each band. Pulse transmitters shall be operated at the nominal repetition rate and pulse width which shall be recorded.

5.2.8.3 Procedure for stability measurement. - The procedure stability measurement shall be as follows:

(a) A frequency readout shall be obtained 15 minutes after the transmitter is turned on and at 15 minute intervals thereafter up to 4 hours, or until a definite trend in data is established, whichever time is less. Frequency accuracy of at least one part per million is required.

5.2.8.4 Presentation of test data. -

Time (minutes)	Frequency (mc)

5.3 Receiver Measurements. - The following tests shall be performed on all receivers unless otherwise indicated.

(a) Sensitivity
(b) Selectivity
(c) Spurious responses
(d) Overall susceptibility
(e) Intermodulation
(f) Adjacent signal interference
(g) Pulse desensitization
(h) CW desensitization
(i) Dynamic range
(j) Oscillator radiation

5.3.1 General requirement. - Since this measurement procedure is dedicated to an absolute rather than a relative system of measurement, use of uniform units of measurement becomes obligatory. In this procedure all data taken on transmitter emission are in dbm, wherever practicable. Therefore, all receiver measurements must be reported in dbm in order that the mutual interference relationships may be established for different equipment. Voltage sensitivity measurements alone provide inadequate common ground for such comparison.

5.3.2 Modulation. - For receiver tests, standard modulation or deviation shall be 30 percent at 400 and 1000 cps, except that if the test sample is designed to operate with a particular audio frequency, pulse repetition rate, waveform, or type of modulation, the modulation shall be that particular type of signal, unless otherwise indicated.

5.3.3 Standard response. - The standard response is defined as a 6 db (S + N)/N output ratio for AM and single side band receivers, or the output level necessary to provide 20 db quieting for FM receivers, both measured at the rated output power or voltage in communication receivers, or minimum visible signal (or mid-pulse minimum visible signal, when applicable) in radar receivers. To measure the standard response, locate a suitable measurement point unless such a measuring point has been previously specified. Based on the design of the receiver to be tested, determine where any special purpose circuits intercept the path of intelligence-bearing signals; select a point for a carrier level indication to avoid the effects on signal level of any such special purpose circuits for observing standard responses. Establish a method of observing the signal at the selected point so that the signal strength at the test point will represent normal operation of the system. Instrumentation for this purpose will vary for different equipments. It may be as simple as a voltmeter or as complex as another receiver tuned to an IF frequency. Examples of setups are given in Figures 8, 9, 10, and 11.

5.3.4 Sensitivity test. -

5.3.4.1 General requirement. - Since the sensitivity of a receiver may vary considerably over the frequency coverage, and may also vary from tuning band to tuning band in multi-band receivers, the sensitivity is to be measured at the standard test frequencies of each tuning band unless otherwise specified.

5.3.4.2 Measurement setup. - The measurement setup shall be as in Figure 12. The measuring equipment shall be adequately shielded to protect the receiver from extraneous signal paths.

5.3.4.3 Procedure for receiver sensitivity measurement. - The procedure for receiver sensitivity measurement shall be as follows:

(a) The receiver shall be tuned to a standard test frequency. Using normal operating manual procedures, adjust the receiver gain to produce the maximum usable sensitivity. The reported data should indicate special considerations which affect the sensitivity required for normal operations. Tune the signal generator to the receiver tuned frequency, and vary the signal level until a standard response is obtained. Record the signal generator output level and the frequency.
(b) Repeat measurements at the other standard test frequencies.

5.3.4.4 Data to be recorded. - The power level in dbm necessary to cause a standard response should be the value recorded. This is the level delivered to the receiver antenna terminal from the signal generator, corrected as necessary by such factors as the insertion loss of the receiver input coupler.

5.3.4.5 Presentation of data. - The sensitivity test data of the receiver shall be presented in tabular form.

Frequency (mc)	Band	Power Input (dbm)

5.3.5 Selectivity. -

5.3.5.1 General requirement. - The selectivity as measured by this test gives an indication of the overall gain and sensitivity at the receiver center tuned frequency, as well as the response at frequencies slightly removed from the tuned frequency. This response, for the most part, is determined by the IF amplifier-tuned circuits and should be fairly symmetrical about the center frequency. The selectivity is a measure of the receiver's ability to discriminate against off-channel radiations, and in reality is a measure of the receiver's bandpass characteristics.

The overall selectivity of the receiver should vary little with tuned frequency because this selectivity is mainly provided by fixed-tuned stages. This may not be true for some VLF or LF sets, where the r-f selectivity is narrower than the IF selectivity.

If the receiver is provided with a manual selectivity control, the selectivity should be measured in the positions of maximum and minimum bandwidth, and for intermediate positions of the control if practicable.

The selectivity is adequately defined by a few measurements, for example, the 3-, 6-, 20-, 40-, and 60-decibel response frequencies. For non-pulse receivers obtain the adjacent, first and second alternate channel rejection as part of this test.

5.3.5.2 Modulation. - For non-pulsed systems, the standard modulation as specified in 5.3.2 shall be used. The receiver AVC and AFC should be turned off during the test.

For pulsed systems, it is desirable to know the selectivity of the system to CW signals. From this information it is possible to deduce the system pulse response to any pulse width.

In order to obtain a selectivity curve of a pulsed system indicative of its CW selectivity, a pulsed signal sufficiently wide to provide a narrow energy spectrum in comparison with the receiver bandwidth, but narrow enough to avoid erroneous bias buildup in the receiver's gain control circuits shall be used. This pulse width is such that an increase or decrease in width by a factor of two will not appreciably change the receiver selectivity measurement. A rule of thumb for preliminary testing might be a pulse width of ten times the nominal system pulse width.

In pulsed systems incorporating instantaneous automatic gain control, such circuits must be disabled prior to the performance of a selectivity test. Where a pulsed receiver does not employ automatic gain control, or where such circuitry must be disabled and replaced by fixed bias, a CW input signal may alternatively be used for the test. The value of fixed bias shall be established on the basis of generated bias levels under normal system operation.

The pulse repetition rate used for this test shall be the nominal rate which the receiver is designed to accept.

5.3.5.3 Measurement setup. - The test setup is the same as that for the sensitivity test (Figure 12) except that a frequency meter with a precision of at least one part per million is also used. This frequency meter is coupled to the signal generator by means of a resistive pad or attenuator, or through an appropriate switching device so that the signal generator can be switched to either the receiver or the frequency meter. Care must be taken to insure that the frequency meter does not couple unwanted frequencies and power into the receiver.

5.3.5.4 Procedure for selectivity measurement. - The procedure for selectivity measurement shall be as follows:

(a) Perform the receiver sensitivity test as described under 5.3.4.
(b) Next, increase the signal generator output 3 db above the sensitivity test input. Tune the generator below the receiver tuned frequency until the output is the same as the sensitivity test output. The change in signal generator frequency ($-\Delta f$) shall be recorded.
(c) Tune the signal generator to the frequency above the receiver tuned frequency at which the output again drops to the sensitivity test output. Record the signal generator frequency ($+\Delta f$).
(d) The above steps shall be repeated for at least 6, 20, 40, and 60 decibel increases above the sensitivity test input.

5.3.5.5 Presentation of test data. - The test data are presented in tabular form as shown below. The response level shall be with respect to the sensitivity test input level.

Band________

Receiver Tuned Frequency (mc)__________

Relative Response (db)	$+\Delta f$ (kc)	$-\Delta f$ (kc)	Bandwidth[1/] (kc)

5.3.6 Spurious Response. -

5.3.6.1 General requirement. - Spurious responses occur when a receiver, due to its circuitry and construction, reacts to off-frequency signals. Spurious responses are often functions of internal frequencies inherent within the receiver, combining with an external signal in such a manner as to cause a response. As such, they constitute families of responses, varying with the frequency to which the receiver is tuned. Examples of spurious responses include those signals which can be identified by the relationship

$$f_{sp} = \frac{p f_{LO} \pm f_{IF}}{q}$$

where p is an integer or zero denoting the harmonic order of the local oscillator; where q is an integer (not zero) that denotes the harmonic order of the input signal; and where f_{LO}, and f_{IF}, and f_{sp} denote the local oscillator frequency, intermediate frequency, and the spurious response frequency, respectively, in a single conversion receiver.

5.3.6.2 Measurement setup. - The measurement setup shall be the same as in Figure 11.

5.3.6.3 Procedure for spurious response measurement. - The procedure for spurious response measurement shall be as follows:

(a) The receiver shall first be tuned to one of the standard test frequencies. The conditions of the receiver must be the same as it was in 5.3.4.3.
(b) Starting at 10 kilocycles, or as otherwise directed, adjust the signal generator output to the maximum setting (at least 0 dbm). Increase the frequency of the signal generator until a response is noted, using sufficient care so as not to pass over weak signals. The receiver sensitivity at this frequency shall be measured in the same manner as for on-frequency sensitivity.
(c) With the receiver still tuned to the same tuned frequency, again adjust the signal generator output to the previous maximum setting, and advance the frequency of the generator until another response is noted. Measure the receiver sensitivity at this frequency. Continue this procedure until the signal generator frequency reaches its maximum value which, unless otherwise specified, shall be 12 kilomegacycles.

1/ Bandwidth is defined as $|+\Delta f| + |-\Delta f|$ at the 3 db power points.

(d) The receiver shall next be tuned to another standard test frequency, and the signal generator scanning procedure shall be repeated. All responses found shall be explored in the manner previously described. The same test shall be repeated at the third standard test frequency of the band.

(e) The above procedure shall be repeated for each receiver operating band.

5.3.6.4 Data to be recorded. - The recorded data shall show tuned frequency of the receiver, frequency of each spurious signal noted, and amplitude of the input signal level necessary to produce a standard output at each spurious frequency.

5.3.6.5 Presentation of data. - The sensitivity of each spurious response shall be presented as shown below. Each response shall be identified with regard to its p and q values and sign in the equation in 5.3.6.1, or with respect to similar constants in multiple conversion equations. The tabular form will be:

Band__________

Receiver Tuned Frequency (mc)______________

Spurious Frequency (mc)	Identification (p, q and sign)	Power Input (dbm)

5.3.7 Overall susceptibility. -

5.3.7.1 General requirement. - The purpose of the test is to determine overall equipment susceptibility at representative spurious response frequencies in order to establish antenna gain functions across the spectrum. This test is similar to the spurious response test, except that the signals shall be generated in the far-field.

The receiver overall susceptibility shall be evaluated at a number of receiver spurious responses. The tests shall be performed at the mid-band standard test frequencies. For each receiver tuned frequency, at least one test shall be performed in each octave band, if possible at frequencies where significant receiver spurious responses exist.

The open-field method, exemplified by Figure 13, shall be used for these tests. The separation between the test antenna and the system antenna shall be approximately the far field distance at the receiver fundamental frequency of test unless otherwise specified. The test antenna, and system antenna if possible, shall be oriented for maximum received energy at each spurious response frequency. The test antenna must be matched to the signal generator.

5.3.7.1.1 Types. - This test applies only to those receivers which are designed to operate with no more than two specific types of antennas or where a transmission line is employed, such as waveguide or coaxial cable, that can support multiplemode propagation below 12 kmc.

5.3.7.2 Procedure. - The procedure for the overall susceptibility measurement shall be as follows:

(a) The receiver shall be tuned to the mid-band standard test frequency. The condition of the receiver must be the same as it was in 5.3.4.3.

(b) Adjust the signal generator output to maximum setting. Select a suitable receiver spurious response frequency (from the spurious response test data) and tune the signal generator to this frequency. Adjust the signal generator output to produce a standard output at the receiver and record the signal generator output and test antenna gain.

(c) Compute the received power density at the system antenna.

(d) Repeat the test at representative spurious response frequencies spaced at approximately octave intervals, if possible.

5.3.7.3 Data to be recorded. - The recorded data shall show the tuned frequency of the receiver, the frequency of each spurious response measured, the power output of the signal generator, the gain of the test antenna and the calculated power density received at the system antenna.

5.3.7.4 Presentation of data. - The tabular form will be:

Band________

Receiver Tuned Frequency (mc)__________

Measurement Distance (Meters)__________

Spurious Frequency (mc)	Signal Generator Power Output (dbm)	Test Antenna Gain (db)	Power Density at System Antenna (dbm/m^2)

5.3.8 Intermodulation test. -

5.3.8.1 General requirement. - The intermodulation characteristics of receivers are of primary importance because they are indications of the interference potential when the receiver is used in the presence of off-channel signals. Assuming that these signals have not been mixed before arriving at the receiver, some mixing may be expected in the r-f amplifier or the first mixer circuits. If one of the extraneous signals generated in this manner happens to fall at the receiver tuned frequency, and is of sufficient amplitude, interference of a co-channel nature is the result.

Usually it is assumed that the third order mix is potentially the most serious type of intermodulation because both signals may be within the passband of the input circuits. The frequency relationships for this type of mix are given by:

$$f_o = 2 f_a - f_b$$

where f_o is the receiver tuned frequency and f_a and f_b are the interfering signal frequencies.

It is also possible that higher order intermodulation products caused by two interfering signals near the tuned frequency could produce interference. An example of a higher order mix is the fifth order, defined by:

$$f_o = 3 f_a - 2 f_b$$

The second order, or primary, mix cannot be neglected as a possible cause of interference. This mix is defined by:

$$f_o = f_b - f_a$$

Care must be taken in conducting this test to insure that intermodulation does not occur within the signal generators themselves. If the signal generators are of a type such that generator intermodulation is a possibility, it is essential that a device be used to couple the generator outputs to the receiver which will provide considerable isolation between the generators.

5.3.8.2 Measurement setup. - The measurement setup shall be as shown in Figure 14. For non-pulse systems, signal generator No. 1 shall be unmodulated and signal generator No. 2 shall be modulated 30 percent with 400 cps for AM receivers; shall be unmodulated for FM and SSB receivers. For pulsed systems, one of the input signals shall be unmodulated, and the other shall be a pulsed signal having a pulse width and repetition rate equal to the nominal pulse characteristics of the system under test.

5.3.8.3 Procedure for receiver intermodulation measurement. - The procedure for receiver intermodulation measurement shall be as follows:

(a) Set the receiver controls to the same positions as in the sensitivity test. Tune signal generator No. 2 to the receiver tuned-frequency. Measure the sensitivity for a standard response. This sensitivity level should then be corrected by subtracting the attenuation (in decibels) of the isolation network.

(b) If primary mixing is to be observed, set signal generator No. 1 to f_a and signal generator No. 2 to $f_b = f_a + f_o$. Keeping the output levels of both signal generators equal, vary the outputs until a standard response is obtained. It may be necessary to retune one signal generator very slightly to maximize the response and then readjust levels to regain the standard response. Record the difference frequency, Δf, between f_a and the receiver tuned frequency, and record the corrected power levels, $P_a = P_b$. Repeat for various frequencies f_a and f_b.

(c) To observe third order intermodulation, repeat the above procedure for various positive and negative values of Δf. For each Δf, $f_a = f_o + \Delta f$ and $f_b = f_o + 2\Delta f$. Equivalent signal generator settings may be found for higher order intermodulation products. Tests shall be performed for all measurable orders of products. This test shall be performed at standard test frequencies within each receiver band. Enough data points should be recorded to plot a smooth curve.

5.3.8.4 Presentation of test data. - The test data are presented in tabular form as shown below

Band_______

Receiver Tuned Frequency (mc)________
Pulse Repetition Rate (Pulse/sec)______
Pulse Width (μsec)_____________

Intermodulation Order	Δf (mc)	Power Input (dbm)

5.3.9 Adjacent signal interference. -

5.3.9.1 General requirement. - The two-signal adjacent frequency test is a measure of the response of a receiver to weak and strong desired signals in the presence of weak and strong off-frequency interfering signals. Interference to the desired signal is simultaneously due to one or more of the following causes: cross-modulation, spurious responses, and desensitization. Thus, this test is a measure of the ability of the receiver to perform its normal function despite these forms of interference caused by off-frequency signals.

5.3.9.2 Measurement setup. - The test setup is as shown in Figure 14. One of the signal generators may be considered the desired signal, while the other may be considered the undesired signal.

5.3.9.3 Modulation. - For non-pulsed systems, use 400 cycle standard modulation for the desired test signal, and 1000 cycle standard modulation of the same type as the desired modulation for the interfering signal.

For pulsed systems, the desired signal characteristics shall be those for which the receiver is designed to operate. The interfering signal shall be unmodulated, unless otherwise specified.

5.3.9.4 Procedure. - The procedure for the adjacent signal interference test shall be as follows:

(a) Set the interfering signal in turn, to one of the standard levels; 0, -6, -12, and -30 dbm. This level will be held fixed for the remainder of each test run. Now detune this signal so that interference effects disappear.

(b) Retune the interfering signal toward the tuned frequency, and reestablish the standard system output response. For FM equipment the standard response output for this test should be a 12 db (S + N)/N ratio established with an FM signal generator modulated with rated deviation. (For non-pulse equipment do not tune closer than the third alternate channel). Record the signal generator frequency and input level. Continue tuning the interfering signal toward the receiver tuned frequency, measuring enough points to define the shape of a curve, until the standard response cannot be obtained.

(c) Repeat the above steps with the interfering signal tuned to the other side of the tuned frequency.

(d) Repeat the above for the previously specified interfering-signal levels. This test shall be performed at the mean frequency in each receiver band.

5.3.9.5 Presentation of test data. - The data are presented in tabular form.

Band________

Receiver Tuned Frequency (mc)__________

Δf (mc)	Desired Signal Power (dbm)	Interfering Signal Power (dbm)

5.3.10 Pulse desensitization (to be measured on pulsed systems only). -

5.3.10.1 General requirement. - The pulse desensitization test is indicative of the capabilities of a receiver under pulsed interference conditions. It measures receiver recovery characteristics following an interfering signal.

5.3.10.2 Measurement setup. - The test setup shall be as shown in Figure 15. A variable video delay device calibrated in microseconds shall be provided to synchronize and delay the desired signal input into the receiver. The pulse characteristics of the two signal generators are to be the nominal characteristics of the receiver under test. Both generators are to be set to the frequency to which the receiver is tuned.

5.3.10.3 Procedure for pulse desensitization measurement. - The procedure for pulse desensitization measurement shall be as follows:

(a) Set the undesired pulse signal generator to deliver 0 dbm output, and adjust the pulse delay to approximately $\frac{1}{2(prf)}$ in seconds, where prf is the pulse repetition rate in pulses per second. Measure the receiver sensitivity to the desired signal in accordance with the procedure under 5.3.4.
(b) Continue to reduce the delay time, measuring enough points to define the change in sensitivity as a function of delay, until the standard response can no longer be achieved.
(c) This test shall be performed at the mean frequency in each receiver band.

5.3.10.4 Presentation of test data. - The data are presented in tabular form.

Band__________

Receiver Tuned Frequency (mc)___________

Desired Pulse Delay (microseconds)	Desired Signal Power (dbm)

5.3.11 CW desensitization. -

5.3.11.1 General requirement. - The CW densensitization test measures the sensitivity of a receiver in the presence of on-frequency CW interference signals. Interference is caused by an adverse change in the bias levels of the receiver's amplifier stages due to the presence of the CW signal. Thus, this test is a measure of the receiver to perform its normal function despite the change in gain caused by the interference signal.

5.3.11.2 Measurement setup. - The test setup is as shown in Figure 14.

5.3.11.3 Modulation. - The desired signal characteristics shall be those for which the receiver is designed to operate. The interfering signal shall be an unmodulated CW signal.

5.3.11.4 Procedure. - The procedure for the CW densensitization measurement shall be as follows:

(a) Set the frequency of both the desired signal and the interfering signal to the frequency to which the receiver is tuned. Adjust the interfering signal level to 0 dbm. Find and record the level of the desired input signal required to produce the standard response.

(b) Reduce the interfering signal level to a lower value (such as -6 dbm), and find and record the level of the desired input signal required to produce the standard response. Repeat this procedure with successively lower interfering signal levels until the presence of the CW interfering signal does not affect the level of the desired signal required for the standard response. Sufficient points should be taken to permit a curve of receiver sensitivity versus CW interfering signal level to be plotted.

(c) This test shall be performed at the mean frequency of the receiver's operating band.

5.3.11.5 Presentation of test data. - The data are presented in tabular form.

Band________

Receiver Tuned Frequency (mc)__________

Interfering CW Signal Power (dbm)	Desired Signal Power (dbm)

5.3.12 Dynamic range. -

5.3.12.1 General requirement. - This test is intended to give an indication of receiver behavior between the standard response level and limiting. It measures the effectiveness of the AVC or AGC system is one exists, and describes the receiver linearity over this range.

5.3.12.2 Measurement setup. - The test setup shall be as shown in Figure 12.

5.3.12.3 Procedure for measuring dynamic range. - The procedure for measuring dynamic range shall be as follows:

(a) Perform the receiver sensitivity test as described under 5.3.4. Next, raise the input level 6 db and record the peak output signal level. Continue this procedure for input increments of 6 db until a change in level produces no significant change in output amplitude. If the receiver under test has a manually controlled IF gain control, perform this test under conditions of at least maximum, minimum, and average receiver gain.

(b) This test shall be performed at the mean frequency in each receiver band.

5.3.12.4 Presentation of test data. - The test data are presented in tabular form as shown below.

Band________

Receiver Tuned Frequency (mc)__________

P_{in} (dbm)	Peak Output (volts)

5.3.13 Oscillator radiation test. -

5.3.13.1 General requirement. - Energy generated within a receiver by local oscillators and other frequency-producing circuits may be radiated from the antenna terminals. For measurement of this energy, the receiver is considered as a transmitter and procedures similar to those of 5.2.2 apply. No attenuators or sampling networks are needed if the nominal input impedance of the frequency-selective voltmeter matches the nominal input impedance of the receiver under test.

5.3.13.2 Presentation of data. -

Frequency (mc)	Identification (Number of Harmonic)	Power Output (dbm)

5.4 Antenna measurements. -

5.4.1 General requirement. - The purpose of these measurements is to obtain a representation of the spatial distribution of power radiated into space or absorbed by a system. A complete set of characteristics for a system would provide absolute field patterns for all measurable transmitter-radiated signals, and for all receiver susceptible frequencies.

5.4.1.1 Objectives. - Alternate objectives of these measurements are:

5.4.1.1.1 To determine the field patterns of the transmitting or receiving equipment complete with antenna, with as little site effects as possible. This information should be obtained for all mobile and semi-portable equipment.

5.4.1.1.2 To determine the field patterns of transmitting or receiving equipment including the effects of the site. Where large fixed installations exist, this may be the only type of measurement that can be performed. The site can then be considered as part of the radiating or receiving system.

5.4.1.2 Ground-level and elevated environment. - Ground-level environment measurements have arbitrarily been defined to be those at or below the height above ground of the system antenna (zero elevation). Those measurements made above this height are defined as elevated measurements.

5.4.2 Antenna patterns. -

5.4.2.1 General procedure. - Antenna pattern information shall be obtained at the mid-band transmitter standard test frequency, and at all its harmonics up to 12 kmc, and when specifically requested, at non-harmonically related spurious outputs and receiver spurious responses. No out-of-band measurements need be taken at frequency intervals closer than 10 percent of the fundamental. Adequate precautions must be provided to prevent extraneous energy and spurious responses in the measurement equipment from affecting the validity of the measurement system. A total measurement range of at least 60 db is required for fundamental patterns; a minimum of 40 db is required for patterns at other frequencies.

The system antenna may be operated in either an active or passive state. Normally, the system antenna will be operated in the active state. If adequate power to provide the required measurement range is not present at non-fundamental frequencies, the system antenna may be driven by a suitably modulated signal generator, or may be used in the passive state. The measurement shall be made in an area unobstructed by buildings and trees. The antennas will be placed so as to minimize unusual ground reflections. In the placement of the test antenna, an objective is to approach free-space conditions, avoiding unusual reflections and the resulting complex wave front.

Where the azimuth and elevation of the system antenna can be varied, both the system and test antenna orientation shall be positioned for maximum received energy. If the system antenna cannot be varied, the test antenna shall be oriented for ground level maximum received energy. Specification for distance between antennas is given in 5.2.3.5.

5.4.2.1.1 Measurement below 20 mc. - The measurement antenna shall be a vertical rod, whip antenna, or calibrated loop equivalent to those furnished with field intensity measurement instruments.

5.4.2.1.2 Measurements between 20 and 400 mc. - The measurement antenna shall be a half-wave dipole tuned to the proper frequency. The measurement antenna shall be located as high above the ground as is practical, and shall be oriented for maximum response.

5.4.2.1.3 Measurements between 400 and 1000 mc. - The measurement antenna may be a dipole with a corner reflector.

5.4.2.1.4 Measurements above 1000 mc. - The measurement antenna shall be directive. It shall have a beamwidth not to exceed 10 degrees in width at the 3-db points at any frequency, and its side-lobe attenuation shall be at least 16 db below the main beam unless otherwise specified.

5.4.2.2 Polarization. - Horizontal and vertical polarization patterns are to be taken for all measurements.

5.4.2.3 Antenna types. - For convenience, antenna types have been divided into a number of categories. Two primary groups are surface-based and airborne. The measurement techniques described in this section apply only to surface-based devices. If patterns are to be taken of airborne antennas located on the ground, the same general procedures will apply.

A further distinction is made between rotatable and non-rotatable antennas, which are in turn categorized as non-scanning and scanning devices. Scanning may occur either in the horizontal (for example, sector scan) or vertical (for example, nodding) planes, and can generally be stopped. Vertical scanning devices shall be stopped in the lowest possible elevation angle. Horizontal scanning devices shall be stopped as close to the geometrical axis of the system antenna as possible. Polarization scanning shall not be stopped. A final breakdown of each of these sub-groups is made in regard to the degree of maneuverability with which the antenna can be positioned in the vertical plane.

5.4.2.4 Rotatable antennas. - For rotatable antennas, the antenna shall be rotated over 360° and measurements shall be recorded by a rapid operating technique. An azimuthal pattern shall be taken with the electrical centers of the test and system antennas at the same height. An additional pattern shall be taken, if possible, so as to intersect the peak of the main lobe. Data should be reported in rectangular coordinates as shown in Figure 16.

5.4.2.4.1 Test antenna locations. - Three measurement locations shall be employed. The minimum angular separation shall be no less than 45° and preferably greater than 90°. Patterns at the fundamental shall be taken at each of the three measurement locations. These patterns shall be analyzed to determine the best location (minimum site effects) at which to take spurious emission patterns and patterns at spurious response frequencies when required. These patterns need be taken only at this one location.

5.4.2.4.2 Elevatable antennas. - If the antenna is readily elevatable, additional azimuthal patterns shall be taken with the system antenna height the same as the test antenna height. One pattern shall be taken with the system antenna at its maximum elevation angle. A minimum of four additional azimuthal patterns shall be taken at elevation angles at which peaks of elevation lobes are observed. These peaks may be located by searching in elevation along an azimuthal angle which intersects the main lobe. An example is shown in Figure 17.

5.4.2.4.3 Semi-elevatable antennas. - If the antenna is elevatable through an angle of less than 80° it shall be treated as an elevatable antenna. Patterns need not be taken at intervals less than 5°. If the antenna is elevatable in steps, azimuthal patterns shall be taken for each available position not to exceed six.

5.4.2.5 Non-rotatable antennas. -

5.4.2.5.1 Test antenna locations. - For all non-rotatable antennas, the test antenna shall be placed at eight approximately equally spaced angular positions, with the electrical centers of the test and system antennas at the same height for the following tests. For antennas having a reflector or other directional arrangement, the locations shall be selected so as to include at least one set of measurements on the electromagnetic axis of the main beam or beams.

5.4.2.5.2 Fixed elevation antennas. - Readings shall be obtained at each of the eight positions specified in 5.4.2.5.1.

5.4.2.5.3 Elevatable antennas. - If the antenna is elevatable, readings shall be taken at the eight positions specified in 5.4.2.5.1. In addition, one set of readings shall be taken with the system antenna at its maximum elevation angle. A minimum of four additional sets of readings shall be taken at intermediate elevation angles, preferably at the peaks of any lobes as illustrated in Figure 17.

5.4.2.5.4 Semi-Elevatable. - Readings shall be taken as for elevatable antennas but need not be taken at intervals of less than 5°; for example, with an antenna capable of being tilted 15° only four readings are required. In the case of incrementally stepped antennas, readings shall be taken at incremental positions but not to exceed six readings.

5.4.3 Presentation of data. - Antenna pattern characteristics shall be submitted in both graphical and tabular form.

5.4.3.1 Graphical data. - A graphical plot of each antenna pattern shall be provided. This plot shall be presented in terms of relative antenna gain in db versus azimuth or elevation angle in degrees. The gain scale shall be linear in db. Rectangular coordinate graphs are required. Contributions to each pattern due to fixed location reflections, transients, limited dynamic range of instrumentation, etc., shall be identified.

5.4.3.2 Numerical data. - A tabulation of antenna pattern data shall be supplied. This tabulation shall be made at 2.5 degree increments referenced with respect to the maximum gain direction at the fundamental system operating frequency except that in the region of the main beam, the tabulation should be at sufficiently closely spaced increments to characterize the main beam structure. Relative amplitude with respect to the maximum amplitude at the frequency of measurement shall be recorded.

Pattern

Frequency__________(mc) Test Antenna Polarization____________
(H or V)

Cut - Azimuth,__________Degrees or

Elevation,__________Degrees

Angle (Degrees)	Relative Amplitude (db)

Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procurement activity or as directed by the contracting officer.)

(Copies of this standard for Military use may be obtained as indicated in the General Provisions to the Index of Department of Defense Index of Specifications and Standards.)

Both the title and identifying symbol number should be stipulated when requesting copies of Military Standards.

Custodians:
Army – Signal Corps
Navy – Ships
Air Force – AFSC

Preparing activity:
Navy – Ships
(Project MISC.–0177)

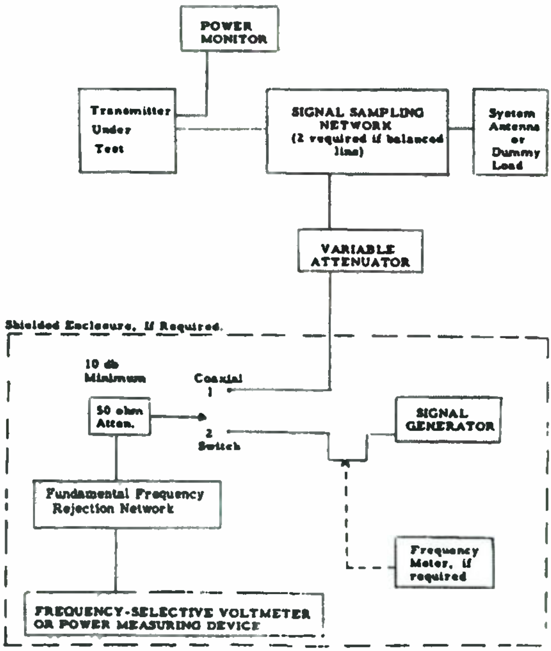


FIGURE 1 TRANSMITTER OUTPUT MEASUREMENT SET-UP

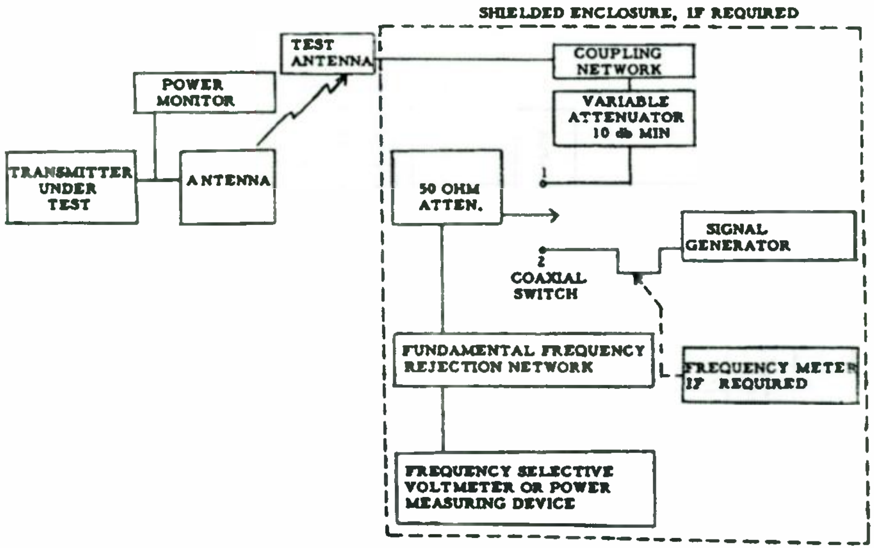


FIGURE 2 SPURIOUS EMISSION TEST SET-UP FOR TRANSMITTERS WITH CIRCULAR OR RECTANGULAR WAVEGUIDE OUTPUT COUPLED TO AN INTEGRATED ANTENNA SYSTEM

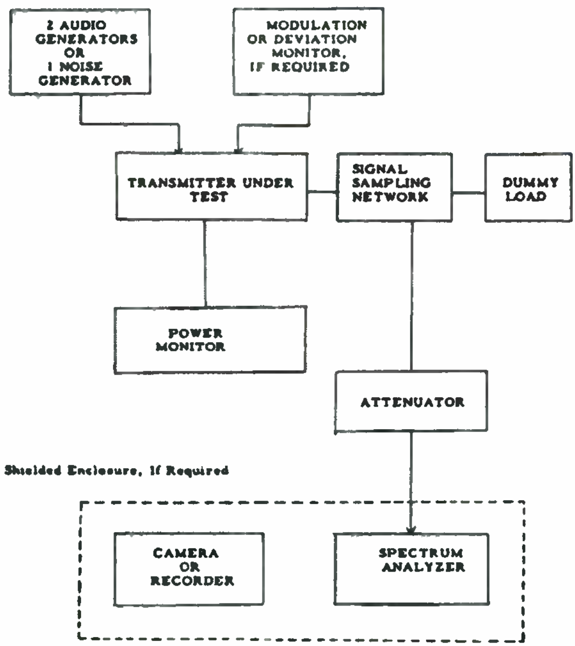


FIGURE 3 SIDEBAND SPLATTER SET-UP

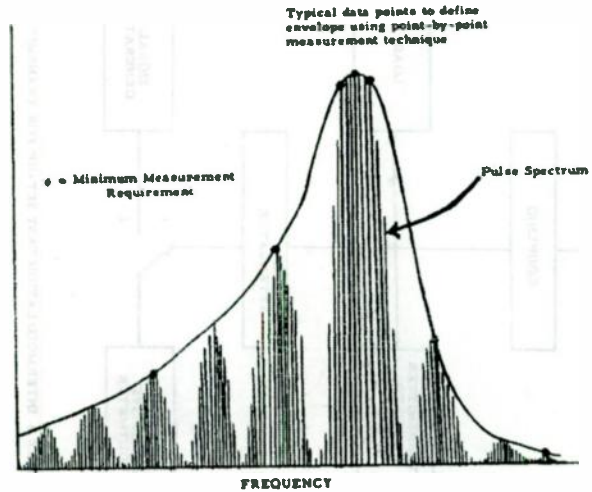


FIGURE 4 TYPICAL BROAD BAND SPECTRAL DISTRIBUTION

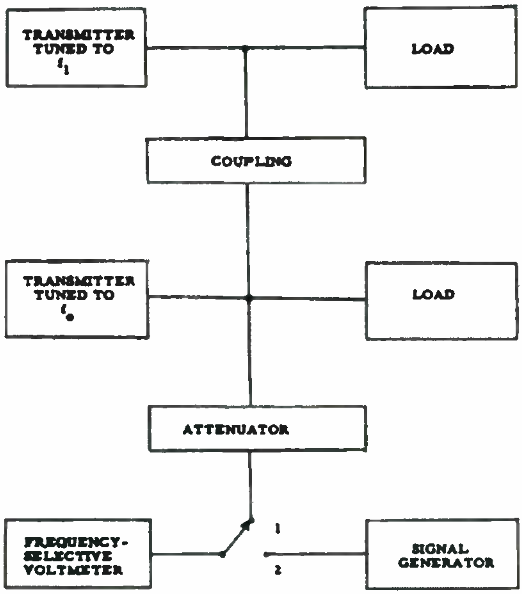


FIGURE 5 INTERMODULATION TEST SET-UP FOR TRANSMITTERS

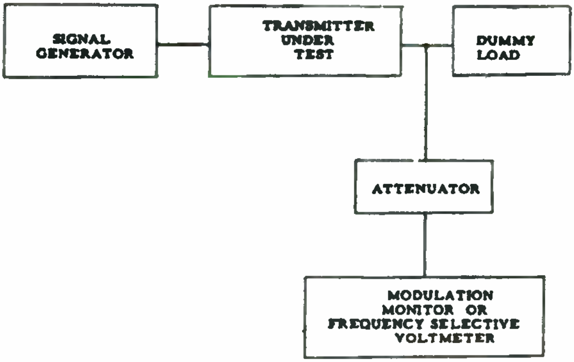


FIGURE 6 MODULATOR BANDWIDTH TEST SET-UP

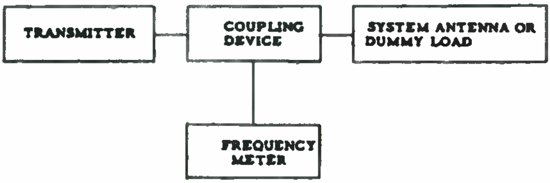


FIGURE 7 FREQUENCY STABILITY TEST SETUP

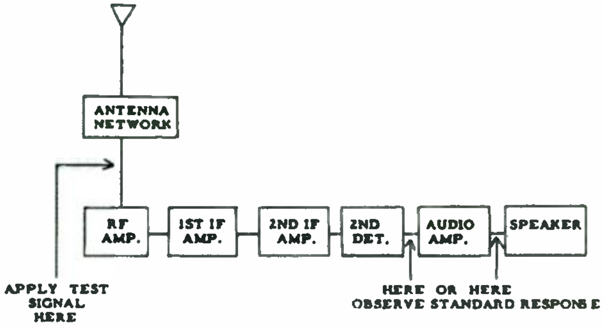


FIGURE 6 EXAMPLE OF LOCATION OF TEST POINTS FOR MEASURING STANDARD RESPONSE SIGNAL

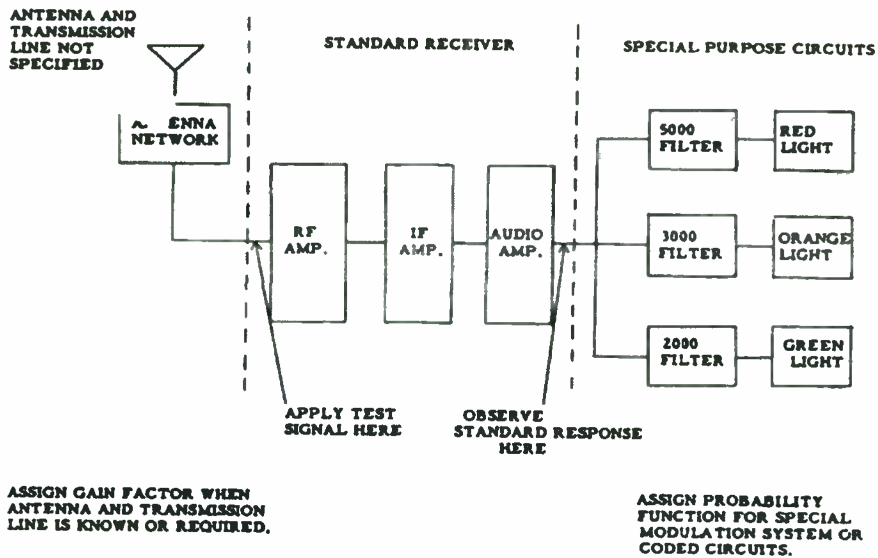


FIGURE 9 EXAMPLE OF LOCATION OF TEST POINTS FOR MEASURING STANDARD RESPONSE SIGNAL

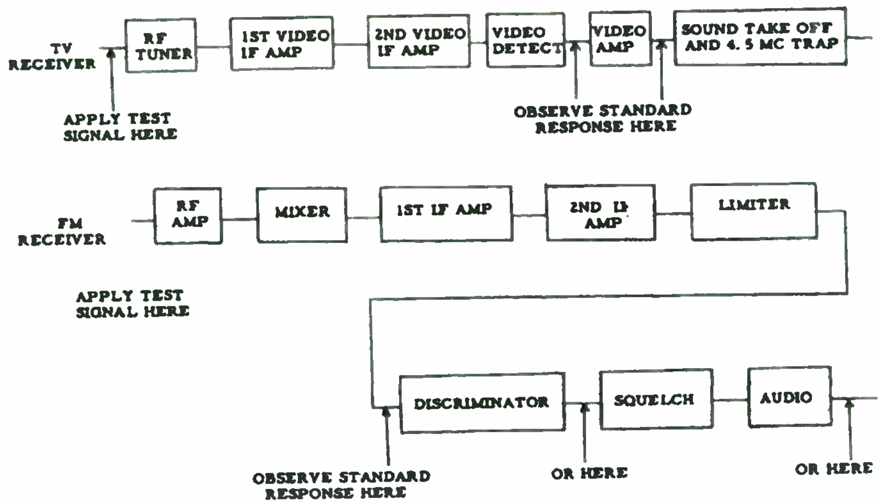


FIGURE 10 EXAMPLE OF LOCATION OF POINTS FOR MEASURING STANDARD RESPONSE SIGNALS

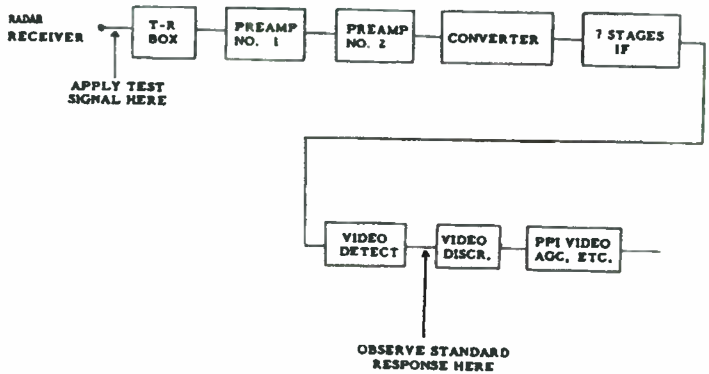


FIGURE 11 EXAMPLE OF LOCATION OF POINTS FOR MEASURING STANDARD RESPONSE SIGNALS

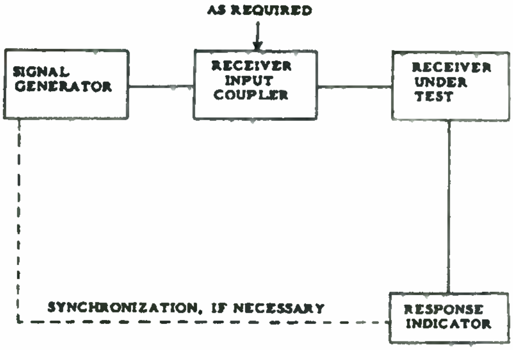


FIGURE 12 RECEIVER RESPONSE MEASURING SET-UP

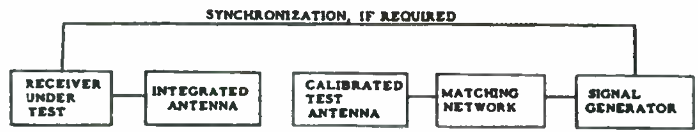


FIGURE 13 RECEIVER ANTENNA GAIN FACTOR TEST SETUP FOR RECEIVERS WITH CIRCULAR OR RECTANGULAR WAVEGUIDE OUTPUT COUPLED TO AN INTEGRATED ANTENNA SYSTEM

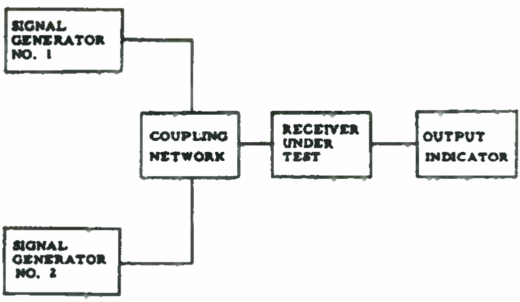


FIGURE 14 RECEIVER INTERMODULATION TEST SET-UP

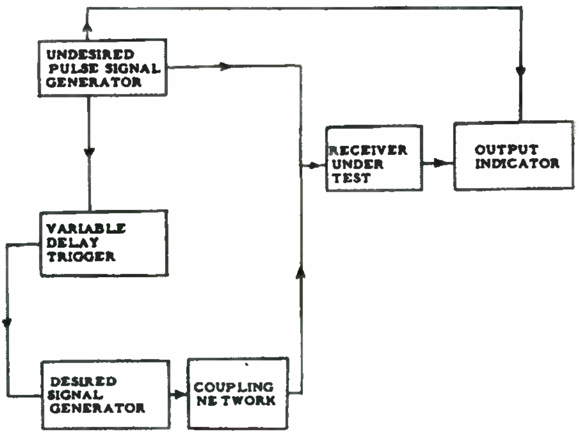


FIGURE 15 PULSE DESENSITIZATION TEST SET-UP

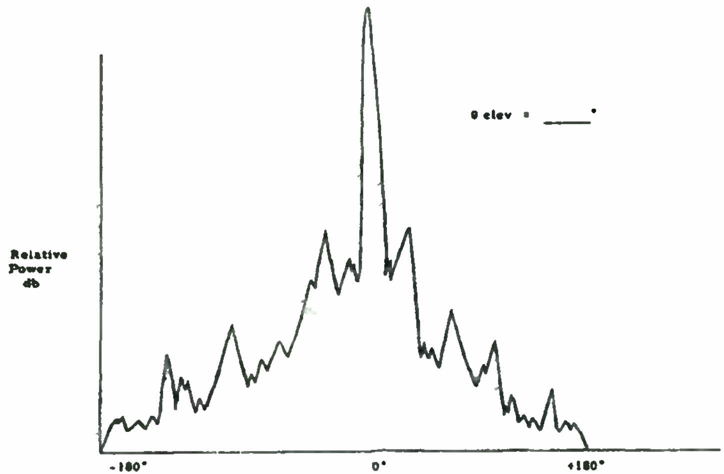


FIGURE 16 TYPICAL AZIMUTH ANTENNA PATTERN PLOT

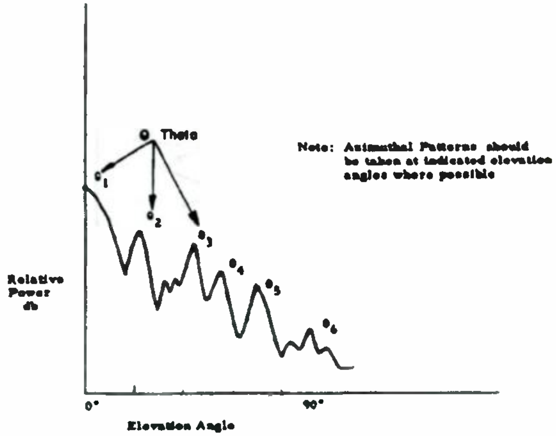


FIGURE 17 TYPICAL ELEVATION ANTENNA PATTERN PLOT

MILITARY SPECIFICATIONS

MIL-E-4957A (ASG)
AMENDMENT - 1
2 FEBRUARY 1956

MILITARY SPECIFICATION

ENCLOSURE, ELECTROMAGNETIC-SHIELDING, DEMOUNTABLE, PREFABRICATED
FOR ELECTRONICS TEST PURPOSES

This amendment forms a part of Military Specification MIL-E-4957A(ASG), dated 17 November 1954, and has been approved by the Department of the Air Force and by the Navy Bureau of Aeronautics.

Page 3, paragraph 3.3 Design and construction: Delete the last sentence and substitute the following:

"Any type of joint construction may be used for the shielding panels provided that compatibility and interchangeability with existing shielding panels constructed as shown in figures 1 and 2, is maintained and approval is obtained from the procuring activity."

Custodians:
Navy - Bureau of Aeronautics
Air Force

-oOo-

MIL-E-4957A (ASG)
17 NOVEMBER 1954

Superseding
MIL-S-4957(USAF)
2 December 1952
MIL-E-8669(Aer)
1 March 1954

MILITARY SPECIFICATION

ENCLOSURE, ELECTROMAGNETIC-SHIELDING, DEMOUNTABLE, PREFABRICATED FOR ELECTRONICS TEST PURPOSES

This specification has been approved by the Department of the Air Force and by the Navy Bureau of Aeronautics.

1. SCOPE

1.1 Scope.- This specification covers shielding enclosures, (screen rooms) which are to provide specified degrees of attenuation of electromagnetic fields within specified frequency ranges for the purpose of test and alinement of electronics equipment and other related purposes.

1.2 Classification.- Shielding enclosures shall be of the following type, as specified:

Type I - Double shielding, wire mesh, cell-type construction, demountable, providing a minimum of 100 db attenuation to electromagnetic fields within the frequency range of 100 kc to 10,000 mc.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein:

SPECIFICATIONS

Federal

FF-B-571	Bolts; Nuts; Studs; and Tap-Rivets (and Materials for same)
FF-S-85	Screws, Cap, Slotted and Hexagon Head
FF-S-111	Screws, Wood, Slotted-Head
QQ-B-611	Brass, Commercial; Bars, Plates, Rods, Shapes, Sheets and Strips
QQ-B-621	Brass, Commercial-Yellow, High-Copper-Yellow, and Naval; Castings

QQ-C-576	Copper Plates, Sawed Bars, Sheets, and Strips
QQ-S-571	Solder; Soft, (Tin, Tin-Lead, and Lead-Silver)
TT-W-571	Wood Preservative; Recommended Treating Practice
TT-W-572	Wood Preservative; Water-Repellent

Military

MIL-C-71	Connectors, "N" for Radio Frequency Cables
MIL-C-3643	Connectors, "HN" for Radio Frequency Cables
MIL-F-15733	Filters, Radio Interference
MIL-I-6181	Interference Limits, Tests and Design Requirements, Aircraft Electrical and Electronic Equipment
MIL-P-66	Plywood; Flat-Panel
MIL-W-6109	Wood; Method for Kiln Drying
MIL-W-6110	Wood; Determination of Moisture Content of
JAN-P-100	Packaging and Packing for Overseas Shipment - General Specification for

STANDARDS

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U. S. Military Property
MIL-STD-220	Method of Insertion-Loss Measurement for Radio-Frequency Filters

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Component parts.- The shielding enclosure shall consist of the required units of one or more each of the following parts and accessories:

(a) Side panel.
(b) Connector panel.
(c) Floor-overhead panel.
(d) Entrance panel.
(e) Flooring section.
(f) Shielded flooring strip (when required).
(g) Nailing blocks and accessories (when required).
(h) Handbooks of service instructions.

3.2 Materials and parts.- All parts and materials shall be in accordance with the designated specifications, and shall be free of flaws and of the best quality obtainable.

3.2.1 Wood.- The wood used in the construction of the framework of the shielding panels shall be seasoned, selected, straight grained, equal to or better than genuine northern white pine. It shall be both air and kiln dried in accordance with Specification MIL-W-6109, and the moisture content shall not be in excess of 10 percent upon application of treatment when tested in accordance with Specification MIL-W-6110. All wood shall be treated in accordance with Specifications TT-W-571 and TT-W-572.

3.2.2 Copper screen.- The copper screen used in the construction of the shielding panels shall be such that its attenuation characteristics will not be unduly affected by aging or exposure to moderate saline atmospheres. It shall be of 22 mesh to the inch, and shall consist of a woof of hard-drawn, unlacquered copper wire of 0.015-inch diameter, and a warp of soft-annealed, unlacquered copper wire of 0.015-inch diameter.

3.2.3 Copper sheet.- Copper sheet used for reenforcing and shielding shall be in accordance with Specification QQ-C-576.

3.2.4 Hinges.- Hinges shall be made of brass in accordance with Specification QQ-B-611, or better, and shall be 5 inches wide and of strong mechanical construction. They shall be smooth on all outer surfaces and, when mounted, shall present no exposed rough edges or sharp protrusions. All edges shall be slightly beveled.

3.2.5 Locks.- The lock assemblies shall be made of brass in accordance with Specification QQ-B-621. They shall be of smooth finish and offer no rough or sharp protrusions.

3.2.6 Connectors.- Radio-frequency transmission-line connectors shall be of three types:

(a) Type "N" in accordance with Specification MIL-C-71.
(b) Twin-conductor type.
(c) Type "HN" in accordance with Specification MIL-C-3643.

3.2.7 Flooring.- Plywood used in construction of the flooring shall be of interior grade A-B wood, and shall be in accordance with Specification MIL-P-66.

3.2.8 Interface.- The interface of hinged panels shall be double contact, spring loaded, and shall be made of beryllium-copper, or Phosphor-bronze, and shall be properly tempered and silver clad on the contact surfaces. Satisfactory provision shall be made to assure permanence of electrical contact between the surfaces of all parts in contact, by virtue of pressure, for long periods of time in the presence of humid, saline atmospheres.

3.2.9 Brass plate.- Brass plate shall be in accordance with Specification QQ-B-611.

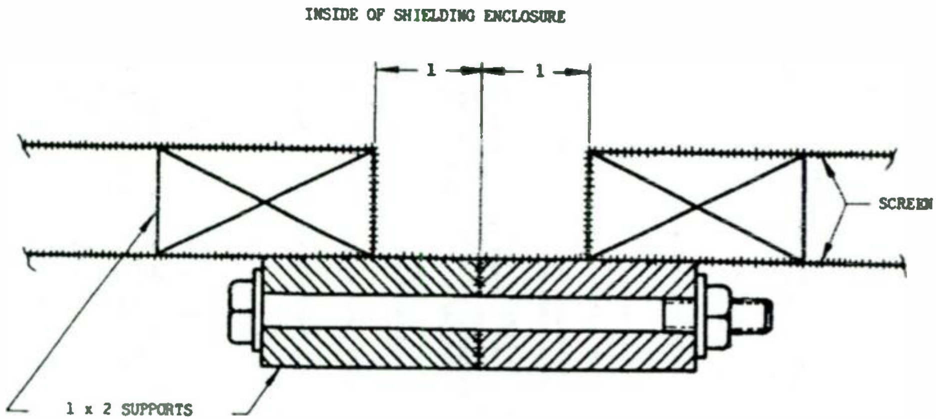
3.2.10 Wood screws.- The wood screws shall be brass and in accordance with Specification FF-S-111.

3.2.11 Machine screws.- Machine screws and nuts shall be brass and in accordance with Specification FF-S-85.

3.2.12 Anchor nuts.- Anchor nuts and bolts shall be brass and in accordance with Specification FF-B-571.

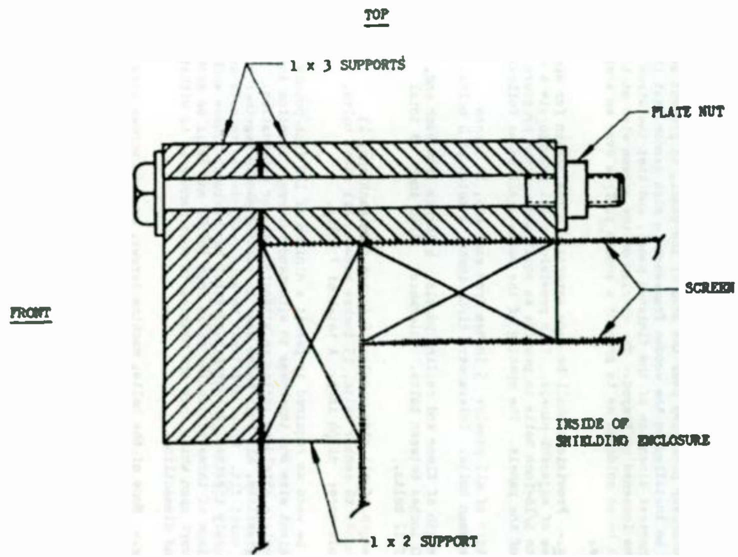
3.2.13 Solder.- Solder shall be soft solder, tin-lead, rosin-flux-cored in accordance with composition SN50 of Specification QQ-S-571.

3.3 Design and construction.- The design and construction of the components of the electromagnetic-shielding enclosure shall be such that the various panels may be assembled into a cubicle 10 feet wide, 8 feet in height, and 10 feet in length, or such other length as the contract may specify, in increments of 40 inches, and shall be mechanically of good strength. All paneling shall be electrically bonded together, and when assembled shall present an effective double shielding wire mesh, cell-type construction to electromagnetic fields. The floor shielding panels of the enclosure shall be protected by flooring sections. All bolting necessary for erection of a completed enclosure shall be accessible from the outside of the enclosure. Joint construction shall be in conformance with the requirements of figures 1 and 2.



DIMENSIONS IN INCHES.

FIGURE 1. Shielding enclosure - side panel joint



DIMENSIONS IN INCHES.

FIGURE 2. Shielding enclosure - side panel to ceiling panel joint

3.3.1 Panel construction.- Panels shall be of wood frame, copper screened on both sides, cell type, and manufactured in two sizes. One size panel shall be completely interchangeable as the top or bottom panels of the enclosure, and the second size shall be completely interchangeable about the sides of the enclosure.

3.3.1.1 Framework.- All panels shall be constructed of a wooden framework of 1-inch by 2-inch material, using mortise- and tenon-type joints suitably reinforced to prevent sagging when assembled in a shielded enclosure. The wood frame shall be finished on all sides to a tolerance of one thirty-second of an inch. The framework shall be covered with copper screen wire on both sides and overlapped a minimum of 0.250 inch at each corner. The screen wire shall be tightly drawn about the framework to provide a uniform spacing of 1 inch between screens, and shall be tacked to the wooden framework structure, wherever necessary over the area of the panel, to prevent sagging. The screen wire shall be installed on the wooden framework in such manner that the warp shall be across the shortest dimension of the finished panel, and that the wires of the screening do not become loosened or frayed. The overlap of the screen wire at the corners of the framework shall be so soldered as to present a smooth surface over an area approximately 0.250 inch wide.

3.3.1.2 Bolting.- Provisions shall be made external to the screen for securing the panels to the edges of adjacent panels. This provision shall incorporate a means of bolting the panels with 5/16-inch bolts to provide an equal and uniform pressure about the entire periphery of the panels. The spacing of the bolts shall be as follows:

(a) Width of all panels: 5 inches from each end, 10 inches between bolts. Tolerance: ±1/64 inch. A total of 4 bolts.

(b) Length of floor and ceiling panels: 4 inches from each end, 10 inches between bolts. Tolerance: ±1/64 inch. A total of 12 bolts.

(c) Length of all side panels: 5 inches from each end, 13 inches to center bolts, 15 inches between all other bolts. Tolerance: ±1/64 inch. A total of 7 bolts.

Pressure plates shall be used as required to permit a minimum of 140 inch-pounds torque, and shall be of sufficient size and thickness to withstand recurrent erection and dismantling of the complete shielding enclosure without damage or deformation. In the interest of interchangeability, all bolt holes used in bolting panels together shall be jig-drilled to assure exact fit. Where difficult to gain ready access to nuts used in tightening panels securely together, anchor plates shall be provided. These anchor plates shall be a minimum of three-sixteenths of an inch thick, and shall be securely fastened to the framework upon which they are mounted in such manner as to withstand occasional erection and dismantling.

3.3.1.3 Bonding.- None of the bolts, machine screws, or wood screws used in the entire assembly for securing wooden framework, accessories, or panels shall extend through from inner to outer surface of the shielding enclosure, unless they are bonded to screening by soldering.

3.3.2 Attenuation.- The shielding effectiveness of a completely assembled enclosure with powerline filters installed, and power fed into the enclosure, shall be measured as described in paragraph 4.4, and shall have the minimum attenuation as specified therein.

3.3.3 Side panels.- The side panels shall be 40 inches in width and 8 feet in length. The number required will depend upon the length of the shielding enclosure specified.

3.3.4 Floor-overhead panels.- The floor and overhead panels shall be 40 inches in width and 9 feet, 10 inches in length. The number required will depend upon the width of the shielding enclosure specified.

3.3.5 Connector panel.- The connector panel shall be interchangeable with a side panel as to size and bolting. Only one shall be required for each shielding enclosure. In addition, it shall be equipped with powerline inlets, powerline filters, and radio-frequency transmission-line feed-through connectors. It shall have mounted upon each side of the panel a sheet of copper reenforcing of sufficient thickness and width to support six power entrance fittings, four powerline filters, (with space for mounting two additional filters) and five radio-frequency transmission-line feed-through connectors. The copper reenforcing sheets shall be installed upon the connector panel in such manner as to withstand continual insertion and removal of coaxial cables, without damage to the connector panel material or deformation of the copper sheets. The copper sheets or plates shall be smooth and the outer edges slightly beveled with no sharp or rough edges exposed. Soldering of the plates to the shielding material shall be continuous about the entire periphery of the plate, and all soldering shall be finished smoothly in order that no sharp or jagged edges or tips are exposed. The powerline inlets shall be metallic waveguides, three-fourths of an inch in diameter, soldered to both copper reenforcing plates.

3.3.5.1 R-f connectors.- Upon the copper reenforcing plates shall be mounted five radio-frequency transmission-line feed-through connectors of the following types and numbers:

(a) Two type "N" assemblies. (The receptacles on each end of these assemblies shall be similar to type UG-58A/U receptacles.)

(b) One UG-421/U twin coaxial plug.

(c) Two type "HN" assemblies. (The receptacles on each end of these assemblies shall be similar to type UG-496/U receptacles.)

3.3.5.1.1 The radio-frequency transmission-line feed-through connectors and the power entrance fittings shall be secured to the shielding panel by means of hexagonal shaped nuts, providing one nut on each side of the panel. All nuts, when securely tightened, shall be soldered about their entire periphery to the copper reenforcing plates on each side of the panel. The copper reenforcing plates on each side of the panel shall also be soldered about their entire periphery to the shielding material.

3.3.5.2 Connector arrangement.- The powerline entrances and powerline filters shall be mounted in close proximity to one end of a side panel described in paragraph 3.1, but no protrusions shall extend over the edge of the panel framework. The radio-frequency transmission-line feed-through connectors shall be mounted adjacent to and under the power entrances, on the same copper reenforcing plates. They shall be located 2 feet 6 inches in from the end of the panel. Installation of the powerline entrances, powerline filters, and radio-frequency transmission-line feed-through connectors shall in no way interfere with the interchangeability of this panel with any other side panels.

3.3.5.3 Captive screws.- All radio-frequency transmission-line feed-through connectors and power entrance fittings shall be provided with captive screw-on caps on each side of the panel.

3.3.5.4 Powerline filters.- The four powerline entrance filters conforming to Specification MIL-F-15733 shall have the following ratings:

(a) 28V dc, 100 amperes, breakdown voltage, 500 volts.

(b) 115V, 60 cycles, ac, 50 amperes, breakdown voltage, 500 volts.

(c) 115V, 400 cycles, ac, 40 amperes, breakdown voltage, 500 volts.

3.3.5.4.1 Two line entrances and filter units shall be for (b) above. The insertion loss for powerline filters used, as measured in accordance with Standard MIL-STD-220, shall be not less than 100 db throughout the frequency range of 100 kc through 1,000 mc.

3.3.5.5 Grounding stud.- A grounding stud, one-half of an inch in diameter, with 13 threads per inch (NC series), extending through and soldered to both the plates, shall be mounted on the copper reenforcing plates and shall be so constructed that it may effectively serve a grounding point for the complete assembled shielding enclosure, both internally and externally.

3.3.6 Entrance panel.- The entrance panel shall be of wood frame, copper screened on both sides, and interchangeable with a side panel as to size and bolting. It shall incorporate a hinged panel. Only one shall be required for each shielding enclosure.

3.3.6.1 Hinged panel.- The hinged panel shall be 34 inches wide by 7 feet 3 inches high. It shall open outward, swing at least 150 degrees, and shall be mechanically strong such that frequent usage will not loosen the framework or deform it in any manner. It shall be mounted on the entrance panel with three hinges, and so designed that it may be installed to open from the left- or right-hand side. A three-point locking system capable of being actuated by one hand, equal or better than the above requirements, will be considered adequate.

3.3.6.1.1 Locks.- The hinged panel shall be provided with two dog-type locks, as herein specified under materials, which are operable from both inside and outside of the shielding enclosure. The locks shall be installed in such manner that when not actually in use in a locked position, they will automatically assume a vertical position and not extend over the edge of the entrance panel.

3.3.6.1.2 Interfaces.- Two sets of multiple-point, spring-loaded contact interfaces shall be mounted on the periphery of the hinged panel, one on the edge of the panel and one on the edge of the brass reenforcing plate. These serrated finger-type electrical contacts shall be installed at 90 degrees to each other in such manner that they effectively straddle the outer corner of the aperture frame when the hinged panel is in the closed position.

3.3.6.1.3 Other details.- The hinged panel shall be provided with 0.125-inch tempered-masonite push-plates on both sides, located near the midpoint at the edge of the opening side. Pull handles shall be provided on each side of the hinged panel and mounted 6 inches in from the edge of the entrance panel. The hinged panel shall be reenforced with a 2-1/2 inch brass strip, one-eighth of an inch thick, extending 1 inch over all edges. The hinged panel in the closed position shall offer no appreciable reduction in the attenuation characteristics inherent in the plain shielding panels. The brass reenforcing shall be brazed and dressed at all corners.

3.3.6.2 Reenforcement.- The sill considered to be the top and bottom horizontal portions of the entrance panel frame shall be reenforced with a brass plate 0.250 inch thick, and the entire surface of the entrance panel shall be covered with a copper sheet of at least 20-mil thickness and shall have soldered seams.

3.3.7 Flooring.- Plywood and tempered-masonite flooring sections shall be constructed as single sections of sufficient size to cover each floor-shielding panel. Each section shall be provided with recessed pull-rings at each end to insert fingers for removal and installation. The sections shall be of such size and fit that when placed in position inside the assembled shielding enclosure they will form a complete covering of the floor panels with minimum space between. When installed, the sections shall be even with the bottom surface of the entrance-panel aperture. Provisions shall be made to insure that the installation of the flooring sections do not damage the floor panels in any way.

3.3.7.1 Thickness.- The thickness of the completed flooring assembly shall not exceed 2 inches.

3.3.7.2 Strength.- The flooring sections shall be reenforced, as necessary, to provide a decking that will withstand a distributed floor loading of 150 pounds per square foot without damage or deformation.

3.3.7.3 Shielded flooring strips.- Wood strips, 1-7/8 inch by 7/8 inch by 2 feet, lined with 2 layers of screen wire and fastened to both adjacent panels by means of wood screws spaced 1 foot apart and provided with flat washers, shall be provided by the contractor in a sufficient number to cover the entire lengths of the grooves in the floor panels, unless the construction of the room precludes the use of such strips.

3.3.8 Nailing blocks and accessories.- Slotted dovetail nailing blocks shall be fabricated of wood, of such size that will press-fit between extended sections of the side panels on the inside of the enclosure. When installed, the nailing blocks shall not protrude over the surface of adjacent shielding panels. These blocks shall be suitable for use in supporting electrical fixtures, charts, test equipment leads and cables, wire clamps, lighting fixtures, and other such devices as necessary to install within the shielding enclosure. The blocks shall be supplied in lengths of 2 feet and in sufficient number to assure accommodation of all reasonable requirements for their use, and as specified by the procuring activity, unless the construction of the room precludes the use of such blocks.

3.4 Identification of product.- All markings shall be in accordance with Standard MIL-STD-130.

3.4.1 All floor and overhead panels shall bear standard metal-plate markings stamped "FLOOR OR OVERHEAD PANEL."

3.4.2 All side panels shall bear standard metal-plate markings stamped "SIDE PANEL."

3.4.3 The entrance panel shall bear standard metal-plate marking stamped "ENTRANCE PANEL."

3.4.4 The panel bearing radio-frequency transmission-line feed-through connectors and powerline entrances and filters shall bear standard metal-plate marking stamped "R-F CONNECTOR AND FILTER PANEL."

3.5 Handbook of service instructions.-

3.5.1 General.- The handbook of service instructions shall meet such requirements as the procuring activity may specify and shall contain the following information.

3.5.2 The handbook of service instructions shall include specific instructions for mounting of 1/4-inch plywood panels on both inner and outer surfaces of the shielding panels in such manner as to preclude the possibility of a resulting decrease in the attenuation characteristics of the assembled enclosure. These panels will be provided by the using activity, to such height and on such sides as may be necessary to protect the shielding materials from mechanical damage.

3.5.3 The handbook of service instructions shall include specific instructions for the using activity to install the necessary power outlets and lighting fixtures without a resulting decrease to the attenuation characteristics of the shielding enclosure.

3.5.4 The handbook of service instructions shall include all necessary instructions on relocation, dismantling, weight on top of room, handling of panels, cleaning of seams and erection, pressure plates, tightness, cleaning of the serrated access-panel fingers, repairs to serrated access-panel fingers, grounding plane of test tables, bonding, bonding jumpers, soldering, metallic objects penetrating the screens, reference ground, all service entrances, transmission-line connectors, fans, filters, decoupling filters, filter entry, attenuation of the shielding enclosure, leakage, use of the access panel, and such other items as may be specifically required by the applicable specification or the procuring activity.

3.5.5 The handbook of service instructions shall describe the satisfactory installation of circuit breakers and switches, both internal and external to the shielding enclosure.

3.5.6 The handbook of service instructions shall include illustrations of all phases of erection and disassembly of the complete shielding enclosure.

3.5.7 Each complete assembly shall contain two handbooks of service instructions as part of the packaged assembly.

3.6 Workmanship.- Workmanship on all components of the shielding enclosure, including all parts and accessories shall be in accordance with accepted standard practices for similar type construction.

3.6.1 Tolerances.- Dimensions and tolerances not specified shall be in accordance with best shop practices.

3.6.2 Screw assemblies.- Assembly screws shall be tight. The word "tight" means that the screw cannot be appreciably tightened further without damage or injury to the screw threads and wood frame or metal parts being assembled.

3.6.3 Cleaning.- All components shall be thoroughly cleaned of metal chips and other foreign material after final assembly. All burrs, protrusions, and sharp edges shall be removed.

3.6.4 Soldering.- All soldering shall be effected in a neat and workmanlike manner, and the surface surrounding the soldered connections shall be free from spatterings and excessive solder. Acid or corrosive fluxes shall not be employed. There shall be no evidence of "cold soldering."

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of tests.- The inspection and testing of shielding enclosures shall be classified as follows:

(a) Preproduction tests: Preproduction tests are those tests performed on samples representative of the production of the item after the award of contract, to determine that the production meets the requirements of this specification.

(b) Acceptance tests: Acceptance tests are those tests performed on individual lots which have been submitted for acceptance.

4.2 Preproduction tests.-

4.2.1 Sampling instructions.- The Preproduction test sample shall consist of one complete enclosure (assembled) which shall be tested at the contractor's plant under the supervision of the procuring activity to determine compliance with all the requirements of this specification. The enclosure to be tested shall have four filtered powerline entrances installed to simulate a standard installation.

4.2.2 Tests.- The Preproduction tests shall consist of all the tests of this specification, as described under "Test methods," and any other tests deemed necessary to determine compliance with the requirements of this specification.

4.3 Acceptance tests.- The Acceptance tests shall consist of Examination of product and Sampling tests.

4.3.1 Examination of product.- All component parts shall be subjected to the following test as described under "Test methods":

(a) Examination of product.

4.3.2 Sampling tests.- One enclosure from each lot of 25 enclosures or fraction thereof shall be assembled and subjected to all the tests of this specification. All components used in assembling the enclosure shall first have passed the Examination of product test.

4.4 Test methods.-

4.4.1 Examination of product.- Each fabricated component and part shall be carefully examined to determine conformance with dimensions, materials, parts, workmanship and, in the case of an assembled enclosure, all fittings, mechanical joints, and ease of operation of all moveable parts.

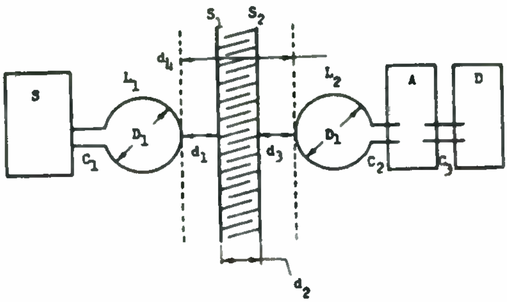
4.4.2 Measurement of attenuation of low impedance (magnetic) fields.- Attenuation of low impedance (magnetic) fields shall be measured as follows, using the test setup described below and in figure 3.

4.4.2.1 Attenuator.- The attenuator A may be a 50- or 72-ohm transmission-line, low input impedance, step attenuator. A signal generator may be used to calibrate the attenuator. The attenuator shall be able to measure an insertion loss of over 70 db.

4.4.2.2 Detector.- The detector may be any receiver, such as the DZ-2 or the BC-348-Q or a field strength meter provided with a low impedance input, such as the AN/PRM-1. A matching device may be used with high input impedance receivers or field-strength meters.

4.4.2.3 Signal source.-

4.4.2.3.1 Signal source S may be a signal generator or power oscillator of sufficient cw, mcw, or pulsed cw output. In case loop L_1 is connected to the output of a signal generator or power oscillator, a tuning capacitor may be connected in series with L_1 to obtain resonance at the test frequency used.



d_1 = 12 INCHES
d_2 = 1 INCH
d_3 = 12 INCHES
d_4 = 25 INCHES - ($d_1 + d_2 + d_3 = d_4$)
S_1 = OUTER SCREEN
S_2 = INNER SCREEN
S = LOW IMPEDANCE SIGNAL SOURCE TO OBTAIN ADEQUATE OUTPUT AT THE FREQUENCY OF TEST.
D_1 = 12 INCHES
FREQUENCY OF TEST = ONE FREQUENCY IN THE 150 TO 200 KC RANGE
L_1 = TRANSMITTING LOOP RADIATOR; LOW IMPEDANCE. ONE TURN OF NO. 6 AWG COPPER WIRE. ORIENTED AT ANY ANGLE IN A PLANE PERPENDICULAR TO THE SHIELDING-ENCLOSURE WALL.
D = DETECTOR OF ADEQUATE SENSITIVITY TUNED TO FREQUENCY OF TEST. USED ONLY AS A REFERENCE LEVEL INDICATOR.
L_2 = RECEIVING LOOP ANTENNA, POSITIONED IN THE SAME PLANE AS L_1.
A = DB ATTENUATOR OF LOW IMPEDANCE INPUT, CALIBRATED AT THE FREQUENCY OF TEST.
C_1, C_2, C_3 = SHIELDED TRANSMISSION-LINE CABLES. AS SHORT AS POSSIBLE AND USED ONLY IF NECESSARY.

FIGURE 3. Test setup, low impedance fields

4.4.2.3.2 If the signal generator has a reliable output attenuator, it may be used instead of the attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the attenuation of the shielding enclosure by using the detector D at the same reference level when the shielding enclosure wall is removed. In this case, no precaution has to be taken to guard against case leakage at the detector.

4.4.2.3.3 A signal source may be constructed as shown in figure 4.

4.4.2.4 Measurement of db attenuation.-

4.4.2.4.1 The attenuation of the enclosure is the increase in the db setting of the attenuator A necessary to obtain the same reference reading level in detector D, when the shielding enclosure wall, S_1, S_2 is removed, without changing the respective positions of L_1 and L_2. The attenuation shall be at least 70 db. (The attenuation in db is also essentially equal to 20 log (base 10) E_1/E_2, where E_2 and E_1 are the voltages induced in the receiving loop, with the enclosure wall in, and the enclosure wall removed, respectively, without changing the respective positions of L_1 and L_2.)

4.4.2.4.2 The position of L_1 with respect to the enclosure shall be anywhere around the enclosure and in any orientation to the section seams, access panel seams, etc. A reading shall be taken on all four sides of the enclosure, and the minimum attenuation recorded. This shall be a minimum of 70 db.

4.4.2.4.3 When it becomes impractical to remove the shielding enclosure wall, S_1, S_2, the loops L_1 and L_2 may be set outside the enclosure in an exactly similar position with no obstruction by any objects between them. Because the strong magnetic field generated by L_1 may penetrate the metal case of detector D and attenuator A, these two equipments may be left inside the enclosure and the loop L_2 should be brought out of the enclosure through a transmission-line connector.

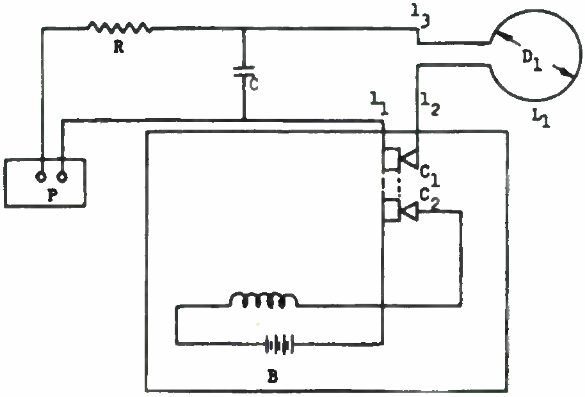
4.4.2.4.4 A test shall be made to insure that no case leakage exists at D and A. The detector shall show no indication whatever above the inherent background when cable C_2 or C_3 is disconnected.

4.4.2.4.5 If detector D shows no indication above the inherent receiver background when the receiving antenna is inside the enclosure, the increase in db necessary to obtain receiver background when the receiving antenna is placed outside the room will indicate that the room has at least that amount of attenuation. If this attenuation measurement is less than 100 db, the signal source S is not sufficiently strong, or the detector D is not sufficiently sensitive.

4.4.3 Measurement of attenuation of high impedance (electric) fields.- Attenuation of high impedance (electric) fields shall be measured as follows, using the test setup described below and in figure 5.

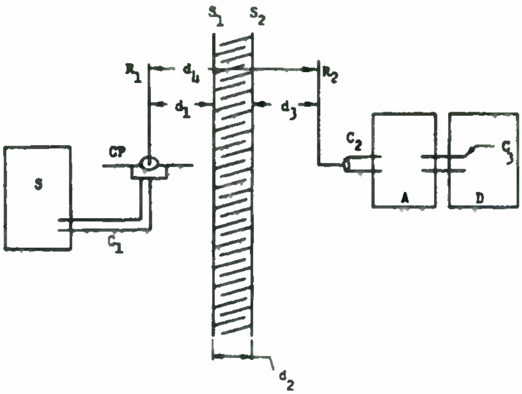
4.4.3.1 Attenuator.- The attenuator used may be a high-impedance capacity-type attenuator, similar to the external attenuator used with the Ferris Model 32A, or constructed similarly to the one used internally on the AN/PRM-1. A signal generator is used to calibrate this attenuator. This attenuator shall be able to measure an insertion loss of over 100 db.

4.4.3.2 Detector.- The detector may be a field strength meter, such as the Ferris 32A or the AN/PRM-1. In this case, attenuator A may be deleted because these instruments can measure induced voltages in the receiving antenna R_2, and are able to record levels 100 db apart. The readings obtained on these instruments shall be checked against a signal generator.



L_1, D_1	-	SEE FIGURE 3.
C	-	1.0 uf PAPER, 600V.
R	-	10,000 OHM, 5 WATT.
B	-	DRY CELL, 3 TO 45V.
P	-	300V DC BATTERY OR RECTIFIER POWER SUPPLY.
C_1	-	CONTACT INTERRUPTER SHORTING OUT CAPACITY C AT A RATE OF 20 TO 100 PULSES PER SECOND. OPERATED BY C_2 BUT NOT ELECTRICALLY CONNECTED TO IT.
V	-	VIBRATOR
l_1, l_2, l_3	-	LEADS, SHOULD BE AS SHORT AS POSSIBLE.

FIGURE 4. Source of intense peak power magnetic field



d_1 = 12 INCHES

d_2 = 1 INCH

d_3 = 12 INCHES

d_4 = 25 INCHES = $(d_1 + d_2 + d_3 = d_4)$

S_1 = OUTER SCREEN.

S_2 = INNER SCREEN.

S = HIGH IMPEDANCE SIGNAL SOURCE TO OBTAIN ADEQUATE OUTPUT AT THE FREQUENCY OF TEST.

FREQUENCIES OF TEST = 200 KC, 1.0 MC and 18.0 MC.

R_1 = TRANSMITTING ROD RADIATOR, 41 INCHES LONG. HIGH IMPEDANCE ORIENTED IN ANY POSITION PARALLEL TO THE SHIELDING-ENCLOSURE WALL.

C_1, C_2 and C_3 = SHIELDED TRANSMISSION-LINE CABLES. AS SHORT AS POSSIBLE AND USED ONLY IF NECESSARY.

A = CAPACITY-TYPE DB ATTENUATOR. HIGH INPUT IMPEDANCE.

CP = COUNTERPOISE.

R_2 = RECEIVING ROD ANTENNA, 41 INCHES LONG. HIGH IMPEDANCE, POSITIONED PARALLEL TO R_1 AND IN THE SAME PLANE.

D = DETECTOR OF ADEQUATE SENSITIVITY. TUNED TO FREQUENCY OF TEST. USED ONLY AS AN EQUAL REFERENCE-LEVEL INDICATOR.

FIGURE 5. Test setup, high impedance fields

4.4.3.2.1 A receiver may be used, such as the BC-348-Q. In this case, they are used only as reference-level indicators. The attenuation may be read on attenuator A. The equal reference level is chosen to be low enough as not to represent any overloading or saturation of the receiver. If necessary, a matching device may be used with low input impedance receivers.

4.4.3.3 Signal source.-

4.4.3.3.1 Signal source S may be a signal generator or power oscillator of sufficient cw, mcw, or pulsed cw output. The termination of cable C_1 may be matched to the signal source S if desired.

4.4.3.3.2 If the signal generator has a reliable output attenuator, it may be used instead of the attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the db attenuation of the enclosure by the detector D at the same reference level when the shielding enclosure wall is removed. In this case, no precaution has to be taken to guard against case leakage at the detector.

4.4.3.3.3 If a large output signal generator or power oscillator is not available, a pulse-signal source may be easily constructed as shown in the three setups in figure 6.

4.4.3.4 Measurement of db attenuation.-

4.4.3.4.1 The attenuation of the enclosure is the increase in the db setting of the attenuator A necessary to obtain the same reference reading level in detector D when the shielding enclosure wall S_1 and S_2 is removed, without changing the respective position of R_1 and R_2. (The attenuation in db is also essentially equal to 20 log (base 10) E_1/E_2, where E_1 and E_2 are the voltages induced in receiving rod with the enclosure wall in and with the enclosure wall removed.)

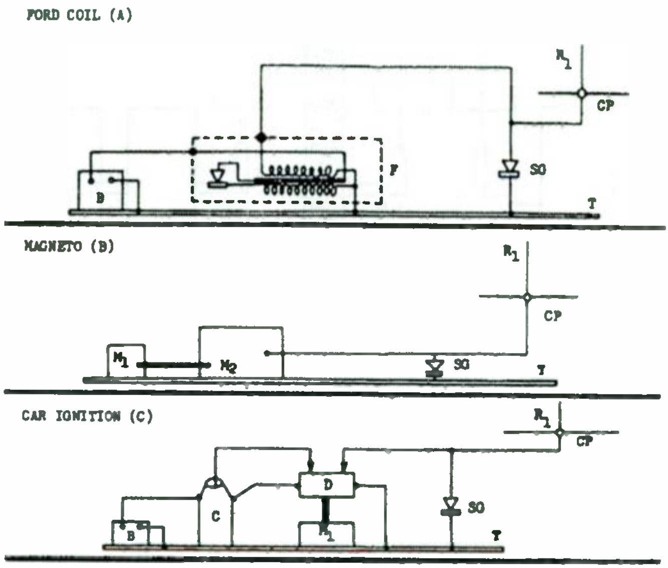
4.4.3.4.2 The positioning of R_1 with respect to the shielding enclosure walls shall be anywhere around the enclosure, in any orientation to the section seams, access-panel seams, etc. A reading must be taken at each side of the shielding enclosure and the minimum attenuation recorded. This minimum shall be over 100 db.

4.4.3.4.3 When it becomes impractical to remove the shielding enclosure walls, S_1 and S_2, both rods R_1 and R_2 may be set outside the enclosure in the exact similar position, with no obstruction by any objects between them. Because the strong electric fields generated by R_1 may penetrate the metal case of detector D and attenuator A, these two equipments may be left inside the enclosure, and the rod R_2 may be brought out of the enclosure through a transmission-line connector. The cable used should be as short as possible.

4.4.3.4.4 A test shall be made to insure that no case leakage exists at D or A. The detector shall show no indication whatsoever above the inherent background when cable C_2 or C_3 is disconnected.

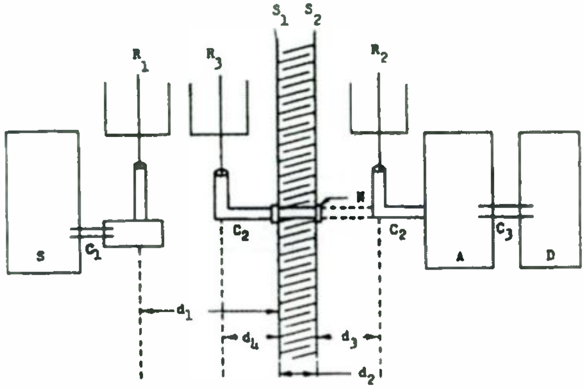
4.4.3.4.5 If detector D shows no indication above the inherent background when the receiving antenna is inside the enclosure, the increase in db necessary to obtain receiver background when the receiving antenna is placed outside the room will indicate that the room has at least that amount of attenuation. If this attenuation measurement is less than 100 db, the signal source S is not sufficiently strong or the detector D is not sufficiently sensitive.

4.4.4 Measurement of attenuation of plane waves.- Attenuation of plane waves shall be measured as follows, using the test setup described below and in figure 7.



R_1 = RADIATOR (FIGURE 5.)
M_1 = MOTOR DRIVE
C = IGNITION COIL
CP = COUNTERPOISE
T = GROUND METAL TABLE
F = FORD COIL (IGNITION)
M_2 = MAGNETO
B = BATTERY
D = IGNITION DISTRIBUTER
SG = SPARK GAP

FIGURE 6. Source for intense peak power electric field



d_1	= 72 INCHES	DISTANCE SHOULD BE AS GREAT AS POSSIBLE AND LIMITED ONLY BY THE OUTPUT OF S. HOWEVER, ALWAYS HOLD MORE THAN TWO TIMES THE WAVELENGTH FROM S_1, S_2.
d_2	= 1 INCH	DISTANCE BETWEEN SCREENS.
d_3	= 2 INCHES	TWO INCHES IS THE MINIMUM VALUE. R_2 IS POSITIONED ANYWHERE INSIDE THE ENCLOSURE AND ORIENTED FOR MAXIMUM INDICATION ON DETECTOR D, IN ORDER TO MINIMIZE THE EFFECT OF REFLECTIONS.
d_4	=	NOT LESS THAN 2 INCHES, AND NOT MORE THAN 8 INCHES. R_3 IS POSITIONED ANYWHERE OUTSIDE THE ENCLOSURE AND ORIENTED FOR MAXIMUM INDICATION ON DETECTOR D, IN ORDER TO MINIMIZE THE EFFECT OF REFLECTIONS. THE ENTIRE REGION, FROM 2 INCHES TO 8 INCHES SHALL BE EXPLORED FOR MAXIMUM INDICATION. R_3 SHALL NEVER BE CLOSER THAN 2 INCHES TO S_1, S_2, IN ORDER TO PREVENT CAPACITY COUPLING.
S_1, S_2	=	OUTER AND INNER SCREENS, RESPECTIVELY.
N	=	TRANSMISSION-LINE CONNECTOR.
S	=	SIGNAL SOURCE, TO OBTAIN ADEQUATE OUTPUT AT THE TEST FREQUENCY.
FREQUENCY OF TEST	=	400 MEGACYCLES.
R_1	=	TRANSMITTING RADIATOR.- DIPOLE, TUNED TO 400 MC. IF A TUNED DIPOLE IS USED WITH A SINGLE COAXIAL LINE, IT SHALL BE A BALANCED DIPOLE, SIMILAR TO THE AT-275/URM-28 OF SPECIFICATION MIL-I-6181. OTHER SUITABLE ANTENNA TYPES ARE: AT-141A/ARC, USED WITH THE AN/ARC-27, AT-49/APR-4, USED WITH THE AN/APR-4, AND AT-90/AP, USED WITH THE AN/APT-5. THE RADIATOR IS POSITIONED TO OBTAIN MAXIMUM FIELD INTENSITY AT THE SHIELDING ENCLOSURE.
R_2 = R_3	=	RECEIVING ANTENNA, MAY BE SIMILAR TO R_1.
C_1, C_2, C_3	=	SHIELDED TRANSMISSION-LINE CABLES. AS SHORT AS POSSIBLE, AND USED ONLY IF NECESSARY.
A	=	ATTENUATOR, CALIBRATED AT THE FREQUENCY OF TEST.
D	=	DETECTOR OF ADEQUATE SENSITIVITY, TUNED TO THE FREQUENCY OF TEST. USED ONLY AS AN EQUAL REFERENCE LEVEL INDICATOR.

FIGURE 7. Test setup for plane waves (wave impedance = 377 ohms)

4.4.4.1 Attenuator.- The attenuator used may be a 50- or 72-ohm transmission-line, constant input impedance, step attenuator. If separate units are available, they may be connected in series. A signal generator may be used to calibrate this attenuator. This attenuator shall be capable of measuring insertion losses in excess of 100 db.

4.4.4.2 Detector.- The detector may be a receiver, such as the AN/APR-4, AN/URM-28, AN/ARC-27, or a field-strength meter, such as the TS-587/U or the AN/URM-17. Detectors which cannot readily give peak indications may be used with an oscilloscope connected to their output.

4.4.4.3 Signal source.-

4.4.4.3.1 Signal source S may be a signal generator or power oscillator of sufficient cw, mcw, or pulsed cw output. The termination of cable C may be used when necessary.

4.4.4.3.2 If the signal generator has a reliable output attenuator, it may be used instead of attenuator A, to obtain an equivalent ratio of E_1/E_2 for the calculation of the attenuation of the enclosure by using the detector D at the same reference level. In this case, precaution may have to be taken to guard against leakage at the detector.

4.4.4.3.3 The signal source may be an AN/ARC-27 transmitter, a high-frequency Rollin signal generator, or an AN/APT-5 radar transmitter. An oscillator, tuned to the frequency of test may be constructed, using a high-voltage plate supply and then pulsed to obtain high-peak power. A signal source may be constructed as shown in figure 8.

4.4.4.4 Measurement of db attenuation.-

4.4.4.4.1 The attenuation of the enclosure in db is equal to the increase in the db setting of attenuator A necessary to obtain the same reference reading level in detector D when the receiving antenna is switched from position R_2 to R_3, without changing the position of R_1. The attenuation shall be a minimum of 100 db. (The attenuation in db is also essentially equal to 20 log (base 10) E_1/E_2, where E_1/E_2 are the voltages induced in R_3 and R_2, respectively.)

4.4.4.4.2 The position of R_1 with respect to the shielding-enclosure walls shall be anywhere around the enclosure in any orientation with respect to the section seams, access-panel seams, etc. Several readings shall be taken, and the minimum attenuation recorded. This minimum shall be over 100 db.

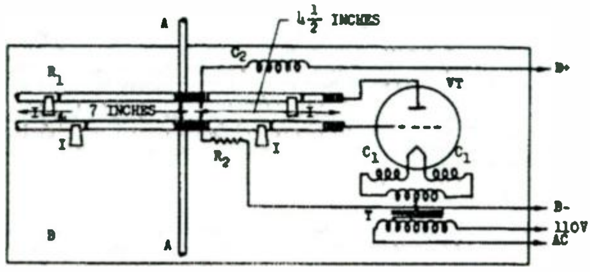
4.4.4.4.3 The test shall be made to insure that no case leakage exists at D or A. The detector D shall show no indication whatsoever above the inherent background when cable C_2 or C_3 is disconnected.

4.4.4.4.4 If D shows no indication above the inherent receiver background when the receiving antenna is inside the enclosure, the increase in db necessary to obtain receiver background when the receiving antenna is placed outside the enclosure will indicate that the room has at least that amount of attenuation. If this attenuation measurement is less than 100 db, the signal source S is not sufficiently strong, or the detector D is not sufficiently sensitive.

5. PREPARATION FOR DELIVERY

5.1 Application.- The requirements of Section 5 apply only to direct purchases by or direct shipments to the Government.

5.2 General.- Packaging, preservation, packing, labeling, and marking shall be in accordance with Specification JAN-P-100 and Standard MIL-STD-129.



A - DIPOLE ANTENNA. EACH ROD 1/16-INCH DIA. 7 FEET LONG, HORIZONTAL.

R_1 - 1/4-INCH SOLID COPPER RODS, ONE-FOURTH OF AN INCH APART, 2 INCHES FROM INSULATING BOARD.

I - PORCELAIN INSULATORS, 2 INCHES HIGH.

C_1 - CHOKES, 30 TURNS NO. 18 WIRE, 1/4-INCH DIA, SUSPENDED IN AIR.

C_2 - CHOKE, 40 TURNS NO. 28 WIRE, 1/4-INCH DIA, SUSPENDED IN AIR.

R_2 - 15,000 OHMS, 10 WATT.

S - FUSE CLIPS.

B - INSULATING BOARD.

T - FILAMENT TRANSFORMER 2-1/2 VOLT SECONDARY, CENTER TAPPED, OR TWO 1-1/2 VOLT DRY CELLS WITH PROPER LIMITING RESISTOR.

VT - VACUUM TUBE W.E. 316A, E_p = 450V, I_p = 80 MA, E_f = 2.0V, I_f = 3.65 AMP, I_g = 12 MA, OUTPUT = 7.5 WATTS.

B+ - PLATE VOLTAGE, 450V DC FROM ANY DRY CELLS OR RECTIFIED A-C POWER SUPPLY; OR 1,000V AC, RMS, 60-CYCLES FROM HIGH VOLTAGE TRANSFORMER.

SIMILAR CIRCUITS MAY BE USED, USING AN RCA 8012A OR 8025A TUBE.

FIGURE 8. Signal source for plane waves at 400 mc

5.3 A handbook of service instructions, as described in paragraph 3.5 shall accompany each complete shielding enclosure shipment, and this item shall be properly packaged and identified, in order that it will be readily available upon receipt by the procuring activity for use in installation of the shielding enclosure assembly.

6. NOTES

6.1 Intended use.- The shielding enclosure covered by this specification is intended to provide an interference-free enclosure for the operation, testing, and alinement of electronic equipments. The completely assembled enclosure is intended to attenuate electromagnetic fields from internal or external sources that cause undesirable interference with the test and alinement or operation of all types of electronic receivers. It is intended that the enclosure will be used in the continental United States and at outlying maintenance bases.

6.2 Approval of Preproduction test sample.- It is expected that the contract or purchase order will specify that one complete shielding enclosure will be required as the Preproduction sample and that the sample will be subjected to the Preproduction tests to determine compliance with the requirements of this specification. The invitation for bids and the contract should specify the point of inspection for these tests.

6.3 Precedence.- When the requirements of the contract, this specification, or applicable subsidiary specifications are in conflict, the following precedence will apply:

(a) Contract: The contract will have precedence over any specification.

(b) This specification: This specification will have precedence over all applicable subsidiary specifications. Any deviation from this specification, or from subsidiary specifications, where applicable, will be specifically approved in writing by the procuring activity or the contracting officer.

(c) Referenced specifications: Any referenced specification will have precedence over all applicable subsidiary specifications referenced therein. All referenced specifications will apply to the extent specified.

Custodians:
Navy - Bureau of Aeronautics
Air Force

MIL-B-5087A(ASG)
AMENDMENT-1
29 JANUARY 1958

MILITARY SPECIFICATION

BONDING; ELECTRICAL (FOR AIRCRAFT)

This amendment forms a part of Military Specification MIL-B-5087A(ASG), 30 July 1954, and has been approved by the Department of the Air Force and by the Navy Bureau of Aeronautics.

Page 1, paragraph 2.1: Under "SPECIFICATIONS" delete the listing:

"Air Force-Navy Aeronautical

AN-J-1 Jumpers; Bonding and Current Return"

Page 5, paragraph 3.6 Quick-disconnecting jumpers.- Delete the paragraph.

Page 5, paragraph 3.7.5: Delete the first sentence and substitute the following: "Large nonconducting projections essential to flight or housing personnel, such as vertical stabilizer parts, wing tips, astrodomes and canopies, shall have a suitable lightning path externally disposed over their exposed area and leading to the aircraft skin; however, flight characteristics, equipment performance and visibility requirements shall take precedence over these requirements." Delete the last sentence.

Page 8, paragraph 3.8.2: Add the following sentence at the end of the paragraph: "For bonding leads carrying high current, size AN-4 (AWG 4) or larger, the connection shall not be made directly to the aircraft structure but shall be made to a tab of suitable size adequately bonded to the aircraft structure."

Custodians:
Navy - Bureau of Aeronautics
Air Force

MIL-B-5087A(ASG)
30 JULY 1954
Superseding
MIL-B-5087
9 November 1949

MILITARY SPECIFICATION

BONDING; ELECTRICAL (FOR AIRCRAFT)

This specification has been approved by the Department of the Air Force and by the Navy Bureau of Aeronautics.

1. SCOPE

1.1 This specification provides requirements for the application and testing of electrical bonding on all-metal aircraft. For aircraft which are not of all-metal construction, the bonding requirements shall be determined by reference to the procuring activity.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standard, drawings, and publication, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

Military

MIL-L-6806	Lacquer; Clear, Aluminum Clad Aluminum Alloy Surfaces
MIL-W-5088	Wiring, Aircraft, Installation of

Air Force-Navy Aeronautical

AN-J-1	Jumpers; Bonding and Current Return

STANDARDS

MS25083	Jumper Assemblies, Bonding and Current Return

DRAWINGS

Air Force-Navy Aeronautical Standard Drawings

AN735	Clamp - Loop Type Bonding
AN742	Clamp - Plain, Tube Support, Loop Type, Aircraft

PUBLICATIONS

Air Force-Navy Aeronautical Bulletin

No. 143	Specifications and Standards; Use of

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Materials.- Materials shall conform to applicable specifications as specified herein. Materials that are not specifically designated shall be of the best quality, of the lightest practicable weight, and suitable for the purpose intended.

3.1.1 Jumpers.- Bonding jumpers shall conform to Standard MS25083.

3.1.2 Clamps.- Clamps shall be plain clamps conforming to Drawing AN735 or AN742. Suitable nonstandard clamps may be used where circular clamps are not usable.

3.1.3 Selection of materials.- Specifications and standards for all materials, parts, and Government certification and approval of processes and equipment, which are not specifically designated herein and which are necessary for the execution of this specification, shall be selected in accordance with ANA Bulletin No. 143, except as provided in the following paragraph.

3.1.3.1 Standard parts.- Standard parts (MS, AN, or JAN) shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, etc, may be used, provided they possess suitable properties and are replaceable by the standard parts (MS, AN, or JAN) without alteration, and provided the corresponding standard part numbers are referenced in the parts list and, if practicable, on the contractor's drawings. In the event there is no suitable corresponding standard part in effect on date of invitation for bids, commercial parts may be used provided they conform to all requirements of this specification.

3.2 Purposes of bonding.- The bonding shall be so designed and so executed as to achieve the following results:

(a) Protect the aircraft and personnel from hazards associated with lightning discharges.

(b) Provide power-current and, where applicable, fault-current return paths.

(c) Provide sufficient homogeneity and stability of conductivity for r-f currents affecting radio transmission and reception.

(d) Prevent the development of r-f potentials on conducting frames and enclosures of electrical and electronic equipment and on conducting objects adjacent to unshielded, transmitting antenna lead-ins.

(e) Protect personnel from the shock hazard resulting from equipment internally power faulted. Shock hazard may be considered non-existing for system voltages of less than 50 volts. This consideration shall in no way obviate the other requirements for bonding, if and when applicable.

(f) Prevent the accumulation of static charge which would produce radio interference or explosion hazard by periodic spark discharge or would constitute a shock hazard.

3.3 Extent of bonding.- The number of bonding jumpers to be installed shall be kept to a minimum by careful design to meet the purpose of this specification.

3.3.1 Parts impractical to bond with jumpers.- Where bonding is necessary, but bonding by jumper types may cause fouling or mechanical malfunction, other suitable means shall be employed which are in accordance with good engineering practice.

3.3.2 Intermittent electrical contact.- Intermittent electrical contact between conducting surfaces, which may become part of a ground plane or a current path, shall be prevented either by bonding, or by insulation if bonding is not necessary to meet the requirements of this specification.

3.3.3 Parts inherently bonded.- Bonding requirements are considered as being met inherently by permanent metal-to-metal joints made by welding, brazing, sweating, or swaging, or by semipermanent metal-to-metal joints of machined metal surfaces held together by lock-threaded devices, riveted joints, tie rods, or structural wires under heavy tension, pinned fittings driven tight and not subjected to wear, and clamped fittings normally permanent and immovable after installation if all insulating finishes are removed from the contact area before assembly. Insulating finishes need not be removed to comply with paragraph 3.12 if the resistance requirement is met without such removal. Insulating finishes need not be removed from between riveted surfaces, provided at least two rivets driven tight are used per joint.

3.4 Applications of bonds.- Bonding connections shall be so installed that vibration, expansion or contraction, or relative movement incident to normal service use will not break the bonding connections nor loosen them to such an extent that the resistance will vary during the movement. Bonding connections should be located in protected areas insofar as practicable, and whenever possible, they shall be located near a hand hole, inspection door, or some other accessible location, to permit ready inspection and replacement.

3.4.1 Parts shall be bonded directly to the basic aircraft structure rather than through other bonded parts insofar as practical. Bonding of shielded cables specifically for the prevention of static discharge or development of r-f potentials may be accomplished by attaching shielding grounds to the shell of the connector in lieu of to basic structure.

3.4.2 Bonding jumpers shall be installed in such manner as not to interfere in any way with the operation of movable components of the aircraft.

3.4.3 All bonding jumpers shall be kept as short and direct as possible and when practicable, shall not exceed 3 inches in length. The use of two or more standard length jumpers in series to make up the necessary length will not be allowed without approval of the procuring activity.

3.4.4 Bonding of structural members shall be accomplished without weakening any vital structure of the aircraft.

3.4.5 Bonding of tubular or cylindrical conducting members not inherently bonded shall be accomplished by means of a plain clamp, or a plain clamp with jumper. Cushion clamps are not acceptable for bonding purposes. If required, bonding clamps on flexible metallic conduit or hose shall be so installed as not to crimp or damage the conduit or hose.

3.4.6 Dissimilar metals.- In bonding, the necessity for joining dissimilar metals is frequently unavoidable. In such cases, the jumpers and other elements of the bonding connection shall be so selected as to minimize the possibility of corrosion and, if possible, to insure that if corrosion does occur, it will be in replaceable elements such as jumpers, washers, or separators rather than in the aircraft structure. Washers should not be surface treated or coated in any manner that would impair electrical conductivity. Unprotected, nonstainless steel shall not be used as a washer.

3.4.6.1 The acceptable methods of making up connections between bonding jumpers and structure of various metals are indicated in table I. Note that the metals are listed in order of decreasing activity in salt water, and the higher metal in the series will be the one attacked in case of galvanic action between any two. In general, the greater the separation between any two listed metals, the more violent the corrosive activity to be expected. The screws and nuts to be used in making the connection are indicated as type I, cadmium or zinc plated, or aluminum; and type II, stainless steel. Where either type screw is indicated as acceptable, the type II is preferred from a corrosion standpoint.

TABLE I

Metal connections

Metal structure (outer finish metal)	Connection for aluminum jumper		Connection for tinned copper jumper	
Magnesium and Mg base alloys	Direct or Mg washer	Type I screw	Al or Mg washer	Type I screw
Zinc, cadmium, aluminum and Al alloys	Direct	Type I screw	Aluminum washer	Type I screw
Steel (except stainless steel)	Direct	Type I screw	Direct	Type I screw
Tin, lead and Pb-Sn solders	Direct	Type I screw	Direct	Type I or II screw
Copper and Cu base alloys	Tinned or cadmium-plated washer	Type I or II screw	Direct	Type I or II screw
Nickel and Ni base alloys	Tinned or cadmium-plated washer	Type I or II screw	Direct	Type I or II screw
Stainless steel	Tinned or cadmium-plated washer	Type I or II screw	Direct	Type I or II screw
Silver, gold, and precious metals	Tinned or cadmium-plated washer	Type I or II screw	Direct	Type I or II screw

3.4.7 Self-tapping screws.- Self-tapping screws shall not be used for bonding purposes.

3.4.8 Jumper connections shall not be compression-fastened through plywood or other nonmetallic material.

3.5 Finish.- When necessary to remove any protective coating on metallic surfaces to meet the requirements of this specification, the completed assembly shall be refinished with its original finish or other suitable protective finish within 24 hours after inspection and within 1 week after removal of the finish. A clear finish conforming to Specification MIL-L-6806 may be used if desired to facilitate subsequent inspection. If abrasives or scrapers are used to remove any protective finish, they shall be of such a nature as to produce a clean, smooth surface without removing excessive material under the protective finish. Abrasives which will cause corrosive action if particles imbed themselves in the metal shall not be used.

3.6 Quick-disconnecting jumpers.- Quick-disconnecting jumpers shall be used only for bonding parts which are frequently removed for servicing. If a disconnect bundle is attached in any manner to an object that moves, this object shall be moved through its travel without inducing any compression, tension, or bending loads on the disconnect. Further, all splices should be staggered.

3.7 Bonding for lightning protection (except on antenna systems).- The detailed requirements given below are designed to achieve a lightning bonding system such that a lightning discharge current may be carried between any two extremities of the aircraft without risk of damaging flight controls or of producing voltages within the aircraft in excess of 500 volts. (These requirements are based upon a lightning current surge which reaches a crest value of 100,000 amperes at 10 microseconds and drops to 50,000 amperes at 20 microseconds.)

3.7.1 Individual bonding jumpers for lightning protection shall be not less, in cross-sectional area, than 6,475 circular mils in case of tinned copper-stranded cable, nor less than 10,000 circular mils in case of stranded-aluminum cable.

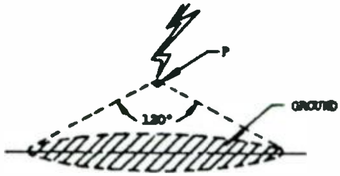
3.7.2 Contact resistance between the jumper terminal and the object or structure shall be made a minimum by cleaning the contact surfaces until they are thoroughly bright and then effecting a positive mechanical connection, in order to prevent burning.

3.7.3 Control surfaces and flaps shall have a bonding jumper across each hinge, and in any case shall have not less than a total of two jumpers. Lightning currents flowing from such surfaces to structure will divide between the jumpers, hinges, and also the control cables and levers attached to such surfaces. The division of current can be expected to vary inversely with impedance, or roughly inversely with the respective length of the discharge paths from the point of stroke to the basic structure. It may be necessary to add additional jumpers between the control surface and structure to protect the control cables and levers, in order that the length of a discharge path through the control system is at least 10 times the length of the path through the jumper or jumpers. Tab surfaces attached to control surfaces by means of piano-type hinges may be considered as self-bonded, provided the resistance across the hinge is less than 1/100 ohm.

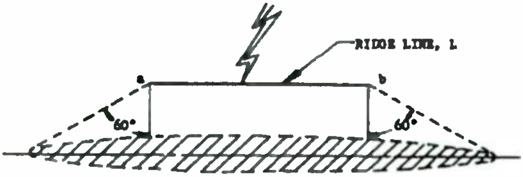
3.7.4 All external electrically isolated conducting objects, except antennas, which protrude above the aircraft surface, shall have a bonding jumper to the aircraft skin or structure.

3.7.5 Large nonconducting projections essential to flight or housing personnel, such as vertical stabilizers, wing tips, astrodomes and canopies, shall have a suitable lightning path externally disposed over their exposed area and leading to the aircraft skin. The path shall be so installed as not to impair the structural integrity of the projection. If conductors are used, they shall have a circular-mil area of not less than 6,475 for copper, nor 10,000 for aluminum. Any conducting object, including personnel inside the protrusion, shall lie within the protective zone formed by the conductive path; the protective zone being as defined, and illustrated in figure 1. If a semiconducting surface or non-linear-graded surface resistance is used to initiate a lightning path, the voltage gradient at any point along the path to the skin shall be less than the breakdown gradient to any grounded object within, and the resistive path shall be at least 1 inch wide. In the case of projections enclosing antennas, this shall be considered a design objective, and the procuring activity may waive the requirement if it is considered impractical to achieve with the present state of the art.

3.7.6 Riveted skin construction.- Close riveted skin construction which divides any lightning current over a number of rivets is considered adequate to provide a lightning discharge current path.



DRAWING 1-A LIGHTNING PROTECTIVE ZONE CREATED BY A SINGLE CONDUCTIVE POINT P, SUITABLY GROUNDED

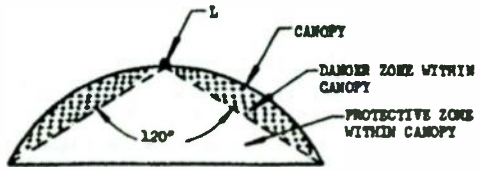


DRAWING 1-B PROTECTIVE ZONE CREATED BY A CONDUCTIVE RIDGE LINE, L, SUITABLY GROUNDED. (THIS ZONE MAY BE CONSIDERED AS DEVELOPED BY A SIMPLE MOTION OF TRANSLATION OF THE CONE IN DRAWING 1-A FROM POINT a, TO POINT b, ABOVE)

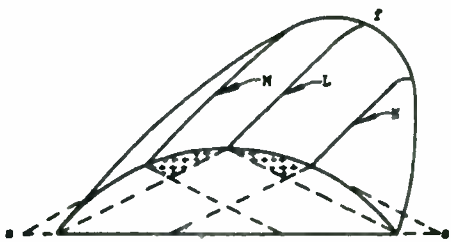
DEFINITION

THE LIGHTNING PROTECTIVE ZONE MAY BE DEFINED GEOMETRICALLY AS THE SPACE OR AREA UNDER THE APEX OF AN IMAGINARY 120° CIRCULAR CONE; OR SUCH SPACE AS IS SWEPT OUT BY ANY HYPOTHETICAL MOTION OF SUCH A CONE NORMAL TO ITS AXIS, WHEN EITHER THE APEX, OR THE RIDGE LINE DEVELOPED BY LATERAL MOTION THEREOF, IS CONSIDERED AS A CONDUCTIVE DISCHARGE POINT, OR EDGE, WHICH ACCORDINGLY IS DIRECTED AT THE LIGHTING SOURCE AND MADE SUITABLY CONDUCTIVE TO THE CONE BASE, OR GROUND

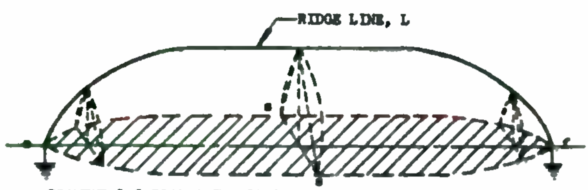
FIGURE 1 (Sheet 1 of 2). Typical protective zones



DRAWING 1-D SECTIONAL VIEW TAKEN THROUGH DRAWING 1-C AT S-S SHOWING INADEQUATE PROTECTIVE ZONE CREATED WITHIN CANOPY WITH BUT A SINGLE CONDUCTOR L, INSTALLED AS SHOWN HERE AND IN DRAWING 1-C.



DRAWING 1-E PERSPECTIVE OF SECTION, s-f-s SHOWN IN DRAWING 1-C AND 1-D, SHOWING HOW A COMPOUND PROTECTIVE ZONE MAY BE BUILT UP BY INSTALLATION OF ADDITIONAL GROUNDED CONDUCTORS, M AND N, WHICH PRODUCE OVERLAPPING PROTECTIVE ZONES.



DRAWING 1-C PROTECTIVE ZONE CREATED BY A SINGLE GROUNDED CONDUCTOR, L, LAID CENTRALLY OVER RIDGE OF TYPICAL DIELECTRIC CANOPY OR BLISTER. (THIS ZONE MAY BE CONSIDERED AS DEVELOPED BY A COMBINED RADIAL AND TRANSLATORY MOTION OF THE APEX, FROM e, TO f.)

FIGURE 1 (Sheet 2 of 2). Typical protective zones

3.8 Bonding to provide power-current return paths.-

3.8.1 The bonding between articles of equipment and the aircraft structure shall be of an adequate cross-sectional area to carry the necessary current. The power-current carrying capacity of a bond is defined as that specified by Specification MIL-W-5088 for cable conductor of the same material and of equal circular-mil area.

3.8.2 The bonding of the aircraft structure shall be adequate to permit the structure to carry the required power return currents without exceeding the voltage drop requirements of Specification MIL-W-5088.

3.9 Bonding of antenna installations.-

3.9.1 Radiating elements, exclusive of radar scanners and similar types, where the counterpoise is actually a part of the equipment, shall be so installed as to be provided with a homogeneous counterpoise, or ground plane, of negligible impedance within the operating frequency ranges of the electronic equipments involved, and of adequate dimensions to insure obtaining satisfactory radiation patterns.

3.9.2 When antennas are so designed that their efficient operation depends on a low resistance, low reactance return current path from a homogeneous ground plane to metal portions of the antenna, they shall be so installed that r-f currents flowing on the external surface of the aircraft will have a low impedance path of minimum length to the appropriate metal portions of the antenna. In particular, mating surfaces designed to be electrically continuous shall be clean metal surfaces, free from anodic film, grease, paint, lacquer, or other high-resistance film to insure negligible r-f impedance between the adjacent metal parts.

3.9.3 Provisions shall be made for circumferential r-f continuity between outer conductors of coaxial antenna transmission lines and ground planes of antennas.

3.10 Bonding to prevent the development of r-f potentials.-

3.10.1 Equipment containing electrical circuits which may produce radio frequencies, either desired or undesired, shall be so installed that there will be a continuous, low impedance path from the equipment enclosure to the aircraft structure. Bonding shall be accomplished by bare, clean, metal-to-metal contact of all mounting plate, rack, shelf, bracket, and structure mating surfaces in order to form a continuous, low impedance ground from the equipment mounting plates. If it is proposed that bonding be accomplished by other than metal-to-metal contact of the mating surfaces, the contractor shall demonstrate by laboratory test that his proposed method results in an r-f impedance of less than 80 milliohms over a frequency range of 0.2 to 20 mc for 1 bond applied in the proposed manner. Bonding jumpers shall not be used. The bond from the equipment enclosure to the mounting plate furnished with it shall comply also with these requirements, except that suitable jumpers may be used across any necessary vibration mounts.

3.10.2 All conducting items having any linear dimension greater than 12 inches that are within 1 foot of unshielded transmitting antenna lead-ins, shall have a bond to structure. Direct metal-to-metal contact with structure is desired, but if a jumper must be used, it shall be as short as possible.

3.11 Bonding to prevent shock hazard resulting from equipment internally power faulted.-

3.11.1 Metallic conduit carrying electrical wiring shall have a low resistance bond of less than 0.1 ohm to structure at each terminating and break point. The bonding path may be through the equipment at which the conduit terminates.

3.11.2 Exposed conducting frames or parts of electrical or electronic equipment shall have a low resistance bond of less than 0.1 ohm to structure. If the equipment design includes a ground terminal or pin which is internally connected to such exposed parts, a ground wire connection to such terminal will satisfy this requirement. If compliance with paragraph 3.10.1 is necessary due to the nature of the equipment, this requirement will be considered to be met as well.

3.12 Bonding to prevent the accumulation of static charge.- All isolated conducting items (except antennas), having any linear dimension greater than 3 inches, which are external to the aircraft, carry fluids in motion, or otherwise are subject to frictional charging, shall have a mechanically secure electrical connection to the aircraft structure, having a resistance when dry of less than 1/2 megohm.

4. INSPECTION AND TESTING

4.1 General.- Inspection or testing of bonding of a subassembly shall in no case be construed as waiving the inspection and testing of the complete assembly. The basic method of inspection shall be examination of the design and construction of the aircraft for conformance with the bonding principles and requirements set forth herein. Resistance measurements need be of limited nature only for verification of the existence of a bond, and shall not be considered as sole proof of satisfactory bonding. The length of jumpers, methods and materials used, and the possibility of loosening of connections in service use shall be taken into consideration as well.

4.2 Resistance.- Limited resistance measurements made as partial proof of satisfactory bonding shall be conducted on two aircraft representative of any particular model. Thereafter, additional measurements need be made only when a change in design or construction is introduced. Visual inspection shall be conducted on all other aircraft to determine that no change in method or materials has been made that would affect conformance with this specification.

4.3 Refinishing.- If, during the testing of the bonding, the finish of any part is damaged, the part shall be suitably refinished.

5. PREPARATION FOR DELIVERY

5.1 Not applicable to this specification.

6. NOTES

6.1 Intended use.- The bonding requirements and tests specified in this document are intended to insure that the structures of military aircraft are electrically stable and free from the hazards of lightning, static discharge, electrical shock, etc, and to provide for the suppression of radio interference resulting from these hazards.

6.2 Definitions.- For the purpose of this specification, the following definitions will apply:

(a) Bond (noun): A bond is any fixed union existing between two metallic objects that results in electrical conductivity between them. Such union results from either physical contact between conductive surfaces of the objects or from the addition of a firm electrical connection between them.

(b) Bonding or to bond: Aircraft electrical bonding is defined as the process of obtaining the necessary electrical conductivity between the component metallic parts of the airplane.

(c) Bonding connector: A bonding connector provides the necessary electrical conductivity between metallic parts in an airplane not in sufficient electrical contact. Examples of bonding connectors are: Bonding jumpers and bonding clamps.

(d) Conducting surfaces or objects: Conducting surfaces or objects, for the purpose of this specification, shall include all objects having a resistivity of less than 1 megohm-centimeter.

(e) Isolated surfaces or objects: For the purpose of this specification, an isolated conducting object is one that is physically separated by intervening insulation from the aircraft structure and from other conductors which are bonded to the structure.

6.3 Examples of objects which require bonding.-

	Object	Requirement	Reason
(a)	Ailerons	Bonding jumper across each hinge.	For lightning protection (paragraph 3.7.3).
(b)	Engine mounts	Bonding connectors shall be adequate to carry the power current return.	To provide a power-current path (paragraph 3.8.1)
(c)	Sleeve antennas	Circumferential metal-to-metal contact between base of sleeve and airplane skin.	To provide ground plane and r-f current return path (paragraph 3.9.2).
(d)	Radio shelves	Bonding by direct contact without jumpers.	To provide low-impedance path (paragraph 3.10).
(e)	Transformer (electrical)	Bond frame to structure	To prevent shock hazard in case fault occurs in the equipment (paragraph 3.11.2).
(f)	Fuel lines and fittings	Bond if resistance to structure exceeds 1/2 megohm.	To prevent accumulation of static charge (paragraph 3.12).
(g)	Access doors	Add bonding connection to structure if doors exceed 3 inches in any dimension and if resistance to structure exceeds 1/2 meghom.	To prevent accumulation of static charge (paragraph 3.12).

6.4 Lightning protection for external antennas (design objective).- It is desired that external antennas be designed to avoid lightning currents entering the aircraft and damaging radio equipment or causing fires. Such design may consist basically of a shunt spark-gap and series capacitor in a suitable housing.

6.5 Protection of projections housing antennas (design objective).- The protection of structures housing antennas imposes the additional requirements that the antenna operation not be adversely affected. The graded high-resistance path is indicated as one suitable means. A surface-conductor path may be broken by gaps to avoid effect on the antenna pattern. No such gap should exceed 1/16 inch in length.

6.6 Protection of nonconducting projections.-

6.6.1 Canopies may be considered as inherently protected if the flashover voltage from any point on the canopy along the surface to the aircraft skin is less than the puncture voltage through the canopy.

6.6.2 On movable canopies the lightning conductive path need not be physically continuous but may terminate in not over a 1/4-inch gap to the skin of the aircraft. In order to avoid precipitation static effects, a spring contact providing a continuous path in the closed position is desirable.

6.6.3 The design of the conductive path shall be such as to contribute a minimum to precipitation static effects. This may be accomplished by bridging the conductor gaps or shielding the conductive path with semiconductive material.

6.6.4 If visibility requirements dictate otherwise, the lightning conductor path need not continue longitudinally to structure if a good connection can be made to a spanwise grounded member.

6.7 Low r-f impedance bonds.-

6.7.1 The r-f impedance of a bond can be measured by an insertion-loss method, as described in Naval Air Development Center Report ADC-EL-172-50.

Custodians:
Army - Transportation Corps
Navy - Bureau of Aeronautics
Air Force

MIL-S-5786(USAF)
22 June 1950
Superseding
USAF No. 32331-A
6 January 1943

MILITARY SPECIFICATION

SUPPRESSOR, ELECTRICAL NOISE, RADIO FREQUENCY

1. CLASSIFICATION

1.1 Type.- This specification covers one type of radio frequency noise suppressor.

2. APPLICABLE SPECIFICATIONS AND OTHER PUBLICATIONS

2.1 The following specifications and bulletin, of the issue in effect on the date of invitation for bids, shall form a part of this specification to the extent specified herein:

2.1.1 Specifications:

2.1.1.1 Federal:

QQ-P-416 Plating; Cadmium (Electro deposited)

2.1.1.2 Military:

JAN-C-25 Capacitors, Direct-Current, Paper-Dielectric, Fixed (Hermetically Sealed in Metallic Cases)
JAN-P-101 Packaging and Packing For Overseas Shipment; Adhesive, Water-Resistant, (For Sealing Fiberboard Boxes)
JAN-P-105 Packaging and Packing For Overseas Shipment; Boxes; Wood, Cleated Plywood
JAN-P-106 Packaging and Packing For Overseas Shipment - Boxes; Wood, Nailed
JAN-P-108 Packaging and Packing For Overseas Shipment - Boxes, Fiberboard (V-Board and W-Board), Exterior and Interior
JAN-P-125 Packaging and Packing For Overseas Shipment - Barrier-Materials, Waterproof, Flexible
JAN-P-140 Packaging and Packing For Overseas Shipment - Adhesives; Water-Resistant, Case-Liner

2.1.1.3 U. S. Air Force:

32412 Capacitors; Fixed (Paper or Mica Dielectric)

40952	Drawings, Specification Data and Data Lists; Preparation of, For Communication Equipment
41065	Equipment; General Specification For Environmental Test of

2.1.1.4 U. S. Army:

94-40645	Marking; Exterior, Domestic and Export Shipment, by Contractors

2.1.2 Specification Bulletin:

2.1.2.1 Air Force-Navy Aeronautical:

143	Specifications and Standards; Use of

3. REQUIREMENTS

3.1 Material:

3.1.1 Specifications and Standards.- Specifications and standards for all materials, parts, and Government certification and approval of processes and equipment, which are not specifically designated herein and which are necessary for the execution of this specification, shall be selected in accordance with Bulletin No. 143, except as provided in the following paragraph.

3.1.1.1 Standard Parts.- AN Standard parts shall be used wherever they are suitable for the purpose, and shall be identified by their part numbers. Commercial utility parts such as screws, bolts, nuts, cotter pins, et cetera, may be used, provided they develop suitable properties and are replaceable by the AN Standard parts without alteration, and provided the corresponding AN part numbers are referenced on the drawings and in the parts lists. In applications for which no suitable corresponding AN part is in effect on date of invitation for bids, commercial parts may be used provided they conform to all requirements of this specification.

3.1.2 Protective Treatment.- When materials are used in the construction of the suppressors that are subject to corrosion in salt air or other atmospheric conditions likely to occur during service usage, they shall be protected against such corrosion in a manner that will in no way prevent compliance with the performance requirements of this specification. The use of any protective coating that will crack, chip, or scale with age or extremes of atmospheric conditions, shall be avoided.

3.2 Design and Construction.- The suppressor shall be designed to reject voltage of any frequency greater than 0.2 megacycle, as shown by the curve on

Figure 1. At frequencies from 0.2 to 3 megacycles, the attenuation provided by the suppressor alone shall equal or exceed that shown on Figure 1. The detailed mechanical and electrical design of the suppressor shall be in accordance with the requirements of this specification, which is detailed only to the extent necessary to assure mechanical and electrical performance and interchangeability.

3.2.1 The suppressor shall be constructed so that no parts will work loose in service. The suppressor shall be built to withstand the strains, jars, vibrations and other conditions incident to shipping, storage, installation and service.

3.2.1.1 The suppressor assembly when not hermetically sealed, shall employ only hermetically sealed metallic encased capacitors.

3.2.2 Protective Finish.- The suppressor case shall be constructed of a suitable metal and shall be protected against corrosion by either hot tin dipping or cadmium plating in accordance with Specification QQ-P-416. The thickness of the protective coating shall be not less than 0.0003-inch when plating is used. It shall be of high quality, smooth, fine grained, free from blisters, pits, nodules, indication of burning and other defects. Hot tin dipped coating shall be used on the suppressor cases of all hermetically sealed units to facilitate the soldering of seams.

3.2.3 Connection.- Input and output terminals to the suppressor shall be connected as shown by Figure 2.

3.2.4 Suppressors designed for use on 28V dc aircraft electrical systems shall be capable of withstanding the application of 200V dc between the terminal and case for not less than one minute. Suppressors designed for 600V dc or less, shall be capable of withstanding the application of four times their rated working voltage for one minute.

3.2.5 Insulation Resistance.- The resistance at 40°C from terminals to case, shall exceed 20 megohms.

3.2.6 Potential Drop.- The potential drop at rated current shall not exceed 0.2V.

3.2.7 Capacitors.- Capacitors used in the construction of the suppressors shall conform to Specification JAN-C-25 or Specification No. 32412.

3.3 Performance.- The filter shall be capable of operating under the following conditions:

3.3.1 Temperature.- From -50 to +50°C. The suppressor shall satisfactorily withstand continuous temperatures of 70°C, while in an inoperative condition.

3.3.2 Humidity.- Up to 95 percent relative humidity.

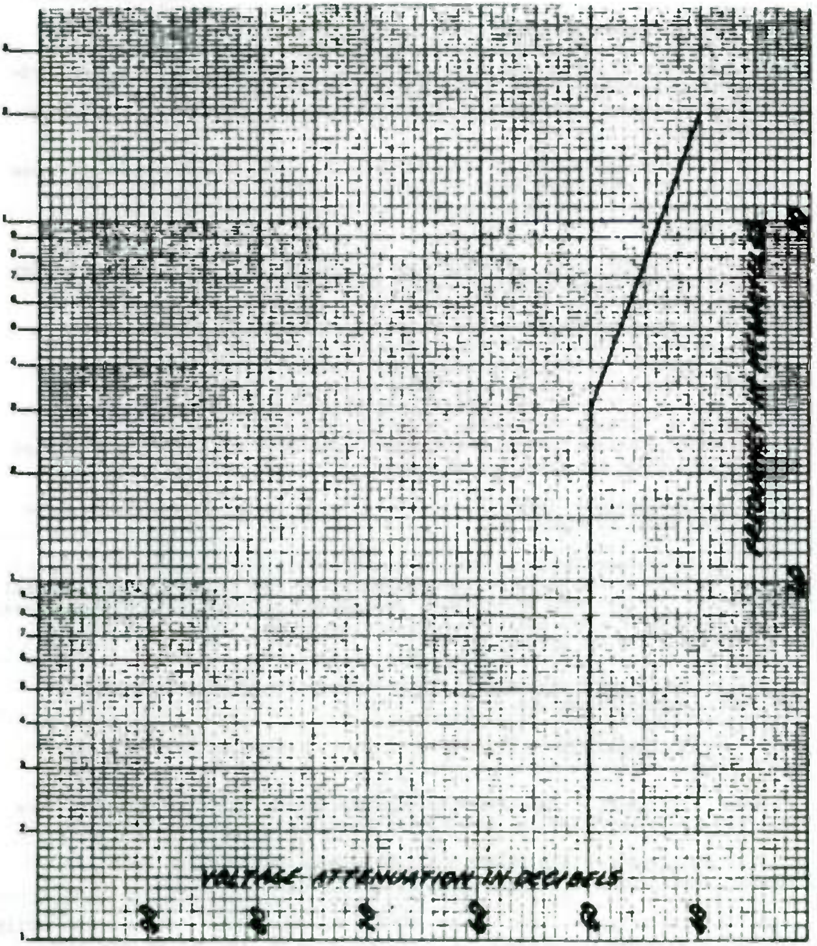
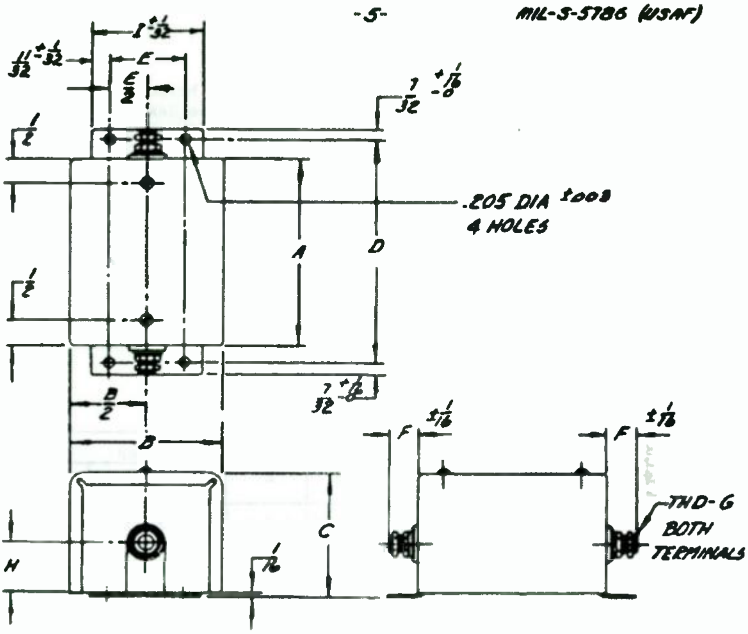


FIGURE 1



DIMENSIONS IN INCHES.
UNLESS OTHERWISE SPECIFIED,
TOLERANCES:
—ANGLES— ±1°
—DECIMALS— ±.010
—FRACTIONS— ± 1/16

FIGURE 2

3.3.3 Moisture.- Salt-laden atmosphere and other conditions which may be encountered during operation in the tropics.

3.3.4 Vibration.- Vibration consisting of simple harmonic motion having an amplitude not to exceed 0.03 of an inch, when the frequency is varied uniformly between the limits of 10 and 55 cps. The entire cycles of frequency shall be accomplished in approximately 1 minute. This motion shall be applied for a period of 5 hours directly to the mounting base of the filter.

3.3.5 Acceleration.- The equivalent effect of acceleration shall be considered as that produced by a steady linear force to any side or face of the filter unit when secured in position. The value of this force shall be 18 times the weight of the unit and shall be applied continuously for at least 10 minutes.

3.4 The dimensions, current rating, and maximum weight of the suppressor units shall conform to Figure 2 and Table I.

TABLE I

CURRENT RATING AMPS.	WT. LBS. MAX.	Dimensions - Inches								
		A MAX.	B MAX.	C MAX.	D	E	F	G	H	I
25	1.5	4	4	2-5/8	4.500	2.000	5/8	10-32	1	2-11/16
50	2.0	4	4	2-5/8	4.500	2.000	3/4	10-32	1	2-11/16
100	2.25	4	4	2-5/8	4.500	2.000	3/4	5/16-24	1	2-11/16
200	3.0	4-1/2	5	3	5.000	2.000	3/4	3/8-24	1	2-11/16

3.5 Interchangeability.- All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of Specification No. 40952.

3.6 Nameplate.- Each suppressor cover shall be legibly marked or labeled with the following information:

Suppressor, Electrical Noise, Radio Frequency
Current Rating__________
Specification MIL-S-5786
Mfr's. Part No.__________
Order No.__________
(Mfr's. Name or Trademark)
U. S. Property

3.7 Workmanship.- The suppressor, including all parts and accessories, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of soldering, wiring, and freedom of parts from burrs and sharp edges.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Unless otherwise specified, contractors' records of all inspection work and tests, giving the results of tests required to determine compliance with the requirements and tests specified herein, shall be kept complete and shall be available to the Government representative at all times. The tests shall be accomplished on articles to be supplied on the contract or order. The record or report of inspection and tests shall be signed or approved by a responsible person specifically assigned by the contractor. Contractors not having laboratory testing facilities satisfactory to the Government shall engage the services of a commercial testing laboratory capable of conducting tests to determine compliance with all the requirements and tests in the specification, and acceptable to the Government.

4.2 Inspection.- Each suppressor shall be inspected to determine compliance with the requirements specified herein.

4.3 Inspection Samples:

4.3.1 Two suppressors shall be selected at random from each lot of 100 or fraction thereof on the order and subjected to the sampling tests. These tests shall be in addition to the individual tests specified herein.

4.3.2 One suppressor of each lot of 20, one of the next lot of 80, and one of the next lot of 500 or less shall be subjected to any or all of the special tests specified herein.

4.3.3 When tests are specified on a quantity of suppressors that are selected as representative of a certain lot, and one or more of this number fails to meet the requirements, additional suppressors of the lot represented shall be tested immediately to determine the cause of failure. Individual performance tests shall not be interrupted, unless the defect is of such a nature that it will seriously affect the performance or safe use of the suppressors.

4.4 Inspection Tests.- Inspection of the suppressor shall consist of the following tests:

Individual tests
Sampling tests
Special tests

4.4.1 Individual Tests.- Each suppressor shall be subjected to the following test:

4.4.1.1 Examination of Product.- Each suppressor shall be visually inspected to determine conformance with this specification with respect to materials, workmanship, weight, and dimensions.

4.4.2 Sampling Tests:

4.4.2.1 Environmental.- The suppressor shall be subjected to the following tests conducted in accordance with Specification No. 41065. There shall be no damage as a result of these tests.

4.4.2.1.1 Low Temperature.- Method 23.

4.4.2.1.2 High Temperature.- Method 11. The suppressor shall be operated at 50°C but not at the 71°C temperature.

4.4.2.1.3 Humidity.- Method 31.

4.4.2.1.4 Salt Spray.- Method 51 for a 50 hour period.

4.4.2.2 Altitude.- The suppressor shall be operated at pressure altitudes corresponding to 40,000 feet.

4.4.3 Special Tests:

4.4.3.1 Suppressor Insertion Loss.- These measurements shall be taken at the following frequencies in megacycles: 0.20, 0.24, 0.32, 0.6, 1.0, 1.4, 1.6, 2.8, 3.6, 4.0, 7.0, 9.0, 10.0, 14.0, 16.0, and 20.0.

4.4.3.1.1 The circuit and general arrangement of the component parts for measuring insertion loss shall be in accordance with Figure 3. The ground terminal of the signal generator, suppressor case, and the ground terminal of the noise meter and coaxial cable shall be electrically connected to the metal base plate.

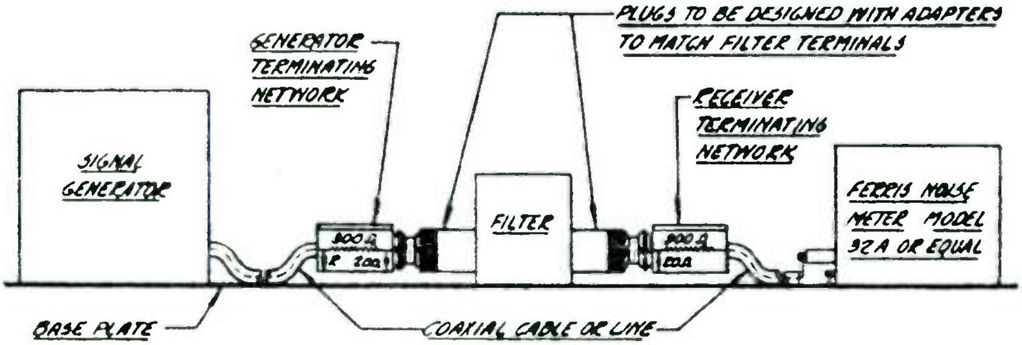
4.4.3.1.2 Method of Measurement.- The signal generator shall be set at the desired frequency and 1 volt output with the suppressor in the circuit, as shown on Figure 3. The output indicator shall then be tuned to read maximum and the reading noted. The output of the signal generator shall then be reduced to zero. The suppressor shall then be removed from the circuit, and the leads connected at the point from which the suppressor is removed. The output of the signal generator shall then be increased until the same indication is obtained on the output indicator, being sure that the output indicator is tuned to resonance. The output of the signal generator shall then be noted, and the db attenuation obtained from the formula $20 \operatorname{Log}_{10}\frac{E_1}{E_2}$ = db, where E_1 = voltage input from signal generator with suppressor in the circuit and E_2 = voltage from the signal generator with filter out of the circuit.

4.4.3.1.2.1 The curve on Figure 1 shows the minimum allowable attenuation, for all frequencies from 0.20 through 20 megacycles. The highest attenuation possible shall be obtained and this shall be taken into consideration in deciding the merit of the suppressors.

4.4.3.1.3 After completing the attenuation tests specified in 4.4.3.1, the suppressor shall be tested at its current rating for one hour to insure that the temperature rise and performance is satisfactory.

4.5 Retest.- Rejected suppressors shall not be resubmitted for inspection without furnishing full particulars concerning previous rejection and measures taken to overcome the defects.

APPROVED APPARATUS FOR INSERTION LOSS TEST OF RADIO NOISE SUPPRESSION FILTERS



NOTE - SIGNAL GENERATOR, COAXIAL CABLE, TERMINATING NETWORKS, FILTER & RECEIVER SHALL BE THOROUGHLY GROUNDED BY MEANS OF A BRASS OR COPPER BASE PLATE

ALL RESISTORS TYPE 529 AS MADE BY ERIE RESISTOR CO., ERIE PA., OR EQUAL

VALUE OF RESISTOR "R" AS SPECIFIED BY SIGNAL GENERATOR MANUFACTURER

SIGNAL GENERATOR SHALL BE MODEL 65B AS MADE BY MEASUREMENTS CORP., BOONTON, N.J., OR EQUAL.

COAXIAL LINE, TERMINATING NETWORKS, JACKS, & PLUGS MAY BE OBTAINED FROM MEASUREMENTS CORP. BOONTON, N.J., COMPLETELY ASSEMBLED.

FIGURE 3

4.6 All parts, specimens, or assemblies destroyed in making tests required by this specification and/or drawings, to determine compliance with the specification and/or drawings, shall be in addition to the quantity specified in the contract or purchase order and shall be furnished without increasing the cost of the contract or order.

5. PREPARATION FOR DELIVERY

5.1 General.- The packaging, packing, and marking requirements specified herein apply only to direct purchases by or direct shipments to the Government.

5.2 Interior Packaging.- Each suppressor shall be packaged in a fiberboard carton in accordance with Specification JAN-P-108. The carton shall be sealed with tape conforming to Specification JAN-P-101.

5.3 Exterior Packing:

5.3.1 Domestic Packing.- Unless otherwise specified, the cartons containing the suppressors shall be packed in a container constructed to insure acceptance by common or other carrier for safe transportation, at the lowest rate, to the point of delivery. Except as specified herein, the container shall conform to the requirements of the Consolidated Freight Classification Rules in effect at the time of shipment, and shall be capable of withstanding storage, rehandling, and reshipment without the necessity of repacking.

5.3.2 Export Packing.- Unless otherwise specified, for export shipment, the cartons containing the suppressors shall be packed in exterior shipping containers conforming to Specification JAN-P-105 or JAN-P-106. If plywood is used, it shall be Type A or B, Condition I. A case liner conforming to Specification JAN-P-125 shall be used and sealed in accordance with Specification JAN-P-140.

5.4 Marking:

5.4.1 Interior Package.- Each interior package shall be durably and legibly marked with the following information in such a manner that the markings will not become damaged when the packages are opened:

Suppressor, Electrical Noise, Radio Frequency
Current Rating__________
Specification MIL-S-5786
Mfr's Part No.__________
Order No.__________
Date of Manufacture__________
Quantity__________
(Mfr's Name or Trademark)
Name of Contractor (if not the same as the manufacturer)

5.4.2 Exterior Shipping Container.- The exterior shipping containers shall be marked in accordance with Specification No. 94-40645.

6. NOTES

6.1 Use.- The suppressor covered by this specification is intended for use in aircraft to attenuate the radio frequency noise influence voltage throughout the electrical system. They are for use with electrical equipment as specified herein.

6.2 Definitions:

6.2.1 Amplitude.- By "amplitude" is meant the extent of vibratory movement as measured from one extreme position to the opposite extreme position.

6.3 Sources.- When requesting publications, refer to both title and number.

6.3.1 Copies of Federal specification may be obtained upon application, accompanied by postal note, money order, coupon, or cash, to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Prices may be obtained from the Superintendent of Documents.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

(Copies of this specification may be obtained from the Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.)

WRR/epl
MCREEO14

MIL-E-6051C
17 JUNE 1960
SUPERSEDING
MIL-I-006051B (USAF)
23 JANUARY 1959

MILITARY SPECIFICATION

ELECTRICAL-ELECTRONIC SYSTEM COMPATIBILITY AND INTERFERENCE CONTROL REQUIREMENTS FOR AERONAUTICAL WEAPON SYSTEMS, ASSOCIATED SUBSYSTEMS AND AIRCRAFT

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification outlines design requirements and test procedures necessary to control the electronic interference environment of weapon systems, associated electronic and electrical subsystems, and aircraft.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY

MIL-B-5087 — Bonding; Electrical (for Aircraft).

MIL-I-6181 — Interference Control Requirements, Aircraft Equipment.

MIL-T-9107 — Test Reports, Preparation of.

MIL-D-9310 — Data for Guided Missile Weapon Systems.

MIL-F-15733 — Filters, Radio Interference.

MIL-I-26600 — Interference Control Requirements, Aeronautical Equipment.

(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 **Electro-interference environment control.** Interference produced by the weapon system shall be controlled to eliminate undesired interaction and malfunctioning of all electronic and electrical subsystems in or associated with the weapon system regardless of whether the ultimate output of the subsystems is electrical, aural, video, or mechanical. This requirement applies to the entire frequency range of the installed subsystems and those for which complete installation provisions have been made. This requirement specifically includes electronic compatibility of subsystems when operating with their installed antennas and when performing their intended radiation or reception function. There shall be neither unacceptable response nor malfunction from the output of any subsystem because of electro-interference produced by any or all of the installed or associated electrical, electronic, and other equipment of the weapon system when tested as specified herein. The data required herein shall be considered to be part of the design compatibility data and the acceptance test reporting for the system as specified in MIL-D-9310.

3.1.1 *Exemption for transients in manned aircraft.* Transient responses are exempted from the requirements specified herein if they cause no malfunctioning or unacceptable degradation of performance, are less than one second in duration, and do not recur during normal operation more frequently than once every three minutes. However, at no time shall the transient voltages across the d-c input source for transistorized equipment exceed a level that is 50 percent greater than nominal power source voltage rating. Further, any transients appearing across the antenna of transistorized equipment shall not cause malfunction.

3.2 Interference control plan. Within ninety days after approval of the weapon system configuration by the procuring activity, the contractor shall submit to the procuring activity a detailed plan outlining his interference control program, the engineering design procedures, and techniques that will be used in complying with this specification. The design aspects of the interference environment which is created by the weapon system, the radio frequency media in which it will operate, utilization of the inherent shielding characteristics of the weapon, antenna location, shielding and bonding techniques, cable routing, and all other pertinent factors shall be included in the interference control plan. Addendums shall be submitted whenever it becomes necessary to revise or supplement the information in the interference control plan or at a date approved by the contracting officer.

3.2.1 The interference control plan is intended to indicate how interference control will be accomplished for a particular system. Military usage may dictate more stringent requirements or permit less stringent requirements resulting in conserving resources. The interference control plan shall be utilized to delineate any changes, including justification deemed advisable by the contractor.

3.3 Interference test plan. The contractor shall submit a detailed test plan showing the means of implementation and the application of the test procedures in this specification to the procuring activity thirty days prior to the starting date of the electrical-electronic compatibility test specified herein, or at such later date as the contracting officer may authorize.

3.4 *Susceptibility characteristics of electrical and electronic subsystem contractor-furnished airborne equipment.* The interference control requirement stated herein shall be considered in the design phases of the weapon system. All support systems and subsystems shall incorporate interference control requirements in accordance with MIL-I-6181 for Army and Navy requirements and for Air Force requirements for class Ia equipment as defined by MIL-I-26600, and in accordance with MIL-I-26600 for other Air Force requirements. Specific attention shall be given to the interference susceptibility characteristics of the subsystem in relation to the predicted electronic interference environment. Where additional requirements are necessary, it shall be the responsibility of the weapon system contractor to impose these requirements on the subsystem. Compliance with the requirements relating to subsystems shall not relieve the weapon system contractor of the overall responsibility of controlling the weapon systems electro-interference.

3.5 Government-furnished equipment. It shall be the responsibility of the weapon system contractor to comply with the requirements stated herein in connection with Government-furnished subsystems, provided these systems comply with the requirement indicated in the interference control plan.

3.6 **Bonding.** Bonding shall be accomplished in accordance with the requirements of MIL-B-5087. Bonding shall be provided for current return paths, antenna installations, and to provide equal potential between all equipments and the basic structure of the weapon system.

3.7 **Shielding.** The materials and construction methods used on weapon systems shall provide an attenuation to electromagnetic emanations that is generally over 60 db, for magnetic fields above 150 kc. This inherent shielding effectiveness is of considerable importance in preventing interference and interaction to subsystems caused by sources outside the weapon system. A great saving in weight, space, and money is realized when maximum use is made of this shielding effectiveness. Continuity of shielding shall be maintained in order to utilize the shielding effectiveness of the fuselage to a maximum degree. All coaxial cables, waveguides, and other antenna lead-ins shall have sufficient shielding effectiveness to use this inherent shielding advantageously. A solid or triple-braided shield may be necessary.

3.8 **Interference control components.** Interference control filters shall be in accordance with MIL-F-15733. When the environmental requirements of the weapon system dictate additional requirements on interference control components, they shall be detailed in the interference control plan. (Suppression components shall be held to a minimum and shall be applied as close to the interference source.)

4. QUALITY ASSURANCE PROVISIONS

4.1 General. All tests performed by the contractor shall be described by test reports and submitted to the procuring activity for approval and possible verification. When the procuring activity waives verification, the tests and test reports shall be approved and certified. Evidence of certification and approval, either by the Government or the contractor, shall be in accordance with MIL-T-9107. The Government reserves the right to have technical representatives of the procuring activity present during testing.

4.2 **Test conditions and procedures.** In general, all electronic and electrical equipment included in the applicable weapon system specification shall be included in the weapon system test complex and shall be in normal operating condition as determined by the test procedures and techniques specified in the detailed subsystem specifications.

4.2.1 *Power limits.* When conducting acceptance tests, all electrical power shall be maintained within the limits specified in the detailed specification for the particular weapon system.

4.2.2 *Test location.* Test locations shall be chosen from areas under the contractor's or Government's control where the electromagnetic environment level is, preferably, not more than 4 db above the receiver internal background level. If this cannot be accomplished, the procuring activity shall approve the test site selected. Tests shall not be conducted in any area or at a time when the external electromagnetic environment would cast doubt as to the validity of the tests. If no reasonably satisfactory test location can be found, flight tests can be made when approved by the procuring activity.

4.2.3 *Adjustments.* During tests all electronic subsystems shall be adjusted for standard performance in an operating condition in accordance with the requirements of the subsystem performance specification for maximum indication of susceptibility.

4.2.4 *Malfunctioning.* Tests to indicate malfunctioning or unacceptable response for each subsystem shall be made at a representative number of frequencies or operating ranges of the subsystem while all subsystems or equipments are operated. Specific tests shall be conducted at the image frequencies, intermediate frequencies, local oscillator frequencies, and fundamental transmitter frequencies through the fifth harmonic frequency. Subsystems with a multitude of fundamental frequencies shall be operated on the minimum number of frequencies necessary to indicate electromagnetic compatibility. Frequencies shall be indicated in the interference test plan.

4.2.5 *Headsets*. Headsets of the proper impedance shall be used for detecting interference in the audio output of receivers. When special headsets are required for an equipment, they shall be used with that equipment when conducting these tests.

4.2.6 *Output response*. A complete description of the device used for measuring electrical, aural, video, and mechanical outputs of all electronic and electrical subsystem elements shall be included in the interference test plan.

4.2.7 *External output meter*. When an external meter is used for audio output measurements it shall have the following characteristics:

Sensitivity of 1,000 ohms/volt.

Damping factor, not more than 1.43.

Response time, not more than ½ second.

Maximum full scale, not less than 10 volts.

Minimum full scale, not more than 2 volts.

4.3 Tests.

4.3.1 *Electrical-electronic compatibility test of system*. The first electrical-electronic weapon system shall be subjected to a complete functional compatibility test. The weapon system shall be instrumented as outlined in the requested test plan to indicate compliance or noncompliance with the requirements herein. Any modification or relocation of the electronic or electrical subsystem or equipment of a production weapon system shall require a retest unless specifically waived by the procuring activity.

4.3.2 *Specification compliance test system*. Any changes or modification required as a result of the electronic compatibility test shall be incorporated in the system. In no case shall the specification compliance weapon system be more than five production systems removed from the electronic compatibility test system unless specifically authorized by the procuring activity. The contractor shall submit engineering details outlining modifications required for effecting compliance with this specification on all weapon systems produced prior to the specification test system.

4.3.3 *General acceptance test*. Each production system shall be given a limited test as outlined in the contractor's test plan to insure production compliance with the stated requirements. Government acceptance crews may conduct this test on manned systems. Each unmanned system shall be subjected to a simulated prelaunch countdown with the minimum instrumentation necessary to insure production compliance.

4.3.4 *Unacceptable response*. Unacceptable response for equipment providing aural outputs is an output greater than 1.125 microwatts (3 millivolts for 8 ohms; 26 millivolts for 600 ohms; and 50 millivolts for 2,000 ohms). The power level is the total output of the subsystem (receiver internal background noise plus extraneous interference). Output responses from any subsystem, regardless of the type of presentation other than aural response, shall be unacceptable when operation of other electrical or electronic subsystems produces a change or indication detrimental to weapon system performance.

4.3.5 *No malfunctioning.* The requirement of "no malfunctioning" shall be considered to have been met when the sum of all extraneous electro-magnetic energy that may be introduced into the most critical point of a subsystem is six db below that desired input which would produce operation, actuation, or functioning of the subsystem or equipment. Detailed test methods, instrumentation, monitoring point, and test procedures applicable to the functional usage of the particular subsystem shall be outlined in the test plan specified herein. For example, the key test point in a guidance subsystem is that relay which actuates a hydraulic valve for control purposes. In this case, an ammeter in the relay circuit, indicating no more than half the current required for operation, would be the no-malfunction limit.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable to this specification.

6. NOTES

6.1 Intended use. The purpose of this specification is to control the electromagnetic interference to the degree necessary to insure interference-free operation of electronic and electrical subsystems in all weapon systems. This specification is applicable to all items of equipment which utilize or may be affected by electrical phenomena. Such items may be operated individually, in combination, or collectively and comprise a portion of or a total weapon system.

6.2 Definitions.

6.2.1 *Weapon system.* A weapon system is composed of equipment, skills, and techniques, the composite of which forms an instrument of combat usually but not necessarily having an air vehicle as its major operational element. The complete weapon system includes all related equipment, materials, services, and personnel required solely for the operation of the air vehicle or other major elements of the system so that the instrument of combat becomes a self-sufficient unit of striking power in its intended operational environment.

6.2.2 *Support system.* A support system is a composite of equipment, skills, and techniques which, while not an instrument of combat, can perform a clearly defined function in support of a military mission. Examples are weather, air-sea rescue, logistics, intelligence, and training systems.

6.2.3 *Subsystem.* A subsystem is a major functional part of a weapon system usually consisting of several equipments, which is essential to the operational completeness of the weapon system. Examples are airframe, propulsion, guidance, navigation, and communication.

6.2.4 *Equipment.* Equipment is a major functional part of a weapon system or subsystem, usually consisting of several components, which is essential to operational completeness of the weapon system or subsystem. Examples are radio compass, radio command set, and electrical power supply.

6.2.5 *Component.* A component is a functional part of a subsystem or equipment essential to operational completeness of the subsystem or equipment. Examples are radio transmitter unit, radio receiver unit, amplifier unit, analyzer unit, computer unit, and control box.

6.2.6 *Government-furnished airborne equipment (GFAE).* GFAE is that portion of equipment which, under the terms of a military vehicle contract is procured and furnished by the military directly to the air vehicle contractor for inclusion in an air vehicle.

6.2.7 *Contractor-furnished airborne equipment (CFAE).* CFAE is that portion of equipment that is furnished and included in the air vehicle by the air vehicle contractor.

6.2.8 *Weapon system contractor*. A weapon system contractor is a prime contractor to the Government for detailed weapon system development, production, and installation of certain portions of weapon system, including necessary planning and scheduling under the supervision and final authority of the Government.

6.2.9 *Prime contractor*. A prime contractor is a contractor having a direct contract with the procuring activity.

6.2.10 *Electromagnetic environment*. The electromagnetic environment or area interference level is the signal and noise complex within which a weapon system, subsystem, or equipment is likely to be immersed for operational use.

6.2.11 *Unacceptable response*. Unacceptable response is an abnormality in the expected operation or output of a receiver or subsystem due to electro-interference which usually cannot be termed a malfunction but which may be considered intolerable.

6.2.12 *Electro-interference*. Electro-interference is an undesired electrical phenomena which is created by, or which adversely affects, any device whose normal functioning is predicated upon the utilization of electrical phenomena. Electrical interference is known coloquially and is referred to as radio and electrical noise or interference, hash, jitter, grass, hunting, ambiguity, cross modulation, TV interference (TVI), hum, etc. The word "interference" may be used alone or with appropriate modifiers in reference to some manifestation of electro-interference when mutually understood.

6.2.13 *Receiver internal background noise*. The receiver internal background noise is the receiver output obtained at the test location under the following conditions:

a. All controls at standard settings.

b. All other aircraft equipment off.

c. The actual aircraft antenna connected to the receiver input.

Custodians:
Army—Signal Corps
Navy—Bureau of Aeronautics
Air Force

Preparing activity:
Air Force

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MIL-I-6181D
25 NOVEMBER 1959
SUPERSEDING
MIL-I-006181C(USAF)
6 JUNE 1957
MIL-I-6181B
29 MAY 1953

MILITARY SPECIFICATION

INTERFERENCE CONTROL REQUIREMENTS, AIRCRAFT EQUIPMENT

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MILITARY SPECIFICATION

INTERFERENCE CONTROL REQUIREMENTS, AIRCRAFT EQUIPMENT

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 Scope. This specification covers design requirements, interference test procedures, and limits for electrical and electronic aeronautical equipment to be installed in or closely associated with aircraft.

1.2 Classification. The test procedures which are specified cover the following types of tests:

(a) Interference tests: Conducted and radiated tests which measure the magnitude of the interference signals emanating from the equipment under test.

(b) Susceptibility tests: Conducted, radiated, intermodulation and front-end rejection tests which determine whether an equipment will operate satisfactorily when exposed to external interference signals.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY

MIL-I-6051—Interference Limits and Methods of Measurements, Electrical and Electronic Installation in Airborne Weapons Systems and Associated Equipment

MIL-T-9107—Test Reports, Preparation of

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Definitions. For definitions of terms used in this specification, see section 6.

3.2 General.

3.2.1 *Operation.* Electrical and electronic equipment shall operate satisfactorily, not only independently but also in conjunction with other equipment which may be installed nearby. This requires that the operation of such equipment shall not be adversely affected by interference voltages and fields reaching it from external sources, and also requires that such equipment shall not, in itself, be a source of interference which might adversely affect the operation of other equipments. The limits specified herein are established to insure that the air vehicles will meet the requirements of Specification MIL-I-6051 or other applicable system specification.

3.2.2 *Short duration interference.* Interference resulting from manual operation of switches, but not including any electrical or electromechanical operations resulting from the manual switching, may deviate from the limits as indicated below. Ignition components used only during engine starting may deviate from the limits by 20 db. Other short duration interference may deviate from the limits as indicated below. Approval shall be obtained from the procuring activity before using these deviations.

Maximum duration	*Maximum recurrence*	*Deviation permitted*
1 second...	Once in 3 minutes...	20 db.
3 seconds...	Twice per normal operational period.	No limitation.

3.3 Design.

3.3.1 *Interference-free design.* Interference control shall be considered in the basic design of all electronic and electrical equipment, components, assemblies, and systems. This design shall be such that, before interference control components are applied, the amount of interference internally generated and propagated is the minimum achievable. The application of interference control components that must be used, such as filtering, shielding, and bonding, shall conform to good engineering practice and, whenever possible, shall be an integral part of the system. Whenever additional interference control components are necessary, the use of miniaturized components is preferred.

3.3.2 *Susceptibility.* The equipment shall be designed to minimize susceptibility to interference from other sources. The enclosing case construction shall be designed not only to minimize interference propagation, but also to minimize interference pickup from external sources. Where conducted energy on the power leads or any external leads might cause interference, the leads shall be isolated from other leads to avoid coupling, and, where necessary shall have line filters at their entry into the enclosing case. Receiving antenna inputs, or any other low-level signal circuits shall be low impedance, or of balanced design, so that coaxial or other shielded transmission lines can be used to insure an interference-free installation. Routing of receiving antenna input or any low-level signal circuit within the equipment shall be so designed and installed that interference is not picked up from power or control leads owing to coupling. Antenna or low-level signal circuit return paths or ground circuit paths shall be so arranged that interference will not occur owing to common conductive paths with other circuits, or with the enclosing case grounding path.

3.3.3 *Case shielding.* The number of mechanical discontinuities in the case (such as covers, inspection plates, and joints) shall be kept to a minimum. All necessary mechanical discontinuities in the case shall be electrically continuous across the interface of the discontinuity so as to provide low impedance current path. Multiple-point spring-located contacts are suggested as a desirable method of obtaining low impedance continuity. Ventilation openings shall be designed to permit conformance to the radiated interference limits. Electrical bonding shall be provided where access doors or cover plates form a part of the shielding. Hinges, in themselves, are not considered satisfactory conductive paths.

3.3.4 *Chassis, case, and mounting continuity.* The mating surface of the chassis, case, and mounting shall be free of all insulating finishes in order to provide a continuous electrical bond between these items and to enable the installing activity to accomplish bonding contact to the basic structure. Such surfaces shall be covered with removable protective coating to prevent corrosion prior to assembly. This requirement shall take precedence over any conflicting requirements in specifications on finishes.

3.3.5 *Component placement.* Components shall be placed and circuitry arranged to obtain minimum undesired coupling and to require a minimum number of filter components.

3.3.6 *Line shielding.* It is preferred that interference reduction be accomplished inside the equipment when such means give results equal to or better than the use of a shielded line. Any line shielding used shall be approved by the procuring activity and shall be prescribed as an installation requirement.

3.3.6.1 Under no condition shall line shielding be used for primary power leads to equipment.

3.3.6.2 Equipment requiring antennas, but not employing waveguides, shall be designed to utilize shielded coaxial cable as lead-in. When it has been determined that a single braid shield is not adequate, a double or triple braid or a solid shield shall be used as required.

3.3.7 *Interference control components.* When additional interference control components are required after careful design in accordance with the foregoing paragraphs, components shall be used that conform to the environmental requirements for the equipment. Hermetically sealed interference control components shall be used even though the equipment is not hermetically sealed. Separately installed and external components shall not be used unless specifically authorized by the procuring activity.

3.4 **Subsystems.** When the procuring activity requires that this specification be applied to a group of units or equipments that are designed to operate together, the group shall be tested as a subsystem, and each individual item does not have to be tested separately, unless individual units are so designed that they may be operated separately or as part of a different group or subsystem. It is recommended that each unit or equipment be designed to include adequate interference control measures.

3.5 **Interference control plan.** The contractor shall submit a detailed plan describing his interference control program and the engineering design procedures and techniques that will be used in complying with this specification. The design aspects of the interference control program shall be emphasized. Such information shall be included as the circuits to be shielded and filtered, methods of eliminating spurious emanations and responses, methods of eliminating spurious resonances, method of obtaining continuous shielding on equipment using pressure or hermetic seals, utilization of compartmentation, thickness of case material required to provide adequate shielding in high power RF equipment, selection of interference-free components to be used on equipment, and any other pertinent information. Any deviations from specified interference control requirements that are necessary or desirable because of the use of the equipment in the environment of a particular air vehicle shall be carefully delineated. This plan shall be submitted to the procuring activity within 90 days after the award of a contract. Addenda shall be submitted whenever it becomes necessary to revise or supplement the information in the interference control plan.

3.6 **Interference control requirements.** All equipment tested for compliance with this specification shall conform to the interference control requirements. For the purposes of this specification, all unwanted signals shall be considered as continuous wave (CW), pulsed CW, or broadband impulsive interference.

3.7 **Interference measuring equipment.** The interference measuring equipment listed in table I shall be used for determining conformance to the interference limits of this specification. Category B instruments which have been modified to meet category A requirements shall not be used as Category A instruments, unless a distinctive nonremovable label has been

TABLE I.[1]—*Acceptable interference measuring instruments*

Category	Frequency range	Commercial model	Notes	Basic military nomenclature	Manufacturer
A	0.15 to 25 mc	NM-20A, B	None	AN/PRM-1	Stoddart.
	0.15 to 30 mc	T-A/NF-105	(2)	None	Empire.
	0.15 to 1,000 mc	None	None	AN/URM-85	USA Sig Corps.
	20 to 400 mc	None	None	AN/URM-7	USA Sig Corps.
	20 to 400 mc	NM-30A	(3)	AN/URM-47	Stoddart.
	20 to 200 mc	T-1/NF-105	None	None	Empire.
	200 to 400 mc	T-2/NF-105	None	None	Empire.
	400 to 1,000 mc	T-3/NF-105	(4)	None	Empire.
	375 to 1,000 mc	NM-50A	None	AN/URM-17	Stoddart.
	1,000 to 10,000 mc	FIM, A, B	None	AN/TRM-6	Polarad.
B	0.15 to 30 mc	T-A/NF-105	(5 6)	None	Empire.
	20 to 400 mc	NM-30A	(6)	AN/URM-47	Stoddart.
	400 to 1,000 mc	T-3/NF-105	(6 7)	None	Empire.
	375 to 1,000 mc	NM-50A	(6)	AN/URM-17	Stoddart.
C-1	0.15 to 1,000 mc	NF-205	None	None	Empire.
	375 to 1,000 mc	NM-52A	None	AN/URM-17B	Stoddart.
C-2	None available at this time.				

[1] This table is subject to change upon reasonable notice to include new instruments having superior performance characteristics and to change the category of older instruments which have become obsolete.
[2] This category applies to tuning units purchased after 11 March 1957.
[3] This category applies when power supply [illegible] is used with instruments numbered 101-1 and higher.
[4] This category applies to instruments purchased after 9 May 1956.
[5] This category applies to instruments purchased prior to 11 March 1957.
[6] These instruments can be modified to category A requirements by the manufacturer.
[7] This category applies to instruments purchased prior to 9 May 1956.

attached by the instrument manufacturer; any restrictions on the usage of the modified instrument, or associated accessories, shall be indicated on the label. Instruments listed in table I are of the following categories:

(*a*) Category A: Category A instruments are those interference measuring instruments which adequately measure the parameters of interference signals as required by this specification and which are approved by the procuring activity. Any combination of category A instruments can be used for the required measurements. Category A instruments can be used without prior approval of the procuring activity.

(*b*) Category B: Category B instruments are those existing instruments which are in use but which do not adequately measure the parameters of interference signals as required by this specification.

(*c*) *Category C-1:* Category C-1 instruments are those which have recently been developed to meet category A requirements, but have not yet been evaluated by the procuring activity. These instruments shall not be used without prior approval of the procuring activity.

(*d*) *Category C-2:* Category C-2 instruments are those which have been recently developed but do not meet Category A requirements, and which can presumably be modified by the manufacturer to attain a category A rating. These instruments shall not be used without prior approval of the procuring activity.

3.7.1 *Antenna system correction.* All instrument readings of radiated interference levels shall be converted to antenna terminal open-circuit ("antenna induced") values, in accordance with correction factors furnished by the instrument manufacturer for the particular antenna type, frequency, and operating procedures used.

3.7.2 *Substitute measuring instruments.*— The use of substitute interference measuring instruments in the frequency range from 1 to 10 kilomegacycles will be considered by the procuring activity. The contractor shall submit, with the test plan, justification explaining why approved instrumentation cannot be used and shall propose substitute instrumentation and test procedures that are capable of measuring the limits. Approval for the use of substitute equipment might not be granted if a commercial test laboratoy can perform the required measurements with approved equipment within a reasonable period of time.

3.8 **Extension of frequency range.** If the contractor believes that some, or all, of the applicable interference requirements should be extended beyond the required frequency range, the interference control plan and the test plan shall be used to give proposed limits, instrumentation, methods of measurements, other pertinent information, and an explanation of the need for the extended frequency range.

4. QUALITY ASSURANCE PROVISIONS

4.1 General provisions.

4.1.1 *Testing.* All tests and test reports specified herein shall be accomplished by the contractor and shall be subject to approval and verification by the procuring activity. When the procuring activity waives verification, the tests and test reports shall be approved and verified by a qualified representative of the contractor's Quality Control department. Evidence of quality control verification and approval, either Government or contractor, shall be contained in the test report. The Government further reserves the right to have a technical representative of the procuring activity present during the testing.

4.1.2 *Test plan.* The contractor shall submit a detailed test plan to the procuring activity showing the means of implementation and the application of the test procedures in this specification to the equipment being procured. Included shall be the proposed method of testing and additional details such as:

(*a*) Nomenclature and serial numbers of test equipment to be used.

(*b*) Methods of calibration to be used.

(*c*) Detector function to be used on measuring equipment.

(*d*) Methods of loading and triggering.

(*e*) Operation of test sample.
(*f*) Control settings on test sample.
(*g*) Frequencies at which interference might be expected, local oscillator, intermediate frequencies, multipliers, etc.
(*h*) Other details requiring approval by the procuring activity.

This test plan shall be submitted before any interference testing is started.

4.1.3 *Test report.* A test report conforming to Specification MIL–T–9107 shall be submitted to the procuring activity prior to submission of the preproduction model for acceptance. In addition to the requirements in Specification MIL–T–9107, the test report shall include such details of testing as:

(*a*) Nomenclature of interference measuring equipment.
(*b*) Serial number of interference measuring equipment.
(*c*) Date of last calibration of interference measuring equipment.
(*d*) Detector functions used on interference measuring equipment.
(*e*) Internal noise level of instrument used on detector function at each test frequency.
(*f*) Descriptions of procedures used (methods of loading and triggering, etc, operation of and control settings on test sample, etc.)
(*g*) Measured line voltages to test sample.
(*h*) Test frequencies.
(*i*) Method of selection of test frequencies.
(*j*) Type of interference measured.
(*k*) Measured level of interference at each test frequency.
(*l*) Specification limit at each test frequency.
(*m*) Graphs showing items (e), (h), (k), and (l).
(*n*) Photographs of the test setup and test sample.
(*o*) Sample calculations (showing how item (k) was obtained for all antennas used).
(*p*) Description and size of screened enclosure.
(*q*) Ground plane used if test is not performed in screened enclosures.
(*r*) Description of open space area, if used.
(*s*) Ambient interference levels.
(*t*) Measured impedance of line stabilization network.
(*u*) Certification required in 4.1.7.

4.1.3.1 *Examples of sample calculation.*

(*a*)

Interference measuring equipment	NF–105
Frequency of cw measurement	460 mc
Antenna factor (DM antenna)	+8 db
Cable loss correction factor at 460 mc	+3 db
Meter reading	+40 db

Interference level = meter reading + cable loss + antenna factor = 40 + 3 + 8 = 51 db

(*b*)

Interference measuring equipment	NM–20B
Frequency of broadband radiated measurement	500 kc
Antenna factor	1
Cable loss correction factor	1
Meter reading	9 microvolts
Effective random bandwidth	3,400 cps

Impulse bandwidth = 1.4 × 3,400 = 4,760 cps = 4.760 kc

$$\text{Interference level} = \frac{(\text{meter reading})\ (\text{antenna factor})\ (\text{cable loss})}{(\text{impulse bandwidth})}$$

$$= \frac{9 \times 1 \times 1}{4.76} = 1.89 \quad \frac{\text{Antenna induced microvolts}}{\text{kc}}$$

= 65.75 db above 1 microvolt per mc (antenna induced)

4.1.3.2 *Identification of test sample.* The test sample shall be completely identified in the test report with complete nomenclature, manufacturer, and serial number. All suppression work performed on the test sample during the interference tests shall be fully described in words as well as by the test data in the test report.

4.1.4 *Operation of measuring instruments.* For both conducted and radiated interference measurements, the instruments used shall be calibrated and operated as indicated in their respective instruction manuals, unless otherwise permitted by this specification.

4.1.4.1 *Calibration.* Interference measuring instrumentation shall be maintained in a known condition of accuracy. Periodic checks on the calibration accuracy shall be made with laboratory generators. Recalibration shall be accomplished when the standardized gain setting fails to reflect a meter reading within ±20 percent of the known input signal. Substitution type measurements can be used in lieu of the calibrated method.

4.1.4.2 *Generator accuracy.* Laboratory-type signal generators and impulse generators capable of an output voltage accuracy of at least 20 percent shall be used to calibrate interference measuring instruments and for substitution measurements.

4.1.4.3 *Broadband interference measurement.* Broadband interference shall be measured by using an impulse generator with the substitution technique, or by calibrating the interference measuring instrument so that it reads directly in decibels above 1 microvolt per unit bandwidth. The peak detector function on the intereference measuring instruments shall be used for broadband and pulsed CW measurements.

4.1.4.4 *CW interference measurements.* CW interference shall be measured by calibrating the interference measuring instrument so that it reads directly in decibels above 1 microvolt or by using a signal generator with a substitution technique.

4.1.4.5 *Pulsed CW interference measurements.* Pulsed CW shall be measured in accordance with the procedures and limits used for broadband interference.

4.1.5 *Bonding measuring instrument.* Interference measuring instruments utilizing dipole antennas shall be bonded to the ground plane or shielded enclosure with the ground clip on the power cord. Instruments used for conducted measurements shall not be bonded to the ground plane except through the interconnecting coaxial cable.

4.1.5.1 The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise. This applies to rod antennas utilizing the interference measuring instrument as a counterpoise, and to rod antennas mounted on a separate counterpoise.

4.1.5.2 The interference measuring instruments shall be physically grounded with only one connection. If the copper strap is used, neither the ground clip, the ground terminals, nor the power supply shall be connected to ground.

4.1.5.3 *Test for leakage.* At any test frequency, when tuned and calibrated for a measurement, the measuring instrument, when used with a shielded dummy antenna, shall show no change from the internal background when the equipment under test is turned "on" and "off."

4.1.6 *Monitoring.* The interference measuring instrument shall be monitored with a headset, loudspeaker, oscilloscope, or other indicating devices, during all measurements. Precaution shall be taken to insure that the monitoring does not influence the meter reading on the interference measuring equipment.

4.1.7 *Test frequencies.* The interference measuring instrument or signal generator for susceptibility tests shall be slowly tuned through each continuous tuning range and the frequencies at which maximum interference or susceptibility is obtained shall be selected as test frequencies. Test frequencies shall not be selected prior to the interference test. The witnessing official or Government representative shall certify in the test report that the test frequencies were selected after each range was scanned. A minimum of three measurements shall be made in each continuous tuning range.

4.1.8 *Tuning.* The interference measuring instrument shall be tuned to and measurements made at the fundamental frequency and all harmonics of equipment containing oscillator circuits. Additional checks shall be made by scanning for and measuring any signal or spurious response that can be anticipated. (The test item shall be adjusted for mode of operation and control settings, including frequency, which may be expected to result in a maximum of interference emanation.)

4.1.9 *Powerline stabilization network.* The powerline stabilization network is shown in figure 1. One network shall be inserted in each ungrounded power supply lead supplying power to the test sample, and shall be used for the complete radio interference tests. The network enclosure shall be bonded to the ground plane for safety and radio frequency purposes.

4.1.9.1 *Performance characteristics.* The current carrying capacity of the network shown is 50 amperes dc to 800 cycles ac. The maximum voltage drop at 50 amperes is not over 2 percent of the supply voltage. The performance characteristics of this device will permit measurements of test items at the following maximum voltage ratings:

dc	600 volts
60 cycles	440 volts
400 cycles	230 volts
800 cycles	115 volts

4.2 **Test conditions.**

4.2.1 *Ambient interference level.* It is desirable that the ambient interference level during testing, measured with the test sample de-energized, be at least 6 db below the allowable specified interefrence limit. However, in the event that at the time of measurement the levels of ambient interference plus test item interference are not above the specified limit, the tested item shall be considered to have met the specified requirements. This requirement shall apply equally to both radiated and conducted ambient interference levels. A shielded enclosure may be used if necessary or desired. If a shielded enclosure is used, the minimum length shall be such that a 35-mc tuned dipole can be placed in the room with at least 12 inches clearance between the antenna extremities and the shielded enclosure.

4.2.2 *Ground plane.* A copper or brass ground plane, 0.01-inch thick minimum for copper, 0.025-inch thick minimum for brass, 12 square feet or more in area with a minimum width of 30 inches, shall be used. In a screen room, the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet and at both ends of the ground plane. The ground plane and screen room walls may be considered equivalent to an aircraft fuselage for purposes of simulating a normal installation. For large equipment systems mounted on a metal test stand, the test stand may be considered, for testing purposes, to be a part of the ground plane and shall be bonded accordingly. When a shielded room is not used, the measuring equipment may be placed on a solid support for operation. The support may be solid earth, steel or iron flooring, metal bedplate, metal-covered planking, or the like.

4.2.3 *Bonding.* Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment case and mount, together or to the ground plane. Where bonding straps are required to complete the test setup, they shall have a length not greater than 5 times the width, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid. Connections made with such bond straps shall have clean metal-to-metal contact.

4.2.3.1 *Shock and vibration isolators.* Test samples shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. Where mounting bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

4.2.3.2 *External ground terminal.* When an external terminal or connector pin is available for a ground connection on the test sample, this terminal shall be connected to the ground plane if the terminal is normally grounded in the installation. If the installation conditions are unknown, the terminal shall not be grounded.

4.2.3.3 *Portable equipment.* Portable equipment shall be tested while it is bonded to the ground plane and also when it is not bonded to the ground plane. Portable equipments that are intended to be grounded through a power cord shall not be bonded to the ground plane by other means.

4.2.4 *Power supply voltage.* The power supply voltages shall be within the tolerance specified in the detail specification for the test sample. The voltages shall be measured at the test sample terminals on the line stabilization networks.

4.2.5 *Arrangement and operating conditions.*—The general arrangement of equipment, interconnecting cable assemblies, and supporting structures shall be such as to simulate actual installation and usage insofar as practicable. The front surface of each unit shall be located 4 inches ±½ inch from the edge of the ground plane; interconnecting cables shall be routed between the units and the edge of the ground plane. In those cases where equipment size exceeds the ground plane dimensions, or where more than two line stabilization networks are required, the above instructions shall be adhered to as closely as possible. The test item shall be adjusted for mode of operation and control settings, including frequency, which may be expected to result in a maximum of interference emanation or susceptibility. All receivers and transmitters shall be tested using a shielded dummy antenna.

4.2.5.1 *Dummy antennas.* Any dummy antenna used shall have electrical characteristics which closely simulate those of the normal antenna, and should be shielded where possible. The dummy antenna shall be capable of handling the power required and shall contain any unusual components which are used in the normal antenna (such as filters, crystal diodes, etc). When the nominal antenna impedance is 50 ohms, a 50-ohm (±20 percent from 0.15–1,000 mc) dummy antenna shall be used.

4.2.5.1.1 Acceptance test of the transmitter may be with cable and dummy antenna of negligible leakage. A test of leakage shall be made with a 5-foot length of double shielded coaxial cable, used between a transmitter and its dummy antenna, to provide information on acceptable cables for actual installations.

4.2.5.2 *Test sample leads.* The test sample leads to the powerline stabilization network shall be 24 inches ±1 inch in length and shall be so arranged that the distance between the leads and from each lead to ground or grounded enclosure is approximately 2 inches. In those cases where more than two impedance stabilization networks are required, the above instructions shall be adhered to as closely as possible.

4.2.5.2.1 *Interconnecting leads.* Whenever possible, interconnecting leads between boxes comprising a test sample shall be not less than 2 feet and not more than 5 feet long. However, if the interconnecting leads are furnished as a part of the equipment, they may be used instead.

4.2.6 *Antenna orientation and positioning in shielding enclosure.* For each measuring instrument, the following procedure shall be used to determine the horizontal positioning of the antennas of the measuring instruments relative to the test sample.

4.2.6.1 *Test samples generating only broadband interference (not intended to generate or receive signals).* The following procedures shall be employed in testing for broadband interference:

(*a*) Set up antenna in accordance with figure 3, 4, 5, or 6, as applicable, opposite the center of the test sample, but without a bond from the instrument to the ground plane.

(*b*) Scan the full frequency range of the lowest tuning band of the test instrument in use for the frequency of maximum interference or susceptibility.

(*c*) Move the antenna horizontally to the position of maximum indication at that frequency, except that dipole antennas of dimension longer than the test sample shall be placed opposite its center.

(*d*) Bond instrument to ground plane when required and proceed with measurement.

4.2.6.2 *Test samples intended to generate or receive signals.* The following procedures shall be employed in testing samples intended to generate or receive signals:

(*a*) Set up antenna in accordance with figure 3, 4, 5, or 6, as applicable, opposite the center of the test sample, but without a bond from the instrument to the ground plane.

(*b*) Adjust sample for a mode of operation and control settings, including frequency, which may be expected to result in a maximum of interference or susceptibility.

(*c*) Scan the full frequency range of the test instrument in use for a maximum indication of interference or susceptibility.

(*d*) Move the antenna horizontally to the position of maximum indication of interference at that frequency.

(*e*) Bond instrument to ground plane when required and proceed with measurements.

4.2.7 *Antenna orientation and positioning (free space).* Those interference measuring instruments which use a rod antenna shall be so placed that the rod antenna is in a vertical position. Those interference measuring instruments which use a dipole antenna shall be so placed that the antenna is parallel with the test sample and on the same level as the midpoint of the test sample. The antenna shall be at the distance from the test sample specified in 4.2.6. The antenna shall be located at a point around the perimeter of the test sample where maximum interference or susceptibility signal is received. All provisions of paragraph 4.2.6 and its subparagraphs not in conflict herewith shall apply.

4.2.8 *Loads.* The equipment under test shall be loaded with the full mechanical and electrical load, or equivalent, for which it is designed. This requirement specifically includes electrical loading of the contacts of mechanisms which are designed to control electrical loads even though such loads are physically separate from the equipment under test. Operation of voltage regulators and other circuits which operate intermittently is required. The loads used shall simulate the resistance, inductance, and capacitance of the actual load.

4.3 Test methods.

4.3.1 *Conducted interference.* Radio interference voltages, in the frequency range of 0.15 to 25 mc, generated by the equipment or system in excess of the values indicated in figures 7, 8, 9, and 10 shall not appear on any conductor, external to the system, which could conduct interference to other equipment. Typical test setups for these measurements are shown in figures 11 and 12. Measurements may be omitted on leads deemed by the procuring activity to be incapable of conducting interference into other equipment.

4.3.1.1 *Conducted interference using stabilization network, 50 amperes and under.* Conducted interference measurements on power leads, 50 amperes and under shall be made by connecting the interference measuring instrument to the noise meter terminal on the line stabilization network with a 50-ohm double-shield coaxial cable. The line stabilization network shall not be used on power frequencies over 800 cps since it will probably burn up. The current probe shall be used for this application.

4.3.1.2 *Conducted interference, over 50 amperes.* Conducted interference measurements on power leads over 50 amperes shall be made with a stabilization network, designed for high current (see fig. 1), or with the network shown in figure 13, at the discretion of the contractor.

4.3.1.3 *Interconnecting leads.* Conducted interference on interconnecting and signal leads and power lines over 800 cps shall be measured by using a clamp-on interference measuring device (current probe Stoddart Aircraft Radio Co. type 91550-1, or equal).

4.3.1.3.1 *Position of probe.* The current probe shall be positioned at the point of maximum interference on the lead to be tested. A maximum movement of 5 feet along power lines is considered adequate. This maximum interference point shall be located at each test frequency. The location of the current probe shall be fully described in the test report.

4.3.2 *Radiated interference.* Radiated interference fields in excess of the values given in figures 14, 15, 16, and 17 shall not radiate from any unit, cable (including control, pulse, IF, video, antenna transmission, and power cables), or interconnecting wiring over the frequency range of 0.15 to 10,000 mc for CW and pulsed CW interference, and 0.15 to 400 mc for broadband impulse interference. This requirement includes the transmitter fundamental frequency radiating from cases or cabling, oscillator radiation, other spurious emanations, and broadband interference. This does not include radiation emanating from antennas. Test setups are illustrated in figures 3, 4, 5, and 6.

4.3.3 *Antenna-conducted spurious emanations.*

4.3.3.1 *Transmitter keyup or receiver.* The RF output of any transmitter keyup or receiver shall not exceed 40 db above 1 microvolt for CW or 60 db above 1 microvolt per mc for pulse CW interference at any frequency between 0.15 and 10,000 mc. Normally, measurements are required up to the 20th harmonic or 1,000 mc, whichever is higher, but in no event above 10,000 mc, unless the contractor can show by scanning or other means that such measurements will not result in any significant data.

4.3.3.2 *Transmitter keydown.* The transmitter shall be operated into a dummy load. A suitable coupling device shall be used to sample the transmitter output and protect the measuring equipment. Bridge "T" rejection networks, filter rejection network, or other adequate devices shall have the approval of the procuring activity. Attention should be given to oscillator frequency and harmonics, outputs from frequency multipliers and crystal saver circuits, beat frequency oscillator outputs, etc. External filters shall not be used unless approval is obtained from the procuring activity. Normally, measurements shall be made up to the 10th harmonic or 1,000 mc, whichever is higher, but in no event above 10,000 mc, unless the contractor can show by scanning or other means that such measurements will not result in any significant data.

4.3.3.2.1 *Spurious emission limits.* The peak power output shall be as follows:

(*a*) Second and third harmonics: The peak power output of the second and third harmonics of the output fundamental frequency shall be at least 60 db below that of the fundamental, or 10^{-8} watts (707 μV into 50 ohms), whichever is greater, but in no event greater than 1 watt.

(*b*) Harmonics above the third, and other spurious emissions: The peak power output of any harmonic above the third, and of any nonharmonic emission, shall be at least 80 db below that of the fundamental, or 10^{-8} watts (707 μV into 50 ohms), whichever is greater, but in no event greater than 10^{-3} watts.

4.3.4 *Susceptibility.* Equipment, such as navigation light flashers, windshield wipers, fuel pump motors, etc., deemed incapable by the procuring activity of being affected by the applied extraneous signals are exempt from susceptibility requirements. On receivers, all external and internal controls shall be set for maximum signal plus noise-to-noise ratio. All external and internal controls for squelch or limiting action shall be set to give minimum limiting action. On other other equipment all external and internal controls shall be set for maximum indication of susceptibility or, if this causes an equipment to malfunction or to become inoperable as a result of such a control setting, the critical control shall be adjusted as directed in the instruction manual. The radio frequency signal shall be modulated 30 percent, 400 or 1,000 cps, on equipments that are not designed for other modulation frequencies or for special forms of modulation. When testing other equipment, the modulation frequency or any other special form of modulation shall be used to modulate the radio frequency.

4.3.4.1 *Conducted susceptibility powerline.* The voltage specified shall be those voltages which are calculated to exist across the output terminals of the signal source when no load, other than that necessary to meet the requirements as to source impedance, is connected to the signal generator. A matching network suitable for use at required test frequencies and voltages shall be used to obtain the proper source impedance. Blocking capacitors having negligible impedance at the test frequency may be inserted in the leads from the signal source to the equipment under test if required for the protection of the signal source.

4.3.4.1.1 *Radio frequency conducted.* No change in indication, malfunctioning, or degradation of performance shall be produced in any equipment when an RF signal of 100,000 microvolts, from a source having an impedance of 50 ohms is applied to the test sample as shown in figure 18. Tests shall be made over the frequency range of 0.150 mc to 10,000 mc.

4.3.4.1.2 *Audio frequency conducted.* No change in indication, malfunctioning, or degradation of performance shall be produced in any equipment when a sine wave audio frequency signal of 3 volts rms, open circuit, is applied as shown in figure 19. Measurements shall be made over a frequency range of 50 to 15,000 cps.

4.3.4.2 *Radio frequency radiated.* No change in indications, malfunction, or degradation of performance shall be produced when the equipment is subjected to a radio frequency field. This field shall be established with a 50-ohm signal generator driving the antenna listed below. Care shall be taken to use matching networks when required. The test setup is shown in figure 20 for the rod antenna and is similar to figures 5 and 6 for the other antennas, with the signal source replacing the interference meter.

Frequency	Open-circuit microvolts	Antenna
0.15 to 25 mc	100,000	41-inch rod.
25 to 35 mc	100,000	35 mc dipole.
35 to 1,000 mc	100,000	Tuned dipole.
1,000 to 10,000 mc	100,000	Same as used for radiation test (4.3.2).

4.3.4.3 *Radio frequency radiated, alternate method (0.15 to 1,000 mc).* The open-circuit microvolts indicated in figure 21 are applied to the prescribed loop probe.

4.3.4.3.1 *Test procedure.* Test for compliance with the susceptibility limit requirements shall be made using shielded dummy antennas, shielded antenna lead-ins, and in accordance with the test procedure described in the following paragraph.

4.3.4.3.2 *Equipment required.*

(1) Loop probe MX-936/URM and 20-foot RG-9/U cable.

(2) RF signal generators covering the frequency range from 0.15 to 1,000 mc, followed by a network, if necessary, to obtain a source impedance of 50 ohms. A minimum output of 10,000 open-circuit microvolts is required.

(3) A line stabilization network for each powerline.

(4) Appropriate instruments for monitoring the normal output indication of the test sample.

(5) A shielded dummy antenna and shielded antenna lead-in.

4.3.4.3.3 *Test setup.* For radiated tests, the setup in figure 22 shall be used. The loop probe MX-936/URM is placed in close proximity at the point of maximum leakage of the equipment under test. The antenna input fitting is shown in this figure as an illustration of the point of maximum leakage. The equipment under test and all accessories shall be bonded to the ground plane as indicated. The output indicator used for monitoring, if not an integral part of the equipment under test, shall be properly shielded in order to insure that it does not constitute a point of leakage. If excessive leakage emanates from the signal generator case, tests should be made inside a shielded enclosure with the signal generator placed outside the enclosure. A shielded enclosure is recommended for all susceptibility tests in order to insure that the equipment under test is not affected by extraneous signals which may affect the internal background considerably.

4.3.4.3.4 *Test method.* The entire frequency range from 0.15 to 1,000 mc shall be scanned, using the appropriate signal generator set at maximum output and, if susceptibility occurs, the test frequency is recorded and the open-circuit microvolts of the generator is decreased to obtain threshold susceptibility. These open-circuit microvolts are now compared for compliance with the susceptibility limits of this specification. Other details of the test method are as follows:

(*a*) Locating point of maximum leakage: First the MX-936/URM loop probe is secured at close proximity to one of the following points of the case of the equipment under test; antenna input connector, any large opening, or powerline entry. The signal generator is set at maximum output and it is scanned until a frequency is found at which maximum leakage occurs. (During scanning, checks are made at the frequencies associated with the operation of the equipment.) The entire equipment is then probed at this frequency and a point is located at which maximum susceptibility is obtained.

(*b*) Placing of loop probe: The MX-936/URM loop probe is placed in close proximity at the point of maximum susceptibility determined above and oriented for maximum coupling, and then (firmly) secured.

4.3.4.4 *Receiver intermodulation.* The contractor shall test the intermodulation properties of receiving type equipment by either of the two tests following.

4.3.4.4.1 *Two-signal intermodulation test.* Receivers, preamplifiers, or antenna couplers shall not produce an output indication when two sine wave signals, representing undesired signals, are connected to the input terminals of the test sample. The two frequencies shall be chosen so that their sum or difference is equal to the test frequency and so that neither will give an output when applied alone. The magnitude of each shall be at least 100 db above 1 microvolt at the test sample terminal; one shall be modulated 30 percent with a 1,000-cycle signal, and other 30 percent with a 400-cycle signal. Impedance matching networks shall be used as required.

4.3.4.4.2 *Broadband intermodulation.* The test sample receiver shall be connected to the standard-impulse generator by means of a 50-ohm coaxial cable terminated with a 10-db resistive pi or T pad with negligible frequency characteristic in the region of the frequency of test. The impulse generator shall be turned on and the output attenuator reading for minimum perceptible receiver output, or other evidence of normal function, shall be noted. The receiver local oscillator (or each oscillator in turn for multiple-conversion superheterodyne receivers) shall be disabled and, if feasible, a 60-cycle voltage (or current) equal to the oscillator signal shall be injected into the mixer. The output of the impulse generator is then raised until the minimum perceptible receiver output, or other evidence of normal function, is again evident. This generator setting in db, less the original setting in db, is the broadband intermodulation in db. The intermodulation of undesired signals introduced across the antenna terminals shall be at least 30 db.

4.3.4.4.2.1 *Impulse generators.* Impulse generators used for intermodulation testing of receivers shall be as shown in table II.

4.3.4.5 *Receiver front-end rejection.* Front-end rejection of receivers shall be equal to or greater than the limit shown in figure 23 except that image frequencies outside the tuning range of the receiver shall be 60 db. This requirement shall apply to each tuning unit on receivers with plug-in or separate tuning units. This test shall be performed with any signal generators equipped with an accurate attenuator and capable of a signal output at least 80 db greater than the minimum signal perceptible at the tuned frequency of the particular receiver being tested. If necessary, matching networks shall be used to obtain a 50-ohm output. All measurements shall be corrected to account for any changes in output voltages owing to addition of matching networks and shall be equal to the open-circuit voltage at the output terminals. With the signal generator and receiver connected with a 50-ohm coaxial cable and tuned to the same frequency, the generator setting which gives the minimum perceptible reading above the receiver background noise shall be noted. Modulation may be used in conjunction with an output meter if the receiver is not equipped to give meter indications of CW signals. The frequency range between 150 kc and 10,000 mc shall then be scanned with the generator output preferably set at least 80 db above the output originally noted. Those frequencies at which output signals are obtained shall be investigated to obtain the generator reading which corresponds to the original receiver output signal. Since all signal generators emit a substantial amount of harmonics, care should be taken that the receiver is not erroneously rejected because of such spurious signal content.

TABLE II.—*Impulse generators*

Receiver tuning range in mc	Impulse generator type	Manufacturer
Below 500	IG–102	Empire Devices Products Corp.
	IG–115	Empire Devices Products Corp.
	Impulse generator incorporated in NF–105 or NF–205.	Empire Devices Products Corp.
	91263–1	Stoddart Aircraft Radio Co.
500–10,000	IG–118	Empire Devices Products Corp.

Front-end rejection is calculated with the following formula:

Front-end rejection = 20 log V_2/V_1

V_1 = Signal generator voltage required for minimum perceptible receiver output on channel or frequency under test.

V_2 = Signal generator voltage required for minimum perceptible receiver output at all other frequencies.

When this test cannot be accomplished owing to the possibility of crystal burnout or for other reasons, the test signals shall be injected into the test sample by using a suitable antenna fed from a signal generator. The test procedure to be used shall be included in the test plan.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable to this specification.

6. NOTES

6.1 **Intended use.** The test procedures and limits specified herein are intended to insure that aeronautical, electrical, and electronic equipments will operate properly in service use when subjected to certain radio and audio interference voltages, and will not cause the malfunction of other equipments by generation of interference voltages. This specification applies to components or systems as specified by the procuring activity or by the detail specification.

6.2 **Bonding.** The requirements of Specification MIL-B-5087 are recommended for study as a guide toward design for compliance with the bonding requirements of this specification.

6.3 **Additional information.** The information contained in the handbook "Design Techniques for Interference-Free Operation of Airborne Electronic Equipment," is recommended as a guide towards design for compliance with this specification. Organizations with a military contract can obtain the handbook, at no cost, from ASTIA, Publication No. ATI-159690. Organizations without a military contract can order the handbook as Report No. P. B. 111051 from the Department of Commerce, Office of Technical Services, Washington 25, D.C. A check for $11.50, payable to the Treasurer of the United States, must accompany the order.

6.4 **Definitions.**

6.4.1 *Interference.* Interference is defined as any electrical or electromagnetic disturbance, phenomenon, signal or emission, man-made or natural, which causes or can cause undesired response, malfunctioning or degradation of performance of electrical and electronic equipment, or premature and undesired location, detection or discovery by enemy forces, except deliberately generated interference (electronic countermeasures).

6.4.2 *Susceptibility.* As used herein, susceptibility is defined as that characteristic which causes an equipment to malfunction or exhibit an undesirable response when its case or any external lead or circuit, excepting antennas, is subjected to the specified radio or audio frequency voltage or field.

6.4.2.1 *Undesirable response.* Undesirable response is defined as a change in the normal output which causes no malfunctioning but is not required for the proper operation of the equipment.

6.4.2.2 *Threshold susceptibility.* Threshold susceptibility is defined as an undesirable response which is barely recognizable from the normal output.

6.4.2.3 *Malfunctioning.* Malfunctioning is defined as a change in the normal output which effectively destroys the proper operation of the equipment.

6.4.3 *Ambient interference.* Ambient interference, for the purpose of this specification, is the interference level emanating from sources other than the test sample, including the internal background noise of the interference measuring equipment.

6.4.4 *Internal background.* Internal background is the indication on the measuring instrument obtained when a shielded dummy antenna is connected at its input. A correct indication is obtained only if the ambient interference does not affect the instrument and the test for leakage.

6.4.5 *Antenna induced microvolts.* Antenna induced microvolts is that voltage which exists across the open-circuited antenna terminals.

6.4.6 *Impulsive interference.* For the purposes of this specification, all broadband noise, including random noise and pulsed CW is considered to be impulsive interference.

6.4.7 *Octave.* An octave is a frequency ratio of 1 to 2, i.e., from 1 to 2 mc, to 2 to 4 mc, 500 to 1,000 mc, etc.

6.4.8 *Microvolts per mc.* The nearest approach to a standard unit of measurement of broadband radio interference is in terms of microvolts per megacycle. Interference intensity in microvolts per megacycle is equal to the number of root mean square sine wave microvolts (unmodulated) applied to the input of the measuring circuit at its center frequency that will result in detector peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the impulse bandwidth of the circuit in megacycles.

6.4.9 *Impulse bandwidth.* The impulse noise bandwidth of the interference measuring instrument should be used in calculation involving broadband noise. Effective (random) bandwidth should not be used. The impulse noise bandwidth of a receiver can be readily obtained by use of an impulse generator of known output in microvolts/kc. The peak response indication of the instrument in input microvolts divided by the output of the impulse generator in microvolts/kc. is the impulse noise bandwidth of the instrument in kc.

6.4.10 *Radio receiver front-end rejection.* Front-end rejection is the measured capability of a receiver, expressed in decibels, in rejecting signals at the antenna terminals that are outside the channel, or frequency, to which the receiver is tuned.

6.4.11 *Open space.* The term "open space," as used in this specification, is intended to designate an ideal site for radiated interference measurements. This ideal site should be open, flat terrain at a considerable distance (100 feet or more) from buildings, electric powerlines, fences, trees, underground cables, and pipe lines. This site should have a sufficiently low ambient level of radiated interference to permit testing to the governing radiated interference limit at any test frequency selected.

6.5 Standard antennas. Because of the nonuniformity of the electromagnetic field which usually exists close to a test sample, it is imperative that tests for radiated interference be conducted with antennas identical to those specified. Attempts to correlate results obtained with other antennas by reducing the results to microvolts per meter, based upon plane wave calculations and antenna effective height, may be erroneous and will not be accepted as indicating compliance with this specification.

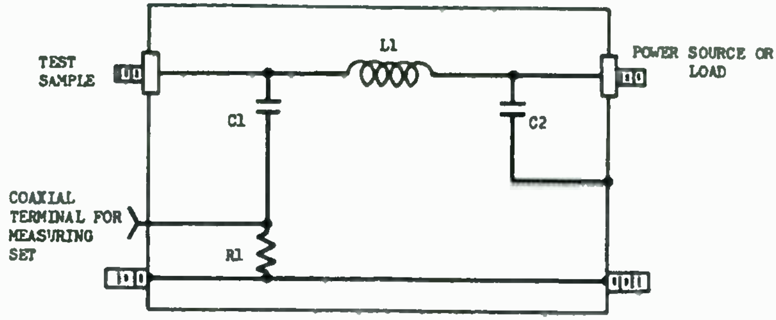
6.6 Operator and observer positions. In those cases where the operator's or observer's location seems to vary a measurement reading, a minimum distance of 3 feet should be maintained between his body and the antenna; the operator should change position slightly until a maximum reading is obtained. In all cases, as few observers as possible should be present in the screen room during the radiated measurements.

6.7 Impulse generators. Satisfactory impulse generators can be obtained from Empire Devices Products Corp., Amsterdam, N.Y., and from Stoddart Aircraft Radio Co., 6644 Santa Monica Boulevard, Hollywood 38, Calif.

6.8 Loop probe MX-936/URM. Loop probe MX-936/URM is commercially available from White Industries, Inc., 421 West 54th Street, New York, N.Y., or from National Co., Inc., 61 Sherman Street, Malden, Mass. (Part No. R8061-1.)

6.9 Coaxial switches. Coaxial switches can be used to advantage for measurements where many manipulations of coaxial cables are required during tests.

6.10 RF radiation hazard. A tri-service limit for exposure to RF radiation has been established at .01 watts/cm.² at any frequency. It is possible to encounter even higher power densities than the established safe maximum limit during the course of tests required by this specification; however, these exceedingly high densities are usually localized. The human eye is highly vulnerable to RF radiation. Adequate safety precautions are recommended.



ENCLOSURE DATA: 14 GAGE (B&S) ALUMINUM SUGGESTED SIZE 9-3/8 IN. BY 4 BY 4 IN.
FORM DATA: 5-1/4 IN. LENGTH, 3 IN. DIA (OD), .125 IN. WALL DRILL 3/8 IN. HOLE 7/16 IN. FROM EACH END.
WIRE DATA: AWG 6, 600 VOLT, .310 IN. DIA (OD).
COIL DATA: L1 = 5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4 IN. WINDING LENGTH.
CAPACITOR: C1 SHALL BE MOUNTED ON 1 IN. INSULATING BLOCK ABOVE GROUND.
CAPACITOR DATA: C1 = .1 UF, 600-VOLT DC, BATHTUB.
C2 = 1 UF, 600-VOLT DC, BATHTUB, SINGLE TERMINAL CASE MOUNTED ON GROUND.
RESISTOR DATA: R1 = 5,000-OHM, 5-WATT CARBON.

1. THE VALUES GIVEN FOR THE COMPONENT PARTS OF THE NETWORK ARE NOMINAL. REGARDLESS OF THE CONSTRUCTION OR DEVIATION FROM NOMINAL VALUES, THE NETWORK MUST HAVE AN IMPEDANCE WITHIN 20 PERCENT OF THAT GIVEN IN FIGURE 2.

2. CONNECTING LEADS TO CONDENSERS AND RESISTORS SHOULD BE AS NEARLY AS POSSIBLE TO ZERO LENGTH.

3. NETWORKS MAY ALSO BE CONSTRUCTED HAVING A 1-OHM SERIES RESISTOR BETWEEN THE LINE AND CAPACITOR C2. THIS 1-OHM RESISTOR SHALL BE MADE UP FROM TEN 10-OHM, 1-WATT COMPOSITION RESISTORS.

4. THE DATA GIVEN IN THIS FIGURE IS SUITABLE FOR THE CONSTRUCTION OF 50-AMPERE NETWORKS. LARGER CURRENT-CARRYING NETWORKS MAY BE CONSTUCTED BY INCREASING THE WIRE SIZE GIVEN FOR THE COIL AND THE SIZE OF THE OVERALL ENCLOSURE.

5. THE 50-OHM TRANSMISSION LINE SHOULD BE EXTENDED WITHIN THE ENCLOSURE RIGHT UP TO THE LOCATION WHERE IT CONNECTS WITH CAPACITOR C1.

6. CAUTION: THE NETWORK SHALL BE PROMINENTLY AND PERMANENTLY MARKED "CAUTION - SHOCK HAZARD - CONNECT CASE TO EARTH GROUND BEFORE CONNECTING A-C POWER LINE."

7. NETWORKS PROCURED PRIOR TO THE DATE OF THIS SPECIFICATION, BUT MEETING THE IMPEDANCE REQUIREMENTS OF FIGURE 2, MAY STILL BE USED.

8. EACH NETWORK SHALL BE PERMANENTLY LABELED WITH THE FOLLOWING DATA: CURRENT RATING IN AMPERES AND VOLTAGE RATING IN VOLTS AT DIRECT CURRENT, 60, 400, AND 800 CPS.

FIGURE 1. *Powerline stabilization network schematic diagram.*

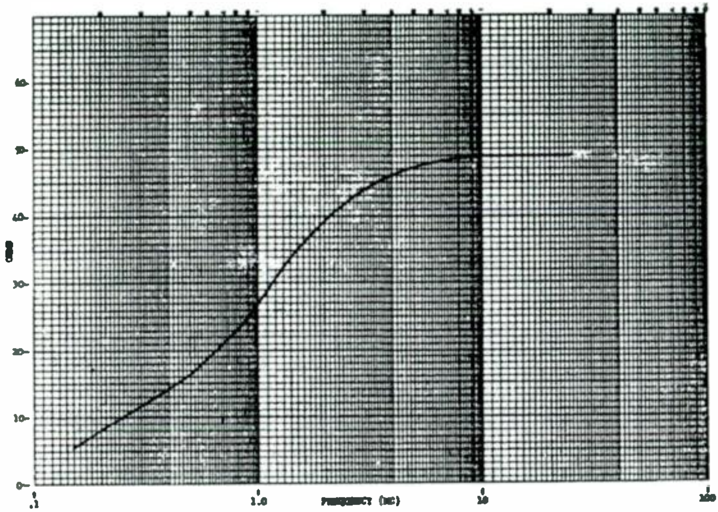


FIGURE 2. *Input impedance at test sample terminal of stabilization network with coaxial connector terminated in 50 ohms, power terminal open.*

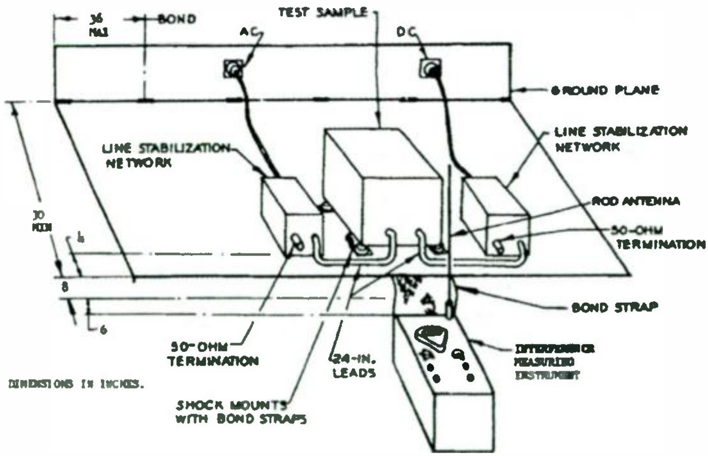


FIGURE 3. *Typical test setup for radiated measurements (rod antenna).*

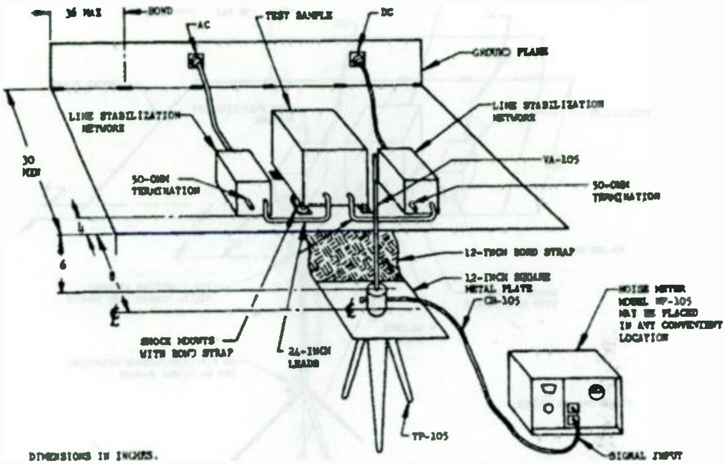


Figure 4. *Test setup for radiated measurements (rod antenna).*

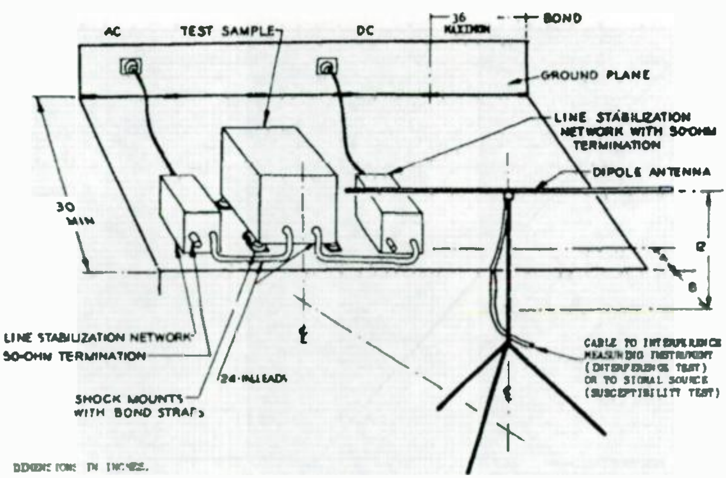


Figure 5. *Typical test setup for radiated and susceptibility measurements (dipole antenna).*

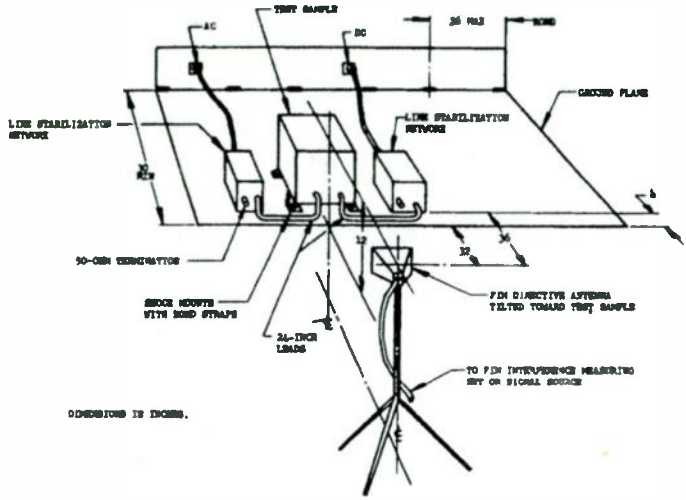


FIGURE 6. *Typical test setup for radiated and susceptibility measurements (microwave-directive antenna).*

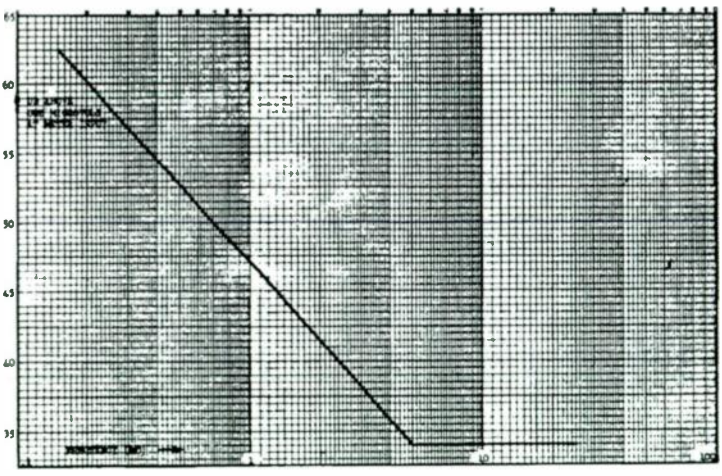


FIGURE 7. *Narrow band (CW) conducted interference limits using stabilization network.*

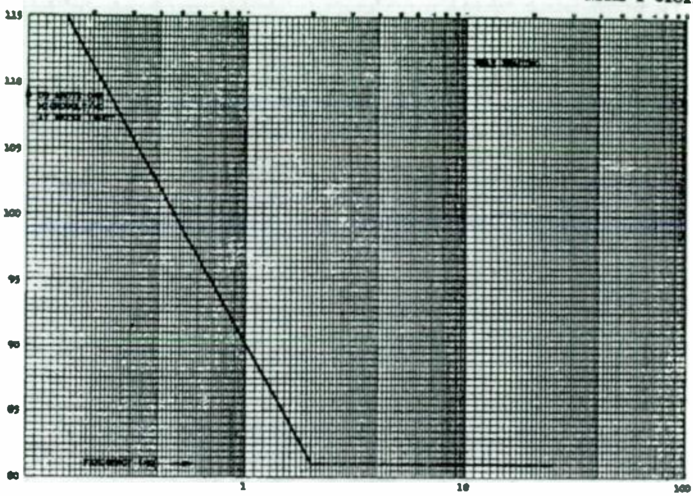


Figure 8. *Broadband and pulsed CW conducted interference limits using stabilization network.*

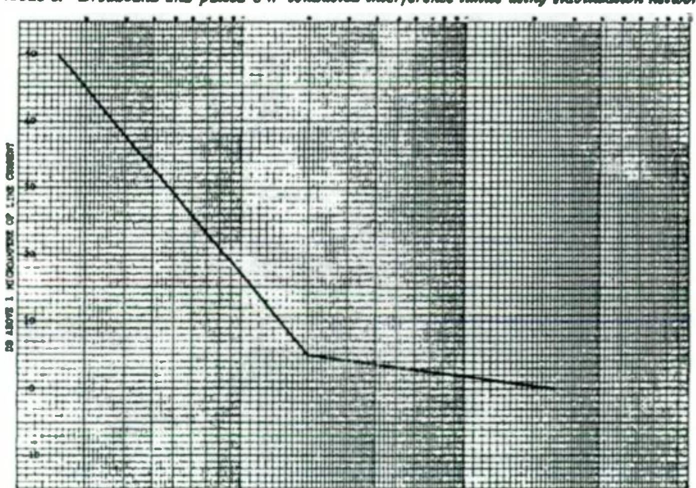


Figure 9. *Narrow band (CW) conducted interference limits using current probe.*

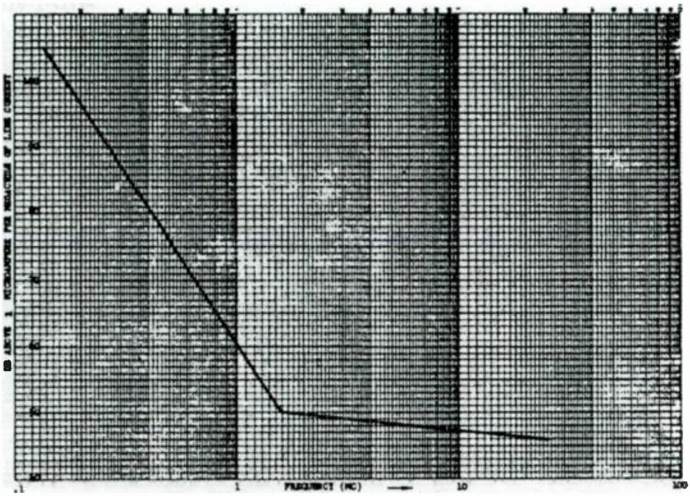


FIGURE 10. *Broadband and pulsed CW conducted interference limits using current probe.*

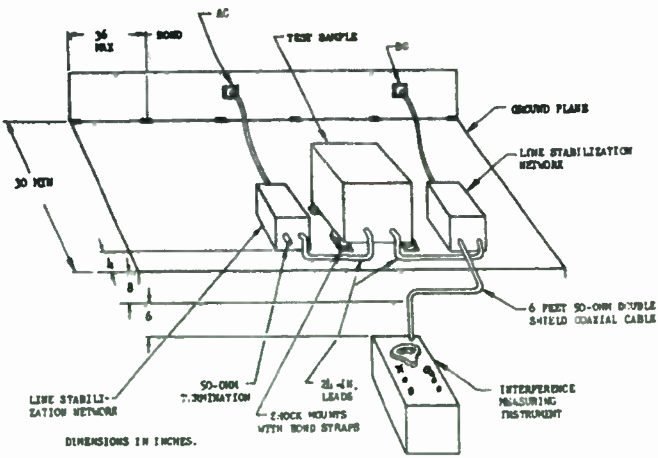


FIGURE 11. *Typical test setup for conducted interference measurements.*

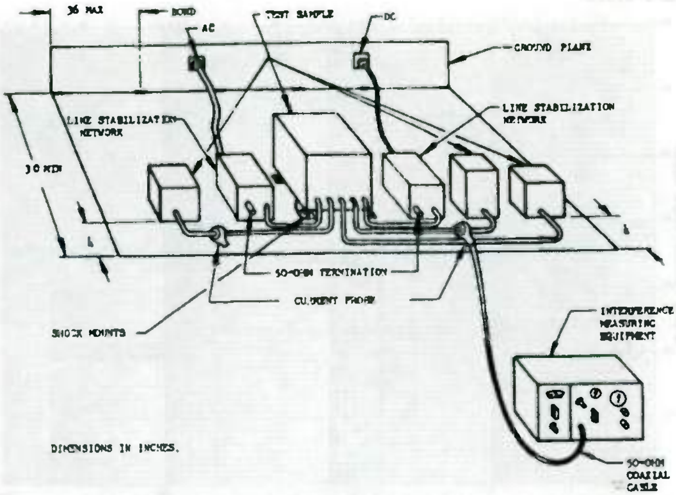
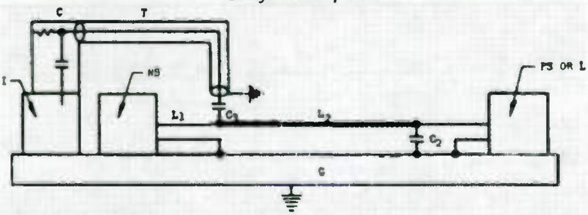


FIGURE 12. *Typical test setup for conducted interference measurements on interconnecting leads using current probe.*



I = AN/PRM-1 METER. G = GROUND COPPER TABLE.

C = CU-197/PRM-1 COUPLER (50-OHM AND 10-MMFD. DUMMY).

T = TRANSMISSION LINE CABLE, 50-OHM, RG-8/U.

C_1 = 0.1 MFD. C_2 = 1.0 MFD.

NS = NOISE SOURCE, TEST SAMPLE.

L_1 = TEST SAMPLE LEADS, 24 INCHES LONG, 2 INCHES APART, 2 INCHES ABOVE GROUND, UNSHIELDED.

L_2 = 10-FOOT LINE, UNSHIELDED, INSULATED, PLACED FLAT ON GROUND.

PS OR L = POWER SUPPLY OR LOAD.

L_1 AND L_2 OF PROPER SIZE TO CARRY LINE CURRENT.

L_2 MAY BE ZIGZAGGED IF DESIRED WHEN TABLE G IS NOT OF SUFFICIENT LENGTH.

FIGURE 13. *Network for conducted interference measurements, line current above 50 amps.*

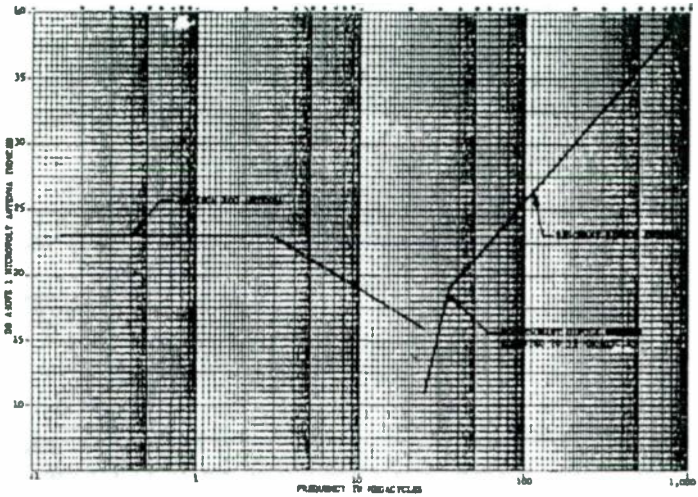


FIGURE 14. *Narrow band (CW) radiated interference limits.*

FIGURE 15. *Narrow band (CW) radiated limits.*

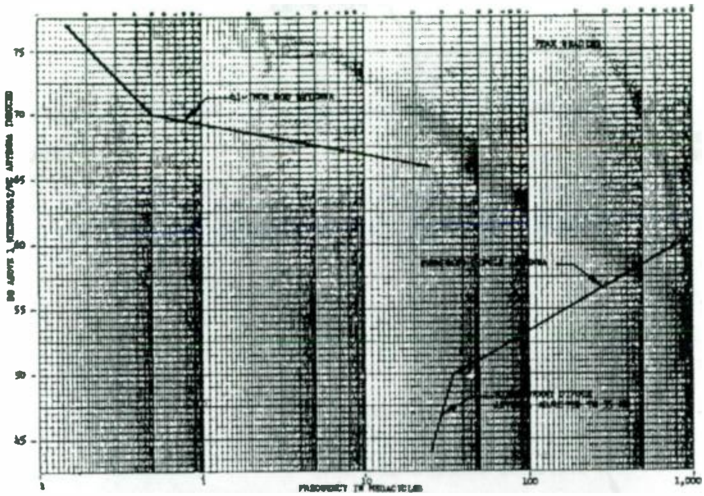


Figure 16. *Broadband and pulsed CW radiated interference limits.*

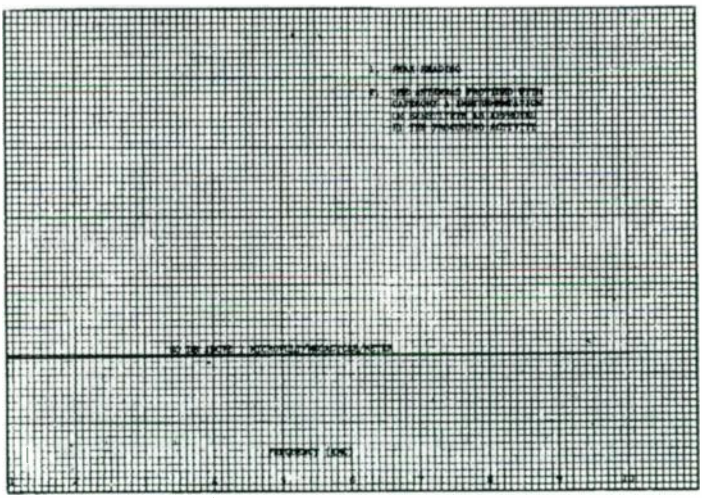


Figure 17. *Pulsed CW radiated limits.*

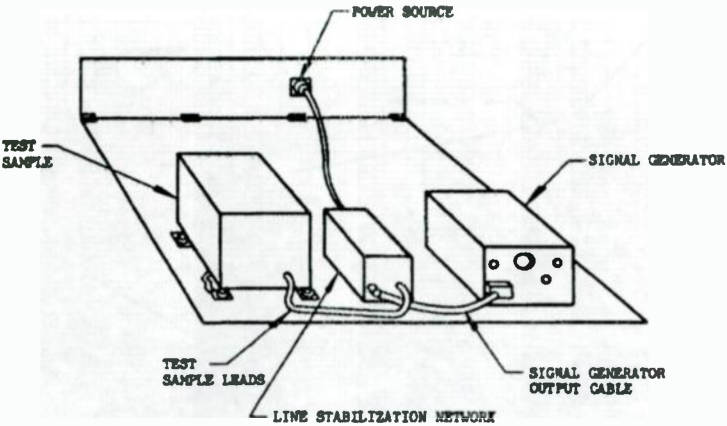
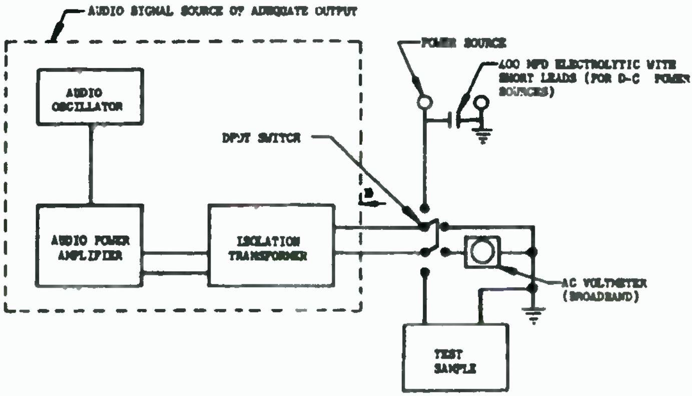


FIGURE 18. *RF susceptibility test setup (conducted).*



1. AUDIO SIGNAL SOURCE SHALL HAVE A SOURCE IMPEDANCE NOT EXCEEDING 0.6 OHM.
2. THE VOLTMETER SHALL READ AN OPEN-CIRCUIT VOLTAGE (TEST SAMPLE DISCONNECTED) OF 3V RMS.
3. ISOLATION TRANSFORMER SHALL CARRY ALL CURRENTS WITHOUT SATURATION.
4. SERIES CONDENSER ON AC VOLTMETER SHALL HAVE REACTANCE NOT GREATER THAN 1/10 METER IMPEDANCE.
5. A VARIABLE AUTOTRANSFORMER CAN BE USED BETWEEN THE ISOLATION TRANSFORMER AND THE AMPLIFIER TO ADJUST FOR THE REQUIRED IMPEDANCE.
6. THE ABOVE VARIABLE AUTOTRANSFORMER MAY ALSO BE USED TO PREVENT HIGH AC LINE VOLTAGES FROM FEEDING INTO THE AMPLIFIER.

FIGURE 19. *AF susceptibility test setup.*

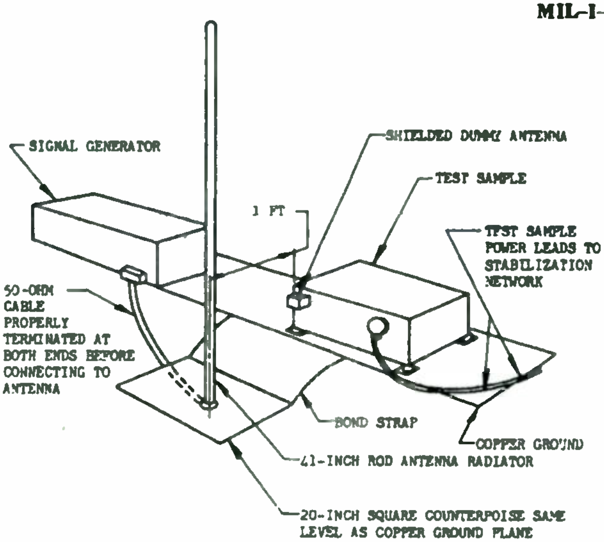


FIGURE 20. *Susceptibility radiated test setup (rod antenna).*

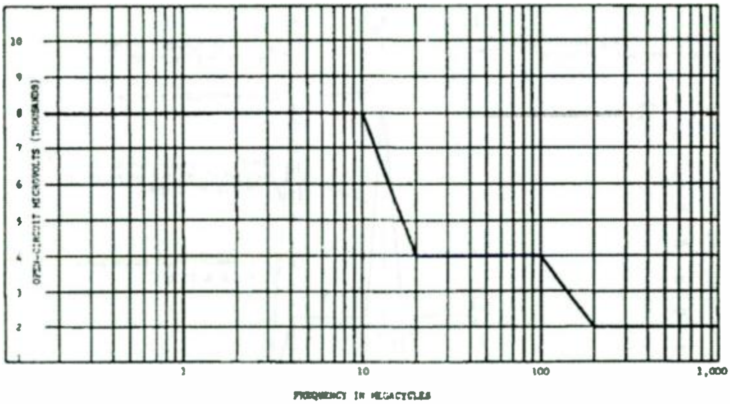


FIGURE 21. *Proposed limits for radiated RF susceptibility tests (equipments using shielded antenna lead-ins).*

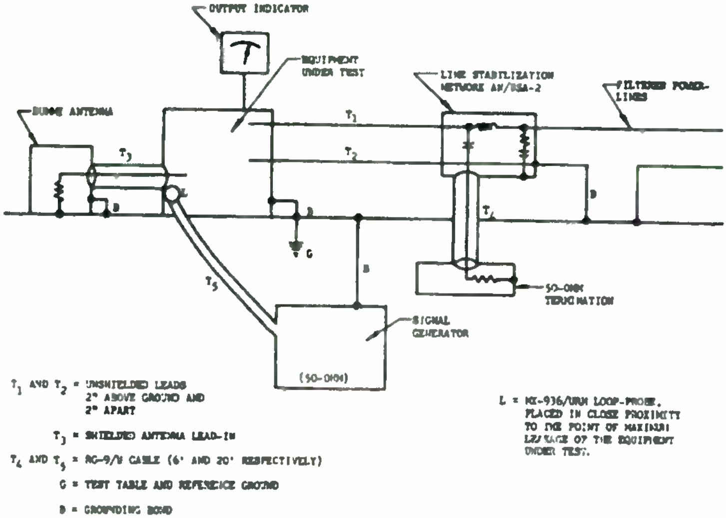


FIGURE 22. *Setup for radiated RF susceptibility tests.*

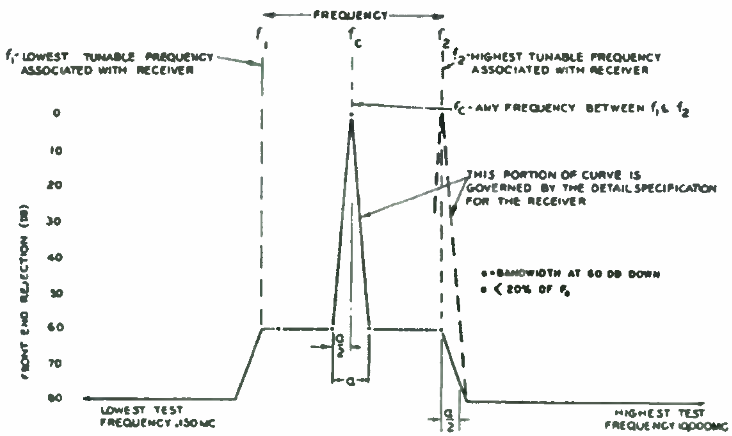


FIGURE 23. *Required receiver front-end rejection.*

Notice: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Army—Signal Corps
Navy—Bureau of Aeronautics
Air Force

Preparing activity:

Air Force

INDEX

TABLES

FIGURES

MIL-I-6722
9 June 1950

MILITARY SPECIFICATION

INTERFERENCE LIMITS; PROPELLER SYSTEMS RADIO

This specification was approved by the Departments of the Army, the Navy, and the Air Force for use of procurement services of the respective Departments, and supersedes the following specification:

AN-I-40
6 August 1947

This specification consists of this cover sheet and Specification AN-I-40, dated 6 August 1947, without modification.

Copies of this specification may be obtained from the Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio; or the Commanding Officer, U. S. Naval Air Station, Johnsville, Pennsylvania.

When a request for this specification is received by a supplying activity, it will be necessary to attach this cover sheet to the pertinent specification before issue.

Custodian:
Air Force

Other interest:
Navy - BuAer

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PO 80774 2

AN-1-40
6 August 1947

ARMY-NAVY AERONAUTICAL SPECIFICATION
INTERFERENCE LIMITS; PROPELLER SYSTEMS RADIO

This specification was approved on the above date by joint action of the War and Navy Departments, for use in the procurement of aeronautical supplies and shall become effective not later than 1 March 1948. It may be put into effect, however, at any earlier date after promulgation.

A. APPLICATION.

A-1. This specification presents the methods and limits to be used in the testing of propeller systems for radio interference. Propeller systems to which this specification is applicable are, among others, those using electrical means for:

- Blade - pitch change
- Blade - pitch reversal
- Governing
- Governor setting
- Synchronizing
- Anti-icing
- Pitch Indication

Equipment which operates only once per flight for a period of less than three seconds or during ground engine starting only, may be exempted from the application of this specification upon the contractor's request and formal approval by the Procuring Agency.

A-2. Approval by the Procuring Agency based upon this specification shall constitute acceptance of the radio-interference performance of a particular propeller system described in the corresponding propeller installation - model specification. Appropriate portions of this specification may be applied at the discretion of the Procuring Agency to the testing of the components of propeller systems.

B. APPLICABLE SPECIFICATIONS.

B-1. Publications.- The following publications of the issue in effect on date of invitation for bids shall form a part of this specification to the extent specified herein:

B-1a. Army-Navy Aeronautical Specification.-

AN-P-23 Propellers; Installation Model Specification (Instruction for Preparation)

B-1b. Army-Navy Aeronautical Standard Drawing.-

AN3065 Probe - Ignition System Radio Noise Test

C. METHODS OF INSPECTION AND TESTS.

C-1. Method of Tests:

C-1a. Two general methods of test are set forth herein: the engine test and the bench test. The choice of the particular method or methods which shall be used shall be determined by the Procuring Agency.

C-2. Accomplishment of Tests.-

C-2a. The radio interference tests shall be accomplished by the Procuring Agency or under the supervision of an authorized representative of the Procuring Agency.

C-3. Test Installation:

C-3a. Engine Test Method.- The propeller to be tested shall be mounted in operating condition on an aircraft engine together with all associated equipment necessary to form the propeller system. The engine shall be of the same type and model as that to be used in the aircraft with the propeller being tested, unless specific approval is obtained from the Procuring Agency for the use of a different type of model of engine.

C-3a(1). All necessary measures shall be taken to insure that the engine ignition system, the equipment used, and all other auxiliary electrical equipment in the vicinity of the test location, shall cause a negligible amount of radio interference as measured with the test equipment.

C-3a(2). The lengths of the conductors associated with the propeller system shall be as required to make a convenient installation. Shielding of the specified type and size shall be used on those conductors and components for which shielding is specified in the installation model specification. These conductors and components which are specified in the installation model specification as being unshielded shall, in the engine test stand be unshielded.

C-3a(3). At each measurement point arrangements shall be such that a coaxial cable (type RG-8/U) can be connected in turn between each system conductor and ground with the shield of the coaxial cable being connected to the ground. This cable shall be connected on the other end to the equipment for measuring MHF conducted interference and shall be of the shortest practicable length.

C-3a(4). A ten foot length of aircraft antenna wire shall be mounted perpendicular to the axis of rotation of the propeller, in such a position that the extended axis of rotation of the propeller will pass through the midpoint of the antenna. The antenna shall be located at a distance from the propeller disc equal to 33 plus or minus 1 percent of the diameter of the propeller. Standard fittings and insulators shall be used to hold this antenna in position. The arrangements are outlined in Figure 1 of this specification. This antenna shall be connected at one end by the shortest practicable length of coaxial cable (type RG-8/U) to the equipment for measuring MHF radiated interference. The central conductor shall be connected to the antenna wire with the shield left unconnected at the antenna end.

C-3a(5). A VHF mast antenna shall be centrally located by non-metallic cables in a vertical position in front of the propeller disc along the axis of rotation of the propeller, distant from the propeller disc an amount equal to 25 plus or minus 1 percent of the propeller diameter. A second such antenna shall be held in position by non-metallic cables in a vertical position and equal distance in front of the propeller disc and distant from the axis of rotation of the propeller by an amount equal to 50 plus or minus 2 percent of the propeller diameter. These arrangements are outlined in Figure 1 of this specification. By means of 25-foot lengths of coaxial cable (type RG-8/U), each of these antennas shall be connected in turn to the equipment for measuring VHF radiated interference.

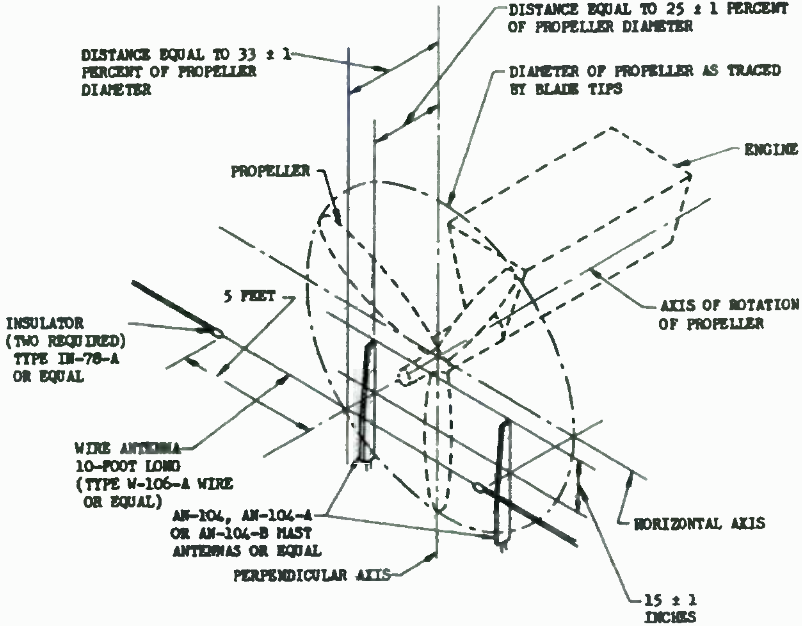

FIGURE 1. Arrangement of Antennas for Measurement of MHF and VHF Radiated Interference in The Engine Test

C-3a(6). Arrangements shall be made so that a probe conforming with Drawing AN3065 may be placed and oriented in the position to obtain maximum pickup over and on the entire external surfaces of the equipment, shielding and along all unshielded circuit conductors of the propeller system with the exception of the equipment, shielding and conductors that rotate with the propeller. In those cases where the cables of probes conforming to Drawing AN3065 are not sufficiently long, probes shall be used having long cables but constructed otherwise in accordance with this drawing; these cables shall be of the shortest practicable length. The cables from the probes shall be connected to the equipment for measuring MHF radiated interference.

C-3a(7). Arrangements shall be made so that a one-inch diameter one-turn electrostatically-shielded probe (Titeflex radio noise probe Model 2, or equal) may be placed and oriented in the position to obtain maximum pickup over and on the entire external surfaces of the equipment, shielding, and along all unshielded circuit conductors of the propeller system with the exception of the equipment, shielding, and unshielded conductors that rotate with the propeller. This probe shall be connected by means of the shortest practicable length of twin-conductor shielded cable (shield cover with an insulating sheath) to the equipment for measuring VHF radiated interference.

C-3b. Bench Test Method.- The propeller system or the component thereof to be tested shall be arranged in a functional model of the actual aircraft installation. The test location shall be such that a negligible amount of extraneous radio interference is present as measured by the test equipment.

C-3b(1). The lengths of the conductors associated with the propeller system shall be as required to make a convenient installation. Shielding of the type and size specified in the installation model specification shall be used on those conductors and components for which shielding is specified in that specification. Those conductors and components which are specified in the installation model specification as unshielded shall be unshielded in the mock-up.

C-3b(2). Arrangements shall be made that a three-inch diameter two-turn electrostatically-shielded probe conforming with Drawing AN3065 may be placed and oriented in the position to obtain maximum pickup over and on the entire external surfaces of the equipment and shielding and along all unshielded circuit conductors of the propeller system of the component under test. This probe shall be connected to the equipment for measuring MHF radiated radio interference.

C-3b(3). Arrangements shall be made so that a one-inch diameter one-turn electrostatically-shielded probe (Titeflex radio noise probe Model 2 or equal) may be placed and oriented in the position to obtain maximum pickup over and on the entire external surfaces of the equipment and shielding and along all unshielded conductors of the propeller system or the component under tests. This probe shall be connected to the equipment for measuring VHF radiated radio interference.

C-3b(4). At each measurement point, arrangements shall be made so that a coaxial cable (type RG-8/U) can be connected in turn between each system conductor and ground, with the shield of the coaxial cable being connected to the ground. This cable shall be connected on the other end to the equipment for measuring MHF conducted interference and shall be of the shortest practicable length.

C-4. Measuring Equipment.- The measuring equipment used in the two methods of test of this specification shall consist of specified radio receivers in normal operating condition together with other equipment specified herein.

C-4a. MHF Radiated Interference.- The equipment used to measure MHF radiated interference shall consist of the following:

C-4a(1). One Radio Receiver BC-348Q.- The receiver shall have sensitivity and background noise characteristics conforming with the requirements of Figure 2 of this specification and the receiver output transformer shall be connected for low impedance output.

CONDITIONS:

SIGNAL GENERATOR: MEASUREMENTS 65-B, OR EQUAL, ON 1000-CPS MODULATION
ARTIFICAL ANTENNA: 100 MMF MICA CONDENSER, IN SERIES
SUPPLY VOLTAGE: 28 ± 0.5 VOLTS
VOLUME CONTROL: FULL "ON"
AVC SWITCH: SET ON "MVC"
OUTPUT METER: "WESTON" MODEL 571, OR EQUAL
OUTPUT LOAD: ONE HS-33 HEADSET (600 OHMS)
OUTPUT TRANSFORMER TAP: "LOW"
CW OSCILLATOR: "OFF"

CRYSTAL: "OUT"

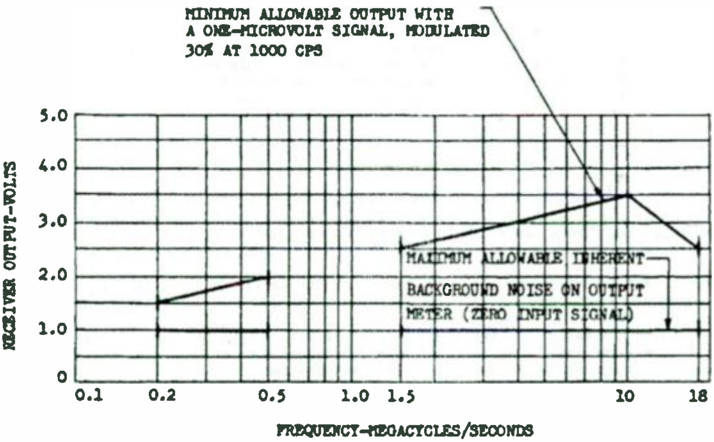

FIGURE 2. MHF Receiver Performance Requirements. Allowable Limits of Background Noise and Sensitivity of BC-348Q Receivers Used for Measurement Purposes

C-4a(2). Headsets employing Receiver ANB-H-1 or ANB-H-1A shall be used.

C-4a(3). One copper-oxide-rectifier output meter of at least 3000 ohms resistance (Weston Model 571, or equal).

C-4a(4). One cathode-ray oscilloscope with internal audio-frequency amplifier and gain control (DuMont Type 208-B, or equal).

C-4a(5). One direct-current voltmeter capable of indicating the receiver supply voltage with an accuracy of two percent (Weston Model 1, range 0-50 volts, or equal).

C-4a(6). A storage battery having a terminal voltage between 28 and 32 volts. This battery shall have no other load than the receiver.

C-4a(7). One rheostat, capable of being set to give the required receiver supply voltage.

C-4a(8). One radio frequency signal generator (Measurements Model 65-B).

C-4a(9). One dummy antenna formed of a 100 plus or minus 5 micromicrofarad mica capacitor suitably mounted and fitted with connections so that it may be used in series between the receiver and the signal generator in calibration.

C-4b. MHF Conducted Interference.- The equipment used to measure MHF conducted interference shall consist of the following.

C-4b(1). The equipment listed in the preceding paragraph headed MHF Radiated Interference, with the exception of the dummy antenna.

C-4b(2). One resistance-type adjustable attenuator capable of being set to give any attenuation between the limits of zero and 60 decibels throughout the frequency ranges of 0.2 to 0.5 and 1.5 to 18 megacycles per second. This attenuator shall have an input impedance of not less than 500 ohms throughout the above frequency range. It shall have a paper-dielectric "non-inductively-wound" capacitor of 0.015 plus or minus 0.003 microfarads capacitance placed in the ungrounded lead of the attenuator to prevent the passage of direct and low-frequency alternating currents of appreciable magnitude through the attenuator. The attenuator shall be placed within a shield can so constructed as to have negligible leakage to radio-interference fields.

C-4b(3). One set of coaxial cables (type RG-8/U) of sufficient number and length so that there is one of equal length to each of the coaxial cables running to the various measurement points. These cables shall be provided with necessary fittings and connectors so that each cable in turn may be connected between the signal generator and the attenuator.

C-4c. VHF Interference.- The equipment used to measure VHF radiated interference shall consist of the following:

C-4c(1). One Radio Receiver BC-639A together with a type RA-42-B rectifier power supply. The receiver shall have sensitivity and background noise characteristics conforming with the requirements of Figure 3 of this specification.

C-4c(2). Headsets employing Receivers ANB-H-1 or ANB-H-1A shall be used.

C-4c(3). One copper-oxide-rectifier output meter of at least 3000 ohms resistance (Weston Model 571, or equal).

C-4c(4). One alternating-current voltmeter capable of indicating the rectifier power supply input voltage with an accuracy of two percent (Weston Model 433, range 0-150 volts, or equal).

CONDITIONS:

SIGNAL GENERATOR: "MEASUREMENTS" MODEL 80, OR EQUAL

ARTIFICIAL ANTENNA: ELECTRICAL EQUIVALENT OF 70-OHM LINE (WITH ABOVE SIG. GEN.; A 20-OHM ± 5% NON-INDUCTIVE RESISTOR)

POWER SUPPLY: RECTIFIER TYPE RA-42-B, INPUT 110 ± 2 VOLTS, 60 CPS; RECTIFIER SET ON TRANSFORMER TAP 4

THRESHOLD SENSITIVITY CONTROL: SET AS TO GIVE SPECIFIED RECEIVER CHARACTERISTICS

VOLUME CONTROL: FULL "ON"

ATTENUATOR SWITCH: SET AT "ZERO" DECIBELS

BIAS CONTROL: SET ON "MANUAL"

OUTPUT METER: "WESTON" MODEL 571, OR EQUAL

OUTPUT LOAD: ONE HS-33 HEADSET (600 OHMS)

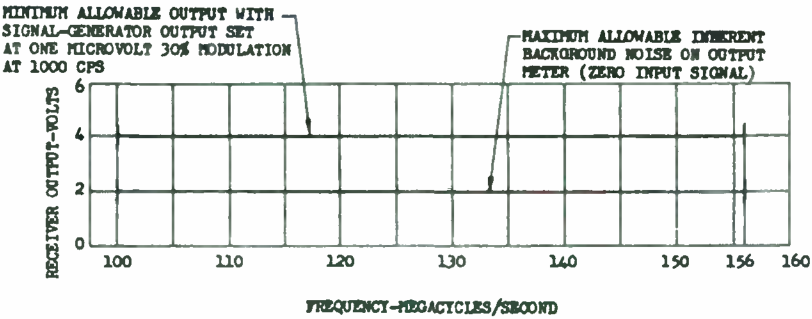

FIGURE 3. VHF Receiver Performance Requirements. Allowable Limits of Background Noise and Sensitivity of BC-639A Receivers Used for Measurement Purposes

C-5. Test Procedure.-

C-5a. Operating Conditions.- The propeller system or the component under test shall be operated under the conditions specified in the paragraphs below:

C-5a(1). The propeller system or component shall be operated at normal rated voltage. In particular, equipment rated for use on a nominal 24-volt system shall be supplied from a storage battery of appropriate capacity having a terminal voltage both under load and at no load between the limits of 27 and 29 volts. This battery shall not have any other load but the propeller system. This battery may be maintained on continuous charge from a rectifier power from an alternating current power line, provided that the arrangements used shall cause a negligible amount of radio interference as measured with the test equipment.

C-5a(2). The propeller system or component shall be operated so that substantially the same operation is obtained as that occurring in normal flight of the aircraft in which the equipment is to be used. In the engine test, the engine shall be run at approximately normal rated cruising speed and power output. When a propeller control system is under test, the engine throttle, or power control, shall be oscillated back and forth to produce cycling of the propeller control system in a manner representative of that occurring in normal flight.

C-5a(3). The actual measurements of radio interference in both the engine and bench tests shall follow a run-in period of at least 10 hours in which the conditions of simulated normal operation will obtain. No retightening of shielding or bonding, no cleaning of slip-rings and no other reconditioning of the propeller system or component shall be done during the run-in period or between that period and the period of interference measurement.

C-5b. Setting up of Measuring Equipment.-

C-5b(1). The equipment described for use in the measurement of MHF radiated interference shall be set up substantially in accordance with the following description: The headset and output meter shall be connected in parallel into one of the output jacks of the receiver. The cathode-ray oscilloscope shall be connected into the second output jack. The power-input terminals of the receiver shall be connected in series with the rheostat across the storage battery. The voltmeter shall be so connected as to indicate voltage at the receiver power-input terminals. The signal generator shall be energized from an appropriate a-c power line. The modulation selector control shall be set to give a modulation frequency of 1000 cycles per second. The modulation amplitude control shall be set to give 30 percent modulation as indicated on the modulation meter of the signal generator.

C-5b(2). The equipment described for use in the measurement of MHF conducted interference shall be set up substantially in accordance with Figure 4 of this specification, and with the description specified herein.

C-5b(3). The equipment described for use in the measurement of VHF radiated interference shall be set up substantially in accordance with the following description: The headset and output meter shall be connected in parallel into the LINE output jack of the receiver. The power supply (Rectifier RA-42-B) shall be set on transformer tap number four and connected to a source of alternating current power. The alternating current voltmeter shall be connected to indicate the input voltage to the rectifier power supply.

C-5c. Methods of Measurement.-

C-5c(1). MHF Interference.- The receiver shall be operated with the supply voltage as indicated on the voltmeter maintained at 28 plus or minus 0.5 volts and with the following control settings:

Volume control: Full "ON"
AVC switch: Set on "MVC"
CW oscillator switch: Set on "OFF"
Crystal switch: Set on "OUT"
Output transformer tap: "LOW"

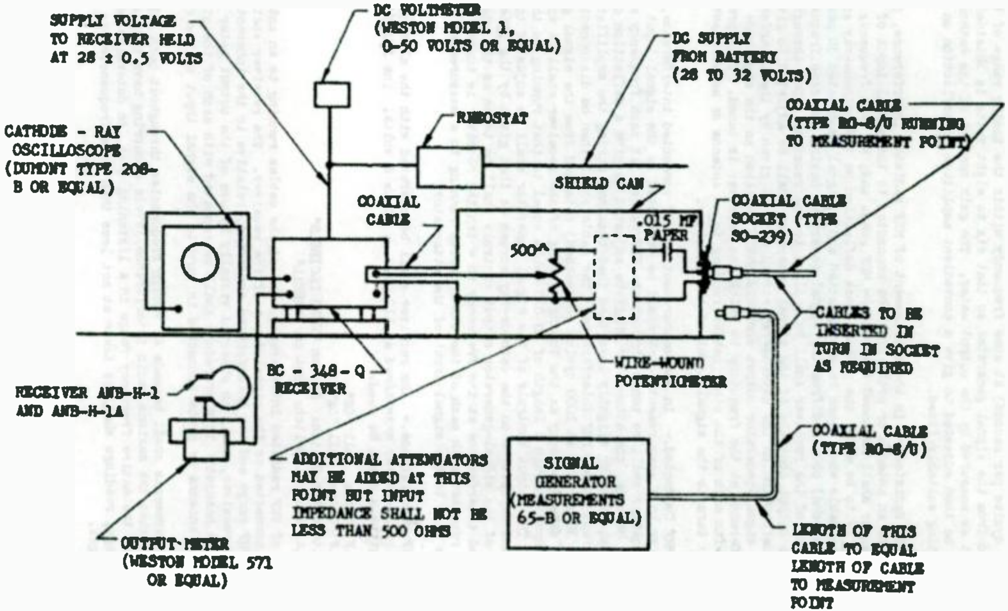

FIGURE 4. Arrangement for The Measurement of MHF Conducted Interference

Before the actual measurements of MHF interference are made, sufficient signal (modulated 30 percent at 1000 cycles per second) at some frequency within the tuning range of the receiver shall be fed from the signal generator so that six to eight volts is obtained at the receiver output as measured by the output meter. The gain control of the cathode-ray oscilloscope shall be then adjusted to give a convenient amplitude of deflection on the screen and the setting suitably fixed.

C-5c(1)a. MHF Radiated.- In the measurement of MHF radiated interference, one of the cables running to an antenna or probe shall be connected to the signal input of the receiver. The receiver shall be tuned through the MHF range and, at each frequency at which a measurement is to be made, the peak-to-peak deflection on the cathode-ray screen shall be noted. The cable shall then be disconnected and a signal (modulated 30 percent at 1000 cycles per second) obtained from the signal generator having the same frequency as the tuning setting of the receiver shall be applied to the receiver input through the dummy antenna. The output controls of the signal generator shall be adjusted to give the same peak-to-peak deflection on the cathode-ray screen as that given by the interference. The setting of the signal-generator output controls shall be taken as the magnitude of the MHF radiated interference at the frequency to which the receiver is tuned. This procedure shall be repeated with each of the other cables running to an antenna or measurement point by connecting it in turn to the signal input of the receiver.

C-5c(1)b. MHF Conducted.- In the measurement of MHF conducted interference, one of the cables running to a measurement point shall be connected to the signal input of the attenuator. The receiver shall be tuned through the MHF range. At each frequency at which a measurement is to be made, the attenuator shall be adjusted to give a deflection on the cathode-ray screen equal to or slightly less than that obtained during the amplifier gain adjustment of paragraph headed MHF Interference. The cable shall then be disconnected. A signal (modulated 30 percent at 1000 cycles per second) obtained from the signal generator and having the same frequency as the tuning setting of the receiver shall be applied to the attenuator input through a length of RG-8/U cable equal to that running to the measurement point. The output controls of the signal generator shall be adjusted to give the same peak-to-peak deflection on the cathode-ray screen as that given by the interference. The setting of the signal-generator output controls shall be taken as the magnitude of the MHF conducted interference at the frequency to which the receiver is tuned. This procedure shall be repeated with each of the other cables running to a measurement point by connecting it in turn to the signal input of the attenuator.

C-5c(2). VHF Interference.- The receiver shall be operated with the alternating-current supply to the rectifier maintained at 110 plus or minus 2 volts. The following receiver control settings shall be used:

A.F. Gain: Full "ON"
R.F. Gain: Full "ON"
Attenuator Switch: Set on "ZERO DECIBELS"
Bias Control Switch: Set on "MANUAL"

In the measurement of VHF radiated interference, one of the cables running to an antenna or probe shall be connected to the signal input of the receiver. The receiver shall be tuned through the VHF range and the interference occurring, relative to the inherent background noise of the receiver, shall be observed visually by use of the output meter and aurally by use of the headset. This procedure shall be repeated with each of the other cables running to an antenna or probe connected in turn to the signal input of the receiver.

C-5c(3). Measurements shall be made at enough frequencies throughout both MHF and VHF ranges to insure that the maximum radio interference levels occurring have been measured. After scanning the entire frequency range in a listening test, to determine points of most severe leakage, readings shall be taken at not less than five frequencies in both the MHF and VHF ranges.

C-6. Limits.- The maximum allowable limits of radio interference according to the method of test are given in Table I of this specification. Figures 5 and 6 form a part of this table.

TABLE I

MAXIMUM LIMITS OF ALLOWABLE RADIO INTERFERENCE AS MEASURED IN ENGINE AND BENCH TESTS

TYPE OF INTERFERENCE	TEST METHOD	MAXIMUM LIMIT
MHF Conducted	Engine and bench	Total deflection (peak-to-peak) on cathode-ray screen equal to that obtained with a signal, 30 percent modulated at 1000 cps of a root-mean-square value given by Figure 5, applied to input of attenuator through cable of same type and length as that running to the measurement point.
MHF Radiated	Engine, using wire antenna	Total deflection (peak-to-peak) on cathode-ray screen equal to that obtained with a one-microvolt (rms) signal 30 percent modulated at 1000 cps applied through the specified dummy antenna to the receiver input.
	Engine and bench, using AN3065 probe	Total deflection (peak-to-peak) on cathode-ray screen equal to that obtained with a signal, 30 percent modulated at 1000 cps applied to receiver input through the specified dummy antenna having a root-mean-square value given by Figure 6.
VHF Radiated	Engine and bench	Inherent background noise level of the VHF receiver, with the specified antenna connected.

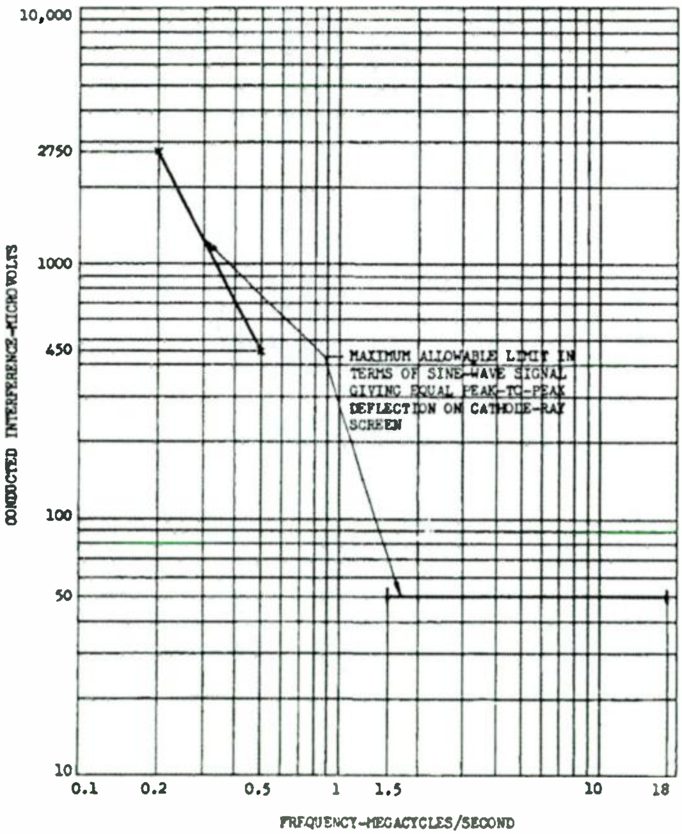

FIGURE 5. Allowable Limits of MHF Conducted Interference
As Measured With Circuit of Figure

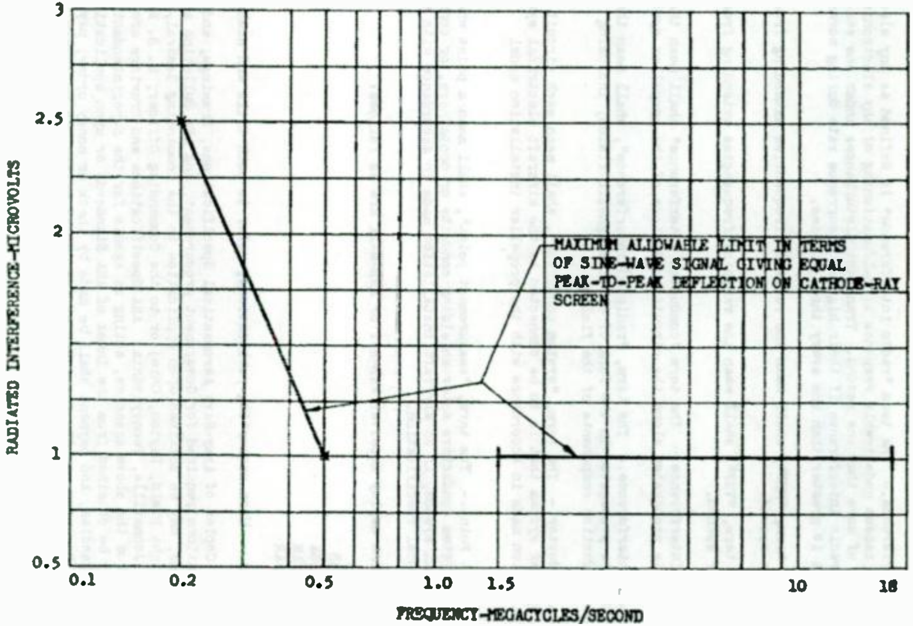

FIGURE 6. Allowable Limits of MRW Radiated Interference As Measured With AN 3065 Probe

D. NOTES.

D-1. Definitions.-

D-1a. Propeller System.- The term, "propeller system", shall mean the propeller and all associated equipment as described in the corresponding propeller installation model specification.

D-1b. Radio Interference.- The term "radio interference" is defined as any electrical disturbance which causes undesirable response or malfunctioning of any electronic equipment for a duration of more than one second. Transient disturbances under one second duration are considered radio interference if their highest recurrence rate during normal operation of the aircraft is greater than one every three minutes.

D-1c. MHF.- The term, "MHF", shall mean the range of frequencies extending from 0.15 to 18 megacycles per second.

D-1d. VHF.- The term, "VHF", shall mean the range of frequencies extending from 100 to 156 megacycles per second.

D-1e. Conducted Interference.- The term "conducted interference" shall mean the radio interference that is propagated along the circuit conductors of the propeller system.

D-1f. Radiated Interference.- The term, "radiated interference", shall mean the radio interference that is propagated in the form of electromagnetic fields, including both the radiated and induction components of the fields.

D-1g. System Conductor.- The term, "system conductor", shall mean each circuit conductor of the propeller system that is to be connected to the aircraft electrical system in an aircraft installation made in accordance with the propeller installation model specification.

D-1h. Measurement Point.- The term, "measurement point", shall mean a point where one or more unshielded system conductors enter shielding conduits or containers, or connect to the aircraft electrical system, in an aircraft installation made in accordance with the propeller installation model specification.

D-2. Headsets which employ Receiver ANB-H-1 or ANB-H-1A are as follows:

Headset HS-3
Headset HS-38
Headset HS-38a
Headset H-1/AR
Headset H-4/AR

D-3. Publications.- When requesting publications, refer to both title and number.

D-3a. Sources.- Copies of Army-Navy Aeronautical Specifications, Drawings, and Joint Army-Navy Specifications required for Government procurement, and ANA Bulletins and the Index of ANA Standards, may be obtained upon application to the Commanding General, Air Materiel Command, Wright Field, Dayton, Ohio; or to the Commanding Officer, U. S. Naval Air Development Station, Johnsville, Pennsylvania. ANA Specifications and Drawings are available for purchase from the above agencies, acting as agents for the Superintendent of Documents. The price may be obtained from the Index of ANA Standards or upon application to either of the above agencies, and payment shall be made by check or money order, payable to the Superintendent of Documents or the Treasurer of the United States, or by coupon.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

GPO 807763

MILITARY SPECIFICATION

INTERFERENCE BLANKER GROUP AN/GPA-28( )

1. SCOPE

1.1 This specification covers one type of mutual radar interference blanker, designated as Interference Blanker Group AN/GPA-28( ), hereinafter referred to as the "blanker group".

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification:

SPECIFICATIONS

Military

MIL-E-4158	Electronic Equipment, Ground; General Requirements For
MIL-T-4807	Tests; Vibration and Shock Ground Electronic Equipment (Requirements For)
MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification For
MIL-T-9107	Test Reports, Preparation Of
MIL-D-9623	Delay Lines MX-1788( )/CPN-18, MX-1789( )/CPS-6B, MX-1790( )/MPN-1, MX-1791( )/FPN-16, and MX-1792( )/TPS-1D
MIL-P-17555	Preparation for Delivery of Electronic Equipment; Miscellaneous Electrical Equipment (Except Rotating Electrical Equipment) and Associated Repair Parts

STANDARDS

Federal

FED-STD-595	Colors

(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

FSC 5840

Military

MIL-STD-189 **Racks, Electrical Equipment, 19-Inch and Associated Panels**

3. REQUIREMENTS

3.1 PREPRODUCTION.- This specification makes provisions for preproduction testing.

3.2 COMPONENTS.- The blanker group shall consist of the following:

Item No.	Quantity	Description	Requirement
1	1 each	Receiver, Radar R-756( )/GPA-28	3.7.1
2	1 each	Blanker, Interference MX-1912( )/GPA-28	3.7.2
3	2 each	Cabinet	3.7.3
4	1 set	Interconnecting Cables for interconnecting the components of the blanker group	3.7.4
5	1 set	Interconnecting cables for connecting the components of the blanker group with the specified radar set	3.7.5

3.3 STANDARD SAMPLE.- A standard sample blanker group will be furnished to demonstrate the minimum acceptable standard of materials, design, workmanship, and performance not specified herein. The standard sample will also be used to determine compliance with the required functional and dimensional interchangeability. If the standard sample conflicts with the requirements of this specification, this specification shall govern.

3.4 GENERAL SPECIFICATION.- The requirements of MIL-E-4158 apply as requirements of this specification. Where the requirements of the general specification and this specification conflict, the requirements of this specification shall govern. Exceptions and additions to the general specification shall be as follows.

3.4.1 AMBIENT TEMPERATURE.- The blanker group shall be designed and constructed to operate in a "Cold Weather Area" and in "Desert and Tropical Areas".

3.4.2 SERVICE CONDITIONS (MECHANICAL).- The blanker group shall not suffer damage nor fail to give the required performance when subjected to conditions encountered during operation, storage, or transit.

3.4.3 SERVICE CONDITIONS (ELECTRICAL).- The blanker group shall be designed to operate from a 120-volt, 60 cycle per second (cps), single-phase alternating-current (a-c) power source with characteristics as specified in MIL-E-4158.

3.4.4 SERVICE LIFE.- The equipment shall be capable of a reliable operating life of at least 23 hours a day for 105 days without requiring any servicing. Further, the equipment shall be designed to have a minimum operating life of 23 hours a day for 5 years with only normal maintenance and without major overhaul. The parts requiring replacement during this latter interval shall be designated by the contractor and be subject to the approval of the procuring activity.

3.5 DESIGN AND CONSTRUCTION.- The blanker group shall be designed to provide normal and moving target indicator (MTI) blanking pulses for eliminating "main-bang" interference from one channel, and normal blanking pulses for two additional channels caused by the operation of other nonsynchronized radar sets. Detailed design of the blanker group shall be in accordance with the requirements of this specification. The requirements are detailed herein only to the extent necessary to obtain the desired performance. Details of design not specified shall conform to the best engineering practices.

3.5.1 PLUG-IN UNITS.- Separate units of the plug-in type shall be used wherever practicable to facilitate servicing.

3.5.2 INITIAL SET-UP.- The design of the equipment shall allow a simple, logical set-up procedure, not requiring advance service or test equipment other than a pulse generator and oscilloscope or synchroscope.

3.5.3 ADJUSTMENT CONTROLS.- Adjustment controls used often shall be located on the front panel. Controls used only for initial set-up may be located elsewhere except that the controls shall be easily accessible. Variable functions requiring critical setting shall be vernier controls.

3.6 PERFORMANCE.- The blanker group shall eliminate interference from one or more radar sets to another, synchronized or unsynchronized. The blanker group shall blank the video output of an interfered-with set. It shall provide normal and MTI blanking gates for eliminating "main-bang" interference for one video channel and normal blanking gates for eliminating interference for two additional video channels. The blanker group shall accept triggers from four interfering radar sets, and the video, from three channels of the protected radar.

3.6.1 DEGRADATION OF RADAR PERFORMANCE.- The blanker group shall cause no degradation of radar set performance other than the actual loss of video information during the blanking time period. Information time loss per pulse shall be held to a minimum by sharply defined gates of fast rise time, fast recovery, and excellent jitter stability.

3.6.2 CHANNELS SERVED.- The blanker group shall serve one MTI and two normal channels of the same radar set simultaneously and both Type A and plan position indicator (PPI) scopes, if desired.

3.6.3 TYPES OF RADAR SETS SERVED.- The blanker group shall serve radar sets having the following characteristics:

a. Type of radar: Normal or MTI

b. Repetition rates:

(1) Interfering set: 0 to 6000 pulses per second (pps)

(2) Interfered-with set: 200 to 6000 pps

c. Transmission pulse width: Not greater than 0.5 microsecond (usec)

d. Intermediate frequency: 30 megacycles (mc)

e. Video Channels:

(1) Type: Normal or MTI

(2) Voltage: 2 to 10 volts

(3) Polarity: Unipolar, positive going

(4) Number: 1 through 3, simultaneously

3.6.4 DELAY LINES.- The blanker unit shall be capable of satisfactory performance when operated with any one of the fixed quartz delay lines specified in 3.7.2.1.9. The blanker group shall be capable of the above only when operated with either Delay Line MX-1788( )/CPN-18 or Delay Line MX-1789( )/CPS-6B. (See 6.4)

3.7 DETAILS OF COMPONENTS

3.7.1 RECEIVER, RADAR R-756( )/GPA-28.- The Receiver, Radar R-756( )/GPA-28, hereinafter referred to as the "radar receiver unit", shall consist of a preamplifier coupler and an interference trigger receiver with built in power supply. The interference trigger receiver with power supply shall be mounted on a common panel.

3.7.1.1 PREAMPLIFIER COUPLER.- The input lead to the coupler shall be approximately 9 inches in length and the coupler shall be capable of mounting as close to the radar mixer as possible. The input impedance to the coupler shall be high enough to prevent any deleterious effects to the radar set, such as decreased sensitivity, decreased selectivity, poorer noise figure, and lower video output.

3.7.1.1.1 FREQUENCY RANGE.- The frequency bandwidth of the preamplifier coupler shall be at least 14 mc at the minus 3 decibel (db) points centered at 30 mc.

3.7.1.1.2 POWER SOURCE.- The necessary plate and filament voltages shall be supplied by the interference trigger receiver power supply with adequate filtering.

3.7.1.1.3 SHIELDING.- The preamplifier coupler shall be effectively shielded from spurious noise pulses originating at the protected radar.

3.7.1.1.4 INPUT.- The input to the preamplifier coupler shall be the output of the mixer of the protected radar set.

3.7.1.1.5 OUTPUT.- The output of the preamplifier coupler shall be fed into the interference trigger receiver. The length of coaxial cable may be anywhere from 10 to 50 feet inclusive.

3.7.1.2 INTERFERENCE TRIGGER RECEIVER.- The interference trigger receiver, hereinafter referred to as the "receiver", shall have a double side band amplifier preceded by a limiter, a detector, and a video amplifier.

3.7.1.2.1 SYNCHRONIZING OF BLANKING GATES.- The synchronizing pulse shall be obtained from the receiver. This device shall discriminate between interference pulses and target returns and generate output triggers from interference. These output pulses shall trigger the Blanker, Interference MX-1912( )/GPA-28 at the interfered-with radar set to eliminate interference caused by interfering radar sets.

3.7.1.2.2 POWER SUPPLY.- The receiver shall contain the power supply for the radar receiver unit. The power supply shall be capable of converting and rectifying the primary power to the required a-c and direct-current (d-c) power for proper operation of the radar receiver unit in accordance with this specification. The power supply shall operate from a single-phase, 105 to 120-volt, 60 cps, primary a-c power source, with characteristics as specified herein.

3.7.1.2.3 INPUT.- The input to the receiver shall be the output of the preamplifier coupler.

3.7.1.2.4 OUTPUT.- The output of the receiver shall be positive video pulses of at least 2 volts amplitude when terminated in 50 ohms. This output shall furnish a trigger to the Blanker, Interference MX-1912( )/GPA-28.

3.7.1.2.5 GAIN.- The overall gain of the receiver, including the preamplifier, double side band amplifier, and video amplifier shall be at least 90 db at the peak frequencies of the double side band amplifier.

3.7.1.2.5.1 GAIN CONTROLS.- Provision shall be made to control the gain of the receiver manually by controlling the bias level on the last two stages of the preamplifier.

3.7.1.2.6 LIMITER.- The bandwidth of the limiter shall be at least 14 mc wide.

3.7.1.2.7 DOUBLE SIDE BAND AMPLIFIER.- The side band center frequencies shall be 24 plus or minus 0.5 mc and 36 plus or minus 0.5 mc. The bandwidth of each side band of the double side band amplifier shall be at least 3 db down at 1.5 mc from each side of the center frequency. In addition, the side band amplifier shall have a rejection band of at least 40 db from 28 to 32 mc. This may be accomplished by the use of traps or filters.

3.7.1.2.8 VIDEO AMPLIFIER

3.7.1.2.8.1 BANDWIDTH.- The bandwidth of the video amplifier shall be from 300 cycles to not less than 1.75 mc at the minus 3 db points.

3.7.1.2.8.2 INPUT.- The input of the video amplifier shall be the detected output of the double side band amplifier.

3.7.1.2.8.3 OUTPUT.- The video output level shall be at least 2 volts positive when terminated in 50 ohms for an input of 50 microvolts to the preamplifier coupler.

3.7.1.2.9 RECEIVER FRONT PANEL CONTROLS.- The following shall be incorporated on the front panel of the receiver in an easily accessible position.

a. Power Switch: The primary power to the receiver shall be controlled by an "ON-OFF" power switch.

b. Power Indicator: A suitable pilot light assembly connected into the primary power circuit shall indicate when primary power has been applied to the receiver.

c. Fuse and Fuse Holder: A fuse holder with a suitable fuse mounted thereon shall be connected into the primary power circuit to protect the circuitry of the receiver against damage from overload conditions due to power surges or failures.

d. Blown Fuse Indicator: A suitable pilot light assembly connected across the fuse in the primary power circuit shall light when the fuse is blown.

e. Standby Switch: A standby power switch shall be wired into the receiver output.

f. Standby Indicator: A suitable pilot light assembly connected into the high voltage circuit of the video amplifier shall indicate when high voltage power has been applied to the video amplifier section of the receiver.

g. Gain Controls: The gain controls specified in 3.7.1.2.4.1 shall be conveniently mounted on three front panels.

3.7.2 BLANKER, INTERFERENCE, MX-1912( )/GPA-28.- The Blanker, Interference, MX-1912( )/GPA-28, hereinafter called the "blanker unit", shall consist of the following subassemblies mounted on a common panel.

a. Interference Blanker Subassembly MX-2228( )/GPA-28

b. Power Supply PP-1773( )/GPA-28

3.7.2.1 INTERFERENCE BLANKER SUBASSEMBLY MX-2228( )/GPA-28.- The interference blanker subassembly operating in conjunction with the Power Supply PP-1773( )/GPA-28 shall perform the actual video blanking of the interfered-with radar set. It shall generate the required blanking gates when triggered by the radar receiver unit. It shall be capable of effectively blanking up to three separate unipolar video channels simultaneously, having a positive excursion of not more than 6 volts and a frequency response up to 3 mc. By means of the delay line, it shall be capable of serving unipolar MTI cancelled video as well as normal radar video channels. It shall offer no degradation to the present operating characteristics of the radar set which it serves except the blanking action. The interference blanker subassembly shall consist of the following:

a. Pulse Generator (3.7.2.1.7)

b. Radio Frequency Amplifier (3.7.2.1.8)

c. One each of any of the following fixed quartz delay lines (3.7.2.1.9)

(1) Delay Line MX-1791( )/FPN-16
(2) Delay Line MX-1788( )/CPN-18

(3) Delay Line MX-1792( )/TPS-1D
(4) Delay Line MX-1789( )/CPS-6B
(5) Delay Line MX-1790( )/MPN-1

d. Variable Delay Line (3.7.2.1.10)

e. Video Delay Line (3.7.2.1.11)

f. Gated Video Amplifier (3.7.2.1.12)

3.7.2.1.1 NORMAL CHANNEL BLANKING.- To accomplish blanking for a normal channel radar set, it shall be necessary only to synchronize the blanking gate to occur simultaneously with the interfering video pulse.

3.7.2.1.2 MOVING TARGET INDICATOR CHANNEL BLANKING.- To accomplish blanking for MTI equipped radar sets, an additional blanking gate shall be synchronized to occur simultaneously with the original interfering video pulse emerging one MTI interval later from the MTI delay line. This shall be accomplished by use of a fixed quartz delay line and a variable delay line.

3.7.2.1.3 INPUT.- The input to the interference blanker subassembly shall be a positive trigger from 2 to 150 volts appearing across a terminating impedance of 50 ohms. The trigger pulse width shall be from 0.5 to 10.0 usec. There shall be four input terminals to accept the four triggers. There shall be three video inputs, one to each video channel.

3.7.2.1.4 OUTPUT.- The output of the interference blanker subassembly shall be the three video channels, one of which contains normal blanked video, one of which contains MTI blanked video, and one of which contains either normal or MTI blanked video, as determined by a switch.

3.7.2.1.5 BLANKING GATE.- The blanking gate generated as a result of the input trigger voltage shall maintain excellent jitter stability and exhibit a fast rise and fall time of at least 0.5 usec. The gate shall cause no adverse effects such as "spoking" to the video signal during the off-gate period. The residual negative gate overshoot appearing in the video output as a function of the blanking gate shall not exceed 0.1 volt maximum. The width of the blanking gate shall be variable between 5 and 120 usec.

3.7.2.1.5.1 BLANKING ATTENUATION.- The effective blanking attenuation per channel to the interfering video signal during the gating period shall be a minimum of 25 db.

3.7.2.1.6 BY-PASSING VIDEO CHANNELS.- In case of failure, any of the video channels shall be by-passed by shorting out the channel by means of a switch.

3.7.2.1.7 PULSE GENERATION.- The gated oscillator shall be tuned to 15 mc. The gated oscillator driver, a blocking oscillator, shall be triggered by the output pulse from the radar receiver unit and shall recover fast enough to handle interfering pulses occurring within 5 usec of each other. The delay line radio frequency (r-f) driving voltage shall be at least 10 volts rms. The delay line driver shall be capable of tuning out the delay line capacitance between 75 to 120 micromicrofarads at 15 mc.

3.7.2.1.8 RADIO-FREQUENCY AMPLIFIER.- The r-f amplifier shall have sufficient gain to compensate for the insertion loss of the delay line. The bandwidth of the amplifier shall be 3 mc between the minus 3 db frequencies.

3.7.2.1.9 FIXED QUARTZ DELAY LINES.- Delay Lines MX-1791( )/FPN-16, MX-1788( )/CPN-18, MX-1790( )/MPN-1, MX-1792( )/TPS-1D, and MX-1789( )/CPS-6B shall be in accordance with MIL-D-9623. One of the above types of delay lines shall be supplied with and mounted on the interference blanker subassembly (see 6.4).

3.7.2.1.10 VARIABLE DELAY LINE.- The variable delay line shall be capable of tuning the delay time of the fixed quartz delay line to within 1 usec of the fixed MTI interval. The input to the variable delay line shall be the amplified output of the fixed quartz delay line. The variable delay line shall be capable of separating the desired once delayed signals from spurious signals.

3.7.2.1.10.1 VARIABLE DELAY TIME.- The variable delay line shall be variable from 0 to 32 usec in 1 usec steps.

3.7.2.1.10.2 BANDWIDTH.- The bandwidth shall be 0.5 mc wide between the minus 3 db frequencies for the complete 32 usec delay.

3.7.2.1.10.3 INSERTION LOSS.- The insertion loss shall be kept to a minimum.

3.7.2.1.10.4 SPURIOUS SIGNALS.- Spurious signals shall be kept at least 15 db below the first time around signals.

3.7.2.1.10.5 RIPPLE.- Variations within the band-pass shall be maintained at a minimum.

3.7.2.1.10.6 AMPLIFICATION.- The gain of the amplifiers following the variable delay line shall be sufficient to trigger the video gating circuits.

3.7.2.1.11 VIDEO DELAY LINE.- The video delay line shall permit the delay of any of the protected radar video channels for synchronization with the blanking gate, if necessary. The video from the protected radar shall pass through a 6 usec video delay line with video taps at 2, 4, and 6 usec.

3.7.2.1.11.1 INPUT AND OUTPUT, VIDEO CHANNELS.- The video channel shall provide for positive polarity input and output signals. The impedance levels of the input and output shall be 50 ohms. The video channel shall be capable of handling inputs up to 2.5 volts without limiting. The maximum video output shall not be less than 2 volts positive when terminated in 50 ohms.

3.7.2.1.11.2 BANDWIDTH, VIDEO CHANNELS.- The normal gain shall be unity. Three screwdriver controls shall be provided on the front panel of the blanker to adjust the video gain from approximately 0.5 to 1.5 to allow for variations in characteristics of the tubes and components.

3.7.2.1.11.3 BANDWIDTH, VIDEO DELAY LINE.- The bandwidth of the video delay line shall be from 300 cps to 2 mc with 6 usec delay.

3.7.2.1.12 GATED VIDEO AMPLIFIER.- The blanking gates and normal radar video from the video delay line shall be fed into the gated video amplifier. There shall be three video channels, one of which shall be capable of blanking normal video, one capable of blanking MTI video, and one capable of blanking either normal or MTI video as determined by a switch.

3.7.2.2 POWER SUPPLY PP-1773( )/GPA-28.- The power supply shall be capable of converting and rectifying the primary power to the required a-c and d-c power for proper operation of the blanker unit in accordance with this specification.

3.7.2.2.1 OPERATING POWER REQUIREMENTS.- The power supply shall operate from a single-phase, 120-volt, 60 cps, primary a-c power source, with characteristics as specified herein.

3.7.3 CABINETS.- The cabinets for housing the radar receiver unit and the blanker unit shall be standard 19-inch closed relay racks in accordance with MIL-STD-189. The cabinets shall include provisions for adequate ventilation. The cabinets and mounting facilities shall meet the shock and vibration requirements specified herein.

3.7.4 INTERCONNECTIONS WITHIN THE BLANKER GROUP.- Power cable assemblies, interconnecting cable assemblies, cabling, connectors, adapters, and miscellaneous hardware required for interconnecting the components shall be included as part of the blanker group.

3.7.5 CONNECTIONS TO RADAR SETS.- Interconnecting cable assemblies, cabling, connectors, adapters, miscellaneous hardware, and installation instructions required for connecting the blanker group to the radar set specified by the procuring activity (see 3.6.4 and 6.2) shall be included as part of the blanker group (see 6.5).

3.8 DIMENSIONS.- The dimensions of the components shall allow installation in a standard 19-inch relay rack. Each unit shall be approximately 19 inches wide by 15 inches deep. Otherwise the dimensions shall be kept to a minimum.

3.9 WEIGHT.- The weight of each component shall be kept to a minimum. The total weight of the blanker group shall not exceed 175 pounds, excluding the cabling and hardware used in connecting the blanker group with the specified radar set (see 3.7.5).

3.10 COLOR.- The exterior surfaces shall be finished in lusterless black, conforming to color No. 37028 in accordance with FED-STD-595.

3.11 GOVERNMENT-LOANED PROPERTY.- When the contract or purchase order so provides, the Government will loan the following to the contractor upon his request:

Item No.	Description	Quantity
1	Blanker, Interference MX-1912( )/GPA-28	1
2	Receiver, Radar R-756( )/GPA-28	1
3	Delay Line MX-1788( )/CPN-18	1

4. QUALITY ASSURANCE PROVISIONS

4.1 CLASSIFICATION OF TESTS.- The inspection and testing of the blanker group shall be classified as follows:

a. Acceptance tests . . . . See 4.2

b. Preproduction tests . . . . See 4.5

4.2 ACCEPTANCE TESTS.- Acceptance tests shall consist of the individual test only.

4.2.1 INDIVIDUAL TEST.- Each blanker group shall be subjected to the following tests as described under 4.4 "TEST METHODS" of this specification:

a. Examination of product

b. Functional tests

c. System operational test

In addition, each blanker group shall be subjected to any other tests in 4.4 which the procuring activity considers necessary to determine compliance with the requirements of this specification.

4.3 TEST CONDITIONS.- Unless otherwise specified herein, all tests shall be conducted at prevailing ambient conditions.

4.4 TEST METHODS

4.4.1 EXAMINATION OF PRODUCT.- Each blanker group shall be given a thorough mechanical and visual inspection and test to determine that the quality of materiel and workmanship is in compliance with the requirements of this specification. Particular attention shall be given to the following:

a. Completeness
b. Nameplates, identification markings and labels
c. Ease of operation of gears, adjustable, and sliding parts, thumb screws, controls and switches
d. Finishes
e. Welded joints
f. Soldered joints
g. Fit of components in their respective positions
h. Check of mounting provisions
i. Check of lubrication and rust prevention
j. Loose fastening and securing devices or parts
k. Accessibility of components and parts for servicing
l. Cable runs between components, including plugs and receptacles
m. Grounding connections
n. Overall dimensions check
o. Weight check

4.4.2 FUNCTIONAL TESTS.- Each blanker group and each individual component thereof shall be given a thorough electrical performance test to determine that all circuits are inherently sound and that overall performance of the equipment in compliance with this specification shall be obtained. Tolerance limits shall be checked to determine that circuit elements have been selected in accordance with the requirements of each application. Electrical tests shall include, but shall not necessarily be limited to, the following tests.

4.4.2.1 CONTINUITY TEST.- Each electrical component and each cord and cable shall be given a continuity test to ascertain that it is wired and connected correctly and that good electrical contact is obtained.

4.4.2.2 OPERATING VOLTAGES.- The operating voltages at all important points shall be checked for conformance with those shown on the circuit labels and schematic drawings. This shall be done with all controls set for normal operation of the equipment.

4.4.3 SYSTEM OPERATIONAL TESTS.- Each blanker group shall be set up and the necessary connections made to serve a normal and an MTI radar set. The system shall then be subjected to such electrical testing as is necessary to determine that the overall performance of the blanker group conforms to the requirements of this specification when used with a radar set.

4.4.4 ENVIRONMENTAL TESTS.- The blanker group shall be subjected to the following environmental tests to prove compliance with the requirements specified herein.

4.4.4.1 The following tests shall be in accordance with MIL-E-5272 with exceptions as specified:

a. High temperature test - Procedure I: Maintain the equipment at plus 71°C for 4 hours; reduce temperature to plus 52°C for 4 hours then operate equipment and compare results.

b. Low temperature test - Procedure II: Operating temperature shall be minus 29°C.

c. Humidity test - Procedure II.

d. Altitude test (operating) - Procedure I: Duration of test shall be 4 hours.

e. Altitude test (nonoperating): Repeat Procedure I at an absolute pressure of 5.54 inches of mercury (altitude of 40,000 feet above sea level) but do not operate the equipment. Visually examine the equipment in accordance with the specification.

f. Fungus resistance test - Procedure I.

g. Salt spray test - Procedure I: Duration of test shall be 100 hours.

h. Rain test - Procedure I.

4.4.5 MECHANICAL TESTS.- The blanker group shall be subjected to the following mechanical tests specified in MIL-T-4807.

a. Vibration test - Method 1B

b. Bounce test - Method 4A

c. Bench handling test - Method 5A

4.4.6 SERVICE LIFE TEST.- The equipment shall be operated continuously for 23 hours a day for 105 days. During this test the voltages, current, loading, and method of excitation shall, insofar as is practical, correspond to actual field conditions. Upon completion of this test the performance of the equipment shall not be below the minimum requirements specified herein. Should the equipment or any of the components fail to pass the test, the test shall be terminated until such defects have been corrected.

4.5 PREPRODUCTION TESTS

4.5.1 PREPRODUCTION TEST SAMPLES.- The preproduction test samples shall consist of models representative of the production equipment. They shall be tested at a laboratory designated by the procuring activity or, when so stated in the contract, at the contractor's plant under supervision of the procuring activity.

4.5.2 TEST PROCEDURES.- Prior to preproduction testing the contractor shall submit a proposed test procedure to the procuring activity for approval.

4.5.3 PREPRODUCTION TEST REPORT.- When the contractor performs the preproduction tests, he shall prepare a preproduction test report in accordance with MIL-T-9107 and furnish three complete copies of the report to the procuring activity.

4.5.4 PREPRODUCTION TESTS.- Preproduction tests shall consist of all tests described under 4.4 "TEST METHODS".

5. PREPARATION FOR DELIVERY

5.1 GENERAL.- The packaging, packing, and marking requirements specified herein apply only to direct purchases by, or direct shipments to the Government.

5.2 PREPARATION FOR SHIPMENT.- The blanker group shall be prepared and marked for shipment in accordance with MIL-P-17555. The shipment marking nomenclature shall be as follows: "Interference Blanker Group AN/GPA-28( )".

6. NOTES

6.1 INTENDED USE.- The Interference Blanker Group AN/GPA-28( ) is to be used with normal and MTI radar sets to eliminate radar interference from one radar set to another by blanking out the interfered-with set during the time interference would be received.

6.2 ORDERING DATA.- Procurement documents should specify the following:

a. Title, number, and date of this specification.

b. Applicable level of preservation, packaging and packing required (see 5.2).

c. Whether the preproduction tests will be conducted by the procuring activity or by the contractor (see 4.5.1).

d. Number of preproduction samples required (see 4.5.1).

e. Conditions under which Government-loaned property will be made available to the contractor (see 3.11).

f. The radar set the equipment is to be used with (see 6.4).

6.3 NOMENCLATURE.- The parenthesis appearing in the nomenclature will be dropped, or replaced by a letter to designate the particular design. Nomenclature for the individual components, where required, will be furnished upon application to the procuring activity.

6.4 The type of fixed quartz delay line required for use with Blanker, Interference MX-1912( )/GPA-28 is determined by the interfered-with radar set and will be specified by the procuring activity to the contractor upon his request (see 6.2 and 3.6.4).

6.5 MODIFICATIONS.- In the event that modification of the specified radar set is necessary for proper connection to the interference blanker group, such modification shall be submitted to the procuring activity for approval. The installation instructions supplied shall cover any such modification.

NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

RDF
RCSSES

GPO 811412

MIL-S-10379A
AMENDMENT 1
23 JULY 1952

MILITARY SPECIFICATION

SUPPRESSION, RADIO INTERFERENCE GENERAL REQUIREMENTS FOR VEHICLES (AND VEHICULAR SUBASSEMBLIES)

This amendment forms a part of Military Specification MIL-S-10379A, 6 July 1951, and was approved by the Departments of the Army, the Navy, and the Air Force for use of procurement services of the respective Departments.

Page 1, paragraph 2: Delete and substitute:

"2. APPLICABLE SPECIFICATIONS, STANDARDS, DRAWINGS, AND PUBLICATIONS

2.1 The following specifications, standards, and drawings, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY

JAN-C-5 —Capacitors, mica-dielectric fixed.

JAN-C-25 —Capacitors, Direct-Current, Paper-Dielectric, Fixed (Hermetically Sealed in Metallic Cases).

JAN-C-91 —Capacitors, Paper Dielectric, Fixed (Non-Metallic Cases).

U. S. ARMY

71-1585 —Resistors - Suppressors, Suppression (Radio Frequency Interference).

71-1667 —Capacitors, By-Pass, Suppression (Radio Frequency Interference).

71-1668 —Filters, Suppression (Radio Frequency Interference).

STANDARDS

MIL-STD-124—Voltage of Electrical Systems in Tactical Vehicles.

DRAWINGS

SIGNAL CORPS

SC-D-28120 —Typical Tactical Vehicle Suppression System.

(Copies of specifications, standards, and drawings required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting Officer)."

Page 3, paragraph 3.2.2: Delete and substitute:

"3.2.2 Nontactical vehicles.—The following types of vehicles shall conform to this specification for nontactical vehicles, unless stated in the bid request and contract that they shall meet the requirements for tactical vehicles: "Administration Vehicles," as defined in MIL-STD-124."

Page 4, paragraph 3.4, line 4: Delete "Drawing SC-D-28119" and substitute "Figure 11."

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Page 4, paragraph 3.4.1, line 4: Delete "Drawing SC-D-28119" and substitute "Figure 11."

Add: "Page 27—Figure 11, Non-tactical vehicle radio interference suppression system minimum application."

Custodians:
Army—Signal Corps
Navy—Bureau of Ships
Air Force

Other interest:
Army—EOT
Navy—AMCY.

NOTE:

ALL RADIO INTERFERENCE PRODUCING ACCESSORIES SHALL BE SUPPRESSED TO THE SAME DEGREE AS THE SYSTEM SHOWN HEREON.

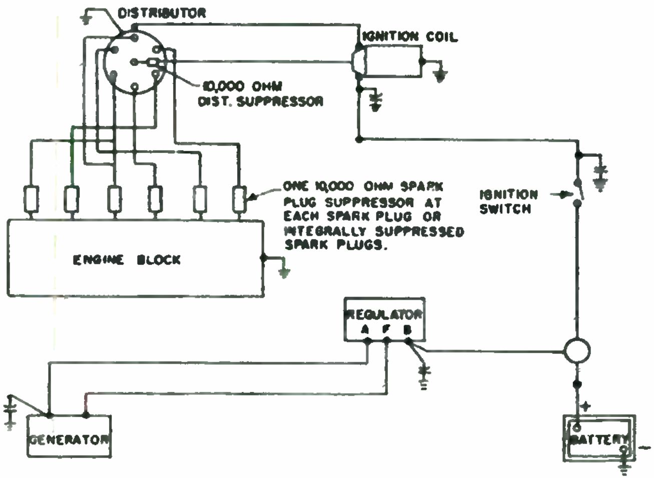

FIGURE 11.—*Nontactical vehicle radio interference suppression system minimum application.*

★ U S GOVERNMENT PRINTING OFFICE: 19…

MIL-S-10379A
6 JULY 1951
SUPERSEDING
MIL-S-10379(SigC)
13 July 1950

MILITARY SPECIFICATION

SUPPRESSION, RADIO INTERFERENCE GENERAL REQUIREMENTS FOR VEHICLES (AND VEHICULAR SUB-ASSEMBLIES)

This specification was approved by the Departments of the Army, the Navy, and the Air Force for use of procurement services of the respective Departments.

1. SCOPE

1.1 This specification covers the requirements for radio interference suppression, within the frequency range of 0.15 to 1000 megacycles, for all internal combustion engine-driven vehicles, tactical and nontactical procured by the Ordnance Corps for all the services, to permit satisfactory reception of intelligence with high sensitivity electronic communication equipment installed as follows:

In the vehicle and connected to the vehicular battery or auxiliary power supply installed in the vehicle as an integral part thereof.

In the vehicle and connected to a separate power source.

Adjacent to the vehicle and connected to a separate power source.

2. APPLICABLE SPECIFICATIONS AND DRAWINGS

2.1 Specifications.—The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification:

MILITARY SPECIFICATIONS

JAN-C-5 —Capacitors, mica-dielectric, fixed.

JAN-C-25 —Capacitors, Direct-Current, Paper-Dielectric, Fixed (Hermetically Sealed in Metallic Cases).

JAN-C-91 —Capacitors, Paper Dielectric, Fixed (Non-Metallic Cases).

U. S. ARMY SPECIFICATIONS

71-1585 —Resistors - Suppressors, Suppression (Radio-Frequency Interference).

71-1667 —Capacitors, By-Pass, Suppression (Radio Frequency Interference).

71-1668 —Filters, Suppression (Radio Frequency Interference).

(*Army.*—Copies of specifications should be obtained from the procuring agency or as directed by that agency. Both the title and identifying number or symbol should be stipulated when requesting copies.)

(*Navy.*—Copies of Military specifications may be obtained upon application to the Bureau of Supplies and Accounts, Navy Department, Washington 25, D. C., except that activities of the Armed Forces should make application to the Commanding Officer, Naval Supply Depot, Scotia 2, N. Y. Both the title and identifying number or symbol should be stipulated when requesting copies.)

(*Air Force.*—Copies of Military, and U. S. Air Force specifications may be obtained upon application to the Commanding General, Air Development Force, Wright-Patterson Air Force Base, Dayton, Ohio. Both the title and identifying number or symbol should be stipulated when requesting copies.)

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2.2 **Drawings.**—The following drawings, of the issue in effect on the date of invitation for bids, form a part of this specification:

SC-D-28119—Typical Non-Tactical Vehicle Radio Interference Suppression System (Battery Ignition).

SC-D-28120—Typical Tactical Vehicle Suppression System.

(Copies of Signal Corps Drawings may be obtained from the Signal Corps Procurement Agency, 225 South 18th Street, Philadelphia 3, Pa.)

3. REQUIREMENTS

3.1 Definitions.

3.1.1 *Radio interference.* — "Radio interference," or simply "interference," is defined as any electrical disturbance which causes undesirable response or malfunctioning of communication equipment. Interference emanating from a source may reach the affected equipment by means of conduction, induction, radiation, or any combination thereof.

3.1.2 *Units for measurement of intensity of interference.*—Intensity of interference is measured, for the purposes of this specification, in terms of microvolt per kilocycle (kc.) or per megacycle (mc.) of bandwidth (uv/kc or uv/mc). Interference intensity in microvolts per kc. or mc. is equal to the number of r.m.s. sinewave microvolts (unmodulated), applied to the input of the measuring circuit at its center frequency, which will result in peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the effective bandwidth of the circuit in kilocycles or megacycles. The effective bandwidth is the area divided by the height, of the voltage-response-versus-radio-frequency, selectivity curve, from antenna to peak detector.

3.1.3 *Suppression.*—"Suppression" of radio interference is reduction of the intensity of the emanated interference by means applied to or at the source.

3.1.4 *Suppression system.* — All components, materials and their application which are used for suppression of the interference emanated by a vehicle will be referred to as the "suppression system."

3.1.5 *Electrical subassemblies.* — An electrical subassembly is defined for purposes of this specification as any vehicular electrical subassembly such as spark plugs, generator, regulator, etc., associated with the basic functioning of the vehicle or its electrical system, which is supplied, stored, and issued as a complete operating assembly.

3.1.6 *Electrical accessory units.*—An electrical accessory unit is defined for the purposes of this specification as any electric motor or electro-mechanical device, such as gun traverse motors, cant correctors, synchro-motors, relay mechanisms, etc., capable of operation independent of the vehicle or its electrical subassemblies except for the power source.

3.1.7 *Type approval.* — An approved-type suppression component is one for which samples of the same make and type have previously been submitted, and tested and approved as being suitable for suppression purposes and in accordance with the applicable subsidiary specification.

3.1.8 *Integral suppression.*—An integrally suppressed electrical subassembly or accessory unit is one in which the suppression components are procured, stored, and issued as integral parts thereof.

3.2 Application of specification.

3.2.1 *Tactical vehicles.* — The following types of vehicles shall conform to this specification for tactical vehicles; unless otherwise specified, all types of self-propelled vehicles which receive installations of communication equipment, all types of tanks, armoured cars ,self-propelled cannon, self-propelled cargo carriers, half-track personnel carriers, half-track cargo vehicles, motor transport vehicles, high-speed tractors, and motorcycles.

3.2.2 *Nontactical vehicles.* — The following types of vehicles shall conform to this specification for nontactical vehicles, unless otherwise stated in the bid request and contract, in which case they shall meet the requirements for tactical vehicles: passenger-type vehicles and buses.

3.2.3 *Self-propelled machinery.*—Self-propelled machinery such as excavators, road graders, fork-lift trucks, slow-speed tractors, etc, shall not be considered as vehicles within the scope of this specification unless otherwise stated in the primary equipment specification. In this case, the latter specification shall state whether the requirements for tactical or nontactical vehicles shall apply.

3.2.4 *Railroad equipment.*—This specification shall apply to all railroad equipment as specified in the primary equipment specification or in the bid request and contract. (See 6.11.)

3.3 **Performance (tactical vehicles).**—The suppression system shall effectively reduce all radio interference emanating from the vehicle, to a level which would not prevent satisfactory reception of a signal which is just strong enough to be easily intelligible, in the absence of interference, on high-sensitivity radio receiving equipment in the required frequency range. This requirement applied to interference generated by the electrical system of the vehicle, auxiliary equipment, accessories, intermittent contact between parts, electrostatic discharge, or any other source which may appear.

3.3.1 *Limits of interference for tactical vehicles.*—Tactical vehicles not emanating interference in excess of the limits stated in 3.3.1.1, 3.3.1.2, and 3.3.1.3 when tested according to this specification, will be considered satisfactory in regard to interference emanation.

3.3.1.1 *Outside radiated interference limits.*—The interference limits stated in table I apply to tactical vehicles and accessories. (See 4.3 and 4.5.)

3.3.1.2 *Inside radiated interference limits.*—The interference limits stated in table II apply to the level of radiated interference permitted inside turreted vehicles being tested under 4.3, 4.3.2 to 4.3.2.2, and 4.5.

TABLE I.—*Outside radiated interference limits.*

Test equipment	Frequency band or tuning unit	Frequency range mc.	Limit	
			uv/unit bandwidth	db above 1 uv/mc.
Test Set AN/URM-3		0.15 to 40.0	.75 uv/kc.	58
R.F. Interference Test	TN-16/APR-4	40 to 95	100 uv/mc.	40
Set AN/URM-29	TN-17/APR-4	96 to 305	200 uv/mc.	46
	TN-187/URM 20	306 to 1000	200 uv/mc.	46

TABLE II.—*Inside radiated interference limits.*

Test equipment	Frequency band or tuning unit	Frequency range mc.	Limit	
			uv/unit bandwidth	db above 1 uv/mc.
Test Set AN/URM-3		1.5 to 40	.25 uv/kc.	48
R.F. Interference Test	TN-16/APR-4	40 to 95	100 uv/mc.	40
Set AN/URM-29	TN-17/APR-4	96 to 305	200 uv/mc.	46
	TN-187/URM-29	306 to 1000	200 uv/mc.	46

3.3.1.3 *Conducted interference limits at terminal boxes.* — The interference limits stated in table III apply to the level of conducted interference between any pair of terminals intended to supply power to communications equipment at any electrical terminal box or contact block in tactical vehicles being tested under 4.3, 4.3.3 to 4.3.3.1, 4.4 and 4.5, with the engine and all electrical equipment in operation.

3.4 **Requirements (nontactical vehicles).**— All nontactical vehicles shall incorporate, as a minimum requirement, the suppression system detailed in Drawing SC-D-28119.

3.4.1 Nontactical vehicles which incorporate any interference-producing device not covered by the minimum suppression system shown on Drawing SC-D-28119 shall be suppressed, with all interference sources operating, to the level of interference which would exist if the vehicle did not incorporate such device. The contracting officer may run tests to determine conformance to this requirement.

3.5 **Approval of suppression components (all vehicles).**—All components of the suppression system for both tactical and nontactical vehicles shall be subject to approval as hereinafter provided.

3.5.1 *Integral suppression components.*— Integral suppression components (see 3.1.8), shall be subject to approval of the particular application in the sub-assembly or accessory for soundness of electrical, mechanical and suppression features. Whenever practicable, such components shall be in accordance with any of the applicable Military or U. S. Army specifications listed in 2.1 of this specification, and shall have type approval as provided in 3.5.2. Whenever components complying with these specifications cannot be used, the specific component used shall be subject to approval for the specific application.

3.5.2 *Nonintegral suppression components.* —Nonintegral suppression components shall be in accordance with Specifications 71-1585, 71-1667 or 71-1668, and shall have type approval. (See 3.1.7) If the bidder or contractor proposes to use any component not previously approved, samples of such components shall be submitted for approval, as described in 6.2. Capacitors conforming to Specifications Jan-C-5, JAN-C-25 or JAN-C-91 are not necessarily suitable for suppression purposes, but specific applications may be approved.

3.5.3 *Use of suppression components beyond specification ratings.*—Capacitors, filters or resistor-suppressors shall not be used under conditions more severe than the conditions specified in the applicable subsidiary specifications, unless specifically authorized in writing by the contracting officer. Such authorization may be obtained only by submission of samples, as described in 3.5.2, accompanied by a complete statement of the service conditions under which the components will be used, and test data showing that the component will withstand such conditions.

TABLE III.—*Conducted interference limits at terminal boxes.*

Test equipment	Coupler unit for connection to terminal box	Frequency range mc.	Limit	
			uv/unit bandwidth	db above 1 uv/mc.
Test Set AN/URM-3	CU-153/URM	1.5 to 10 10 to 40	10/uv/kc. 5/uv/kc.	80 74

3.5.4 *Suppression components not covered by subsidiary specifications.*

3.5.4.1 Approval of the use of any capacitor, filter, filter assembly, or resistor-suppressor or suppression, other than those covered by 3.5 to 3.5.3, inclusive, will be granted by the contracting officer only if the contractor show that suppression or electrical requirements, operating conditions, or limitations of space prevent the use of types in accordance with the applicable subsidiary specifications. In such cases, samples shall be submitted to the contracting officer in accordance with 3.5.4.3.

3.5.4.2 At the discretion of the contracting officer, suppression components other than those covered by 3.5 to 3.5.3, inclusive such as shields and shielding, lockwashers and bonds, shall be subject to inspection for mechanical, electrical and suppression effectiveness before approval for use. Samples shall be submitted for the purpose in accordance with 3.5.4.3.

3.5.4.3 *Submission of samples for inspection, test and approval.*—A maximum of 12 samples shall be submitted of any component covered by 3.5.4.1 and 3.5.4.2. These samples shall be constructed using the materials, parts, tools, and methods which will be used in quantity production. When submitted, they shall be acompanied by five copies of detail drawings showing dimensions, materials, and construction, a complete statement of the service conditions under which the component will be used, and test data showing that the component will withstand such conditions.

3.6 Integrally suppressed electrical subassemblies and accessory units.—Integral suppression of electrical subassemblies and accessories shall be used whenever practical, in order to improve suppression, simplify the maintenance of the suppression system, and reduce the chances that it may unintentionally be rendered ineffective during the course of vehicle maintenance.

3.7 Pilot model (tactical vehicles).

3.7.1 *Submission of pilot model.*—The contractor shall submit an experimental pilot model of each vehicle to the bureau or agency designated in the bid request and contract, for inspection and test of the suppression system. The experimental pilot model shall be a preproduction vehicle, and may be handbuilt. The contractor shall equip this model with suppression components in the same manner that he intends to equip production vehicles. Before submission for approval, he shall test it for conformance with this specification. (See 6.3.) The first experimental pilot model shall be accompanied by two copies of each of the following:

- Detailed list and description of the suppression components, integral and nonintegral, indicating for each suppression component the manufacturer's name and model number, and location on the vehicle or in the subassembly or accessory.
- List of all electrical equipment, except lights and horn, used on vehicle. Each such item of electrical equipment shall be identified on the list by manufacturer's name and model number.
- Print of the complete electrical system of the suppressed vehicle, showing electrical location and connections of all suppression components, whether integral or nonintegral.

Each of the above items shall be marked with the date of submission of vehicle, contract number, name and address of the contractor, the nomenclature of the vehicle, and its serial and U. S. registration numbers.

3.7.2 *Approval of pilot model.*—The pilot model will be inspected and tested by the designated Government agency for compliance with this specification (see 6.4), and will then be returned to the contractor. If the pilot model is disapproved, the contractor shall correct the deficiencies and submit it, unless otherwise allowed, until approval is obtained. Each corrected model shall be accompanied by a complete description of the changes made to correct the faults of the preceding rejected model. Approval of the pilot model shall not constitute a waiver of any specified requirement.

3.7.3 *Report on pilot model.*—The Government testing agency will furnish the contracting officer a report on the approved pilot model, setting forth the detailed suppression requirements to be followed on production vehicles and accessories; however, if subsequent tests on production vehicles indicate that these requirements must be modified to provide a satisfactory suppression system, the modified requirements shall be followed thereafter. The contracting officer will furnish the contractor with instructions, based on the report of the approved pilot model, detailing the suppression system to be supplied on production vehicles. Authority in writing shall be obtained from the contracting officer for any exceptions to, or deviations from, the suppression system approved for production.

3.7.4 *Approval of electrical accessory units and subassemblies.*

3.7.4.1 *Accessories.*—A model of each noncommercial type electrical accessory as defined in 3.1.6 (or redesigned commercial type) designed by the contractor or his subcontractor for the particular vehicle on the contract, and not approved since the date of this specification for use on Army vehicles, shall be submitted, for inspection and test of its suppression system (including all pertinent nonintegral suppression components), prior to submission of the experimental pilot model of the vehicle, to the agency designated in the bid request and contract. The model of the accessory shall be accompanied by two copies of a detailed list and description of the suppression components, both integral and nonintegral, indicating for each suppression component the manufacturer's name and model number, and location in or relative to the accessory.

3.7.4.2 *Subassemblies.*—No pilot testing of vehicular electrical subassemblies as defined in 3.1.5 shall be required under this specification, as suppression tests will be performed on the pilot and production models of the vehicles incorporating the subassemblies.

3.7.5 *Changes after approval of pilot model.*—After approval of the pilot model all production vehicles, accessories, and subassemblies shall unless otherwise allowed or required, be identical in all respects to the approved pilot model and the report on that model (3.7.3) except as described below:

3.7.5.1 *Substitution of suppression components.*—

3.7.5.1.1 The contractor may, at his discretion, substitute a suppression component with identical electrical characteristics and mechanically interchangeable construction, but of different manufacture, for a corresponding component, provided that the substitute component has received type approval as described in 3.5 to 3.5.3, inclusive.

3.7.5.1.2 Any other substitution or change of a suppression component shall be made only if approved in writing by the contracting officer. Request for permission to make such a substitution or change shall be accompanied by a detailed description of the proposed substitute suppression component and its method of application, and shall include data showing that the proposed substitute is at least the equal of the item it will replace. (If the proposed substitute is an item requiring type approval under 3.5 and has not yet received such approval, the contractor shall submit samples in accordance with that paragraph.) At the discretion of the contracting officer, the contractor shall submit another pilot model, identical with the previously approved pilot model except for the changes being submitted for approval.

3.7.5.1.3 *Changes in integral components.*—In the case of substitutions or changes of integral suppression components incorporated in electrical subassemblies or accessory units, the contracting officer may require submittal of a model of the original and of the revised subassembly or accessory unit, and if the revised version is found inferior as to suppression characteristics, the contracting officer may then require test of an additional pilot model of the vehicle incorporating the revised subassembly or accessory unit.

3.7.5.2 *Changes in the vehicle (tactical only)*.—The contracting officer shall be notified as early as possible in writing by the contractor of any changes made or planned in the electrical components, subassemblies or accessories of the vehicle, their location or wiring. He shall likewise be notified of any changes in the structure or electrical bonding (including use of tooth-type lockwashers) of the vehicle which might affect generation or emanation of interference. If the contractor does not submit data satisfactory to the contracting officer showing that the changes will not result in failure to conform to this specification, the contracting officer may, at his discretion, require the contractor to submit another pilot model, identical with the previously approved pilot model except for the changes being submitted for approval. This pilot model shall meet the same requirements as the original pilot model.

3.8 Spare parts.

3.8.1 *Suppression components*. — Spare suppression components for all vehicles shall conform to 3.10 for interchangeability with corresponding parts used on the vehicle, and shall also conform to 3.5.

3.8.2 *Other components*. — Where components of the vehicle, such as fenders and radiators, which are not part of the suppression system, have been modified for suppression purposes by preparing surfaces for bonding or by any other means, the corresponding spare components shall be similarly modified to provide an equal degree of suppression.

3.9 Methods of suppression.—Suppression of ignition, charging circuit, and other electrical interference shall be effected by resistor-suppressors, capacitors and/or filter, shielding, proper bonding and grounding of radiating elements, proper routing of wiring, and proper location of parts.

3.9.1 *Filters and capacitors*.—Filters shall be used only where adequate suppression cannot be effected by reasonable application of capacitors.

3.9.2 *Resistor-suppressors*.—Resistor-suppressors shall be used in the high-tension ignition circuits to minimize the suppression requirements of the shielding and critical mantenance thereof.

3.9.3 *Separation of wiring*.—High-tension ignition wiring, primary ignition wiring, and charging-circuit wiring shall not be routed any closer than necessary to each other or combined with auxiliary wiring. Adequate support shall be given all wiring to maintain separation and position. When interference from electrical fuel pumps and other interference-producing devices cannot be suppressed at the source, wiring for such devices, if combined with other wiring, shall be separately shielded unless it can be demonstrated that the interference caused by the auxiliary devices is of such value and frequency that the vehicle meets specification requirements without the shielding. Connections between the several electrical components of the vehicle and the associated bypass capacitors or filters of the suppression system shall be as short as possible, and shall be separated from other wiring wherever practicable.

3.9.4 *Shielding*. — Flexible metal hose, solid-wall conduit and wire braid, utilized as part of the suppression system or as mechanical support of the wiring, shall be terminated and grounded at both ends by means of suitable fittings or clamps. Pigtail connections are not acceptable. Where shielding terminates at a case or bulkhead, a good electrical contact shall be insured between the metal case or bulkhead and the shielding, and the metal case shall be grounded as specified in 3.9.5. Long lengths of shielding or protecting members shall be clamped at intervals no greater than 2 feet, by clamps which are soldered to, or exert pressure on, the shielding or protecting member, to insure good and permanent radio-frequency electrical grounding and mechanical support. Contacting surfaces of the clamp, shielding, or supporting member, and the part to which the clamp is affixed, shall be treated as specified in 3.11.3. Where continuity of electrical contact along a seam or joint in shielding or fittings is necessary to obtain adequate suppression, the seam or joint shall be corrosion-resistant and mechanically designed to maintain the contact for the required life of the parts, including necessary disassembly and reassembly. Electrically conductive gaskets may be used for this purpose.

3.9.4.1 However, shielding boxes, terminal boxes, junction boxes, and similar parts need not be plated or metal-dipped, provided that continuous-seam contact proves unnecessary for suppression, and provided that each box and its cover, and all conduit terminations, are effectively grounded by the use of tooth-type lockwashers. When threaded conduit fittings are welded to a box, the threaded nipple shall be plated or made of corrosion-resistant metal.

3.9.5 *Grounding.*—All components of the electrical and suppression system and parts of the vehicle which require radio-frequency return paths to ground shall be so grounded that a corrosion-resistant low-impedance electrical connection will be assured throughout the life of the equipment. Metallic guides which support high-tension wiring shall be grounded to meet these requirements. Mechanical parts such as choke, throttle, speedometer and tachometer cables, oil lines, conduit and steering columns, when they project into the field of radio interference, shall be grounded in such a manner as to prevent reradiation that may cause radio interference. Grounding shall be accomplished by bond straps, tooth-type lockwashers, electrically conductive gaskets or other suitable means.

3.9.6 *Bonds.* — Each bonding strap shall have a length and cross-sectional shape and dimensions consistent with best electrical and mechanical practice. All bonding straps shall be installed so that they will not be broken by vibration or stress due to service conditions. Bonding straps shall be mounted, if practicable, in such a manner that they may be readily replaced. Bonds mounted by bolts shall have suitable terminals. Sheet metal screws shall not be used for fastening bonds. At least one end of each bond shall be bolted in order that the vehicle may be readily disassembled without adversely affecting the suppression.

3.9.7 *Machine-finished surfaces.* — Machine-finished surfaces to which suppression components are affixed need not be plated. Such mating surfaces of machine-finished parts shall be free of corrosion, paint, or other foreign material, and shall not be treated in any manner that will impair their electrical conductivity on the mating surfaces.

3.9.8 *Ignition coil.*—In order to minimize suppression treatment and to aid in providing lasting, effective suppression, the ignition coil, unless otherwise allowed by the contracting officer, shall be located close to or combined with the distributor. If separate, it shall be mounted on a bracket, affixed to the engine block, providing good grounding for the case of the coil.

3.10 Interchangeability.—All parts of the suppression system on any vehicle, and all spare parts for the suppression system, shall be electrically and mechanically interchangeable with all corresponding parts on any other vehicles manufactured under the same contract, and wherever possible, with all other vehicles of the same type.

3.11 Material and workmanship.

3.11.1 *Material.* — The material for each part shall be as specified. The best material commercially available for the purpose, and capable of withstanding the extremes of temperature, humidity and other operating conditions encountered in arctic and tropical service, shall be used when a definite material is not designated.

3.11.1.1 *Insulation material.* — Insulation material which is exposed to the air shall not be subject to rapid combustion or explode from electrical spark or from heating. The use of flammable or explosive varnish is prohibited.

3.11.2 *Soldering.* — Whenever practicable, soldering shall be done with rosin, or rosin and alcohol, flux. If it proves necessary to use any other flux it shall be chemically neutralized and removed after soldering. Soldering shall not be depended upon for mechanical strength of connections. Where flexible shielding, bonds, etc., are soldered, the flexibility of these parts shall be unaffected.

3.11.3 *Corrosion.* — To prevent corrosion, all hardware (bolts, screws, nuts, lockwashers, retaining nuts, elbows, ferrules, etc.) used in the installation of the suppression system shall be plated by an electrolytic or hot-dip process with a metallic material of high electrical conductivity. The finished surfaces shall be capable of withstanding the test specified in 4.6, after which there shall be not more than six corroded areas per square foot, not more than two corroded areas on any part having a total surface of less than 1/3 square foot, nor any corroded area larger than 1/16 inch in diameter. At the discretion of the contracting officer, samples may be required for the corrosion test: (See 6.2).

3.12 Technical manual and instruction book.—Any technical manual or instruction book regarding the vehicle, prepared and furnished as part of the order by which the vehicle is procured, shall contain complete technical information, including photographs and/or drawings, on the functioning and maintenance of the suppression system.

3.13 Workmanship. — All parts shall be manufactured and finished in a thoroughly workmanlike manner, and in accordance with the best commercial practice for arctic and tropical use. All dimensons, except where tolerances are given on drawings, shall be held as close as is consistent with good shop practice. All parts shall fit and operate in a good, workmanlike manner.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Acceptance inspection.—Unless otherwise specified, acceptance inspection shall be conducted by the Government inspector when equipment is submitted for acceptance on contract.

4.1.1 *Scope of acceptance inspection.*—Acceptance inspection shall include the tests of 4.5 and such other inspection and nondestructive testing of material, parts, components and complete suppression systems as are considered necessary by the Government inspector to determine compliance with this specification and its subsidiaries.

4.2 Test equipment for pilot and production tests.

4.2.1 *Measuring equipment.*—Interference measuring equipment as follows, for conducting interference tests on tactical vehicles, will be provided by the contracting officer and used by the Government inspectors:

Test Set AN/URM-3, 0.15-40 megacycles.

R.F. Interference Test Set AN/URM-29, 40-1000 megacycles.

Upon request, the contractor may obtain information which he requires concerning this test equipment and the manner in which it will be used, to enable him to suppress the pilot model to meet the required tests. Limits of allowable interference are stated in 3.3.1 through 3.3.1.3, and the units in which the interference shall be measured are defined in 3.1.2.

4.3 Government tests on pilot models.—Pilot models of vehicles and electrical accessories will be tested by the Government at the location specified by the contracting officer. If the vehicle under test is equipped with accessory items such as heaters, fans, windshield wipers, traversing motors and similar equipment, the tests shall also be performed with all of these components operating.

4.3.1 *Radiation Tests (tactical vehicles).*—The radio interference radiated from all tactical vehicles shall be measured on at least three sides, over the frequency range of .15 to 1000 mc. Radiation tests shall be conducted with all electrical equipment in the vehicle in operation.

4.3.1.1 *Test Set AN/URM-3.*—The test limits specified in table I apply. Over the frequency range .15 to 40 mc, using Test Set AN/URM-3, the test equipment shall be located as shown in figures 1, 2, 3 and 4. Whenever Test Set AN/URM-3 is placed on the vehicle, it shall be insulated therefrom by a nonconducting material of adequate size. With Test Set AN/URM-3 located on the fender as close as possible to the engine compartment and arranged so that the antenna is situated near the lateral axis of the engine, the 9 foot, rod antenna shall be sloped across the engine compartment so that the tip of the antenna is located in a vertical plane through the edge of the opposite fender or similar outermost extremity of metal, but the mid-point of the antenna shall not be placed closer than 1 foot from the top of the engine compartment. When testing front or rear radiation, depending upon location of engine compartment, Test Set AN/URM-3 shall be located so that the base of the antenna lies in same horizontal plane as the top of the front radiator grill or rear lower edge of top radiator grill. The 9 foot rod antenna shall be sloped across the engine comparment so that the mid-point of the antenna is not more than 24 or less than 12 inches above the engine compartment. If antenna is unobstructed with Test Set AN/URM-3 as close as possible to the vehicle or engine compartment, the antenna shall be sloped so that the mid-point is 12 inches above the engine compartment.

4.3.1.2 *R.f. interference test Set AN/URM-29.*—Over the frequency range of 40 to 1000 mc, the antenna of r.f. interference Test Set AN/URM-29 shall be located as shown in figures 5, 6, 7 and 8. The apex of the cone is located 3 feet from the edge of the engine compartment on the lateral or longitudinal axis of the engine. The antenna configuration used for the various frequency bands and tuning heads is as follows:

(a) 40 to 55 mc. (TN-16/APR-4) Antenna AT-292/URM-29, with 6 Mast Sections AB-21/GR at center of cone
(b) 56 to 95 mc. (TN-16/APR-4) Antenna AT-292/URM-29 with 2 Mast Sections AB-21/GR on periphery of cone at each 120 degrees
(c) 96 to 305 mc. (TN-17/APR-4) Antenna AT-292/URM-29, with 1 Mast Section AB-21/GR on periphery of cone at each 120 degrees
(d) 306 to 1000 mc. (TN-187/URM-29) Antenna AT-292/URM-29, without Mast Sections AB-21/GR

The antenna shall be tilted so that an extension of the ground plane intersects the near edge of the engine compartment at its mid-point.

4.3.1.3 *Radiation test, electrical accessory units (tactical vehicles).*—The radio interference radiated from all electrical accessory units submitted for test in accordance with 3.7.4 shall be measured over the frequency range of .15 to 1000 mc. The accessories shall be tested ungrounded, and powered by their standard power supply.

4.3.1.3.1 *Test Set AN/URM-3.*—Test Set AN/URM-3 shall be arranged with the center of horizontal 9 foot rod antenna located over the mid-point of the sub-assembly and separated 12 inches therefrom for radiation tests from .15 to 40 mc. The limits specified in table I apply.

4.3.1.3.2 *R.f. interference test set AN/URM-29.*—For radiation tests from 40 to 1000 mc. the apex of the cone of the antenna shall be located 18 inches from the nearest part of the accessory under test, and the antenna shall be so oriented that a line from the apex of the cone to the center of the accessory bisects the angle between the cone and the plane. The tests shall be made with the antenna configurations as described for the various frequency bands in 4.3.1.2. The test limits specified in table I apply.

4.3.2 *Inside radiation test for turreted vehicles (tactical).*—In addition to the outside radiation test, all turreted type tactical vehicles shall have an inside radiation test conducted over the frequency range of 1.5 to 1000 mc. Inside radiation tests shall be conducted with all electrical equipment in the vehicle in operation. The test limits specified in table II apply.

4.3.2.1 *Test Set AN/URM-3.* — Test Set AN/URM-3 shall be placed on an insulating board on the outside of the vehicle as close as possible to each antenna outlet normally provided in the vehicle. A 9 foot length of antenna lead-in Wire (W-128) shall be routed successfully in each lateral direction around the inside of the vehicle as shown by routings A and B on figure 9, and connected to Test Set AN/URM-3 with the shortest possible length of antenna wire external to the vehicle. The inside radiation tests shall be conducted with all hatches closed in order to minimize pick-up of ambient noise. The radio interference shall be measured for both routings of the antenna wire at each antenna outlet location over the frequency range of 1.5 to 40 mc.

4.3.2.2 *R.f. interference test Set AN/URM-29.*—The antenna of r.f. interference test Set AN/URM-29 shall be placed inside of the turret of the vehicle as shown on figure 10, and the radio interference measured inside the vehicle over the frequency range of 40 to 1000 mc. The antenna configuration used for the various bands shall be as follows:

(a) 40 to 305 mc. Antenna AT-292/URM-29, with 1 Mast Section AB-21/GR on periphery of cone at each 120 degrees.

(b) 306 to 1000 mc. Antenna AT-292/URM-29, without Mast Sections AB-21/GR

The plane shall be placed in a horizontal position approximately 6 inches from inside top of turret for all inside radiation tests. The limits of Table II specified apply.

4.3.3 *Conducted interference test (tactical vehicles).* — This test will be made on all types of tactical vehicles designed for installation of communication equipment, and on electrical accessories for such vehicles, over the frequency range of 1.5 to 40 megacycles. The test limits specified in table III apply. The conducted interference level shall be measured with Test Set AN/URM-3, with the required coupling network connected successively between each pair of terminals intended to supply power to communications equipment and between each such terminal and ground, at each electrical terminal box, contact block or connector.

4.3.4 *Pilot tests on nontactical vehicles.*—Pilot tests on nontactical vehicles will be run by the Government only in cases covered by 3.4.1. (See 6.12.)

4.4 Tests of electrical accessory units.—The conducted interference level of electrical accessories being tested under 3.7.4 shall be measured with Test Set AN/URM-3 with the required coupling network connected successfully across the terminals, and between each terminal and ground, at the power input terminals of the accessory. The limits specified in table III apply.

4.5 Government production testing.

4.5.1 *Tactical vehicles.* — All production tactical vehicles shall be subject to inspection by the Government in accordance with 4.5.1.1 through 4.5.1.8.

4.5.1.1 *Field test.* — The contractor shall submit, at an electrical-interference-free area approved by the contracting officer, tactical vehicles required by the Government for test, to determine that such vehicles are suppressed in accordance with this specification, and to determine the thoroughness of the visual inspection. The field test shall be conducted by authorized representatives of the contracting officer, using the equipment and procedure specified for pilot model tests.

4.5.1.2 *Initial inspection.*—An initial group of not less than 5 nor more than 25 vehicles from the first production of each type of vehicle, shall be subjected by the Government to radio interference field tests in accordance with 4.5.1.1 to determine whether the production application of the suppression system is satisfactory. If it is unsatisfactory, the contractor shall repair the rejected vehicles, and shall change his production methods to correct the cause of failure. The contracting officer may then require the testing of such additional quantity of vehicles as is considered necessary to determine that the corrected production application of the suppression system is satisfactory.

4.5.1.2.1 When a group of vehicles is submitted for the initial inspection it shall be accompanied by two copies of a list of the required and/or authorized changes of the electrical and suppression systems from the approved experimental pilot model, marked with the date of submission of the vehicles, contract number, name and address of the contractor, the nomenclature of the vehicles, and the serial number and U. S. registration number of each vehicle submitted for test.

4.5.1.3 *Production sampling of tactical vehicles.*—After vehicles have satisfactorily passed the initial inspection specified in 4.5.1.1 to 4. 5. 1. 2. 1, inclusive, the quality of the suppression system on all additional vehicles shall be controlled by subjecting random vehicles to similar tests. Whenever required by the contracting officer, a maximum of 1 percent of the vehicles shall be selected for the test. If less than 100 vehicles are being procured, at least one vehicle shall be tested after the initial inspection. If any vehicle fails to pass the test the contractor shall change his production methods to correct the cause of the failure. In addition, the contracting officer shall require the testing of such additional vehicles as is considered necessary to insure that satisfactory vehicles will be provided.

4.5.1.4 *Condition of vehicles to be tested.*—No experimental pilot model or production vehicle shall be submitted for test of radio interference unless reasonably dry and free from rain, ice, and snow. The expression "reasonably dry" shall be interpreted to mean that the vehicle shall not be visibly wet.

4.5.1.5 *Electrical subassemblies and accessories.*—No Government production testing of the vehicular electrical subassemblies or accessories, separate from the vehicle, is required.

4.5.1.6 *Incompletely assembled vehicles.*—Where vehicles are shipped in other than a completely assembled condition the required field tests shall be made on vehicles which have been assembled for road test.

4.5.1.7 *Integral suppression components.*—A spot check of integral suppression components by visual or electrical test may be required, at the discretion of the contracting officer.

4.5.1.3 *Visual inspection of suppression system.*—In each vehicle, a thorough visual inspection shall be made of the complete installation of the suppression system, except integral suppression components, for proper mechanical and electrical connection of all suppression components, for proper mechanical and electrical connection of all suppression components such as bonds, bypass capacitors, resistor-suppressors, filters, etc., to determine conformance to the pilot model report (3.7.3). Where vehicles are shipped in other than a completely assembled condition this inspection may be made on the partially assembled vehicles. This inspection shall be performed at a point or points in the production line determined by the contracting officer. Until the initial inspection (4.5.1.1 to 4.5.1.2.1, inclusive) is completed, acceptance shall be based on compliance with the pilot model report. After completion of the initial inspection, acceptance shall be based on compliance with instructions issued by the contracting officer, based on results of the tests.

4.5.2 *Inspection, nontactical vehicles.* — Production models of all nontactical vehicles shall be subjected to a visual inspection for compliance with this specification.

4.5.3 *Check for use of Government-inspected suppression components.*—Inspection shall insure that all suppression components covered by 3.5 furnished on production vehicles, both tactical and nontactical, have been subjected to tests as required by the subsidiary specifications listed in 2.1. Inspection shall also insure that suppression components covered by 3.5 have been subjected to tests as required by the contracting officer. Where the tests of suppression components are performed at a sub-contractor's plant, inspection at the plant of the vehicle manufacturer shall determine that the components, or packages thereof, bear the stamp of the Government inspector.

4.6 Corrosion test. — Parts which must meet the requirements of 3.11.3 shall be tested as follows: Just prior to testing, wash the parts in petroleum ether, then in alcohol, and dry. Subject the parts to a salt spray for 200 hours at a temperature of 95 ±4° F., using a 20 percent (by weight) aqueous solution of sodium chloride. Conduct the test in a closed tank of material nonreactive to the salt spray. The spray shall be finely divided. The tank shall be so designed that there will be no direct impinging or dripping of spray upon the parts. The spray shall circulate freely about all the parts to the same degree, and no liquid which has come in contact with the parts shall return to the aspirator to be resprayed. (See 6.2 to 6.3, inclusive.)

5. PREPARATION FOR DELIVERY

5.1 The applicable section of the equipment specification shall apply.

6. NOTES

6.1 Type approval.—Current Army Qualified Products Lists (AQPL's) of type-approved suppression capacitors, filters and resistor-suppressors may be obtained by contracting officers from the Signal Corps Procurement Agency, 225 South 18th Street, Philadelphia 3, Pa., by referring to the Specification Number covering the particular component. The AQPL's should be distributed by the contracting officer to contractors or prospective contractors. Indication of approval of any item, by its inclusion in an AQPL or by other means, as being suitable for suppression purposes and in accordance with the applicable specification, covers use of the component only for suppression purposes. Current QPL's of type-approved JAN capacitors are also available from the same source; however, see 3.5.2.

6.2 Contractual samples. — The samples mentioned in 3.5.1 through 3.5.4.3, and 3.11.3 should be submitted as described in 6.2.1. Each sample should be securely tagged with sufficient identifying information such as name and address of the manufacturer of the component, his type or model number for the components, the name and the address of the prospective bidder or contractor on the order for the equipment, the order and contract number pertaining to the procurement of the equipment, and the notation "CONTRACTUAL SAMPLE." Such samples should be accompanied by a statement from the contractor giving all pertinent information concerning the reason for requesting that the samples be inspected and tested, and providing engineering information and wiring diagrams concerning the proposed application of the items represented by the samples.

6.2.1 Contractual samples received by the contracting officer should be submitted to the Signal Property Officer, Bldg. 41, Supply Division, Evans Signal Laboratory, Belmar, N. J., Attn: Suppression and General Engineering Branch, Coles Signal Laboratory.

6.3 Noncontractual samples.—Noncontractual samples of suppression components (those not submitted in accordance with 3.5.1 through 3.5.4.3, and 3.11.3) may be submitted to the address specified as given in paragraph 6.2.1 for inspection and test. The samples should be accompanied by a statement from the Government agency concerned, giving all pertinent information concerning the reasons for requesting that they be tested and their proposed application. Each sample should be securely tagged with sufficient identifying information such as name and address of the manufacturer and his type or model number, and the notation "NONCONTRACTUAL SAMPLE." The samples should be accompanied by two copies of a statement of release from obligation, as indicated below:

Number of Samples:_______Type______
Remarks: __________________________

The undersigned distinctly understands and agrees that the sample(s) itemized above are offered the Government free of charge and without any obligation whatsoever on the part of the Government, either expressed or implied. It is further understood that the Government shall be under no obligation to test the samples, to furnish results of the tests, enter into any correspondence concerning the sample(s), or to return the sample(s). The undersigned state that it is their standard and commercial practice to furnish such sample(s), in the quantity listed above, to the trade without charge.

____
(Signature)

____
(Firm Name)

____
(Date)

6.4 Testing of pilot model and production vehicles.—Test equipment and personnel for conducting the inspection and test of the suppression systems on pilot models, and on production vehicles undergoing the Government field tests, will be provided by Coles Signal Laboratory. Contracting officers should notify the Director, Coles Signal Laboratory, Fort Monmouth, New Jersey *at least 10 days* before a pilot model will be available for inspection and test of the suppression system. Results of the tests, and a report covering the method of suppression to be followed on any subsequent pilot model and/or production unit will be furnished to the contracting officer. The report should be included as part of any approval of the pilot model to which it applies.

6.5 Representatives of the contracting officer.—The contracting officer represents the U. S. Government in all dealings with a contractor who is furnishing equipment that is required to be suppressed in accordance with this specification, and in all direct dealings with the manufacturer (sub-contractor) who is furnishing suppression components or electrical components or accessories to the contractor for installation on the equipment. It is to be understood that any Government agency or representative can perform those functions of the contracting officer that are mentioned in this specification, to the extent that the contracting officer has specifically delegated his authority to such Government agency or representative. It is to be further understood that Government inspectors represent the contracting officer for supervision of inspection and testing of equipment and the components and parts thereof, at the contractor's or manufacturer's plant.

6.5.1 The proposal request and contract will usually delegate the following functions to a Government engineering agency:

(1) Approval for the use of capacitors or filters under conditions that are more severe than the one specified in the applicable specification therefor.

(2) Testing of capacitors or filters that do not conform to the applicable specification to determine whether such components are acceptable for the proposed application.

(3) Inspection, testing, and approval of samples of suppression components to be approved before being furnished as part of the equipment on order.

(4) Inspection, testing, and approval of the suppression system on the pilot model.

(5) Use and maintenance of Government test equipment.

(6) The Government agency designated to perform the above functions will usually be Coles Signal Laboratory, Fort Monmouth, New Jersey.

6.6 **Proposal request and contract.**

6.6.1 *General information.*—The following general information is given for the guidance of the contracting officer:

6.6.2 *Inspection of the suppression system.*—Government inspectors representing the procuring service concerned should be responsible for supervision of the visual inspection of the suppression system on production units. Assistance from representatives of Coles Signal Laboratory may be obtained for the following:

(1) Approval of interference-free area.

(2) Use and maintenance of Government test equipment for testing production models.

6.6.3 *Responsibility for testing of samples and pilot models.* — It is recommended that the contracting officer delegate the testing of the suppression system on the pilot models, the testing of samples submitted in accordance with 3.5.1 through 3.5.4.3 of this specification, and the testing of samples of other items relating to suppression of the vehicle, to the Coles Signal Laboratory.

6.6.4 *Recommendations.*

6.6.4.1 The contracting officer should direct that all drawings, prints, lists of suppression components, etc., that are required by this specification to be provided by the contractor, be sent to the Coles Signal Laboratory for information and necessary action.

6.6.4.2 If requested by the contractor, information covering test procedure and Government test equipment may be obtained by the contracting officer upon application to the Coles Signal Laboratory.

6.6.4.3 Close coordination should be maintained among the contracting officer, the inspection agency, and the Coles Signal Laboratory to insure that any changes in pilot models or production items that might affect radio interference suppression will be satisfactorily provided for by necessary changes in the suppression system.

6.7 **Sources of electrical interferences.**—The more common sources and emanators of interference are listed below, but should not be considered as the only possible sources of interference:

a. Ignition system of the engine:

(1) High-tension ignition circuit, including all high-voltage wiring of the ignition system, the ignition coil or magneto, distributor and spark plugs.

(2) Low-tension ignition system, including low-voltage wiring of the ignition system, ignition coil, ignition switch and breaker points.

b. Charging circuit, including the generator, regulator, and associated wiring.

c. Low-voltage electrical system, which includes all wiring for the electrical subassemblies and accessories of the vehicles, such as:

(1) Electric fans, windshield wipers, indicating devices, traversing equipment, gyrostabilizer equipment, etc.

(2) Auxiliary engine-generator units.

d. Intermittent contact between parts.

e. Electrostatic discharges from track systems of track-laying vehicles, nondriven wheels, and fan belts.

6.8 Contractor's tests on pilot model.—The contractor, in making the tests required by 3.7.1 on the pilot model, may use commercial radio noise meters or sensitive radio receivers covering the required frequency range; however, the fact that a vehicle may be suppressed to the point of emanating no interference detectable on such equipment does not necessarily indicate that it will be satisfactory when tested with the Government's test equipment.

6.9 Tests and consultation on suppression of automotive electrical subassemblies.—Automotive electrical subassemblies, as defined in 3.1.5, may be submitted by the contractor or sub-contractor, for qualitative tests of the suppression characteristics and assistance in the design of suitable suppression systems, to Signal Property Officer, Building 41, Supply Division, Evans Signal Laboratory, Belmar, N. J. Attn: Suppression and General Engineering Branch, Coles Signal Laboratory. Consultation on design characteristics of electrical subassemblies in the development stages, and on integral suppression components for inclusion therein, to facilitate suppression over the frequency range required by this specification, can be obtained from Coles Signal Laboratory, Fort Monmouth, New Jersey.

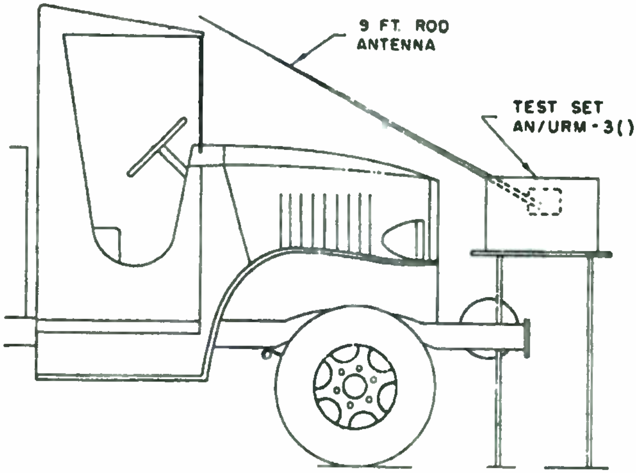
6.10 Tactical vehicle suppression system.—Signal Corps Drawing SC-D-28120 "Typical Tactical Vehicle Suppression System," is available for the information of the contractor; however, the use of a system such as shown therein does not assure that the vehicle to which it is applied will meet the requirements of this specification.

6.11 Railroad equipment. — It is recommended that the contracting officer furnish complete information regarding the nature and intended use of railroad equipment to be suppressed, to Coles Signal Laboratory, Fort Monmouth, N. J. in order to obtain information regarding the applicable paragraphs of this specification, for inclusion in the bid request and contract.

6.12 Information on the test equipment and the manner in which it will be used for the testing of non-tactical vehicles may be obtained from Coles Signal Laboratory, Fort Monmouth, N. J.

Custodian:
Army—Signal Corps

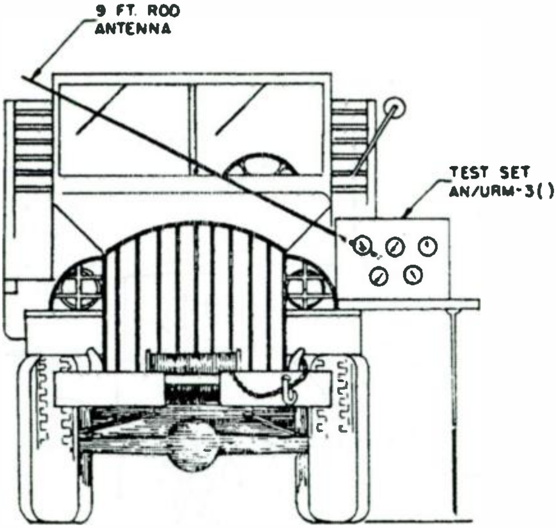
Other interest:
Army—EOT
Navy—ShAMCY
Air Force.



NOTE

1. THE TEST SET SHALL BE LOCATED ON THE LONGITUDINAL AXIS OF THE VEHICLE.
2. THE TOP OF THE TEST SET SHALL BE IN THE SAME PLANE AS THE TOP OF THE RADIATOR GRILL.
3. THE TEST SET SHALL BE LOCATED AS CLOSE AS POSSIBLE TO THE VEHICLE WITHOUT THE CENTER OF THE ANTENNA EXCEEDING TWO FEET FROM TOP OF ENGINE COMPARTMENT OR APPROACHING CLOSER THAN ONE FOOT THERETO.

FIGURE 1.—*Antenna position for trucks front radiation test, 0.15–40 mc.*



NOTE:

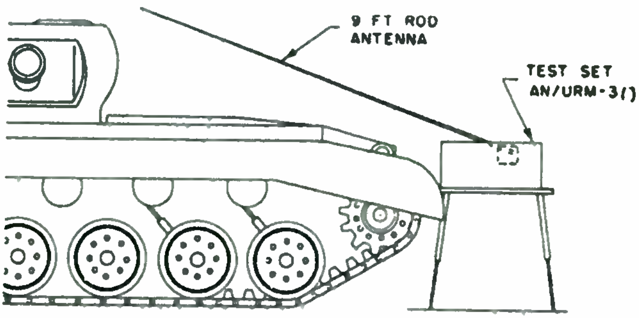
1. THE TEST SET SHALL BE INSULATED FROM THE BODY OF THE VEHICLE WITH A NON-CONDUCTING MATERIAL.

2. THE ROD ANTENNA SHALL BE LOCATED AS CLOSE AS POSSIBLE TO THE LATERAL AXIS OF THE ENGINE.

3. THE TIP OF THE ANTENNA SHALL BE LOCATED IN A VERTICAL PLANE THROUGH THE EDGE OF THE OPPOSITE FENDER OR SIMILAR OUTERMOST EXTREMITY OF METAL, BUT THE MIDPOINT OF THE ANTENNA SHALL NOT BE PLACED CLOSER THAN ONE FOOT FROM THE TOP OF THE ENGINE COMPARTMENT FOR ANY VEHICLE.

4. A SIDE RADIATION TEST IS TO BE PERFORMED WITH THE TEST SET LOCATED ON BOTH RIGHT AND LEFT FENDERS.

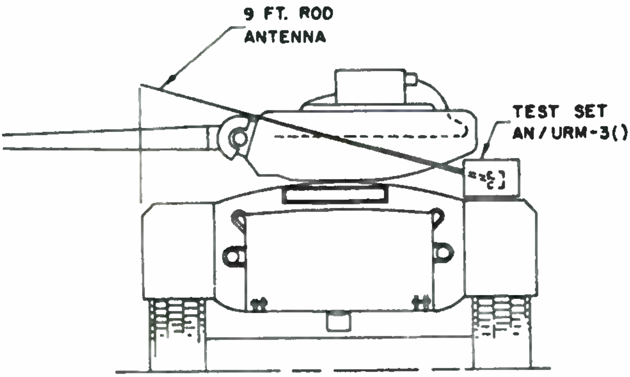
FIGURE 2.—*Antenna position for trucks side radiation test, 0.15–60 mc.*



NOTE:

1. THE ANTENNA SHALL BE PLACED ALONG THE LONGITUDINAL AXIS OF THE VEHICLE.
2. THE TOP OF THE TEST SET SHALL BE IN THE SAME PLANE AS THE LOWER REAR EDGE OF THE AIR OUTLET GRILL.
3. ALL TESTS SHALL BE CONDUCTED WITH THE GUN ROTATED PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE VEHICLE.
4. THE TEST SET SHALL BE LOCATED AS CLOSE AS POSSIBLE TO THE VEHICLE WITHOUT THE MID-POINT OF THE ROD ANTENNA EXCEEDING TWO FEET FROM TOP OF ENGINE COMPARTMENT OR APPROACHING CLOSER THAN ONE FOOT THERETO.

FIGURE 3.—*Antenna position for tanks and tank type vehicles and radiation test, 0.15–40 mc.*



NOTE:
1. THE TEST SET SHALL BE INSULATED FROM THE BODY OF THE VEHICLE WITH A NON-CONDUCTING MATERIAL.
2. GUN SHALL BE ROTATED PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE VEHICLE.
3. THE ROD ANTENNA SHALL BE LOCATED AS CLOSE TO THE LATERAL AXIS OF THE ENGINE AS POSSIBLE.
4. THE TIP OF THE ANTENNA SHALL BE LOCATED IN A VERTICAL PLANE THROUGH THE EDGE OF THE OF THE OPPOSITE FENDER OR SIMILAR OUTERMOST EXTREMITY OF METAL, BUT THE MIDPOINT OF THE ANTENNA SHALL NOT BE PLACED CLOSER THAN ONE FOOT FROM THE TOP OF THE ENGINE COMPARTMENT FOR ANY VEHICLE.
5. A SIDE RADIATION TEST IS TO BE PERFORMED WITH THE TEST SET LOCATED ON BOTH THE RIGHT AND LEFT FENDER.

FIGURE 4.—*Antenna position for tanks and tank type vehicles—radiation side radiation, 0.15–40 mc.*

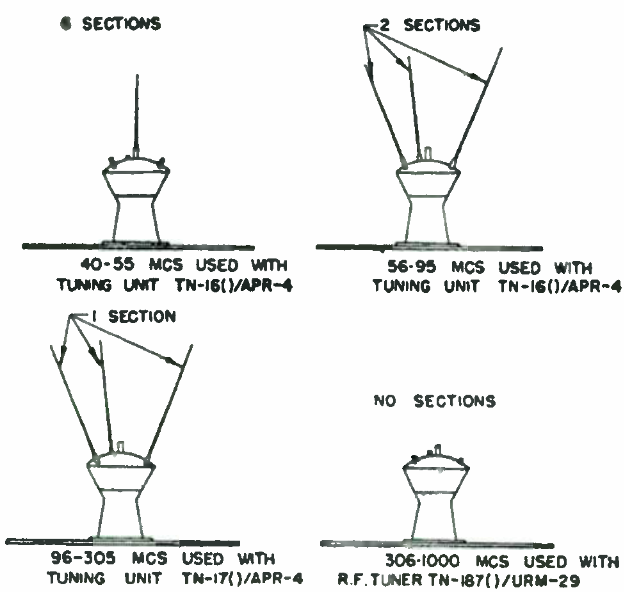
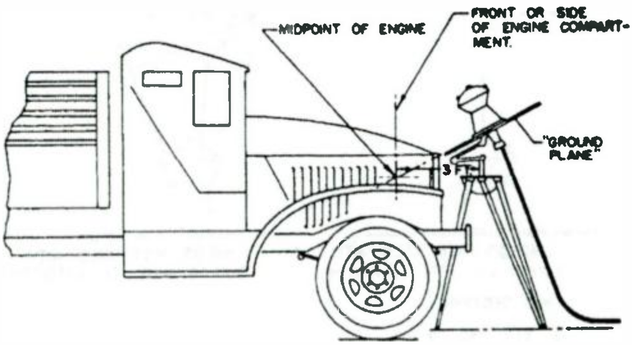


FIGURE 5.—*Antenna AT-292( )/URM-29 and mast sections AB-21/GR for outside radiation test 40-1000 mc.*



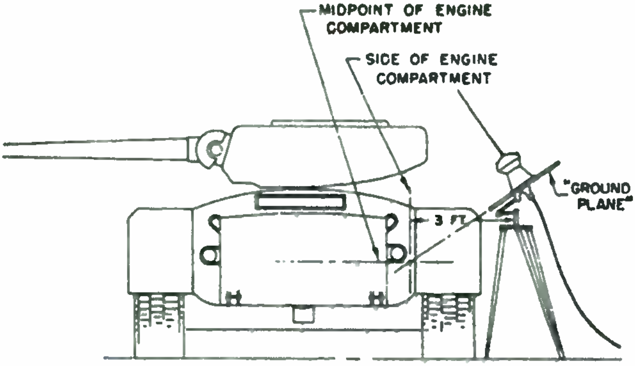
NOTE.

1. RADIATION TESTS ARE REQUIRED ON THREE SIDES OF EACH TRUCK OVER FREQUENCY RANGE 40 TO 1000 MC WITH SAME ANTENNA AND "GROUND PLANE" POSITIONING.

2. PRIOR TO TILTING, "GROUND PLANE" SHALL BE IN THE SAME HORIZONTAL PLANE AS TOP OF RADIATOR.

3 ANTENNA TILTED SO THAT EXTENSION OF "GROUND PLANE" INTERSECTS FRONT OR SIDES OF ENGINE COMPARTMENT AT MIDPOINT.

FIGURE 6.—*Antenna positioning of test Set AN/URM-29 ( ) in radiation test of trucks 40–1000 mc.*



NOTE:

1 GUN SHALL BE ROTATED PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE VEHICLE.

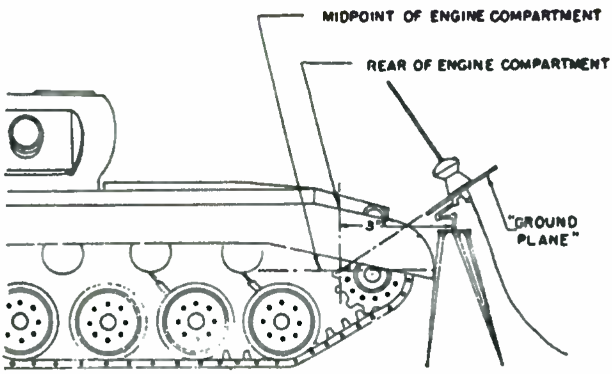
2. THE ANTENNA SHALL BE LOCATED AS CLOSE AS POSSIBLE TO THE LATERAL AXIS OF THE ENGINE.

3. PRIOR TO TILTING, "GROUND PLANE" SHALL BE IN THE SAME HORIZONTAL PLANE AS THE LOWER EDGE OF THE AIR OUTLET GRILL.

4. ANTENNA TILTED SO THAT EXTENSION OF "GROUND PLANE" INTERSECTS NEAR SIDE OF ENGINE COMPARTMENT AT VERTICAL MIDPOINT.

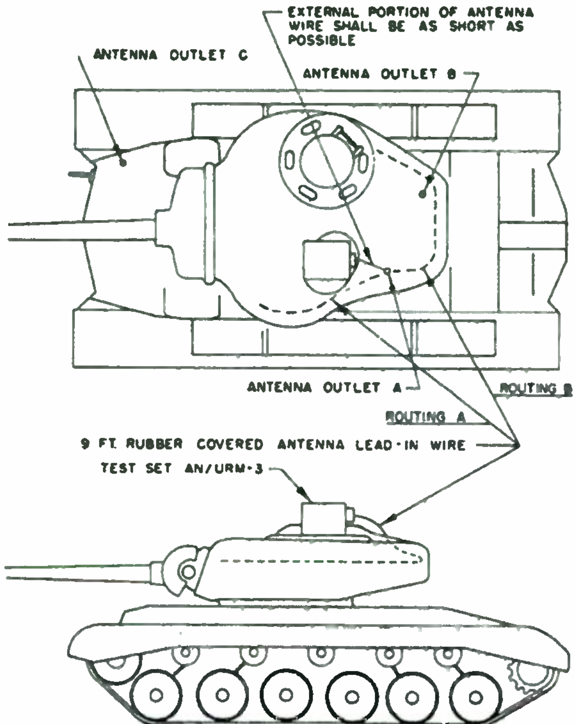
5 A SIDE RADIATION TEST IS TO BE PERFORMED WITH THE ANTENNA LOCATED ON EACH SIDE, ON THE LATERAL AXIS OF THE ENGINE.

FIGURE 7.—*Antenna position for tanks and tank type vehicles—radiation 40-1000 mc.*



NOTE
1. THE TEST SHALL BE CONDUCTED WITH THE GUN ROTATED PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE VEHICLE
2. THE ANTENNA SHALL BE PLACED ALONG THE LONGITUDINAL AXIS OF THE VEHICLE.
3. PRIOR TO TILTING,"GROUND PLANE" SHALL BE IN THE SAME HORIZONAL PLANE AS THE LOWER EDGE OF THE AIR OUTLET GRILL.
4. ANTENNA TILTED SO THAT EXTENSION OF "GROUND PLANE" INTERSECTS REAR OF ENGINE COMPARTMENT AT MIDPOINT.

FIGURE 8.—*Antenna position for tanks and tank type vehicles radiation, 10–1000 mc.*



NOTE:

1. THE TEST SET SHALL BE INSULATED FROM THE BODY OF THE VEHICLE WITH A NON-CONDUCTING MATERIAL.

2. A RADIATION TEST IS REQUIRED FOR BOTH ANTENNA ROUTINGS AT EACH ANTENNA OUTLET ON THE VEHICLE.

FIGURE 9.—*Antenna positioning for inside radiation test 0.15–40 mc.*

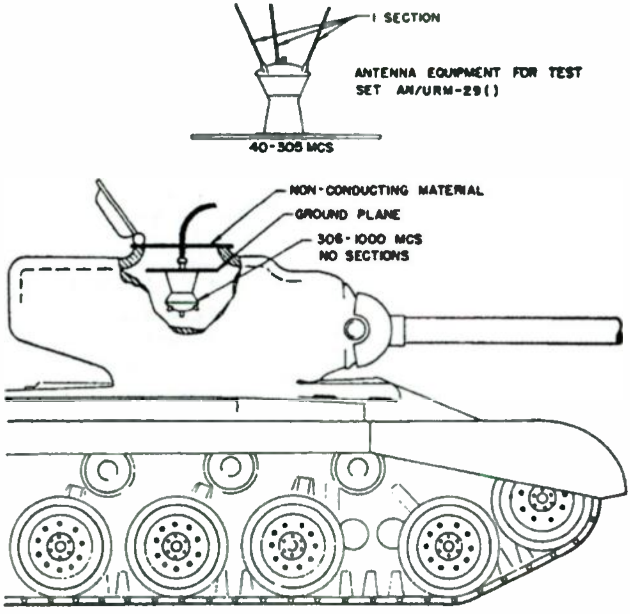


FIGURE 10.—*Antenna positioning of test Set AN/URM-29( ) for inside radiation test, 40 to 1000 mcs.*

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3 January 1956
USED IN LIEU OF
MIL-I-11683A
19 January 1953

MILITARY SPECIFICATION
INTERFERENCE SUPPRESSION, RADIO, REQUIREMENTS FOR ENGINE GENERATORS AND MISCELLANEOUS ENGINES

This Limited Coordination Military Specification has been prepared by the Signal Corps based upon currently available technical information, but it has not been approved for promulgation as a revision of Military Specification MIL-I-11683A. It is subject to modification. However pending its promulgation as a Coordinated Military Specification, it may be used in procurement.

1. SCOPE

1.1 This specification covers the requirements for radio interference reduction within the frequency range of 0.15 to 1000 mc for all internal combustion engine-driven generators, and all miscellaneous internal combustion engine-driven equipment (except equipments installed in aircraft or on Naval ships and vehicles covered by Military Specification MIL-S-10379A) to permit satisfactory reception of intelligence with high sensitivity electronic communication equipment located adjacent thereto or electrically powered thereby.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standards, and drawings of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

FEDERAL

QQ-M-151 Metals: General Specification for Inspection of.

MILITARY

MIL-C-3162 Cable, Ignition, High Tension.
MIL-C-11693 Capacitors, Feed-Through, Suppression, AC and DC.
MIL-S-12944 Suppressors, Ignition Interference.
MIL-C-12889 Capacitors, By-Pass, Suppression.
MIL-F-15733B Filters, Radio Interference.

(Copies of specifications, standards, drawings, and publications. required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer. Both the title and identifying number or symbol should be stipulated when requesting copies.)

3. REQUIREMENTS

3.1 Definitions. - The following definitions apply for the purpose of this specification.

3.1.1 Radio interference. -"Radio Interference." or simply "Interference," is defined as any electrical disturbance which causes undesirable response or malfunctioning of communication equipment. Interference may reach the affected equipment by means of conduction, induction, radiation, or any combination thereof.

3.1.2 Units for measurement of intensity of interference. -Intensity of interference is measured, for the purpose of this specification, in terms of microvolts per kilocycle (or per megacycle) of bandwidth (μV/kc or μv/mc). Interference intensi ty in microvolts per kc (or mc) is equal to the number of rms sine wave microvolts (unmodulated), applied to the input of the measuring circuit at its center frequency, which will result in peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the effective bandwidth of the circuit kilocycles or megacycles.

3.1.3 Radio interference suppression. - "Suppression" of radio interference is the reduction of the intensity of the emanated interference by means applied to or at the source.

3.1.4 Suppression system. - All components, and materials including shielding and their application used for reduction or radio interference will be referred to as the "suppression system."

3.1.5 Electrical subassembly. - An electrical subassembly is defined for purpose of this specification as any engine or engine generator electrical subassembly such as spark plugs, generator, regulator, distributor, etc., associated with the basic functioning of the unit or its electrical system, which is supplied, stored and issued as a complete operating assembly.

3.1.6 Electrical accessory units. - An electrical accessory unit is defined for the purpose of this specification as any electric motor or electro-mechanical device, such as electric windshield wipers, electric heaters, relay mechanisms, etc., capable of operation independent of the unit or its electrical subassemblies, except for the power source, and which is not associated with the basic functioning of the equipment.

3.1.7 Type approved suppression component. - A type-approved suppression component is one for which samples of the same make and type have previously been submitted, tested, and approved as being suitable for suppression purposes in accordance with the applicable subsidiary specification. See subsidiary specification for procedure to be followed to obtain type approval. (See 6.1.1).

3.1.7.1 Application approved suppression component. - An application approved suppression component is defined for the purpose of this specification as any capacitor, filter, etc., not covered by applicable subsidiary specification which has been properly submitted to and approved by the designated agency for a specific suppression application. (See 6.1.1 and 6.1.2.2).

3.1.8 Integral suppression. - An integrally suppressed electrical subassembly or accessory is one in which shielding and suppression components are incorporated as an integral part thereof and are supplied, stored and issued therewith.

3.1.9 Ignition unit. - An ignition unit is referred to for purposes of this specification as a distributor and ignition coil combined physically as a single shielded electrical subassembly.

3.1.10 Shielding. - A metallic covering or enclosure used to reduce radiation of radio interference from wiring or electrical subassemblies.

3.2 Application of specification. - This specification applies to the following equipments, except where these equipments are components of other equipment subject to more stringent suppression requirements, (an engine-driven auxiliary charging generator in an armored vehicle is an example of such an equipment).

3.2.1 All engine-driven generators and the electrical equipment associated therewith providing direct or alternating currents of all voltage and power ratings, except as specifically exempted herein.

3.2.2 All types of engines used to power or drive such miscellaneous equipment as bulldozers, cranes, graders, rollers, fork lift trucks, compressors, laundry units, pumps, etc., including the electrical equipment associated with these equipments such as the charging system components, and accessory devices such as heaters, windshield wipers, relays and signal devices.

3.3 Performance. - The suppression system shall effectively reduce all radio interference from the unit to the levels specified herein. The unit shall be capable of meeting these requirements after subjection to such environmental, endurance, and "run in" tests as may be required by the equipment specification. The suppression system, components, or the application thereof shall cause no malfunctioning of the unit under the environmental conditions specified in the equipment specification and shall not impair the performance of the unit beyond the limits prescribed in the equipment specification.

3.3.1 Engine generator units. - Engine generator units shall meet the operational performance requirements for radiated interference as determined by tests performed with the specified measuring equipment at a distance of 5 feet, in accordance with paragraph 4.3.1, and the conducted interference requirements as measured in accordance with paragraph 4.3.2.

3.3.1.1 Radiated interference limits engine generator units. - The limits of radiated interference stated in table I below apply to all engine generator units of less than 60 KW capacity tested in accordance with paragraph 4.3.1.

3.3.1.2 Conducted interference limits, engine generator units. - The interference limits shown in figure 10 are the maximum levels permissible between any external power terminal and ground, measured in accordance with paragraph 4.3.2. These limits do not apply to engine generator units having output ratings exceeding 500 volts AC or DC, 100 KW, or both.

3.3.2 Miscellaneous engines (and engine-driven equipment). - Miscellaneous engines and engine-driven equipment shall meet the operational performance requirements as determined by test performed with the specified measuring equipment at a distance of 5 feet in accordance with paragraph 4.3.1.

Table I. - Radiated interference limits

Freq. Range Mc	AN/URM-3 AN/PRM-14 9' Whip Per Fig. 3-4	AN/URM-7 AT-292 Per Fig. 5-6-7	Ferris 32* 41* Rod Per Fig. 3-4	Measure-ments 58 Dipole Per Fig. 4-5	AN/PRM-1 (Peak) 41" Rod Per Fig. 4-5	TS-587** (Peak) Dipole Per Fig. 8-9	AN/URM-17 (Peak) Dipole Per Fig. 8-9
	Microvolts/kc		Indicated Microvolts		Indicated Microvolts		
.15-1/6	1.0		5.		10.		
1.65-5.0	.75		5.		10.		
5.1-20	.75		2.5		5.		
21.38	.75			25		60	
40-60		.75		25		60	
66-95		.5		20		50	
96-125		.5		20		50	
126-150		.5		15		100	
155-295		.5				75	
300-395		.6				75	
400-1000		.6					350

* These instruments do not measure true peak. Limits apply for repetition rates of approximately 150 impulses/second. For interference having appreciable higher repetition rates multiply meter reading by factor obtained from figure 11.

** TS-587 Indicated Microvolts = Meter Indication X - Correction Factor shown in Inclosure A, of Instruction Manual and scale factor of X2 and Band no. 3.

3.3.2.1 Interference limits miscellaneous engines (and engine-driven equipments. - The radiated interference limits stated in table I apply to all miscellaneous engines and engine-driven equipment when tested in accordance with paragraph 4.3.1. There are no requirements for conducted interference measurements on these equipments.

3.4 Approval of suppression system components. - All components of the suppression system for equipments covered by this specification shall be subject to approval as hereinafter provided.

3.4.1 Non-integral suppression components. - All non-integral suppression components shall be typed approved and in accordance with applicable subsidiary specifications listed in 2.1 unless specific authorization is granted by the contracting officer for the use of the other types, in which case "application approval" as defined in paragraph 3.1.7.1 is required.

3.4.1.1 Navy approval. - Filters, when required to meet the requirements of this specification shall, wherever practicable, be of the type approved in accordance with Specification MIL-F-15733B. Where filters other than those so approved are used, the contractor shall assume responsibility for the electrical and physical performance thereof and for any malfunctioning of the equipment resulting from the filters or its application.

3.4.1.2 Air Force Approval. - Application approval may be automatically granted under Air Force inspection on suppression component application previously approved for use on a similar electrical subassembly or accessory in aircraft.

3.4.2 Integral suppression components. - Integral suppression components incorporated in electrical subassemblies or accessories shall be subject to approval by the designated Government agency for electrical and radio frequency characteristics, and dependability of the application in the particular subassembly or accessory. Where practicable, such suppression components shall be in accordance with the applicable specification listed in 2.1. See 6.3 for exemptions under Air Force inspection.

3.4.3 Submission of samples for inspection, test and approval. - Submission of components covered by 3.4.1 and 3.4.2 shall be in accordance with the applicable (or appropriate) specification listed in 2.1, unless otherwise specified by the contracting officer. See 6.1, and 6.3 for details pertaining to individual Service inspection procedures for obtaining application approvals.

3.5 Approval of pilot model. -

3.5.1 Submission of pilot model. - Army inspection. - The contractor shall submit an experimental pilot or pre-production pilot model of each type of unit to the agency designated in the bid request and contract, for inspection and test of suppression system. Such models shall be equipped with the suppression intended for production units. The first experimental pilot or the preproduction pilot model shall be accompanied by two copies of the following:

(a) Detailed list and description of the suppression components, integral and non-integral, indicating for each, the manufacturer's name and model number and location.

(b) List of all electrical equipment, used on the unit except lights, horn, and manual switches, each shall be identified by manufacturer's name and model number.

(c) Print of the complete electrical system of the suppressed unit showing electrical location and connections of all suppression components.

Each of the above items shall be marked with the date of submission of the unit, contract number, name and address of the contractor, the nomenclature of the unit, and its serial and U.S. Registration numbers.

3.5.1.1 Approval of pilot models. - Army inspection. - The (experimental and preproduction) pilot models will be inspected and tested by the designated Army agency without charge to the contractor for compliance with the requirements of the specification (see 6.1.3) at which time a verbal report relative to the results of the tests will be furnished the contracting officer and the contractractor, together with such information as is necessary for the contractor to correct any deficiencies in the suppression system. If the pilot model is disapproved, the contractor shall correct the deficiencies in accordance with the recommendations of the designated Army agency, and resubmit the pilot model for test. Correction and retest of the pilot model is usually accomplished during the original pilot model test.

3.5.1.1.1 Approval of electrical accessory units. - A pilot model of any electrical accessory as defined in 3.1.6 may be submitted prior to submittal of the complete equipment for suppression tests by the designated Government agency to determine compliance with the requirements

3.3.2.1 Interference limits miscellaneous engines (and engine-driven equipments. - The radiated interference limits stated in table I apply to all miscellaneous engines and engine-driven equipment when tested in accordance with paragraph 4.3.1. There are no requirements for conducted interference measurements on these equipments.

3.4 Approval of suppression system components. - All components of the suppression system for equipments covered by this specification shall be subject to approval as hereinafter provided.

3.4.1 Non-integral suppression components. - All non-integral suppression components shall be typed approved and in accordance with applicable subsidiary specifications listed in 2.1 unless specific authorization is granted by the contracting officer for the use of the other types, in which case "application approval" as defined in paragraph 3.1.7.1 is required.

3.4.1.1 Navy approval. - Filters, when required to meet the requirements of this specification shall, wherever practicable, be of the type approved in accordance with Specification MIL-F-15733B. Where filters other than those so approved are used, the contractor shall assume responsibility for the electrical and physical performance thereof and for any malfunctioning of the equipment resulting from the filters or its application.

3.4.1.2 Air Force Approval. - Application approval may be automatically granted under Air Force inspection on suppression component application previously approved for use on a similar electrical subassembly or accessory in aircraft.

3.4.2 Integral suppression components. - Integral suppression components incorporated in electrical subassemblies or accessories shall be subject to approval by the designated Government agency for electrical and radio frequency characteristics, and dependability of the application in the particular subassembly or accessory. Where practicable, such suppression components shall be in accordance with the applicable specification listed in 2.1. See 6.3 for exemptions under Air Force inspection.

3.4.3 Submission of samples for inspection, test and approval. - Submission of components covered by 3.4.1 and 3.4.2 shall be in accordance with the applicable (or appropriate) specification listed in 2.1, unless otherwise specified by the contracting officer. See 6.1, and 6.3 for details pertaining to individual Service inspection procedures for obtaining application approvals.

3.5 Approval of pilot model. -

3.5.1 Submission of pilot model. - Army inspection. - The contractor shall submit an experimental pilot or pre-production pilot model of each type of unit to the agency designated in the bid request and contract, for inspection and test of suppression system. Such models shall be equipped with the suppression intended for production units. The first experimental pilot or the preproduction pilot model shall be accompanied by two copies of the following:

(a) Detailed list and description of the suppression components, integral and non-integral, indicating for each, the manufacturer's name and model number and location.

(b) List of all electrical equipment, used on the unit except lights, horn, and manual switches, each shall be identified by manufacturer's name and model number.

(c) Print of the complete electrical system of the suppressed unit showing electrical location and connections of all suppression components.

Each of the above items shall be marked with the date of submission of the unit, contract number, name and address of the contractor, the nomenclature of the unit, and its serial and U.S. Registration numbers.

3.5.1.1 Approval of pilot models. - Army inspection. - The (experimental and preproduction) pilot models will be inspected and tested by the designated Army agency without charge to the contractor for compliance with the requirements of the specification (see 6.1.3) at which time a verbal report relative to the results of the tests will be furnished the contracting officer and the contractractor, together with such information as is necessary for the contractor to correct any deficiencies in the suppression system. If the pilot model is disapproved, the contractor shall correct the deficiencies in accordance with the recommendations of the designated Army agency, and resubmit the pilot model for test. Correction and retest of the pilot model is usually accomplished during the original pilot model test.

3.5.1.1.1 Approval of electrical accessory units. - A pilot model of any electrical accessory as defined in 3.1.6 may be submitted prior to submittal of the complete equipment for suppression tests by the designated Government agency to determine compliance with the requirements of this specification (see 6.1.3). No pilot testing of electrical subassemblies, as defined in 3.1.5, is required under this specification.

3.5.1.2 Production pilot model. - If tests on a production pilot model indicate deficiencies requiring changes or modification of the suppression system, the modified system shall be applied thereafter. The contracting officer will furnish the contractor with details of the suppression system to be applied to production units, based on the report of the final approved pilot model. Authority in writing must be obtained from the contracting officer for any exceptions to, or deviations from, the suppression system approved for production.

3.5.1.3 Report on pilot models. - The army testing agency will furnish the contracting officer a report on the approved pilot model, detailing the suppression system to be applied in production.

3.5.1.4 Changes after approval of pilot model. - After approval of the production pilot model, all production units, including accessories and subassemblies shall, unless otherwise allowed or required, be identical in all respects to the approved pilot production model and the report of recommendations therein on the model (see 3.5.1.3) except as described below.

3.5.1.4.1 Substitution of suppression components. - The contractor may, at his discretion, substitute a suppression component with identical electrical characteristics and mechanically interchangeable construction, but of different manufacture, provided the substitute component has received approval as described in 3.4. No other substitution or change of a suppression component may be made without approval in writing by the contracting officer. Request for permission to make such a substitution or change shall be accompanied by a detailed description of the proposed substitute suppression component and its method of application, together with data showing that the proposed substitute is at least the equal of the item it will replace. (If the proposed substitute is an item requiring type approval under 3.4, and has not yet received such approval, the contractor shall submit samples in accordance with the applicable specification.) The contracting officer, may require test of an additional pilot model, incorporating the proposed changes for approval.

3.5.1.4.2. Changes in integral components. - In the case of substitutions or changes of suppression components incorporated in integrally suppressed electrical subassemblies or accessory units, the contracting officer may require submittal of a model of the original and the revised subassembly or accessory unit for comparative test by the designated agency.

If the revised version is found to have inferior suppression characteristics, the contracting officer may require test of an additional pilot model of the unit incorporating the revised subassembly or accessory.

3.5.1.4.3 Changes in the equipment. - The contracting officer shall be notified as early as possible in writing by the contractor of any changes made or contemplated in the electrical system, subassemblies, or accessories of the unit. He shall likewise be notified of any changes in the structure or electrical bonding of the unit which might affect generation or emanation of interference. If the contractor fails to submit data satisfactory to the contracting officer showing that the changes will not result in failure to conform to this specification, the contracting officer, may, at his discretion, require the contractor to submit another pilot production model incorporating the changes being submitted for approval. This pilot model shall be required to meet the same requirements as the original pilot production model.

3.5.2 Approval of pilot model. - Air Force inspection. - The contractor shall perform all tests specified herein for compliance with the requirements of this specification under the supervision of, and subject to the approval of the Government inspector. Approval may be granted by the Government inspector or the contracting officer on the basis of radiation tests performed over a lesser frequency range than specified herein. When reports of the tests are required by the contract, such reports shall describe in detail the test set-up, modes of operation, and the test equipment used in addition to the test results.

3.5.2.1 At the discretion of the contracting officer, approval of pilot models may be granted based on tests and approval by the designated Army Testing Agency.

3.6 Spare parts. -

3.6.1 Suppression components. - Spare suppression components for all units shall meet the requirements of 3.8 for interchangeability with corresponding parts used on the unit, and shall also meet all the requirements of 3.4.

3.6.2 Other components. - Where components of the unit, such as engine generator covers and radiators, have been modified for suppression purposed by preparing surfaces for bending or other means, the corresponding spare components shall be similarly modified.

3.7 Methods of suppression. - Suppression of ignition, charging circuit and other electrical interference shall be effected by integrally shielded and suppressed electrical subassemblies, (Such as spark plugs, distributors, voltage regulators, magnetos, etc.) capacitors, filters, shielding, proper grounding of radiating elements, routing of wiring, and location of parts.

3.7.1 Integrally suppressed electrical subassemblies. - The use of integrally suppressed electrical subassemblies is mandatory wherever practicable, unless precluded by space requirements, unavailability from commercial sources, or the ability to meet the performance requirements of this specification by other relatively simple means which would effect an appreciable saving.

3.7.2 Magnetos. - Magnetos of the fully enclosed, self contained type shall be fully shielded in compliance with the applicable portions of 3.7.6, 3.7.7 and 3.7.9 and shall be provided with 11/16" -24, threaded high tension outlets. Feed-thru type ignition (breaker point) capacitors, incorporated in or utilized as, the stop lead terminal shall, wherever practicable, be employed in magnetos having provision for remote stop switches. (See 6.4.1). Externally applied feed-thru capacitors are acceptable on magnetos of earlier design and those in which space limitations preclude proper integral mounting.

3.7.3 Integrally shielded and suppressed spark plugs. - Standard commercial shielded type spark plugs incorporating 10,000 ohm integral resistor-suppressor shall be utilized except where their use is precluded by other imperative requirements. The upper or top thread shall be 5/8" -24. The resistance of the resistor-suppressor shall be 10,000 ohms plus or minus 25% measured at 5 kilovolts peak.

3.7.3.1 The use of ceramic terminal sleeves for connection of the ignition cable conductor to the spark plug terminal contact shall be mandatory.

3.7.4 Ignition cable. - Type II ignition cable in accordance with Specification MIL-C-3162 shall be used except where flexible metallic hose or other acceptable types are required for other than radio interference suppression purposes.

3.7.5 Capacitors and filters. - Filters shall be used only where adequate suppression cannot be effected by reasonable and proper application of capacitors.

3.7.6 Shielding. - Integrally shielded ignition cable, flexible metallic hose, solid wall conduit, and wire braid shielding, utilized as part of the suppression system or as mechanical support of the wiring, shall be terminated and grounded at both ends by means of suitable fittings or cable clamps treated in accordance with paragraph 3.10.3. Cable clamps, when used, shall be soldered to the shielding and shall terminate the shielding in accordance with the grounding provisions of paragraph 3.7.7 as close as practicable to the cable terminals. "Pigtail" connections shall be utilized only where the use of mechanical fittings or clamps is impracticable contacting surfaces of the fittings, shielding, or supporting member and the mating part, shall be treated for corrosion resistance as specified in 3.10.3. Where continuous electrical contact along a seam or joint in shielding or fitting is necessary, the seam or joint shall be corrosion resistant and designed to maintain electrical continuity for the required life of the parts including necessary assembly and dis-assembly. Electrically conducting gaskets or spherical mating surfaces may be required for this purpose.

3.7.7 Grounding. - All components of the electrical and suppression system and parts of the unit which require radio-frequency return paths to ground or between meeting parts shall be so grounded that a corrosion-resistant low-impedance electrical connection will be assured through the life of the equipment.

3.7.8 Bonds. - Each bonding strap shall have a length and cross-sectional shape and dimensions consistant with best radio frequency and mechanical practice, and shall be so installed as to minimize damage by vibration or stress under service conditions. Bonding straps shall, wherever practicable, be fastened by bolts in a manner enabling easy replacement, and shall have suitable terminals. All bonds shall be bolted at one end in order that the equipment may be readily disassembled. Sheet metal screws shall not be used for fastening bonds.

3.7.9 Machine-finished surfaces. - Machine-finished surfaces to which suppression components are affixed or mating surfaces between parts of electrical sub-assemblies (such as those of magneto cover and base) need not be plated. Such mating surfaces of machine-finished parts shall be free of corrosion, paint or other foreign material, and shall not be treated in any manner that will impair their electrical conductivity between the mating surfaces.

3.8 Interchangeability. - All parts of the suppression system on any equipment, including spares, shall be electrically and mechanically interchangeable with corresponding parts on any other equipment manufactured under the same contract, and shall, wherever possible, be interchangeable with those of all other units of the same Military or manufacturers type number.

3.9 Ease of maintenance. - Shielding and integrally suppressed subassemblies shall be so applied or designed as to allow ready accessibility to all high mortality parts for maintenance and adjustment with conventional, general purpose, tools.

3.10 Material and workmanship. -

3.10.1 Material. - When a specific material is not specified the best material of commercial grade available for the purpose, capable of withstanding the extremes of temperature, humidity and other operating conditions shall be used.

3.10.1.1 Dissimilar metals. - Contact between dissimilar metals which might cause deterioration of parts by galvanic corrosion shall be avoided insofar as practicable.

3.10.2 Workmanship. - All parts shall be manufactured and finished in a thoroughly workmanlike manner in accordance with the best commercial practice. All dimensions, except where tolerances are given on drawings, shall be consistent with good shop practice.

3.10.2.1 Soldering. - Soldering shall not be depended upon for mechanical strength of connections. Where flexible shielding, bonds, etc., are soldered, the flexibility of these parts shall not be seriously affected.

3.10.3 Corrosion. - All hardware (bolts, screws, nuts, lockwashers, retaining nuts, elbows, connectors, ferrules, etc.), used in the installation of the suppression system shall be of corrosion resistant material or plated by an electrolytic or hotdip process with a metallic material of high electrical conductivity. The finished surfaces shall be capable of withstanding the test described in 4.3.3 after which there shall be not more than 6 corroded areas per square foot, not more than 2 corroded areas on any part having a total surface of less than 1/3 square foot, nor any corroded areas larger than 1/16 inch in diameter.

3.11 Technical manual and instruction book. - Any technical manual or instruction book covering the equipment furnished as part of the order by which the unit is procured, shall contain complete technical information, including photographs and drawings relative to the functioning and maintenance of the suppression system.

4. QUALITY ASSURANCE PROVISIONS

4.1 Acceptance inspection. - Acceptance inspection shall include the tests of 4.3 and such other inspection and non-destructive testing of material, parts, components and the complete suppression system as are considered necessary by the Government agency to determine compliance with this specification and its subsidiaries.

4.1.1 Army inspection. - Acceptance inspection for conformance with the requirements of this specification shall be conducted by the designated Army Agency without charge to the contractor when the equipment is submitted for acceptance on the contract or at such time as may be specified by the contracting officer.

4.1.2 Air Force inspection. - Unless otherwise specified, acceptance inspection for conformance with the requirements of this specification shall be made by the contractor under the supervision of, and subject to the approval of, the Government inspector. When required, reports of the test shall be prepared by the contractor.

4.1.3 Navy inspection. - Tests for the suppression of interference to determine conformance with this specification shall be conducted in accordance with paragraph 4.3.1 and 4.3.2. The contractor shall furnish either directly or by sub-contract all facilities for conducting the radio interference tests including test equipment, a suitable location for the performance of tests, and the necessary qualified technical personnel. Tests shall be conducted on at least one sample of each production lot as selected by the Government inspector.

4.2 Test equipment for pilot and production tests. -

4.2.1 Army inspection. - The interference measuring equipment listed below will be provided by the contracting officer and operated by Government personnel in performing the interference tests on equipment covered by this specification.

Test Set AN/URM-3( ), -0.15 - 38 megacycles (MC).
Radio Interference Measuring Set AN/PRM-14 (NF-114) - .15-40MC.
Radio Interference Measuring Set AN/URM-7 (NF-105) - 40-1000 MC.

Upon request, the contractor may obtain such information as he may require concerning this test equipment and the manner in which it will be used, to assist in suppressing the pilot model to meet the required tests. Allowable limits of interference are stated in 3.3.1 through 3.3.2.1 and the units in which the interference shall be measured are defined in paragraph 3.1.2.

4.2.2 Air Force and Navy Inspection. - The following measuring equipment or identical electrical equivalents may be used for Air Force and Navy Procurements in the frequency ranges shown below:

A.	UN/URM-6(NM-10A)	.014 to .25 mc
B.	Ferris Model 32A and B	.15 to 20 mc
C.	AN/PRM-1 (NMA-20A)	.15 to 25 mc
D.	TS-587(NMA-5)	25. to 400 mc
E.	Measurements Model 58	20 to 150 mc
F.	AN/URM-17	400 to 1000 mc

4.2.2.1 Measuring equipment calibration. - The measuring equipment listed in paragraph 4.2.2. shall be in proper operating condition and shall be within specified tolerances with regard to sensitivity and bandwidth.

4.3 Pilot model tests. - Pilot models of equipment covered by this specification will be tested at the location specified by the contracting officer or the designated agency. Radiation tests shall be conducted in an area sufficiently free from ambient interference to allow accurate determination of conformance with the interference limits specified herein, and shall be performed with all electrical units and electrical accessories of the equipment operating. Battery condition and electrical load shall be such that the battery charging and output voltage regulators are operating during all tests.

4.3.1 Radiation tests. - The radio interference radiated from complete equipments shall be measured at a distance of five (5) feet from the frame or other structural extremity normally considered as an outer overall dimension under operating conditions. Interference shall be measured on two sides of the equipment over the frequency range of .15 to 1000 mc. Radiation tests will not be required on engine generators of over sixty (60) KW rating. A detailed visual inspection of the suppression system will be required to determine conformance with either of the ignition systems detailed in figures 1 and 2, or suppression system design utilized on smaller generators having met the requirements of this specification.

4.3.1.1 Engine generators. - Engine generator units shall be tested with the measurement antennas in the positions shown in figures 3, 5, and 9 as applicable.

4.3.1.2 Miscellaneous engines. - Miscellaneous engine driven equipments other than engine generators having a single engine shall be tested with the measurement antennas in the positions shown in figures 4 and 6 or 8, as applicable.

4.3.1.2.1 Engine driven equipments, (other than engine generators), having more than one (1) engine shall be tested with the measurement antennas as shown in figures 4 and 6, or 8, relative to each engine.

4.3.1.2.2 Engines intended as general purpose prime movers and engines which are normally operated without surrounding structure (such as certain pump units) shall be tested with the measurement antennas in the position shown in figures 4 and 6, or 8, except that the distance (5 feet) shall be measured from the outer extremity of the engine.

4.3.2 Conducted interference test (engine generator units). - Conducted interference shall be measured between each line and ground (frame of equipment) at all electrical power terminals which may be connected to external equipment. Measurements shall be made using the specified 50 ohm unbalanced coupling network (figure 12) over the frequency range of 1.5 to 40 megacycles under full load and one half load conditions. The electrical load shall be primarily resistive and shall be connected to the output terminals of the unit thru a 75 foot cable of appropriate current carrying capacity. Wherever practicable, the leads connecting the coupling network to the test circuit shall not exceed three inches in length. The limits of conducted interference for the various measuring equipments in figure 10 apply. Conducted interference tests are not required on Engine Generator Units rated in excess of 500 volts or 100 KW.

4.3.3 Corrosion test. - Parts which must meet the requirements of 3.10.3 shall be tested in accordance with Federal Specification QQ-M-151 subjecting the parts to salt spray for a period of 96 hours at a temperature of 95°F, using a 20% (by weight) aqueous solution of sodium chloride.

4.4 Production testing - Army inspection. -

4.4.1 Complete equipment. - All production units of equipment covered by this specification shall be subject to inspection in accordance with paragraph 4.4.1.1. through 4.4.1.5.2. Paragraphs 4.4.1.5.1 and 4.4.1.4.2 apply to Army procurement only.

4.4.1.1 Initial inspection. - An initial production model from the first production of each type of equipment shall be subjected to radio interference tests to determine whether the production application of the suppression system is satisfactory. If it is unsatisfactory, the contractor shall repair the rejected units and shall change his production methods to correct the cause of failure. The contracting officer may then require the testing of such additional units as deemed necessary to insure that the corrected production applications of the suppression system is satisfactory.

4.4.1.2 Production sampling of equipment. - After units have satisfactorily passed the initial inspection specified in 4.4.1.1 the quality of the suppression system on production units shall be controlled by subjecting random units to similar tests. If less than a hundred units are being procured, at least one unit shall be tested after the initial inspection. If any unit fails to pass the test the contractor shall change his production methods to correct the cause of the failure.

4.4.1.3 Incompletely assembled units. - Where units are shipped in other than a compl etely assembled condition, contractor shall assemble sufficient units for required field tests.

4.4.1.4 Integral suppression components. - A spot check of integral suppression components by visual or electrical test will be required, on a maximum of 1% of the total units on the contract unless the contractor certifies that approved suppression components have been properly applied to each integrally suppressed subassembly or accessory.

4.4.1.5 Visual inspection of suppression system. - A thorough visual inspection shall be made periodically by the Government inspectors of the complete installation of the suppression system, to determine conformance to the pilot model report (3.7.1) or approved suppression system. This inspection shall be performed at a point or points in the production line determined by the contracting officer.

4.4.1.5.1 Check for use of Government-inspected suppression components. - Inspection shall insure that all non-integral suppression components covered by 3.4 furnished on production units have been subjected to inspection and tests as required by the subsidiary specifications or drawings listed in 2.1. This inspection shall also insure that suppression components covered by 3.4 but not covered by subsidiary specifications or drawings have been subjected to tests as required by the contracting officer. Where the tests of suppression components are performed at a sub-contractor's plant under supervision of Government inspectors, inspection at the plant of the prime contractor shall insure that the components, or packages thereof, bear the stamp of the Government inspector.

4.4.1.5.2 Contractor's inspection. - A thorough visual inspection shall be made of the complete installation of the suppression system, for conformance with the pilot model report (see 3.5.1.3. or 3.5.2). Units shipped in other than completely assembled condition shall be inspected partially assembled at the point or points in the production line determined by the contracting officer.

4.5 Production testing - Navy inspection. -

4.5.1 Sampling of complete equipments. - The sampling of complete equipments incorporating suppression systems shall be as prescribed in the equipment specification. At least one production unit of each type or model shall be selected at random by the Government inspector for production tests. Other units may be selected by the inspector periodically to check uniformity of production units.

4.5.1.1. Production tests of the suppression systems on complete equipments shall be performed at the place of manufacture and shall consist of the following:

(a) Determination that the suppression components being applied to production units are representative of units which have been previously approved under the applicable subsidiary specification or otherwise approved by the designated agency.

(b) Visual examination of the suppression system for conformance with the system originally approved.

(c) Radio interference tests in accordance with paragraph 4.3.1 and 4.3.2 where applicable.

5. PREPARATION FOR DELIVERY

5.1 The applicable section of the equipment specification shall apply.

6. NOTES

6.1 Army. -

6.1.1 List of approved suppression components. - Current Army Qualified Products Lists (AQPL) of type-approved suppression capacitors, filters and resistor-suppressors under the applicable subsidiary specification of 2.1 may be obtained by contracting officer from the Signal Corps Supply Agency, 225 South Eighteenth Street, Philadelphia 3, Pennsylvania, by referring to the specification number covering the particular component. Indication of approval of any item, by its inclusion in an AQPL or by other means, as being suitable for suppression purposes and in accordance with the applicable specifications, covers use of the component only for suppression purposes. A list of manufacturers of suppression components having type approved and application approval under the subsidiary specification of paragraph 2.1 may be obtained upon application to the contracting officer.

6.1.2 Submission of samples of suppression components. -

6.1.2.1 Type approval. - Samples for qualification approval (see 3.1.7) under subsidiary specifications listed in 2.1 shall be submitted as prescribed in the applicable subsidiary specification.

6.1.2.2 Application approval. - Samples for application approval (see 3.1.7.1) (twelve each) may be submitted to the Signal Property Officer, SCEL, Bldg. 141, Coles Signal Laboratory, Fort Monmouth, New Jersey, ATTN: Suppression and General Engineering Branch, together with the following information:

(a) Description or drawings of the proposed application.

(b) Manufacturer's name, address and model number of prime equipment or subassembly on which the application is proposed.

(c) Electrical data, current, voltage, etc., pertaining to the circuit in which the component is to be employed.

(d) Manufacturer, number, and electrical ratings (current, voltage, capacitance, etc.) of the samples.

(e) If the component is proposed to replace another type, or that of another manufacturer, the manufacturer and type number of the component to be replaced by the units submitted.

(f) Contract number of prime equipment or subassembly. (If the suppression component is being applied in a subassembly or accessory unit being proposed by its manufacturer for use on equipments covered by this specification, the information required by (a) thru (d) above, together with any other pertinent information is sufficient.)

(g) Samples submitted by a suppression component manufacturer must be accompanied by evidence of the prime or sub-contractor's request for samples, or his approval of the submittal, in addition to the information required by (a) thru (f) above. The latter may be furnished either by the component manufacturer, prime contractor, subcontractor or contracting officer.

6.1.3 Government test agency. - The Government technical activity designated to perform the testing and engineering functions required for the implementation of this specification, those functions prescribed as the responsibility of the Chief Signal Officer under Army Regulation AR-105-86, "Communications Radio Interference Reduction." shall be Coles Signal Laboratory, Signal Corps Engineering Laboratories (SCEL), Fort Monmouth, New Jersey; (Suppression and General Engineering Branch). This agency shall represent the contracting officer in dealings with contractors and sub-contractors on technical matters pertaining to these functions including the following:

(a) Approval for the use of capacitors or filters under conditions that are more severe than those specified in the applicable specification therefor.

(b) Testing of capacitors or filters that do not conform to the applicable specification to determine whether such components are acceptable for the proposed application.

(c) Inspection, testing, and approval of samples of suppression components, sub-assemblies or accessories to be approved before being furnished as part of the equipment on order.

(d) Inspection, testing and approval of the suppression system on the pilot model.

6.1.3.1 Testing of pilot model and production units. - Test equipment and personnel for conducting the inspection and test of the suppression systems on pilot models, and on production units undergoing the Government field tests, will be provided by Coles Signal Laboratory. Contracting officers should notify the Director, Coles Signal Laboratory, SCEL, Fort Monmouth, New Jersey, at least 10 days before a pilot model will be available for inspection and test of the suppression system. Results of the test, and a report covering the method of suppression to be followed on any subsequent pilot model or production unit will be furnished to the contracting officer. The report should be included by him as part of any approval of the pilot model to which it applies.

6.1.4 Proposal request and contract. -

6.1.4.1 Expenses. - It is to be understood that the contractor will bear all expenses arising in connection with the following:

(a) Transportation of Government inspector, test equipment, pilot models, production units, electrical sub-assemblies and accessories, and suppression components from the contractor's plant to the test point designated by the Government, if such point is within 25 miles of the contractor's plant. If the test point is over 25 miles from the contractor's plant, transportation only for the items to be tested.

(b) Preparation and submission of prints and parts list submitted with the models.

(c) Submission of samples for type approval.

(d) Damage to pilot models or to samples resulting from testing, disassembly or reassembly.

(e) Samples that are not returned to the bidder or contractor.

6.2 Navy: To be coordinated with Navy Department policy.

6.3 Air Force

6.3.1 Air Force exemption. - Components incorporated in integrally suppressed sub-assemblies or accessories (generators, motors controls, etc.), designed for and approved by the Air Force for use in aircraft are exempt from the requirements of 3.4.2, providing the interference limits of this specification are met.

6.4 General information. -

6.4.1 Magneto stop lead. - The incorporation of a feed-thru type ignition capacitor in the magneto in general precludes the necessity for a shielded stop lead and stop switch to meet the requirements of this specification, provided reasonable care is exercised in routing the stop lead, and providing its length does not exceed approximately six feet. In equipments or installations wherein the stop lead must be extended to a point remote from the engine chassis, connected to, or closely associated with, circuits remote from the unit, a relay should be employed for magneto disabling. A feed-thru or by-pass capacitor may then be applied across the relay actuating coil to prevent coupling of interference voltages into the remote lead or other circuitry.

6.4.2 Gauges and instruments. -

6.4.2.1 The use of sending units of the thermal, or bimetal-contact type should be avoided. Certain types of indicating units, those of the thermal type which employ contact points that open when bimetal-strip heats, should likewise be avoided. Whereas the units described above can be suppressed to meet the requirements of this specification, the cost of the suppression application may approach, or even exceed, the cost of the gauge. Variable resistance type sending units with magnetic (ammeter type) indicating units, or Bourdan type (non-electrical) gauges are recommended.

6.4.2.2 Electric tachometers are generally a source of interference of varying magnitude depending upon the type of unit. Shielding the lead between the sending unit and the indicating unit, or the application of a feed-thru or multiple feed-thru capacitor in the output of the sending unit is generally required.

6.4.3 Drive belts. - Drive belts (fan, generator, waterpump, etc.) often generate radio interference as a result of electrostatic charges developed on the belt discharging to the drive or driven pulleys. This interference may sometimes be mistakingly identified as regulator interference, since it is often characterized by impulses of irregular amplitude and recurrence. It may be readily isolated, however, by disconnecting the generator-to-regulator leads, in which case belt interference will continue, or by applying a small amount of water to the belt while listening to the interference, which case drive belt interference will disappear. Electrically conducting drive belts conforming to the conductivity requirements of MIL-B-11040 "Belts V-Type, Engine Accessory Drive" will reduce drive belt interference to within the limits prescribed herein.

6.4.4 Generator shaft interference. - Belt driven generators (those with an exposed pulley or those having an appreciable length of exposed shaft) often produce interference of a type which may have the characteristics of either regulator interference or generator hash, and which does not respond to the application of capacitors or shielding of leads. This interference generally appears in the VHF range and is caused by interference voltages induced in the shaft (which is electrically isolated from the frame by the oil film in the bearings) and in turn radiated by the exposed pulley or shaft. This type of interference is reduced by shaft grounding brushes applied at the drive end of the shaft.

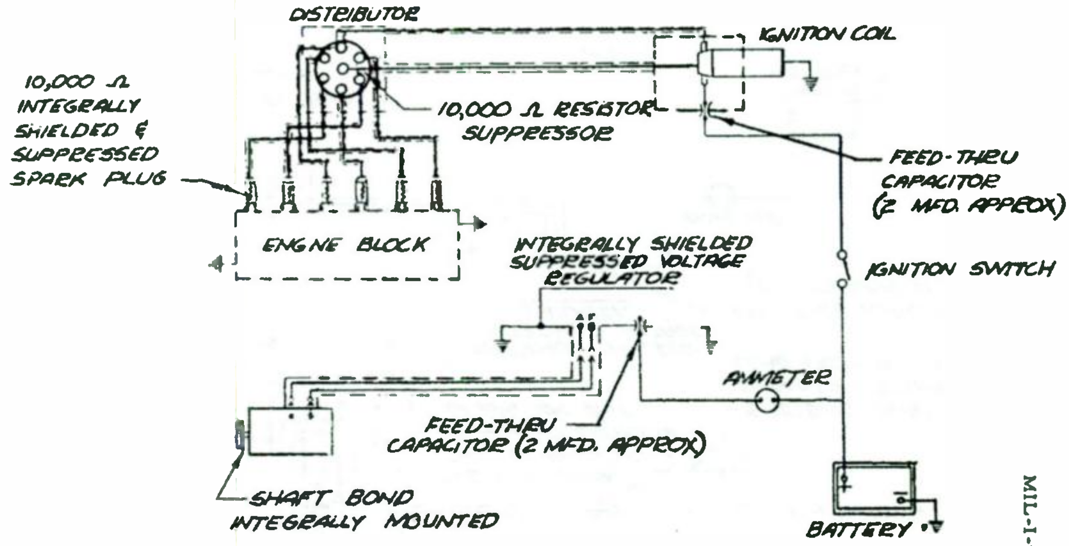

Figure 1

Typical Radio Interference Suppression System

for Gasoline Engines Using General Purpose Shields

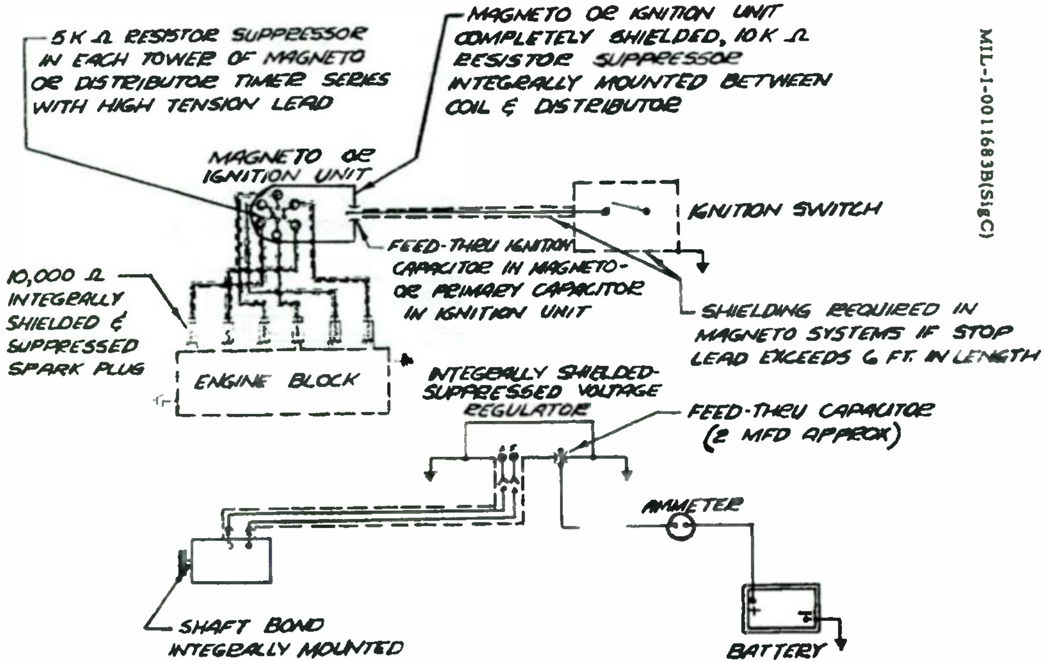

Figure 2

Typical Radio Interference

Suppression System for Gasoline Engines

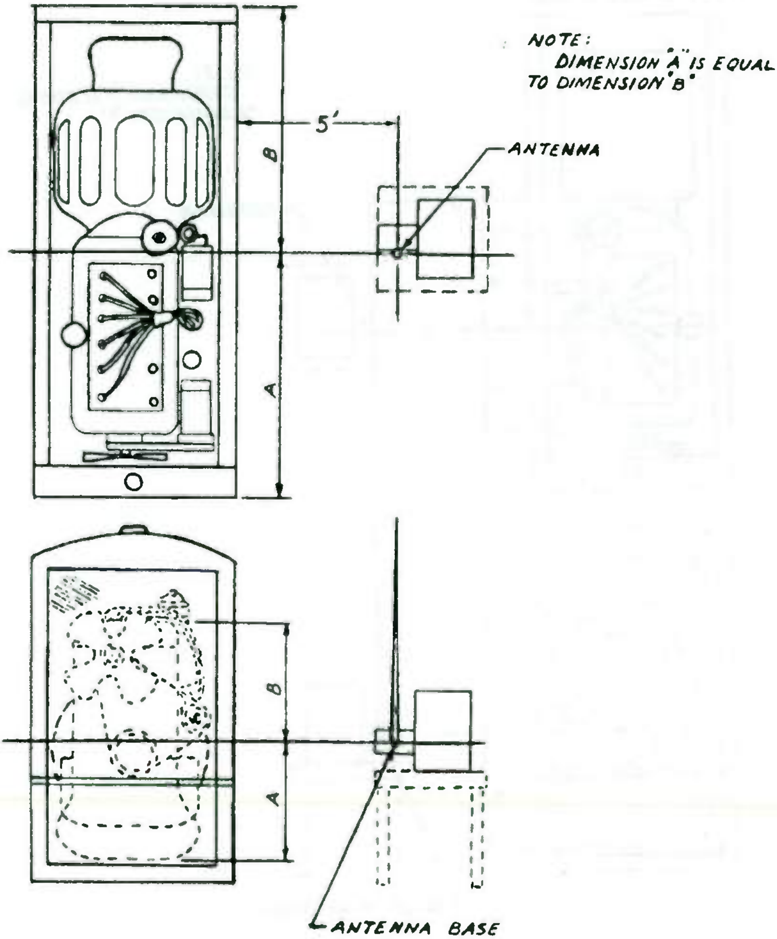

Figure 3

Rod Antenna Positioning

Engine Generator Units

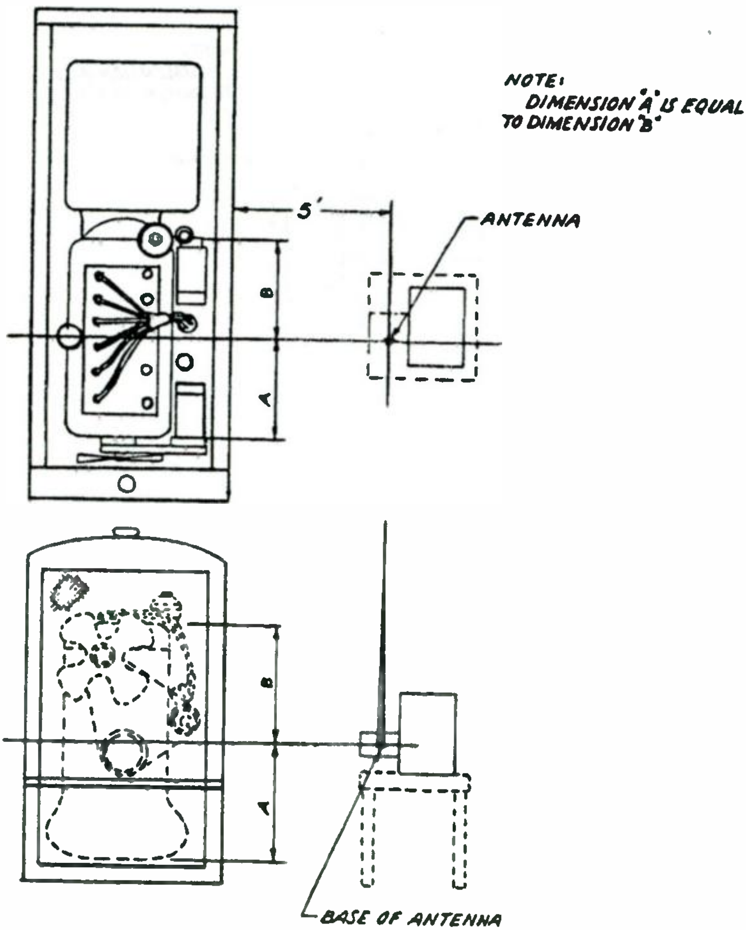

Figure 4

Rod Antenna Positioning

Miscellaneous Engine Driven Equipments

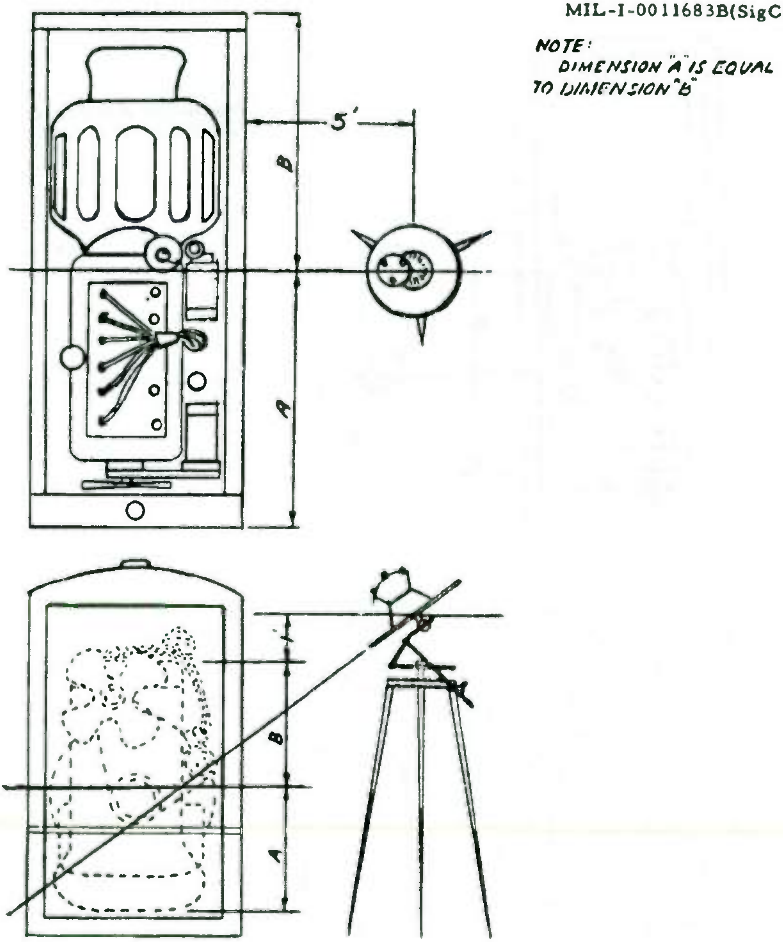

Figure 5

Antenna Positioning Antenna AT-292/URM 29

Engine Generator Units

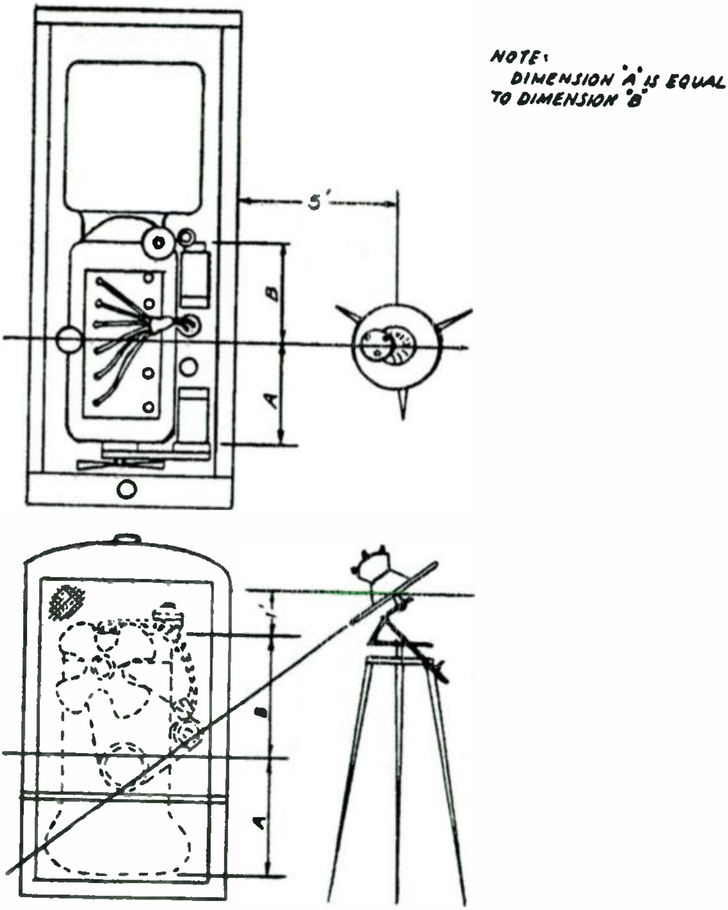

Figure 6

Antenna Positioning Antenna AT-292/URM 89

Miscellaneous Engine Driven Equipments

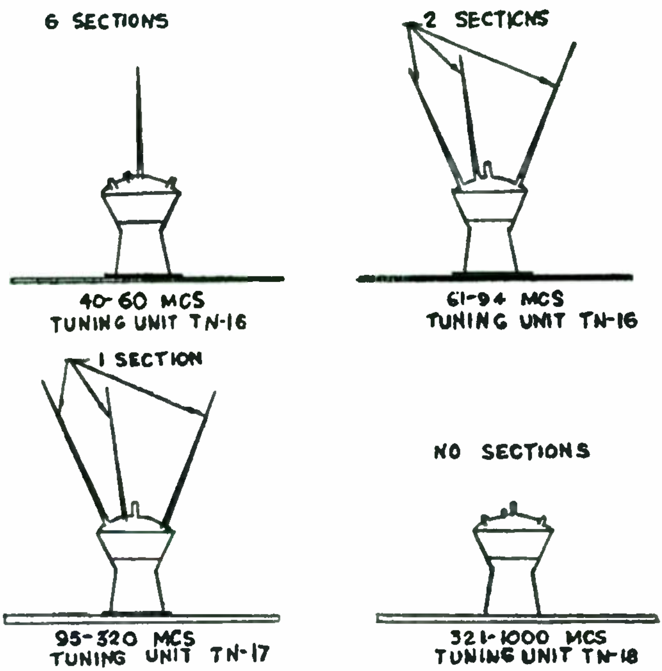

Figure 7

Antenna Equipment for Test Set AN/URM-29

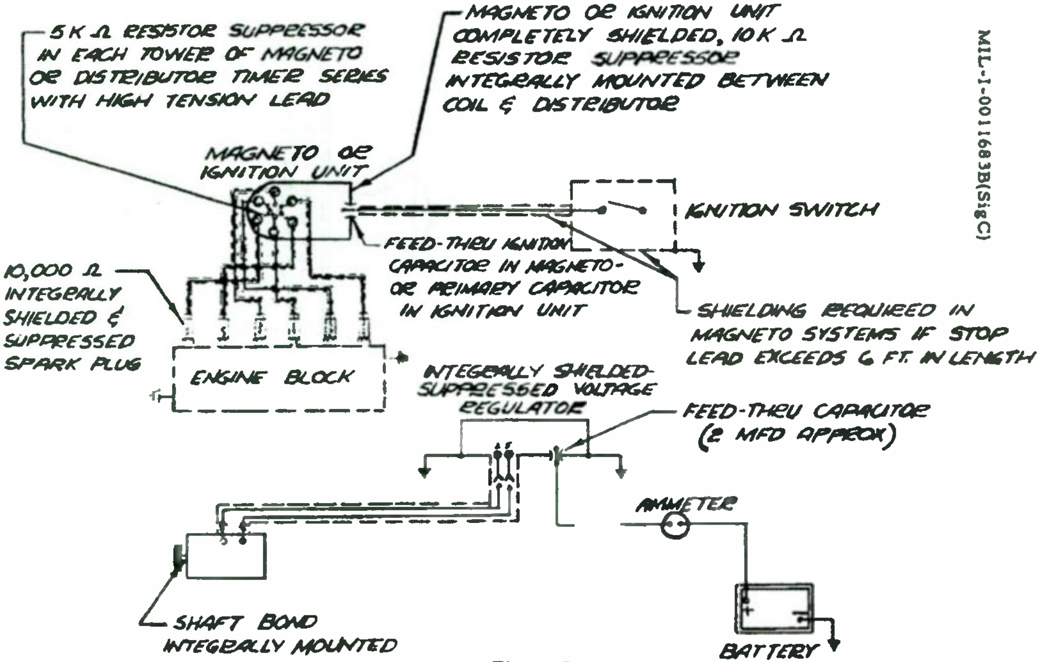

Figure 2

Typical Radio Interference

Suppression System for Gasoline Engines

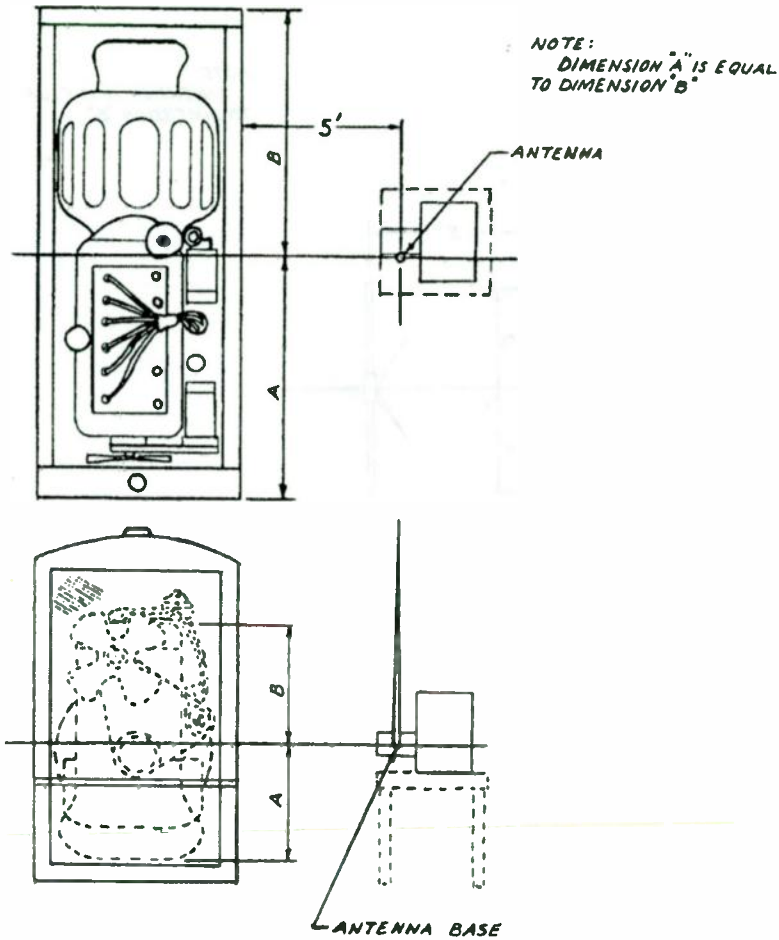

Figure 3

Rod Antenna Positioning

Engine Generator Units

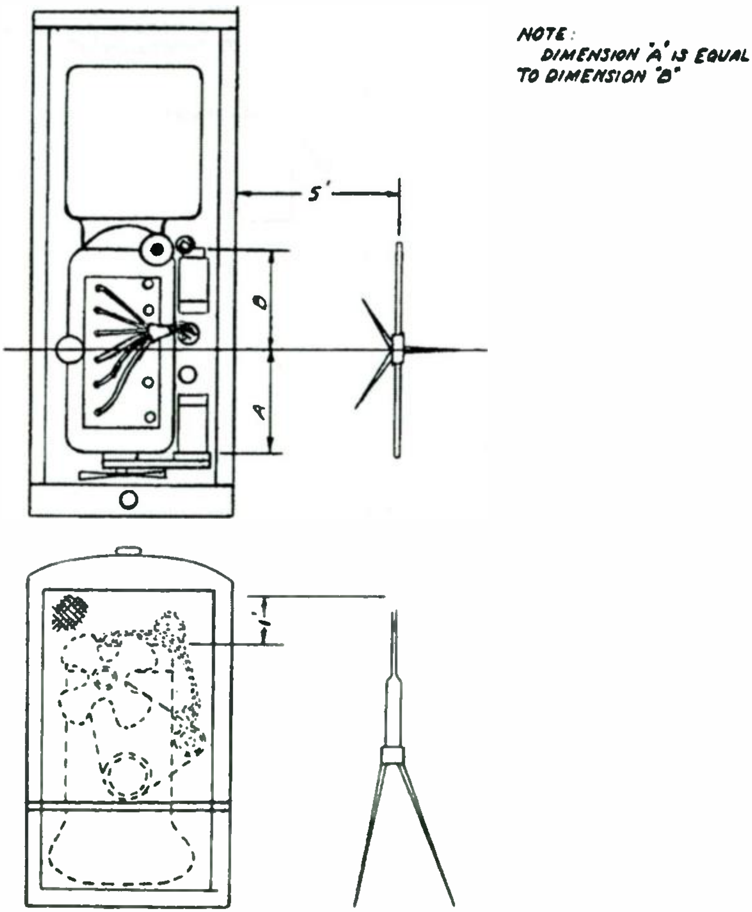

Figure 8

Dipole Antenna Positioning

Miscellaneous Engine Driven Equipments

NOTE:
DIMENSION "A" IS EQUAL
TO DIMENSION "E"

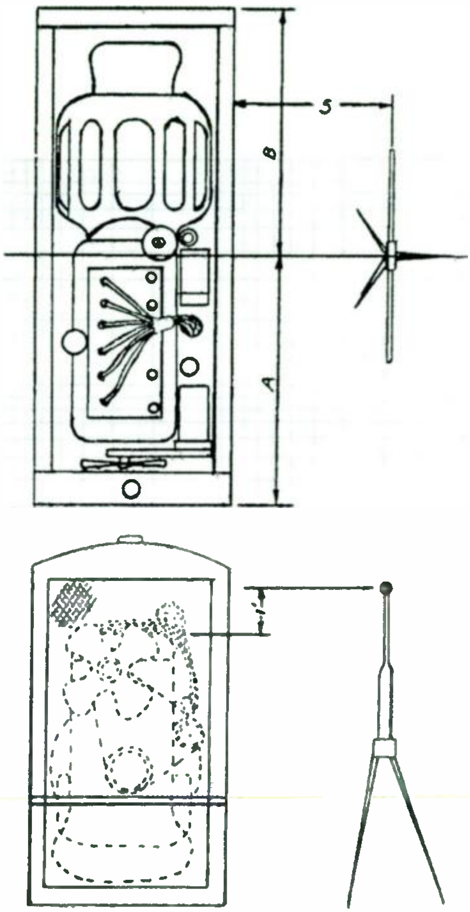

Figure 9

Dipole Antenna Positioning

Engine Generator Units

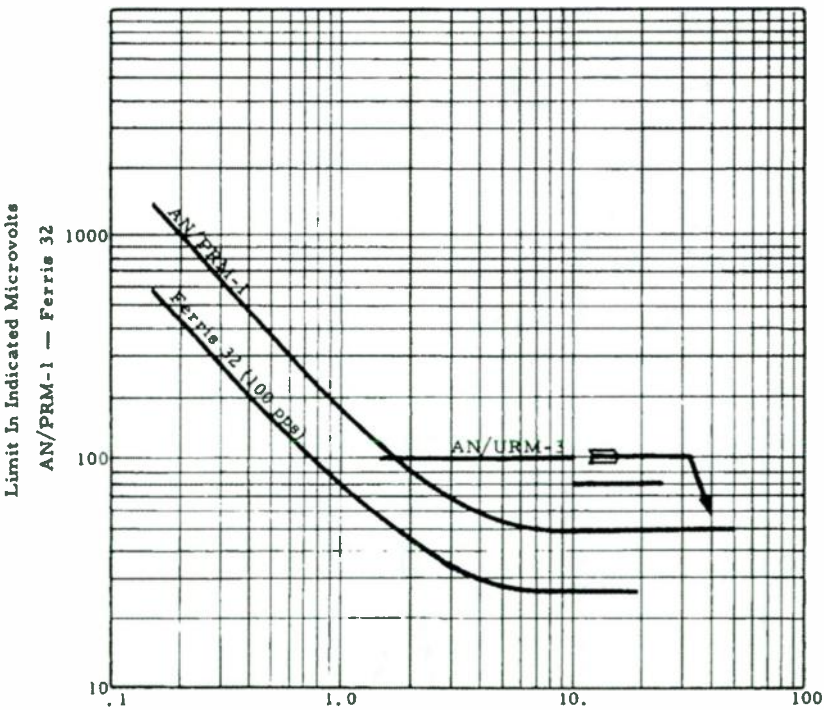

Figure 10

Conducted Interference Limits

Engine Generator Units

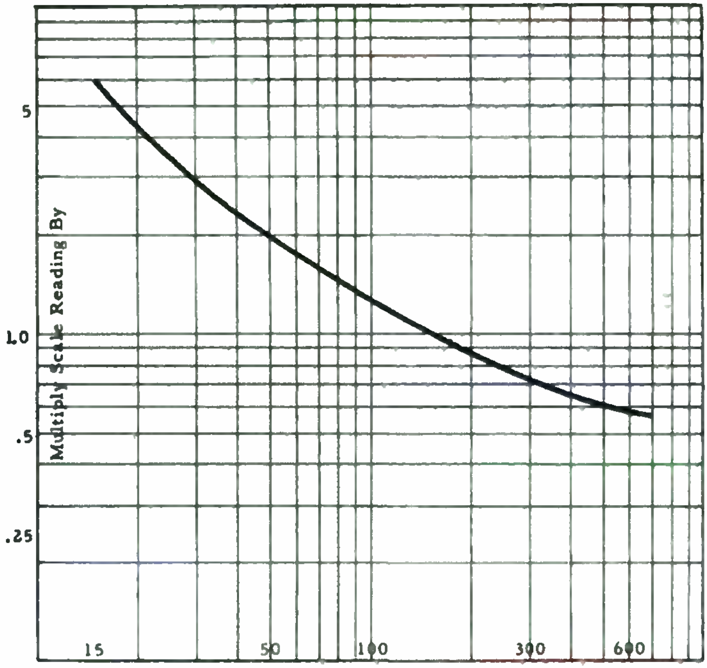

Figure 11

Pulse Repetition Rate

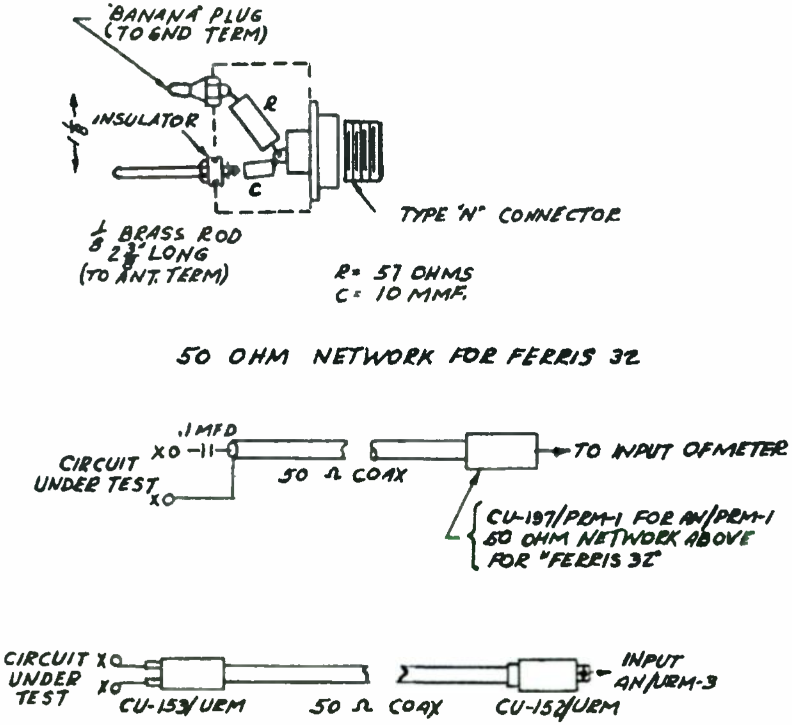

Figure 12

Circuit Arrangements and Coupling Networks

for Conducted Interference Measurements

MIL-I-11748B(SigC)
Amendment 3
11 January 1962

MILITARY
SPECIFICATION

INTERFERENCE REDUCTION FOR ELECTRICAL AND ELECTRONIC EQUIPMENT

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1. Paragraph 2.1 Under "SPECIFICATIONS," delete "FEDERAL, QQ-M-51, Metals: General Specification for Inspection of".

2. Paragraph 2.1 Add:

"STANDARDS

FEDERAL TEST METHODS

No. 151 Metals: Test Methods"

3. Paragraph 3.1.5.2 Add: "(see 6.6)"

4. Paragraph 3.1.6 Change to read as follows:

3.1.6 Susceptibility. - Susceptibility is the response of an equipment or component to any signal applied, either conductively or by an electromagnetic field in space, at other than the normal input terminals.

5. Paragraph 3.1.7 Change to read as follows:

3.1.7 Extraneous response. - An extraneous response is any undesired response of a receiver, recorder, or other sensitive device due to any undesired signal or to any interaction between a desired signal and an undesired signal, applied to the normal input terminals.

6. Paragraph 3.1.10 replace by:

3.1.10 Qualification-approved (formerly type-approved) suppression component. - A qualification-approved suppression component is one for which samples of the same make and type have been approved by the designated Government agency as conforming to a set of electrical (including radio-frequency) and mechanical characteristics detailed in the applicable subsidiary specification. (See 6.2.1).

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7. Paragraph 3.1.11, replace by:

3.1.11 Contractually-approved (formerly application-approved) suppression component. - A contractually-approved suppression component is one not conforming to a set of electrical and mechanical characteristics detailed in an applicable subsidiary specification, but of which samples of the same make and type have been approved by the designated Government agency as being acceptable for a specific suppression application. (See 6.2.2).

8. Insert:

3.1.20 Equipment item. - An equipment item is any separate and distinct unit of a type which, if procured separately, would normally be subject to test for conformance to this or some other military interference reduction specification.

9. Insert:

3.1.21 System. - A system is an aggregation of equipment items and those auxiliary items, if any, used therewith to coordinate them into a functional whole having a capability beyond that of the individual equipment items.

10. Insert:

3.2.10 Electromagnetic Compatibility control plan. - Except on procurements in which the end item is exclusively Class III (see 4.1.1.2.1), the contractor shall submit a detailed plan (5 copies) describing his program for control of interference emission, susceptibility to undesired radiated, induced and conducted voltages and fields, and the compatible operation of the subject equipment items and/or systems in the electromagnetic environments in which they are designed to operate. The plan shall be submitted to the procuring activity within 90 days after contract award, or as otherwise specified in the contract.

3.2.10.1 Content. - The control plan shall discuss the following:

(a) The design aspects of the contractual program, including such areas as preferred circuitry from the compatibility control standpoint, circuits to be shielded, the degree of shielding required, r-f filtering and/or by-passing required to prevent extraneous emissions and susceptibility to extraneous voltages or fields, integral suppression of interference producing devices, etc. Block diagrams of equipments and systems, showing major or critical components and subassemblies, shall be supplied. The degree of shielding or isolation required of equipment cases, shelters and vans shall be discussed from the emission, susceptibility and human safety aspects, and indications given of the methods by which this will be achieved. If any incident field from 0.014-40,000 mc may be expected to exceed 1.0 volt/meter, it shall be specifically pointed out in this plan.

(b) Facilities, on hand and to be procured or subcontracted, that will enable the contractor to determine the degree of compatibility control being incorporated in the equipment item or system.

(c) Available or estimated data on the interference characteristics of equipment items to be incorporated in the end item.

3.2.10.2 Addenda to this plan shall be submitted whenever additional data becomes available or it becomes apparent that the plan should be revised or supplemented to keep it up to date and in consonance with the known facts and latest thinking.

11. Paragraph 3.3. Delete the second and third sentences.

12. Paragraph 3.3, Class Ic. Change to read:

c. Test equipment and other equipment intentionally generating or utilizing r-f energy, for purposes other than power applications as covered by Class II, but not intended to radiate.

13. Paragraph 3.4.2.1. Delete.

14. Insert:

3.4.4 Equipment items not being procured under a system contract. - (See 3.1.20) The above-defined classes and the limits applicable thereto shall apply, except that when an equipment item of one class becomes installed in, or is incorporated as an integral part of, an equipment item of another class, the overall equipment item shall conform to the class having the more severe requirements.

3.4.5 Systems. - (See 3.1.21) The system as a whole shall meet, as a minimum, the requirements of the equipment class therein having the most severe requirements. However, regardless of the interference requirements stated in the following subparagraphs for the individual equipment items of a system, and their conformance or non-conformance to their class requirements, the system contractor shall take any additional measures necessary to assure that no electromagnetic emission or susceptibility characteristic of these equipment items will result in undesirable response or malfunctioning of the system or any part thereof.

3.4.5.1 Equipment items of a system. - Each equipment item of a system, produced on a system contract or a subcontract thereof, or purchased by the contractor as a commercial item, shall meet or be modified by him to meet the class requirements applicable to that item.

3.4.5.2 Government-furnished equipment items of a system. - Equipment items furnished by the Government to a contractor for incorporation into a system shall, unless the test data is furnished by the Government, be tested by the contractor for conformance to their class requirements.

(a) If the class requirements are not met, but the application of minor external suppression measures will result in meeting those requirements, the contractor shall so indicate in the control plan, (3.2.10-3.2.10.2), and shall apply suppression as needed to meet those requirements. Test data confirming the effectiveness of the measures shall be furnished in the plan or in an addendum to it.

(b) If extensive, difficult, or impractical internal procedures or structural or circuit modifications would be required to meet the class requirements, full data on the difficulties, costs, etc. shall be furnished the contracting officer as early as possible, and shall be included as a part of the control plan or an addendum thereto. (3.2.10-3.2.10.2).

15. Paragraph 3.5, line 3: After "radiation" insert "and".

16. Table 11, last Column. Delete "BB" in all three instances.

17. Table 111-a: Heading of column 3 should read "Approx. Equivalent μV/mc".

18. Table 111-a: Heading of column 5 should read "Approx. Equivalent μV".

19. Table 111-a: Last entry of Column 1 should read "3000 + to 36000."

20. Table 111-b, text, end of line 4, replace "those" by "the".

21. Table 111-b, opposite "11-a." Replace "100" by "no test."

22. Table IV: Columns 1 and 2, and 3 and 4, should be separated so headings are separately readable, as in Table 111-a.

23. Table IV: Column 1, change "30" to "65".

24. Paragraph 3.5.1.2.1: Change "0.15-30 mc" to "0.15-65 mc".

25. Paragraph 3.5.2.1.1.1: Change to read as follows:

3.5.2.1.1.1 Harmonics. - The peak power output of the second and third harmonics shall be at least 60 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 1 watt, when measured according to 4.3, 4.4, and their applicable sub-paragraphs.

26. Paragraph 3.5.2.1.1.2. Change to read as follows:

3.5.2.1.1.2 Other extraneous emissions. - The peak power output of any harmonic above the third, and of any non-harmonic extraneous emission shall be at least 80 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 10^{-2} watts, when measured in accordance with 4.3, 4.4, and their applicable sub-paragraphs.

27. Paragraph 3.5.3.2. Change to read as follows:

3.5.3.2. Class 11b. - Equipment of this class, when set up as for its intended use, shall meet the requirements of Tables 111a, 111b and IV at the fundamental as well as all other generated frequencies up to the tenth harmonic or 1000 mc, whichever is higher, but not over 36,000 mc.

28. Paragraph 3.5.4.2: Change "0.15-30 mc" to "0.15-65 mc".

29. Paragraph 3.6.1, line 2: Change "type-approved" to "qualification-approved."

30. Paragraph 3.6.1, line 4: Change "application approval" to "contractual approval."

31. Paragraph 3.6.2, replace by:

3.6.2 Integral suppression components. - Integral suppression components incorporated in electrical and electronic components, subassemblies, and accessories shall be subject to contractual approval (3.1.11) by the designated Government agency for electrical (including radio-frequency) and mechanical characteristics pertinent to the particular application, and shall conform, insofar as practicable, to the applicable subsidiary specifications listed in 2.1.

32. Paragraph 3.6.3. Delete.

33. Replace 4.1.1.1 by:

4.1.1.1 Inspection by the contractor. - Except as stated in 4.1.1.2.1, the contractor shall conduct all tests required by this specification to determine conformance to the requirements hereof, using test equipment, test setups and procedures herein specified. The Government reserves the right to witness all tests carried out by the contractor, his testing agency, or subcontractor. (See 6.3.1).

4.1.1.1.1 Electromagnetic Compatibility Test Plan. - Except on procurements in which the end item is exclusively Class III (see 4.1.1.2.1), the contractor shall submit 5 copies of a comprehensive test plan to the procuring activity showing the tests which will be run on each equipment item and on the system as a whole, to determine conformance to this specification. Each equipment item of a system capable of separate operation (e.g. receiver, transmitter, teletypewriter) shall be individually tested according to its class prior to system tests. (See 3.4.4 through 3.4.5.4). This plan shall be submitted 90 days prior to the start of electromagnetic compatibility acceptance tests, or as otherwise directed in the contract. Approval of the test plan shall precede the start of formal testing. Included in the delineation of the proposed tests shall be the following.

(a) Nomenclature and salient characteristics of test equipment to be used.

(b) Types and methods of calibration of standards, and calculations to show the expected accuracy of each.

(c) Dummy loads, signal-line filters, dummy antennas, signal samplers, etc., to be used, together with VSWR and insertion loss, if applicable, in the frequency range of interest.

(d) Detector functions (peak, average, etc.) to be used in measuring equipment.

(e) Modes of operation of subject items, including control settings, etc.

(f) Test frequencies and modulations, and computations to indicate frequencies at which extraneous outputs, susceptibilities, and intermodulation products may be expected.

(g) Pertinent details of test setups and procedures not covered by this specification, and other details requiring approval of the procuring agency.

(h) Expected overall accuracy of each test.

4.1.1.1.2 Electromagnetic Compatibility Test Report. - Except on procurements in which the end item is exclusively Class III, the contractor shall submit to the procuring agency as directed in the contract, but prior to the submission of the equipment for acceptance, a test report (5 copies), conforming to the format of the "Preliminary Engineering Reports" section of SCL-2101. The test report shall show in detail the application of the Electromagnetic Compatibility Test Plan in the determination of the compliance of the test item with the requirements and limits of this specification. In addition to the details required in the test plan, the following data shall be included in the test report:

(a) Dates of all tests.

(b) Ambient interference and internal noise level of radio interference measuring set receivers for each detector function used and at each frequency of test.

(c) Detailed description of procedures used. The maximum use of photographs and/or diagrams is required.

(d) Measured line voltage(s) to test sample.

(e) Test frequencies and modulations, and basis of their choice if different than stated in the test plan.

(f) Type of interference or susceptibility measured, its source, and accuracy of measured values.

(g) Remedial actions required and taken as a result of testing.

(h) Nomenclatures and serial numbers of test equipment used, and last date of calibration prior to test.

34. Paragraph 4.1.1.2.1 Change to read as follows:

4.1.1.2.1 Army procurement of separate Class III items. - Inspection and testing of preproduction units, and spot testing of production units of Class III items for conformance to the requirements of this specification will be carried out by the Army, except when they are being procured as part of a Class 1 item, and under the same contract. The contractor shall visually inspect each production unit and shall certify its conformance to the report of the contracting officer on the approved suppression system. See 6.3.2 thru 6.3.2.2.1. On Class III-d items the contractor's visual inspection of the suppression system need be made only on those units which are subject to at least one other production examination or test.

35. Paragraph 4.2.1. Change final period to comma and add: "pending availability of suitable instruments."

36. Paragraph 4.2.2.6. Change parenthetical expression to read "(other than internal tube and circuit noise)".

37. Paragraph 4.2.2.7, line 1. Delete "including."

38. Paragraph 4.2.3.2, line 3: Change "4.2.2.29" to "4.2.2.9."

39. Table V(a): Change the first seven lines under the column headings to read as follows:

0.014 - 0.15	NM-10A	a	
0.014 - 1000	NF-105	b	1, 8
0.014 - 1000	NF-205	b	1, 3, 8
20 - 400	NM-30A	a	8
400 - 1000	NM-50A	a	8
400 - 1000	NM-52A	a	8
1000 - 10,000	NF-112	b	

40. Table V-b: Delete "Notes" in heading between last two columns, and add a line under the three column headings as follows:

1000 - 10,000	AN/TRM-6	6

41. Table V, add Note 8 as follows:

8. Radiation measurements shall be made only by series injection substitution at base of antenna, using an injection network of Table VII, and either an impulse calibrator of Table VIII, one built into an instrument of Table V, or a standard-signal generator.

42. Table VI(a), fourth line below headings: Replace "LM-105-SC" by "VA-205-SC".

43. Table VI(b), column 2: Change "10,000" to "1000".

44. Table VII(a), add a line as follows under the three column headings, respectively:

92288-1	a	91280-1

45. Table VIII, note 5. Change "0.15 mc" to "1.5 mc".

46. Paragraph 4.3.1.3 line 8: Change "with" to "within".

47. Paragraph 4.3.1.4. Add: "CAUTION---SHOCK HAZARD; Connect cases of networks to earth ground BEFORE connecting a-c to power line."

48. Paragraph 4.3.1.5.2. Add: "Cases of impedance stabilization networks shall be earth grounded."

49. Paragraph 4.3.2.1, add commas as follows:

line 3, after "band"

line 3, after "switching"

line 7, after "only"

50. Paragraph 4.3.2.1, lines 4-5. Change "1.25" to "1.4", and delete the parenthetical phrase.

51. Paragraph 4.3.3: Change "0.15-30 mc" to "0.15-65 mc".

52. Paragraph 4.4.1. Delete last sentence.

53. Paragraph 4.4.2: Change "0.15-30 mc" to "0.15-65 mc".

54. Paragraph 4.4.4.1, line 9: Change "1.20" to "1.3".

55. Paragraph 4.4.4.2, last line. Place comma after "bandwidth."

56. Paragraph 4.5.1, first sentence. Place a period after "network" and delete remainder of sentence.

57. Paragraph 4.5.2, line 3: Change "ration" to "ratio".

58. Paragraph 4.5.2, line 3: Change "open-circuit" to "50-ohm-loaded."

59. Paragraph 4.5.3.1, line 2: Change "4.3.1.2" to "4.3.1.3".

60. Paragraph 4.5.3.1.3 Add: "The ground plane shall be earth grounded for safety. (See 4.3.1.4)".

61. Paragraph 4.5.4.2, end. Replace "Table VII" and parenthetical expression by "Table VIII." (Note 1, but not note 5, is immaterial for this test.)"

62. Paragraph 4.6. Replace by:

4.6 Corrosion test. - Parts which must meet the requirements of 3.2.7 shall be tested in accordance with Federal Test Method Standard 151, subjecting the parts to salt spray for a period of 96 hours at a temperature of 95 degrees Fahrenheit using a 20 percent by weight aqueous solution of sodium chloride.

63. Paragraph 6.1. Replace by:

6.1 List of approved suppression components. - Current Qualified Products Lists (QPL) of qualification-approved suppression capacitors, filters and resistor suppressors, under the applicable subsidiary specifications of 2.1, may be obtained from the Contracting Officer, U.S. Army Signal Supply Agency, 225 South Eighteenth Street, Philadelphia 3, Pennsylvania, by referring to the specification number covering the particular component. Indication of approval of any item, by its inclusion in QPL or by other means, as being suitable for suppression purposes and in accordance with the applicable specifications, covers use of the component only for suppression purposes. A list of manufacturers of suppression components having qualification approval under the subsidiary specifications of paragraph 2.1 may be obtained upon application to the Contracting Officer.

64. Paragraph 6.2, replace by:

6.2 Approval of suppression components.

65. Paragraph 6.2.1, replace by:

6.2.1 Qualification approval. - Qualification approval of suppression components (3.1.10) may be obtained in accordance with procedures and through the agencies designated in the applicable subsidiary specifications.

66. Paragraph 6.2.2, replace by:

6.2.2 Contractual approval. - Contractual approval of suppression components (3.1.11) may be obtained through the U.S. Army Signal Materiel Support Agency, Field Engineering Division, Fort Monmouth, N.J.

67. Paragraph 6.3.1, change to read as follows:

6.3.1 Testing by the contractor. Tests required of the contractor (see 4.1.1.1) may be performed for him, all or in part, by a private testing agency or by a subcontractor supplying him with equipment items. In any event, paragraphs 4.1.1.1.1 and 4.1.1.1.2 are applicable.

68. Paragraph 6.3.2, line 2. Replace all beginning with "such" and ending with "etc" by "including Army inspection and testing of such items for approval before being furnished as part of an equipment on order".

69. Paragraph 6.3.2, line 7 et seq. Place a period after "functions" and delete remainder of paragraph.

70. Paragraph 6.3.2.2.1. Delete items "c" and "e" and change "d" to "c".

71. Add:

6.6 Broadband interference. - The linear relationship of peak response to the bandwidth of the measuring instrument is accurate for impulses sufficiently separated in time so that the successive transients do not overlap in the measuring instrument, up to the peak detector. Transient duration is approximately twice the reciprocal of the 6-db-down bandwidth. For extreme overlap, as with thermal noise, the peak response is proportional to the square root of the bandwidth. Broad-band interference generated by man-made equipment such as commutators, relays, automotive ignition systems, etc, when measured with a peak detector, has been found experimentally to fall in the range of linear response versus bandwidth in almost all instances, for the bandwidths of typical interference measuring instruments not designed to work below 150 kilocycles.

72. Insert:

6.7 Radio Interference testing waiver for Class III-b, c, and d items. - The contractor should furnish as a part of his bid a full description of all electrical sub-assemblies and accessories of the end item. If the description indicates that the end item is inherently interference-free, or is not likely to be operated sufficiently often or long to be a significant source of interference, the contracting officer may grant a waiver of the interference testing requirements.

"NOTICE. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto."

MILITARY
SPECIFICATION

MIL-I-11748B(SigC)
Amendment 2
9 June 1959

INTERFERENCE REDUCTION FOR ELECTRICAL AND ELECTRONIC EQUIPMENT

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1. Paragraph 2.1 Under "SPECIFICATIONS," delete "FEDERAL QQ-M-51, Metals: General Specification for Inspection of".

2. Paragraph 2.1 Add:

"STANDARDS

FEDERAL

No. 151 Metals; Test Methods"

3. Paragraph 3.1.5.2 Add: "(see 6.6)".

4. Paragraph 3.1.6 Change to read as follows:

"3.1.6 Susceptibility. - Susceptibility is the response of an equipment or component to any signal applied, either conductively or by an electromagnetic field in space, at other than the normal input terminals."

5. Paragraph 3.1.7 Change to read as follows:

"3.1.7 Extraneous response. - An extraneous response is any undesired response of a receiver, recorder, or other sensitive device due to any undesired signal or to any interaction between a desired signal and an undesired signal, applied to the normal input terminals."

6. Paragraph 3.1.10 replace by:

3.1.10 Qualification-approved (formerly type-approved) suppression component. - A qualification-approved suppression component is one for which samples of the same make and type have been approved by the designated Government agency as conforming to a set of electrical (including radio-frequency) and mechanical characteristics detailed in the applicable subsidiary specification. (See 6.2.1).

7. Paragraph 3.1.11, replace by:

3.1.11 Contractually-approved (formerly application-approved) suppression component. - A contractually-approved suppression component is one not conforming to a set of electrical and mechanical characteristics detailed in an applicable subsidiary specification, but of which samples of the same make and type have been approved by the designated Government agency as being acceptable for a specific suppression application. (See 6.2.2).

8. Paragraph 3.3, Class Ic. Change to read:

"c. Test equipment and other equipment intentionally generating or utilizing r-f energy, for purposes other than power applications as covered by Class II, but not intended to radiate."

9. Paragraph 3.4.2.1 Delete.

10. Table II, last Column. Delete "BB" in all three instances.

11. Table III-a: Heading of column 3 should read "approx. Equivalent μV/mc".

12. Table III-a: Heading of column 5 should read "Approx. Equivalent μV".

13. Table III-a: Last entry of Column 1 should read "3000 + 36000".

14. Table III-b, text, end of line 4, replace "those" by "the".

15. Table III-b, opposite "II-a". Replace "100" by "no test."

16. Table IV: Columns 1 and 2, and 3 and 4, should be separated so headings are separately readable, as in Table III-a.

17. Paragraph 3.5.2.1.1.1. Change to read as follows:

"3.5.2.1.1.1 Harmonics. - The peak power output of the second and third harmonics shall be at least 60 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 1 watt, when measured according to 4.3, 4.4, and their applicable sub-paragraphs."

18. Paragraph 3.5.2.1.1.2 Change to read as follows:

"3.5.2.1.1.2 Other extraneous emissions. - The peak power output of any harmonic above the third, and of any non-harmonic extraneous emission shall be at least 80 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 10^{-2} watts, when measured in accordance with 4.3, 4.4, and their applicable sub-paragraphs.

19. Paragraph 3.5.3.2 Change to read as follows:

"3.5.3.2 Class IIb. - Equipment of this class, when set up as for its intended use, shall meet the requirements of Tables IIIa, IIIb, and IV at the fundamental as well as all other generated frequencies up to the tenth harmonic or 1000 mc, whichever is higher, but not over 36,000 mc."

20. Paragraph 3.6.1, line 2: Change "type-approved" to "qualification-approved."

21. Paragraph 3.6.1, line 4: Change "application approval" to "contractual approval."

22. Paragraph 3.6.2, replace by:

3.6.2 Integral suppression components. - Integral suppression components incorporated in electrical and electronic components, subassemblies, and accessories shall be subject to contractual approval (3.1.11) by the designated Government agency for electrical (including radio-frequency) and mechanical characteristics pertinent to the particular application, and shall conform, insofar as practicable, to the applicable subsidiary specifications listed in 2.1.

23. Paragraph 3.6.3 Delete

24. Paragraph 4.2.1 Change final period to comma and add: "pending availability of suitable instruments."

25. Paragraph 4.2.2.6 Change parenthetical expression to read "(other than internal tube and circuit noise)".

26. Paragraph 4.2.2.7, line 1. Delete "including."

27. Paragraph 4.2.3.2, line 3: Change "4.2.2.29" to "4.2.2.9."

28. Table V-a: Delete "NF-112" and all else on that line.

29. Table V-b: Delete "Notes" in heading between last two columns.

Column 1, add "1000-10,000"

Column 2, add "AN/TRM-6"

Column 3, add "6"

30. Table VIII, note 5. Change "0.15 mc" to "1.5 mc"

31. Paragraph 4.3.1.3 line 8: Change "with" to "within."

32. Paragraph 4.3.1.4. Add: "CAUTION---SHOCK HAZARD; Connect cases of networks to earth ground BEFORE connecting a-c to power line."

33. Paragraph 4.3.1.5.2. Add: "Cases of impedance stabilization networks shall be earth grounded."

34. Paragraph 4.3.2.1, add commas as follows:

line 3, after "band"

line 3, after "switching"

line 7, after "only"

35. Paragraph 4.3.2.1, lines 4-5. Change "1.25" to "1.4", and delete the parenthetical phrase.

36. Paragraph 4.4.1 Delete last sentence.

37. Paragraph 4.4.4.1, line 9: Change "1.20" to "1.3".

38. Paragraph 4.4.4.2, last line. Place comma after "bandwidth."

39. Paragraph 4.5.1, first sentence. Place a period after "network" and delete remainder of sentence.

40. Paragraph 4.5.2, line 3: Change "ration" to "ratio".

41. Paragraph 4.5.2, line 3: Change "open-circuit" to "50-ohm-loaded."

42. Paragraph 4.5.3.1, line 2: Change "4.3.1.2" to "4.3.1.3".

43. Paragraph 4.5.3.1.3 Add: "The ground plane shall be earth-grounded for safety. (See 4.3.1.4)".

44. Paragraph 4.5.4.2, enc. Replace "Table VII" and parenthetical expression by "Table VIII. (Note 1, but not note 5, is immaterial for this test.)"

45. Paragraph 4.6 Replace by:

"4.6 Corrosion test. - Parts which must meet the requirements of 3.2.7 shall be tested in accordance with Federal Test Method Standard 151, subjecting the parts to salt spray for a period of 96 hours at a temperature of 95 degrees Fahrenheit using a 20 percent by weight aqueous solution of sodium chloride."

46. Paragraph 6.1 Replace by:

"6.1 List of approved suppression components. - Current Qualified Products Lists (QPL) of qualification-approved suppression capacitors, filters and resistor suppressors, under the applicable subsidiary specifications of 2.1, may be obtained from the Contracting Officer, U.S. Army Signal Supply Agency, 225 South Eighteenth Street, Philadelphia 3, Pennsylvania, by referring to the specification number covering the particular component. Indication of approval of any item, by its inclusion in QPL or by other means, as being suitable for suppression purposes and in accordance with the applicable specifications, covers use of the component only for suppression purposes. A list of manufacturers of suppression components having qualification approval under the subsidiary specifications of paragraph 2.1 may be obtained upon application to the Contracting Officer.

47. Paragraph 6.2, replace by:

"6.2 Approval of suppression components."

48. Paragraph 6.2.1, replace by:

"6.2.1 Qualification approval. - Qualification approval of suppression components (3.1.10) may be obtained in accordance with procedures and through the agencies designated in the applicable subsidiary specifications."

49. Paragraph 6.2.2, replace by:

"6.2.2 Contractual approval. - Contractual approval of suppression components (3.1.11) may be obtained through the U.S. Army Signal Equipment Support Agency, Field Engineering Division, Fort Monmouth, N.J.

50. Paragraph 6.3.2, line 2. Replace all beginning with "such" and ending with "etc" by "including Army inspection and testing of such items for approval before being furnished as part of an equipment on order".

51. Paragraph 6.3.2, line 7 et seq. Place a period after "functions" and delete remainder of paragraph.

52. Paragraph 6.3.2.2.1 Delete items "c" and "e" and change "d" to "c".

53. Add:

"6.6 Broadband interference. - The linear relationship of peak response to the bandwidth of the measuring instrument is accurate for impulses sufficiently separated in time so that the successive transients do not overlap in the measuring instrument, up to the peak detector. Transient duration is approximately twice the reciprocal of the 6-db-down bandwidth. For extreme overlap, as with thermal noise, the peak response is proportional to the square root of the bandwidth. Broad-band interference generated by man-made equipment such as commutators, relays, automotive ignition systems, etc, when measured with a peak detector, has been found experimentally to fall in the range of linear response versus bandwidth in almost all instances, for the bandwidths of typical interference measuring instruments not designed to work below 150 kilocycles.

"Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto."

MIL-I-11748B(SigC)
4 November 1958
Superseding
MIL-I-11748A(SigC)
5 May 1956

MILITARY
SPECIFICATION

INTERFERENCE REDUCTION FOR ELECTRICAL AND ELECTRONIC EQUIPMENT

1. SCOPE

1.1 Scope. - This specification covers the radio interference limits, tests, and design requirements for the reduction of radio-frequency interference emanation, and susceptibility to such emanations, over the frequency range of 0.014 - 36,000 mc, for all electrical and electronic equipment and systems, including that intended for, but not yet actually installed in or serving as integral parts of ground vehicles, internal combustion engines, internal-combustion-engine-driven equipment, railroad rolling stock, watercraft, or air vehicles (including missiles).

2. APPLICABLE DOCUMENTS

2.1 Specifications. - The following specifications of the issue in effect on the date of invitation for bids form a part of this specification:

SPECIFICATIONS

FEDERAL

QQ-M-151	Metals: General Specification for Inspection of

MILITARY

MIL-C-5	Capacitors, Fixed, Mica-Dielectric
MIL-C-25	Capacitors, Direct Current, Paper Dielectric, Fixed (Hermetically Sealed in Metallic Cases)
MIL-C-91	Capacitors, Fixed, Paper Dielectric: (Non-Metallic Cases)
MIL-C-11693	Capacitors, Feed-Through, Radio-Interference Reduction, Paper Dielectric, AC and DC (Hermetically Sealed in Metallic Cases)
MIL-C-12889	Capacitors, By-Pass, Radio-Interference Reduction, Paper Dielectric, AC and DC (Hermetically Sealed in Metallic Cases), General Spec. For
MIL-F-15733	Filters, Radio Interference

3. REQUIREMENTS.

3.1. Definitions.

3.1.1 Radio interference. - Radio Interference, or simply interference, is defined as any conducted, induced, or radiated electrical disturbance, including transients, which may cause undesirable response or otherwise impair the operation of electrical or electronic equipment.

3.1.2 Ambient interference. - That level of interference indicated by the interference measuring set when sited, set up, tuned, and calibrated for the intended interference measurement, with the equipment under test turned off. Atmospherics, interference from other sources, and circuit noise generated within the measuring instrument make up the "ambient" level.

3.1.3 Narrow-band interference. - Interference due to continuous-wave (CW) signals, modulated (including pulsed) or unmodulated, such as the carrier frequency or a transmitter. The response ot interference measuring sets to narrow-band interference is substantially independent of the receiver bandwidth if the latter is wider than the principal spectrum of the interference being measured.

3.1.4 Broad-band interference. - All interference other than narrow-band signals; such as impulse noise, thermal noise, shot noise, and other non-sinusoidal interference of which the energy is distributed over a spectrum of frequencies which is wide compared with the bandwidth of the interference measuring equipment. The response of an interference measuring set to broad-band interference is a function of the effective bandwidth of the receiver, and cognizance must be taken of this fact in the calibration of the measuring instrument.

3.1.5 Units of measurement.

3.1.5.1 Narrow-band interference. - CW or narrow-band interference, at a pair of terminals, is measured, for the purposes of this specification, in decibels above one microvolt (db/1μV). For unmodulated CW or CW modulated by other than pulse waveforms, the limits are stated in terms of .707 of the average envelope amplitude. For pulse-modulated CW the limits are stated in terms of .707 of the peak envelope amplitude.

3.1.5.2 Broad-band interference. - The intensity of broad-band interference at a pair of terminals is measured, for the purposes of this specification, in terms of decibels relative to one microvolt per megacycle of bandwidth (abbreviated "dbmc"). The interference intensity in microvolts per megacycle of bandwidth ($\mu V/mc$) is the number of r.m.s. sine-wave microvolts (unmodulated) which will result in peak response in the circuit equal to that resulting from the interference being measured, divided by the impulse bandwidth of the measuring instrument in megacycles. One microvolt per kilocycle of bandwidth ($\mu V/kc$) is equal to 1000 microvolts per megacycle of bandwidth, or 60 dbmc.

3.1.6 Susceptibility. - Susceptibility is the response of an equipment or component to any signal applied at other than the normal input terminals, or to any signal other than the desired one, applied at the normal input terminals, relative to its response to a desired signal applied at the normal input terminals.

3.1.7 Extraneous response. - Any undesired response of a receiver, recorder, or other susceptible device, due to the desired signals, undesired signals, or any combination or interaction among them; for example, images, cross modulation.

3.1.8 Radio interference suppression. - Suppression of radio interference is the reduction of the intensity of the emanated interference by means applied to, or at, the source.

3.1.9 Suppression system. - All components and materials integrally incorporated in, or applied to, the source of interference, including shielding and circuitry and the application thereof used for reduction of radio interference, will be referred to as the suppression system.

3.1.10 Type-approved suppression component. - A type-approved suppression component is one for which samples of the same make and type have previously been submitted, tested, and approved as being suitable for suppression purposes in accordance with the applicable subsidiary specification. (See 3.6-3.6.3)

3.1.11 Application-approved suppression component. - An application-approved suppression component is defined, for the purposes of this specification, as any capacitor, filter, or other suppression component not covered by applicable subsidiary specifications, which has been properly submitted to, and approved by, the designated agency for a specific suppression application. (See 3.6-3.6.3)

3.1.12 Integral suppression. - An integrally-suppressed electrical or electronic item is one in which shielding and suppression components are incorporated as integral parts thereof, and are therefore supplied, stored, and issued therewith.

3.1.13 Extraneous emission. - Any emission of a transmitter or transponder, other than any output carrier fundamental and those of its sidebands intentionally employed for the transmission of intelligence.

3.1.14 Harmonic emission. - Any extraneous emission which is an integral multiple of the output fundamental frequency.

3.1.15 Radio receiver front-end rejection. - The response of a receiver to signals applied to its normal input terminal at frequencies other than that to which the receiver is tuned, relative to its response at the center tuned frequency e.g., image rejection, i-f rejection.

3.1.16 Antenna induced microvolts. - The open-circuit voltage existing across the antenna terminals.

3.1.17 Minimum normal signal input. - The minimum normal signal at the receiver input which will produce the intended function or the minimum useable response as prescribed in the equipment specification or instructions.

3.1.18 Communication. - Communication is the transmission and reception of intelligence or information in any form. This includes not only messages and data in the usually understood sense, but all types of radar, navigation and IFF functions as well.

3.1.19 Radiation. - Radiation, within the frequency range covered by this specification, is intended to include all emanation of electromagnetic energy accomplished by means of electromagnetic fields not intentionally guided by conductors or dielectrics. The term therefore includes both radiation and induction in the more correct usage.

3.2 Design requirements, general.

3.2.1 Interference-free design. - The reduction of interference shall be a basic consideration in the design of all electronic and electrical systems, equipments, and components. Where practical, components, equipments, and systems shall utilize interference-free devices and circuits. The design shall insure that the intensity of radio interference inherently generated and propagated is the minimum achievable compatible with the state of the art, prior to the application of suppression measures. The need for shielding or suppression components in the end equipment to provide further interference reduction does not preclude this requirement. The application of such interference reduction components as must be used, and the suppression techniques involved, such as filtering, shielding, bonding, grounding, and isolation, shall comply with good engineering practice, and shall be incorporated as integral parts of the system, except where other requirements such as space limitations, temperature rise, or operational features make integral suppression impractical. Equipment enclosures and housings, including access doors, panels and other apertures shall provide continuous electrical shielding with a minimum of discontinuities so that maximum shielding effectiveness will be provided at all frequencies covered herein. Electrically conductive gaskets shall be used as necessary to implement this requirement. Insulating or poorly conducting finishes shall be removed from mating surfaces, since their presence would reduce grounding and shielding effectiveness. Such surfaces should be protected from corrosion by plating or other treatment which will not conflict with the requirements for good electrical conductivity. This requirement will take precedence over any conflicting requirement in the specifications for finishes. Where shock mounts are utilized, they shall be shunted with solid, flexible bond straps arranged to be readily removable for maintenance. Ground points for circuits and suppression components shall be chosen to minimize stray couplings caused by common ground impedances and circulating currents in the chassis.

3.2.2 Mutual interference. - Since in a tactical situation many electronic systems may be operated in relatively close proximity, every effort shall be made to minimize extraneous emissions and extraneous responses, which may cause mutual interference not only among elements of a given system, but also among systems.

3.2.2.1 Frequency conservation. - In the interests of reducing interference due to frequency congestion, and reducing the vulnerability of the system to outside interference sources, multiplexing, coding, and sampling procedures shall be used wherever appropriate.

3.2.2.1.1 Transmitters. - Transmitters shall be designed to emit the minimum practicable bandwidth compatible with system requirements, and, where practicable, to permit control of output power, in order to emit the minimum power adequate for the situation of use.

3.2.2.1.2 Receivers. - The minimum bandwidth necessary for reception of the desired intelligence shall be employed. Extraneous responses shall be reduced to the minimum levels consistent with good engineering practice and the state of the art.

3.2.2.2 Harmonic and other extraneous emissions. - Extraneous electromagnetic emanations from all electronic devices shall be reduced to the minimum level consistent with good engineering practice and the state of the art. In particular, harmonics and other extraneous emissions from transmitters and transponders, and the fundamentals, harmonics, and other frequencies resulting from oscillations generated in receivers shall be reduced to minimum output levels consistent with system operational requirements.

3.2.2.3 Susceptibility, general. - The reduction of susceptibility to radio-frequency interference shall be a prime consideration throughout component or system design. Equipment enclosures shall be designed not only to minimize interference emanation, but also to minimize susceptibility to external interference sources.

3.2.2.4 Conducted interference. - Cables and wiring entering or leaving an enclosure shall be filtered, by-passed, shielded, and shields grounded, as necessary to insure that the shielding integrity of the enclosure is maintained against emanation of and susceptibility to radiated interference. However, power lines shall not be shielded without express permission of the procuring agency. The level of interference conducted on power lines, cables, and other wiring which interconnect elements of a system, and susceptibility to such interference, shall be such that no malfunctioning of the equipment will occur under any normal condition of operation and interconnection.

3.2.3 Components. - Suppression components shall comply with applicable military specifications, shall be approved in accordance with paragraph 3.6 and its subparagraphs, and, where possible, shall be installed as integral parts of the equipment. As an alternative, if space limitations prohibit integral installation, the suppression components may be attached externally to the equipment, provided that the connecting wiring is adequately shielded and the suppression components are permanently bonded to the case, and provided these components meet altitude and other environmental requirements.

3.2.3.1 Environment. - If any of the environmental requirements of the component specifications are less severe than those of the intended application of the component, the component shall be required to meet the more severe requirements.

3.2.3.2 Capacitors and filters. - Filters shall not be used where the requirements of this specification can be met by reasonable and proper application of capacitors. Feed-through capacitors shall be used wherever practicable in lieu of filters. Filters and feed-through capacitors shall be installed in such a manner, wherever practicable, as to provide shielding and/or isolation between input (unfiltered) and output (filtered) circuits. Filters and feed-through capacitors are most effective when installed through a bulkhead.

3.2.3.3 Shock hazard. - The total capacitance (including that in filters) applied from any one power line to case, frame, or chassis in electric tools, business machines, and other appliances which may ever be operated from an A-C power line with the case, frame, or chassis ungrounded shall not exceed the values shown by Figure 7.

3.2.4 Volume and weight. - The suppression system shall utilize component parts of the minimum practicable volume and weight in applications where these factors are of importance. In any case where compliance with this specification requires excessively large or heavy suppression components the contractor shall call this to the attention of the procuring agency.

3.2.5 Material. - When a specific material is not specified, the best material of commercial grade available for the purpose, capable of withstanding the extremes of temperature, humidity and other operating conditions shall be used.

3.2.5.1 Dissimilar metals. - Electrical contact between those dissimilar metals which might cause deterioration of parts by galvanic corrosion shall be avoided insofar as practicable. Selection of metals for this purpose shall be based upon the prime equipment requirements.

3.2.6 Soldering. - Soldering shall not be depended upon for mechanical strength of connections. Where flexible shielding, bonds, etc., are soldered, the flexibility of these parts shall not be seriously affected. Only non-corrosive fluxes shall be used in soldering.

3.2.7 Corrosion. - All hardware, (bolts, screws, nuts, lock-washers, retaining nuts, connectors, ferrules, mating surfaces of shielding, etc.) used for suppression purposes shall be of corrosion-resistant metal or plated by an electrolytic or hot-dip process with a metallic material of high electrical conductivity. The finished surfaces shall be capable of withstanding the test described in 4.6, after which there shall be not more than 6 corroded areas per square foot, nor any corroded area larger than 1/16 inch in diameter. If the equipment specification states a more stringent requirement, that requirement shall apply.

3.2.8 Technical manual or instruction book. - Any technical manual or instruction book regarding the equipment, prepared and furnished as a part of the order by which the equipment is procured, shall contain complete technical information, including photographs or drawings, or both, on the functioning and maintenance of the suppression system. The designated Government agency will, upon request, review the technical manual or instruction book for technical accuracy of suppression information.

3.2.9 Workmanship. - All parts shall be manufactured and finished in accordance with the applicable specifications, and, if not specified, in accordance with the best commercial practice. All dimensions and tolerances not specified shall be consistent with good shop practice.

3.3 Classes of equipment. - Equipment covered by this specification is divided into the following classes for purposes of determining the interference requirements to be met. Unless otherwise stated in the equipment specification, contract, or order the following classes, and the limits applicable thereto, shall apply. However, when equipment of one class becomes installed in or is incorporated as an integral part of equipment of another class, the overall equipment shall meet the requirements of the class having the more severe requirements.

CLASS I

Equipment for generating, amplifying, transmitting, receiving, or utilizing radio-frequency electrical energy, within the frequency range covered by this specification, for purposes of communication in any form (see para 3.1.18) by wire or radio methods, or for test or maintenance of such communication equipment:

a. All types of radio-frequency receiving equipment, including navigation, telemetering, transponders, radar, fire-control, guidance, etc.

b. All types of radio-frequency transmitting equipment for communication and communication test purposes, including transmitters proper and any elements thereof such as r-f power amplifiers, exciters, pulse generators, modulators, etc., which could generate, amplify, transfer, or emit interference generated within itself or in another element of a transmitter.

c. Test equipment for communication equipment, generating or utilizing radio-frequency energy, but not intended to radiate.

CLASS II

Equipment for generating, amplifying, controlling or utilizing radio-frequency energy for purposes other than those covered by Class I, and of which any of the fundamental or other output falls within the frequency range covered by this specification. This includes medical diathermy and electrosurgical equipment, r-f induction and dielectric heating equipment, r-f stabilized arc welders, etc.

a. Equipment of this class which meets all requirements of the Federal Communications Commission at the time of the request for bids, regarding frequency and bandwidth of the output fundamental for unlicensed operation of industrial, scientific, and medical equipment.

b. Equipment of this class which does not meet the FCC requirements referred to in a, above.

CLASS III

Equipment capable of unintentionally generating radio-frequency energy while utilizing mechanical or non-radio-frequency electric power in the performance of its intended function.

a. Equipment of this class which is a component of, supplies power to, or is used in close association with, equipment of Classes I-a, b, and c, such as: generators, dynamotors, rectifiers, blowers: also lighting, heating, air-conditioning, and ventilating equipment used in communication shelters, etc.

b. Tactical support (field) equipment, such as: photographic, mapping, and reproduction equipment; Medical Corps equipment for field use (except that folling in Class II) including dental drills, suction pumps, etc.

c. Electrically-driven tools, maintenance and material-handling equipment such as electric drills, compressors, mobile machine shop equipment, electric fork-lift trucks and winches, etc.

d. Kitchen equipment for field use such as refrigerators, electric appliances, etc, and office machinery such as calculating machines, electric typewriters, duplicating equipment, etc.

3.4 Performance, general

3.4.1 Equipment with suppression system installed. - All equipment covered by this specification shall be capable of meeting the requirements and interference limits specified herein, after subjection to such environmental, endurance, and run-in tests as may be required by the equipment specification. The equipment shall be capable of meeting all requirements prescribed in the equipment specification with the complete suppression system applied. However, over-voltage or over-current tests in which the applied voltage or current exceeds the test ratings of suppression components approved for the application may be performed with the pertinent suppression components removed or otherwise protected.

3.4.2 Short-duration interference. - Interference which has a maximum duration not exceeding one second and a recurrence rate not exceeding one in three minutes is permitted to exceed by 20 db the normal limits for the class of equipment involved.

3.4.2.1 Manual switching transients. - Interference resulting from manual operation of switches, but not including sequential electrical or electromechanical operations resulting from manual switching, is exempt from the interference limits of this specification.

3.4.3 Internal electrical components. - Interference generated by integral or internal electrical components or subassemblies shall cause no malfunction or undesired response in the equipment in which they are installed.

3.5 Tests required, and limits. - The types of tests required to be performed are tabulated by equipment class in Table I for interference emanation, and Table II for susceptibility. Limits of permissible radiation test distances by class are given in Tables III-a and III-b, respectively, and limits of permissible conducted interference for power lines are shown in Table IV. Other performance requirements and limits follow the tables.

TABLE I
INTERFERENCE EMANATION
TESTS REQUIRED*

Equipment Class (See Para. 3.3)	Antenna Terminal Conducted		Case and Cable Radiation	Power Line Conducted
	Receiver Local Osc. and Transmitter Standby	Transmitter Operating		
I - a Receivers	N-B		N-B B-B	N-B B-B
I - b Transmitters	N-B	N-B	N-B B-B	N-B B-B
I - c Test Equipment, non-Emanating			N-B B-B	N-B B-B
II - a and b Power Equipment a R-F			N-B B-B	N-B B-B
III - a Associated with Class I			B-B	B-B
III - b Tact. Support (Field) Eqpt.			B-B	B-B
III - c Elec. Tools & Maint. Eqpt.			B-B	
III - d Kitchen & Office Eqpt.			B-B	

* N-B: Narrow-band interference
B-B: Broad-band interference

TABLE II
INTERFERENCE SUSCEPTIBILITY TESTS REQUIRED

Equipment Class	CONDUCTED: Antenna and Signal Lines	CONDUCTED: Power and non-Signal Lines	Radiated (Case Leakage)
I - a Receivers	CW BB	CW BB	CW BB
I - b Transmitters		CW BB	CW BB
I - c, Test Equipment, non-signal emanating		CW BB	CW BB

TABLE 111a
INTERFERENCE LIMITS
CASE RADIATION - ALL EQUIPMENT

Frequency Range MC	Broad-band		Narrow-band	
	Dbmc (Db/1 uV/mc)	Approx. Equivalent	Db/1uV	Approx. Equivalent
0.014 to 0.15-	66	2,000	24	16
0.15 to 1.5	63	1,400	24	16
1.5+ to 20	50	320	20	10
20+ to 100	50	320	14	5
100+ to 300	54	500	20	10
300+ to 3000	54	500	30	32
3000+ to 36000	54	500	40	100

TABLE IIIb

DISTANCE BETWEEN MEASUREMENT ANTENNA AND ITEM UNDER TEST

The test distance shall be equal to the largest of: (1) the greatest vertical or horizontal dimension of the test item measured parallel to one of the faces, (2) the minimum distance which will permit the nominal vertical and horizontal 6-db-down points of the main lobe of the measurement antenna to encompass, respectively, those vertical and horizontal dimensions of the test item, or, (3) the minimum test distance shown in the table below for the pertinent class of equipment. This is plotted graphically in Figure 5 for the antennas specified in Table VI. The beam widths used in determining test distance, for antennas used up to 1,000 mc, shall be considered only with vertical electric field polarization. Above 1000 mc, the distance shall be determined with the broader beam width aligned with the greater dimension of the test item. If the test item consists of two or more interconnected units normally separated by a distance greater than the horizontal dimension of the smaller, they shall be considered as separate units for case radiation test, unless the group is small enough to require testing at the minimum test distance.

Equipment Class	Minimum Test Distance, Feet	Equipment Class	Minimum Test Distance, Feet
I a	3	III a	3
b	3	b	20
c	3	c	20
		d	50
II a	100		
b	100		

3.5.1 Class I - a, receiving equipment. - Receiving-type equipment shall conform to the following additional requirements, not covered by tables III and IV.

3.5.1.1 Antenna-terminal conducted interference. - Narrow-band r-f energy appearing at the antenna terminal due to any frequency generated within the receiver shall not exceed 400 micro-microwatts peak at any test frequency when tested in accordance with 4.4.3.

3.5.1.2 Interference susceptibility.

3.5.1.2.1 Power-line conducted susceptibility. - Power-line conducted broadband and narrow-band interference susceptibility shall conform to the following for the frequency range from 0.15-30 mc. Limit: No undesirable response or malfunctioning when tested according to 4.5.1 and 4.5.2.

3.5.1.2.2 Antenna terminal susceptibility (front-end rejection). - The rejection of undesired signals introduced across the antenna terminals shall be at least 30 db for the broad-band test, and 60 db for the CW test, when tested in accordance with 4.5.4.

3.5.1.2.3 Susceptibility to radiation. - Susceptibility to electromagnetic fields shall be such that no undesirable response or malfunctioning will occur when tested in accordance with 4.5.3.

3.5.2 Class I - b. Transmitting equipment.

3.5.2.1 Interference emanation, transmit condition.

3.5.2.1.1 Extraneous emission, antenna conducted, not lying between 0.8 and 1.2 times the output fundamental frequency.

3.5.2.1.1.1 Harmonics. - The peak r.m.s. power output of any harmonic shall be at least 60 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 1 watt, when measured according to 4.3, 4.4, and their applicable sub-paragraphs.

3.5.2.1.1.2 Other extraneous emissions. - The peak r.m.s. power output of any non-harmonic extraneous emission shall be at least 80 db below that of the fundamental, or 10^{-8} watts, whichever is greater, but in no event greater than 10^{-2} watts, when measured in accordance with 4.3, 4.4, and their applicable sub-paragraphs.

3.5.2.1.2 Extraneous emissions, antenna conducted, close to output fundamental frequency. - Any emission, other than the fundamental frequency with its required intelligence-bearing sidebands, which lies between 0.8 and 1.20 times the fundamental frequency shall not exceed, in voltage amplitude, the voltage level of the idealized modulation spectrum at that frequency by more than 2 db. Any emitted spectral component of peak amplitude at least 60 db below the peak level of the fundamental or of the largest sideband, whichever is greater, is exempt from this requirement. Tests shall be in accordance with 4.3, 4.4, and their applicable sub-paragraphs.

3.5.2.2 Interference emanation, transmitter in stand-by or key-up condition.

3.5.2.2.1 Emissions, antenna conducted, narrow-band. - The intensity of each discrete output frequency with its sidebands, if any, shall not exceed 400 micromicrowatts when tested in accordance with the applicable sub-paragraphs under 4.2 and 4.4.

3.5.3 Class II, r-f power equipment.

3.5.3.1 Class II-a. - Equipment of this class is not required to meet any further requirement than that stated in the class definition as far as the output fundamental is concerned. However, all extraneous emissions shall meet the requirements of Tables III and IV when measured in accordance with 4.3, 4.4, and their applicable sub-paragraphs.

3.5.3.2 Class II-b. - For equipment of this class, the fundamental as well as all other generated frequencies shall be considered extraneous, and shall meet the requirements of Tables III and IV when tested according to 4.3, 4.4, and their applicable sub-paragraphs.

3.5.4 Classes III-a, b, c, d. Equipment not intentionally generating radio-frequency energy.

3.5.4.1 Radiated interference. - Equipment of Classes III-a, b, c, d, shall be tested for radiation (broad-band only) over the frequency range of 0.014 to 1000 mc, plus such additional frequency range from 1000 to 36,000 mc as may be required by the procuring agency. It shall conform to the limits of Table III when tested according to 4.3, 4.4, and their applicable sub-paragraphs.

3.5.4.2 <u>Conducted interference, classes III-a, b only.</u> - Equipment of these classes shall be tested over the frequency range of 0.15 to 30 mc for broad-band interference conducted on all power input and power output lines deemed capable in any normal application of conducting interference into any susceptible equipment. It shall conform to Table IV when tested according to 4.3, 4.4, and their applicable sub-paragraphs.

3.6 <u>Approval of suppression components.</u> - All components of the suppression systems, as defined in 3.1.9 for equipments covered by this specification, shall be subject to approval as hereinafter provided. (See 6.2)

3.6.1 <u>Non-integral suppression components.</u> - All non-integral suppression components shall be type-approved (3.1.10) and in accordance with applicable subsidiary specifications listed in 2.1, unless specific authorization is granted by the contracting officer for the use of other types, in which case "application approval" as defined in paragraph 3.1.11 is required.

3.6.2 <u>Integral suppression components.</u> - Integral suppression components incorporated in electrical and electronic components, subassemblies, or accessories shall be subject to approval by the designated Government agency for electrical and radio-frequency characteristics, and dependability of the application in the particular unit or accessary. Where practicable, such suppression components shall be in accordance with the applicable specification listed in 2.1.

3.6.3 <u>Submission of samples for inspection, test, and approval.</u> - Submission of components covered by 3.6.1 and 3.6.2 shall be in accordance with the applicable specification listed in 2.1, unless otherwise specified by the contracting officer. Samples for application approval (12 of each component) shall be submitted together with the following information:

a. Description or drawings of the proposed information:

b. Manufacturer's name, address, and military nomenclature or model number of prime equipment or subassembly on which the application is proposed.

c. Electrical data, current, voltage, ambient temperature range, etc, pertaining to the circuit and environment in which the component is to be employed.

d. Manufacturer, type number, and electrical and temperature ratings (current, voltage, capacitance, etc.) of the samples.

e. If the component is proposed to replace another type, or that of another manufacturer, the manufacturer and type number of the component to be replaced by the units submitted.

f. Contract number of prime equipment or subassembly. (If the suppression component is being applied in a subassembly or accessory unit being proposed by its manufacturer for use on equipments covered by this specification, the information required by "a" thru "d" above, together with any other pertinent information is sufficient.)

g. Samples submitted by a suppression component manufacturer must be accompanied by evidence of the prime of sub-contractor's request for samples, or his approval of the submittal, in addition to the information required by "a" thru "f" above. The latter may be furnished either by the component manufacturer, prime contractor, sub-contractor, or contracting officer.

3.7 Production model changes.

3.7.1 Suppression system. - If tests on a production model of a test item indicate defficiencies requiring change or modification of the suppression system, the modified system shall be applied thereafter. Authority in writing must be obtained from the contracting officer for any exceptions to, or deviations from, the model as approved for production.

3.7.2 Changes in the equipment. - The contracting officer shall be notified as early as possible, in writing, by the contractor, of any changes made or contemplated in the electrical system, circuitry, subassemblies, or of any changes in the structure or electrical bonding of the unit which might affect generation or emanation of interference. The contracting officer may require submission of another production model incorporating the proposed changes being submitted for approval.

4. QUALITY ASSURANCE PROVISIONS.

4.1 Acceptance inspection. - For Army procurements, acceptance inspection shall be in accordance with the following sub-paragraphs.

4.1.1 Scope of acceptance inspection. - Acceptance inspection shall include the tests required by this specification and such other inspection and testing of material, parts, and complete suppression systems, as are considered by the designated Government agency to be necessary to determine compliance with this specification and its subsidiaries.

4.1.1.1 Inspection by the contractor. - Except as stated in 4.1.1.2.1, the contractor shall conduct all tests required by this specification to determine conformance to the requirements hereof, using test equipment, test setups, and procedures herein specified. He shall certify in writing upon submittal of the equipment that it meets the requirements of this specification, and shall supply therewith the full test data and related information as confirmation. The Government reserves the right to witness all tests carried out by the contractor or his testing agency. (See 6.3.1)

4.1.1.2 Inspection by the Government. - The Government reserves the right to conduct tests required by this specification, and such other inspection and testing of materials, parts, and complete suppression systems as it deems necessary to determine conformance to the intent of this specification.

4.1.1.2.1 Army procurement of Class III items. - Inspection and testing of Class III items on Army procurements will be carried out by the Army. See 6.3.2 through 6.3.2.2.1.

4.2 Interference measurement equipment. - The interference measuring equipment used for determining conformance to the interference limits of this specification shall have general characteristics as follows. Acceptable instruments and accessories are listed in 4.2.4, Tables V through VIII.

4.2.1 Instruments for 0.014-0.15 mc. - Instruments for this frequency range should conform, as far as possible, to the general characteristics stated in 4.2.2 for instruments for 0.15-1000 mc. However, the characteristics stated in 4.2.2 are waived to the extent necessary to permit use of the AN/URM-6 and the NM-10A instruments below 0.15 mc, with the antennas listed in Table VI.

4.2.2 Instruments for 0.15-1000 mc.

4.2.2.1 Antennas. - Equipment shall make use of the antennas, appropriate to the instrument and frequency range considered, listed in Table VI.

4.2.2.2 Voltage to be measured. - The equipment shall measure open-circuit antenna terminal voltage ("antenna induced voltage") by means of injection of the calibrating signal in series with the antenna, thru an acceptable injection network as listed in Table VII.

4.2.2.3 Units of measurement.

4.2.2.3.1 Broad-band interference shall be measured in decibels above 1 μV/mc (dbmc), or in μV/mc.

4.2.2.3.2 Narrow-band interference shall be measured in terms of db above 1 uV, or in microvolts.

4.2.2.4 Calibration. - For the frequency range from 0.15-1000 mc the equipment shall be used with a generator which provides, over the full frequency range of use of the instrument, a broad-band repetitive (10 or more ips) impulse signal of known dbmc level (see Table VIII for acceptable impulse generators), and/or a sine wave of know level, at the calibration-signal input to the antenna injection network, for injection in series with the antenna. If only one of these two is provided, the overall impulse band-width of the instrument up through the peak detector (4.2.2.5) must be known over its entire frequency range and at all input levels and impulse repetition rates within the range of the instrument. If the measurement is to be made by injecting the calibrating signal at a level other than that of the unknown interference, the instrument's attenuator ratios and linearity must be such as to assure negligible resulting error. Data on coaxial cable losses to the antenna shall be furnished.

4.2.2.5 Peak detector. - A slide-back peak detector for comparison of the peak level of unknown impulse interference with that of the standard-impulse or sine-wave generator shall be employed. If only a sine-wave generator is used, the slideback voltage shall be metered for comparison against the metered level of the sinewave. Hum level and feed-through shall be low enough to assure sharp cutoff and accurate slideback measurements using headphone indication.

4.2.2.6 Usable sensitivity. - In the absence of significant ambient interference (interference other than that being measured) the equipment shall be capable of measuring the limits of interference as set forth in this specification.

4.2.2.7 Extraneous responses. - Extraneous responses, including shielding leakage and "back-door" response, both sine-wave and broad-band, shall be sufficiently low to prevent significant error from these causes in any required measurement at any level within the rated range of the instrument.

4.2.2.8 Voltage standing wave ratios. - VSWR shall be sufficiently low at all points in the equipment to result in negligible error in measurements, or correction data shall be furnished. Under any condition in which this characteristic is not met, measurements shall be only by the direct substitution method in which the VSWR error is cancelled out.

4.2.2.9 Audio gain. - Audio gain, to a set of headphones, shall be sufficient to permit accurate and facile slideback measurements and monitoring of the interference being measured.

4.2.2.10 Conducted interference measurement. The equipment shall be capable of use as a two-terminal r-f voltmeter for measurement of broad-band and narrow-band interference conducted on lines or terminals, in the frequency range required by this specification. The input impedance shall be substantially 50 ohms for this purpose. The sensitivity shall permit measuring the interference limits set forth in this specification, while using any matching pads necessary to assure a 50 ohm input impedance.

4.2.3 Instruments for 1000-36,000 mc. - Instruments for this frequency range shall, insofar as practicable, conform to the general characteristics listed under 4.2.2. It is recognized, however, that standard-impulse generators with known spectral distribution, and suitable antenna injection networks, are not generally available above 1000 mc; therefore, shunt calibration from a sine-wave standard is acceptable. Equipment models listed for use above 1000 mc are suggested, not mandatory. Others acceptable to the procuring agency may be used instead.

4.2.3.1 Antennas. - Antennas used shall be of known effective length or effective area, and of known impedance relative to those of the calibrator and the instrument, in order that field intensity may be determined. Correction data shall be furnished for any significant mismatch or VSWR errors, and for pertinent cable or waveguide losses. Data on the vertical and horizontal beam widths at the 6-db-down points shall be furnished by the manufacturer, or otherwise determined, for use in conjunction with Table III-b and Fig. 5.

4.2.3.2. Other characteristics. - These instruments should conform insofar as practicable to the characteristics of 4.2.2.3, 4.2.2.4 except as applied to series injection, and 4.2.2.5 thru 4.2.2.9.

4.2.3.3 Spectrum analyzers. - Spectrum analyzers as listed under 4.2.4.1, or others of adequate resolution and linearity, are to be used for measurement of extraneous emissions in the region of the carriers of transmitters within their frequency range, and may be used for the measurement of other extraneous emissions of transmitters, relative to the carrier intensity.

4.2.4 Acceptable interference measuring equipment.

4.2.4.1 Instruments.

TABLE V

(a) Commercial Instruments

Frequency Range, Mc (Note 7)	Model No. (Note 1)	Source (Note 2)	Other Notes
0.014 - 0.15	NM-10A	a	
0.014 - 1000	NF-105	b	
0.014 - 1000	NF-205	b	3
20 - 400	NM-30A	a	
400 - 1000	NM-50A	a	
1000-10,000	NF-112	b	
1000-10,000	FIM	c	6
10 - 16,000	LA-17	d	4, 6
10 - 33,000	Du	c	4, 6
10 - 36,000	SA-84	c	4, 6

TABLE V

(b) Military Instruments

Frequency Range, Mc: (Note 7)	Model No. (Note 1)	Notes
0.014 - 0.15	AN/URM-6	
0.15 - 20	AN/URM-3	5
0.15 - 1000	AN/URM-85	
20 - 400	AN/URM-47	
20 - 400	AN/URM-7	
400 - 1000	AN/URM-17	
1000 - 10,000	AN/URM-42	6
10 - 16,000	AN/UPM-17	4, 6
10 - 36,000	AN/UPM-84	

Notes for Table V:

1. Including all plug-in heads (if any) required for the stated frequency range.

2. a. Stoddart Aircraft Radio Co., Inc.

b. Empire Devices Products Corp.

c. Polarad Electronics Corp.

d. Lavoie Laboratories

3. Preferred to NF-105 for accuracy, reliability, ease of operation and maintenance.

4. These instruments are swept-frequency oscilloscopic spectrum analyzers.

5. Usable only for broad-band interference measurements.

6. Equipment models listed for use above 1000 mc are suggested, not mandatory.

7. The frequency ranges given are those within which the particular instruments are to be used for the purposes of this specification, and are not necessarily the full frequency ranges of the instruments.

4.2.4.2 Antennas, 0.014 to 36,000 mc

TABLE VI

(a) Commercial Antennas

Description and Model No.	Source (Note 1)	Frequency Range, Mc	Used With
Whip, 90077-2	a	0.014 - 0.15	NM-10A
Whip, LK-105-SC	b	0.014 - 0.15	NF-105
Whip, LK-205-SC	b	0.014 - 0.15	NF-205
Whip, 9 feet; LM-105-SC (includes plane, matching transformers, and injection network, for remote operation thru 50-ohm cable.)	b	0.15 - 20	NF-105 NF-205
Broad-band discone, BB-105 (Note 2)	b	20-1000	NF-105, NF-205, NM-30A, NM-50A
Broad-band discone, model 91280-1 (Note 2)	a	20-1000	NF-105, NF-205, NM-30A, NM-50A
AS specified by mfr. of measuring instrument, and in accordance with 4.2.3.1		1000-36,000	

TABLE VI

(b) Military Antennas

Description and Model No.	Frequency Range, Mc	Used with
Rod, 7 feet; AT-204/URM-6	0.014 - 0.15	AN/URM-6
Rod, 9 feet; Antenna AT-558/URM-3	0.15 - 20	AN/URM-3
Whip, 9 feet; (includes plane, matching transformers, and injection network for remote operation thru 50-ohm cable, Part of AN/URM-85	0.15 - 20	AN/URM-85
Broad-band discone, antenna AT-292A (note 2)	20 - 10000	(AN/URM-7, (AN/URM-85, (AN/URM-47, (AN/URM-17
As specified for the instrument used and by 4.2.3.1	1000 - 36,000	

Notes for Table VI:

1. Sources as in Note 2 of Table V.

2. Including a total of six mast sections, used in each of the three peripheral sockets as follows: 20-100 mc, 2 sections; above 100 mc to 300 mc, 1 section; above 300 mc to 1000 mc, none.

4.2.4.3 Antenna Injection Networks, Up to 1000 mc

TABLE VII

(a) Commercial Networks

Model No. (Note 1)	Source (Note 2)	Used with Antenna
UN-105	b	BB-105
(b) Military Networks		
Part of AN/UEM-7 & AN/UEM-85 (Note 3)		AT-292A
Model No. (Note 1)		Used with Antenna

Notes for Table VII:

1. The military and commercial models listed are electrically and mechanically interchangeable.

2. Sources: Same key as Table V, Note 2

3. The antenna injection network for the AN/URM-3 is built into the set.

4.2.4.4 Impulse calibrators.

TABLE VIII

(a) Commercial Calibrators

Model No.	Frequency Range, MC	Source (Note 4)	Notes
IG-102	0.15 - 1000	b	1, 2
IG-115	0.15 - 1000	b	1, 3
91263-1	0.15 - 1000	a	1, 3
IG-118	0.15 - 10,000	b	5

(b) Military Calibrators

Nomenclature	Frequency Range, MC	Notes
Generator, Pulse, SG-128/U	0.15 - 1000	1, 3
Generator, Pulse, SG-245/U	0.15 - 1000	1, 3

Notes for Table VIII:

1. These impulse generators are not to be used below 0.15 mc or above 1000 mc because of unreliability of output level.

2. Basically similar to that built into the ND-105.

3. Basically similar to that built into the NF-205, AN/URM-7, and AN/URM-85.

4. Same key as Table V, Note 2.

5. Not to be used below 1.5 mc or above 10,000 mc.

4.3 Test conditions and test frequencies, general

4.3.1 Test setup. - The equipment to be tested shall, except as otherwise specified herein, be set up in a manner simulating as nearly as possible a typical operating condition in regard to mounting base, shock mounts, ground plane, grounding, height above ground, layout of components relative to each other, and lay of interconnecting and power cables.

4.3.1.1 Loads. - Unless otherwise specified herein for specific types or classes of equipments, interference measurements shall be made at normal operating load (or under simulated normal operating conditions) and, if applicable, at no load. The equipment shall be loaded electrically (including radio frequency) and mechanically as applicable.

4.3.1.2 Power supply voltage. - The power supply voltage shall be maintained within the rated operating voltage range of the equipment under test, but in no event shall it differ from the mean of that range by more than 5 percent. It shall be sufficiently stabilized to assure repeatability of interference and susceptibility measurements.

4.3.1.3 Interference-free test area. - Radiation tests shall be conducted in an open area sufficiently free from ambient interference and at least 10 times as far (up to 100 yards) from any large metallic objects, buildings, or other obstructions as the distance between the antenna and the test item. The ambient interference level during measurements shall be at least 6 db below the interference limits specified herein, except that if the sum of the ambient interference and that of the equipment under test does not exceed the stated limit, the latter interference will be considered with the limit. Alternatively, an electromagnetic anechoic room with not over 10 percent reflection at the test frequency may be used if it is large enough for the required test setup.

4.3.1.3.1 Conduction tests. - Measurements of conducted interference and susceptibility, whether on antenna terminals or power lines, may be made in a shielded room, or in a laboratory, as well as in an interference-free area, provided that necessary precautions are taken to prevent ambient interference from entering the measuring circuit.

4.3.1.4 Impedance stabilization network. —An impedance stabilization network, Filtron type FSR-702SC, or equal, shall be used in each external electric power or load line for all tests of radiated and conducted interference and susceptibility, except in those installations in which the power leads are deemed incapable, in normal use, of conducting interference into susceptible equipments, and circuits in which the application of the network would cause malfunctioning of the equipment under test. Typical test arrangements and setups are shown in Figures 1 and 2 (See 6.4). The housings of the networks shall be grounded to the ground plane if one is used, and to each other if no ground plane is used.

4.3.1.4.1 R-F termination. - For antenna-terminal and radiated interference measurements a 50-ohm resistive termination shall be connected directly to the type N connector on each network. For power-line conducted interference and susceptibility measurements a 50-ohm r-f resistive termination shall be applied to the type N connector of each network not being used for interference measurement or injection. The termination shall have a VSWR not over 1.2 up to 1000 mc. No equipment or device other than that under test shall be connected to the interference input (test item) terminals of the stabilization networks.

4.3.1.5 Grounding and ground planes.

4.3.1.5.1 Normally grounded equipment. - Components and subassemblies (motors, power supplies, blowers, etc.) and electronic equipment to be installed in vehicles, shelters, etc., which are not normally operated independent of other metallic structures shall be provided with a copper, brass, or aluminum ground plane of 12 square feet or more in area during all tests. The ground plane shall be provided with an "earth ground" consisting of a "ground stake" of at least 30 inches, or other suitable means. The equipment under test shall be attached to the ground plane in a manner simulating its normal operating installation.

4.3.1.5.2 Normally ungrounded equipment. - Equipments normally operating ungrounded such as hand tools, appliances, portable office machines, portable radio sets, paint sprayers, etc., shall be tested ungrounded and shall be placed on a 30" square insulating test stand or table 30 inches above the ground or ground plane during measurements. The stand supporting the equipment shall be centrally located on the ground plane.

4.3.1.5.3 Non-portable, fixed plant and semi-fixed complete equipments. - Equipments such as complete radar orfire-control systems, heavy machinery, long-range transmitters, etc., shall be grounded in a manner simulating as closely as practicable the normal installation or conditions of use.

4.3.1.6 Power cables and power cords. - The cable between the equipment under test and the impedance stabilization network shall be or simulate that normally used. Shielded cables shall be used only if shielded power cables are used in actual operation or installation, and shall be of the same type number and length normally used. If unshielded power cables permanently attached to the equipment are normally used, similar cables of the same length shall be employed between the equipment and the stabilization network. For equipment falling under 4.3.1.5.2, the power cable or cord shall proceed from the equipment over the edge of the test stand straight down to the ground, and then be wound closely around the base of the test stand until the length is just sufficient to connect to the impedance stabilization network(s).

4.3.2 Frequency selection for test items and measuring equipment, except for power-line conducted tests.

4.3.2.1 Class I equipment. - Tests shall be run with the test item tuned to a frequency or channel not more than 5 percent in frequency from each extreme of each continuously tunable band without band switching or of each range of fixed channels, and on frequencies or channels at frequency increments of not more than 1.25 times (1.50 times for broadband tests) the next lower frequency or channel tested, but not less than three frequencies unless the equipment has less than three channels. It shall also be tested, for narrowband tests only at such additional frequencies or channels as may be expected, from consideration of frequency synthesizer circuits, frequency conversions, intermediate frequencies, etc., to be potentially more subject to extraneous emissions and/or extraneous responses than those chosen on the stated arithmetic basis. The contractor shall submit an analysis of the equipment's expected extraneous emissions and responses as a justification for the test frequencies chosen. For each chosen frequency setting of the test item, the interference measuring instrument (for interference emanation tests), or the signal source (for susceptibility tests), shall be scanned continuously in frequency over the range required by this specification. Some oscillators, such as magnetrons, generate extraneous emissions at unpredictable frequencies both above and below the fundamental. Attention must also be given to subharmonic, harmonic, image, i-f and other frequencies where emanation or susceptibility may be expected to occur. Harmonics shall be considered up to the tenth or 1000 mc, whichever is higher, but not above 36,000 mc for transmitters in the transmit condition, and up to the twentieth or 1000 mc, whichever is higher, but not over 36,000 mc for antenna conducted measurements on receivers, and on transmitters in the standby condition.

4.3.2.2 Class II-a equipment. - This equipment shall be operated within its FCC-assigned band, and the interference measuring equipment scanned continuously to cover all harmonics, (up to the tenth or 1000 mc, whichever is higher, but not above 36,000 mc) sub-harmonics, etc., which fall within the required frequency range of measurements.

4.3.2.3 Class II-b equipment. - This equipment shall be treated as Class I equipment for selection of test frequencies, except that the fundamental is also considered as an extraneous emission.

4.3.2.4 Class III equipment. - This class of equipment in non-tunable. Interference measurements shall be made at three or more frequencies approximately evenly distributed over each tuning band of the measuring instrument, from 0.014 to 1000 mc, and at each additional frequency indicated by scanning to represent a maximum in the emanated spectrum.

4.3.3 Frequency selection for test items and measuring equipment power-line conducted tests. - For tests of this kind, frequencies are limited to the range of 0.15 - 30 mc, but the frequencies shall be selected on the same basis as described under 4.3.2 for the same classes of equipment.

4.3.4 Control settings. -

4.3.4.1 Test item. - All controls of the equipment under test shall be adjusted, within normal operating ranges and at each test frequency, to produce maximum interference emanation or susceptibility, as the case may be.

4.3.4.2 Test signal. - The test signal used in susceptibility tests shall have characteristics, including type and degree of modulation, which will result in a maximum indication of susceptibility.

4.4 Interference emanation tests.

4.4.1 Interference radiation (case and cable leakage). Radiation measurements for interference leakage from case, power lines, etc., shall be performed over the required frequency ranges and at the test distances specified in Table III-b for the various classes of equipment. The test distance is the horizontal distance from the base of the antenna of the interference measuring equipment to the nearest perimeter of the equipment under test.

4.4.1.1 Radiation tests, 0.014 - 0.15 mc. - Radiation tests from 0.014 to 0.15 mc shall be performed with the specified antenna vertical, with its base 36 inches above ground and at a distance from the nearest perimeter of the item under test as determined from Table III-b.

4.4.1.2 Radiation tests, 0.15 - 20 mcs. - Radiation tests from 0.15 - 20 mc shall be performed with the base of the antenna 36 inches above ground, and at the distance from the nearest perimeter of the item under test as determined from Table III-b. If the test distance is 5 feet or less, the antenna shall be tilted toward the item under test so that its minimum clearance from the latter is 24 inches. At distances greater than 5 feet the antenna shall be vertical.

4.4.1.3 Radiation tests, 20 thru 1000 megacycles. - For all classes of equipment an antenna as specified in Table VI shall be used. Distance specified in Table III-b shall be measured from the nearest perimeter of the equipment under test to the apex of the cone. The discone antenna shall be tilted so that a line from the center of the equipment under test to the apex of the cone bisects the angle formed between the cone and the plane. See figure 3 for applicable antenna configurations covering the range of 20 to 1000 mc.

4.4.1.4 Radiation tests, 1000 - 36,000 mc. - Test distances as specified in Table III-b apply. Discone antennas for this range shall be treated as those for lower frequencies. Test distances for horn and "dish" antennas shall be measured from the center of the plane of the rim of the dish, or from the center of the plane of the open end of the horn.

4.4.2 Conducted interference tests, power lines. - Conducted interference shall be measured from line to ground (frame or chassis) over the frequency range of 0.15 thru 30 mc on each external power supply and power load conductor, using the line impedance stabilization networks, Filtron Type FSR 7025C, or equal, in the manner prescribed in figures 1 and 2. Conditions shall be as prescribed in 4.3.1, 4.3.3 thru 4.3.4.2 and figures 1 and 2, except where deviations are specifically prescribed herein.

4.4.2.1 Power equipment. - Conducted interference measurements on equipments furnishing or converting electrical power for electronic equipment shall be made on both input (power supply) and output (load) terminals, except where such power supplies are integral with and inseparable from the basic equipment. In the latter case, in addition to the requirements for conducted and radiated interference on the overall equipment, tests shall be conducted to determine any audible, visible, or other undesired response or malfunctioning of the basic equipment resulting from interference generated in the power equipment.

4.4.3 Receiver self-generated and transmitter stand-by interference. - Measurements for conformance to 3.5.1, 3.5.1.1 and 3.5.2.2 shall be made across the antenna terminals of the equipment. Measurements on equipment operating in the range above 20 megacycles shall be made across a 50-ohm resistive load. Measurements on equipment operating in the frequency range below 20 megacycles shall be made across a 50-ohm and a 300-ohm load. Equipment with balanced circuits shall be tested alternately with 50- and 300-ohm loads from each line to ground. The total power for the balanced case shall be the arithmetic sum of the power in the two loads (50 ohms-50 ohms, or 300 ohms-300 ohms, whichever is greater). The loads shall be of such design as to exhibit essentially flat impedance-versus-frequency characteristics throughout the frequency range over which the measurements are made, and shall provide a VSWR not exceeding 1.20.

4.4.4 Transmitter harmonic and other extraneous emissions-key down. - Conformance with 3.5.2.1 shall be determined by measurement of the extraneous r-f voltage appearing across the antenna terminals of the transmitter under test relative to that produced at the fundamental frequency. Measurements shall be made using the appropriate measuring instruments listed in 4.2, or with suitable calibrated receivers in conjunction with calibrated external attenuators and standard signal generators.

4.4.4.1 Extraneous output not close to carrier. - The test setup shall be as shown in figure 4. The "T" connection attenuator shown in the figure shall be a capacitive or inductive coupling with known insertion loss vs frequency. The total rejection of the T-connection attenuator, the rejection network, and the receiver front-end to the fundamental when tuned to the frequency of the extraneous output being measured, shall be at least 20 db greater than the required minimum ratio of fundamental to extraneous. The resistive attenuator pads, the coaxial switch, and the coaxial cables used shall introduce, singly or in combination, a voltage standing wave ratio no greater than 1.20 into the measurement system simultaneously at the fundamental and at any required frequency of measurement. The signal generator used for this test shall be calibrated for output across a 50-ohm resistive load. The transmitter shall deliver its rated output to the dummy load for this test.

4.4.4.1.1 Dummy loads. - For fundamental frequencies above 20 mc, the dummy load shall be a 50-ohm resistance of adequate power handling capacity. For fundamentals 20 mc and below, the dummy load for unbalanced transmitters shall be either 50 ohms resistive or 300 ohms resistive, to whichever the transmitter is capable of delivering greater power when adjusted as prescribed by the instruction manual for maximum output. The load VSWR shall not exceed 1.30 simultaneously at the fundamental and at any measurement frequency. For balanced output systems above 20 mc, the rated power shall be applied across two unbalanced 50-ohm resistive loads, one from each line to ground. For balanced output systems 20 mc and below, the load from each line to ground shall be that which would be used in an unbalanced system. For measuring the extraneous output of a balanced transmitter, the system of figure 4 shall be applied between ground and one of the two lines, and the other line shall be loaded by an equal dummy load from the latter line to ground. The extraneous output ratios shall be measured as for an unbalanced transmitter. Then the two transmitter output lines shall be interchanged and extraneous output ratios measured again at the same frequencies. The ratio of the sum of the extraneous outputs of the two lines, at a given frequency, to the sum of the fundamental outputs of the two lines, shall not exceed the values stated in 3.5.2.1.

4.4.4.2 Extraneous emissions close to carrier frequency. - Extraneous emissions within the range of 0.8 f_c to 1.20 f_c, where f_c is the carrier frequency, shall be measured for conformance to 3.5.2.1.2 by means of a Spectrum Analyzer AN/UPM-17, AN/UPM-84, or other suitable panoramic oscilloscopic-presentation instrument of equivalent resolution and linearity. The spectrum analyzer shall be operated in accordance with its instruction manual. No carrier-frequency rejection network shall be used for this test. The transmitter shall be operated at maximum rated modulation level, modulation bandwidth and power. Dummy load shall be as for 4.4.4.1.1.

4.4.5 Transmitter shielding. - Radiation tests on transmitters to determine conformance to Table III shall be made with the transmitter operating into a shielded dummy load. Measurements shall be performed in accordance with the general procedures for radiated interference measurements of 4.3, and 4.4.1 thru 4.4.1.4. With the transmitter adjusted for rated output, all narrow-band and broad-band emanations shall be measured for conformance to the limits of Table III. The power line impedance stabilization networks, power cables, and other test conditions shall be as prescribed in the applicable portions of 4.3.

4.5 Interference susceptibility tests. -

4.5.1 General. - The test setup for susceptibility measurements shall be as shown in figure 2 for r-f conduction tests, except that the signal source is substituted for the interference measuring set at the coaxial connector of the appropriate impedance stabilization network, and shall be as described in 4.5.3 and its sub-paragraphs for r-f radiation tests. On receivers, all external controls shall be set as for reception of a minimum signal as prescribed in the applicable instructions. On other equipment having manual controls, all external controls shall be set for maximum indication of susceptibility unless such settings are not normally employed in intended use, in which case the controls shall be adjusted as directed in the equipment instruction manual. On all radio-frequency susceptibility tests, the r-f voltage shall be modulated 30 percent at 400 to 1000 cps, except that if the test sample is designed to operate with a particular audio frequency, pulse repetition rate, waveform, or type of modulation, the r-f voltage shall be modulated with that particular type of signal.

4.5.2 R-F susceptibility, power-line conducted. - The generators, CW and impulse, shall have nominal source impedances of 50 ohms resistive, with maximum voltage-standing-wave ratio of 1.3. The open-circuit voltage of the CW generator shall be 0.1 volt, and of the impulse generator 90 dbmc (db above 1 µv per megacycle of bandwidth). This source shall be applied to the test sample as shown in figure 2. Measurements shall be made over a frequency range of 0.15 to 30 mc.

4.5.3 Susceptibility to r-f radiation.

4.5.3.1 Physical setup for test. - All measurements shall be made in the interference-free area (4.3.1.3). Three points shall be chosen forming an isosceles right triangle. The apex of the 90-degree angle shall be called the "radiation source point". The other ends of the two equal sides shall be called the "field measurement point" and the "test sample point". The length of the equal sides shall be 25 feet in the frequency range 0.014 to 50 mc, 10 feet in the frequency range from above 50 to 1000 mc, and above 1000 mc the length shall be such that the narrower beam width of the main lobe of the radiating antenna at the 6-db-down points will cover at least the maximum projected vertical or horizontal dimension of the test sample. The minimum distance at which this condition can be met, as a function of beam width and test item dimensions, is plotted in figure 5.

4.5.3.1.1 Radiation source point. - The radiation source antenna shall be a 5-foot rod in the frequency range 0.014 to 50 mc, a resonant half-wave dipole in the frequency range from 50 to 1000 mc, and a horn, dish, discone, or other suitable antenna above 1000 mc. In the frequency range 50 mc and below, only vertically polarized measurements are required. Above 50 mc both horizontally and vertically polarized measurements are required, and care shall be taken to minimize radiation of the undesired polarization, using baluns as necessary.

4.5.3.1.2 Field measurement point. - The test instruments for the field measurement point shall be of those listed in Table V. The instruments chosen shall be operated with calibrated antennas designed for field intensity measurements with the particular instrument. These antennas shall be placed on the ground when irradiating the test sample, in order to minimize reflections.

4.5.3.1.3 Test sample point. - The test sample shall be provided with a shielded dummy antenna, if applicable, and shall be energized and adjusted for maximum susceptibility consistent with normal modes of operation. It shall be placed on a ground plane with an area of no less than 12 square feet and with a smaller dimension of no less than 2-1/2 feet. The sample shall be placed on the plane so that the front panel and each side in turn will face the radiation source antenna. A turntable with ground plane no higher than 1 foot above the ground may be used for this test. The test sample shall be bonded to the ground plane by a short, low-impedance strap.

4.5.3.2. Test operations. - The radiation source shall be set up with its antenna directed toward the field measurement point and the signal source output increased until the field measurement point instrument indicates a signal intensity of 0.1 volt per meter. The radiating antenna shall then be directed towards the test sample point, successively irradiating the four sides of the test sample. Conformance with the requirements of 3.5.1.2.3 shall be determined at each test frequency and for each vertical face.

4.5.4 Receiver front-end rejection. -

4.5.4.1 CW rejection. - Test frequencies shall be the same as specified in 4.3.2. The frequency range to be scanned by the generator at each test frequency, f_c, shall be from 0.1 to 10 times f_c, except the frequency range between the 80-db-down points on the receiver selectivity curve. The highest frequency for these tests is 36,000 mc and the lowest frequency is 0.014 mc. The signal generator shall have a 50-ohm source impedance with a maximum VSWR of 1.3 and shall be modualted 30 percent at 400 or 1000 cycles; if, however, the receiver under test is designed to operate at a particular audio frequency or pulse repetition rate, the r-f voltage shall be modulated with that particular frequency. Since most signal generators emit significant amounts of harmonics, care should be taken that the receiver is not erroneously rejected because of such extraneous signal content. Front-end rejection is calculated with the following formula;

$$\text{Front end rejection} = 20 \log V_2/V_1$$

V_1 = Signal generator voltage required for minimum perceptible receiver output on channel or frequency under test.

V_2 = Signal generator voltage required for minimum perceptible receiver output at all other frequencies.

4.5.4.2 Broad-band rejection. - The test sample receiver shall be connected to the standard-impulse generator by means of a 50-ohm coaxial cable terminated with a 10-db resistive pi or T pad with negligible frequency characteristic in the region of the frequency of test. The impulse generator shall be turned on and the output attenuator reading for minimum perceptible receiver output, or other evidence of normal function, shall be noted. The receiver local oscillator (or each oscillator in turn for multiple-conversion superheterodyne receivers) shall be disabled and a 60-cycle voltage (or current) equal to the oscillator signal shall be injected into the mixer. The output of the impulse generator is then raised until the minimum perceptible receiver output, or other evidence of normal function, is again evident. This generator setting in db, less the original setting in db, is the broad-band rejection requirements of 3.5.1.2.2. The frequencies of test shall be chosen in accordance with 4.3.2.1. Impulse generators acceptable for this test are listed in Table VIII.

4.6 Corrosion Test. - Parts which must meet the requirements of 3.2.7 shall be tested in accordance with Specification QQ-M-151, subjecting the parts to salt spray for a period of 96 hours at a temperature of 95°F, using a 20% (by weight) aqueous solution of sodium chloride.

5. PREPARATION FOR DELIVERY

5.1 The applicable section of the equipment specification shall apply.

6. NOTES

6.1 List of approved suppression components. - Current Army Qualified Products Lists (AQPL's) of Type-approved suppression capacitors, filters and resistor suppressors, under the applicable subsidiary specification of 2.1, may be obtained by contracting officers from the Signal Corps Procurement Agency, 2800 South 20th St., Philadelphia 45, Pa., by referring to the specification number covering the particular component. Indication of approval of any item, by its inclusion in an AQPL or by other means, as being suitable for suppression purposes and in accordance with the applicable specifications, covers use of the component only for suppression purposes. A list of manufacturers of suppression components having type approval and application approval under the subsidiary specifications of paragraph 2.1 may be obtained upon application to the contracting officer.

6.2 Submission of samples of suppression components. -

6.2.1 Type approval. - Samples for qualification approval (type approval, 3.1.10), covered by subsidiary specifications listed in 2.1, should be submitted as prescribed in the applicable subsidiary specification.

6.2.2. Application approval. - Samples for application approval (3.1.11) should be submitted to the Accountable Property Officer, Bldg. 2700 USASRDL, Fort Monmouth, New Jersey, ATTN: S&GD Div., Comm Dept.

6.3 Testing agency.

6.3.1 Private testing agency. - For testing required of the contractor, the latter may engage a private testing organization whose test equipment and facilities have been approved by the procuring agency.

6.3.2 Government testing agency. - On Army procurements of Class III items, such as electric motor, fans, electric power tools, etc. the bid request and contract should state that the testing of such items for conformance to this specification will be carried out by the Communications Department, USASRDL, Fort Monmouth, N.J. (Suppression and General Engineering Division). This agency will represent the Contracting Officer in dealings with contractors and sub-contractors on technical matters pertaining to these functions, including the following:

(1) Approval for the use of capacitors of filters under conditions more severe than those specified in the applicable specification therefor.

(2) Testing of capacitors or filters that do not conform to the applicable specification to determine whether such components are acceptable for the proposed application.

(3) Inspection, testing, and approval of samples of suppression components, electrical sub-assemblies or accessories to be approved before being furnished as part of the equipment on order.

(4) Inspection, testing, and approval of the suppression system on the model.

6.3.2.1 Testing of preproduction and production units. - Test equipment and personnel for conducting the inspection and test of the suppression system on pilot models and production units of Class III items undergoing government tests will be provided by the Communications Department, USASRDL, Fort Monmouth, N. J. The Contracting Officer shall be notified in writing at least 10 days before a pilot or production model will be available for test of the suppression system. Results of the tests, and a report covering the method of suppression to be followed on any subsequent pilot model or production unit will be furnished to the contracting officer. The report should be included by him as part of any approval of the pilot or preproduction model to which it applies.

6.3.2.2 Proposal request and contract. -

6.3.2.2.1 Expenses. - It is to be understood that in regard to the test and inspection by the Army of Class III equipment the contractor will bear all expenses arising in connection with the following:

a. Transportation of government inspector, test equipment, pilot models, production units, electrical sub-assemblies and accessories, and suppression components from the contractor's plant to the test point designated by the Government, if such point is within 25 miles of the contractor's plant. If the test point is over 25 miles from the contractor's plant, transportation is required to be furnished only for the items to be tested.

b. Preparation and submission of prints and parts lists submitted with the models.

c. Submission of samples for type-approval and application approval.

d. Damage to pilot models or to samples resulting from testing, disassembly or reassembly.

e. Samples or suppression components that are not returned to the bidder or contractor.

6.4 Impedance stabilization network. - The impedance stabilization network named in para. 4.3.1.4 is usable in power circuits not exceeding 250 volts AC or 600 volts, DC, and up to 100 amperes. It may be used at power frequencies up to 400 cycles at full rated voltage, or up to 800 cycles at half rated voltage. The power-line drop per network, versus line current, is shown in figure 6.

6.5 T-Connector-attenuator. - The T-connector-attenuator shown in figure 4 may be constructed using 1 each coaxial T connector UG-107B/U and straight connector UG-29B/U. The male pin of the UG-107/U which is threaded into the straight-thru double-ended female pin, is removed and cut off approximately 1/4" from the shoulder on the threaded end. A screw driver slot is cut in the short section to facilitate its replacement. The male pin is then inserted into the female pin of the UG-29B/U and carefully soldered in place. The end of the pin protruding from the UG-29B/U is ground off to obtain the desired attenuation. Attenuation of the order of 120 db, and greater, at 20 megacycles may readily be attained. Attenuation decreases with increasing frequency at the rate of 6 db per octave when terminated in 50 ohms, as long as the capacitive reactance remains large compared with 50 ohms. Alternatively, the General Radio 874-GA attenuator (waveguide below cutoff) may be used from 100-4000 mc, or other arrangements suitable for the frequency range and transmitter power involved, and acceptable to the procuring agency, may be used.

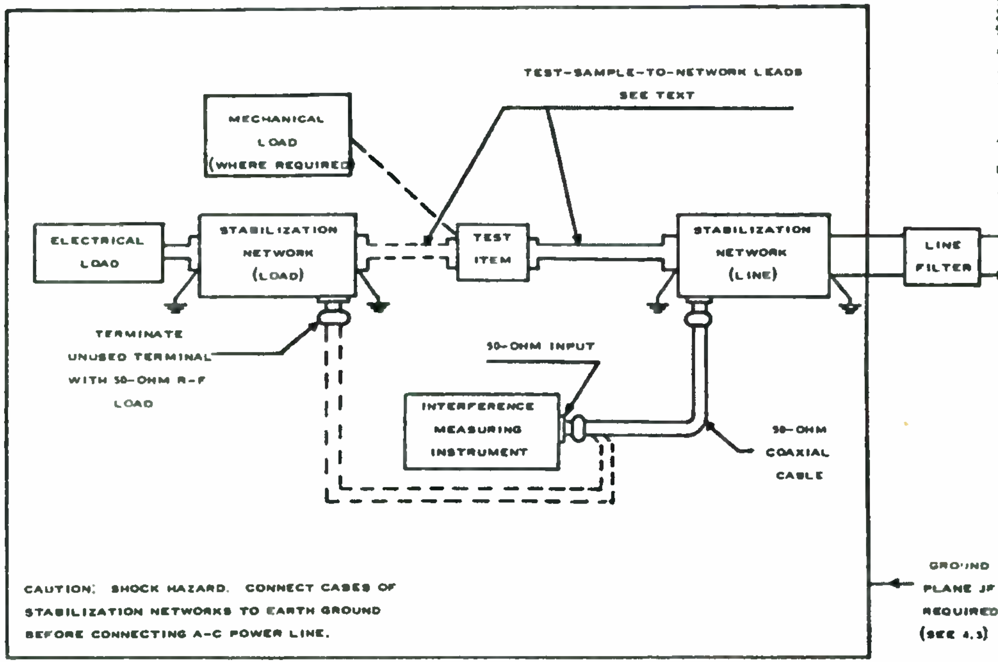


Figure 1

General Test Setup for Power-Line Conducted Interference Measurements

Single Wire Grounded System

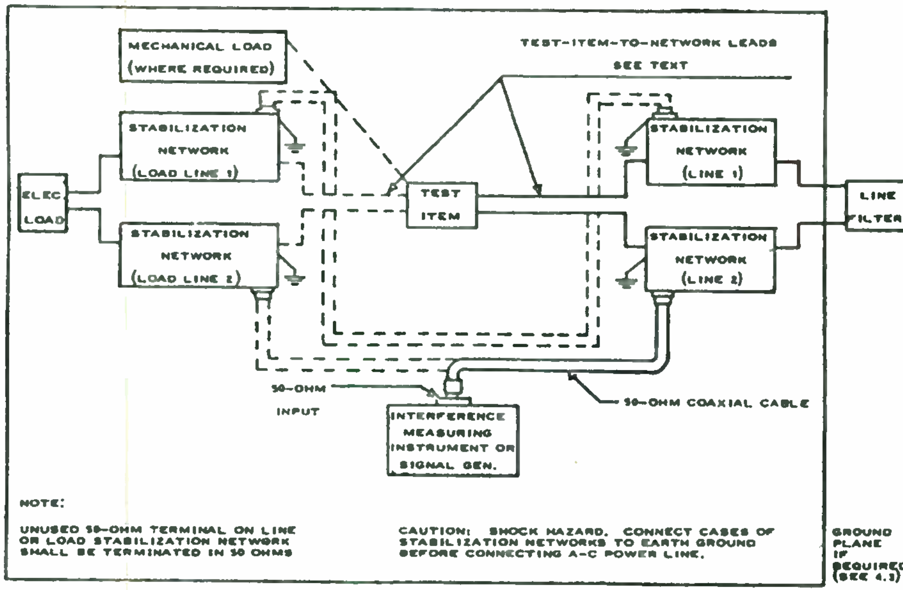


Figure 2

General Test Setup for Power-Line Conducted Interference and Susceptibility Measurement, Multiple Wire Ungrounded System, 2 Wire System Shown, Additional Networks Required for Each Additional Line. These Connections Are Retained for Tests of Interference Radiation, and Susceptibility to Radiation, Except That a 50-Ohm R-F Termination Replaces the Measuring Instrument or Signal Source.

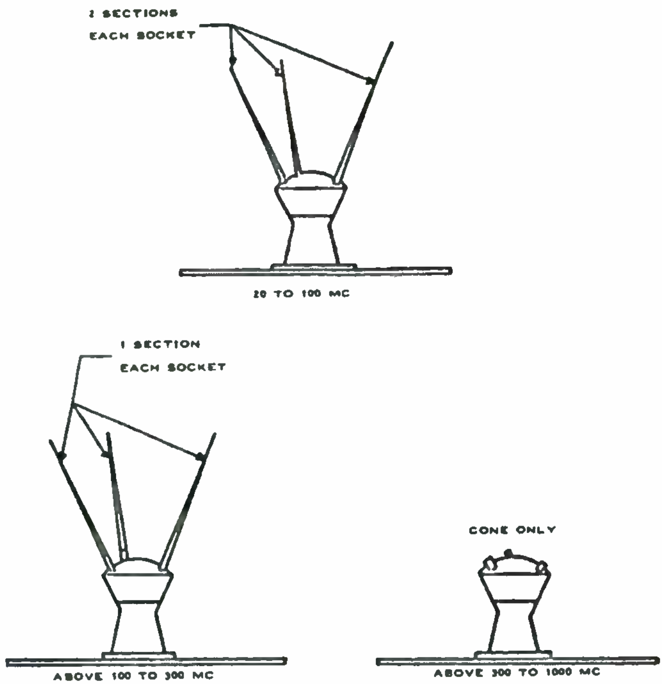


Figure 3

Broad Band Discone Antenna and Mast Sections AB-21/GR

for Radiation Tests 20-1000 MC

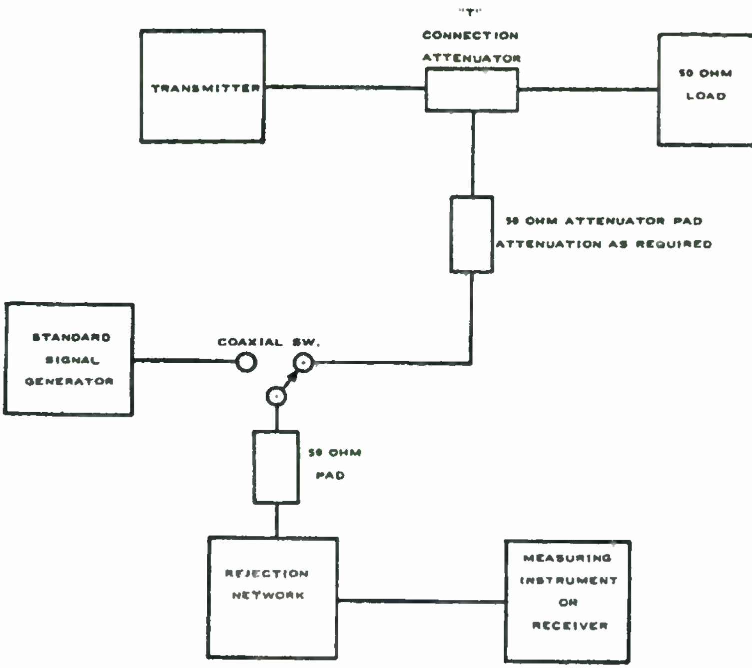


Figure 4
Typical Test Setup for Measurement
of Transmitter Extraneous Emissions

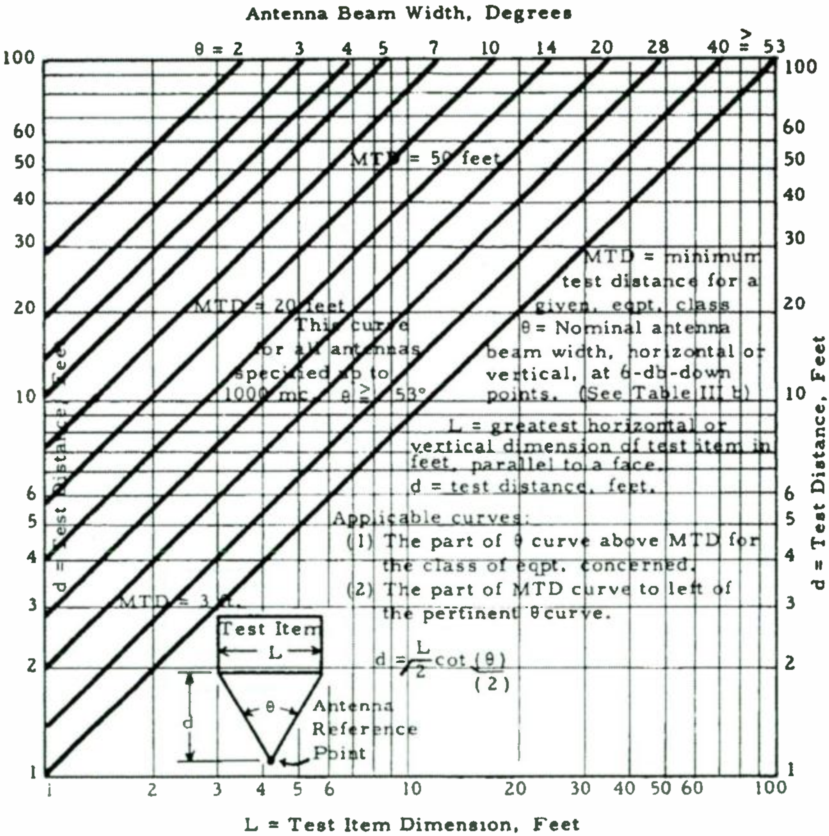

Antenna Beam Width, Degrees
θ = 2
3
4
5
7
10
14
20
28
40
≥ 53
100
60
50
40
30
20
10
6
5
4
3
2
1
MTD = 50 feet
MTD = minimum test distance for a given eqpt. class
θ = Nominal antenna beam width, horizontal or vertical, at 6-db-down points. (See Table III b)
MTD = 20 feet
This curve for all antennas specified up to 1000 mc. θ ≥ 53°
L = greatest horizontal or vertical dimension of test item in feet, parallel to a face.
d = test distance, feet.
Applicable curves:
(1) The part of θ curve above MTD for the class of eqpt. concerned.
(2) The part of MTD curve to left of the pertinent θ curve.
MTD = 3 ft.
Test Item
L
θ
d
Antenna Reference Point
d = L/2 cot (θ/2)
d = Test Distance, Feet
1
2
3
4
5
6
10
20
30
40
50
60
100
L = Test Item Dimension, Feet

Figure 5

IMPEDANCE STABILIZATION NETWORK
FILTRON FSR 702SC OR EQUAL
VOLTAGE DROP VS CURRENT

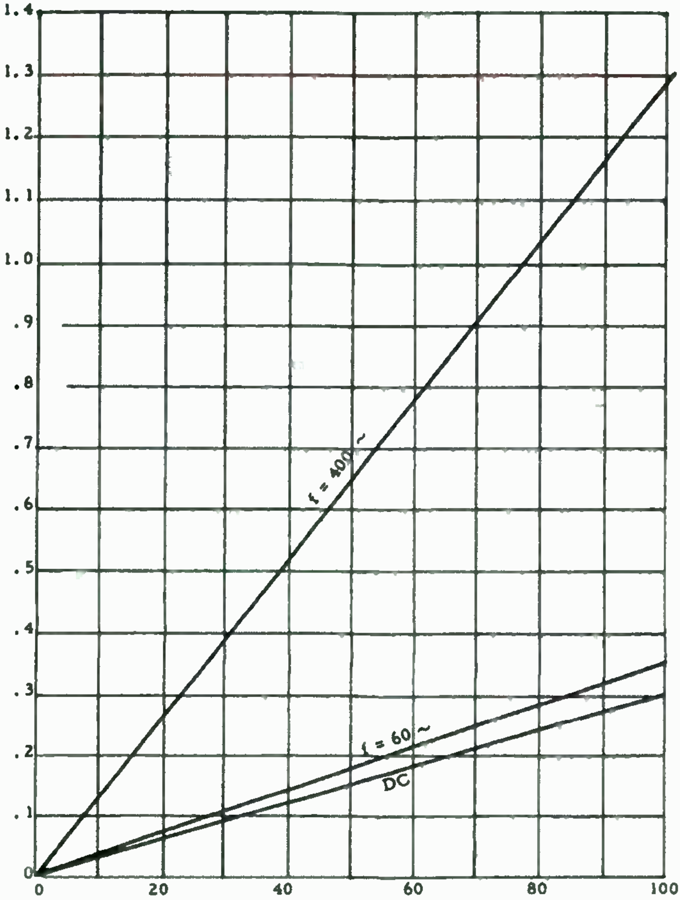
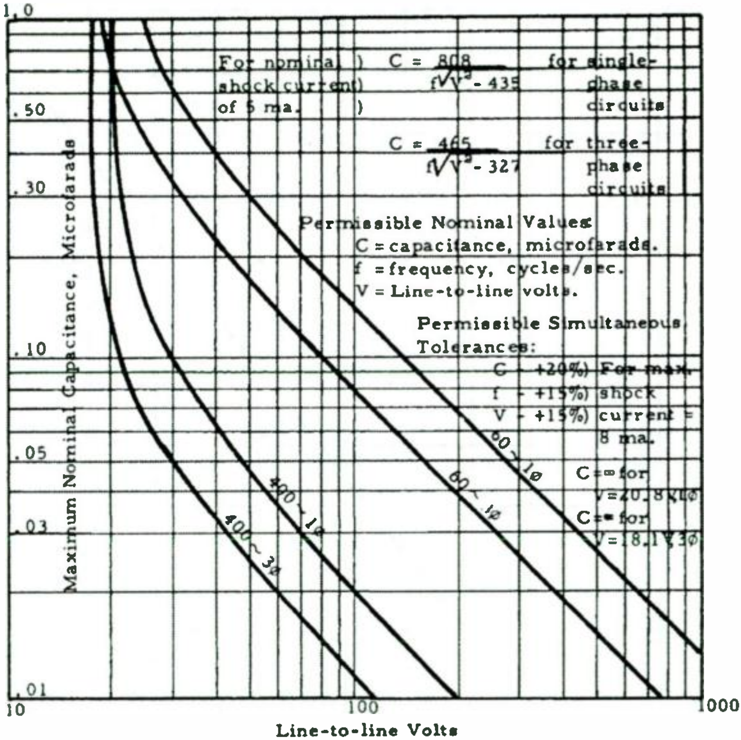


Figure 6



Maximum Nominal Capacitance
From Each Line to Frame as Limited
by Shock Hazard.
All Capacitances Equal.

Figure 7

MIL-F-15733D
AMENDMENT 1
10 APRIL 1961

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, GENERAL SPECIFICATION FOR

This amendment forms a part of Military Specification MIL-F-15733D, dated 22 March 1960, and has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

Page 2, paragraph 1.2.14: Delete "1.2.14" and substitute "1.2.1.4".

Page 2, paragraph 2.1: Delete "specifications, detail specifications, and standards" and substitute "documents"; in line 4, following "specification," insert "to the extent specified herein."

Page 2, paragraph 2.1., list of federal specifications, title of PPP-B-636: Delete and substitute "Box, Fiberboard"; title of PPP-T-76: Following "Resistant," insert "(for Carton Sealing)."

Page 2, paragraph 2.1, list of military specifications and standards, title of MIL-E-2036: Beginning with "(Naval," delete rest of title and substitute, "Naval Shipboard."; title of MIL-STD-220: Beginning with "for," delete rest of title.

Page 3, paragraph 2.2, line 2: Following "specification," insert "to the extent specified herein."
Page 5, paragraph 3.6, lines 2 and 3: Delete "evi-dnce" and substitute "evidence."

Page 7, paragraph 3.14, heading: Delete "(when applicable)."

Page 8, paragraph 4.1.1: Delete and substitute:

"4.1.1 *Supplier*. The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements."

Page 8, paragraph 4.1.2: Delete.

Page 8, paragraph 4.4.3, line 2: Delete "qualication" and substitute "qualification."

Page 9, table IX, group I examinations and tests, line 8: Following "resistance," insert "(terminal to ground)."

Page 9, table IX, group I examinations and tests, last test: Delete "(when applicable)."

Page 9, paragraph 4.5.1.3.1, line 3: Following "105," insert "for ordinary inspection."

Page 9, paragraph 4.5.1.4.1, first sentence: Delete and substitute "The sampling plan shall be in accordance with Standard MIL-STD-105 for small-sample inspection."; third sentence: Delete and substitute "For small-sample reduced inspection, procedure R-1 shall be used."

Page 10, table X, column 1, line 11: Following "resistance," insert "(terminal to ground)."

Page 10, table XI, column 1, lines 3 and 4: Delete "(when applicable)."; in line 5, delete "on" and substitute "of."

Page 10, paragraph 4.5.1.4.3: Delete.

Page 11, paragraph 4.5.1.5.3: Delete and substitute:

"4.5.1.5.3 *Noncompliance*. If a sample fails to pass group C inspection, the supplier shall take corrective action on the materials or process,

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or both, as warranted, and on all units of product which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials, processes, etc., and which are considered subject to the same failure. Acceptance of the product shall be discontinued until corrective action, acceptable to the Government, has been taken. After the corrective action has been taken, group C inspection shall be repeated on additional sample units (all inspection, or the inspection which the original sample failed, at the option of the Government). Groups A and B inspection may be reinstituted; however, final acceptance shall be withheld until the group C reinspection has shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure and the corrective action taken shall be furnished to the contracting officer."

Page 11, paragraph 4.5.2: Delete and substitute:

"4.5.2 *Inspection of preparation for delivery*. Sample items and packs shall be selected and inspected in accordance with Specification MIL-P-116 to verify conformance with requirements in section 5 of this specification."

Page 11, paragraph 4.6.4, line 3: Following "at," insert "maximum."

Page 12, paragraph 4.6.5, (c) 1, next to last line: Following "the," insert "maximum."

Page 13, paragraph 4.6.7.1, line 5: Following "at," insert "maximum."

Page 13, paragraph 4.6.8, *Insertion loss (check test)*.: Delete "4.6.8" and substitute "4.6.8.1."

Page 13, paragraph 4.6.9, line 4: Following "at," insert "maximum"; at end of paragraph following "respectively," insert "Filters shall be visually examined for evidence of physical damage."

Page 14, paragraph 4.6.10, heading: Delete "(*when applicable*)."

Page 14, paragraph 4.6.10.1: In lines 1 and 2 delete "force of the specified magnitude" and substitute "5-pound pull for solder-lug terminals and a 10-pound pull for threaded-stud and radially-tapped stud terminals"; at end of paragraph, delete "(see 3.1)."

Page 15, paragraph 4.6.17, lines 2: Following "at," insert "maximum"; at end of paragraph following "respectively," insert "Filters shall be visually examined for evidence of mechanical damage."

Custodians:
Army—Signal Corps
Navy—Bureau of Ships
Air Force

Preparing activity:
Army—Signal Corps

U. S. GOVERNMENT PRINTING OFFICE 1961

MIL-F-15733D
22 MARCH 1960

SUPERSEDING
MIL-F-15733C
21 SEPTEMBER 1955
MIL-F-18344A(SHIPS)
5 OCTOBER 1955

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, GENERAL SPECIFICATION FOR

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 Scope. This specification covers the general requirements for current-carrying filters (alternating current (ac) and direct current (dc)), for use primarily in the reduction of broadband radio interference.

1.2 Classification.

1.2.1 *Type designation.* The type designation shall be in the following form, and as specified (see 3.1 and 6.1):

FL22	D	D	1E	A	1
Style (1.2.1.1)	Current rating (1.2.1.2)	Insertion-loss characteristic (1.2.1.3)	Terminal identification (1.2.1.4)	Operating temperature range (1.2.1.5)	Grade (1.2.1.6)

1.2.1.1 *Style.* The style is identified by the two-letter symbol FL followed by a two-digit number. The letters identify radio-interference filters; the digits identify the general shape and mounting of the case.

1.2.1.2 *Current rating.* The current rating is identified by a single letter in accordance with table I.

1.2.1.3 *Insertion-loss characteristic.* The insertion-loss characteristic is identified by a single letter in accordance with table II.

TABLE I. *Current rating*

Symbol	Rated current	Symbol	Rated current
	Amperes		Amperes
A	0.1	L	30
B	0.25	M	50
C	0.5	P	70
D	1	R	100
E	3	S	150
F	5	T	200
G	10	U	300
H	15	V	500
J	20		

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TABLE II. *Minimum insertion loss under full load*

Symbol	Frequency in megacycles shown as column head and insertion loss shown in column										
	0.15	0.3	0.6	1	10	20	40	100	500	1,000	10,000
	db	db	db	db	db	db	db	db	db	db	db
B	40	50	60	60	60	60	60	60	60	60	......
C	50	60	60	60	60	60	60	......	......	......	......
D	50	60	60	60	60	60	60	60	60	60	......
H	50	50	60	60	60	60	60	60	50	60	......
J	60	70	80	80	80	80	80	80	80	80	......
K	40	50	60	60	60	60	60	60	60	60	60
L	70	70	70	70	60	60	60	60	60	60	60

1.2.1.4 *Terminal identification.* Terminals are identified by a number and a letter in accordance with table III. The number identifies the type of terminal and the letter identifies the thread (or other dimensions).

TABLE III. *Terminal types and dimensions*

Symbol	Type of terminal	Thread or dimension
1E	Solder lug	....
2G	Radially tapped permanent stud.	8-32 NC-2B
2H	Radially tapped permanent stud.	10-32 NF-2B
3F	Threaded stud	4-40 NC-2A
3L	Threaded stud	6-32 NC-2A
3J	Threaded stud	8-32 NC-2A
3K	Threaded stud	10-32 NF-2A

1.2.1.5 *Operating temperature range.* The operating temperature range is identified by a single letter in accordance with table IV.

TABLE IV. *Operating temperature range*

Symbol	Temperature range
	°C.
A	—55 to + 85, incl
B	—55 to +125, incl
C	—55 to +200, incl

1.2.1.6 *Grade.* The grade is identified by a single digit in accordance with table V.

TABLE V. *Grade*

Symbol	Vibration condition
	Cps
1	10 to 55, incl
2	10 to 500, incl
3	10 to 2,000, incl

2. APPLICABLE DOCUMENTS

2.1 The following specifications, detail specifications, and standards, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

FEDERAL

FF-S-85 — Screws, Cap, Slotted and Hexagon Head.

FF-S-92 — Screws, Machine; Slotted or Cross-Recessed.

PPP-B-566 — Boxes, Folding, Paperboard.

PPP-B-585 — Boxes, Wood, Wirebound.

PPP-B-591 — Boxes, Fiberboard, Wood-Cleated.

PPP-B-601 — Boxes, Wood, Cleated-Plywood.

PPP-B-621 — Boxes, Wood, Nailed and Lock-Corner.

PPP-B-636 — Boxes, Fiber.

PPP-B-665 — Boxes; Paperboard, Metal Stayed (Including Stay Material).

PPP-B-676 — Boxes, Setup, Paperboard.

PPP-T-76 — Tape, Pressure-Sensitive Adhesive, Paper, Water Resistant.

PPP-T-97 — Tape, Pressure-Sensitive Adhesive, Filament Reinforced.

MILITARY

MIL-P-116 — Preservation, Methods of.

MIL-E-2036 — Enclosures for Electric and Electronic Equipment (Naval Shipboard Use).

MIL-B-10377 — Box, Wood, Cleated, Veneer, Paper Overlaid.

MIL-L-10547 — Liners, Case, Waterproof.

DETAIL SPECIFICATIONS

(For applicable detail specifications, see Supplement 1).

STANDARDS

MILITARY

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes.

MIL-STD-129 — Marking for Shipment and Storage.

MIL-STD-130 — Identification Marking of U. S. Military Property.

MIL-STD-202 — Test Methods for Electronic and Electrical Component Parts.

MIL-STD-220 — Method of Insertion-Loss Measurement for Radio-Frequency Filters.

(Copies of specifications, detail specifications, and standards required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

DEPARTMENT OF DEFENSE

Handbook H4-1 — Federal Supply Code for Manufacturers (Part I).

NATIONAL BUREAU OF STANDARDS

Handbook H28 — Screw-Thread Standards for Federal Services.

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington 25, D. C.)

OFFICIAL CLASSIFICATION COMMITTEE

Uniform Freight Classification Rules.

(Application for copies should be addressed to the Official Classification Committee, One Park Ave, at 33rd Street, New York 16, N. Y.)

AMERICAN SOCIETY FOR TESTING MATERIALS

D92-57 — Method of Test for Flash and Fire Points by Cleveland Open Cup.

(Application for copies should be addressed to the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.)

3. REQUIREMENTS

3.1 Detail requirements for individual filter styles. Detail requirements or exceptions applicable to individual styles of filters shall be as specified in the detail specifications listed in Supplement 1 to this specification. In the event of any conflict between requirement of this specification and the detail specifications, the latter shall govern (see 6.1).

3.2 Qualification. Filters furnished under this specification shall be a product which has been tested and has passed the qualification tests specified in 4.4, and has been listed on or approved for listing on the applicable Qualified Products List (see 6.2).

3.3 Material. When a definite material is not specified, a material shall be used which will enable the filters to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

3.3.1 *Impregnating and potting compounds.* Compounds used in the impregnating and potting of filters shall be chemically inactive with respect to the filter unit and the case (see 3.4.1). The compound, either in the state of original application or as a result of having aged, shall have no adverse effect on the performance of the filter. For oil-filled filters, the same material shall be used for impregnating as is used for filling.

3.4 Design and construction. Filters shall be of the design, construction, and physical dimensions specified (see 3.1).

3.4.1 *Case.* Filters shall be enclosed in metallic cases which shall protect the filter elements from moisture and mechanical damage under all test conditions specified herein. All external bonding or grounding surfaces shall be free from all insulating protective finishes.

3.4.2 *Finish.* All exposed metallic surfaces shall be suitably protected against corrosion by plating, lead-alloy coating, or other means. The finish shall provide good electrical contact when used on a terminal or as a conductor (see 6.3); shall have uniform texture and appearance; shall be adherent; and shall be free from blisters, pinholes, and other defects that may affect the protective value of the coating.

3.4.3 *Threaded parts.* Unless otherwise specified, all threaded parts shall be in accordance with Handbook H28. Where practical, all threads shall be in conformity with the coarse-thread series. The fine-thread series shall be used only for applications that might show a definite advantage through their use. Where a special diameter-pitch combination is required, the thread shall be of American National Form and of any pitch between 16 and 36 which is used in the fine-thread series. Screws shall conform to Specification FF-S-85 or FF-S-92, as applicable.

3.4.3.1 *Engagement of threaded parts.* The length of all threaded parts shall be as specified (see 3.1).

3.4.4 *Weight (when applicable).* Filters shall be of the weight specified (see 3.1).

3.5 Creepage and clearance distances (when applicable).

3.5.1 *Distances for nonaircraft, nonelectronic, electrical power equipment.* The minimum external creepage and clearance distances between filter sections or between any filter section and ground shall be in accordance with table VI.

3.5.1.1 *Creepage.* Creepage distance is defined as the shortest path between uninsulated current-carrying parts along the surface of an insulating material. Cemented or butted joints do not add to the creepage path. Insulating barriers shall be used wherever practical to avoid a continuous unidirectional surface creepage path. It is to be emphasized that the values specified in table VI represent the minimum acceptable limits for nonarcing rigid construction and that they only take into consideration the average degree of enclosure and service exposure. Where such uninsulated parts are arc-rupturing or where there is any question of rigidity of mounting, higher voltage equipment, or exceptionally severe exposure, the minimum distances shall be increased as necessary, consistent with minimum space and weight requirements, to assure service reliability.

3.5.1.2 *Clearance.* Clearance distance is defined as the shortest point-to-point path in air between uninsulated current-carrying parts.

3.5.2 *Relationship to enclosure.* Group I enclosures (see table VI) are those which permit more transmission of air than drip-proof as specified in Specification MIL-E-2036. For top-curved surfaces having a radius greater than 3 inches and for top-flat surfaces, surface-creepage distance in group 1 enclosures shall be increased 33 percent where these surfaces have irregularities which permit the accumulation of dust and moisture. Group 2 enclosures (see table VI) shall be drip-proof as defined in Specification MIL-E-2036 or permit less transmission of air than drip-proof.

TABLE VI. *Creepage and clearance distances*

Voltage (ac or dc)	Set[1]	Clearance	Creepage[2]	
			Open, group 1 enclosure	Enclosed drip-proof or better group 2 enclosure
Volts		*Inch*	*Inches*	*Inches*
	A	1/16	1/16	1/16
Up to 150	B	1/8	1/4	1/8
	C	1/4	3/8	3/8
	A	1/16	1/16	1/16
150 to 300	B	1/8	1/4	1/4
	C	1/4	3/8	1/2
	A	1/16	1/8	1/8
300 to 600	B	1/8	1/4	1/4
	C	1/4	3/8	1/2
	A	1/8	1/2	3/8
600 to 1,000	B	1/4	1	3/4
	C	1/2	2	1 1/2

[1] See 3.5.3.
[2] See 3.5.2.

3.5.3 *Relationship to power.*

3.5.3.1 *Set A.* Set A spacings shall be used in equipment where the effect of a short circuit is limited to the unit and where normal volt-ampere (va) ratings up to 50 are involved.

3.5.3.2 *Set B.* Set B spacings shall be used for applications where secondary short-circuit protection in the form of fuses and circuit breakers is provided and where the normal operating va ratings are over 50 and up to 2,000.

3.5.3.3 *Set C.* Set C spacings shall be used for applications having va ratings in excess of 2,000 but still protected by secondary devices which can safely interrupt resultant short-circuit currents.

3.6 **Seal.** When filters are tested in accordance with 4.6.2, there shall be no evidnce of leakage.

3.7 **Capacitance to ground (when applicable.** When filters are tested in accordance with 4.6.3, the capacitance to ground shall be as specified (see 3.1).

3.8 **Temperature rise.** When filters are tested in accordance with 4.6.4, the temperature rise shall be as specified (see 3.1).

3.9 **Dielectric withstanding voltage.** When filters are tested in accordance with 4.6.5, there shall be no breakdown, flashover, or impairment of any characteristic qualities sufficient to cause failure of the filter.

3.10 **Insulation resistance (terminal to ground).** When measured in accordance with 4.6.6, the insulation resistance of any filter section shall be not less than the applicable value shown on figure 1. The value of insulation resistance varies with temperature, and it is necessary to apply a correction factor to measurements made at a temperature other than 25° C. Correction factors for measurements made at temperatures between 20° and 35° C. are given in table VII. The required value of insulation resistance shall be multiplied by the correction factor to determine the new value required at the test temperature.

TABLE VII. *Insulation-resistance correction factors*

Degrees centigrade	Correction factor	Degrees centigrade	Correction factor
20	1.42	28	0.82
21	1.33	29	0.76
22	1.24	30	0.71
23	1.16	31	0.67
24	1.08	32	0.63
25	1.00	33	0.59
26	0.94	34	0.55
27	0.87	35	0.51

3.11 **Voltage drop.** When filters are tested in accordance with 4.6.7, the voltage drop shall be as specified (see 3.1).

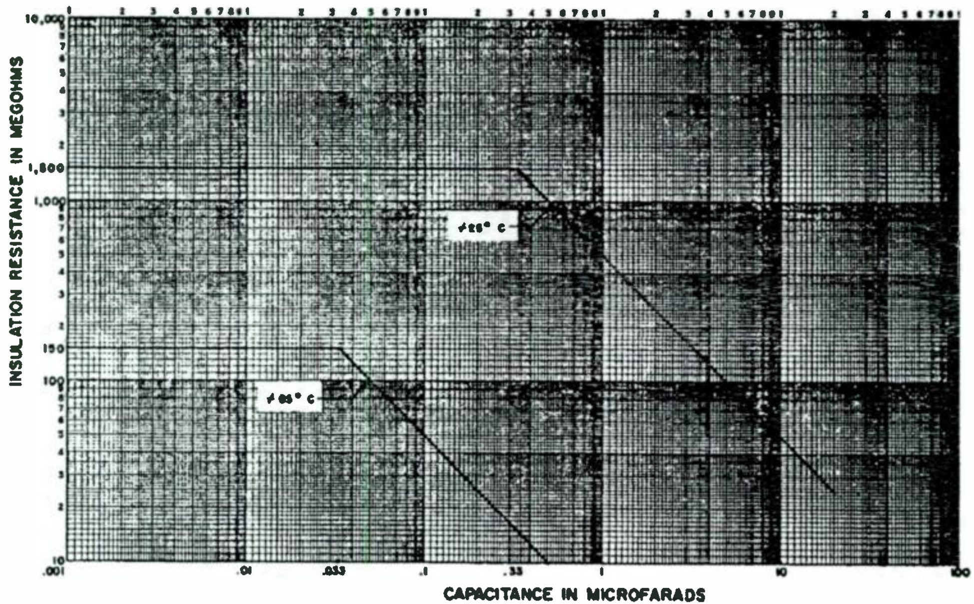

FIGURE 1. *Graphical representation of insulation-resistance requirements.*

3.12 Insertion loss. When filters are tested in accordance with 4.6.8, the insertion loss shall be as specified in table II.

3.13 Overload. When filters are tested in accordance with 4.6.9, the insulation resistance and voltage drop shall be as specified in 3.10 and 3.11, respectively. There shall be no physical damage to the filters.

3.14 Terminal strength (when applicable). When filters are tested in accordance with 4.6.10, no part of the terminals shall loosen or rupture and no other damage shall result. Bends shall not be considered as damage unless an incipient break occurs.

3.15 Flashpoint of impregnant or potting compound. When measured in accordance with 4.6.11, the flashpoint of the impregnant or potting compound shall be not lower than specified in table VIII.

TABLE VIII. *Flashpoint of impregnant or potting compound*

Operating-temperature-range symbol	High operating temperature	Minimum allowable flashpoint
	°C	°C
A	85	145
B	125	165
C	200	240

3.16 Effect of soldering (soldered terminals only). When filters are tested in accordance with 4.6.12, there shall be no damage to the filters or to the terminal insulators which will cause electrical failure of the filters, or which will cause hermetically sealed filters to leak. Chipping of terminals insulators alone shall not be cause for failure unless the chipping extends to the outer periphery.

3.17 Vibration. When filters are tested in accordance with 4.6.13, there shall be no intermittent open- or short-circuiting during vibration. After the test, there shall be no evidence of physical damage to the filters.

3.18 Salt spray (corrosion). When filters are tested in accordance with 4.6.14, there shall be no harmful or extensive corrosion, and at least 90 percent of any exposed metallic surfaces of the filter shall be protected by the finish. The marking shall remain legible. In addition, there shall be not more than 10-percent corrosion of the terminal hardware or mounting surface.

3.19 Temperature and immersion cycling. When tested as specified in 4.6.15, filters shall meet the following requirements:

Dielectric withstanding voltage.	As specified in 3.9.
Insulation resistance.	Not less than 30 percent of the value specified in 3.10.
Insertion loss	As specified in 3.12.
Visual examination.	Corroded areas shall not exceed the limits specified in 3.18 and marking shall remain legible after the test.

3.20 Moisture resistance. When tested as specified in 4.6.16, filters shall meet the following requirements:

Dielectric withstanding voltage.	As specified in 3.9.
Insulation resistance.	Not less than 30 percent of the value specified in 3.10.
Insertion loss	As specified in 3.12.
Visual examination.	Corroded areas shall not exceed the limits specified in 3.18 and marking shall remain legible after the test

3.21 Life. When tested as specified in 4.6.17, filters shall meet the following requirements:

Dielectric withstanding voltage.	As specified in 3.9.
Insulation resistance.	Not less than 30 percent of the value specified in 3.10.
Insertion loss	As specified in 3.12.
Visual examination.	There shall be no visible mechanical damage.

3.22 Marking. Filters shall be marked in accordance with Standard MIL-STD-130, with the type designation, manufacturer's code-symbol numbers in accordance with Handbook H4-1, voltage, current, input or output terminals (if the filter is not electrically symmetric), and the maximum operating (power) frequency. If sufficient space is available, the manufacturer's name or registered trademark may be added. The location of the marking shall be as specified (see 3.1).

3.23 Workmanship. Filters shall be processed in such a manner as to be uniform in quality and shall be free from cold soldering, corrosion (see 3.18), pits, dents, cracks, rough edges, misalinements, and other defects that will affect life, serviceability, or appearance.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection.

4.1.1 *Supplier.* Unless otherwise specified herein, the supplier is responsible for the performance of all inspection requirements prior to submission for Government inspection and aceptance. Unless otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government, as specified in the contract or order.

4.1.1.1 *Test equipment and inspection facilities.* Test equipment and inspection facilities shall be of sufficient accuracy, quality, and quantity to permit performance of the required inspection. The supplier shall establish calibration of inspection equipment to the satisfaction of the Government.

4.1.2 *Government.* Acceptance of the filters shall be based upon verification by the Government of the supplier's compliance with the requirements of this specification. The Government may, at its option, repeat any or all of the inspection specified herein.

4.2 Classification of inspection. The examination and testing of filters shall be classified as follows:

(a) Qualification inspection (see 4.4).

(b) Acceptance inspection (see 4.5).

1. Inspection of product for delivery (see 4.5.1).
2. Inspection of preparation for delivery (see 4.5.2).

4.3 Inspection conditions. Unless otherwise specified herein, all inspection shall be made at room ambient relative humidity and pressure at a temperature of $25^\circ {+10^\circ \atop -5^\circ}$ C.

4.4 Qualification inspection.

4.4.1 *Location of inspection.* Qualification inspection will be performed at a laboratory designated by the Government (see 6.2).

4.4.2 *Sample.* The number of specimens comprising a sample of filters to be submitted for qualification inspection shall be as specified in the appendix to this specification.

4.4.3 *Test routine.* Specimens will be subjected to the qualication inspection specified in table IX, in the order shown. All specimens will be subjected to the inspection of group I. The specimens will then be divided equally into three groups of four units each. The specimens will then be subjected to the inspection for their particular group, for alternate-terminal-type submission, each type will be equally represented in each group.

4.4.4 *Defectives.* Defectives in excess of those allowed in table IX will be cause for refusal to grant qualification.

4.5 Acceptance inspection.

4.5.1 *Inspection of product for delivery.* Inspection of product for delivery shall consist of groups A, B, and C.

4.5.1.1 *Inspection lot.* An inspection lot, as far as practicable, shall consist of all the filters of the same style, current rating, insertion-loss characteristic, terminal identifi-

TABLE IX. *Qualification inspection*

Examination or test	Requirement paragraph	Method paragraph	Number of specimens to be inspected	Number of defectives allowed[1]	
Flashpoint of impregnant or potting compound	3.15	4.6.11	----------	0	
Group I					
Visual and mechanical examination: Material, design, construction, marking[2], and workmanship.	3.1, 3.3 to 3.5.3.3, incl, 3.22, and 3.23	4.6.1	[3]13	1	
Seal	3.6	4.6.2			
Capacitance to ground (when applicable)	3.7	4.6.3			
Temperature rise	3.8	4.6.4			
Dielectric withstanding voltage	3.9	4.6.5			
Insulation resistance	3.10	4.6.6			
Voltage drop	3.11	4.6.7			
Insertion loss (3 specimens only)	3.12	4.6.8			
Overload	3.13	4.6.9			
Terminal strength (when applicable)	3.14	4.6.10			
Group II					
Effect of soldering (soldered terminals only)	3.16	4.6.12	4	1	
Vibration	3.17	4.6.13			
Salt spray (corrosion)	3.18	4.6.14			
Temperature and immersion cycling	3.19	4.6.15			
Group III					2
Moisture resistance	3.20	4.6.16	4	1	
Group IV					
Life	3.21	4.6.17	4	1	

[1] A specimen having one or more defects will be charged as a single defective.
[2] Marking will be considered a defect only if it becomes illegible as a result of the inspection.
[3] One additional specimen is included in each sample of 13 or 7 specimens (see 20.1.1) to permit substitution for the allowable defective in group I.

cation, operating temperature range, and grade, produced under essentially the same conditions, and offered for inspection at one time.

4.5.1.2 *Resubmitted lots.* If an inspection lot is rejected, the supplier may replace it with a new lot, rework it to correct the defects, or screen out the defective units, and submit it again for inspection. Resubmitted lots shall be kept separate from new lots and shall be clearly identified as resubmitted lots. Resubmitted lots shall be inspected, using tightened inspection.

4.5.1.3 *Group A inspection.* Group A inspection shall consist of the examinations and tests specified in table X, and shall be made on the same set of sample units, in the order shown.

4.5.1.3.1 *Sampling plan. Statistical sampling* and inspection shall be in accordance with Standard MIL-STD-105. The acceptable quality levels (AQL) shall be as specified in table X. Major and minor defects shall be as defined in Standard MIL-STD-105.

4.5.1.4 *Group B inspection.* Group B inspection shall consist of the tests specified in table XI, in the order shown.

4.5.1.4.1 *Sampling plan.* The sampling plan shall be in accordance with "Sampling for Expensive Testing by Attributes" in Standard MIL-STD-105. Unless otherwise speci-

TABLE X. *Group A inspection*

Examination or test	Requirement paragraph	Method paragraph	AQL (percent defective)	
			Major	Minor
Visual and mechanical examination:[1]		4.6.1	1.0	4.0
Material	3.3 and 3.3.1			
Body dimensions	3.4			
Design and construction (other than body dimensions).	3.4 to 3.5.3.3 incl.			
Marking	3.22			
Workmanship	3.23			
Seal	3.6	4.6.2	1.0	
Capacitance to ground (when applicable)	3.7	4.6.3		
Dielectric withstanding voltage	3.9	4.6.5		
Insulation resistance	3.10	4.6.6		
Voltage drop	3.11	4.6.7		
Insertion loss (check test) (3 sample units only)	3.12	4.6.8.1		

[1] Visual and mechanical examination may be performed before or after the units are sealed, whichever is applicable.

TABLE XI. *Group B inspection*

Test	Requirement paragraph	Method paragraph
Temperature rise	3.8	4.6.4
Overload	3.13	4.6.9
Terminal strength (when applicable).	3.14	4.6.10
Effect on soldering (soldered terminals only).	3.16	4.6.12
Vibration	3.17	4.6.13
Temperature and immersion cycling.	3.19	4.6.15

fied herein, normal inspection shall be used at the start of the contract. The reduced inspection procedure shall be R–1. The AQL shall be 4.0 (percent defective) for the group combined, and the inspection level shall be L8 for normal and tightened inspection, and L6 for reduced inspection.

4.5.1.4.2 *Disposition of sample units.* Sample units which have been subjected to group B inspection shall not be delivered on the contract or order.

4.5.1.4.3 *Action in case of lot rejection.* When an inspection lot is rejected on group B inspection, the supplier shall immediately investigate the cause of failure and take corrective action to assure that subsequent lots do not contain the same defect or defects.

4.5.1.5 *Group C inspection.* Group C inspection shall consist of the tests specified in table XII, in the order shown for each subgroup. The number of sample units to be inspected for each subgroup shall be as specified in table XII. Separate samples shall be used for each subgroup.

4.5.1.5.1 *Sampling plan.* Once each calendar month, sample units shall be selected according to style. The current rating, insertion-loss characteristic, and terminal type shall be left to the discretion of the Government.

TABLE XII. *Group C inspection*

Test	Requirement paragraph	Method paragraph	Number of sample units to be inspected	Number of defectives allowed
Subgroup 1				
Insertion loss	3.12	4.6.8	4	1
Salt spray (corrosion).	3.18	4.6.14		
Subgroup 2				
Moisture resistance.	3.20	4.6.16	4	
Subgroup 3				
Life	3.21	4.6.17	4	1

4.5.1.5.2 *Disposition of sample units.* Sample units which have been subjected to group

C inspection shall not be delivered on the contract or order.

4.5.1.5.3 *Noncompliance.* If a sample fails to pass group C inspection, the supplier shall take corrective action on the process and on all units of product which can be corrected and which were manufactured under the same conditions, and with the same materials, processes, etc, and which are considered subject to the same failure. Acceptance inspection shall be discontinued until corrective action has been taken. After the corrective action has been taken, additional sample units shall be subjected to group C inspection (all inspections, or the inspection which the original sample failed, at the option of the Government). Groups A and B inspection may be reinstituted; however, final acceptance shall be withheld until the group C inspection has shown that the corrective action was successful.

4.5.2 *Inspection of preparation for delivery.* Unless otherwise specified herein, sample items and packs shall be selected in accordance with Specification MIL-P-116 and shall be inspected in accordance with methods described therein to verify conformance with requirements in section 5 of this specification.

4.6 Methods of examination and test.

4.6.1 *Visual and mechanical examination.* Filters shall be examined to verify that the materials, design, construction, physical dimensions, creepage and clearance distances, marking, and workmanship are in accordance with the applicable requirements (see 3.1, 3.3 to 3.5.3.3, incl, 3.22, and 3.23).

4.6.2 *Seal (see 3.6).*

4.6.2.1 *Liquid- and wax-filled filters.* Filters shall be placed, with their terminals horizontal, on clean paper, and brought to a case temperature within ±5° C. of the specified maximum operating temperature (see 3.1) for a period of not less than 10 minutes after the filter has reached temperature stability. An oil spot or spots appearing on the paper under the filter, or any oil or impregnant appearing on the outside of the case, is considered evidence of leakage. However, when a high operating altitude is specified, this test shall also be conducted at a temperature of $25^\circ \begin{smallmatrix}+10^\circ \\ -5^\circ\end{smallmatrix}$ C. and at the atmospheric pressure specified (see 3.1).

4.6.2.2 *Other filters.* Filters shall be immersed for a minimum of 2 minutes in oil or water maintained at a temperature within ±5° C. of the specified maximum operating temperature (see 3.1), during which time the filter shall be observed for repetitive bubbling. However, when a high operating altitude is specified (see 3.1), this test shall be conducted at a temperature of $25^\circ \begin{smallmatrix}+10^\circ \\ -5^\circ\end{smallmatrix}$ C. and at the atmospheric pressure specified.

4.6.3 *Capacitance to ground (when applicable) (see 3.7).* Capacitance to ground shall be measured in accordance with method 305 of Standard MIL-STD-202. The following details shall apply:

(a) Test frequency — 1,000 ± 100 cycles per second (cps) where the nominal capacitance to ground is 1 microfarad (μf) or less, and 60 ± 6 cps where the nominal capacitance to ground is more than 1 μf.

(b) Limit of accuracy — within ± 2 percent.

4.6.4 *Temperature rise (see 3.8).* Filters shall be suspended by their terminals and shall be energized with rated current at rated frequency (see 3.1). Lead wires shall be of copper, 6 inches long, and of the size specified in table XIII. After thermal stability has been reached and while the filter is still energized, the maximum hotspot on the filter case shall be determined by the use of thermocouples.

TABLE XIII. *Lead wire sizes*

Rated current of filter	Wire size
Amperes	*AWG*
Up to 3	24
3+ to 5	22
5+ to 11	20
11+ to 16	18
16+ to 22	16
22+ to 32	14
32+ to 41	12
41+ to 55	10
55+ to 73	8
73+ to 101	6
101+ to 135	4
135+ to 181	2
181+ to 211	1

4.6.5 *Dielectric withstanding voltage* (*see 3.9*). Filters shall be tested in accordance with method 301 of Standard MIL-STD-202. The following details and exceptions shall apply:

(a) Special condition — When a high operating altitude is specified (see 3.1), a qualification test shall also be conducted at the atmospheric pressure specified; the qualification-test voltage shall be 125 percent of rated voltage.

(b) Magnitude and nature of test voltage — dc test voltage of the potential specified in table XIV shall be used.

TABLE XIV. *Dielectric withstanding voltages*

Rated voltage of filter	Test voltage, dc	
	For qualification inspection	For acceptance inspection
Volts	*Volts*	*Volts*
Up to 100, incl, dc	200	250
Over 100, dc	2 x rated	2.5 x rated
Ac	2.8 x rated rms	4.2 x rated rms

(c) Duration of application of test voltage:

1. For qualification inspection — The voltage (see table XIV) shall be applied for a period of 1 minute after the filter has reached thermal stability at the maximum operating temperature produced by passage of rated current at the rated frequency (see 3.1).

2. For acceptance inspection—The voltage (see table XIV) shall be applied for 1 second. However, at the discretion of the supplier, the qualification-inspection voltage may be applied for 1 minute.

(d) Points of application of test voltage — The test voltage shall be applied between the case (ground) and all live (not grounded) terminals of the same circuit connected together.

(e) Limiting value of surge current — A current-limiting resistor shall be connected in series with the filter to limit the surge current to the maximum rated current or 1 ampere, whichever is less.

4.6.6 *Insulation resistance* (*terminal to ground*) (*see 3.10*). Filters shall be tested in accordance with method 302 of Standard MIL-STD-202. The following details shall apply:

(a) Test-condition letter — A.

(b) Special preparations or conditions— Measurements shall be carefully made to prevent damage to the filter seal. When filters fail this test due to ambient relative humidity in excess of 50 percent, they may be retested at any relative humidity from 20 to 50 percent.

(c) Points of measurement — Between the case (ground) and all live (not grounded) terminals of the same circuit connected together.

4.6.7 *Voltage drop* (*see 3.11*).

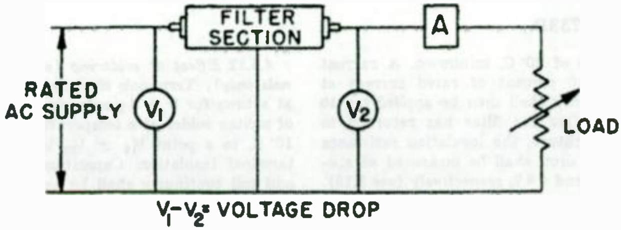

FIGURE 2. *Ac filters; measurement of voltage drop.*

4.6.7.1 *For ac filters.* The voltage drop is the difference between the input voltage to the filter and the output voltage of the filter when the filter is carrying rated current at rated voltage, with a resistive load at rated frequency (see 3.1). The method of voltage measurement is shown on figure 2. Measurements shall be made by using expanded scale-type meters which will enable voltage differences of less than 1 volt to be read.

4.6.7.2 *For dc filters (see 3.1).* The voltage drop shall be determined in accordance with figure 3. Measurements shall be made by using a dc reading meter.

4.6.8 *Insertion loss.* Filters shall be tested under load in accordance with Standard MIL-STD-220, except that adapters may be modified to fit the particular style of the filter. Measurements shall be taken at a sufficient number of frequencies to plot a curve of insertion loss versus frequency, accurate to within ± 3 decibels (db) over the specified frequency range (see 3.12).

4.6.8 *Insertion loss (check test).* Insertion-loss measurements (any method accurate to within ± 3 db) need be made only at the lowest and highest frequencies of the specified frequency range and at the one intermediate frequency; that is, the frequency at which the measured insertion loss (as determined from previous insertion-loss tests performed during the qualification inspection or group B inspection) is closest to the minimum insertion-loss requirements (see 3.12).

4.6.9 *Overload.* Filters shall be suspended by their conductors in free air at an ambient

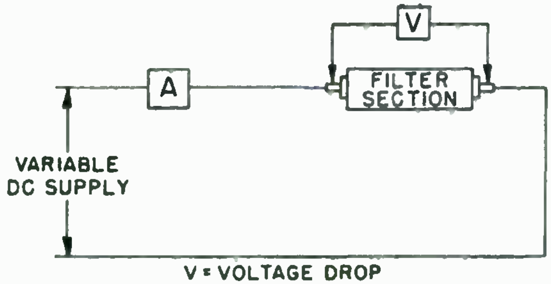

FIGURE 3. *Dc filters; measurement of series-element voltage drop at rated current.*

temperature of 20° C, minimum. A current equal to 140 percent of rated current at rated frequency shall then be applied for 15 minutes. After the filter has returned to room temperature, the insulation resistance and voltage drop shall be measured as specified in 4.6.6 and 4.6.7, respectively (see 3.13).

4.6.10 *Terminal strength (when applicable) (see 3.14).*

4.6.10.1 *Pull.* A force of the specified magnitude shall be applied to the terminal at the point where the lead from the external circuit connects to it. The force may be applied in any direction, including the weakest, and shall be increased gradually to the specified magnitude and held at that value for at least 30 seconds (see 3.1).

4.6.10.2 *Bend (applicable only to solder-lug terminals).* Any terminal that shows visible bending in the terminal-pull test (see 4.6.10.1) shall be bent back and forth five times to an angle of 45° each side of center (terminal bent through an arc of 90°).

4.6.10.3 *Twist.* Terminals with external screw threads shall be subjected to the torque specified in table XV.

TABLE XV. *Torque*

Screw size	Torque
	lb-in.
6–32	9
8–32	14
10–32	18
¼–20	30
5/16–24	50
⅜–24	100
7/16–20	150
½–20	250
½–28	200

4.6.11 *Flashpoint of impregnant or potting compound.* The flashpoint of the impregnant or potting compound shall be measured as specified in Publication D92-57. However, the paragraphs covering firepoint and precision do not apply to this test (see 3.15).

4.6.12 *Effect of soldering (soldered terminals only).* Terminals shall be immersed one at a time for 3 ± ½ seconds each in a pot of molten solder at a temperature of 250° ± 10° C, to a point 1/16 ± 1/32 inch from the terminal insulation. Capacitance to ground and coil continuity shall be checked 1 hour after immersion (see 3.16).

4.6.13 *Vibration (see 3.17).*

4.6.13.1 *Low frequency (grade 1).* Filters shall be tested in accordance with method 201 of Standard MIL-STD-202. The following details and exception shall apply:

(a) Tests and measurements prior to vibration — Not applicable.

(b) Method of mounting — Securely fastened by normal mounting means.

(c) Duration of vibration — 3 hours (1 hr. in each direction).

(d) Electrical-load conditions — Rated voltage and rated current (see 3.1) shall be applied continuously during vibration.

(e) Tests during vibration. Attached instrumentation shall be such as to indicate intermittent open- or short-circuiting.

(f) Examination after test — Filters shall be visually examined for evidence of physical damage.

4.6.13.2 *High frequency (grades 2 and 3).* Filters shall be tested in accordance with method 204 of Standard MIL-STD-202. The following details and exceptions shall apply.

(a) Mounting of specimens — Filters shall be rigidly mounted by the body.

(b) Electrical-load conditions — As specified in 4.6.13.1(d).

(c) Test-condition letter — A for grade 2; B for grade 3.

(d) Tests during vibration — During the last cycle in each direction, an electrical measurement shall be made to determine intermittent open- or short-circuiting.

(e) Examination after test — As specified in 4.6.13.1(f).

4.6.14 *Salt spray (corrosion) (see 3.18)*. Filters shall be tested in accordance with method 101 of Standard MIL-STD-202. The following details and exception shall apply:

(a) Test-condition letter — As specified (see 3.1).

(b) Measurements after exposure — Not applicable.

(c) Visual examination — After the test, filters shall be visually examined for corrosion (see 3.18) and obliteration of marking.

4.6.15 *Temperature and immersion cycling (see 3.19)*.

4.6.15.1 *Temperature cycling*. Filters shall be tested in accordance with method 102 of Standard MIL-STD-202. The following detail and exception shall apply:

(a) Test-condition letter — D.

(b) Measurements before and after cycling — Not applicable.

4.6.15.2 *Immersion cycling*. Following temperature cycling, filters shall be tested in accordance with method 104 of Standard MIL-STD-202. The following details shall apply:

(a) Test-condition letter — A.

(b) Measurement after final cycle — Dielectric withstanding voltage with 90 percent of the voltage specified in 4.6.5 applied for 5 ± 1 seconds, insulation resistance, and insertion loss (check test) shall be measured as specified in 4.6.5, 4.6.6, and 4.6.8.1, respectively.

(c) Visual examination — After the test, filters shall be visually examined for corrosion (see 3.18) and obliteration of marking.

4.6.16 *Moisture resistance (see 3.20)*. Filters shall be tested in accordance with method 102, test condition D, of Standard MIL-STD-202, except that no measurements shall be made before and after cycling. Filters shall then be tested in accordance with method 106 of Standard MIL-STD-202. The following details and exceptions shall apply:

(a) Mounting — Securely fastened by normal mounting means.

(b) Initial measurements — Not applicable.

(c) Polarization voltage — During steps 1 to 6, inclusive, a dc potential of 100 volts shall be applied between the terminals and case. The potential applied to the terminals shall be positive with respect to the case.

(d) Final measurements — Following the 24-hour conditioning period, dielectric withstanding voltage with 90 percent of the voltage specified in 4.6.5 applied for 5 ± 1 seconds, insulation resistance, and insertion loss (check test) shall be measured as specified in 4.6.5, 4.6.6, and 4.6.8.1, respectively.

(e) Visual examination — After the test, filters shall be visually examined for corrosion (see 3.18) and obliteration of marking.

4.6.17 *Life*. Filters shall be energized with rated current at rated frequency, and with the specified percent of rated voltage (see 3.1) applied between the terminals and the case for a period of 250 ± 8 hours. During this test, the filters shall be suspended by their terminals within a test chamber and maintained at the specified maximum operating temperature (see 3.1) throughout the test. The filters shall be separated from each other by a distance of not less than 1 inch, to allow free circulation of air past all surfaces of each filter. During the life test, radiant shields may be placed between units so that the overheating of one filter will not affect a nearby filter. Upon completion of the life test, dielectric withstanding voltage with 90 percent of the voltage specified in 4.6.5 applied for 5 ± 1 seconds, insulation resistance, and insertion loss (check test) shall be measured as specified in 4.6.5, 4.6.6, and 4.6.8.1, respectively (see 3.21).

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging (see 6.1).

5.1.1 *Level A.* Filters shall be individually protected and unit-packaged in accordance with method III of Specification MIL-P-116. Prior to packaging, mounting hardware shall be assembled to the filter. Unless otherwise specified (see 6.1), five unit packages or a multiple thereof shall be further packaged in intermediate containers conforming to Specification PPP-B-566, PPP-B-665, or PPP-B-676. The gross weight of the intermediate container shall not exceed 10 pounds.

5.1.2 *Level C.* Filters shall be afforded preservation and packaging in accordance with the manufacturer's normal commercial practice.

5.2 Packing (see 6.1).

5.2.1 *Level A.* Filters packaged as specified (see 6.1) shall be packed in overseas-type wirebound wood, wood-cleated fiberboard, wood-cleated plywood, nailed wood, fiber (class 2 or 3, as specified (see 6.1)), or wood-cleated paper-overlaid boxes conforming to Specification PPP-B-585, PPP-B-591, PPP-B-601, PPP-B-621, PPP-B-636, and MIL-B-10377, respectively, at the option of the manufacturer. Shipping containers shall have case liners conforming to Specification MIL-L-10547; the case liners shall be closed and sealed in accordance with the appendix thereto. Case liners for boxes conforming to Specification PPP-B-636 may be omitted provided the center and edge seams and manufacturers' joints are sealed with tape, at least 1½ inches wide, conforming to Specification PPP-T-76. Box closures and strapping shall be as specified in the applicable box specification or appendix thereto. Fiber boxes conforming to Specification PPP-B-636 may be banded with tape conforming to type IV of Specification PPP-T-97 and appendix thereto in lieu of steel straps. The gross weight of wood boxes shall not exceed 200 pounds; fiberboard boxes shall not exceed the weight limitations of the applicable box specification.

5.2.2 *Level B.* Filters packaged as specified (see 6.1) shall be packed in domestic-type wirebound wood, wood-cleated fiberboard, wood-cleated plywood, nailed wood, fiber (class 1 or 2, as specified (see 6.1)), or wood-cleated paper-overlaid boxes conforming to Specifications PPP-B-585, PPP-B-601, PPP-B-621, PPP-B-636, and MIL-B-10377, respectively, at the option of the manufacturer. Box closures shall be as specified in the applicable box specification or appendix thereto. The gross weight of wood boxes shall not exceed 200 pounds; fiberboard boxes shall not exceed the weight limitations of the applicable box specification.

5.2.3 *Level C.* Filters packaged as specified (see 6.1) shall be packed in containers of the type, size, and kind commonly used for the purpose, in a manner that will insure acceptance by common carrier and safe delivery at destination. Shipping containers shall comply with the Uniform Freight Classification Rules, or regulations of other carriers as applicable to the mode of transportation.

5.2.4 *General.* Insofar as possible and practical, exterior containers shall be uniform in shape and size, shall be of minimum cube and tare consistent with the protection required, and shall contain identical quantities of identical items.

5.3 Marking. In addition to any special marking required by the contract or order, unit packages, intermediate packages, and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129 (see 6.1).

6. NOTES

6.1 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Title, number, and date of the applicable detail specification, and the complete type designation (see 1.2.1 and 3.1).

(c) Levels of preservation and packaging and packing, and applicable marking (see sec. 5).

(d) Number of unit packages if other than that specified in 5.1.1.

(e) Class of fiber (see 5.2.1 and 5.2.2).

6.1.1 *For filter types not covered by this specification.* Procurement documents should specify the following:

(a) Title, number, and date of this specification.

(b) Voltage, current, and frequency ratings.

(c) Type of impregnant.

(d) Case, terminal, and mounting dimensions.

(e) Weight.

(f) Filter marking.

(g) Maximum operating temperature.

(h) Altitude (sea level or high altitude (50,000 feet)).

(i) Minimum capacitance to ground.

(j) Maximum temperature rise.

(k) Insulation resistance at room temperature and at maximum operating temperature.

(l) Maximum voltage drop.

(m) Insertion-loss characteristic.

(n) Overload requirement (percent of rated current).

(o) Terminal pull.

(p) Manufacturer's name and part number.

(q) Government identification number, if applicable.

(r) Levels of preservation and packaging and packing, and applicable marking (see sec. 5).

(s) Number of unit packages, if other than that specified in 5.1.1.

(t) Class of fiber (see 5.2.1 and 5.2.2).

6.1.2 *Indirect shipments.* The packaging, packing, and marking specified in section 5 apply only to direct purchases by or direct shipments to the Government and are not intended to apply to contracts or orders between the manufacturer and prime contractor.

6.2 Qualification. With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is Signal Corps; however, information pertaining to qualification of products may be obtained from the Armed Services Electro-Standards Agency (ASESA), Fort Monmouth, N. J.

6.3 **Solder coating.** It is intended that solder coatings on parts used for terminals withstand extended storage without deterioration of soldering qualities or appreciable increase in resistance. Pure-tin coatings usually do not store satisfactorily.

Notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:
Army—Signal Corps
Navy—Bureau of Ships
Air Force

Preparing activity:
Army—Signal Corps

APPENDIX

PROCEDURE FOR QUALIFICATION INSPECTION

10. SCOPE

10.1 This appendix details the procedure for submission of samples, with related data, for qualification inspection of filters covered by this specification. The procedure for extending qualification of the required sample to other filters covered by this specification is also outlined herein.

20. SUBMISSION

20.1 **Sample.** A sample consisting of 13 specimens of the highest current rating in each insertion-loss characteristic for which qualification is sought shall be submitted. Each sample shall be accompanied with the following information:

- (a) Attenuation curve in accordance with Standard MIL-STD-220.
- (b) Certification as to the flashpoint of the impregnant or potting compound based on the Cleveland-cup process (see 4.6.11), or a minimum of 200 cubic centimeters of the impregnant used in the filters.
- (c) Schematic diagram of the filter, including nominal values of the components.

20.1.1 *Alternate terminals.* When qualification for a specific style of filter has been granted in accordance with 30.1 and qualification is sought for an alternate terminal design, seven filters of the same style, with the alternate terminal design for which qualification is sought, shall be submitted (see 30.1.1).

20.2 **Test data.** Each submission shall be accompanied by test data covering the nondestructive tests listed in table IX which have been performed on the submitted specimens. The performance of the destructive tests by the manufacturer on a duplicate set of specimens is encouraged, although not required. All test data shall be submitted in duplicate.

20.3 **Certification of material.** When submitting samples for qualification, the manufacturer shall submit certification, in duplicate, that the materials used in his filters are in accordance with the applicable specification requirements.

20.4 **Description of items.** The manufacturer shall submit a detailed description of the filters being submitted for test, including the type and quantity of impregnant; material, thickness, and applied finish of case; and details of the terminal.

30. EXTENT OF QUALIFICATION

30.1 Current-rating qualification will be restricted to values equal to and less than the current rating submitted. Qualification of one insertion-loss characteristic may be the basis for qualification of another insertion-loss characteristic, as indicated in table XVI. Qualification of one style may be the basis for qualification of another style, as indicated in table XVII, provided that the internal design and impregnants are the same. Qualification of grade 3 may be the basis for qualification of grades 1 and 2, or qualification of grade 2 may be the basis for qualification of grade 1, provided that the internal design and impregnants are the same.

TABLE XVI. *Insertion-loss qualification*

Qualification of characteristic	May also qualify characteristic
D	B, C
J	H
L	K

TABLE XVII. *Style qualification*

Qualification of style	May also qualify style
FL56	FL51
FL57	FL53
FL58	FL54

30.1.1 *Alternate terminals.* Each submission of filters using an alternate terminal (see 20.1.1) will confer eligibility for qualification of the terminal submitted, in accordance with the existing qualification of the style inspected.

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MIL-F-15733D
SUPPLEMENT 1
22 MARCH 1960

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, GENERAL SPECIFICATION FOR

This supplement forms a part of Military Specification MIL-F-15733D, and has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

DETAIL SPECIFICATIONS

MIL-F-15733/1 — Filters, Radio Interference, Style FL22.

MIL-F-15733/2 — Filters, Radio Interference, Style FL24.

MIL-F-15733/3 — Filters, Radio Interference, Styles FL51 and FL56.

MIL-F-15733/4 — Filters, Radio Interference, Styles FL53 and FL57.

MIL-F-15733/5 — Filters, Radio Interference, Styles FL54 and FL58.

MIL-F-15733/1
23 MARCH 1960

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, STYLE FL22

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers the detail requirements for style FL22 tubular filters. These filters are suitable for operation over the temperature range of −55° to +85°C, inclusive.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification

SPECIFICATIONS

MILITARY

MIL-F-15733 — Filters, Radio Interference, General Specification for.

(Copies of specifications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General. Requirements shall be in accordance with Specification MIL-F-15733, and as specified herein.

3.2 Design and construction. Filters shall be of the design, construction, and physical dimensions specified on figure 1

3.3 Temperature rise. The temperature rise shall not exceed 25° C.

3.4 Voltage drop. The voltage drop shall not exceed 0.5 volt.

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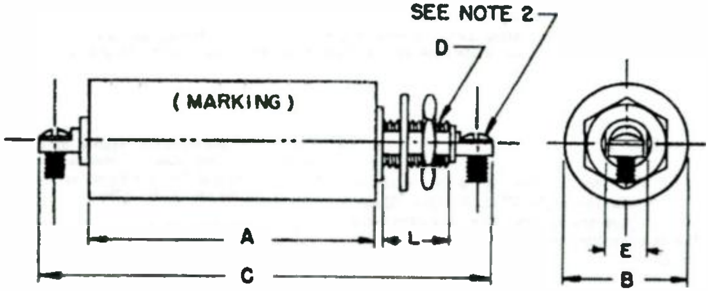


1 All dimensions in inches
2 Filter is also available with solder-lug and threaded-stud terminals
3 Mounting hardware shall be supplied with the filter

FIGURE 1. *Style FL22 filter*

Type designation [1]	Rated voltage	Rated current	Insertion-loss characteristic	Dimensions						Available terminal identification letter		
				A±1/16	B±1/16	C maximum	D	E	L	Terminal 1	Terminal 2	Terminal 3
	Volts dc	Amp.		Inches	Inches	Inches	Thread	Inch	Inch			
FL22DD	100	1	D	2 3/32	3/4	3 19/32	5/16-24 UNEF-2A	0.245-0.255	0.281	E	...	J, L
FL22FB	100	5	B	2 3/8	1	4 7/16	1/2-28 UNEF-2A	0.435-0.445	0.375	E	G, H	J, K
FL22FD	100	5	D	2 3/4	1	4 13/16	1/2-28 UNEF-2A	0.435-0.445	0.375	E	G, H	J, K
FL22GB	100	10	B	2 3/4	1 1/8	4 13/16	7/16-20 UNEF-2A	0.365-0.375	0.375	E	G, H	J, K
FL22GD	100	10	D	2 1/2	1 1/4	4 11/32	5/8-24 NEF-2A	0.525-0.535	0.375	E	G, H	J, K
FL22JD	100	20	D	3	1 3/8	4 21/32	5/8-24 NEF-2A	0.525-0.535	0.375	...	G, H	J, K
FL22LD	100	30	D	3 1/4	1 1/2	5 5/16	3/4-20 UNEF-2A	0.650-0.660	0.375	...	G, H	J, K

[1] Complete type designation will include symbols to indicate type of terminals operating temperature range, and grade.

FIGURE 1.—Continued

4.1 **Sampling and inspection.** Sampling and inspection shall be in accordance with Specification MIL-F-15733, and as specified herein.

4.2 **Terminal strength.** Terminal strength is not applicable.

4.3 **Salt spray (corrosion).** Filters shall be tested in accordance with test condition A.

4.4 **Life.** A potential of 140 percent of rated dc voltage shall be applied between the terminals.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-F-15733.

6. NOTES

6.1 The notes specified in Specification MIL-F-15733 are applicable to this specification.

Custodians:
- Army—Signal Corps
- Navy—Bureau of Ships
- Air Force

Preparing activity:
- Army—Signal Corps

☆ U. S. GOVERNMENT PRINTING OFFICE: 521511—1960—(602)

MIL-F-15733/3
22 MARCH 1960

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, STYLES FL51 AND FL56

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers the detail requirements for bathtub style FL51 (flange-mount) and FL56 (bulkhead-mount) filters. These filters are suitable for operation over the temperature range of −55° to +85°C., inclusive.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY

MIL–F–15733 — Filters, Radio Interference, General Specification for.

(Copies of specifications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General. Requirements shall be in accordance with Specification MIL–F–15733, and as specified herein.

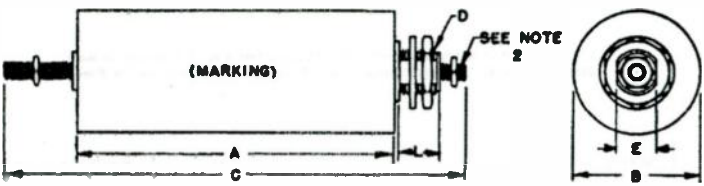
3.2 Design and construction. Filters shall be of the design, construction, and physical dimensions specified on figure 1.

3.3 Temperature rise. The temperature rise shall not exceed 25°C.

3.4 Voltage drop. The voltage drop shall not exceed 0.5 volt.

4. QUALITY ASSURANCE PROVISIONS

FSC 5915



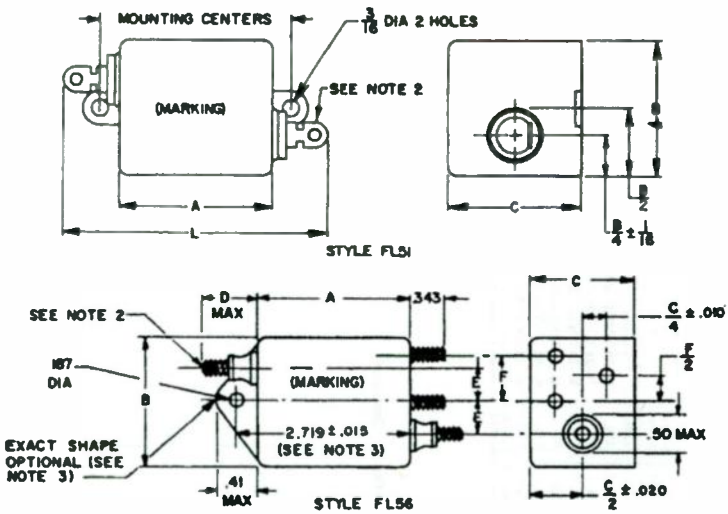
1 All dimensions in inches.
2 Filter is also available with permanent-stud (radially tapped) and solder-lug terminals
3 Mounting hardware shall be supplied with the filter

FIGURE 1. *Style FL34 filter*

Type designation [a]	Rated voltage		Rated current	Insertion-loss characteristic	Dimensions						Available terminal identification letter		
					A±1/16	B±1/16	C maximum	D	E	L	Terminal 1-	Terminal 2-	Terminal 3-
	Volts dc	*Volts ac*	*Amp.*		*Inches*	*Inches*	*Inches*	*Thread*	*Inches*	*Inch*			
FL24DD	400	125	1	D	2 9/16	5/8	4 1/32	½-28 UNEF-2A	0.435-0.445	0.375	E	....	J, L
FL24FD	400	125	5	D	3 3/8	1 1/8	5 5/8	5/8-24 UNEF-2A	0.525-0.535	0.375	E	....	J, L
FL24GD	400	125	10	D	3 3/8	1 1/8	5 15/16	¾-20 UNEF-2A	0.650-0.660	0.375	E	G, H	J, K
FL24HD	400	125	15	D	4 1/8	1 3/8	6 5/16	¾-20 UNEF-2A	0.650-0.660	0.375	....	G, H	J, K
FL24JD	400	125	20	D	4 9/32	1 1/8	6 9/32	¾-20 UNEF-2A	0.650-0.660	0.375	....	G, H	J, K
FL24MD	400	125	50	D	4 1/8	2 1/4	6 5/16	1 1/16-18 NEF-2A	1.050-1.060	0.500	....	G, H	J, K

[a] Complete type designation will include symbols to indicate type of terminals, operating temperature range, and grade.

FIGURE 1.—Continued



1 All dimensions in inches
2 Filters also available with radially-tapped permanent-stud terminals
3 Applicable to 50-ampere filters only

FIGURE 1. *Styles FL51 and FL56 filters*

Type designation [1]	Rated voltage	Rated current	Insertion-loss characteristic	Dimensions								Available terminal identification letter		
				A±1/16	B±1/16	C±1/16	D max.	[2] E±.03	[2] F±.015	L max.	Mtg ctr [3]	Terminal 1	Terminal 2	Terminal 3
	Volts dc	Amp.		Inches	Inches	Inches	Inch	Inch	Inch	Inches	Inches			
FL5-DD	100	1	D	1⅝	1¼	⅝	0.62	0.281	0.312	3 13/32	2⅛	E	...	J, L
FL5-ED	100	3	D	1⅝	1¼	1	0.62	0.281	0.312	3 13/32	2¼	E	...	J, L
FL5-FB	100	5	B	1⅝	1¼	1⅛	0.62	0.281	0.562	3 13/32	2⅛	E	...	J, L
FL5-FD	100	5	D	2	2	1	0.88	0.50	0.562	3 13/32	2⅜	E	...	J, L
FL5-GD	100	10	D	2	2	1⅛	0.88	0.50	0.562	3 13/32	2⅜	...	G, H	J, K
FL5-HD	100	15	D	2	2	1¼	0.88	0.50	0.562	3 13/32	2⅜	...	G, H	J, K
FL5-LB	100	30	B	2	2	1⅛	0.88	0.50	0.562	3 13/32	2⅜	...	G, H	J, K
FL5-LD	100	30	D	2⅛	2	1⅜	0.88	0.50	0.562	4 7/32	2 11/16	...	G, H	J, K
FL5-MB	100	50	B	2⅜	2¼	1 5/16	0.88	0.50	0.562	4 13/32	3⅛	...	G, H	J, K
FL5-MD	100	50	D	2⅜	2¼	1⅜	0.88	0.50	0.562	4 13/32	3⅛	...	G, H	J, K

[1] Complete type designation will include symbols to complete style designation and to indicate type of terminals, operating temperature range, and grade.
[2] Applicable to style FL44 only.
[3] Applicable to style FL41 only.

FIGURE 1.—Continued

4.1 Sampling and inspection. Sampling and inspection shall be in accordance with Specification MIL-F-15733, and as specified herein.

4.2 Terminal strength. Terminal strength is not applicable.

4.3 Salt spray (corrosion). Filters shall be tested in accordance with test condition A.

4.4 Life. A potential of 140 percent of rated voltage shall be applied between one of the terminals and the case.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-F-15733.

6. NOTES

6.1 The notes specified in Specification MIL-F-15733 are applicable to this specification.

Custodians:
Army—Signal Corps
Navy—Bureau of Ships
Air Force

Preparing activity:
Army—Signal Corps

☆ U. S. GOVERNMENT PRINTING OFFICE: 521511—1960—(600)

MIL-F-15733/4
22 MARCH 1960

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, STYLES FL53 AND FL57

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers the detail requirements for bathtub style FL53 (flange-mount) and FL57 (bulkhead-mount) filters. These filters are suitable for operation over the temperature range of — 55° to + 85° C., inclusive, and the frequency range of 0 to 400 cycles per second, inclusive.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY

MIL-F-15733 — Filters, Radio Interference, General Specification for.

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer).

3. REQUIREMENTS

3.1 General. Requirements shall be in accordance with Specification MIL-F-15733, and as specified herein.

3.2 **Design and construction.** Filters shall be of the design, construction, and physical dimensions specified on figure 1.

3.3 **Temperature rise.** The temperature rise shall not exceed 25° C.

3.4 **Voltage drop.** The voltage drop shall not exceed 0.5 volt.

4. QUALITY ASSURANCE PROVISIONS

4.1 **Sampling and inspection.** Sampling and inspection shall be in accordance with Specification MIL-F-15733, and as specified herein.

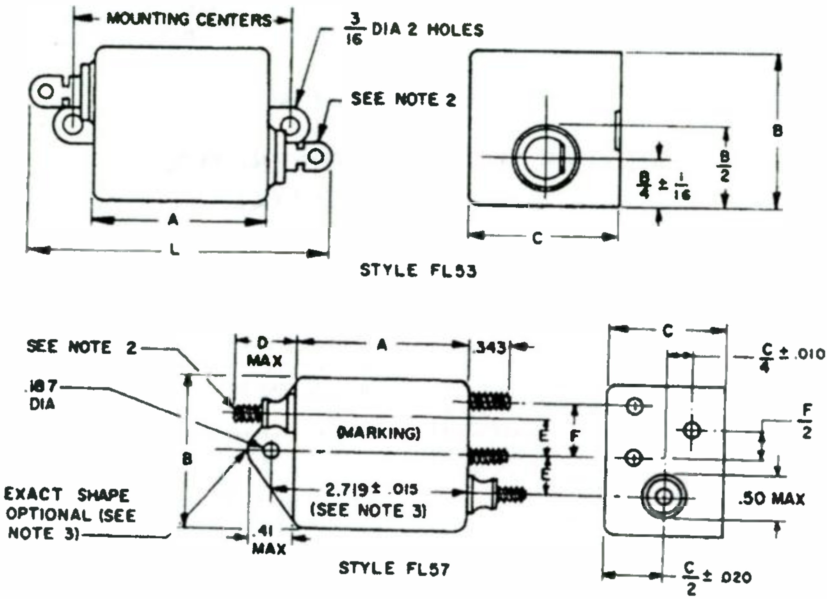
4.2 **Terminal strength.** Terminal strength is not applicable.

4.3 **Salt spray (corrosion).** Filters shall be tested in accordance with test condition A.

4.4 **Life.** A potential of 140 percent of rated dc voltage shall be applied between one of the terminals and the case.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-F-15733.



1 All dimensions in inches

2 Filters also available with radially-tapped permanent-stud terminals

3 Applicable to 50-ampere filters only

FIGURE 1. *Styles FL53 and FL57 filters.*

Type designation[1]	Rated voltage		Rated current	Insertion-loss characteristic	Dimensions								Available terminal identification letter		
					A±1/16	B±1/16	C±1/16	D max	[2]E±.02	[3]F±.015	L max	Mtg ctrs[2]	Terminal 1-	Terminal 2-	Terminal 3-
	Volts ac	Volts dc	Amperes		Inches	Inches	Inches	Inch	Inch	Inch	Inches	Inches			
FL5-DD	125	400	1	D	1⅝	1⅝	⅝	0.62	0.281	0.312	3 15/16	2¼	E	——	J, L
FL5-ED	125	400	3	D	2	2	⅝	0.88	0.50	0.562	3 15/16	2⅜	E	——	J, L
FL5-FD	125	400	5	D	2	2	1⅛	0.88	0.50	0.562	3 15/16	2⅜	E	——	J, L
FL5-GD	125	400	10	D	2	2	1½	0.88	0.50	0.562	3 15/16	2⅜	——	G, H	J, K
FL5-HB	125	400	15	B	2⅛	2	1⅛	0.88	0.50	0.562	4 5/16	2 15/16	——	G, H	J, K
FL5-HD	125	400	15	D	2⅛	2	1¾	0.88	0.50	0.562	4 5/16	2 15/16	——	G, H	J, K
FL5-LB	125	400	30	B	2⅛	2	2⅛	0.88	0.50	0.562	4 5/16	2 15/16	——	G, H	J, K
FL5-LD	125	400	30	D	3¼	2¼	2⅛	0.88	0.50	0.562	4 21/32	3⅜	——	G, H	J, K
FL5-LB	125	400	50	B	3 9/16	2⅝	2⅛	0.88	0.50	0.562	4 23/32	3 1/16	——	G, H	J, K
FL5-LD	125	400	50	D	3 9/16	2 15/16	2⅛	0.88	0.50	0.562	5 1/32	3 15/16	——	G, H	J, K

[1] Complete type designation will include symbols to complete style designation and to indicate type of terminals, operating temperature range, and grade.
[2] Applicable to style FL57 only.
[3] Applicable to style FL53 only.

FIGURE 1. *Continued.*

6. NOTES

6.1 The notes specified in Specification MIL-F-15733 are applicable to this specification.

Notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:
- Army—Signals Corps
- Navy—Bureau of Ships
- Air Force

Preparing activity:
- Army—Signals Corps

U. S. GOVERNMENT PRINTING OFFICE 1960

MILITARY SPECIFICATION

FILTERS, RADIO INTERFERENCE, STYLES FL54 AND FL58

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers the detail requirements for bathtub style FL54 (flange-mount) and FL58 (bulkhead-mount) filters. These filters are suitable for operation over the temperature range of —55° to +85°C., inclusive, and the frequency range of 0 to 400 cycles per second, inclusive.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification.

SPECIFICATIONS

MILITARY

MIL-F-15733 — Filters, Radio Interference, General Specification for.

(Copies of specifications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 **General.** Requirements shall be in accordance with Specification MIL-F-15733, and as specified herein.

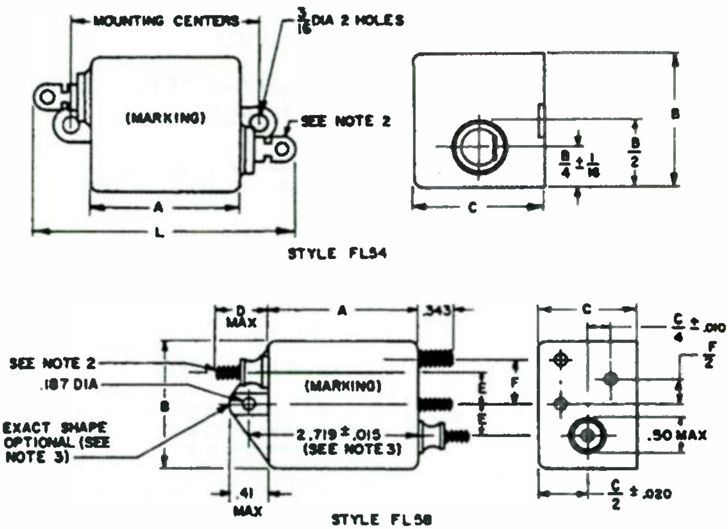
3.2 **Design and construction.** Filters shall be of the design, construction, and physical dimensions specified in figure 1.

3.3 **Temperature rise.** The temperature rise shall not exceed 25°C.

3.4 **Voltage drop.** The voltage drop shall not exceed 0.5 volt.

4. QUALITY ASSURANCE PROVISIONS

FSC 5915



1 All dimensions in inches
2 Filters also available with radially-tapped permanent-stud terminals
3 Applicable to 50-ampere filters only.

Figure 1. *Styles FL54 and FL58 filters*

Type designation [1]	Rated voltage		Rated current	Insertion-loss characteristic	Dimensions								Available terminal identification letter		
					A±1/16	B±1/16	C±1/16	D maximum	[2] E±.03	[2] F±.015	L maximum	Mtg centers [3]	Terminal 1-	Terminal 2-	Terminal 3-
	Volts ac	*Volts dc*	*Amp.*		*Inches*	*Inches*	*Inches*	*Inch*	*Inch*	*Inch*	*Inches*	*Inches*			
FLS–DD	250	600	1	D	1⅜	1¼	1	0.62	0.281	0.312	3 11/32	2⅛	E	...	J, L
FLS–ED	250	600	3	D	2	2	1	0.88	0.50	0.562	3 15/32	2⅜	E	...	J, L
FLS–FD	250	600	5	D	2	2	1¼	0.88	0.50	0.562	3 15/32	2⅜	E	...	J, L
FLS–GD	250	600	10	D	2	2	1¼	0.88	0.50	0.562	3 15/32	2⅜	...	G, H	J, K
FLS–HB	250	600	15	B	2⅛	2	1⅜	0.88	0.50	0.562	4 5/32	2 15/16	...	G, H	J, K
FLS–HD	250	600	15	D	2⅜	2⅛	1¼	0.88	0.50	0.562	4 5/32	3¼	...	G, H	J, K
FLS–LD	250	600	20	D	3 1/16	2⅜	2⅛	0.88	0.50	0.562	4 21/32	3 11/16	...	G, H	J, K
FLS–MB	250	600	50	B	3 1/16	3 1/16	2⅛	0.88	0.50	0.562	4 21/32	3 11/16	...	G, H	J, K
FLS–MD	250	600	50	D	3⅛	3⅛	2⅛	0.88	0.50	0.562	5 5/32	4¼	...	G, H	J, K

[1] Complete type designation will include symbols to complete designation and to indicate type of terminals, operating temperature range, and grade.
[2] Applicable to style FLS3 only.
[3] Applicable to style FLS4 only.

FIGURE 1.—Continued

4.1 **Sampling and inspection.** Sampling and inspection shall be in accordance with Specification MIL-F-15733, and as specified herein.

4.2 **Terminal strength.** Terminal strength is not applicable.

4.3 **Salt spray (corrosion).** Filters shall be tested in accordance with test condition A.

4.4 **Life.** A potential of 140 percent of rated dc voltage shall be applied between one of the terminals and the case.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-F-15733.

6. NOTES

6.1 The notes specified in Specification MIL-F-15733 are applicable to this specification.

Notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:
Army—Signal Corps
Navy—Bureau of Ships
Air Force

Preparing activity:
Army—Signal Corps

☆ U. S. GOVERNMENT PRINTING OFFICE: 521511—1960—(685)

MIL-I-16165D(SHIPS)
22 August 1961
SUPERSEDING
MIL-I-16165C(SHIPS)
25 November 1955

MILITARY SPECIFICATION

INTERFERENCE SHIELDING, ENGINE ELECTRICAL SYSTEMS

1. SCOPE

1.1 This specification covers requirements for interference shielding items and shielded harnesses for engine electrical systems aboard Naval ships, at advance bases, and in the vicinity of electronic installations. It includes the allowable interference limits for such items and the permissible limits for auxiliary devices normally installed on electrical wiring systems associated with these engines.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY
MIL-E-16400 - Electronic Equipment, Navy Ship and Shore: General Specification.
MIL-I-16910 - Interference Measurement, Radio Methods and Limits, 14 Kilocycles to 1000 Megacycles.

STANDARDS

MILITARY
MIL-STD-167 - Mechanical Vibrations of Shipboard Equipment.

AIR FORCE-NAVY
AN-D10206 - Plugs-Shielded Aircraft Engine Spark.
AN-4164 - Sleeve-Spark Plug Terminal.

DRAWINGS

BUREAU OF SHIPS
9000-S6202-73724 - Salt Spraying Machine.
RE49A501 - Couplings, Spherical Seat, Design Data.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications.- The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

NATIONAL BUREAU OF STANDARDS
PUBLICATION
Handbook H-28 - Screw Thread Standards for Federal Services.

(Applications for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington 25, D.C.)

OFFICIAL CLASSIFICATION COMMITTEE
Uniform Freight Classification Rules.

(Application for copies should be addressed to the Official Classification Committee, Park Avenue at 33rd Street, New York 16, N.Y.)

3. REQUIREMENTS

3.1 Qualification.- The interference shielding electrical systems furnished under this specification shall be a product which has been tested and passed the qualification tests specified herein and has been listed or approved for listing on the applicable qualified products list.

3.2 Design objective.- Reliability of operation shall be stressed throughout the design and manufacture of the shielding.

3.2.1 Reliability.- The shielding will be subjected to continuous use for long periods under the varied and severe conditions of Military service without overhaul and with little maintenance. If it is to meet these conditions it is imperative that reliability of operation be considered of prime importance in the design and manufacture of the shielding. The manufacture shall employ all methods possible in the process of manufacture which will assure quality and maximum reliability consistent with the state of the art. In the functional application of parts to equipment circuits, adequate factors of safety shall be provided in order to insure high equipment reliability under all service conditions. The design shall include all possible features which will result in reliable and stable operation with reduced requirements for adjustment and alignment, reduced frequency of

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failure, reduced requirement for maintenance and simplified maintenance thus reducing requirements for highly skilled maintenance personnel.

3.3 Definitions.- The definitions specified in 3.3.1 through 3.3.4 shall apply to this specification.

3.3.1 Shielded harness.- A metal covering intimately and totally enclosing and shielding the engine ignition wiring system (not a box).

3.3.2 Shielding item.- Parts, the whole number of which comprise a shielding harness.

3.3.3 Assembly.- A complete equipment, one unit of which is an internal combustion engine.

3.3.4 Enclosure.- A box which encloses a part of the ignition system. Such parts are distributors, magnetors, and such.

3.4 Composition.- The shielding items directly associated with engine electrical systems shall be any of the following as specified (see 6.1): These items when assembled together comprise a shielded electrical harness.

(a) Spark plugs shielded.
(b) Cable shielding.
(c) Connectors.
(d) Enclosures.
(e) Filters.
(f) Cable terminal.

3.5 Devices associated with the primary electrical system such as generator and regulator, and devices associated with the general electrical system such as relays, heaters, windshield wipers, pumps, fans, gauges, and signal devices shall comply with the interference limits specified in 3.14.

3.6 Suitability.- Shielding items shall not adversely affect the operation of the engines on which they are installed.

3.7 Protection against corrosion.- Metal parts shall be of corrosion-resisting materials or other materials treated in a manner to render them resistant to corrosion when tested as specified in 4.3.6.

3.8 Coupling fittings.- Coupling fittings may be bored for safety wiring to prevent loosening under vibration.

3.9 Assembly and maintenance.- Shielding items shall be easily assembled and maintained with a minimum of upkeep by normal maintenance personnel. No special tools shall be required. Special tools are defined as those tools not listed in the Catalog of Naval Material, General Stores Section. (Copies of this catalog may be consulted in the office of the Government inspector.)

3.10 Joints.- Cable shielding shall be joined to enclosures, fittings, or connectors by means of brazing, welding, or soldering. The seal when accomplished shall be mechanically secure, and electrically meet the requirements of this specification.

3.11 Dissimilar metals.-

3.11.1 Except where required for electric reasons including grounding, contact between dissimilar metals shall be avoided. If dissimilar metals are used, they shall be selected in accordance with Specification MIL-E-16400.

3.11.2 Where it is necessary that stationary dissimilar metals be assembled in intimate contact with each other and electrical conductivity is nonessential, an interposing material compatible to each shall be used. Zinc-chromate primer, or equivalent, is acceptable. Insulating material will not be required between austenitic corrosion-resistant steel inserts and aluminum castings.

3.12 Shielding items.-

3.12.1 Spark plug shielding shall be in accordance with Standard AN-D10206 and shall be capable of withstanding the torque test specified in 4.3.2. The assembly of the cable terminal within the plug shield shall be in accordance with Part Number AN-4164-2 or AN-4164-4 of Standard AN-4164. The plug shall be sealed against entrance of moisture from the cable of shielding conduit.

3.12.1.1 The sleeve of the cable terminal assembly, if ceramic, shall be of fired glazed aluminum oxide type ceramic. If other materials are used, they shall be equally resistant to heat, breakage, and tearing and evidence to this effect shall be furnished the Government inspector.

3.12.1.2 Rubber materials of the cable terminal assembly shall be one of the following two types as specified (see 6.1), and shall be capable of withstanding without deterioration, the temperature tests specified in 4.3.8.

(a) Type NT - 250°F.
(b) Type HT - 400°F.

3.12.2 Cable shielding conduit.- Cable shielding flexible conduit utilized with engines or interconnections with associated equipment shall be double braid over sealed bellows conduit of a type approved by the bureau or agency concerned. Brass bellows-type inner cores shall contain a minimum of 80 percent copper in copper-zinc alloy. Additional corrosion-resistant treatment of conduit, such as iridite 17P, may be used when specified (see 6.1). The metal band identifying the manufacturer of the shielding conduit shall be retained permanently on the shielded ignition harness.

3.12.3 Shielding cable connectors. - Connectors, except connection with spark plug, shall be of the spherical seat type as shown on Drawing RE49A501. Material thickness may be varied from the dimensions shown to obtain the required strength. Connectors shall meet the tests specified in 4.3.1 to 4.3.7 inclusive. The spark plug connector shall incorporate a flat seat ferrule and shall fit the plug as shown on Standard AN-D10206. Connectors of other design shall be submitted for approval of the bureau or agency concerned.

3.12.4 Shielding enclosures. - Shielding enclosures, other than hermetically sealed units, shall utilize one of the following type of joints, as applicable, between base and cap:

(a) Type SC - Spherical-cone seating.
(b) Type MF - Multiple face joint.
(c) Type F - Flat joint - The minimum width of face shall be 5/16 inch.
(d) Type WT - Watertight - When specified (see 6.1), type WT shall be watertight, shall be constructed of Naval brass, and shall be any one type of joint as specified in (a), (b) or (c) above.

3.12.4.1 Gaskets. - Gaskets, if used, shall be of metallic construction. The gasket shall remain firmly in place on the joint face of either base or cap during disassembly and reassembly.

3.12.4.2 Shielding enclosures. - Shielding enclosures shall be capable of withstanding the tests specified in 4.3.1 to 4.3.7 inclusive.

3.12.4.3 Fittings. - Fittings for the joining of shielding conduit to enclosures shall be of the spherical cone seating type and capable of withstanding a tightening or twisting torque of 325-inch pounds as specified in 4.3.2.

3.12.4.4 Fastening devices. - Cover hold-down fasteners or machine screws shall conform to the thread configuration as specified in Handbook H-28 and shall be held captive on the removable cover.

3.12.4.5 Ventilation. - Enclosures containing electrical contacts shall be provided with means for ventilation where needed to prevent corrosion due to products of the sparking. Proof that ventilation would not be required shall be submitted by the manufacturer, and such proof shall be furnished with a sample unventilated enclosure submitted for qualification tests specified in 4.2.

3.12.4.6 Condensation. - Enclosures shall be provided with appropriate means for the drainage of condensation. Enclosures shall be such that engine starting, and operation shall not be adversely affected by their use.

3.12.4.7 Test lead connection. - Distributor enclosures shall incorporate one additional tower, similar to that provided for spark plug leads. This tower is for the purpose of connecting test leads expeditiously.

3.13 Temperature. - The shielding effectiveness of shielding items or harness shall not deteriorate under temperature conditions between -54°C. and +75°C. Tests relative thereto shall be performed in accordance with 4.3.5.

3.14 Interference. -

3.14.1 Shielding items, spark plugs, shielding conduit, connectors, enclosures, filters, and other devices specified in 3.5 shall be capable of meeting the interference limits of Specification MIL-I-16910 when tested in accordance with 4.3.4. Shielded harnesses shall also be capable of meeting these limits.

3.14.2 Complete assemblies shall be capable of meeting the limits specified in 3.14.1, except that, where no electronic equipment is associated with the wiring of the engine electrical system, radiated limits only shall apply in determining acceptability of the shielding.

3.14.3 Engine ignition shielding harnesses shall be marked "IF16165" in a conspicuous and durable manner after inspection.

3.15 Engines in non-critical Naval areas. - Ignition interference from internal combustion engines, in areas 1000 feet distance from electronic devices and installations, shall conform to the requirements for such engines as specified in Specification MIL-I-16910. Components other than engines, tested separately therefrom shall conform to the interference limits specified in 3.14.

3.16 New type ignition system. - Information and data concerning ignition systems other than high tension type shall be submitted to the Bureau of Ships for evaluation and approval relative to interference characteristics.

3.17 Workmanship. - Workmanship and material shall be of such quality that the shielding has electrical characteristics as specified herein, shall be sturdy, of excellent appearance, and of high standard with respect to tolerances and mechanical fit (see 4.3.1).

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Qualification tests. - Qualification tests shall be conducted at a laboratory satisfactory to the Bureau of Ships. Qualification tests shall consist of the tests specified in 4.3.

4.2.1 The minimum number of units of each type or model of shielding items to be submitted for qualification tests shall be as follows: Each item shall incorporate identification markings.

(a) Shielded spark plugs - 6.
(b) Connectors - 12.
(c) Cable shielding conduit - Sufficient for a particular engine harness, and one extra 3-foot length.
(d) Enclosures - 1 of each type (see 3.12.4).
(e) Shielding harness - 1 complete harness and such shielding items as may be required.
(f) Sleeves - 12.
(g) Rubber seals associated with sleeve - 12.

Application for Qualification tests shall be made in accordance with "Provisions Governing Qualification" (see 6.2 and 6.2.1).

4.3 Tests. -

4.3.1 Examination of test sample. - The test sample shall be examined for material, workmanship, finish, internal parts, and mechanical fits, with particular emphasis on mechanical fits and contacts, to determine conformance with this specification. Items may be rejected on the basis of this examination (see 3.17).

4.3.2 Torque test. - The shielding items shall be assembled in a harness and installed on an appropriate engine or test block. Using a torque wrench capable of measuring above 325 pound-inches, a tightening torque of 325 pound-inches shall be applied to coupling nuts, towers and fittings under test. Any cracking, breaking, or deformation shall be cause for rejection. Laboratory tests shall be performed to determine the extent of any cracking, breaking or deformation. Prior to testing, all oil, burrs, and other non-uniformities shall be removed from the threads and mating surfaces.

4.3.3 Vibration. - Vibration tests shall be performed in accordance with Standard MIL-STD-167. In preparation for this test, the shielding item shall be assembled in harness form and installed on a test block or engine. The block with harness shall be mounted on the vibration machine. During and upon completion of the test, a visual examination of the shielding item or harness under test shall be made to detect any loosening or deformation.

4.3.4 Interference tests. - Interference tests shall be performed in accordance with the applicable requirements of Specification MIL-I-16910. The tests shall be conducted following the torque and vibration tests.

4.3.5 Temperature test. -

4.3.5.1 Shielding items shall be assembled in a standard harness mounted on an appropriate test block or engine and shall be subjected to an ambient temperature of -54°C. (-65°F.) for a time period of 4 hours.

4.3.5.2 Shielding items assembled as specified in 4.3.5.1 shall be subjected to an ambient temperature of 75°C. for a time period of 4 hours.

4.3.6 Corrosion resistance. - Unless otherwise specified in the contract or order, the test sample shall be subjected to the salt spray test of 4.3.6.1. This test shall be performed after all other tests specified herein are completed. Items tested separately shall have all openings closed which are not normally exposed. Nonwatertight enclosures shall be fitted with special gaskets to preclude leakage to the interior.

4.3.6.1 Salt spray test. - Shielding items shall be subjected, under continuous ultra-violet light, to a 20 percent hot salt spray at 130°F. for a period of 3 minutes, followed by a hot air blast at 130°F. for a period of 3 minutes. The cycle shall be repeated continuously for 100 hours. Upon completion of the test, the unit shall be washed with fresh water, dried and examined. Examination after the salt spray test shall show no appreciable corrosion in or on the test sample or other damage to parts due to the salt spray. During test, all shielding shall be mounted in its normal installed position. Test equipment shall be equivalent to the Navy standard salt spraying machine as shown on Drawing 9000-S6202-73724.

4.3.7 Interference check tests. - Interference check tests shall be performed following the temperature and salt spray tests. The test shall be at frequencies at which maximum interference was obtained in the test specified in 4.3.4. Interference values shall not exceed those obtained in the test of 4.3.4 by more than 20 decibels (db).

4.3.8 Cable terminal assembly (rubber seal) temperature test.- The rubber material of the cable terminal assembly shall be placed within a tightly closed container and subjected to the degrees of temperature specified hereinafter, for a period of 6 hours. No deterioration in form or sealing properties shall occur:

(a) Type NT - 250°F.
(b) Type HT - 400°F.

4.3.9 Interference tests at the plant of the equipment builder.- Interference tests of shielding items and shielding harnesses shall consist of the following:

(a) Determine that shielding items are those which are included on the Qualified Products List.
(b) Examination of test sample (see 4.3.1).
(c) Interference measurement tests (see 4.3.9.2 and 4.3.4).

4.3.9.1 When assemblies are too large to make the tests specified in 4.3.9(c), practical consideration shall be given to requiring the testing of interference producing components separately.

4.3.9.2 Interference tests shall be performed to the fullest extent necessary to determine conformance with Specification MIL-I-16910. Testing, however, shall be minimized. To this end, satisfactory prior test reports on identical equipment of the same manufacturer with identical shielding may be accepted in lieu of further testing. A bureau or agency concerned letter of approval based on like conditions of equipment and testing may also be accepted in lieu of further interference testing.

5. PREPARATION FOR DELIVERY

5.1 Domestic shipment and early material use.-

5.1.1 Shielding.-

5.1.1.1 Preservation and packaging.- Preservation and packaging shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the using activity and until early use.

5.1.1.2 Packing.- Packing shall be accomplished in a manner which will insure acceptance by common carrier and will afford protection against physical or mechanical damage during direct shipment from the supply source to the using activity for early use. The shipping container or method of packing shall conform to the Uniform Freight Classification Rules and Regulations or other carrier regulations as applicable to the mode of transportation.

5.1.1.3 Marking.- Shipment marking information shall be provided on interior packages and exterior shipping containers in accordance with the contractor's commercial practice. The information shall include nomenclature, Federal stock number or manufacturer's part number, contract or order number, contractor's name and destination.

5.2 Domestic shipment and storage or overseas shipment.- The requirements and levels of preservation, packaging, packing and marking for shipment shall be specified by the procuring activity (see 6.1).

(5.2.1. The following provides various levels of protection during domestic shipment and storage or overseas shipment, which may be required when procurement is made.

5.2.1.1 Preservation and packaging.-

5.2.1.1.1 Level A.- The shielding shall be unit protected and packaged in accordance with method III of Specification MIL-P-116. Unit containers shall conform to Specification PPP-B-566, PPP-B-636, PPP-B-665 and PPP-B-676 at the option of the contractor. Box closure shall be as specified in the applicable box specification or appendix thereto.

5.2.1.1.2 Level C.- Preservation and packaging shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the using activity and until early use.

5.2.1.2 Packing.-

5.2.1.2.1 Level A.- Shielding, shall be packed in containers conforming to any one of the following specifications at the option of the supplier:

Specifications	Type or class
PPP-B-585	Class 3 use
PPP-B-591	Overseas type
PPP-B-601	Overseas type
PPP-B-621	Class 2
PPP-B-636	Class 2
MIL-B-10377	Overseas type

Shipping containers shall have caseliners conforming to Specification MIL-L-10547. Caseliners shall be closed and sealed in accordance with the appendix to Specification MIL-L-10547. Caseliners for class 2 fiberboard boxes conforming to Specification

PPP-B-636 may be omitted provided all corners and edge seams and manufacturer's joints are sealed with minimum 2 inch wide tape conforming to Specification PPP-T-76. Boxes shall be closed and banded in accordance with the applicable box specification or appendix thereto. The gross weight of wood or wood-cleated boxes shall not exceed 200 pounds.

5.2.1.2.2 Level B.- Shielding shall be packed in boxes conforming to any of the following specifications at the option of the supplier:

Specification	Type or class
PPP-B-585	Class 1 or 2 use
PPP-B-591	Domestic type
PPP-B-601	Domestic type
PPP-B-621	Class 1
PPP-B-636	Class 1
MIL-B-10377	Domestic type

Box closures shall be as specified in the applicable box specification or appendix thereto. The gross weight of wood or wood-cleated boxes shall not exceed 200 pounds.

5.2.1.3 Marking.- In addition to any special marking required by the contract or order, interior packages and exterior shipping containers shall be marked in accordance with Standard MIL-STD-129, and in addition shall include the electrical and mechanical operational characteristics or ratings (as applicable).)

6. NOTES

6.1 Ordering data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Shielding items required (see 3.4).
(c) Type of rubber material required (see 3.12.1.2).
(d) If additional corrosion resistant treatment of conduit is required (see 3.12.2).
(e) Whether a watertight joint is required (see 3.12.4 (d)).

6.2 With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in Qualified Products List QPL 16165, whether or not such products have actually been so listed by that date. The attention of the suppliers is called to this requirement and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the qualified products list is the Bureau of Ships, Department of the Navy, Washington 25, D.C., and information pertaining to qualification of products may be obtained from that activity. Application for Qualification tests shall be made in accordance with "Provisions Governing Qualification" (see 6.2.1).

6.2.1 Copies of "Provisions Governing Qualification" may be obtained upon application to Commanding Officer, Naval Supply Depot, 5801 Tabor Avenue, Philadelphia 20, Pennsylvania.

Preparing activity:
Navy - Ships
Project No. 2920-N006Sh

SPECIFICATION ANALYSIS SHEET

Instructions

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Bureau of Ships

This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost.

Comments and the return of this form will be appreciated.

Fold on dotted lines on reverse side, staple in corner, and send to Bureau of Ships, Specifications and Standardization Branch, Washington 25, D. C.

Specification

Organization	City	State

Contract No.

Quantity of Items Procured	Dollar Amount $

Material procured under a direct Government contract ☐ or a subcontract ☐

1. Has any part of the specification created problems or required interpretation in procurement?
   a. Give paragraph number and wording.

   b. Recommendations for correcting the deficiencies.

2. Comment on any specification requirement considered too rigid.

3. Is the specification restrictive? If the answer is "Yes", in what way?

   ☐ Yes ☐ No

4. Remarks (Attach any pertinent data which may be of use in improving this specification.)
Place this form and papers in an envelope and send to the Bureau.

Submitted by (Print name and activity)	Date

MIL-I-16910A(SHIPS)
AMENDMENT - 2
1 November 1957
SUPERSEDING
Amendment - 1
16 May 1957

MILITARY SPECIFICATION

INTERFERENCE MEASUREMENT, RADIO, METHODS AND LIMITS; 14 KILOCYCLES TO 1000 MEGACYCLES

This amendment forms a part of Military Specification MIL-I-16910A(SHIPS), 30 August 1954.

Page 2: Add as paragraph 3.1.11:

"3.1.11 Equipment spectrum signature. - An equipment spectrum signature is a summary and presentation of data showing all radio frequency energy radiations, both desired and undesired, of electronic equipments that generate electromagnetic energy for either internal or external use. It also includes the sensitivity characteristics of electronic equipment, including receivers, that are influenced by electromagnetic energy."

Page 3, table I: Delete and substitute:

"Table I - Interference measuring equipment.

Frequency range	Interference instrument	Classification[1]
15 kc. to 150 kc.	Radio Test Set AN/URM-6	I
150 kc. to 20 mc.	Radio Test Set AN/PRM-1	I
15. kc. to 40 mc.	Test Set AN/URM-3	II
20 mc. to 400 mc.	Radio Test Set AN/URM-7	II
	Noise Field Intensity Meters TS-587/U	IV
20 mc. to 400 mc.	Radio Interference Measuring Set AN/URM-47	I
150 mc. to 1000 mc.	Radio Interference Measuring Set AN/TRM-4	III
400 mc. to 1000 mc.	Radio Test Set AN/URM-17	I

[1]This classification is subject to change on reasonable notice to include new instrumentation of tested and approved superior performance characteristics."

Page 4, paragraphs 3.4.3 through 3.4.3.4: Delete and substitute:

"3.4.3 Short duration interference. - Not more than one of the following exceptions shall be granted when applicable:

"3.4.3.1 Interference of less than 1 second in duration occurring not more than once every 30 seconds shall be permitted a limit of ten times (or 20 decibels) above the limits shown on figures 8 and 11.

"3.4.3.2 Impulsive interference with a repetition rate of not more than 10 pulses per second shall be permitted a limit of two times (or 6 decibels) above the limits shown on figures 8 and 11.

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"3.4.3.3 Randomly controlled impulsive interference having average repetition rates less than 10 pulses per second shall be permitted a minimum limit of 2 times (or 6 decibels) above the limits shown on figures 8 and 11 with limit multiples for lower repetition rates as shown on figure 8a.

"3.4.3.4 Interference of less than 1 second in duration occurring not more than once every 3 minutes shall be exempt from the requirements of this specification."

Page 5, paragraph 3.6.1.1.5: Delete and substitute:

"3.6.1.1.5 Shock hazard. - Where equipment covered by this specification requires the use of radio interference filters or capacitors to comply with the interference limits and fall within the definition of portable equipment, the maximum safe values of capacitance allowed between the power line and frame or chassis of the equipment shall not exceed the value calculated with the following applicable formula:

(a) For single-phase equipments:

$$C = \frac{I}{2\pi f V}$$

(b) For three-phase equipments:

$$C = \frac{I}{\sqrt{2}\pi f V}$$

Where:
C = Capacitance in farads.
I = 0.005 ampere (maximum permissible current).
V = Phase voltage (line-to-line).
f = Power line frequency in cycles per second.

"3.6.1.1.5.1 Additional requirements. - For portable electric equipment, the general limits shown on figures 7, 8, 9 and 10, increased by a factor of ten (20 decibels) shall be applicable. Figure 53 is a graph of power line voltages for single phase equipments versus allowable capacitance for various power line frequencies."

Page 6: Add as paragraph 3.6.3.3:

"3.6.3.3 Engine generators, vehicles and miscellaneous engine-driven equipments used in noncritical areas. - The interference radiated from engine generators, vehicles and miscellaneous engine-driven equipments intended for use in noncritical areas shall not exceed the limits specified in figure 8b over the frequency range 20 to 400 megacycles when measured at a distance of 50 feet from the nearest part of the vehicle or engine-powered equipment under test. The center of the resonant dipole antenna, in vertical polarization, of the measuring instrument shall be 7 feet above ground."

Page 7: Add as paragraphs 3.8 through 3.8.6:

"3.8 Equipment spectrum signature. - All electronic equipments that generate electromagnetic energy intended for either internal or external use (including transmitting and receiving equipments, transfer or conversion equipments having local oscillators or other sources of electromagnetic energy) shall be subjected to tests to determine their radio frequency spectrum occupancy characteristics over the frequency range 14 kc. to 10 kmc. These tests shall include radiations under normal operating and switching functions of transmit, receive, tuning and band selection. Equipments intended for operation with antennas or radiating or receiving elements of any type shall have the transmission line or waveguide to the antenna, radiating or receiving element or elements terminated in a shielded dummy load which closely simulates the electrical characteristics of the antenna, radiating or pick-up elements. A band rejection filter, acceptable to the bureau or agency concerned, tuned to the fundamental frequency, shall be inserted between the dummy load and the measuring instrument when performing measurements on a transmitter.

"3.8.1 Measurements shall then be made of the electronic equipment over the frequency range 14 kc. to 1,000 mc. using the instrumentation specified in table I. For frequencies between 1,000 and 10,000 megacycles, use may be made of commercially available spectrum analyzers or interference and field intensity meters. The contractor, laboratory or test facility performing the measurements above 1,000 megacycles shall provide the bureau or agency concerned with the identification and data concerning the measuring instruments and an estimate of the degree of accuracy of data derived from their use.

"3.8.2 The measuring instrument shall be tuned to the oscillator frequency of the equipment under test, and to its harmonics, outputs from frequency multipliers and crystal saver circuits, beat frequency oscillator outputs, and similar items, and adjusted to give a maximum indication. A further check for spurious energy shall be made by scanning the frequency range of interest.

"3.8.3 The data thus obtained is in terms of microvolts across the characteristic impedance of the dummy load. This data shall be converted into decibels above 1 milliwatt and plotted versus frequency on graph paper, Codex Book Company, Inc. No. 32,228; 20 divisions per inch by 6 cycles ratio ruling, or equivalent. The ordinate on such graph paper shall be from minus 100 to plus 140 dbm. on the left-hand side, and in corresponding watts in powers of ten on the right-hand side; and the abscissa shall be from 10 kc. to 10,000 mc. In addition, response curves shall be plotted on graph paper having linear ordinates from minus 100 to plus 140 dbm., and a frequency excursion on a logarithmic basis of sufficient cycles to accommodate the full frequency coverage of the respective equipment.

"3.8.4 <u>Susceptibility.-</u>

"3.8.4.1 For three discreet frequencies per octave over the tuning range of the receiver, utilizing a signal generator as input to the receiver, with both the signal generator and receiver adjusted to same frequency, the receiver shall be adjusted to maximum sensitivity. The signal generator output shall be reduced to a receiver minimum perceptible level. The output of signal generator shall be recorded.

"3.8.4.2 The receiver shall be tuned, in turn, to each of the frequencies specified in 3.8.4.1 and the spectrum range of 14 kc. to 10 kmc. shall be scanned with signal generators. The signal generators shall furnish a minimum input level, to the receiver antenna terminals, of 86 db above the receiver minimum perceptible level specified in 3.8.4.1. At those signal generator frequencies at which receiver response is obtained, the signal generator output shall be adjusted to obtain the minimum perceptible level originally recorded for this receiver frequency. This shall be recorded as V2 and shall be used in the formula specified in 3.8.4.3.

"3.8.4.3 The receiver spectrum signature shall be calculated as follows:

$$\text{Decibels rejection} = 20 \log \frac{V2}{V1}$$

Where:
V1 = Signal generator voltage required for minimum perceptible receiver output.
V2 = Signal generator voltage required for receiver output at all frequencies other than desired frequency.

"3.8.4.4 The voltages V1 and V2 shall be converted into decibels related to 1 milliwatt and plotted versus frequency on graph paper as specified in 3.8.3.

"3.8.4.5 Such determinations shall be made throughout the tuning range of the receiver at intervals not less than those test frequencies per band or frequency octave, whichever is greater as shown on figure 52. The lowest values of signal generator output (V2) obtained shall be the values used for plotting curves.

"3.8.4.5.1 When using those measuring instruments or receivers capable of frequency scanning, all other frequencies not selected for measurement shall be scanned while monitoring with an oscilloscope, headphones or a loudspeaker. If radio frequency energy or receiver response occurs while scanning, measurements shall be made at each frequency at which such energy or response occurs.

"3.8.5 Tests and submission of data. -

"3.8.5.1 Tests. - The equipment spectrum signature data shall be submitted for the first functioning development model or on the prototype model submitted for preproduction inspection. On production contracts, the equipment frequency spectrum shall be obtained only on the first equipment of the production run. In the event that the first equipment produced cannot be made available for this purpose, the second equipment produced shall be selected. Repetition of this test during the course of a production run is required when design changes have been introduced which affect the radiation and susceptibility characteristics of the equipment. Repetition of the test may also be directed by the Government inspector or required by the bureau or agency concerned.

"3.8.5.2 Submission of data. - The spectrum signature data obtained shall be submitted to the bureau or agency concerned within 30 days of completion of the spectrum measurements. A copy of the fully executed "Equipment Characteristics" form (see 6.9 and figure 51) is part of the spectrum signature data and shall be submitted therewith. The number of copies to be submitted shall be as specified in the contract or order.

"3.8.5.2.1 "Equipment Characteristics" form (see figure 51). - The contractor shall execute the "Equipment Characteristics" form (see 6.9 and figure 51) for inclusion in each progress report submitted as required by the contract or order.

"3.8.6 Use of equipment spectrum signature data. - The equipment frequency spectrum signature data is not required for the purpose of acceptance or rejection of the equipments. This data is vitally important to the bureau or agency concerned for planning installations and for the determination of compatibility of this equipment operating in the presence of other electronic equipments and systems."

Page 26, paragraph 6.7: Delete and substitute:

"6.7 Interference filters and capacitors. - Interference filters and capacitors employed for the reduction of interference, in order to meet the requirements of this specification should be products which have been subjected to the required tests and found satisfactory for inclusion in the Qualified Products Lists of Specifications MIL-F-18344 for filters and MIL-C-19080 and MIL-C-19624 for capacitors."

Page 26: Add as paragraph 6.9:

"6.9 Instructions for completion of "Equipment Spectrum Signature" form (see figure 51). - The instructions specified hereinafter should be followed for completion of the "Equipment Spectrum Signature" form (see figure 51):

"(a) Item 1a. - List the frequency band or specific frequencies on which the equipment is to operate. Also list the technically feasible limits in which it is believed that the required operation can be performed.
"(b) Items 1b, 1c, 1d, 1e, 1f, 1g and 1h. - Not to be filled in by the contractor.
"(c) Item 2a. - List joint nomenclature, or service nomenclature. If no nomenclature has been assigned, state, "NONE".
"(d) Item 2b. - Not to be filled in by contractor.
"(e) Item 2c. - List actual frequency bands or frequencies, within the proposed band allocation, on which the transmitter can operate satisfactorily.
"(f) Item 2d. - List type of emission, such as "A3," "P0," "F3," "A5."

"(g) Item 2e. - List the necessary bandwidth for communication in the case of AM and FM. In the case of pulse and similar emissions, list the bandwidth for specified power level points. For example: 5,000 KCS at 3 db point, etc.

"(h) Item 2f. - State the pulse repetition rate, rates, or ranges thereof. For example: 200, 400 and 800 p.p.s.; or 1,000 to 2,500 p.p.s. (variable). For data transmission systems, specify the data rate in bits per second.

"(i) Item 2g. - List pulse width range in microseconds. For example: 2 and 4 microseconds; or 0.5 to 1.5 microseconds (variable).

"(j) Item 2h. - List modulation, if any, and give general description of any coding system. Example: FM subcarrier or pulse time coding.

"(k) Item 2i. - List power in kw. Use peak power and average power in the case of pulse emission.

"(ℓ) Item 2j. - List antenna characteristics indicated.

"(m) Item 2k. - List type of frequency control. For example: crystal; or, tuneable magnetron type 5J26.

"(n) Item 2ℓ. - Indicate the frequency stability of the transmitter. Example: 0.001 percent.

"(o) Item 2m. - List the status of development of transmitter or system to which the submitted data applies.

"(p) Item 2n. - Not to be filled in by contractor.

"(q) Item 3a. - List nomenclature of receiver if not included in system nomenclature.

"(r) Item 3b. - Not to be filled in by contractor.

"(s) Items 3c, and 3d. - Fill in as indicated.

"(t) Item 3e. - List effective frequency selectivity of overall receiver system at 3 db, 20 db and 60 db points. Example: 20 kc. at 3 db points, etc.

"(u) Item 3f. - List sensitivity of the receiver in microvolts per meter.

"(v) Item 3g. - State whether r.f. preselection is employed and type of preselection used. For example: Filter, tuned or untuned r.f. stage.

"(w) Items 3h, 3i and 3j. - Fill in as indicated.

"(x) Item 3k. - Indicate type of antenna employed. For example: Half wave dipole, 3 element YAGI, rhombic, etc.

"(y) Item 3ℓ. - List antenna gain.

"(z) Item 3m. - List receiver stability.

"(aa) Item 3n. - List status of development of receiver or system to which the submitted data applies.

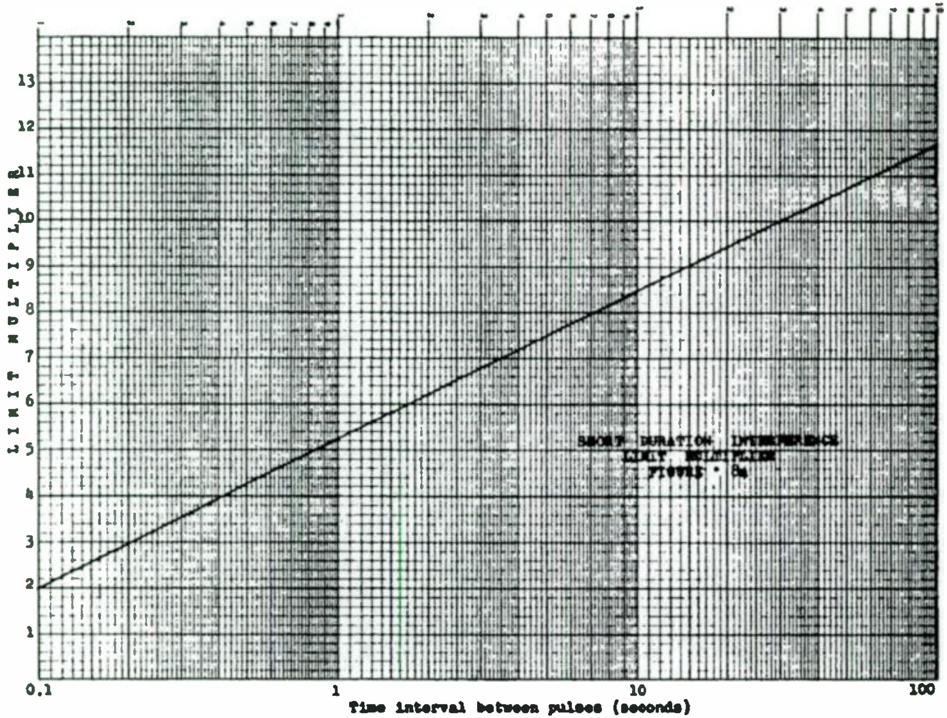
"(bb) Item 3o. - Not to be filled in by contractor.

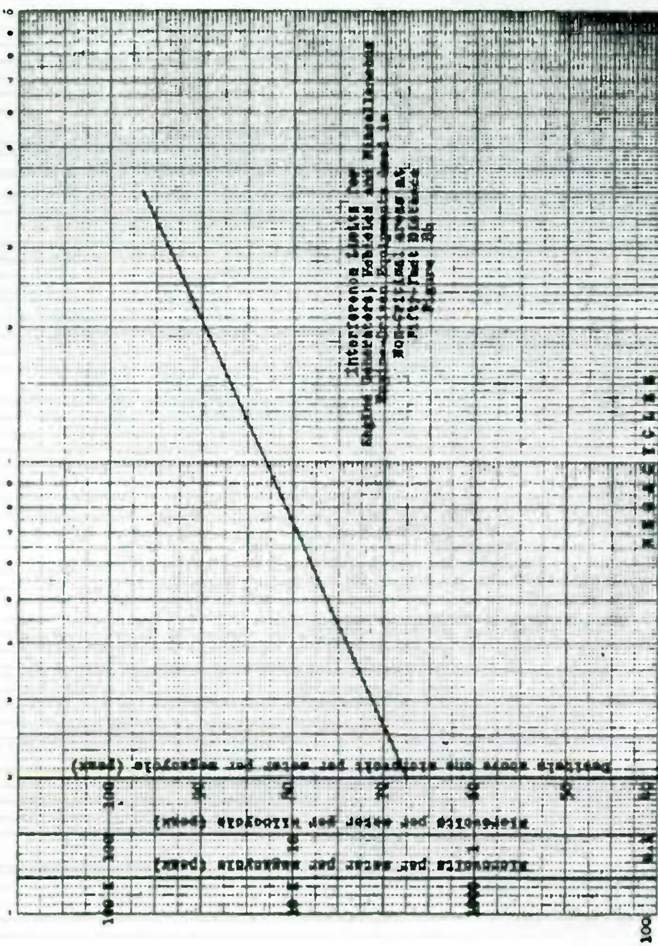
"(cc) Item 4a. - It is intended that the contractor or laboratory give consideration to the circumstances under which the system or equipment will be operated (operational environment). As a result, include (available) information as to the other equipments and systems which must be accommodated for simultaneous operations in the same frequency range and operating area.

"(dd) Item 4b. - There should be indicated, to the extent possible, any limitations which it is believed necessary to impose the equipment in order to avoid interference between existing equipments or systems and the subject equipment systems.

"(ee) Item 4c. - Add any information which it is believed will assist in evaluating the probability of interference or incompatibility between the proposed equipment and established operations. Where applicable, include the results of any tests conducted to determine the extent of interference or compatibility."

Add figures 8a, 8b, 51, 52 and 53:





Interference Limits for
Engine Generators, Vehicles and Miscellaneous
Engine-Driven Equipments Used in
Non-Critical areas at
Fifty-Foot Distance
Figure 8b

	Equipment characteristics[1]
	1. General equipment description
	a. Frequency band:
NOT TO BE FILLED IN BY CONTRACTOR	b. Function:
	c. Description of purpose and method of operation:
	d. Geographical area:
	e. Extent of use:
	f. Degree of protection required:
	g. Target dates for additional development ______ service tests ______ prototype and production models ______
	h. Previous allocation and/or other equipment to be changed or superseded:
	2. Transmitter
	a. Nomenclature of transmitter or system:
Not req'd by Contr.	b. Installation:
	c. Actual tuning range and/or operating frequencies:
	d. Type emission:
	e. Bandwidth: 3 db ______ 20 db ______ 60 db ______
	f. Pulse repetition rate: ______ Data rate: ______
	g. Pulse width:
	h. Modulation and coding:
	i. Power output:
	Antenna:
	j. (1) Description:
	(2) Scan:
	(3) Gain:
	(4) Beam width (AZ):
	(5) Beam width (EL):
	k. Frequency control:
	l. Stability:
	m. Status of development:
Not req'd by Contr.	n. Target date for operational availability:
	3. Receiver:
	a. Nomenclature:
Not req'd by Contr.	b. Installation:
	c. Actual tuning range or operating frequencies:
	d. IF frequency:
	e. Selectivity: 3 db ______ 20 db ______ 60 db ______
	f. Sensitivity:
	g. RF preselection:
	h. Frequency range of local oscillator:
	i. Does local oscillator normally operate above or below 1st detector frequency?
	j. Is receiver designed so that the local oscillator can be readily adjusted above or below the first detector frequency?
	k. Antenna description:
	l. Antenna gain:
	m. Stability:
	n. Status of development:
Not req'd by Contr.	o. Target date for operational availability:
	4. Remarks
	a. (See instructions)
	b. (See instructions)
	c. (See instructions)

[1]See 6.9 for instructions.

SAMPLE

Figure 51 - Typical data sheet

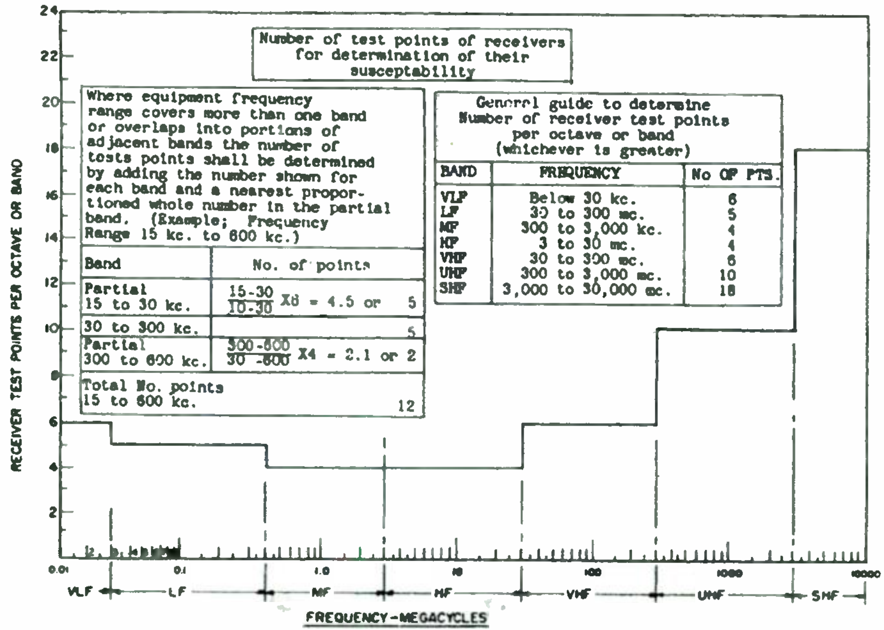

Number of test points of receivers for determination of their susceptability
Where equipment frequency range covers more than one band or overlaps into portions of adjacent bands the number of tests points shall be determined by adding the number shown for each band and a nearest proportioned whole number in the partial band. (Example; Frequency Range 15 kc. to 600 kc.)
Band | No. of points
Partial 15 to 30 kc. | 15-30 / 10-30 X8 = 4.5 or 5
30 to 300 kc. | 5
Partial 300 to 600 kc. | 300-600 / 30 -600 X4 = 2.1 or 2
Total No. points 15 to 600 kc. | 12
General guide to determine Number of receiver test points per octave or band (whichever is greater)
BAND | FREQUENCY | No OF PTS.
VLF | Below 30 kc. | 6
LF | 30 to 300 mc. | 5
MF | 300 to 3,000 kc. | 4
HF | 3 to 30 mc. | 4
VHF | 30 to 300 mc. | 6
UHF | 300 to 3,000 mc. | 10
SHF | 3,000 to 30,000 mc. | 18
RECEIVER TEST POINTS PER OCTAVE OR BAND
FREQUENCY-MEGACYCLES
VLF
LF
MF
HF
VHF
UHF
SHF

Figure 52

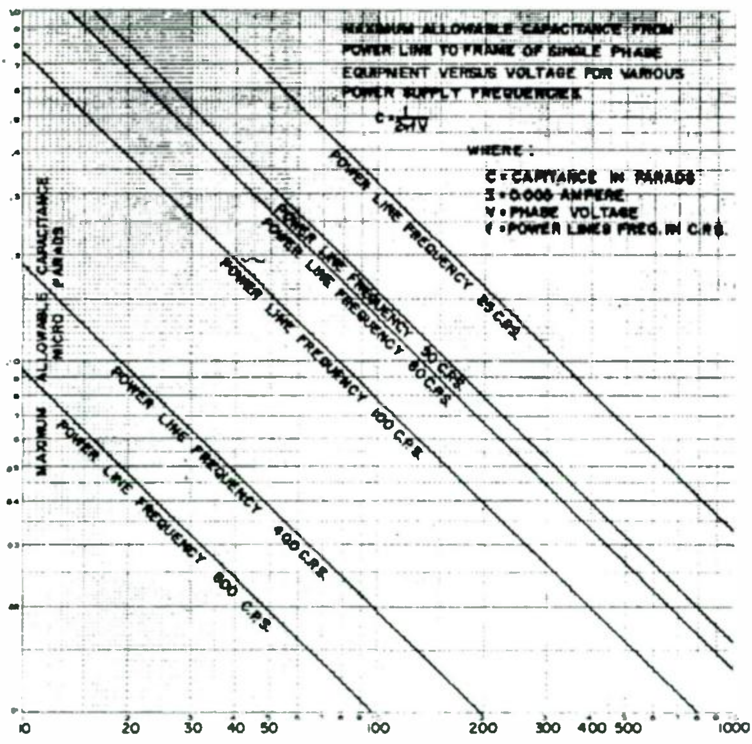


Figure 13 - Power line potential (volts).

MIL-I-16910A(SHIPS)
30 August 1954
SUPERSEDING
MIL-I-16910(SHIPS)
14 January 1952

MILITARY SPECIFICATION

INTERFERENCE MEASUREMENT, RADIO, METHODS AND LIMITS;

14 KILOCYCLES TO 1000 MEGACYCLES

1. SCOPE

1.1 This specification covers methods for use in the measurement of radio interference produced by electrical, electronic, and mechanical equipment in the frequency range from 14 kilocycles (kc.) to 1000 megacycles (mc.). It also provides basic limits of radio interference in table or graph form. It is the intent of this specification to provide means whereby significant and uniform measurements of radio interference produced by electronic, electrical, and mechanical equipment can be obtained with consideration for the testing of components and systems.

2. APPLICABLE DOCUMENTS

2.1 The following specification, of the issue in effect on date of invitation for bids, forms a part of this specification:

SPECIFICATIONS

NAVY DEPARTMENT
General Specifications for Inspection of Material.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Definitions. - For the purpose of this specification, the following definitions shall apply:

3.1.1 Radio interference. - Radio interference is defined as undesired conducted or radiated electrical disturbances, including transients, within the range of frequencies covered by this specification, which may interfere with the operation of electrical or electronic communication equipment or other electronic equipment.

3.1.2 Major unit. - A major unit is a group of parts or subassemblies, electrically or mechanically connected to perform a specific function. (Example: Radio receiver, radar transmitter, sonar transducer, modulator, propeller synchronizer.)

3.1.3 Set. - A set is a grouping of items having the same basic name for use in connection with or the performance of closely related operations. A set normally consists of a fixed number of major units or items, not all having the same basic name, which are required for the performance of a specific operational function. A set is not dependent upon other sets or accessories to perform its function.

3.1.4 System. - A system consists of two or more sets or major units located at two or more points with interdependent or interrelated operations for the accomplishment of a specific objective. (Example: AEW Electronic System, GCS Electronic System, Propeller Control System.)

3.1.5 Laboratory tests. - Measurements of radiated radio interference made upon a test item in the laboratory screen room, or in a confined area of low ambient interference level shall be defined as laboratory tests. Measurements of conducted radio interference performed under controlled conditions of ambient interference levels (see 4.1.4.3), use of load or line impedance stabilization device (see 4.3.2), and operation of the test item under simulated normal operating conditions are considered laboratory tests of conducted interference. In the performance of laboratory tests of conducted interference, all requirements listed in 4.1 shall be complied with unless otherwise specified in the individual equipment specification. The 50-ohm line coupling device (see 4.3.1.1) shall be used.

3.1.6 Field tests. - Measurements of radiated radio interference made upon a test item in open space (as defined in 3.1.7) with the test item operating under conditions simulating normal operation are defined as field tests. Measurements of conducted interference made upon a test item at the actual site of installation of the item and with the test item operating under normal conditions shall be considered a field test of conducted interference. Field tests of conducted interference shall be made by attaching the appropriate line-coupling-device (see 4.3.1), at the desired point of test, all measurements being made line-to-ground unless otherwise specified in the individual equipment specification. Use of impedance stabilization devices in line or load is specifically exempted when making field tests.

3.1.7 Open space. - The term "open space" as used in this specification is intended to designate an ideal site for radiated interference measurements. This ideal site shall be open, flat terrain at a considerable distance (100 feet or more) from buildings, electric lines, fences, and trees, as well as sufficiently free from known underground cables and pipelines. This site shall have a sufficiently low ambient level of radiated interference to permit testing to the governing radiated interference limit specified herein or otherwise specified by the individual equipment specification; and in no event shall exceed the specification limit at any test frequency selected.

3.1.8 Interference measurement instruments. - The instruments employed to perform the measurements of radio interference described in this specification shall be known as the interference measurement instruments. These instruments shall comply, insofar as the present state of the art provides, with the performance characteristics specified in 6.1. It shall be the option of the bureau or agency concerned to specify the use of any specific instrument or instruments listed in table I.

3.1.9 Microvolts per kc. - Interference intensity in microvolts per kc. is equal to the number or root mean square (r.m.s.) sinewave microvolts (unmodulated), applied to the input of the measuring circuit at its center frequency, which will result in peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the effective bandwidth of the circuit in kilocycles. The effective bandwidth is the area divided by the height, of the voltage-response-versus-radio-frequency selectivity curve, from antenna to peak detector.

3.1.9.1 Typical bandwidth curves. - Typical 6 decibels (db) bandwidth curves for interference measuring equipment are shown on figures 1 through 6. These values shall be used in determining microvolts per meter per kc. as shown on figure 7.

3.1.10 Portable electric equipment. - Portable electric equipment includes equipments which are equipped with line cords so that their operation from any convenient electric outlet may be possible.

3.2 Classification of interference measurement instruments. - Four classes of interference measurement instruments are available at the date of this specification. Class III instruments may in the future be promoted to class I or II, however, class IV instruments will not be promoted and are acceptable only because they are in existence or because another instrument covering that particular frequency range has not been developed as yet.

3.2.1 Class I. - Radio interference and field intensity meters which have been designed to conform with the standards established and which have been approved by the Armed Services performance characteristics for these instruments are as specified in 6.1.

3.2.2 Class II. - Instruments which have been designed for a special purpose and insofar as their intended special purpose is concerned conform with the performance characteristics for class I instruments and which have been approved for such special purpose by the Armed Services.

3.2.3 Class III. - Meters designed as class I or class II instruments but which have not been evaluated. When approved by the Armed Services, these will be redesignated as class I or class II instruments.

3.2.4 Class IV. - Existing meters which are in general use but which do not conform to the approved standards. Use of these instruments is permissible unit conditions permit their replacement by class I or class II meters only if procured by the contractor prior to the effective date of this specification.

3.2.5 Table I is a listing of interference measurement instruments with respect to frequency range and showing the present classification.

3.2.6 When measuring equipment other than those specified in table I are proposed for use, the test results thereof shall be related to results from the meters of table I.

Table I - Interference measuring equipment.

Frequency range	Interference instrument	Classification[1]
15 kc. to 150 kc.	Radio Test Set AN/URM-6	I
	Ferris Model 64 AB	III
150 kc. to 20 mc.	Radio Test Set AN/PRM-1	I
	Ferris Model 64 BC	III
	Ferris Model 32A and 32B	IV
	Navy Model OF and OF-2	IV
150 kc. to 40 mc.	Test Set AN/URM-3	II
20 mc. to 150 mc.	Measurements Corp., Model 58	IV
	Measurements Corp., Model 58A	IV
20 mc. to 400 mc.	Radio Test Set AN/URM-7	II
	Noise Field Intensity Meters TS-587/U	IV
20 mc. to 400 mc.	Radio Interference Measuring Set AN/URM-47	III
40 mc. to 1000 mc.	RF Interference Test Set AN/URM-28	IV
	RF Interference Test Set AN/URM-29	IV
150 mc. to 1000 mc.	Radio Interference Measuring Set AN/TRM-4	III
400 mc. to 1000 mc.	Radio Test Set AN/URM-17	III

[1] This classification is subject to change on reasonable notice to include new instrumentation of tested and approved superior performance characteristics.

3.3 Standard units of interference. -

3.3.1 Radiated. - The standard unit of radiated broadband interference shall be microvolts per meter per kilocycle bandwidth, based on measurements made in open space, remote from any influence such as reflections, distortions, or disturbances which cannot be attributed directly to the sample under test. Continuous-wave (cw.) type interference shall be in terms of microvolts per meter.

3.3.2 Conducted. - The standard unit of conducted broadband interference shall be microvolts per kilocycle bandwidth as measured from line-to-ground. Continuous-wave type conducted interference shall be in terms of microvolts.

3.4 Interference limits. -

3.4.1 Radiated interference limits. - General limits of radiated interference in terms of the standard units are established and presented in graphic form on figures 7, and 8. General limits of broadband radiated interference in terms of indicated microvolts is shown on figure 9. If the individual equipment specification references this specification but fails to designate a specific limit, then the limits of figures 7 and 8 shall be intended and adhered to.

3.4.2 Conducted interference limits. - General limits of conducted interference in terms of the standard units are established and presented in graphic form on figures 10 and 11. General limits of broadband conducted interference in terms of indicated microvolts are shown on figure 12. If the individual equipment specification references this specification, but fails to designate a specific limit, then the limits of figures 10, 11 and 12 shall be intended and adhered to.

3.4.3 Short duration interference. -

3.4.3.1 Impulsive interference with a repetition rate of not more than 10 pulses per second (p.p.s.) is permitted, a limit of two times or 6 db above the limits shown on figures 7, 8, 9 and 10.

3.4.3.2 Interference of less than 1 second in duration, occurring not more than once every 30 seconds is permitted, a limit of 10 times or 20 db above the limits shown on figures 7, 8, 9 and 10.

3.4.3.3 Interference of less than 1 second in duration occurring not more than once during a time interval between 30 seconds and 3 minutes is permitted a limit of 30 times or 31.62 db above the limits shown on figures 7, 8, 9 and 10.

3.4.3.4 Interference of less than 1 second in duration occurring not more than once every 3 minutes shall be exempt from the requirements of this specification.

3.4.4 Determination of interference type. - To determine, whether observed interference is CW or broadband the ratio of readings, quasi-peak to field-intensity, (taken on class I radio interference instruments) shall be determined. If the ratio QP/FI is equal to or greater than 1.8 to 1, the limit for broadband interference shall apply. For ratios less than 1.8 to 1, the limit for CW interference shall apply. (See figure 13.)

3.5 Calibration of interference measuring instruments. - The standard of calibration shall be the r.m.s. voltage of an unmodulated sine wave, such as obtained from a standard signal generator.

3.5.1 Calibration with external signal generator. - The interference measurement instrument calibration with instrument properly terminated, shall, unless otherwise specified by the bureau or agency concerned, be checked using a suitable standard sine wave signal generator in accordance with instructions contained in the instruction manual for the instrument. The time interval between calibration checks shall not exceed 6 months, and checks shall be made more often if required by the bureau or agency concerned; and in any event shall be made immediately after exposure to conditions which might affect calibration. Recalibration of the instrument shall be made when checks indicate a deviation in normal calibration greater than 10 percent.

3.6 Specific requirements. - Because of the variety of equipment with respect to size, function, power rating, and contemplated use, specific requirements (and test procedures) are included in this specification. The applicable paragraph of specific requirements shall be complied with in addition to compliance with the general requirements specified in 3.1 through 3.5. The invididual equipment specification will designate which classification is applicable in cases where there is possibility for more than one classification.

3.6.1 Electronic and communications equipment. - This portion of the specification provides procedures for testing radio, radar, interphone, and electronic communications equipment, to insure satisfactory performance in regard to radio interference when operating in conjunction with other equipment in a system.

3.6.1.1 Interference limits. -

3.6.1.1.1 Radiated. - Over the frequency range of 0.014 to 1000 mc., interference radiated from any unit, cable (including control and input power cables) or interconnecting wiring of the equipment shall not exceed the limits specified herein or otherwise specified in the individual equipment specification. This requirement specifically includes oscillator interference and spurious emissions in addition to random interference from units, wiring, shielded antenna lead-in and systems.

3.6.1.1.2 Conducted. - Radio interference voltage appearing on the external power conductors or on any external systems connection shall not exceed the limits specified herein or otherwise specified in the individual equipment specification over the frequency range of 0.15 to 100 mc.

3.6.1.1.3 Receiver oscillator interference. - Receivers shall not exhibit any oscillator interference in excess of the limits specified herein or otherwise specified in the individual equipment specification when subjected to the receiver oscillator interference test specified in 4.5.1.3.1 and the conducted interference test specified in 4.3.

3.6.1.1.4 Transmitter key-up interference. - In the key-up position, the transmitter shall be considered equivalent to a receiver, for purposes of test and shall conform to 3.6.1.1.3.

3.6.1.1.5 Additional requirements. - Where equipments covered by this specification are required to comply with minimum values of capacitance (0.1 microfarad (μf) or less), or limiting values of current between any exposed metal part of the equipment and earth ground, and fall within the definition of portable electric equipment, the general limits shown on figures 7, 8, 9 and 10, increased by a factor of 10 or 20 db, shall be applicable.

3.6.1.2 Undesired radiation. -

3.6.1.2.1 Receiver oscillator radiation. - Receivers shall not exhibit any oscillator radiation in excess of 400 micromicrowatts when subjected to the receiver oscillator radiation test specified in 4.5.1.4 and the conducted interference test specified in 4.3.

3.6.1.2.2 Transmitter key-up or standby radiation. - Radio frequency radiation under key-up or standby (carrier-off) condition shall not exceed 400 micromicrowatts when measured as specified in 4.5.1.4.

3.6.1.2.3 Transmitter key-down radiation, other than fundamental. - Radio frequency radiation under key-down or transmit condition, on frequencies other than the fundamental (carrier plus minimum sideband frequencies required for the intelligence transmitter) shall not be greater than a level equivalent to 50 db below the full power carrier output as measured across the output terminals of the transmitter when terminated in an impedance equivalent to the normal operating load.

3.6.1.2.4 Radiation from equipment other than receivers or transmitters. - The requirements of 3.6.1.2.2 shall apply to any equipment when adjusted to a no-output condition.

3.6.2 Engine generators and miscellaneous engine driven equipment. -

3.6.2.1 This portion of the specification applies to the following equipment, except where this equipment is a component of other equipment subject to more restrictive requirements:

(a) All engine driven generators and the electrical equipment associated therewith providing direct current (d.c.) or alternating currents (a.c.), of all voltage and power ratings, except that the radiated interference test will not be required on units of power output rating greater than 60 kilovolt-ampere (kva.), or the conducted interference test on units of voltage rating greater than 500 volts a.c. or d.c.

(b) All types of engines used to power or drive such miscellaneous equipment as bulldozers, cranes, graders, rollers, fork lift trucks, compressors, laundry units, and pumps, as well as the electrical equipment associated with these equipments.

3.6.2.2 Interference limits. - All equipment covered in this section shall not emanate interference, either conducted or radiated, in excess of the general limits for interference as specified herein or otherwise specified by the individual equipment specification.

3.6.3 Vehicles, tactical. - The following types of vehicles shall conform to the requirements for tactical vehicles: All types of self-propelled vehicles which receive installations of communication equipment, all types of tanks, armored cars, self-propelled cannon, self-propelled cargo carriers, half-track personnel carriers, half-track cargo vehicles, motor transport vehicles, high-speed tractors, and motorcycles.

3.6.3.1 Self-propelled machinery. - Self-propelled machinery such as excavators, road graders, fork-lift trucks, and slow-speed tractors, shall not be considered as vehicles within this scope unless otherwise stated in the individual equipment specification. In this case, the requirements shall be as specified in the individual equipment specification.

3.6.3.2 Limits of interference for tactical vehicles. - Interference limits, both radiated and conducted, shall be as specified herein or otherwise specified in the individual equipment specification. If limits are not specified in the individual equipment specification, the general limits of interference as shown on figures 7, 8, 10 and 11 shall apply.

3.6.4 Interference testing for large equipment and for high voltage circuits.

3.6.4.1 Unless specifically required in the individual equipment specification, interference tests in relation to very large stationary electrical or mechanical equipment shall be confined to tests of the electrical components separately. If the components conform to the interference requirements and are properly assembled, the completed equipment shall be considered to conform to the requirements of this specification.

3.6.4.2 Interference tests or rotating electrical equipment for use individually or as components, shall be confined to machines of less than 60 kva. power input or output rating.

3.6.4.3 Conducted interference tests are not required by this specification on circuits of greater voltage than 500 volts a.c. or d.c. In the event the contract or order requires tests on circuits of greater voltage, the voltage on the wiring associated with the measurement equipment shall be appropriately reduced.

3.7 Radio interference free marking. - All equipment determined to comply with this specification shall be identified by a green colored identification plate permanently attached adjacent to the equipment identification plate unless otherwise specified in the individual equipment specification. This identification plate shall be inscribed "Interference Free MIL-I-16910".

4. QUALITY ASSURANCE PROVISIONS

4.1 Preliminary tests. - Prior to submission of qualification, preproduction or contract suitability models to the Government for official tests, complete radio interference tests as specified herein or by the individual equipment specification shall be performed by the contractor to determine that the equipment complies with the applicable specification. A report of tests certified by the test laboratory shall be furnished the Government Inspector. Two copies of this test report shall be forwarded to the bureau or agency concerned to substantiate the fact that radio interference tests have been performed and the specification requirements met. Any expense incurred as a result of radio interference tests shall be borne by the contractor.

4.1.1 Radio interference test. - The manufacturer shall furnish either directly in his own plant or through the facilities of an acceptable commercial laboratory all facilities for performing the interference tests curved by this specification, including test equipment, a suitable location for the performance of tests, and qualified technical personnel. Tests shall be performed on not less than one representative unit of each design.

4.1.2 Equipment not requiring tests. - In general, the following types of equipment are usually inherently interference free, and therefore interference reduction is not required:

Ammeter	Reactor, electric
Circuit breaker, manual	Resistor
Controller, motor, manual	Rheostat, manual
Cubicle, power	Starter, engine
Incandescent lighting fixture	Starter, motor, manual
Meter, electric	Switchboard, power
Motor, squirrel cage	Transformer
Push button	Voltmeter
Panel, welding	

4.1.2.1 Establishing equipment not requiring tests. - As a means of establishing that equipment will not require tests, the manufacturer shall forward to the contracting officer a complete description of the electric items incorporated in the equipment to be furnished. If it is determined that the equipment falls into the category specified in 4.1.2, no radio interference tests will be required for that specific equipment.

4.1.3 Equipment which is identical with that which was previously tested in accordance with this specification, found staisfactory and accepted will not require further testing unless otherwise specified by the bureau or agency concerned. A copy of the previous test report, or reference thereto with an adequate abstract, shall be forwarded by letter to the bureau or agency concerned to verify the previous test results.

4.1.4 Operating conditions. - Unless otherwise specified herein for specific types and classes of equipments or otherwise specified in the individual equipment specification, interference measurements, both radiated and conducted, shall be made at normal operating load (or under simulated normal operating conditions) and at no load (see 4.1.4.4).

4.1.4.1 Power supply. - The power supply shall be at rated voltage of the equipment under test, plus or minus 5 percent. Rated voltage shall be as specified in the individual equipment specification.

4.1.4.2 Preliminary operation of test sample. - When specifically required by the Government inspector, the sample under test shall be operated for a sufficient period of time to approximate normal operating conditions.

4.1.4.3 Ambient interference level. - It is desirable that the ambient interference level during testing (measured with the test sample de-energized) be at least 6 db below the allowable specified interference limit. However, in the event that at the time of measurement the levels of ambient interference plus test item interference are not above the specified limit, such tested item shall be considered in accordance with the specification requirements. This requirement shall apply equally to both radiated and conducted ambient interference levels.

4.1.4.4 Load. - Unless specifically stated otherwise, (see 4.1.4) a load (either electrical or mechanical), capable of loading the test sample up to appropriate rating or simulating normal operating conditions shall be used. Transmitters and receivers shall be operated into a shielded dummy antenna with simulated load condition.

4.1.4.5 Temperature. - The ambient temperature of the testing location shall preferably be within the range from 10° to 40° Centigrade (C.) (50° to 104° Fahrenheit (F.)). However, measurements made in temperatures beyond these limits may be accepted provided the test sample, interference measuring instruments, all indicating devices, and equipment shall be at the testing location for a sufficient length of time prior to making of measurements for the temperature thereof to be equalized with the temperature of the testing location. Evidence shall be given that the calibration of the interference measuring instruments used is accurate for temperatures outside the stated temperature range.

4.1.4.6 Humidity. - Measurements shall be made at a time when humidity and temperature conditions do not cause condensation of moisture on the apparatus, unless it is normal for the test item to operate under such conditions.

4.1.4.7 Use of indicating meters during interference measurements. - During the time of measurement of radio interference, no external electrical meter or electrical indicating device other than the interference measuring instrument and its associated leads shall be in the input or output circuits of the sample under test. However, such meters or devices may be located between the power supply impedance stabilizing network and the power source or between the load impedance stabilizing network and the electrical load.

4.1.4.8 All interference measurements shall be monitored using either a headset or loudspeaker. The precaution shall be taken to check that no feed-back is introduced into the interference meter by the use of the headset or speaker, thereby giving a false indication of the interference level being measured.

4.2 Radiated measurements (14 kc. to 1000 mc.). - Measurements of radiated interference shall be made using the rod or resonant dipole antenna supplied with the particular test instrument employed. When specifically required in the individual equipment specification, measurements using a loop antenna shall be made over the frequency range of 14 kc. to 25 mc. or portions thereof.

4.2.1 Antenna orientation and positioning. - These interference measuring instruments equipped with rod antennas shall be placed so that the rod antenna is in the position of maximum pick-up and the base of the antenna unless otherwise specified in 4.5 is 3 feet from the nearest perimeter of the test item. These interference measuring instruments equipped with resonant dipole antennas shall have the dipole positioned for maximum pick-up with the center of the dipole at a distance of 3 feet from the nearest perimeter of the test item.

4.2.2 Placement of items and space limitations. - The test sample shall, as far as is practicable, be centrally located in the screened room or other area of low ambient interference (see figures 14 and 15).

4.2.2.1 Correlation with field tests. - Acceptance of items tested for radiated interference will be based on the performance of the test sample in open space. Certain items may be specifically exempted from this correlation requirement by the individual equipment specification because of unusual size or weight, or because the equipment is to be used ultimately in metallic enclosures, such as aircraft, or ships.

4.2.2.2 Placement of antennas. - Unless otherwise specified in 4.5, the measurement antenna shall be oriented and positioned with respect to the test sample as specified in 4.2.1, with the exception that when extension of dipole antenna elements would protrude beyond the confines of the screened area such dipole elements shall not be extended closer than 1 foot from the confines of the screened enclosures. When shortened (non-resonant) dipole lengths are employed, the reduced effective height shall be taken into consideration when calculating indicated values of measured interference.

4.2.2.3 Grounding of interference measurement instrument. - All measurements of radiated interference made in the screened room shall be made with the interference measurement instrument either bonded to ground, as specified in 4.3.3.4, or resting upon the ground plane and making good electrical contact with the ground plane. This provision applies to measurements of radiated interference in the screened room only.

4.2.2.4 Test item leads. - On those equipments normally equipped with unshielded power or load leads, the following procedure shall apply for frequencies above 25 mc. A 24-inch unshielded lead shall be installed in place of the normal lead or leads. Radiated measurements shall be made in the normal manner outlined in 4.2, 3 feet from the lead or leads. Any reading obtained under these conditions indicates the presence of interference on the lead or leads. Where equipment normally operates with shielded leads, radiated interference shall be measured as specified in 4.2.2 through 4.2.2.3.

4.2.3 Loop antenna method of measurement, (14 kc. to 25 mc.). - Measurement of radiated interference made using the loop antenna of the interference measurement instrument shall be made by placing the loop antenna at a distance of 3 feet from the nearest point of the test sample, measured from nearest point of sample to axis of the loop antenna. With the interference measurement instrument in operation and calibrated at the desired frequency, the loop antenna shall be oriented and positioned with respect to the test sample for maximum meter indication of interference.

4.3 Conducted measurements (14 kc. to 20 mc.) aircraft, flight; and (150 kc. to 100 mc.) non-flight equipment. - All measurements of conducted interference shall be made from line to ground unless otherwise specified herein. Balanced input line-coupling devices shall not be used. Line-coupling devices shall be as specified in 4.3.1. The 50-ohm line shall be used unless otherwise designated by the Government inspector. Test procedures shall conform with figure 16 insofar as is practicable.

4.3.1 Line-coupling devices. - Line-coupling devices are described as follows: Test lead lengths will vary in accordance with the particular coupler used and thus is prescribed in conjunction with each individual coupler.

4.3.1.1 50-ohm line. - The 50-ohm line shall consist of a test lead of 50-ohm coaxial cable, (RG-9A/U) or equivalent 1/2-inch outer diameter, double braid shielded or better, and a 50-ohm terminating device at the input of the measuring instrument (such as is provided with class I instruments). The length of this lead shall be as needed, and shall be connected to the measurement terminal of the impedance stabilization network. Correction factors for various cable lengths shall be as shown on figure 17.

4.3.1.2 Field test line. - For measurements of conducted interference under field test conditions, the test line shall consist of the 50-ohm line specified in 4.3.1.1 but shall be connected to the power terminals of the test item through a 0.1 microfarad capacitor placed in series with the ungrounded lead of the test line.

4.3.2 Line and load impedance stabilization network. - The stabilization network specified in 6.2 and shown on figures 18 through 24 shall be used unless the insertion of this device causes malfunctioning of the test item. This device shall be inserted in power leads only. A terminal shall be provided on this device, fitted with a type N connector, to which the interference measurement instrument cable may be attached for conducted interference measurements. The ground plane of this device shall be the same as that of the test item or shall be made a part of the test item ground plane by means of bonding in accordance with 4.3.3.4. One such network shall be inserted, where called for, in each power or electrical load lead when making measurements (see figure 25).

4.3.2.1 Cable correction factor. - Meter readings shall be multiplied by a correction factor depending on the frequency and on the length of RG-9A/U cable used between the stabilization network and the interference meter. This correction factor shall be as shown on figure 17.

4.3.3 Ground planes, bonding, and grounding. -

4.3.3.1 Ground planes. - A copper or brass ground plane, 0.010 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12 square feet or more in area shall be used in all cases where a shielded room is to be used. The ground plane shall be bonded to the shielded room at intervals no greater than 3 feet.

4.3.3.2 When a ground plane is not specified, or when the use of a shielded room is impracticable, the test sample shall be placed on a solid support for operation. The support may be solid earth, steel, or iron flooring, metal bedplate, metal-sheet covered planking, or the like. If the test sample is intended for normal operation with shock or vibration mounts that insulate the sample from the foundation, the sample shall be grounded to its support or foundation by bridging the insulating mounts in a manner similar to that employed at the place of installation and used by means of bonding straps. If bonding straps are provided with the test item, then these shall be used in lieu of the type specified in 4.3.3.4.

4.3.3.3 The test item shall be grounded in a manner simulating actual usage conditions, where practicable, whether the test is performed in a screened room or not. It is not necessary to ground the interference measurement instrument except by means of the connecting leads utilizing the instrument as a two-terminal voltmeter.

4.3.3.4 When bonding straps must be furnished, such straps shall have a width to length ratio of 1 to 5 or greater, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid.

4.3.3.5 Internally grounded equipment. - When the test item is furnished with an internal ground terminal connection, and when this connection is used in actual installation conditions, the ground lead shall be brought out and connected to the ground plane simulating actual installation conditions in addition to grounding the framework or chassis of the test item.

4.3.3.6 Test sample leads. - The leads of the test sample when furnished unterminated shall be as short as possible outside the enclosure of the test sample. These leads shall be connected to the test terminal. If shielded leads are supplied, these leads shall be used for the test.

4.4 Test procedures. - The following requirements shall be adhered to unless otherwise stated in the individual equipment specification:

4.4.1 Measurements under type testing conditions shall be made on not less than three frequencies per octave. The frequencies selected shall be chosen in such a manner as to prevent crowding of readings at one end of the band and shall be at calibrated points. Measurements during production testing shall be made on not less than one frequency for each octave. When using those instruments capable of frequency scanning, all other frequencies not selected for measurement shall be scanned while monitoring with headphones or a loudspeaker. If interference peaks appear while scanning, measurements shall be made at each frequency at which such a peak occurs.

4.4.2 If station reception is encountered at any frequency, another frequency on one or the other side of the station frequency shall be used.

4.4.3 Unless otherwise specified in the individual equipment specification, those measurement instruments equipped with peak (slideback) circuitry shall be set in the peak (slideback) position for measurement of broadband interference. Those instruments not equipped with the peak (slideback) circuitry shall be set in the quasi-peak position. Methods of conversion of the readings so obtained into the standard units of interference will be provided by the bureau or agency concerned. All instruments shall be set in the quasi-peak position for measurement of CW type interference. The results of measurements made in this manner will determine the acceptability of the test sample.

4.5 Specific test conditions and test methods. -

4.5.1 Electronic and communications equipment. -

4.5.1.1 Interference tests. -

4.5.1.1.1 In general, all interference tests shall be conducted in accordance with applicable figures but with the following modifications and additional instructions.

4.5.1.1.2 The modes of operation, arrangement of equipment interconnecting cable assemblies, and supporting structures shall be such as to simulate an actual installation insofar as is practicable. Shielded loads or cables shall be used only where they will be so used in actual practice.

4.5.1.2 Interference meter adjustment. -

4.5.1.2.1 The acceptability of the test item with respect to CW interference shall be governed by the measurement made with the function switch of the interference measurement instrument, regardless of class, set in the quasi-peak (or equivalent) position.

4.5.1.2.2 The acceptability of the test item with respect to broadband radio interference shall be governed by the measurement made with the function switch of the Ferris model 32A set to the "radio noise" position; the Measurements Corporation Model 58 function switch set to the "peak" position; the TS-587/U, AN/PRM-1, and AN/URM-6 function switch set to the "peak" position.

4.5.1.3 Communication equipment. -

4.5.1.3.1 Receiver oscillator interference. - This test shall be conducted in a shielded room provided with shielded power line filters which are effective over the frequency range in which measurements are to be made. The power supply voltage to the receiver under test shall be carefully maintained at a constant value throughout the measurement, as the interference varies with variation in input voltage.

4.5.1.3.1.1 Receiver antenna termination.- Those receivers designed to operate under normal conditions with an antenna termination of 50 ohms, shall be coupled to the antenna input of the interference measurement instrument using a 50-ohm impedance matching network such as is supplied with class I measurement instruments. Those receivers designed to operate under normal conditions with a high impedance antenna termination shall be coupled to the antenna input of the interference measurement instrument through a 500-ohm impedance network, constructed of non-inductive resistors. All transmission-line cabling shall be shielded coaxial cable with type N connectors when possible or with clip fasteners if necessary. Cable lengths shall not be excessive.

4.5.1.3.1.2 The interference measurement instrument shall be tuned to the oscillator frequency of the receiver under test and adjusted, through frequency tuning, to give a maximum indication on the meter of the measurement equipment.

4.5.1.3.1.3 Control setting.- All controls on the receiver under test shall be adjusted to give MAXIMUM output meter indication on the measurement instrument. If the receiver under test has an antenna trimmer, the trimmer shall be adjusted for MAXIMUM indication.

4.5.1.3.1.4 Shielding.- In all of the foregoing test methods, care shall be exercised to be certain that excessive leakage does not affect the results. Leakage may be through power lines, phone or output cords, or may be due to poor bonding or shielding of either the receiver under test or the measuring apparatus. Leakage can be checked by employing a good low impedance short circuit at the antenna terminals of the receiver under test and measuring the apparent voltage developed. It should be possible to keep leakage down to 0.1 percent of the open circuit voltage. If it is not this low, better shielding and bonding are probably required. Complete shielding around the antenna terminals is extremely important.

4.5.1.4 Undesired radiation test.-

4.5.1.4.1 General.- The receiver to be measured is considered as a radio frequency generator having an unknown generated voltage and internal impedance. It is possible that at several frequencies the receiving antenna will be the conjugate of this internal impedance and will take maximum power from the receiver. For this reason, radiation is specified in terms of maximum possible radio frequency (r.f.) power which can be taken from the antenna terminals.

4.5.1.4.2 Test equipment.- It is recommended that two adjoining double copper shielded booths be used for making radiation measurements. If a.c. power is used, each booth shall be provided with shielded power line filters which are effective over the frequency range in which measurements are to be made. One booth shall contain the receiver to be measured, the dummy antenna load, and a signal generator. The second booth shall contain the voltmeter (measuring) receiver and its associated output indicating meter.

4.5.1.4.3 Power supply voltage.- The power supply voltage to the receiver under test and all associated measuring equipment shall be carefully maintained at a constant value throughout the measurement, as the radiated power varies as the square of the voltage.

4.5.1.4.4 Connections to voltmeter (measuring) receiver.- The antenna terminals of the receiver under test shall be connected to its appropriate load and fed into the antenna input of the voltmeter receiver. The voltmeter receiver shall be tuned to the oscillator frequency of the receiver under test and shall be adjusted to give a 1000 cycles per second (c.p.s.) beat note output. The output level of the voltmeter receiver shall be adjusted as necessary to maintain some arbitrary reference on the output meter below resonant overload.

4.5.1.4.5 Control setting. - All controls on the receiver under test shall be adjusted to give maximum output meter indication on the voltmeter receiver. If the receiver under test has an antenna trimmer, the trimmer shall be adjusted for maximum radiation. The volume control of the receiver under test affects radiation indirectly by affecting plate supply voltage or tube capacitance. Usually maximum radiation occurs at minimum volume setting.

4.5.1.4.6 Power. - After the maximum radiated output indication has been obtained, the receiver under test shall be removed from the circuit and a signal generator, operating on the same frequency as the radiated signal, shall be substituted for the receiver under test. The signal generator output shall be adjusted to give the same voltmeter receiver output as was obtained from the receiver under test. The power in watts is then the signal generator voltage squared divided by the load resistance. It is usually more convenient to express the power in micromicrowatts or as microwatts in powers of ten.

4.5.1.4.7 Loads. - The value of the loads and the amount of their reactance must be known at the frequencies involved. Power computations may be eliminated by using a separate log to log plot of microvolts versus power for each load used. A curve of power versus load resistance shall then be plotted, and from this curve the maximum power is obtained. This shall be done at each frequency where a measurement is desired.

4.5.1.4.8 Shielding. - In all of the following test methods, care shall be exercised to be certain that excessive leakage does not affect the results. Leakage may be through power lines, phone or output cords, or may be due to poor bonding or shielding of either the receiver under test or the measuring apparatus. Leakage can be checked by employing a good low impedance short circuit at the antenna terminals of the receiver under test and measuring the apparent voltage developed. It should be possible to keep leakage down to 0.1 percent of the open circuit voltage. If it is not this low, better shielding and bonding are probably required. Complete shielding around the antenna terminals is extremely important.

4.5.1.4.9 Accuracy. - The accuracy of all of the test depends on the voltage accuracy of the signal generators so frequent calibration is necessary. For communication receivers at frequencies of 200 mc. and below, it has been found that sufficient accuracy is obtained by determining the power obtained in the optimum pure resistance load without attempting to tune out the reactive component.

4.5.1.4.10 Measurements at frequencies 30 mc. and below. -

4.5.1.4.10.1 Accuracy. - At frequencies of 30 mc. and below, a wafer switch may be used to change the connections from the receiver under test to the signal generator without introducing appreciable error. The external switch lead lengths can be reduced by employing a switch can and plug in loads as shown on figure 26.

4.5.1.4.10.2 Load. - An arbitrary load (consisting of a noninductive resistor with extremely short leads) shall be used. The maximum radiated power shall be determined for several loads (not less than five).

4.5.1.4.10.3 Decoupler resistor. - A decoupler resistor, having approximately ten times the resistance of the load shall be inserted in the input line to the voltmeter receiver. It shall prevent the voltmeter receiver's input impedance and the shunt capacity of the interconnecting cable from loading the receiver under test. The decoupler shall be readily replaceable so it can be maintained at approximately ten times the load value. Too high a value of decoupler results in loss of sensitivity to weak radiation, while too low a value results in the voltmeter receiver and cable loading the receiver under test and giving too favorable indications.

4.5.1.4.11 Measurements at frequencies above 30 to 200 mc. - Above 30 mc., the convenience of switching from the receiver under test to the signal generator shall be sacrificed in favor of transfer of coaxial cable. The loads themselves shall also be made with less inductance. The shielded radial arrangement of noninductive resistors and connections shown on figure 27 accomplish these purposes. One of the loads is made up with five radial wires as a short circuit for leakage tests. This arrangement is good up to 200 mc. The input cable to the voltmeter shall contain a decoupler resistor as specified in 4.5.1.4.10.3.

4.5.1.4.12 Measurement at frequencies above 200 mc. - When it becomes necessary to measure radiation at frequencies above 200 mc., an arrangement similar to that shown on figure 28 will be necessary. This high frequency system consists of a high Q coaxial line operated as an auto-transformer to match the impedance of the voltmeter receiver to that of the receiver under test. No decoupling resistor is needed. The line length and the position of the input and output taps are all adjustable and are set to give maximum voltmeter receiver response. The signal generator is then substituted for the receiver under test. All adjustments are reset for maximum and the generator output is adjusted to give the same voltmeter receiver output. The maximum radiated power is then the generator voltage squared divided by the generator resistance, which must be known.

4.5.2 Engine generators and miscellaneous engine driven equipment. -

4.5.2.1 Radiation tests, engine generators and miscellaneous engine driven equipments. - The radio interference radiated from engines and engine driven equipment shall be measured on each side at a distance of 5 feet from the frame or other structural extremity normally considered as an outer dimension under operating conditions.

4.5.2.1.1 Miscellaneous engine driven equipments (other than engine generator units) having a single engine shall be tested with the measurement antennas positioned as shown on figure 29, 30 or 31 whichever is applicable.

4.5.2.1.2 Engine generator units shall be tested with the measurement antennas positioned as shown on figure 32, 33, or 34, whichever is applicable.

4.5.2.1.3 Engine driven equipments (other than engine generator units) having more than one engine shall be tested with the measurement antennas positioned as shown on figure 29, 30 or 31 relative to each engine.

4.5.2.1.4 Engines intended as general purpose prime movers and those which are normally operated without surrounding structure shall be tested with the measurement antennas positioned as shown on figure 29, 30 or 31, except that the distance (5 feet) shall be measured from the outer extremity of the engine.

4.5.2.1.5 Radiation tests shall be performed with all electrical units of the engine or equipment in operation. Battery condition or electrical load shall be such that the charging system or output voltage regulators are in operation throughout the tests.

4.5.2.1.6 Rod antenna, 150 kc. to 38 mc. - The rod antenna of the measuring equipment shall be in a vertical position 5 feet from the equipment with its base at the approximate height of the vertical center of the engine as shown on figures 29 and 32.

4.5.2.1.7 Resonant dipole antenna, 20 to 1000 mc. - The dipole antenna shall be oriented in a horizontal plane parallel to and at a distance of 5 feet from the outer extremity of the equipment under test, as shown on figures 30 and 33.

4.5.2.1.8 Antenna AT-292/URM-29, 40 to 1000 mc.- The antenna shall be so placed and oriented that the apex of the cone shall be 5 feet from the extremity of the equipment under test at a height of 1 foot above the top of the engine as shown on figures 31 and 32. The antenna configurations used for the various frequency ranges are shown on figure 35.

4.5.2.2 Conducted interference tests, engine generator units.- Conducted interference shall be measured between each line and ground at the power output terminals using the appropriate 50-ohm unbalanced coupling network for the measuring equipment used.

4.5.2.2.1 Load.- Measurements shall be performed at half and full load. The electrical load shall be primarily resistive and shall be connected to the output terminals of the unit through a 75-foot unshielded cable of appropriate current carrying capacity.

4.5.2.3 Alternate test method.- Engine generator and miscellaneous engine driven equipment may also be tested in accordance with 4.5.1 if so specified by the bureau or agency concerned.

4.5.3 Vehicles, tactical.-

4.5.3.1 Outside radiation tests.- The radio interference radiated from all tactical vehicles shall be measured on at least three sides, over the frequency range of 0.15 to 1000 mc. Radiation tests shall be conducted with all electrical equipment in the vehicle in operation.

4.5.3.1.1 Over the frequency range 0.15 to 40 mc., the test equipment shall be located as shown on figures 36, 37, 38, 39, 40, 41, 42, and 43. Whenever the measurement equipment is placed on the vehicle, it shall be insulated therefrom by a non-conducting material of adequate size. With the measurement equipment located on the fender as close as possible to the engine compartment and arranged so that the antenna is situated near the lateral axis of the engine, the rod antenna shall be sloped across the engine compartment so that the tip of the antenna is located in a vertical plane through the edge of the opposite fender or similar outermost extremity of metal, but the midpoint of the antenna shall not be placed closer than 1 foot from the top of the engine compartment. When testing front or rear radiation, depending upon location of engine compartment, the measurement equipment shall be located so that the base of the antenna lies in same horizontal plane as the top of the front radiator grill or rear lower edge of top radiator grill. The rod antenna shall be sloped across the engine compartment so that the midpoint of the antenna is not more than 24 inches nor less than 12 inches above the engine compartment. If the antenna is unobstructed with the measurement equipment as close as possible to the vehicle or engine compartment, the antenna shall be sloped so that the midpoint is 12 inches above the engine compartment.

4.5.3.1.2 Over the frequency range of 40 to 1000 mc., the antenna of interference test equipment shall be located as shown on figures 44, 45, 46, 47, 48 and 49.

4.5.3.2 Inside radiation test for turreted vehicles (tactical).- In addition to the outside radiation test (see 4.5.3.1), all turreted type tactical vehicles shall have an inside radiation test conducted over the frequency range of 1.5 to 40 mc. Inside radiation tests shall be conducted with all electrical equipment in the vehicle in operation.

4.5.3.2.1 The measurement equipment shall be placed on an insulating board on the outside of the vehicle as close as possible to each antenna outlet normally provided in the vehicle. A 9-foot length of antenna lead-in wire (W-128) shall be routed successively in each lateral direction around the inside of the vehicle as shown by routings A and B on figure 50, and connected to the measurement equipment with the shortest possible length of antenna wire external to the vehicle. The inside radiation tests shall be conducted with all hatches closed in order to minimize pick-up of ambient noise. The radio interference shall be measured for both routings of the antenna wire at each antenna outlet location over the frequency range of 1.5 to 40 mc.

4.5.3.3 Conducted interference test (tactical vehicles). - This test will be made on all types of tactical vehicles designed for installation of communication equipment, and on electrical accessories for such vehicles, over the frequency range of 1.5 to 40 mc. The conducted interference level shall be measured with the required coupling network connected successively between each pair of terminals intended to supply power to communications equipments and between each such terminal and ground, at each electrical terminal box, contact block, or connector.

4.6 Inspection procedures. - For Naval purchases, the general inspection procedures shall be in accordance with General Specifications for Inspection of Material.

5. PREPARATION FOR DELIVERY

5.1 Not applicable.

6. NOTES

6.1 Performance characteristics of reference measuring instruments. -

6.1.1 Radio interference and field intensity meters for the range of 0.015 to 25 mc. - The following characteristics are of radio interference and field intensity meters intended for use under this specification for the measurement of radio interference.

6.1.1.1 The reference measuring instrument should use the superheterodyne circuit with a calibrated output indicator in the second detector and an audio frequency amplifier for the operation of headphones.

6.1.1.2 The reference instrument should be provided with a rod antenna and input connections for loop and probe antennas and for two terminal assymetrical voltage measurements.

6.1.1.3 For adjustment purposes, the reference instrument should include a signal source to be used as a secondary or transfer standard, which should be calibrated in terms of the primary standard.

6.1.1.4 The primary standard for reference calibration should be the r.m.s. voltage of an unmodulated sine wave, such as obtained from a standard signal generator.

6.1.1.5 For measurement of field intensities, the value in r.m.s. microvolts per meter should be calculated from a voltage calibration and the value of the effective height of the rod antenna or the loop constants as stated in the manufacturer's certificate.

6.1.1.6 Frequency ranges. -

6.1.1.6.1 The reference measuring instrument or instruments may have one or two of the following frequency ranges:

(a) Range A, 14 to 150 kc.
(b) Range B, 150 kc. to 2 mc.
(c) Range C, 2 to 25 mc.

6.1.1.6.2 The frequency range covered should be continuous within any range.

6.1.1.6.3 Two range meters may cover either ranges A and B, or ranges B and C. In either case, at least a 5 percent frequency overlap between ranges should be provided.

6.1.1.6.4 The indicated frequency, in all ranges, should be correct to within 2 percent.

6.1.1.7 Radio frequency voltage and field intensity ranges (minimum). -

6.1.1.7.1 The radio frequency voltage range for two-terminal assymetrical voltage measurements made without external multipliers should include for frequency range A, 10 microvolts to 1 volt; for frequency range B, 10 microvolts to 1 volt; for frequency range C, 10 microvolts to 1 volt.

6.1.1.7.2 The radio frequency field intensity measurements range with rod antenna should include for frequency range A, 10 microvolts per meter to 2 volts per meter; for frequency range B, 20 microvolts per meter to 2 volts per meter; for frequency range C, 20 microvolts per meter to 2 volts per meter.

6.1.1.7.3 A small loop or loops should be supplied which may be used for probing operations.

6.1.1.8 Indicating output meter scales. - The indicating instrument output meter should have two scales as follows:

(a) Scale 1, approximately linear, calibrated in decibels above 1 microvolt.
(b) Scale 2, two decades, approximately logarithmic, calibrated in microvolts.

6.1.1.9 Antennas. -

6.1.1.9.1 Each meter should be provided with rod antenna adjusted to give an effective height of approximately 1/2 meter.

6.1.1.9.2 The meter should be provided with connections and an input combination following good engineering practice to permit the use of a loop antenna for field intensity measurements.

6.1.1.9.3 The meter should be provided with connections for a shielded loop probe not more than 2 inches in diameter.

6.1.1.10 Input impedance. -

6.1.1.10.1 The input impedance for use as a two terminal voltmeter should be at least 50,000 ohms below 150 kc., at least 5,000 ohms below 2 mc., and at least 400 ohms below 25 mc.

6.1.1.11 Attenuator. -

6.1.1.11.1 At least five steps of attenuation should be provided with ratios of 1, 10, 100, 1000 and 10,000 so connected in the circuit as to have substantially no effect on the input impedance.

6.1.1.11.2 At least two of the four decades of the attenuator should be ahead of the amplifying tubes.

6.1.1.12 Sensitivity. -

6.1.1.12.1 The standard sensitivity of the meter should be such that with a sine wave signal of the minimum strength specified in 6.1.1.7 applied to the input terminals at any frequency within the tuning range, an angular deflection of the output indicator due to the signal of not less than 5 percent of full scale deflection will occur on scale 1.

6.1.1.13 Audio sensitivity and fidelity. -

6.1.1.13.1 The audio sensitivity should be sufficient to provide 100 milliwatts across a 600-ohm load with a minimum input voltage specified in 6.1.1.7 modulated 30 percent.

6.1.1.13.2 The audio amplifier response, when applied to the proper terminating impedance should not vary more than 15 percent from its value at 400 c.p.s. for a frequency range of 100 to 4,000 c.p.s.

6.1.1.14 Selectivity. -

6.1.1.14.1 The overall selectivity or effective bandwidth of standard meters over their entire frequency range should be known. Such data should be furnished in the form of tables or curves when r.f. stages ahead of the intermediate amplifier stages influence overall equipment bandwidth.

6.1.1.14.2 It is recommended that no over-coupled or stagger-tuned circuits be used.

6.1.1.15 Cross-modulated selectivity. - At least one tuned circuit embodying good engineering practice should be used ahead of the first radio frequency amplifier in order to minimize cross-modulation.

6.1.1.16 Spurious response rejection. -

6.1.1.16.1 Spurious response rejection (including primary image) is a measure of the degree to which the equipment is capable of rejecting signals off resonance, which, when combined with the fundamental or any harmonic or the conversion oscillator system, produce intermediate frequencies which are amplified by the i.f. amplifier and result in spurious responses. It is expressed in terms of the attenuation, in decibels relative to the desired signals, introduced to image frequencies or other spurious responses with respect to a desired signal.

6.1.1.16.2 The spurious response rejection should be 50 db or better, throughout the frequency range of the meter.

6.1.1.17 Detector circuits. - Suitable switching arrangements should be provided in the detector circuit to permit selection of the proper circuit constants and means for obtaining any one of the three measurements specified in 6.1.1.17.1, 6.1.1.17.2 and 6.1.1.17.3.

6.1.1.17.1 Average value. - The circuits and time constant for this measurement should be such that the output meter indication will not change more than 5 percent when the carrier is modulated 80 percent at a frequency equal to 1/2 the nominal i.f. bandwidth.

6.1.1.17.2 Quasi-peak value. - The charge time and discharge time of the circuit for this measurement should be:

(a) Charge time 1 ± 0.5 millisecond
(b) Discharge time 600 ± 120 milliseconds

6.1.1.17.3 Peak value. - The circuits should provide means for measurement of the peak value of the i.f. envelope in the detector circuits. The "slideback" method may be used for this purpose.

6.1.1.17.4 Conversion factors for quasi-peak only instruments. - On those instruments without a peak reading circuit, the curves shown on figure 51 may be utilized to determine what the true peak is if the repetition rate of the impulsive interference is known.

6.1.1.18 Automatic gain control. - If automatic gain control is used, the threshold of operation of the AGC should be low enough to obtain essentially logarithmic indicating meter response and the time constant in quasi-peak position should be short compared to the detector time constants. Also the output meter actuating voltage should be a single valued function of the AGC voltage.

6.1.1.19 Overload characteristics. -

6.1.1.19.1 The overload factor is the ratio between the value of the sine wave input voltage which causes 10 percent departure from linearity to the value of the lower input voltage which causes full-scale deflection of the indicating instrument.

6.1.1.19.2 In making the test to determine overload factor, during the application of the higher voltage the AGC voltage should be held constant at the value which existed when the full scale deflection was obtained. The test should be made for each of the five positions of the step attenuator and the smallest ratio so obtained shall be taken as the overload factor of the instrument.

6.1.1.19.3 The overload factor should be 12 ± 2 db.

6.1.1.19.4 The circuit characteristics should, in addition to meeting these specific requirements, minimize the likelihood of overloading the first r.f. stage by sharp pulses applied at the input before operation of the meter is limited by the overload factor.

6.1.1.20 Indicating instrument characteristics. -

6.1.1.20.1 The indicating instrument, with its circuit resistance as used in the meter, should be nearly critically damped with a preferred overshoot of 1 to 6 percent.

6.1.1.20.2 Under the conditions of use in the meter, the response time of the indicating instrument should be 275 ± 75 milliseconds.

6.1.1.20.3 The response time is the time required after an abrupt change has occurred in the measured quantity to a new constant value until the pointer, or indicating means, has come to apparent rest in its new position.

6.1.1.20.3.1 Since, in some instruments, the response time depends on the magnitude of the deflection, a value corresponding to an initial deflection from zero to end scale is used in determining the response time for rating purposes.

6.1.1.20.3.2 The pointer is at apparent rest when it remains within a range of 3 percent of either side of its final position.

6.1.1.21 Shielding and filtering. - The shielding or filtering of the equipment and those circuits to which external connections should be made by external shielded cables should be such that with equipment tuned to a signal of any frequency and of any field intensity within its normal range and the antennas, transmission lines, loops, or any input devices disconnected, the radio noise meter indication should decrease by a factor of at least 1,000 or 60 db.

6.1.1.22 Power supply. -

6.1.1.22.1 The equipment should operate satisfactorily with the power supply units specified in 6.1.1.22.2 and 6.1.1.22.3.

6.1.1.22.2 A battery power supply unit should be available as an operational part of the meter. It should be capable of satisfactorily operating the meter for a continuous period of 5 hours. Provision should be made to permit intermittent monitoring of battery voltages.

6.1.1.22.3 An a.c. power supply unit should be available as a unit that may physically replace the battery power unit. It should be capable of satisfactorily operating the meter from a power source of 105 to 125 volts, single-phase, 50 to 400 c.p.s.

6.1.1.23 Output receptacles. - Three output receptacles, fitted with such radio-frequency filters as may be necessary, should be provided.

6.1.1.23.1 A receptacle for connection of a 0 to 1 ma. recording milliammeter should be so connected that the recording instrument and the indicating instrument may be used simultaneously.

6.1.1.23.2 A shielded receptacle should permit connection of an oscilloscope to the output of the a.f. amplifier. One plug and a properly shielded cable at least 3 feet long should be provided with the meter. The connections and shielding should be such that proper use of the oscilloscope will not affect the accuracy of the meter.

6.1.1.23.3 A standard telephone jack should be provided for connection of headphones.

6.1.2 Radio interference and field intensity meters for the range of 20 to 1000 mc. - The following characteristics are of radio interference and field intensity meters for the range of 20 to 1000 mc. per second intended for use under this specification for the measurement of interference.

6.1.2.1 The reference meters should use the superheterodyne circuit with a calibrated output indicator following the second detector and an audio frequency amplifier for the operation of headphones and oscilloscope.

6.1.2.2 The reference meters should be provided with calibrated antennas and with input connections for probe antennas and for two-terminal voltage measurements.

6.1.2.3 The primary standard for reference calibration should be the r.m.s. voltage of an unmodulated sine wave, such as obtained from a standard signal generator.

6.1.2.4 For calibration purposes, the meters should include a signal source to be used as a secondary or transfer standard, which should be established in terms of the primary standard.

6.1.2.5 For field intensity measurements, the value should be calculated from (a) the voltage calibration and (b) the value of the effective length of the antenna. For other input devices requiring calibration, appropriate factor should be provided to arrive at the true voltage.

6.1.2.6 Frequency ranges. -

6.1.2.6.1 The recommended frequency ranges for these meters are:

(a) Range A	20 to 250 mc.
(b) Range B	200 to 1000 mc.

6.1.2.6.1.1 Meters with different frequency ranges are suitable if they conform in all other respects with this specification.

6.1.2.6.2 There should be at least a 5 percent overlap in frequency at any discontinuity caused by a band or meter change.

6.1.2.6.3 The indicated frequency should be correct to within 2 percent.

6.1.2.7 Radio frequency voltage range. -

6.1.2.7.1 The radio frequency voltage range for two-terminal assymetrical voltage measurements without external multipliers should be:

(a) Frequency range A	5 microvolts to 1 volt.
(b) Frequency range B	10 microvolts to 1 volt for recommended bandwidth of 0.10 mc. and 30 microvolts to 1 volt for recommended bandwidth of 1.0 mc. (see 6.1.2.14).

6.1.2.8 Output instrument scales (indicating). - The output indicating instrument should have a scale of two decades approximately logarithmic. It is desirable to include a (one decade), approximately linear voltage scale.

6.1.2.9 Antennas and probes. -

6.1.2.9.1 Antennas with calibrations should be provided throughout the frequency range. It is recommended that the maximum total length should be 10 feet (3.05 meters).

6.1.2.9.2 A substantially non-metallic tripod should be furnished with the antenna members so mounted that the direction of polarization in the vertical plane may be rotated through at least 90 degrees. The height of the antenna center should be adjustable to at least 1/4 wave length above the ground level.

6.1.2.9.3 The transmission line connecting antennas to the meter should be at least 20 feet (6.32 meters) long. An extension line 20 feet (6.32 meters) long should be provided. If the attenuation along these lines is such as to cause an error in reading field intensity of 10 percent or more, curves showing corrections should be furnished.

6.1.2.9.4 The shielding of the transmission line should be at least as good as RG-55/U cable. (This cable has double braid of tinned copper wires No. 36 A.W.G.)

6.1.2.9.5 The meters should be provided with connections for shielding loop probes. The probes, included with the meters, should have sufficient insulation over the shielding to permit safe contact with low voltage (not over 600 volts) apparatus under test. The diameter of the probes should be:

(a) Frequency range A — 3 inches (5.08 cm.) or smaller.
(b) Frequency range B — 1 inch (2.54 cm.) or smaller.

6.1.2.10 Input impedance. -

6.1.2.10.1 The input of instruments should be of the coaxial type for a nominal impedance of 52 ohms. Overall performance, in accordance with the requirements of this specification, should be in terms of a two-terminal assymetrical voltmeter referred to this coaxial input.

6.1.2.10.2 A device of minimum insertion loss should be furnished as a separate unit that will present the highest practical impedance to the circuit under measurement. Such high impedance devices may be provided with controls for adjustment to resonance over the equipment frequency range. A calibration chart should be furnished with the unit to allow calibrated operation as a voltmeter.

6.1.2.11 Attenuator. -

6.1.2.11.1 An attenuator should be provided with ratios of 1, 10, 100, 1,000 and 10,000 and should be so connected in the circuit as to have substantially no effect on the input impedance.

6.1.2.11.2 At least three of the attenuator decades should be ahead of the amplifying tubes.

6.1.2.11.3 The attenuator accuracy based on sine wave measurements should be within plus or minus 1 db on each attenuator position.

6.1.2.12 Sensitivity. -

6.1.2.12.1 The standard sensitivity should be such that with a sine wave signal of the minimum strength stated in 6.1.2.7 applied to the input terminals at any frequency within the tuning range, an increase in angular deflection of the output indicator of not less than 5 percent of full-scale deflection will occur.

6.1.2.12.2 The internal noise level should be not more than 30 percent of the minimum signal values given under ranges A and B of 6.1.2.7 on step one of the attenuator and less on other steps of the attenuator.

6.1.2.12.3 It is recommended that an additional gain of at least 10 db above that specified in 6.1.2.12.1 be provided for measurement of low level signals.

6.1.2.13 Audio sensitivity and fidelity. -

6.1.2.13.1 The audio sensitivity should be defined as the value of the radio frequency sine wave voltage modulated 30 percent at 400 c.p.s. that is necessary to produce 10 milliwatt to a 600-ohm load in the audio output.

6.1.2.13.2 The audio sensitivity as defined above should be at least:

(a) Frequency range A	5 microvolts.
(b) Frequency range B	10 microvolts.

6.1.2.13.3 The audio response voltage, when impressed on the proper terminating impedance, should not vary more than plus or minus 30 percent from its value at 400 cycles in the range of 100 to 10,000 c.p.s.

6.1.2.14 Bandwidth. - The recommended nominal bandwidths of the meter circuits are as follows:

(a) Frequency range A	0.10 mc. per second at -6 db.
(b) Frequency range B	0.10 mc. per second at -6 db and 1.0 mc. per second at -6 db.

6.1.2.14.1 The manufacturer should state the overall bandwidth as a function of frequency in terms of average single frequency voltages and also in terms of average single frequency voltages squared.

6.1.2.14.2 It is recommended that no over-coupled circuits be used

6.1.2.15 Cross response rejection. - At least one tuned circuit embodying good engineering practice should be used ahead of the first radio frequency amplifier to minimize cross-modulation and over-loading.

6.1.2.16 Spurious response rejection. - Spurious response rejection (including primary image) is a measure of the degree to which the equipment is capable of rejecting those signals off resonance, which when combined with the fundamental or any harmonic or the conversion oscillator system, produce intermediate frequencies that are amplified by the intermediate frequency amplifier and result in spurious responses. Degree of rejection is expressed in terms of the attenuation, in db relative to the desired signals, introduced to image frequencies or other spurious responses with respect to a desired signal.

6.1.2.16.1 The spurious response rejection should be 40 db or better.

6.1.2.17 Detector circuits. - Switching arrangements should be provided in the detector circuit to select the proper circuit constants to obtain any one of the three measurements indicated in 6.1.2.17.1, 6.1.2.17.2 and 6.1.2.17.3.

6.1.2.17.1 Average value. - The charge time and discharge time of the circuit for this measurement should be equal to or less than 1/5F where F is the nominal bandwidth.

6.1.2.17.2 Quasi-peak value. - The charge time and discharge time of the circuit for this measurement should be:

(a) Charge time 1 ± 0.5 millisecond (closer tolerances are desirable).
(b) Discharge time 600 ± 120 milliseconds (closer tolerances are desirable).

6.1.2.17.3 Peak value. - The circuits should provide means for measurement of the peak value of the intermediate frequency envelope in the detector circuits. The "slideback" or equivalent method should be used for this purpose.

6.1.2.17.4 Conversion factors for quasi-peak only instruments. - On those instruments without a peak reading circuit, the curves shown on figure 51 may be utilized to determine what the true peak is if the repetition rate of the impulsive interference is known.

6.1.2.18 Automatic gain control. - If automatic gain control is used, its threshold of operation should be sufficiently low to obtain essentially logarithmic indicating instrument response. The meter actuating voltage should be a linear function of the automatic gain control voltage.

6.1.2.19 Overload characteristics. - The overload factor is the ratio of the peak value of the pulse input voltage that causes 10 percent departure from linearity to the peak value of pulse input voltage that causes full-scale deflection of the indicating instrument. Here, peak value refers to 6.1.2.17.3. The duration of the pulse signal used should be less than the reciprocal of the effective bandwidth.

6.1.2.19.1 In making the test to determine the overload factor during the application of the higher voltage, the automatic gain control voltage, if used, should be held constant at the value that existed when the full-scale deflection was obtained. The test should be made for each position of the attenuator.

6.1.2.19.2 The overload factor should be 18 ± 2 db.

6.1.2.20 Indicating instrument characteristics. -

6.1.2.20.1 The indicating instrument, with its circuit resistance as used in the meter, should be nearly critically damped with a preferred overshoot of not less than 1 percent nor more than 6 percent.

6.1.2.20.2 Under the conditions of use in the meter, the response time of the indicating instrument should be 275 ± 75 milliseconds.

6.1.2.20.3 The response time is the time required, after an abrupt change has occurred in the measured quantity, for the pointer, or indicating means to come to apparent rest in its new position.

6.1.2.20.3.1 Since, in some instruments, the response time depends on the magnitude of the deflection, a value corresponding to an initial deflection from zero to end scale is used in determining the response time for rating purposes.

6.1.2.20.3.2 The pointer is at apparent rest when it remains within a range of 3 percent of either side of its final position.

6.1.2.21 Shielding and filtering. - The shielding and filtering of the equipment and those circuits to which external connections should be made by external shielded cables, should be such that with equipment tuned to a signal of any frequency and of any field intensity within its normal range and the antennas, transmission lines, loops, or any input devices removed, the instrument indication should decrease by at least 60 db in all attenuator positions. Attention should be given to minimize the penetration through instrument case of fields outside the frequency of the meter.

6.1.2.21.1 Any limitation in the use of the calibrating source due to external fields should be stated by the manufacturer.

6.1.2.22 Power supply. -

6.1.2.22.1 The equipment should operate according to specification from the following power sources:

(a) From d.c. source of 6 volts.
(b) From an a.c. source of 105-125 volts and 210-250 volts, 50 to 1,000 c.p.s.

6.1.2.22.2 The power consumption should not be greater than 125 watts.

6.1.2.22.3 The effects of changes in source voltage on the calibration should be stated by the manufacturer.

6.1.2.23 Output receptacles. - Three output receptacles, fitted with such radio frequency filters as may be necessary, should be provided.

6.1.2.23.1 A receptacle for connection of a 0 to 1 ma. recording milliammeter or remote indicating meter should be so connected that either one may be used simultaneously with the indicating instrument on the radio noise meter.

6.1.2.23.2 A shielded receptacle should permit connection of an oscilloscope to the output of the audio frequency amplifier. One plug and a properly shielded cable at least 3 feet long should be provided with the meter. The connections and shielding should be such that proper use of the oscilloscope will not affect the accuracy of the meter.

6.1.2.23.3 A standard telephone jack should be provided for the connection of headphones.

6.2 Line and load impedance stabilization network. - The network described herein should be used when making measurements of conducted interference, as specified in 4.3. One network should be inserted, where called for, in each power or electrical load leak when making measurements.

6.2.1 Performance characteristics. - The performance characteristics of this device will permit conducted measurements of test items of the following voltage ratings:

D.c.	600 volts
60 cycles	440 volts
400 cycles	230 volts
800 cycles	115 volts

6.2.1.1 The current carrying capacity is 50 amperes, d.c. to 800 cycles a.c. The maximum voltage drop at 50 amperes is not over 1 percent of the supply voltage. The shunt current drawn by the network is 0.5 ampere maximum at 115 volts, 800 c.p.s. It is estimated that this impedance stabilization device will permit conducted interference tests of about 90 percent of items requiring such tests.

6.2.2 Design of network. - Working drawings and an electrical schematic of this device are included as figures 19 through 24. A curve showing the average input impedance of the stabilization network is shown on figure 23.

6.3 Design. - Radio interference should be carefully considered in the basic design of all equipment major units, assemblies, and systems. Electrical and electronic equipment should operate satisfactorily not only alone, but also in conjunction with other such equipment which may be placed nearby. This requires that the operation of all such equipment should not be adversely affected by radio interference voltages and fields reaching it from external sources, and also requires that such equipment should not itself be of a source of radio interferences which might adversely affect the operation of other nearby equipment. Therefore, design should be such that the least practical amount of radio interference is inherently generated and propagated before interference reduction major units are applied. Such radio interference reduction major units and techniques that should be used, such as filtering, shielding and bonding, should be in conformance with good engineering practice and should be used efficiently in order to minimize space and weight penalties. All possible advantages should be taken of the use of radio interference source reduction such as the use of mica capacitors directly at the interference source. The recommendations in the following paragraphs will aid in meeting these requirements.

6.3.1 Major unit placement. - Major units should be placed and circuitry arranged in such order as to result in a minimum of coupling and in the use of a minimum of filter major units.

6.3.2 Case shielding. - The number of mechanical discontinuities in the case (such as covers, inspection plates, front plates, and joints), should be kept to the minimum. All necessary mechanical discontinuities in the case should be electrically continuous across the interface of the discontinuity so as to provide a low impedance current path throughout the frequency range specified in this specification. A multiple point spring-loaded contact interface is suggested as a desirable method of obtaining a low impedance electrical continuity. Where ventilation openings are necessary, they should be so designed or screened as to permit conformance with the limits of radiated interference specified. Expanded mesh or bond screening of fine mesh, will assist in meeting these limits if used to cover all louvers and other openings in such a way as to have low impedance electrical continuity with the case around the entire periphery of the mesh. Electrical bonding should be provided where access doors or cover plates form a part of the shielding. Hinges, in themselves, are not considered as satisfactory conducting means for bonding.

6.3.3 Shielded antenna lead-in. - When practicable, communications equipment should be so designed that proper operation may be obtained when used with a shielded antenna lead-in.

6.3.4 Radio interference filters. - Where additional interference reduction is required after careful design in conformance with the foregoing, the interference reduction major units should be installed inside the enclosing case of the interference source. Filter assemblies not hermetically sealed should employ only hermetically sealed metallic encased capacitors, and should be capable of withstanding all of the service operating conditions of the interference source. As a second choice, where space does not permit the installation of filters within the case of the interference source, they may be attached to the outside of the case of the interference source, provided that the wiring between the interference source and the filter is properly shielded, and that the filter is permanently bonded thereto. Separately installed interference filters should not be used unless specifically authorized by the individual equipment specification, in which case a shielded interconnecting cable should be used between the interference source and the externally mounted filter. The shielding should be permanently bonded to the equipment and the filter case.

6.3.5 Bonding. - Bonding should be accomplished by clean, metal-to-metal contact wherever possible. Bond jumpers should only be used when other direct means are impractical. Internal or sub-assembly bonding of units and provisions for installation or mounting bonding should be such as to provide adequate current path, interference-free operation and safety of personnel where voltages are in excess of 30 volts. Where sliding, swinging, or hinged construction is used, adequate bonding should be provided for all operating conditions. Where rail or slide mounted construction is used for adjustment or servicing, there should be adequate provisions (usually two or more) for attachment of bond jumpers, with a quick detachable feature. All bond jumpers should be wide, thin, solid metallic strips rather than braid. (This does not apply to high current jumpers.)

6.4 This specification covers only radio interference requirements and methods of determining compliance therewith; therefor, the details of performance of the equipment and the ordering information must be specified elsewhere. Attention of design engineers is invited to the items listed below which may be expanded in the individual equipment specification:

(a) Laboratory tests of conducted interference, if all do not apply (see 3.1.5).
(b) Point of test, if line-to-ground does not apply (see 3.1.6).
(c) Radiated interference limits (see 3.1.7, 3.4.1, and 3.6.1.1.1).
(d) Conducted interference limits (see 3.4.2 and 3.6.1.1.2).
(e) Applicable classification of interference instruments (see 3.2 and 3.6).
(f) Receiver oscillator interference limits (see 3.6.1.1.3).
(g) Requirements for self-propelled machinery, if required (see 3.6.3.1).
(h) Radiated and conducted interference limits for tactical vehicles (see 3.6.3.2).
(i) Test for very large stationary electrical or mechanical equipment, if other than specified (see 3.6.4).
(j) Preliminary radio interference tests, if other than specified (see 4.1).
(k) Conditions under which radiated and conducted interference measurements shall be made, if not at normal operating load and at no load (see 4.1.4).
(l) Rated voltage (see 4.1.4.1).
(m) Use of loop antenna for radiated interference measurement, if desired (see 4.2).
(n) Items exempted from open space radiated interference tests, if any (see 4.2.2.1).
(o) Test procedures, if other than those in 4.4.
(p) Position in which measurement instruments shall be set for measurement of broadband interference, if other than peak (slideback) (see 4.4.3).

6.5 Measurement techniques in the presence of internal noise. - Internal noise is that energy present inherently in the input circuit and which causes a meter indication with no radio frequency input in the measuring instruments specified in 6.1. This internal noise is caused by thermal agitation in the resistance of the input circuit and the tubes used in the first stages of the instrument. It has been determined that it is advantageous not to balance out the internal noise present in measuring instruments as the sensitivity of the instrument would be impaired. This internal noise has been taken into account in the limits curves shown on figures 7 and 10.

6.6 Interference reduction by proper design. - Interference minimization should be considered in the basic design of the equipment. As a means of insuring that interference minimization is considered in the initial design, motors and generators should be of such design and construction that when operated at no-load, half-load, or at full-rated-load with no external filtering, the indicated quasi-peak conducted interference shall not exceed 5000 microvolts within the frequency range of 0.15 to 20 mc.

6.7 Radio interference filters. - Radio interference filters or capacitors employed for the reduction of interference should be Navy approved types in accordance with Specification MIL-F-15733.

6.7.1 Interference reduction networks other than filters, such as are sometimes used for special applications including portable electric tools, need not be submitted separately for qualification approval as a filter, but should be capable of conforming to any requirements, concerning operation, heating, dielectric, capacitance, for a particular equipment in which the network may be installed.

6.8 Shielding. - When flexible metallic conduit and associated connectors are used they should conform to Specification MIL-R-16165. In lieu thereof, rigid metallic conduit properly installed for cable shielding may be used.

Patent notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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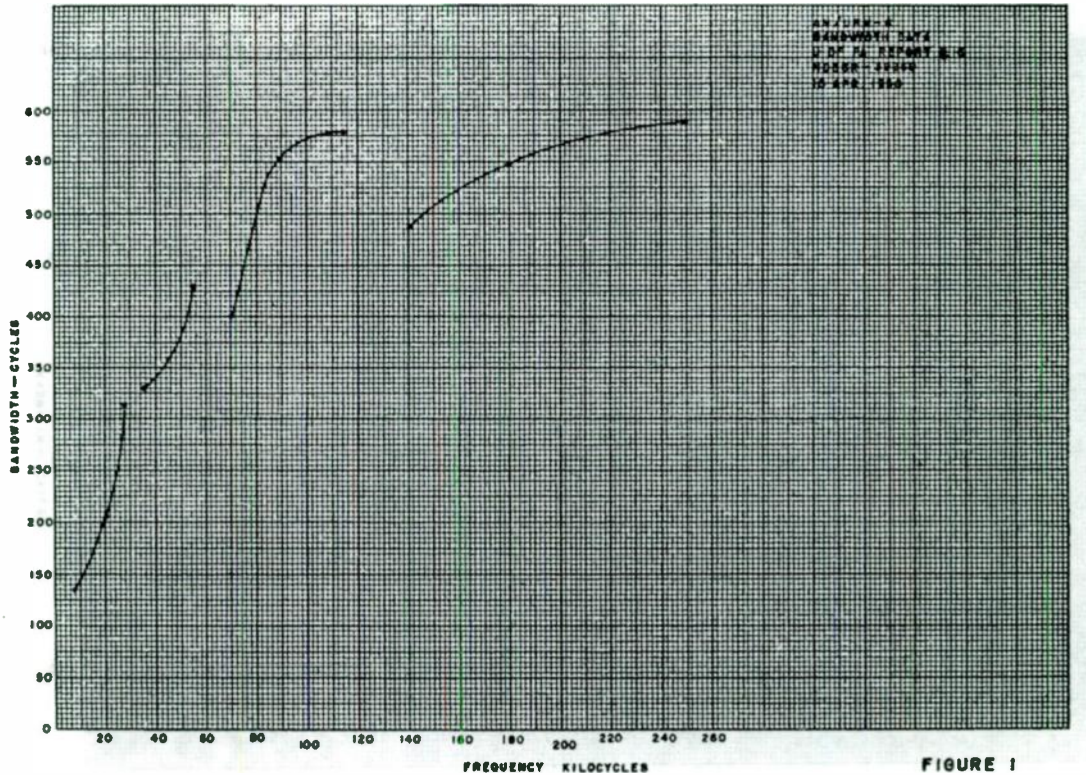

BANDWIDTH — CYCLES
600
550
500
450
400
350
300
250
200
150
100
50
0
20
40
60
80
100
120
140
160
180
200
220
240
260
FREQUENCY KILOCYCLES

FIGURE 1

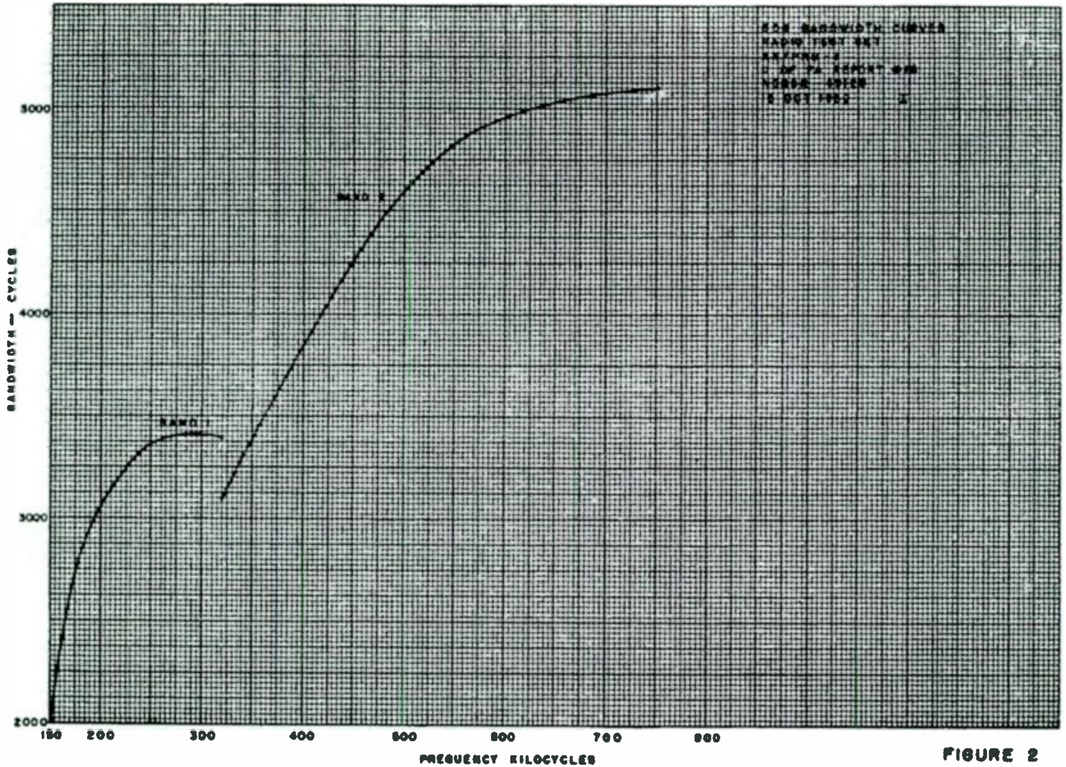

BAND 1
BAND 2
5000
4000
3000
2000
BANDWIDTH — CYCLES
150
200
300
400
500
600
700
800
FREQUENCY KILOCYCLES

FIGURE 2

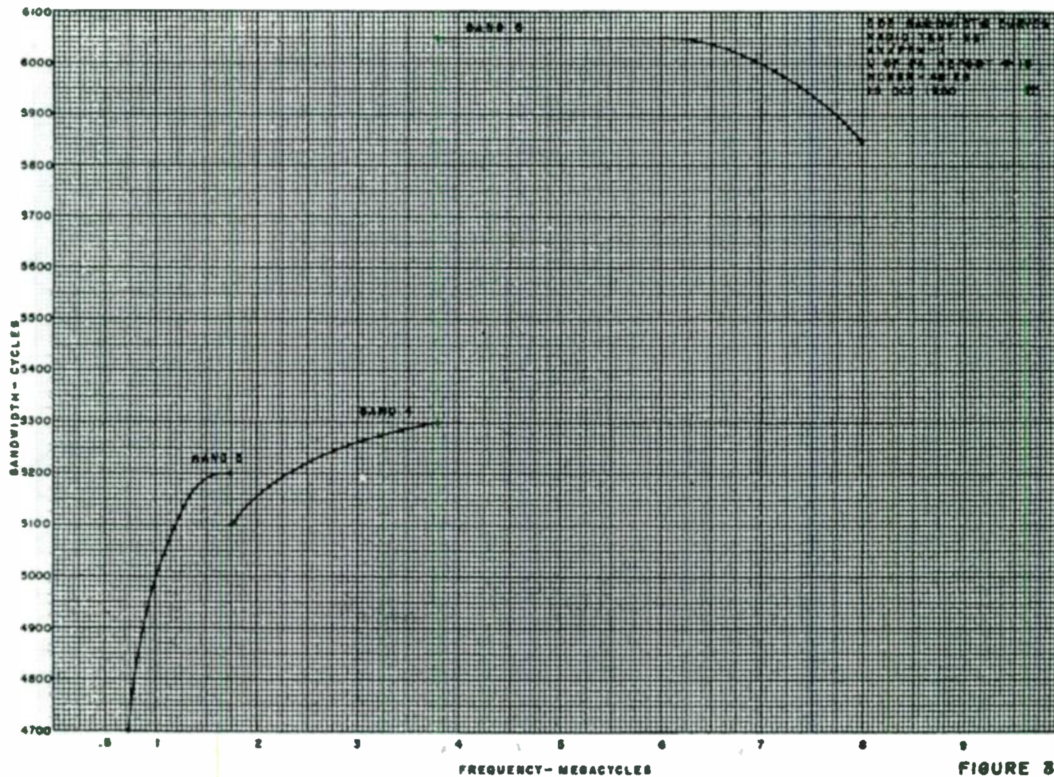
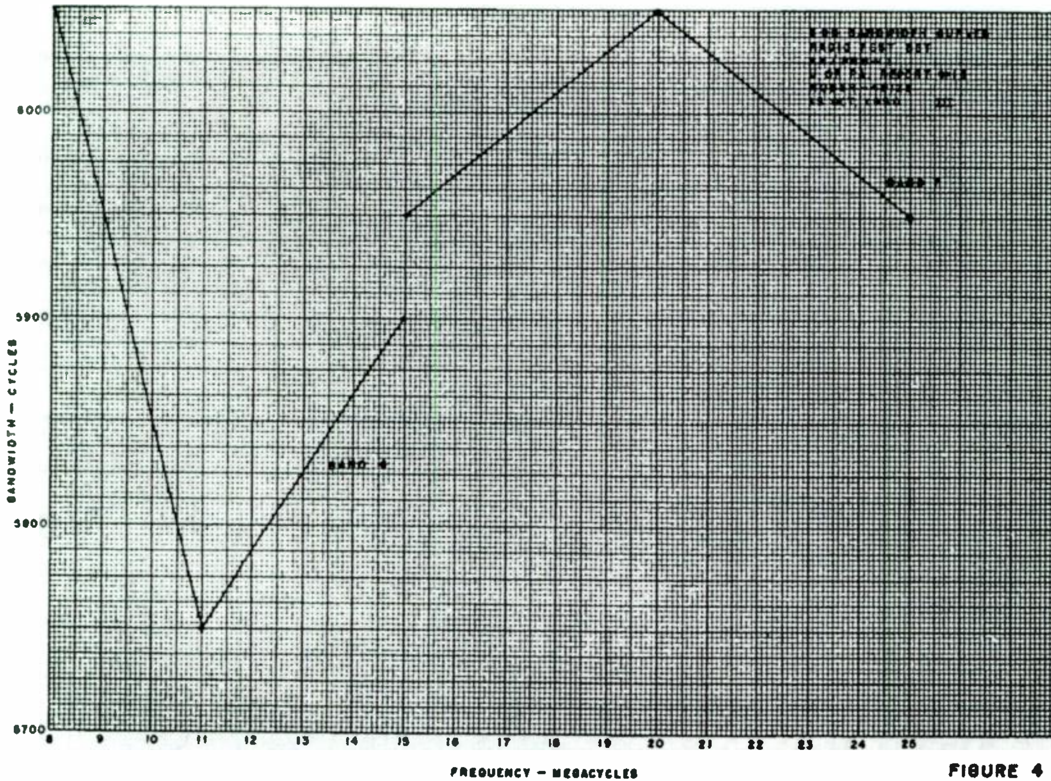
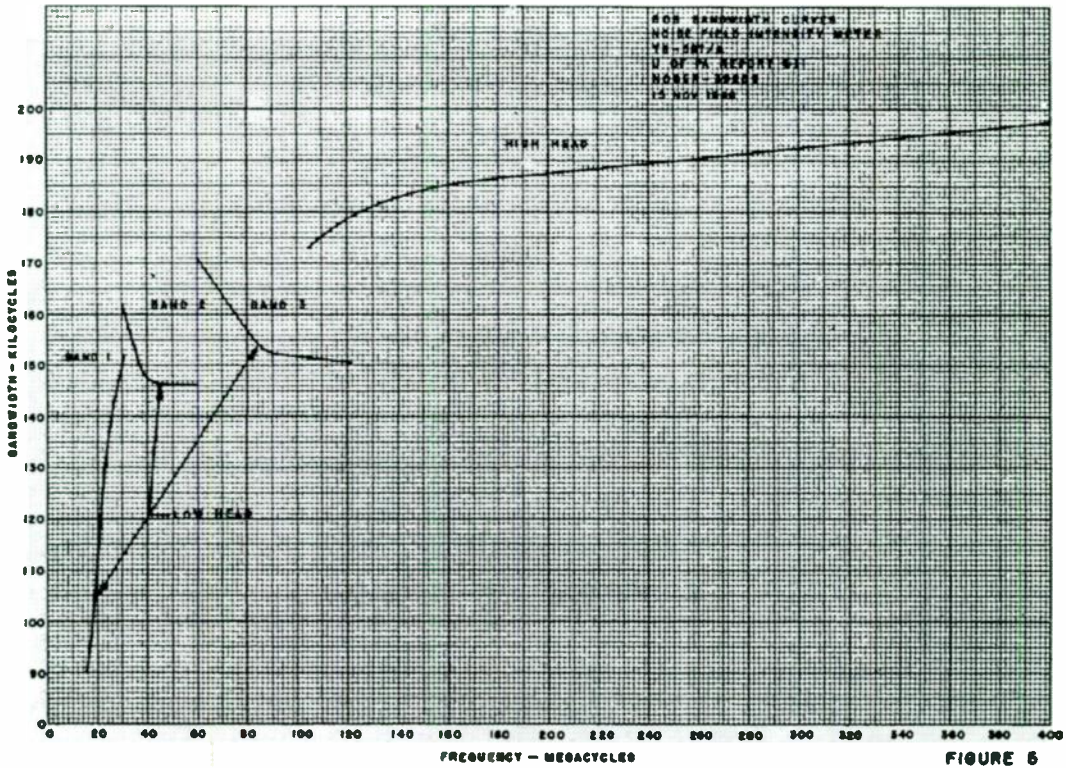

BANDWIDTH - CYCLES
FREQUENCY - MEGACYCLES
BAND 6
BAND 5
BAND 4
6100
6000
5900
5800
5700
5600
5500
5400
5300
5200
5100
5000
4900
4800
4700
.8
1
2
3
4
5
6
7
8
9

FIGURE 8



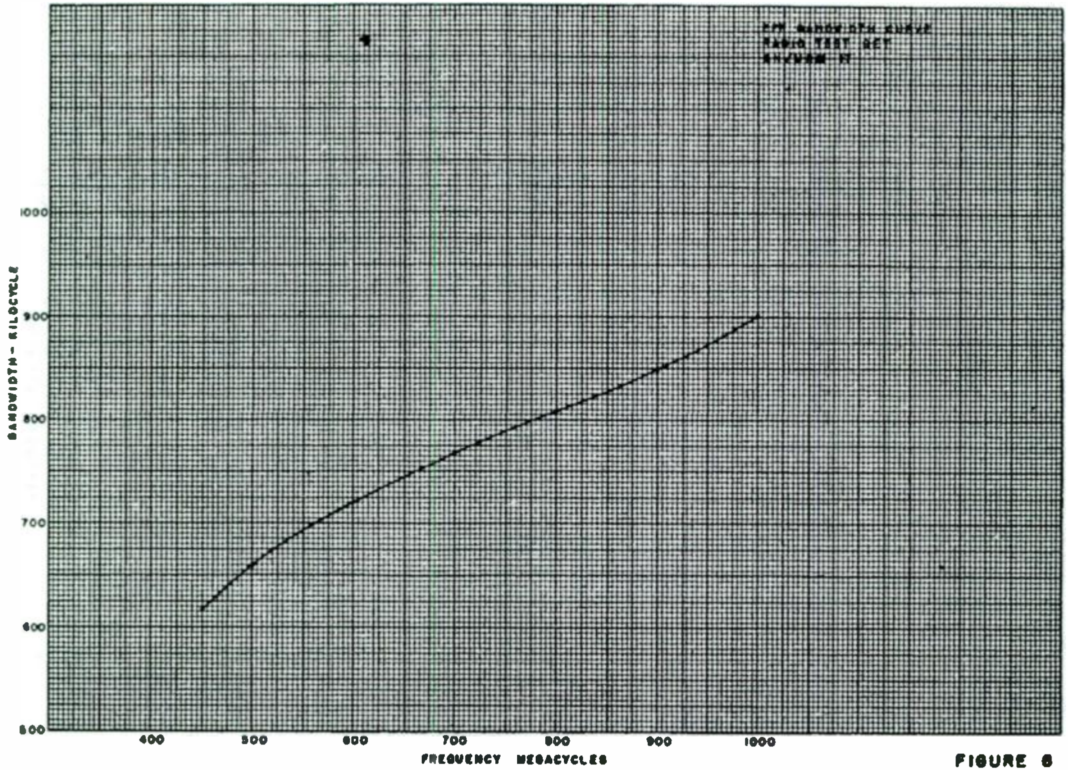
BANDWIDTH — CYCLES
6000
5900
5800
5700
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
BAND 4
BAND 7
FREQUENCY — MEGACYCLES

FIGURE 4



BANDWIDTH CURVES
NOISE FIELD INTENSITY METER
BANDWIDTH - KILOCYCLES
90
100
110
120
130
140
150
160
170
180
190
200
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
BAND 1
BAND 2
BAND 3
LOW HEAD
HIGH HEAD
FREQUENCY — MEGACYCLES

FIGURE 5



1000
900
800
700
600
500
BANDWIDTH - KILOCYCLE
400
500
600
700
800
900
1000
FREQUENCY MEGACYCLES

FIGURE 8

BROADBAND RADIATED INTERFERENCE LIMITS — EXPRESSED IN TERMS OF STANDARD UNITS

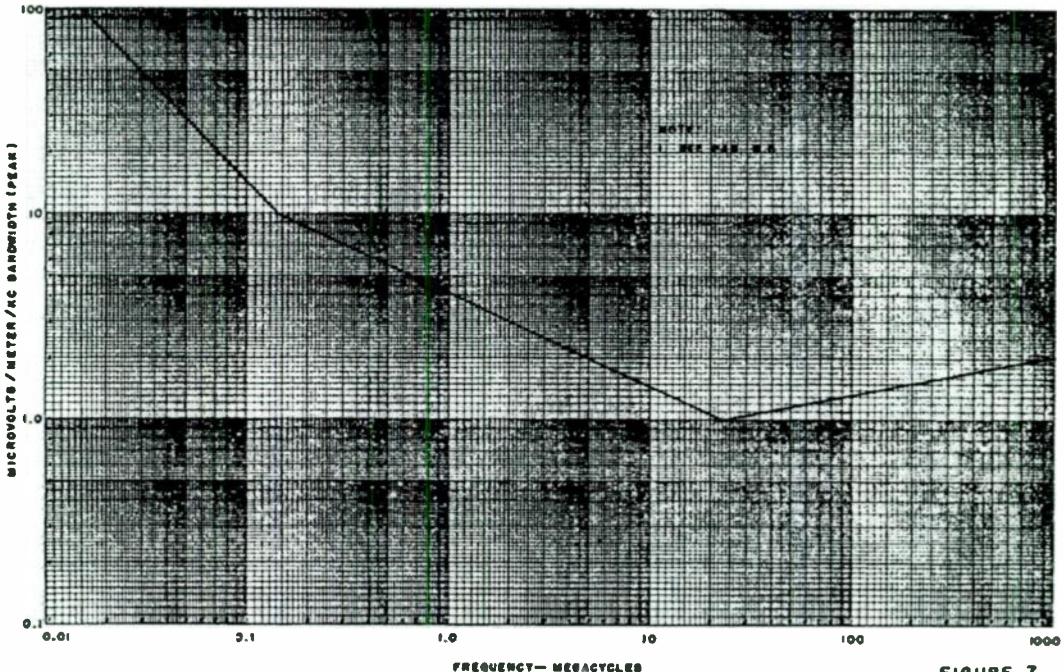


FIGURE 7

CW (SINE WAVE) RADIATED INTERFERENCE LIMITS - EXPRESSED IN TERMS OF STANDARD UNITS

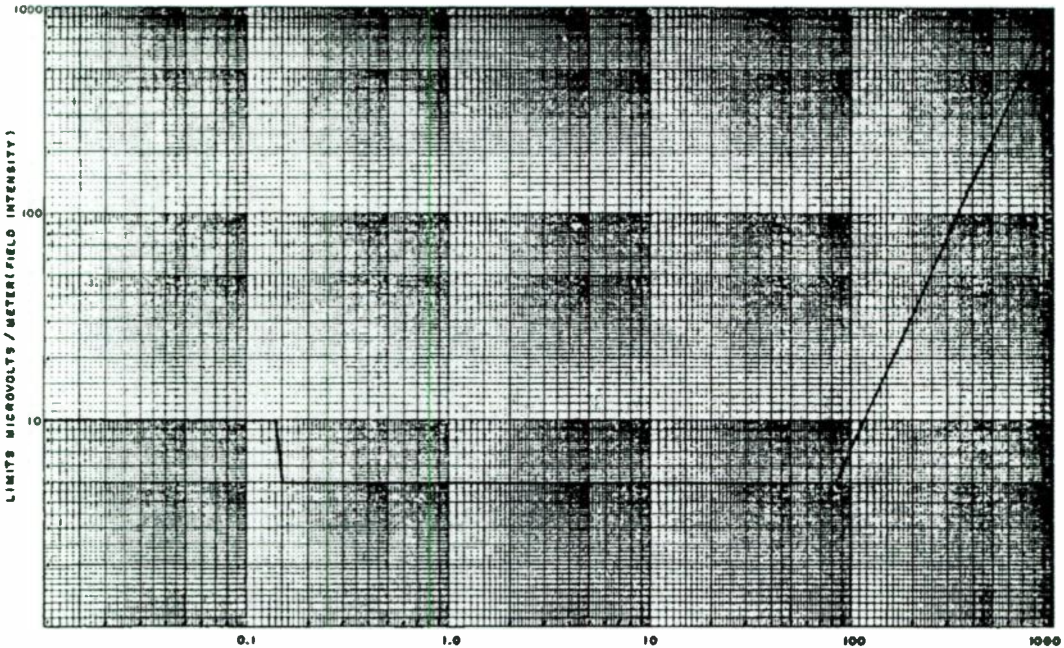


FIGURE 8

BROADBAND RADIATED INTERFERENCE LIMITS-EXPRESSED IN
TERMS OF INDICATED MICROVOLTS FOR PARTICULAR INSTRUMENTS

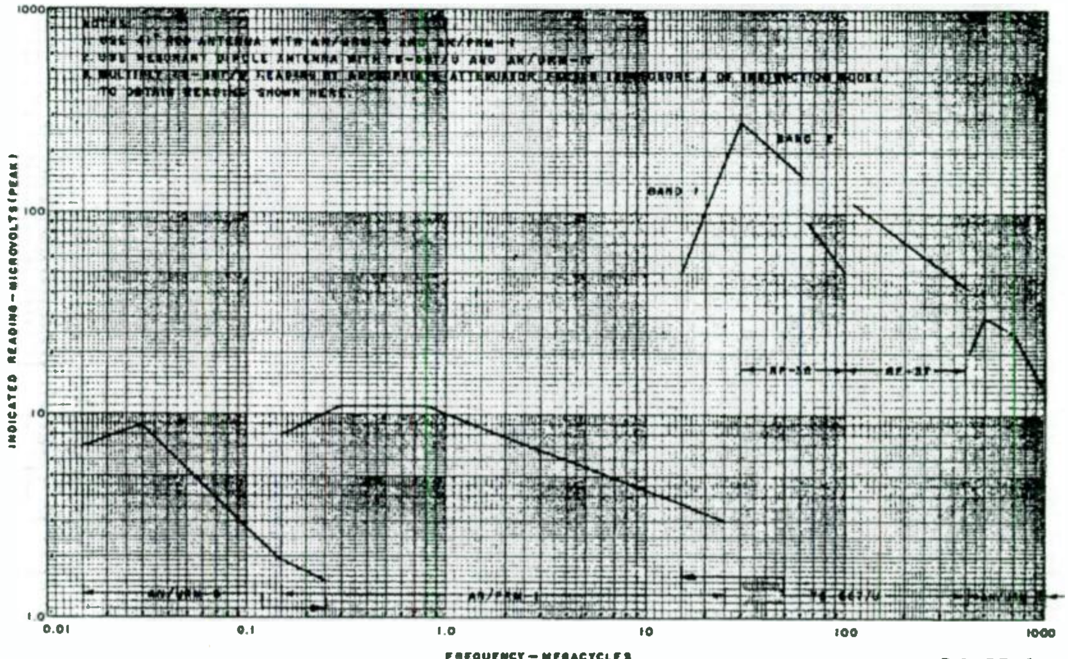
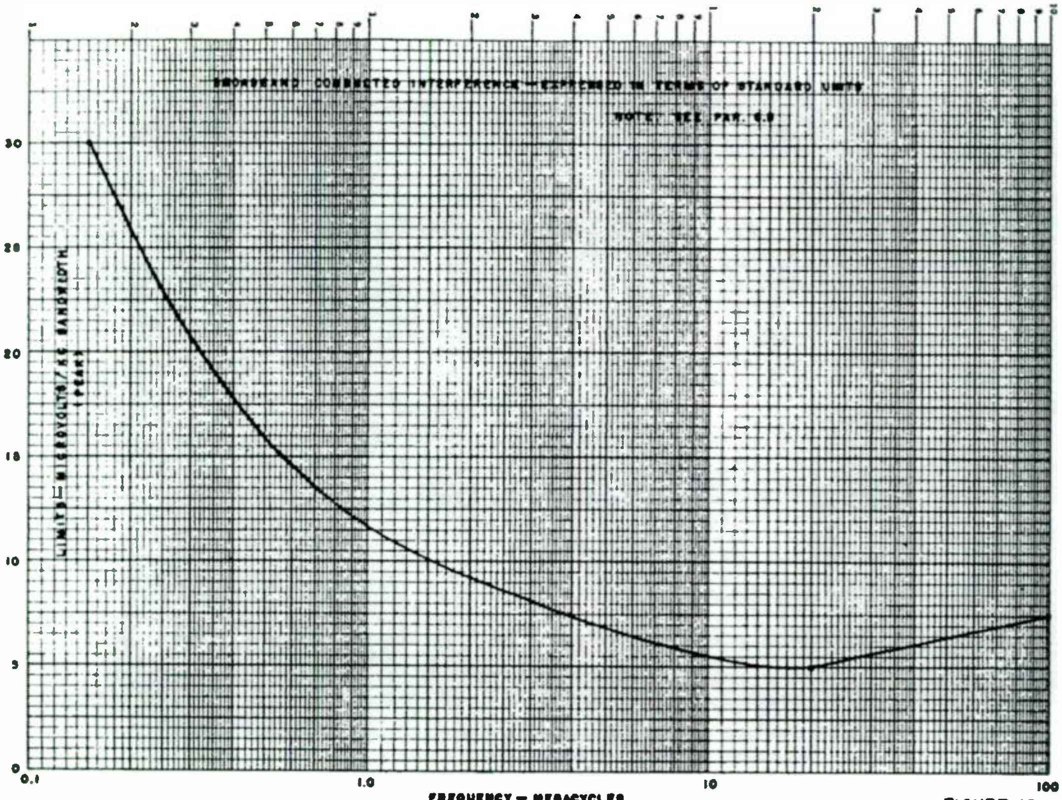


FIGURE 9



BROADBAND CONDUCTED INTERFERENCE — EXPRESSED IN TERMS OF STANDARD UNITS
NOTE: SEE PAR.
LIMITS IN MICROVOLTS/KC BANDWIDTH (PEAK)
30
25
20
15
10
5
0
0.1
1.0
10
100
FREQUENCY — MEGACYCLES

FIGURE 10

CW (SINE WAVE) CONDUCTED INTERFERENCE— EXPRESSED IN TERMS OF STANDARD UNITS

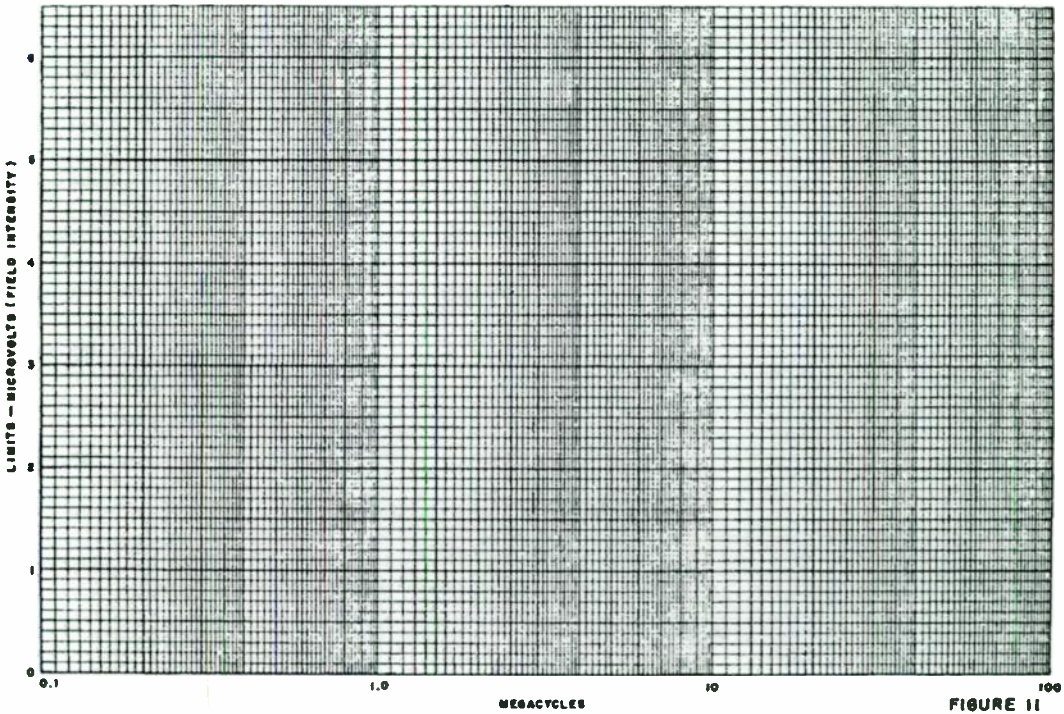


FIGURE 11

BROADBAND CONDUCTED INTERFERENCE - EXPRESSED IN TERMS OF INDICATED MICROVOLTS WITH AN/PRM-1 AND TS-587/U

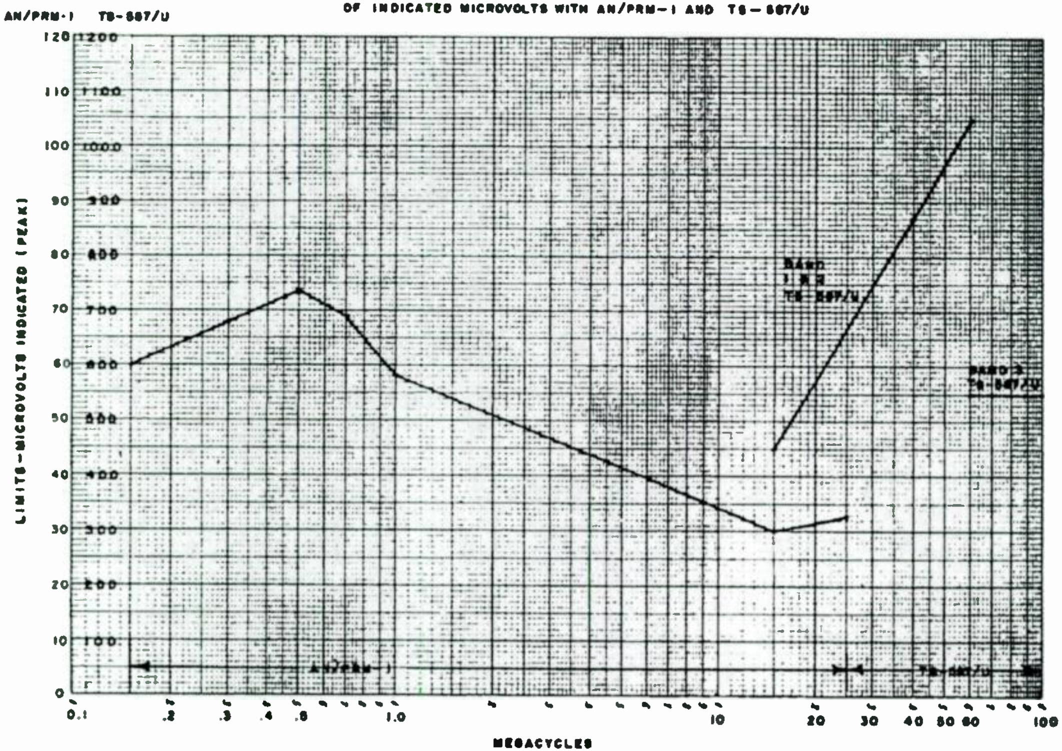
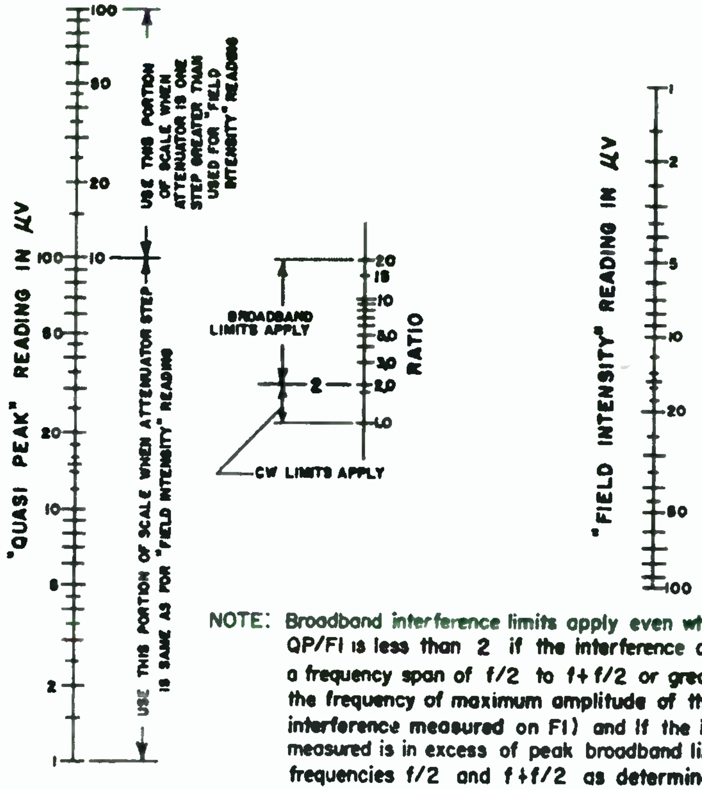


FIGURE 12



NOTE: Broadband interference limits apply even when the ratio QP/FI is less than 2 if the interference detected covers a frequency span of f/2 to f+f/2 or greater (f being the frequency of maximum amplitude of the detected interference measured on FI) and if the interference measured is in excess of peak broadband limits at the frequencies f/2 and f+f/2 as determined above.

FIGURE 13

CHART FOR DETERMINING TYPE OR CHARACTER OF INTERFERENCE

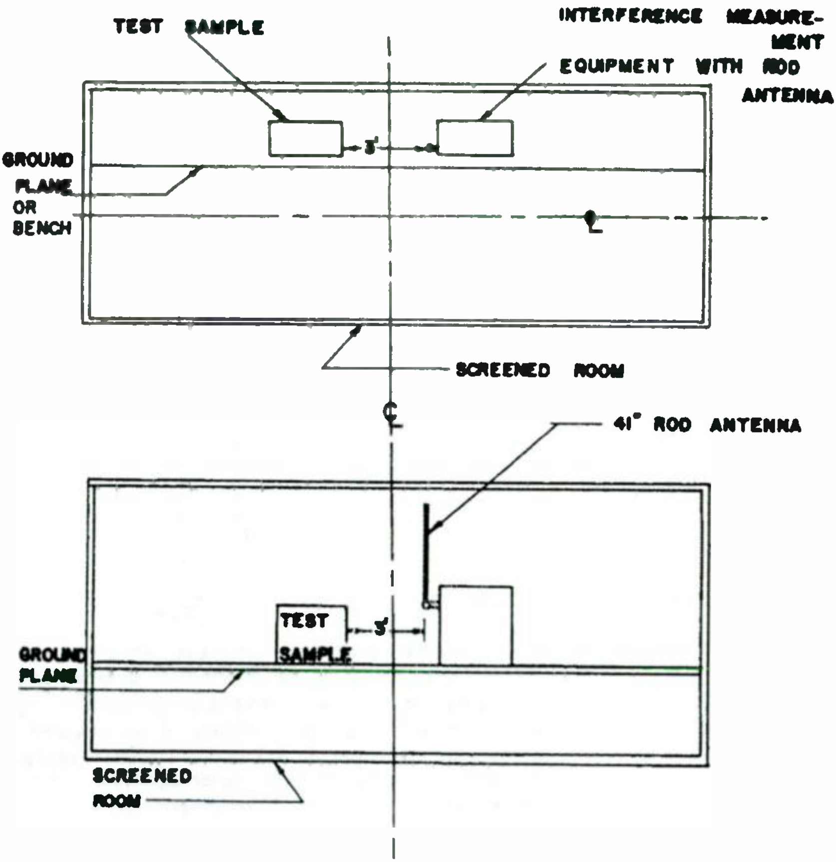


Figure 14- Rod antenna orientation and positioning.

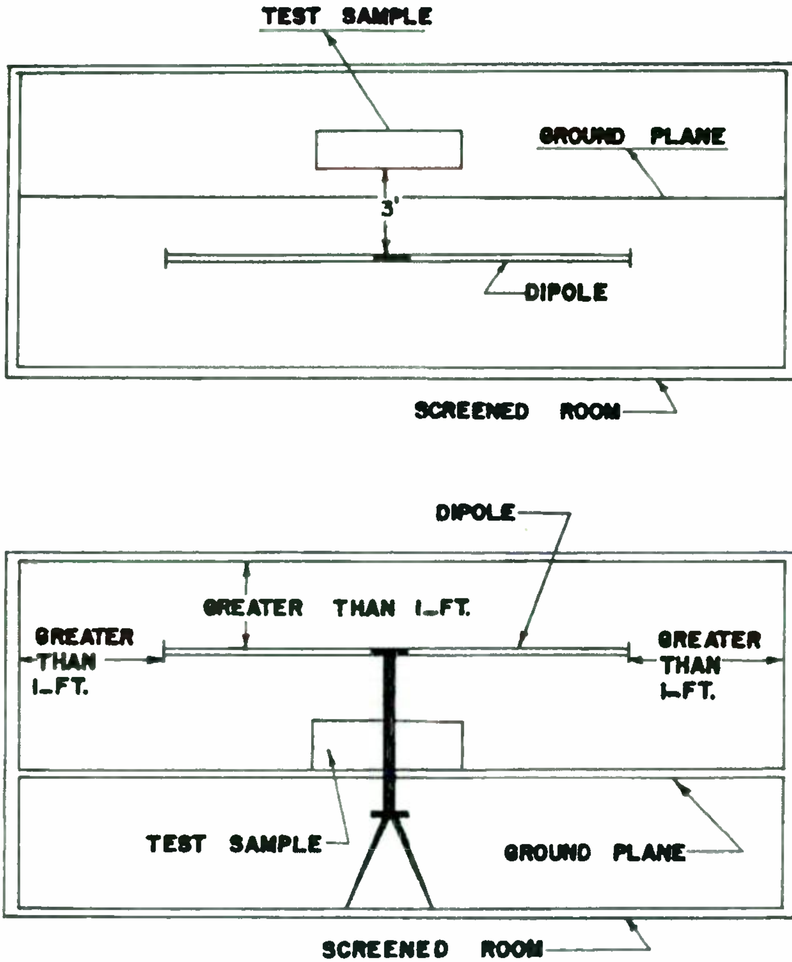
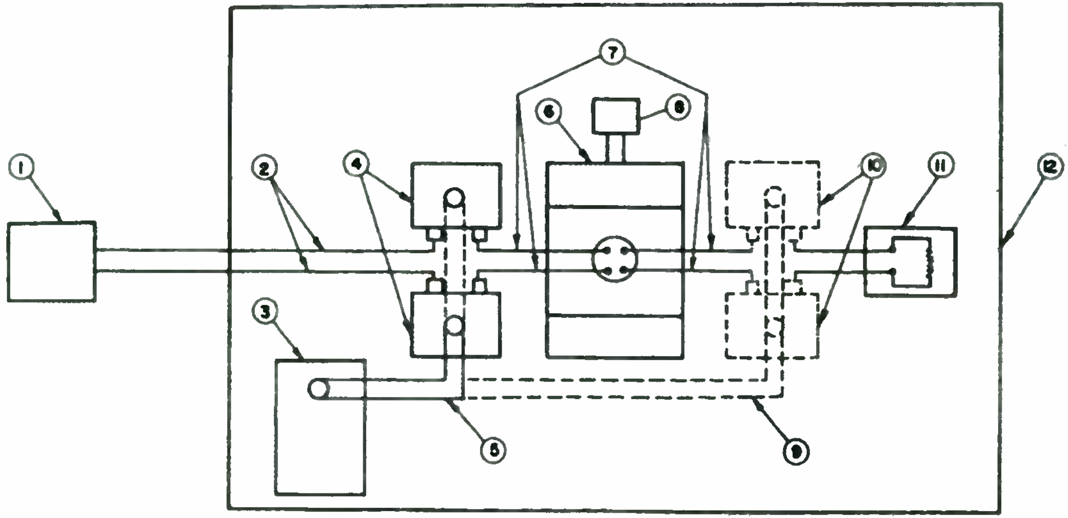
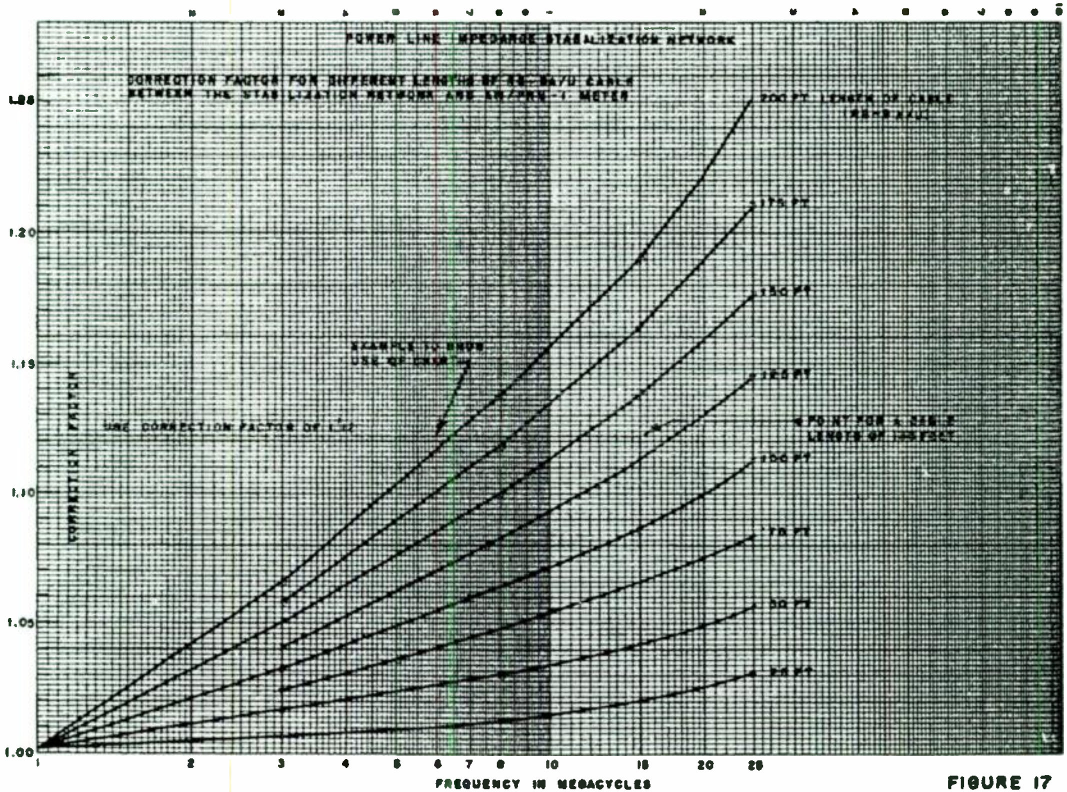


Figure 15. -Dipole antenna orientation and positioning.



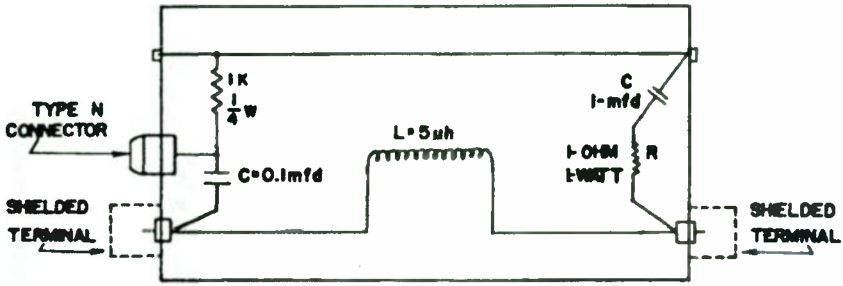
1. Filtered power source.
2. Power leads.
3. Interference measurement instrument.
4. Impedance stabilization network.
5. Leads, (see 4.3.1.1)
6. Test sample.
7. Leads as short as practicable.
8. Mechanical load where required.
9. Item 5 as required.
10. Item 4 as required.
11. Electrical load where required.
12. Ground plane.

Figure 16 - General test procedures for conducted interference measurements.



POWER LINE IMPEDANCE STABILIZATION NETWORK
200 FT
175 FT
150 FT
125 FT
100 FT
CORRECTION FACTOR
1.20
1.15
1.10
1.05
1.00
1
2
3
4
5
6
7
8
10
15
20
25
FREQUENCY IN MEGACYCLES

FIGURE 17



COIL DATA (50 amps.)-

1. L = 4.9 microhenrys at 1.0 mc.
2. 18 Turns #10 wire, heavy insulated.
3. Bakelite tubing 1-5/8 inches diameter.

NOTE:

1. For use above 50 amperes, replace coil with 5 microhenry coil of suitable dimensions capable of carrying desired current.

Figure 19.- Impedance stabilization network.

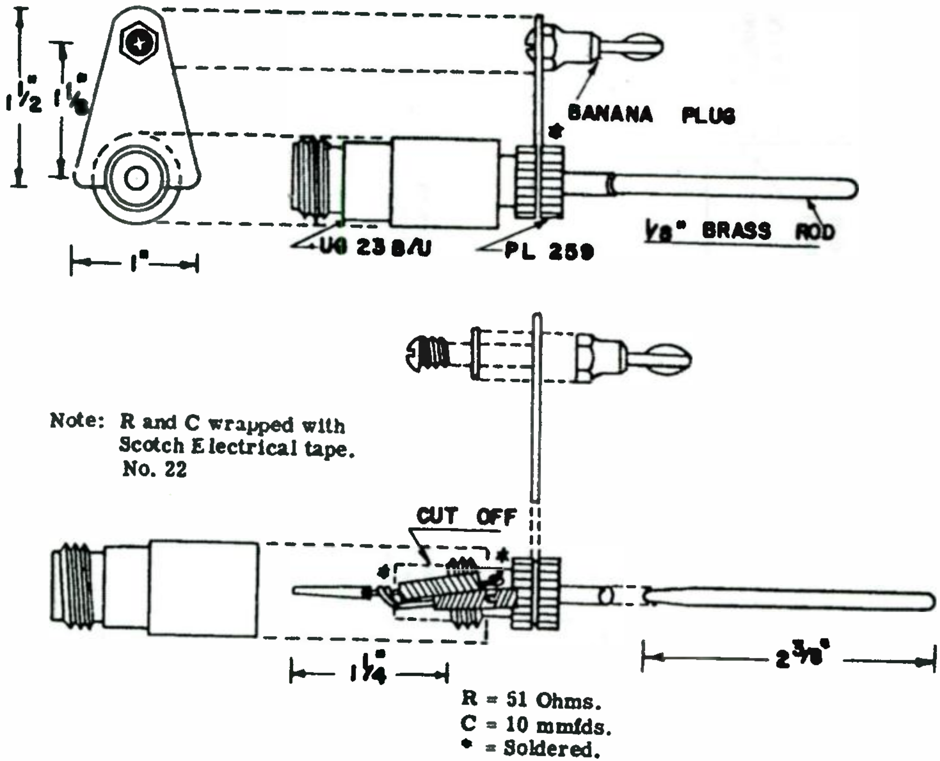


Figure 20.-Matching connector for use with the Ferris meter, model 32A and 32B.

NOTE: SHADED PORTIONS TO BE DISCARDED.

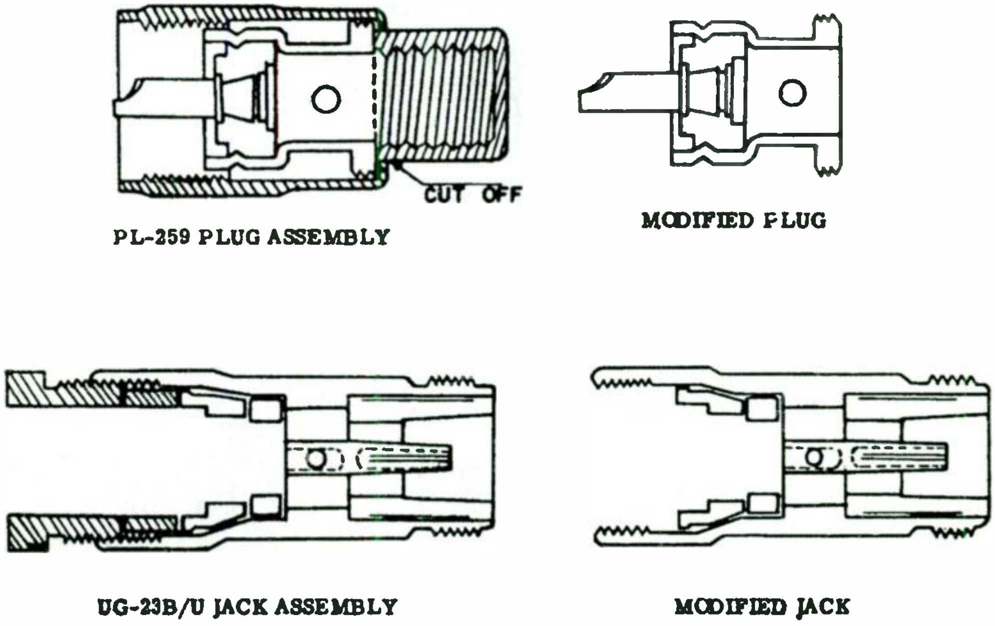


Figure 21. - Parts used in the construction of connector of figure 18 before and after modfications.

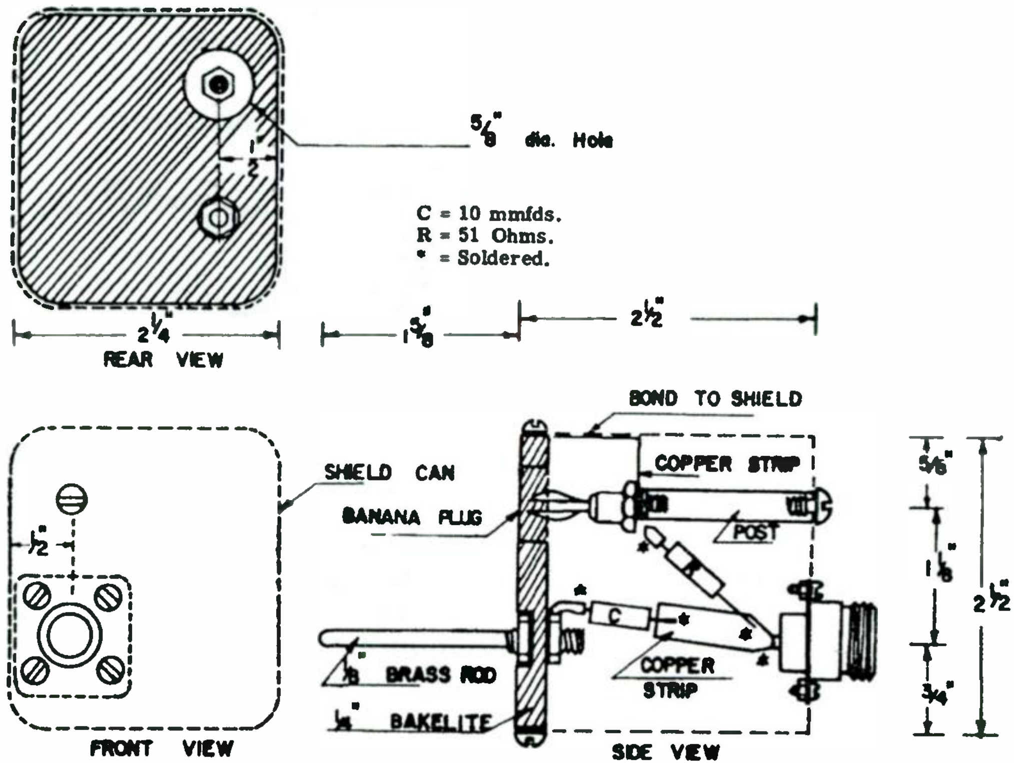
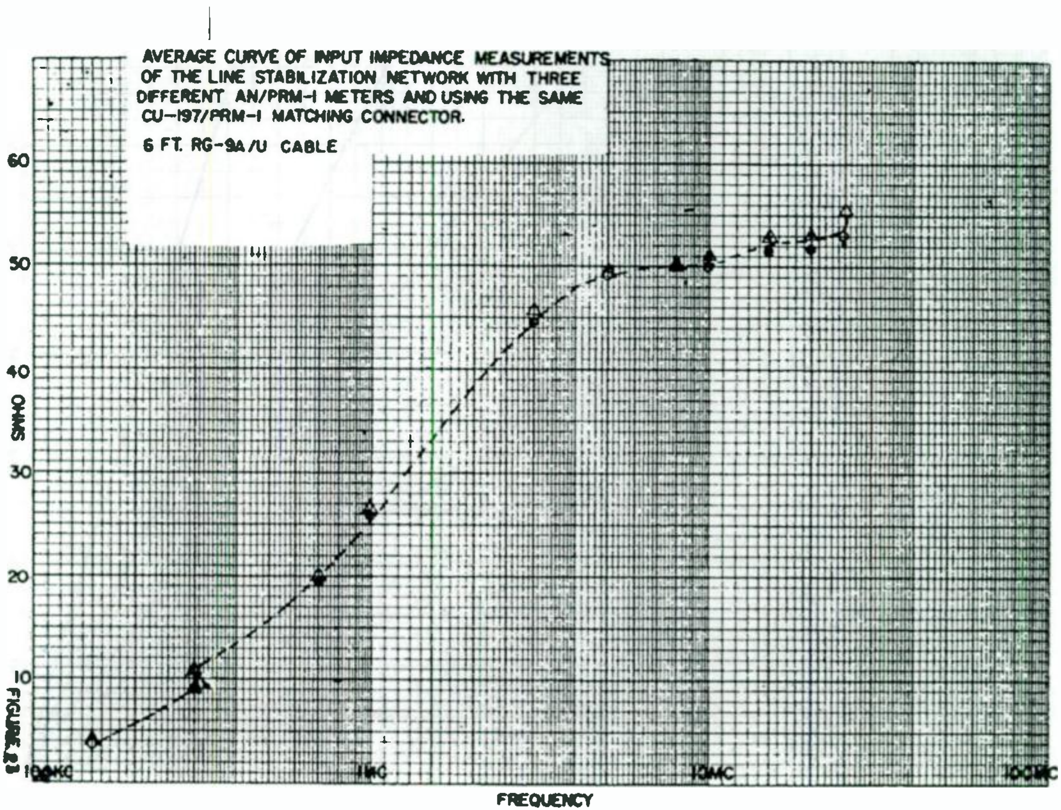


Figure 22.- Drawing of an alternate connector for use with the Ferris meter, model 32A and 32B.


AVERAGE CURVE OF INPUT IMPEDANCE MEASUREMENTS OF THE LINE STABILIZATION NETWORK WITH THREE DIFFERENT AN/PRM-1 METERS AND USING THE SAME CU-197/PRM-1 MATCHING CONNECTOR.
6 FT. RG-9A/U CABLE
60
50
40
30
20
10
OHMS
100KC
1MC
10MC
100MC
FREQUENCY
FIGURE 23

VOLTAGE DROP ACROSS STABILIZATION NETWORK

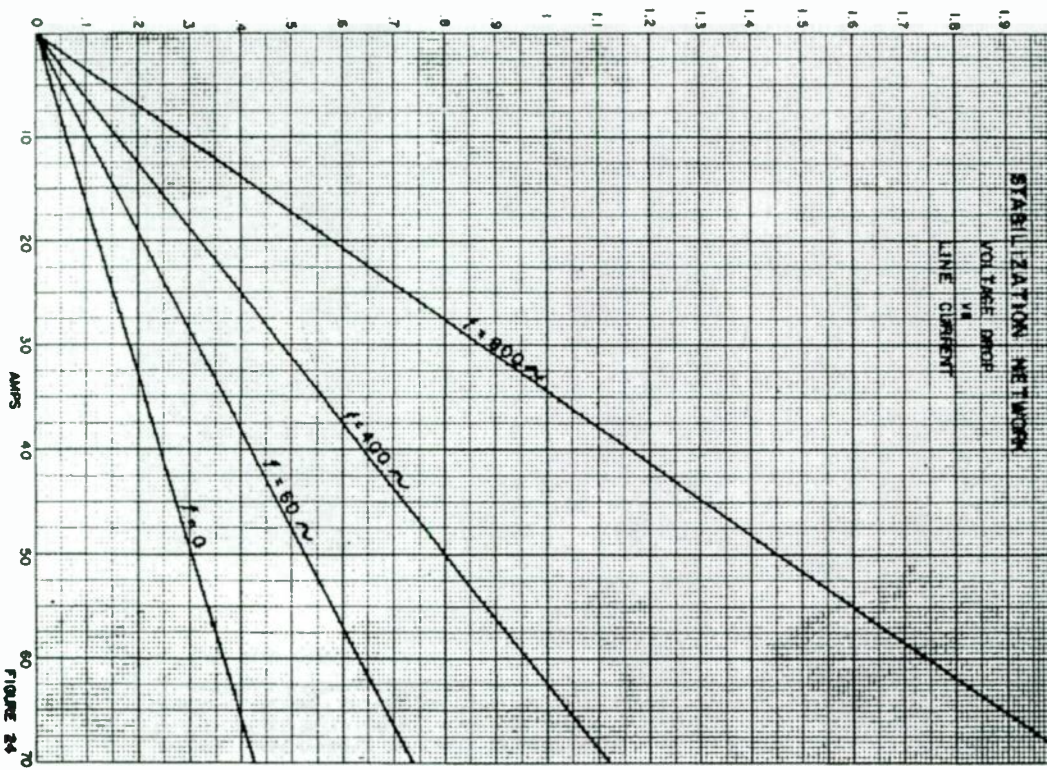


FIGURE 24

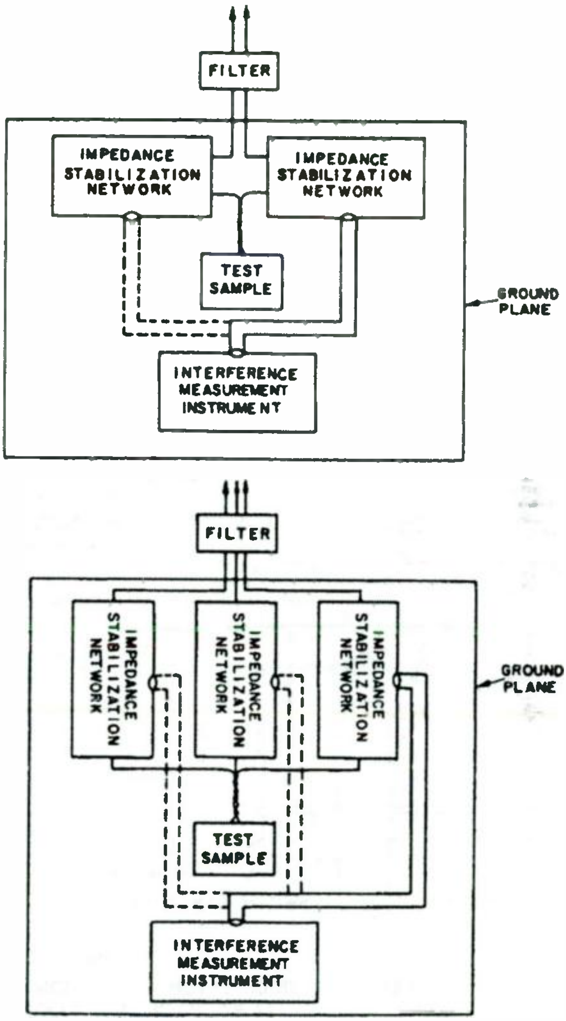


Figure 25. - Procedure for use of line and load impedance stabilization network.

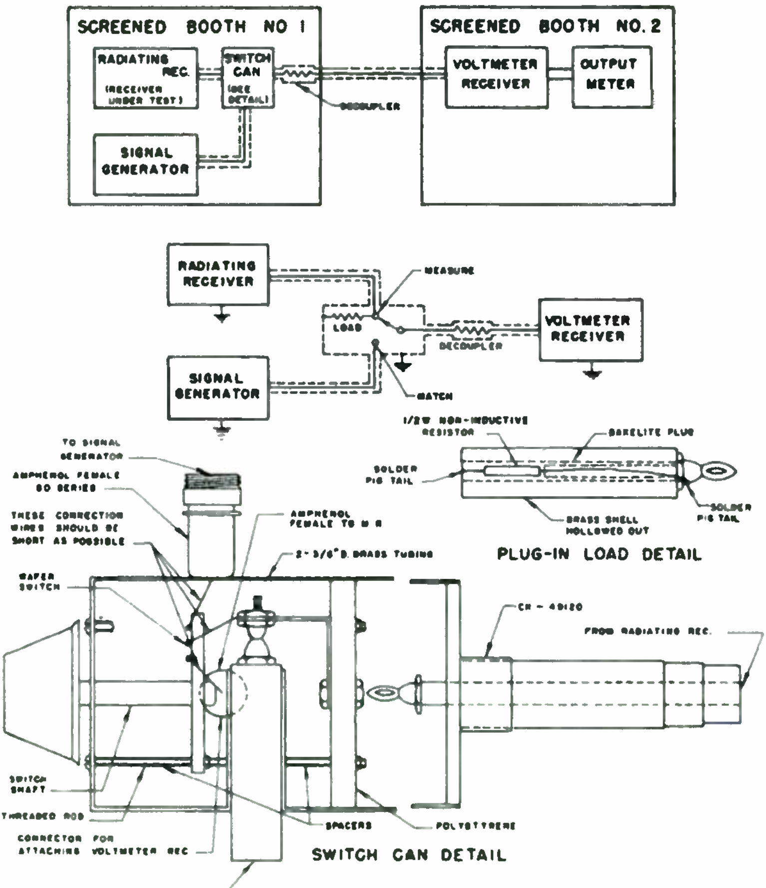


FIG. 26
RECEIVER OSCILLATOR RADIATION MEASUREMENT
14 KC TO 30 MC RANGE
USING SWITCH CAN

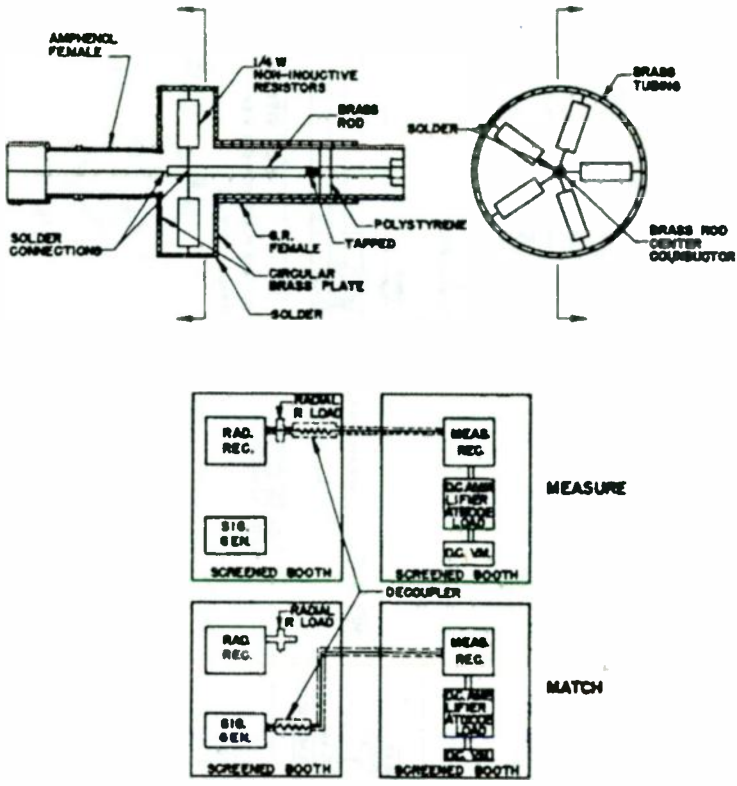


FIGURE 27

RECEIVER OSCILLATOR RADIATION MEASUREMENT

30 MC TO 200 MC

USING RADIAL RESISTOR LOADS

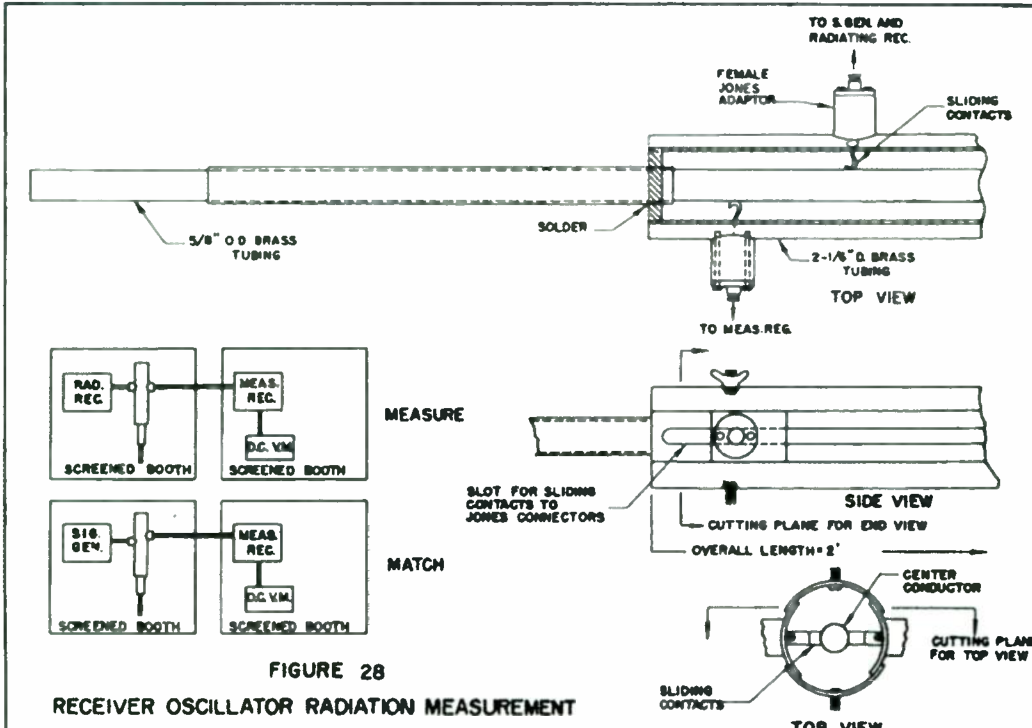


FIGURE 28

RECEIVER OSCILLATOR RADIATION MEASUREMENT
200 MC TO AT LEAST 1000 MC
USING QUARTER OR THREE QUARTER WAVE LINE

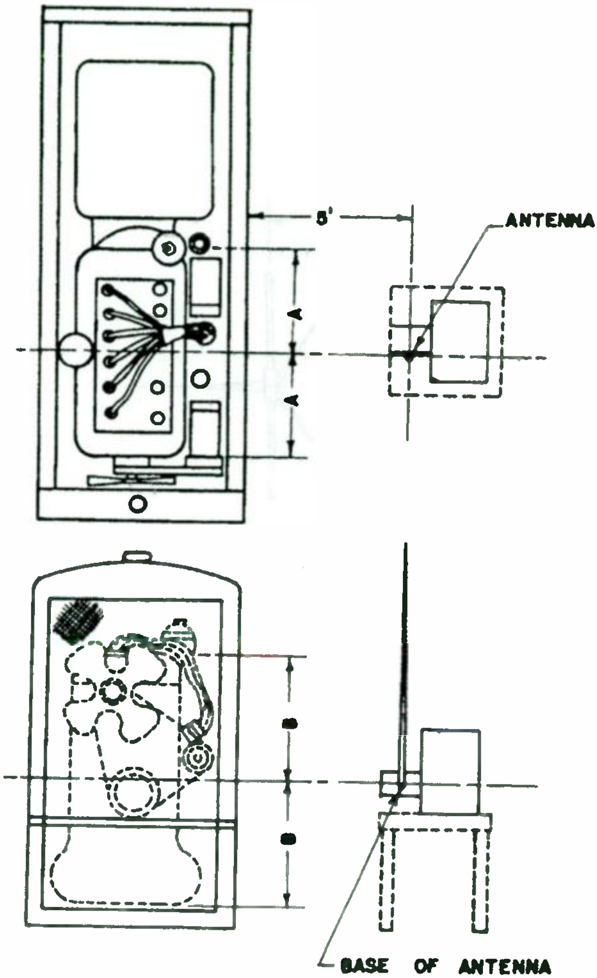


Figure 29. - Rod antenna positioning miscellaneous engine driven equipments.

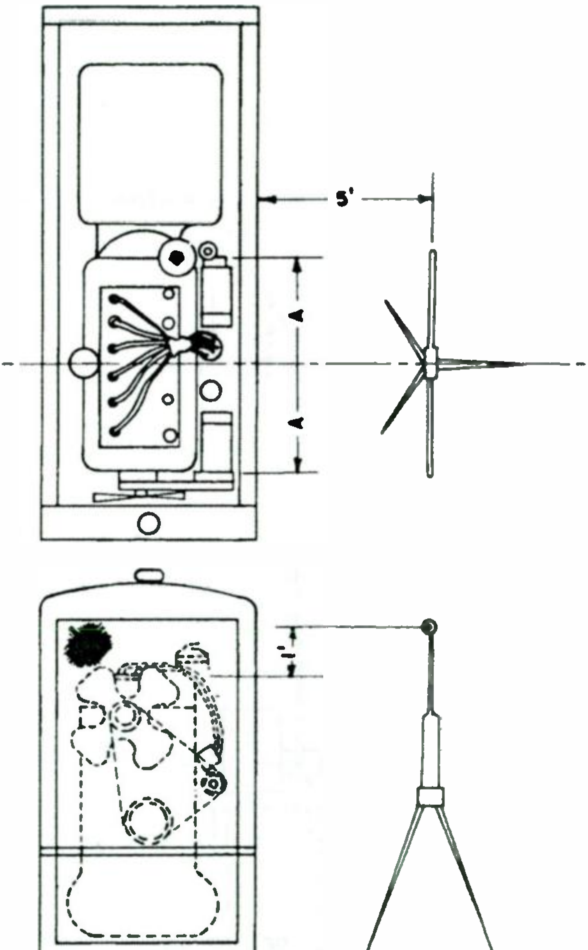


Figure 30 - Dipole antenna positioning miscellaneous engine driven equipments.

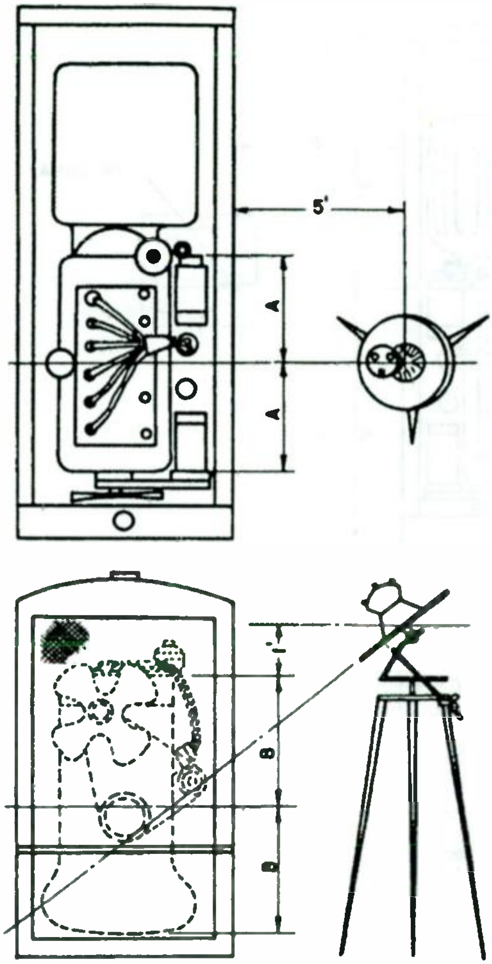


Figure 31. - Antenna positioning antenna AT-292/URM 20 miscellaneous engine driven equipments.

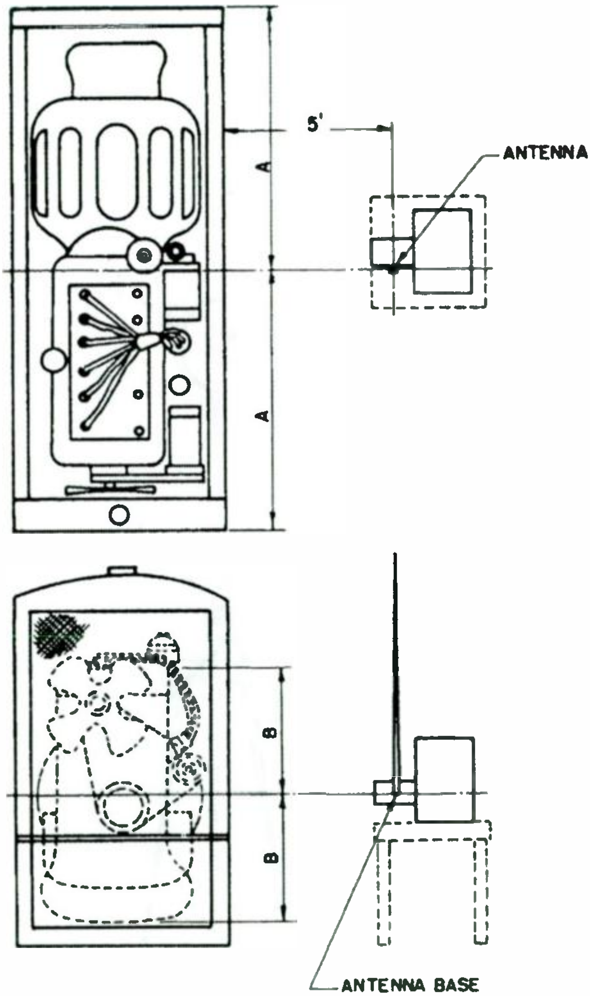


Figure 22. - Rod antenna positioning engine generator units.

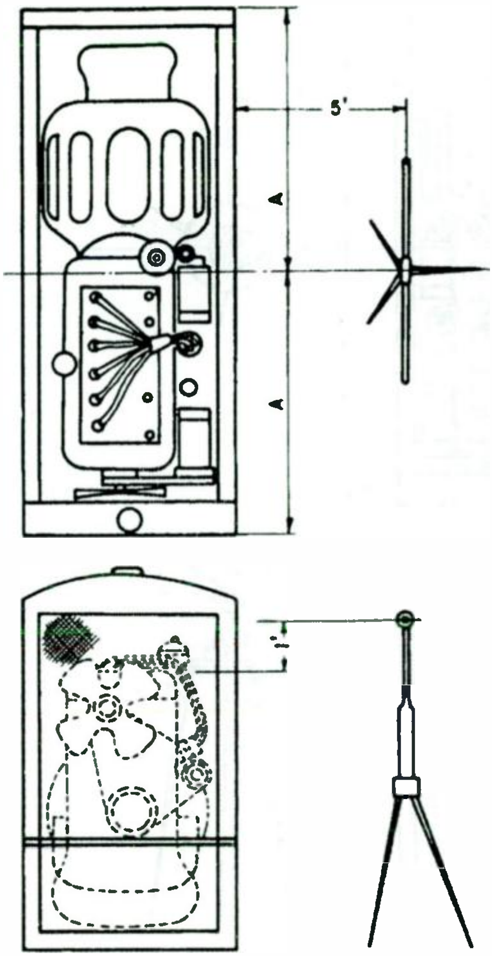


Figure 33. - Dipole antenna positioning engine generator units.

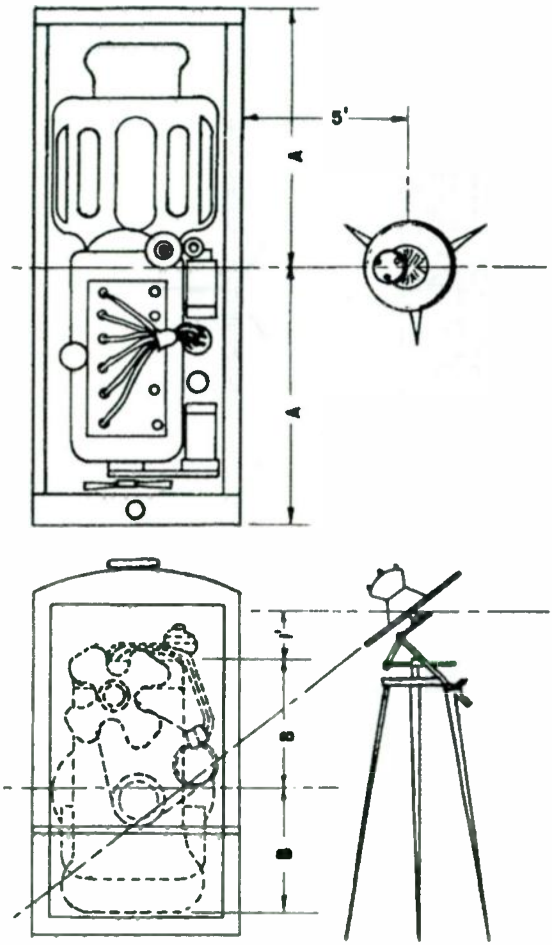
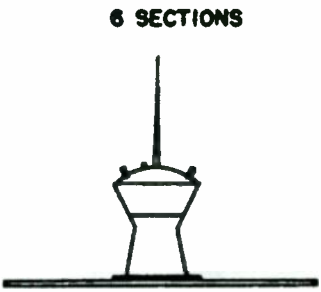
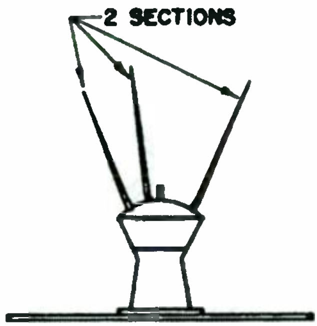


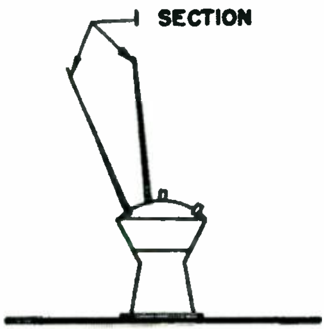
Figure 34. - Antenna positioning antenna AT-292/URM-29 engine generator units.



40 to 55 mc. used with Tuning Unit TN-16( )/APR-4



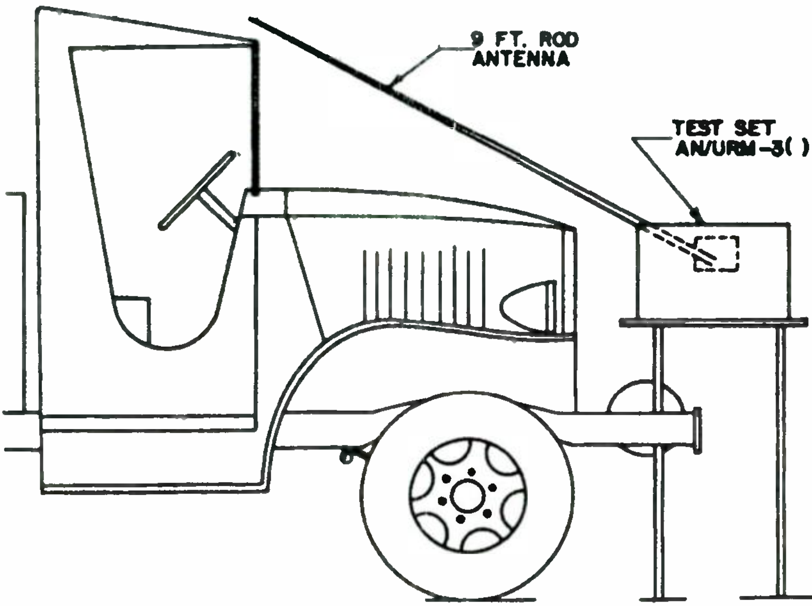
56 to 95 mc. used with Tuning Unit TN-16( )/APR-4



96 to 305 mc. used with Tuning Unit TN-17( )/APR-4

306 to 1000 mc. used with R. F. Tuner TN-187( )/URM-29

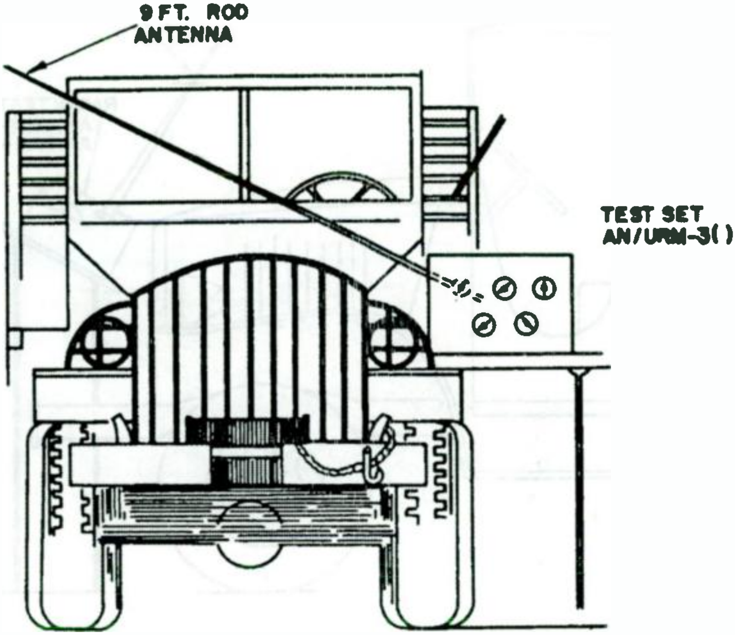
Figure 35. - Antenna AT-292( )/URM-29 and mast sections AB-21/GR for outside radiation test 40 to 1000 mc.



NOTE:

1. The test set shall be located on the longitudinal axis of the vehicle.
2. The top of the test set shall be in the same plane as the top of the radiator grill.
3. The test set shall be located as close as possible to the vehicle without the center of the antenna exceeding 2 feet from top of engine compartment or approaching closer than 1 foot thereto.

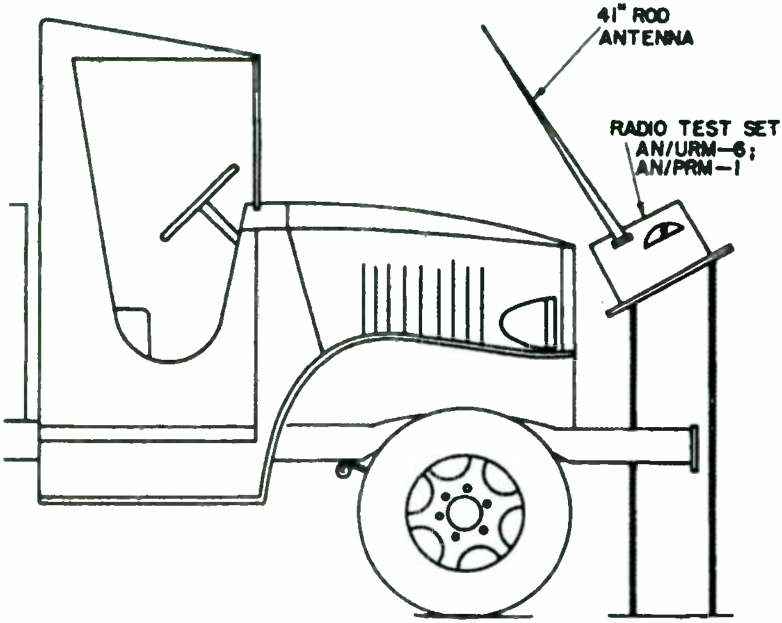
Figure 36. - Antenna position for trucks front radiation test, 0.15 to 40 mc.



NOTE:

1. The test set shall be insulated from the body of the vehicle with a non-conducting material.
2. The rod antenna shall be located as close as possible to the lateral axis of the engine.
3. The tip of the antenna shall be located in a vertical plane through the edge of the opposite fender or similar outermost extremity of metal, but the midpoint of the antenna shall not be placed closer than 1 foot from the top of the engine compartment for any vehicle.
4. A side radiation test shall be performed with the test set located on both right and left fenders.

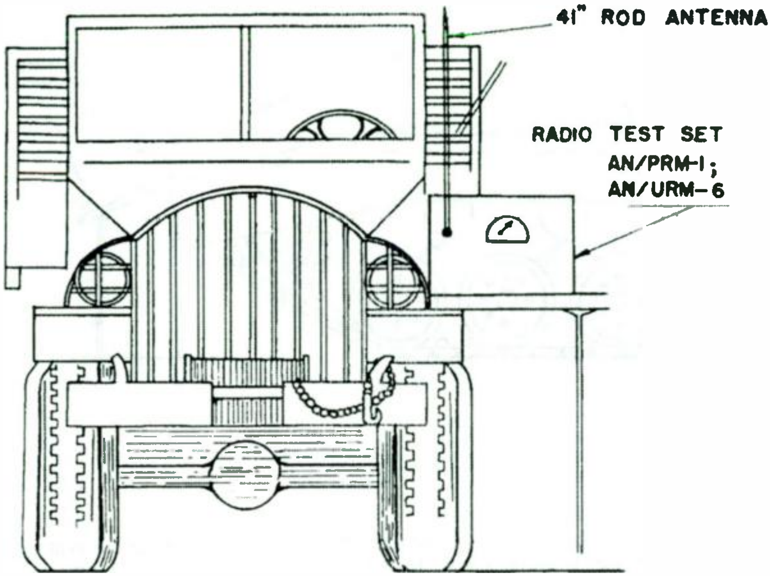
Figure 37. - Antenna position for trucks side radiation tests, 0.15 to 40 mc.



NOTE:

1. The test set shall be located on the longitudinal axis of the vehicle.
2. The antenna base shall be in the same plane as the top of the radiator grill.
3. The test set shall be located as close as possible to the vehicle without the center of the antenna exceeding 2 feet from top of engine compartment or approaching closer than 1 foot thereto.

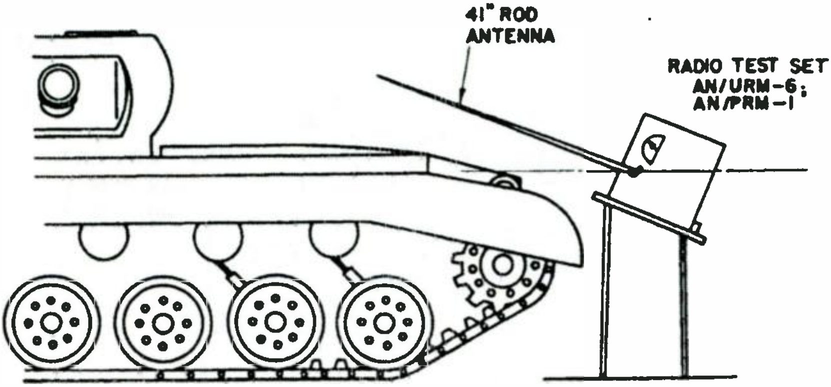
Figure 38. - Antenna position for trucks front radiation test, 14 kc. to 25 mc.



NOTE:

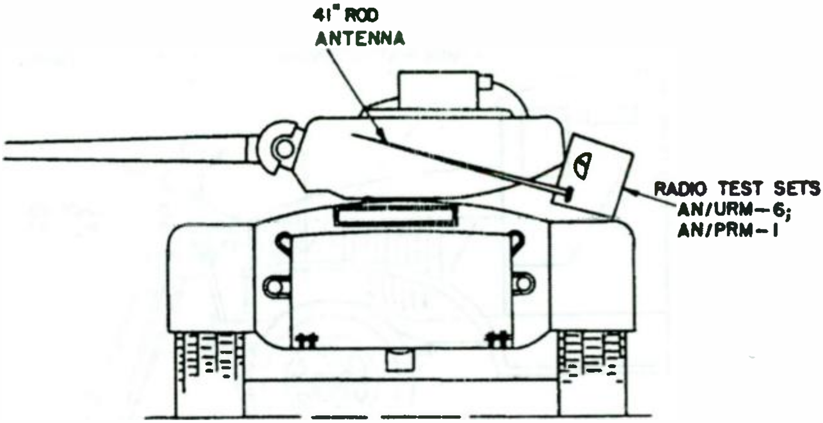
1. The test set shall be insulated from the body of the vehicle with a non-conducting material.
2. The rod antenna shall be located as close as possible to the lateral axis of the engine.
3. The antenna shall be located in a vertical plane with the midpoint of the antenna no closer than 1 foot from the side of the engine compartment for any vehicle.
4. A side radiation test shall be performed with the test set located on both right and left fenders.

Figure 39. - Antenna position for trucks side radiation tests, 14 kc. to 25 mc.



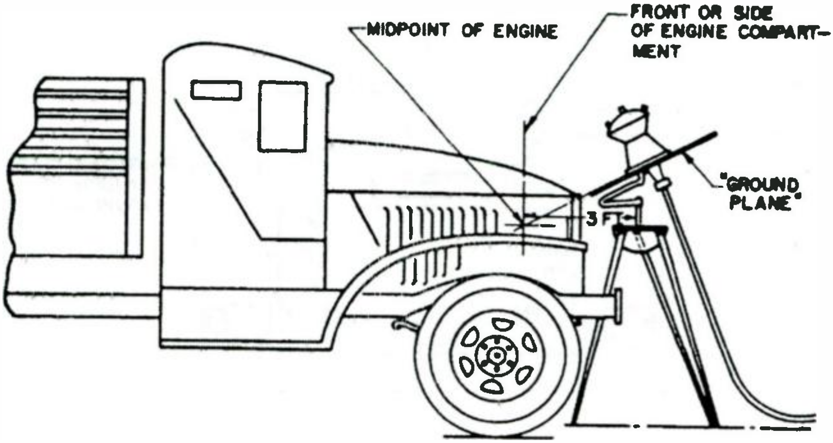
NOTE:
1. The antenna shall be placed along the longitudinal axis of the vehicle.
2. The base of antenna shall be in the same plane as the lower rear edge of the air outlet grill.
3. All tests shall be conducted with the gun rotated perpendicular to the longitudinal axis of the vehicle.
4. The test set shall be located as close as possible to the vehicle without the mid-point of the rod antenna exceeding 2 feet from top of engine compartment or approaching closer than 1 foot thereto.

Figure 42.- Antenna position for tanks and tank type vehicles, end radiation test, 14 kc. to 25 mc.



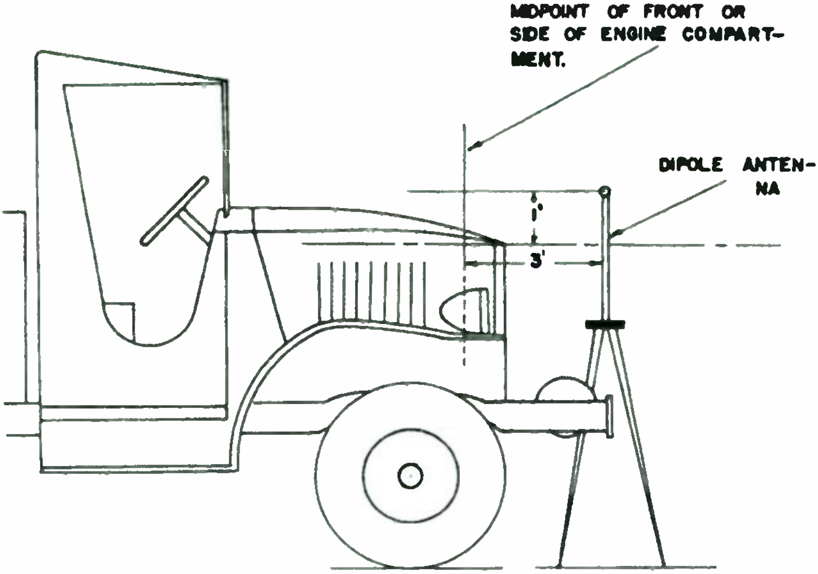
NOTE:
1. The test set shall be insulated from the body of the vehicle with a non-conducting material.
2. Gun shall be rotated perpendicular to the longitudinal axis of the vehicle.
3. The rod antenna shall be located as close to the lateral axis of the engine as possible.
4. The midpoint of the antenna shall not be placed closer than 1 foot from the top of the engine compartment for any vehicle.
5. A side radiation test shall be performed with the test set located on both the right and left fender.

Figure 43. - Antenna position for tanks and tank type vehicles - radiation side radiation, test 14 kc. to 25 mc.



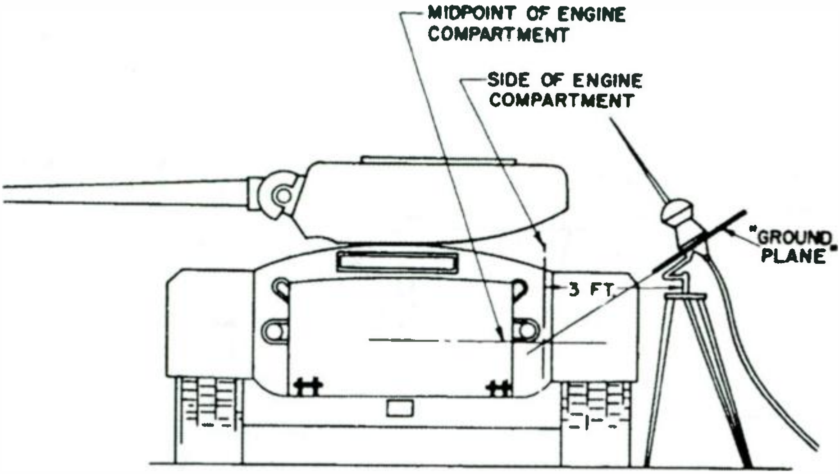
NOTE:
1. Radiation tests are required on three sides of each truck over frequency range 40 to 1000 mc. with same antenna and "Ground Plane" positioning.
2. Prior to tilting, "Ground Plane" shall be in the same horizontal plane as top of radiator.
3. Antenna tilted so that extension of "Ground Plane" intersects front or sides of engine compartment at midpoint.

Figure 44.- Antenna positioning of test set AN/URM-29( ) in radiation test of trucks 40 to 1000 mc.



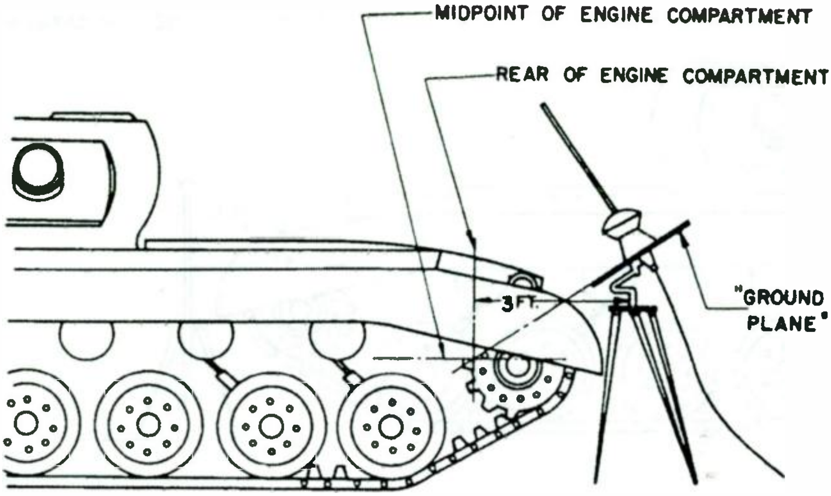
NOTE:
1. Radiation tests are required on three sides of each truck over frequency range 25 to 100 mc. with same antenna positioning.
2. Dipole antenna shall be 1 foot above plane of top of radiator grill, oriented horizontally, with dipole parallel to plane of front or side of vehicle.

Figure 45. - Antenna positioning of test set in radiation test of trucks, 25 to 1000 mc.



NOTE:
1. Gun shall be rotated perpendicular to the longitudinal axis of the vehicle.
2. The antenna shall be located as close as possible to the lateral axis of the engine.
3. Prior to tilting, "Ground Plane" shall be in the same horizontal plane as the lower edge of the air outlet grill.
4. Antenna tilted so that extension of "Ground Plane" intersects near side of engine compartment at vertical midpoint.
5. A side radiation test shall be performed, with the antenna located on each side, on the lateral axis of the engine.

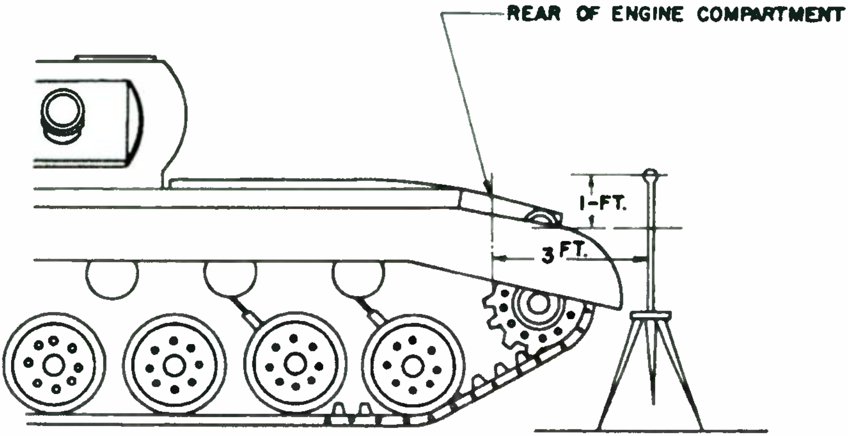
Figure 46. - Antenna position for tanks and tank type vehicles-radiation 40 to 1000 mc.



NOTE:

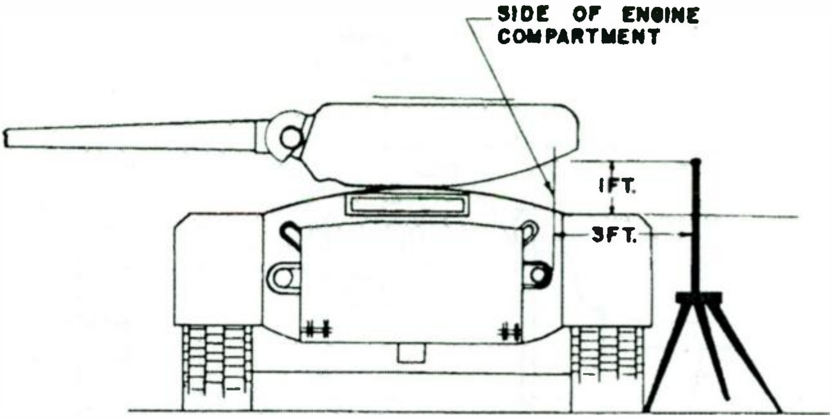
1. The test shall be conducted with the gun rotated perpendicular to the longitudinal axis of the vehicle.
2. The antenna shall be placed along the longitudinal axis of the vehicle.
3. Prior to tilting, "Ground Plane" shall be in the same horizontal plane as the lower edge of the air outlet grill.
4. Antenna tilted so that extension of "Ground Plane" intersects rear of engine compartment at midpoint.

Figure 47. - Antenna position for tanks and tank type vehicles radiation, 40 to 1000 mc.



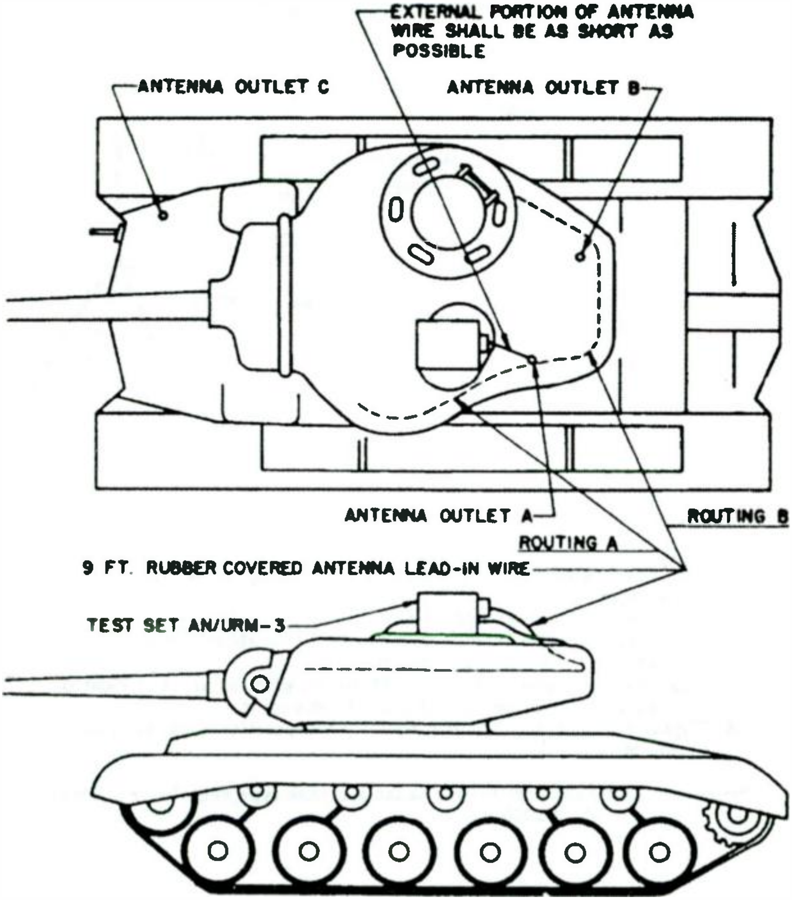
NOTE:
1. The test shall be conducted with the gun rotated perpendicular to the longitudinal axis of the vehicle.
2. The antenna shall be placed along the longitudinal axis of the vehicle, with dipole 1 foot above plane of lower edge of air outlet grill.
3. Dipole shall be oriented horizontally and positioned paralled to end of tank.

Figure 48. - Antenna position for tanks and tank type vehicles radiation, 25 to 1000 mc.



NOTE:
1. Gun shall be rotated perpendicular to the longitudinal axis of the vehicle.
2. The antenna shall be located as close as possible to the lateral axis of the engine with dipole 1 foot above plane of lower edge of the air outlet grill.
3. A side radiation test shall be performed, with the antenna located on each side, on the lateral axis of the engine.
4. Dipole shall be oriented horizontally and positioned parallel to side of tank.

Figure 49. - Antenna position for tanks and tank type vehicles radiation 25 to 1000 mc.



NOTE:
1. The test set shall be insulated from the body of the vehicle with a non-conducting material.
2. A radiation test is required for both antenna routings at each antenna outlet on the vehicle.

Figure 50. - Antenna positioning for inside radiation test 1.5 to 40 mc.

MIL-I-17623(NAVY)
AMENDMENT - 3
2 July 1967
SUPERSEDING
Amendment - 2
26 January 1965

MILITARY SPECIFICATION

INTERFERENCE, RADIO, REQUIREMENTS, METHODS

AND LIMITS (14Kc TO 1000 Mc) FOR ELECTRIC OFFICE

MACHINES, PRINTING AND LITHOGRAPHIC EQUIPMENT

This amendment forms a part of Military Specification MIL-I-17623(NAVY), 10 September 1963, and has been concurred in by all interested Bureaus of the Department of the Navy and the Marine Corps.

Page 3, paragraph 3.5.5, line 1: Delete "Portable electric equipment" and substitute "Additional requirements".

Page 4; Add the following paragraph:

"3.6.2 Design. - Interference reduction shall be performed in the basic design of all equipments and systems. Interference free components shall be selected. Commutator type motors before incorporation in the machine, shall without the addition of filters, not to exceed the interference characteristics of 2000 microvolts quasi-peak conducted (universal motors 5000) within the frequency range of 150 kc. to 20 mc."

Page 4: Add as paragraph 3.7:

"3.7 Radio interference free marking. - All equipment determined to comply with this specification shall be identified by a green colored identification plate inscribed 'Interference Free Specification MIL-I-17623'."

Page 5, paragraph 4.2.1, lines 3 and 5: Delete "1 foot" and substitute "3 feet".

Page 7, paragraph 6.2: Add the following:

"(vv) Blueprint machines.
"(ww) Direct process reproduction machines."

Page 8, paragraph 6.3: Delete.

Custodian:
Bureau of Ships
Other interest:
Navy - AMCS

Preparing activity:
Navy - Bureau of Ships

MILITARY SPECIFICATION

INTERFERENCE, RADIO, REQUIREMENTS, METHODS AND LIMITS (14 Kc TO 1000 Mc) FOR ELECTRIC OFFICE MACHINES, PRINTING AND LITHOGRAPHIC EQUIPMENT

All interested Bureaus of the Navy Department and the Marine Corps have concurred in the use of this specification.

1. SCOPE

1.1 This specification covers the radio interference requirements associated with electric office machines, printing and lithographic equipment.

2. APPLICABLE SPECIFICATIONS, STANDARDS, DRAWINGS, AND PUBLICATIONS

2.1 The following specifications, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

MILITARY
- JAN-C-17 - Cables, Coaxial and Twin-Conductor, for Radio Frequency.
- MIL-C-71 - Connectors "N" for Radio Frequency Cables.

(Copies of specifications, standards, and drawings required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Definitions. - For the purpose of this specification, the following definitions shall apply:

3.1.1 Radio interference. - Radio interference is defined as undesired conducted or radiated electrical disturbances, which may interfere with the operation of electrical or electronic communication equipment or other electronic equipment.

GPO—O—NAVY—L 70

3.1.2 Microvolts per kilocycle. - Interference intensity in microvolts per kilocycle (kc.) is equal to the number of root-mean-square (r.m.s.) sine wave microvolts (unmodulated), applied to the input of the measuring circuit at its center frequency, which will result in peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the effective bandwidth of the circuit in kilocycles. The effective bandwidth is the area divided by the height, of the voltage-response-versus-radio-frequency selectivity curve, from antenna to peak detector.

3.1.3 Portable electric equipment. - Portable electric equipment includes certain of the equipments listed above which are equipped with line cords so that their operation from any convenient electric outlet may be possible.

3.2 Classification of interference measurement instruments. - Four classes of interference instruments are available at the date of this specification. Class III instruments may in the future be promoted to class I or class II; however, class IV instruments will not be promoted and are acceptable only because they are in existence or because another instrument covering that particular frequency range has not been developed as yet.

3.2.1 Class I. - Radio interference and field intensity meters which have been designed to conform with the standards established and which have been approved by the Armed services.

3.2.2 Class II. - Instruments which have been designed for a special purpose and insofar as their intended special purpose is concerned conform with the specifications for class I instruments and which have been approved for such special purpose by the Armed services.

3.2.3 Class III. - Meters designed as class I or class II instruments but which have not been evaluated. When approved by the Armed services, these will be redesignated as class I or class II instruments.

3.2.4 Class IV. - Existing meters which are in general use but which do not conform to the approved standards. Use of these instruments is permissible until conditions permit their replacement by class I or class II meters only if procured by the contractor prior to the effective date of this specification.

3.2.5 Table I is a listing of interference measurement instruments with respect to frequency range and the present classification.

3.2.6 When measuring equipment other than those specified in table I are proposed for use, the test results thereof shall be related to results from the meters of table I.

Table I - Interference measuring equipment.

Frequency range	Interference instrument	Classification [1]
14 to 250 kc.	Radio Test Set AN/URM-6	I
150 kc. to 25 mc.	Radio Test Set [illegible]	I
	Ferris Model 32A and 32B	IV
	Navy Model OF and OF-2	IV
150 kc. to 4.0 mc.	Radio Interference Measuring Set AN/URM-3	II
20 to 150 mc.	Measurements Corp., Model 58	IV
	Measurements Corp., Model 58A	IV
20 to 400 mc.	Radio Test Set AN/URM-7	II
	Noise Field Intensity Meter TS-587/U	IV
	Radio Interference Measuring Set AN/URM-47	III
40 to 1000 mc.	RF Interference Test Set AN/URM-28	IV
	Radio Interference Measuring Set [illegible]	IV
400 to 1000 mc.	Radio Test Set AN/URM-17	III

[1] This classification is subject to change on reasonable notice to include new instrumentation of tested and approved superior performance characteristics.

3.3 Standard units of radiated interference. -

3.3.1 Broadband interference. - Radiated broadband interference measured in close proximity to the interference source, shall be in terms of antenna induced microvolts per kilocycle bandwidth, utilizing the antenna specified for each measuring instrument.

3.3.2 Continuous wave interference. - Continuous wave type interference shall be in terms of antenna induced microvolts, utilizing the antenna specified for measuring equipment.

3.3.3 Measurement of radiated broadband interference will be influenced by conducting objects, including personnel, in the vicinity of the antenna which change the current distribution in the antenna resulting in a changed effective height and antenna terminal impedance.

3.4 Standard units of conducted interference. -

3.4.1 Broadband interference. - The standard unit of conducted broadband interference shall be microvolts per kilocycle bandwidth as measured from line-to-ground.

3.4.2 Continuous wave interference. - Continuous wave type conducted interference shall be in terms of microvolts.

3.5 Interference limits. -

3.5.1 Radiated. - General limits of radiated interference in terms of the standard units are established and presented in graphic form on figures 1 and 2. Over the frequency range of 14 kc. to 1000 megacycles (mc.), interference radiated from any unit, cable (including control and input power cables) or interconnecting wiring of the equipment shall not exceed the limits specified herein or otherwise specified in the individual equipment specification. This requirement specifically includes oscillator interference and spurious emissions in addition to random interference from units, wiring, and systems.

3.5.2 Conducted. - General limits of conducted interference in terms of the standard units are established and presented in graphic form on figures 3 and 4. Radio interference voltage appearing on the external power conductors or on any external systems connection shall not exceed the limits specified herein or otherwise specified in the individual equipment specification over the frequency range of 150 kc. to 20 mc.

3.5.3 Short duration interference. -

3.5.3.1 Impulsive interference with a repetition rate of not more than 10 pulses per second is permitted, a limit of two times or 6 decibels above the limits shown on figures 1, 2, 3, and 4.

3.5.3.2 Interference of less than one second in duration, occurring not more than once every 30 seconds is permitted, a limit of 10 times or 20 decibels above the limits shown on figures 1, 2, 3, and 4.

3.5.3.3 Interference of less than one second in duration occurring not more than once every 3 minutes shall be exempt from the requirements of this specification.

3.5.4 Determination of interference type. - To determine whether observed interference is continuous wave (CW) or broadband, the ratio of readings, quasi-peak to field intensity, shall be determined. If the ratio QP/FI is equal to or greater than 2 to 1, the limit for broadband interference shall apply. For ratios less than 2 to 1 the limit for CW interference shall apply (see fig. 5).

3.5.5 Portable electric equipment. - Where equipments covered by this specification are required to comply with minimum values of capacitance (0.1 microfarad or less), or limiting values of current between any exposed metal part of the equipment and earth ground, and fall within the definition of portable electric equipment, the general limits shown on figures 1, 2, 3, and 4, increased by a factor of 10 or 20 decibels, shall be applicable.

3.6 Calibration of interference measuring instruments. - The standard of calibration shall be the r.m.s. voltage of an unmodulated sine wave, such as obtained from a standard signal generator.

3.6.1 Calibration with external signal generator. - The interference measurement instrument calibration with the instrument properly terminated shall, unless otherwise specified in the individual equipment specification, be checked using a standard sine wave signal generator in accordance with instructions contained in the instruction manual for the instrument. The time interval between calibration checks shall not exceed 60 days, and checks shall be made more often if required by the bureau or agency concerned, and in any event shall be made immediately after exposure to conditions which might affect calibration. Recalibration of the instrument shall be made when checks indicate a deviation in normal calibration greater than 10 percent.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Interference measurements. - Measurements shall be conducted to determine compliance with 3.5, and a report indicating the results of the tests shall be submitted to the bureau or agency concerned. The manufacturer shall be responsible for furnishing all measuring equipment, qualified personnel, and test facilities, including test space, where the ambient interference does not exceed the limits specified in 3.5. The number of equipments to be tested shall be specified in the individual equipment specification.

4.1.1 Operating conditions. - Interference measurements, both radiated and conducted, shall be made at normal operating load (or under simulated normal operating conditions) and at no load (see 4.1.1.4) where such conditions may be attained.

4.1.1.1 Power supply. - The power supply shall be at rated voltage of the equipment under test, ±5 percent. Rated voltage shall be as specified in the individual equipment specification.

4.1.1.2 Preliminary operation of test sample. - When specifically required by the Government inspector, the sample under test shall be operated for a sufficient period of time to approximate normal operating conditions.

4.1.1.3 Ambient interference level. - It is desirable that the ambient interference level during testing (measured with the test sample deenergized) be at least 6 db below the allowable specified interference limit. However, in the event that at the time of measurement the levels of ambient interference plus test item interference are not above the specified limit, such tested item shall be considered in accordance with the specification requirements. This requirement shall apply equally to both radiated and conducted ambient interference levels.

4.1.1.4 Load. - Unless otherwise specified in the individual equipment specification, a load (either electrical or mechanical), capable of loading the test sample up to appropriate rating and simulating normal operating conditions shall be used.

4.1.1.5 Temperature. - The ambient temperature of the testing location shall preferably be within the range from 10° to 40° Centigrade (C.) (50° to 104° Fahrenheit (F.)). However, measurements made in temperatures beyond these limits may be accepted provided the test sample, interference measuring instruments, all indicating devices, and equipment shall be at the testing location for a sufficient length of time prior to making of measurements for the temperature thereof to be equalized with the temperature of the testing location. Evidence shall be given that the calibration of the interference measuring instruments used is accurate for temperatures outside the stated temperature range.

4.1.1.6 Humidity. - Measurements shall be made at a time when humidity and temperature conditions do not cause condensation of moisture on the apparatus, unless it is normal for the test item to operate under such conditions.

4.1.1.7 Use of indicating meters during interference measurements. - During the time of measurement of radio interference, no external electrical meter or electrical indicating device other than the interference measuring instrument and its associated leads shall be in the input or output circuits of the sample under test. However, such meters or devices may be located between the power supply impedance stabilizing network and the power source or between the load impedance stabilizing network and the electrical load.

4.1.1.8 All interference measurements shall be monitored using either a headset or loudspeaker. The precaution shall be taken to check that no feed-back is introduced into the interference meter by the use of the headset or speaker, thereby giving a false indication of the interference level being measured.

4.1.2 Test sample leads. - Where furnished, the test sample line cord shall be removed. The test sample leads to the line impedance stabilization network specified in 4.1.3 shall be 24 inches ± 1 inch in length and shall be arranged so that the distance between them and from each lead to ground or grounded enclosure is a nominal of 2 inches.

4.1.3 Line stabilization network. - The line stabilization network shown on figures 8 and 9 shall be used as illustrated on figures 6, 7, 8, 9, and 12 for all radiated and conducted radio interference tests, unless the insertion of the device causes malfunctioning of the test item. One such network shall be inserted in each power supply lead and electrical load lead (if used) when making measurements (see fig. 12). A terminal shall be provided on the device, fitted with a type N connector conforming to Specification MIL-C-71, to which the interference measurement instrument may be connected, by means of a 50-ohm RG-9A/U or RG-9B/U coaxial cable conforming to Specification JAN-C-17, for conducted interference measurements. The 50-ohm cable shall be terminated in 50 ohms for all conducted interference tests. For radiated interference tests, the 50-ohm cable and termination are omitted. The equipment under test shall be connected to the same side of the network as the 0.1-microfarad capacitor. The ground plane of the network enclosure shall be the same as that of the test item or shall be made a part of the test item ground plane by means of bonding in accordance with 4.4.2.4.

4.1.3.1 Performance characteristics. - The current carrying capacity of the network is 50 amperes direct current (d.c.) to 800 cycles alternating current (a.c.). The maximum voltage drop at 50 amperes is not over 1 percent of the supply voltage. The performance characteristics of the device will permit measurements of test items of the following voltage ratings:

D.c.	600 volts
60 cycles	440 volts
400 cycles	230 volts
800 cycles	115 volts

4.1.3.2 Design of network. - Working drawings and an electrical schematic of the device are included as figures 10, 11, and 12. A curve showing the average input impedance of the stabilization network is shown on figure 11.

4.2 Radiated measurements (14 kc. to 1000 mc.). - Measurements of radiated interference shall be made using the rod or resonant dipole antenna supplied with the particular test instrument employed.

4.2.1 Antenna orientation and positioning. - Those interference measuring instruments equipped with rod antennas shall be placed so that the rod antenna is in a vertical position and the base of the antenna, unless otherwise specified in the individual equipment specification, is 1 foot from the nearest perimeter of the test item (see fig. 6). Those interference measuring instruments equipped with resonant dipole antennas shall have the dipole positioned horizontally with center of the dipole at a distance of 1 foot from the nearest perimeter of the test item. The dipole shall be oriented so that its length is tangential to the nearest perimeter (see fig. 7). Within the limitations imposed by the test location and the requirements above, the antenna and instrument shall be moved about so as to obtain maximum indication. External wires or straps shall not be attached to the interference measuring instrument for grounding purposes during field tests.

4.2.2 Placement of items and space limitations. - The test sample shall, as far as is practicable, be centrally located in the screened room or other area of low ambient interference (see figs. 6 and 7).

4.2.2.1 Placement of antennas. - The measurement antenna shall be oriented and positioned with respect to the test sample as specified in 4.2.1 with the exception that when extension of dipole antenna elements in the horizontal position would protrude beyond the confines of the shielded area such dipole elements shall not be extended closer than 1 foot from the walls of the shielded enclosure. When shortened (nonresonant) dipole lengths are employed, the reduced effective height shall be taken into consideration when calculating indicated values of measured interference.

4.3 Grounding of interference measurement instrument. - All measurements of radiated interference made in the shielded enclosure shall be made with the interference measurement instrument either bonded to ground in accordance with 4.4.2.4, or resting upon the ground plane and making good electrical contact with the ground plane. This provision applies to measurements of radiated interference in the shielded enclosure only.

4.4 Conducted measurements (150 kc. to 20 mc.). - All measurements of conducted interference shall be made from line-to-ground, unless otherwise specified in the individual equipment specification. Balanced input line-coupling devices shall not be used unless specified in the individual equipment specification. Line-coupling devices shall be as specified in 4.1.3. The 50-ohm line shall be used unless otherwise specified by the Government inspector. Test procedures shall conform to figure 8 insofar as is practicable.

4.4.1 Conducted interference measurements on power leads shall be made at the end of the terminated 50-ohm cable of the network specified in 4.1.3 and figure 9. A separate network shall be used for each ungrounded lead, and all networks shall be left in place for complete radio interference tests.

4.4.2 Ground planes, bonding, and grounding. -

4.4.2.1 Ground planes. - A copper or brass ground plane, 0.010 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12 square feet or more in area shall be used in all cases where a shielded enclosure is to be used. The ground plane shall be bonded to the shielded enclosure at intervals no greater than 3 feet.

4.4.2.2 When a ground plane is not specified, or when the use of a shielded enclosure is impracticable, the test sample shall be placed on a solid support for operation. The support may be solid earth, steel, or iron flooring, metal bedplate, metal-sheet covered planking, or the like. If the test sample is intended for normal operation with shock or vibration mounts that insulate the sample from the foundation, the sample shall be grounded to its support or foundation by bridging the insulating mounts in a manner similar to that employed at the place of installation and use by means of bonding straps. If bonding straps are provided with the test item, then these shall be used in lieu of the type specified in 4.4.2.4.

4.4.2.3 The test item shall be grounded in a manner simulating actual usage conditions, where practicable, whether the test is performed in a shielded enclosure or not. It is not necessary to ground the interference measurement instrument except by means of the connecting leads utilizing the instrument as a two-terminal voltmeter, except when measurements are made in a shielded enclosure.

4.4.2.4 When bonding straps must be furnished, such straps shall have a width-to-length ratio of 1 to 5 or greater, shall have minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid.

4.4.2.5 Internally grounded equipment. - When the test item is furnished with an internal ground terminal connection, and when this connection is used in actual installation conditions, the ground lead shall be brought out and connected to the ground plane simulating actual installation conditions in addition to grounding the framework or chassis of the test item.

4.5 Test procedures. - Measurements under acceptability testing conditions on a preproduction model shall be made on not less than three frequencies per octave. The frequencies selected shall be chosen in such a manner as to prevent crowding of readings at one end of the band and shall be at calibrated points. Measurements during production testing shall be made on not less than one frequency for each octave. When using the instruments capable of frequency scanning, all other frequencies not selected for measurement shall be scanned while monitoring with headphones or a loudspeaker. If interference peaks appear while scanning, measurements shall be made at each frequency at which such a peak occurs.

4.5.1 If station reception is encountered at any frequency, another frequency on one or the other side of the station frequency shall be used.

4.5.2 The measurement instruments equipped with peak (slideback) circuitry shall be set in the peak (slideback) position for measurement of broadband interference. The instruments not equipped with the peak (slideback) circuitry shall be set in the quasi-peak or radio noise position. Methods of conversion of the readings so obtained into the standard units of interference will be provided by the bureau or agency concerned. All instruments shall be set in the quasi-peak or radio noise position for measurement of CW type interference. The results of measurements made in this manner will determine the acceptability of the test sample.

4.5.2.1 Correction for pulse recurrence frequency (p.r.f.). - For radio interference measurements with a nonpeak reading instrument (Ferris 32, Measurements Corporation 58 and AN/URM-28) a correction shall be made in accordance with figures 13, 14, and 15 when the p.r.f. of the interference is greater or less than 23 pulses per second (p.p.s.) of the pulses of greatest amplitude.

5. PREPARATION FOR DELIVERY

5.1 Not applicable.

6. NOTES

6.1 This specification covers only radio interference requirements and methods of determining compliance therewith; therefore, the details of performance to the equipment and the ordering information must be specified elsewhere. Attention of design engineers is invited to the items listed below which may be expanded in the individual equipment specification:

(a) Radiated interference limits (see 3.5.1).
(b) Conducted interference limits (see 3.5.2).
(c) Instrument used to check calibration (see 3.6.1)
(d) Number of equipments to be tested (see 4.1).
(e) Rated voltage (see 4.1.1.1).
(f) Load to be used for testing (see 4.1.1.4).
(g) Distance of antenna from test item (see 4.2.1).
(h) Point of test, if line-to-ground does not apply (see 4.4).
(i) Line-coupling device (see 4.4).

6.2 Type of equipment. - The following is a partial list of the equipment covered by this specification:

(a) Accounting and posting machines.
(b) Adding machines.
(c) Addressing machines.
(d) Autographic registers.
(e) Billing machines.
(f) Bookkeeping machines.
(g) Calculating machines.
(h) Camera (with arc lights).
(i) Cash registering machines.
(j) Change making machines.
(k) Check cancelling, cutting, dating, endorsing, numbering, perforating, signing, sorting, and writing machines.

(ℓ) Coil counting, sorting, and wrapping machines.
(m) Composing machines.
(n) Duplicating machines, such as direct process, offset, and stencil paper principle.
(o) Embossing machines.
(p) Envelope folding, handling, mailing, opening, and sealing machines.
(q) Folding machines.
(r) Grainers.
(s) Graphotypes.
(t) Lithographic presses.
(u) Microfilming, enlarging, and printing equipment.
(v) Multiliths.
(w) Paper cutting machines.
(x) Paper drilling machines.
(y) Paper fastening machines.
(z) Paper folding machines.
(aa) Payroll machines.
(bb) Perforating machines.
(cc) Photo offset plate reproducers.
(dd) Postage meters.
(ee) Postal permit mailing machines.
(ff) Postmarking and cancelling machines.
(gg) Printing presses.
(hh) Proportional spacing typing machines.
(ii) Punch card tabulating and accounting machines.
(jj) Shorthand writing machines.
(kk) Sound recording and reproducing devices used for dictation, transcription, telephone recording, conference recording, and similar office functions.
(ℓℓ) Stamp affixing machines.
(mm) Stapling machines.
(nn) Tabulating machines.
(oo) Time recorders.
(pp) Time stamps.
(qq) Typewriters.
(rr) Vacuum printing frames.
(ss) Varitypers.
(tt) Whirlers.
(uu) Wire stitching machines.

6.3 Design. - Radio interference should be carefully considered in the basic design of all equipment major units, assemblies, and systems. Electrical and electronic equipment must operate satisfactorily not only alone, but also in conjunction with other such equipment which may be placed nearby. This requires that the operation of all such equipment should not be adversely affected by radio interference voltages and fields reaching it from external sources, and also requires that such equipment should not itself be a source of radio interferences which might adversely affect the operation of other nearby equipment. Therefore, design should be such that the least practical amount of radio interference is inherently generated and propagated before interference reduction major units are applied. Such radio interference reduction major units and techniques that must be used, such as filtering, shielding, and bonding, should be in conformance with good engineering practice and should be used efficiently in order to minimize space and weight penalties. All possible advantages should be taken of the use of radio interference source reduction such as the use of mica capacitors directly at the interference source.

6.4 Measurement techniques in the presence of internal noise. - Internal noise is that energy present inherently in the input circuit and which causes a meter indication with no radio frequency input in the measuring instruments. The internal noise is caused by thermal agitation in the resistance of the input circuit and the tubes used in the first stages of the instrument. The internal noise has been taken into account in the limits curves shown on figures 1 and 3.

Notice. - When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder, or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:
Bureau of Ships
Other interest:
MC

BROADBAND RADIATED INTERFERENCE LIMITS — EXPRESSED IN TERMS OF STANDARD UNITS

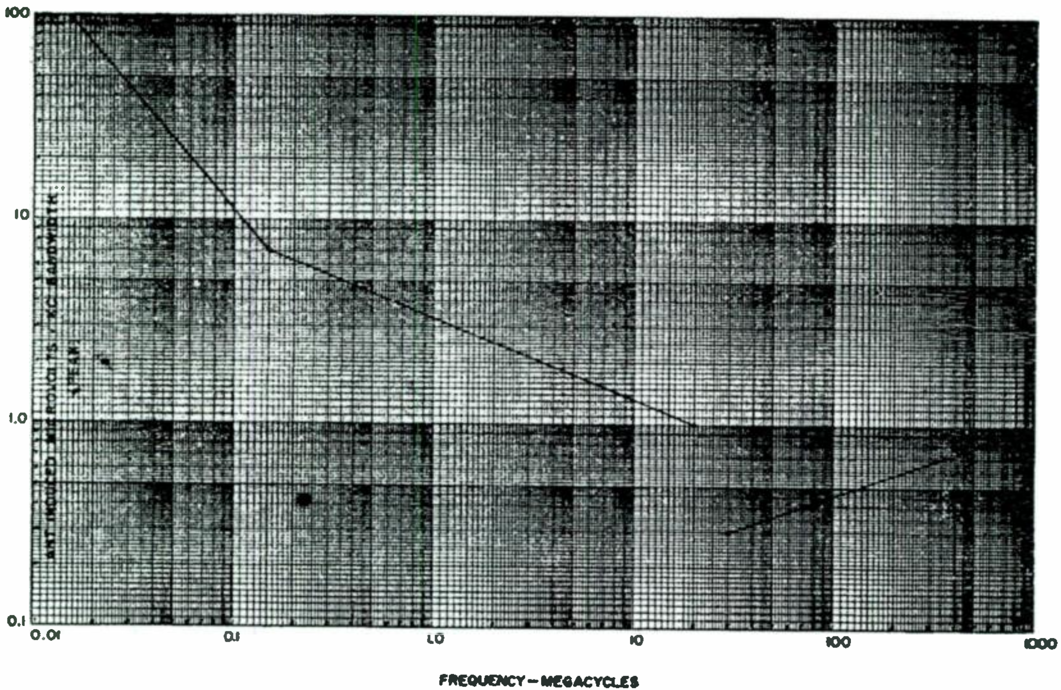


Figure 1

CW RADIATED (SINE WAVE) INTERFERENCE LIMITS — EXPRESSED IN TERMS OF STANDARD UNITS

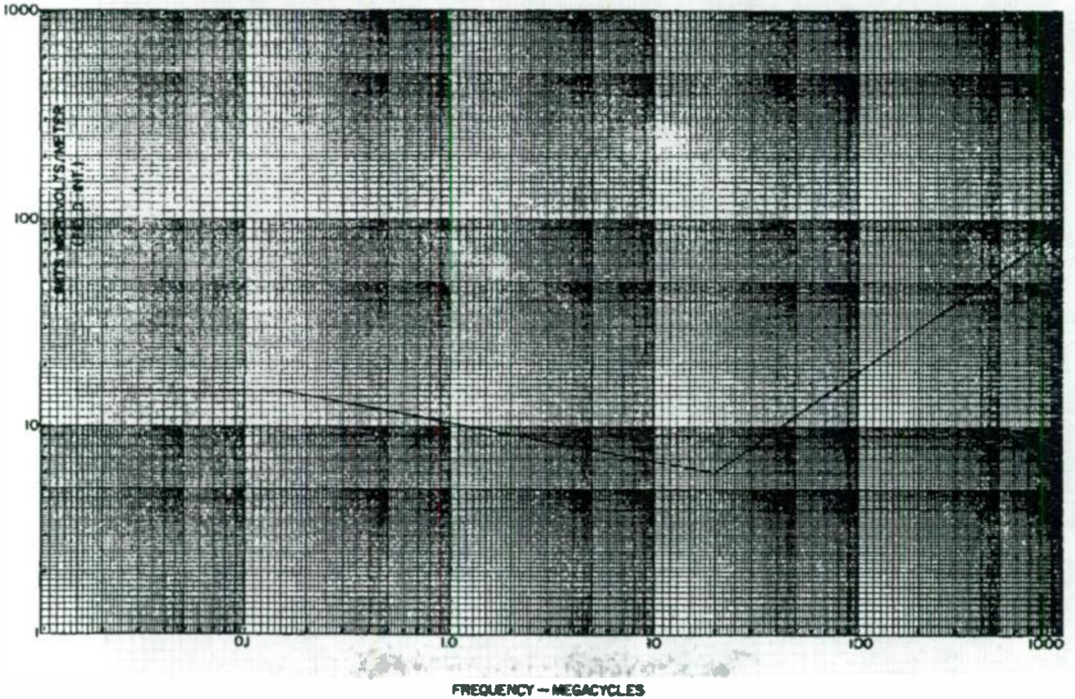


Figure 2

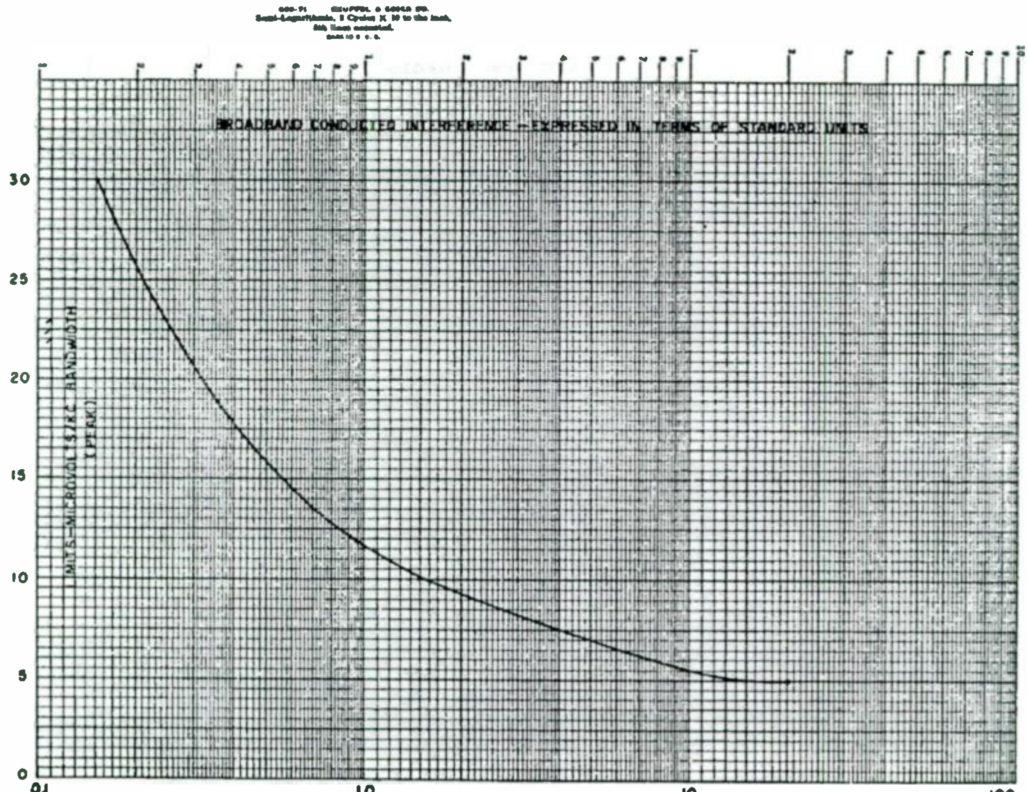


Figure 3 - Frequency - Megacycles

CW CONDUCTED (SINE WAVE) INTERFERENCE — EXPRESSED IN TERMS OF STANDARD UNITS

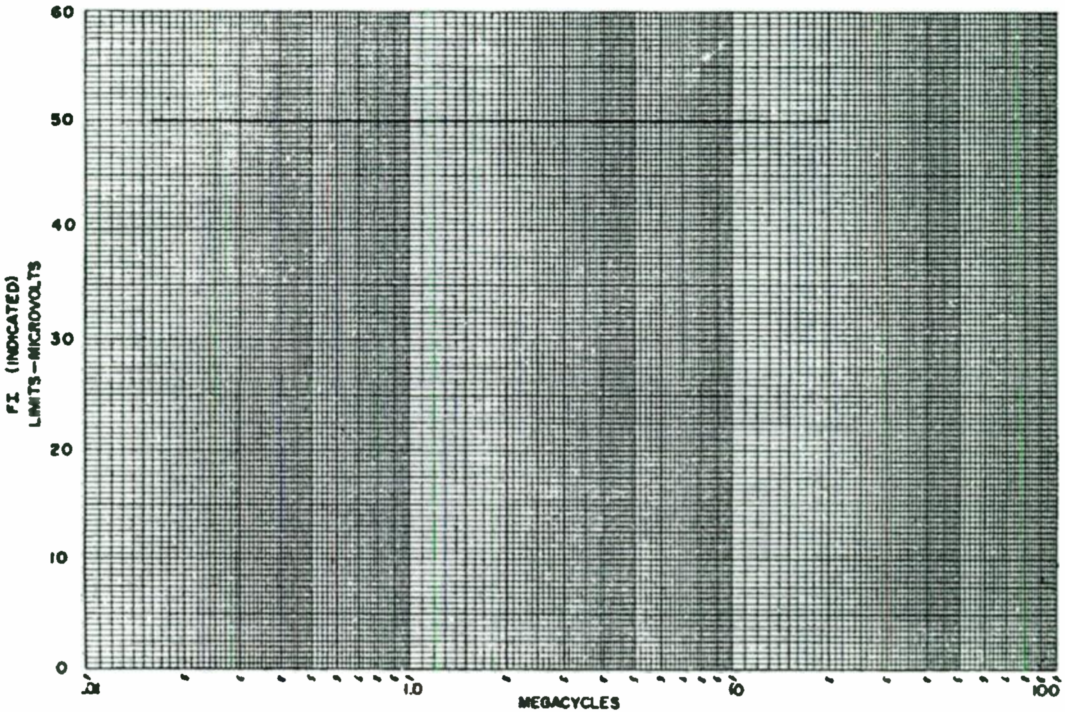
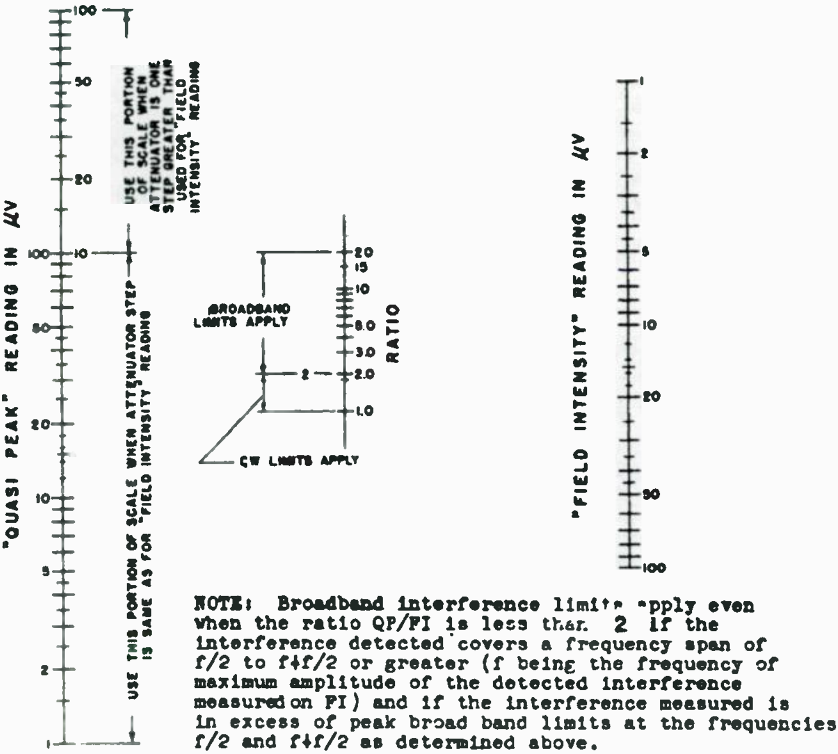


Figure 4



NOTE: Broadband interference limits apply even when the ratio QP/FI is less than 2 if the interference detected covers a frequency span of f/2 to f+f/2 or greater (f being the frequency of maximum amplitude of the detected interference measured on FI) and if the interference measured is in excess of peak broad band limits at the frequencies f/2 and f+f/2 as determined above.

Figure 5

CHART FOR DETERMINING TYPE OR CHARACTER OF INTERFERENCE

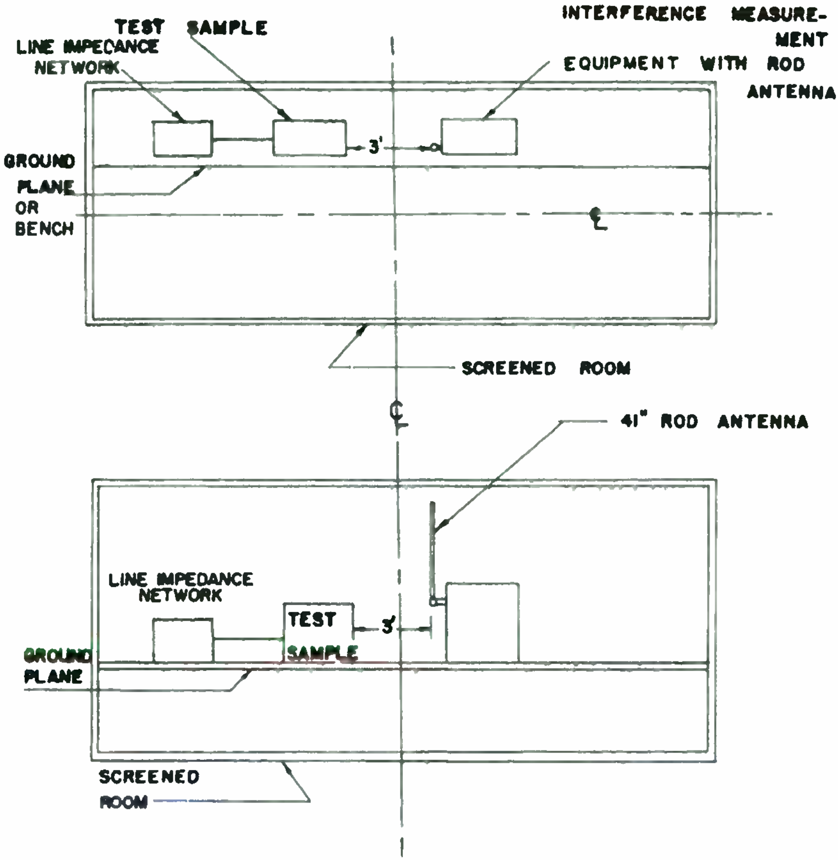


Figure 6.- Rod antenna orientation and positioning.

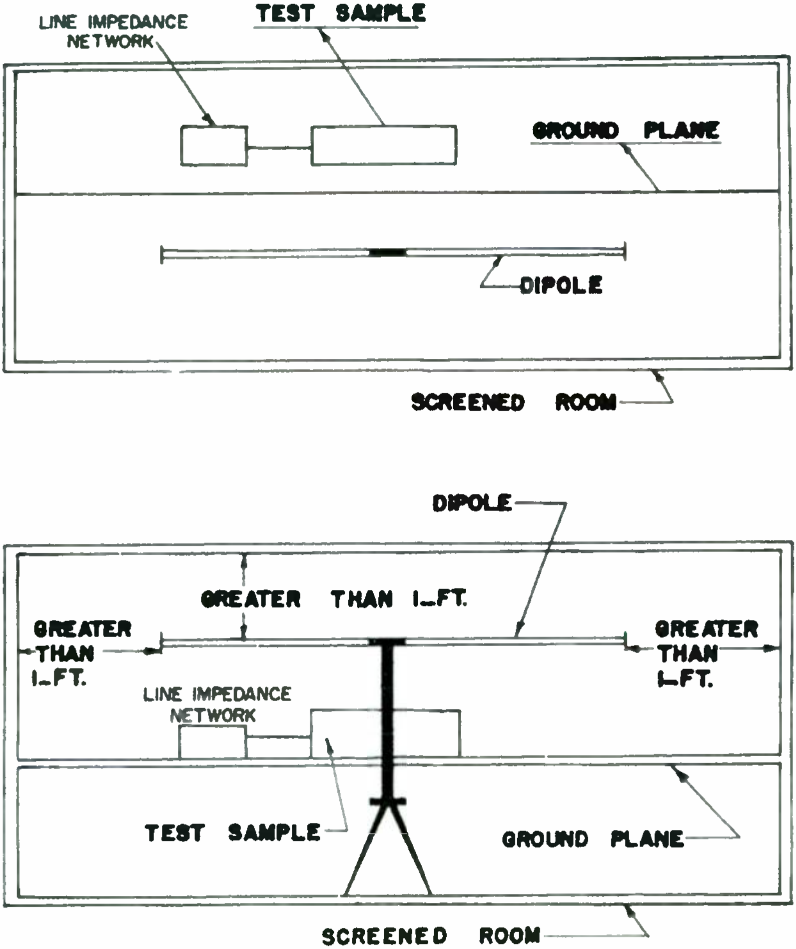
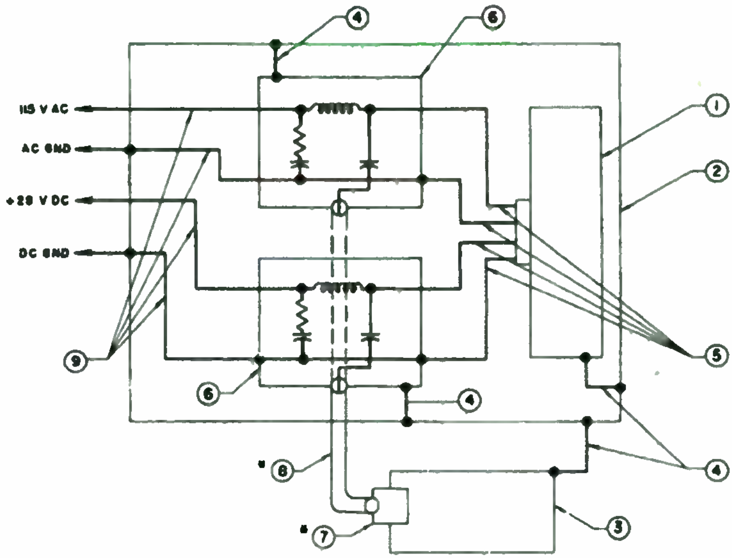


Figure 7.- Dipole antenna orientation and positioning.



① EQUIPMENT UNDER TEST (NOISE SOURCE)

② GROUND PLANE (TABLE TOP) SEE 4.4.2

③ RADIO INTERFERENCE MEASURING INSTRUMENT

④ BONDING STRAPS. SEE 4.4.2.4

⑤ TEST SAMPLE POWER LEADS. SEE 4.1.2

⑥ LINE STABILIZATION NETWORK. SEE 4.1.3

⑦ MATCHING CONNECTOR. FOR FERRIS METER SEE FIG. 9 AND 16; FOR STODDARD AN/PRM-1 METER SEE FIG. 9 (CU/197).

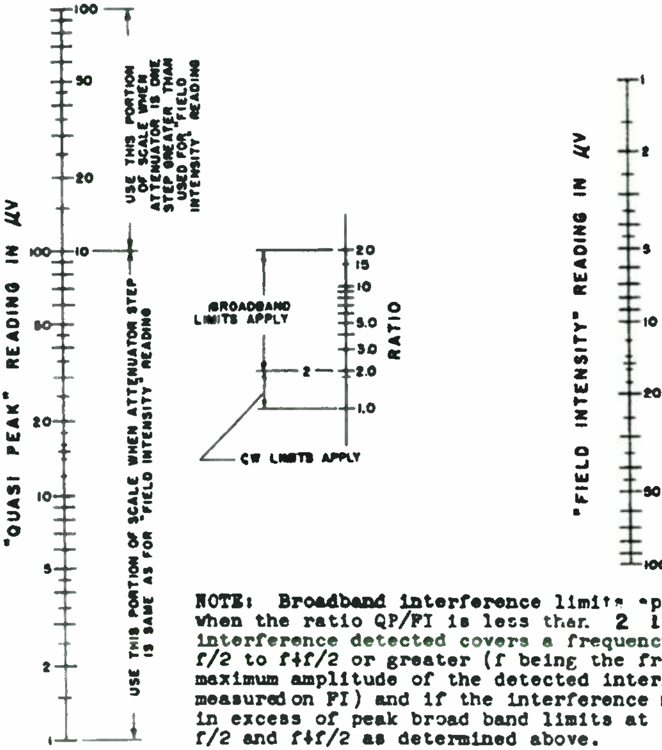
⑧ SIX FEET OF RG-9/U CABLE TERMINATED IN TYPE N CONNECTORS

⑨ FILTERED POWER INPUT LEADS.

*ITEMS 7 AND 8 ARE OMITTED WHEN MAKING RADIATED INTERFERENCE TESTS.

TYPICAL TEST SETUP FOR RADIO INTERFERENCE TESTS

Figure 8



NOTE: Broadband interference limits apply even when the ratio QP/FI is less than 2 if the interference detected covers a frequency span of f/2 to f+f/2 or greater (f being the frequency of maximum amplitude of the detected interference measured on FI) and if the interference measured is in excess of peak broad band limits at the frequencies f/2 and f+f/2 as determined above.

Figure 5

CHART FOR DETERMINING TYPE OR CHARACTER OF INTERFERENCE

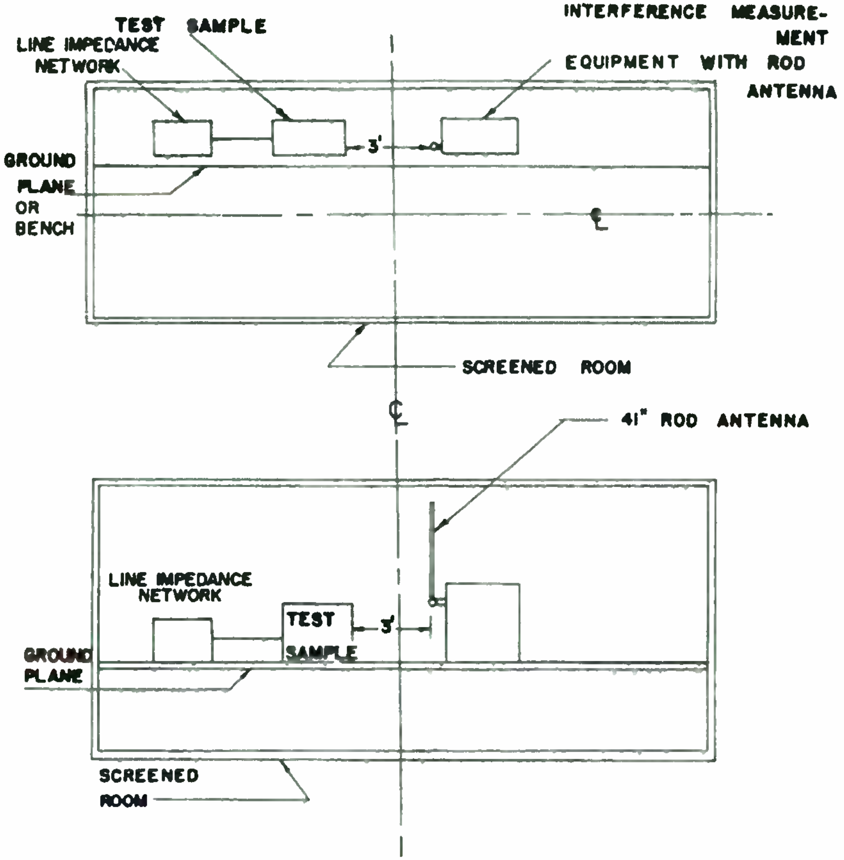


Figure 6.- Rod antenna orientation and positioning.

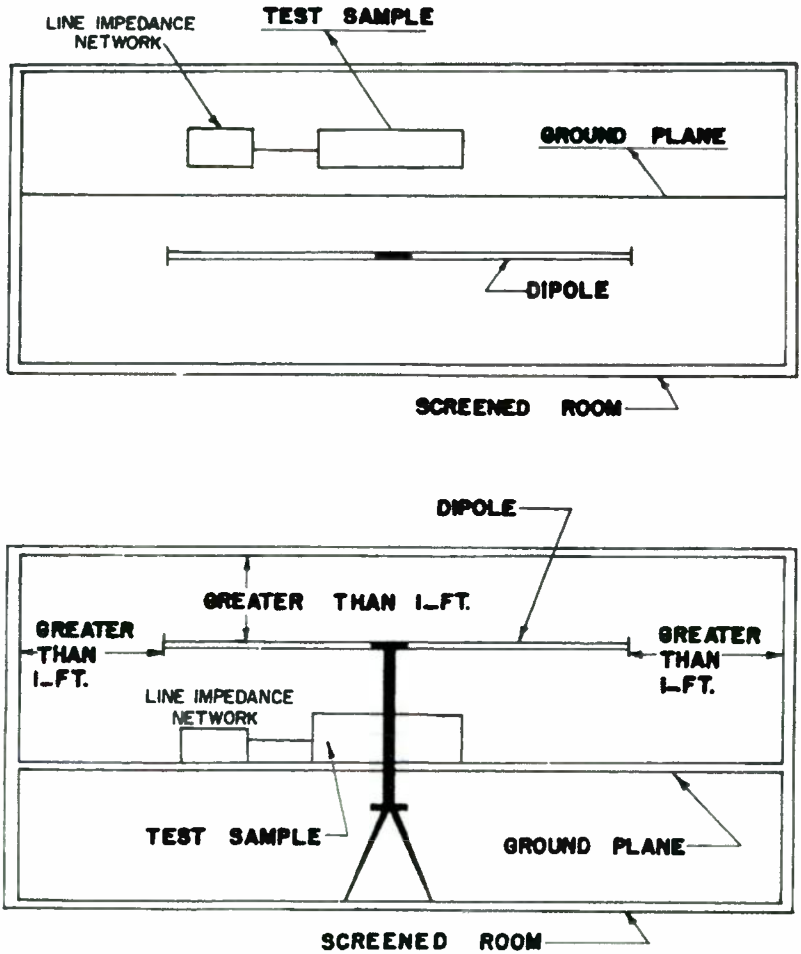
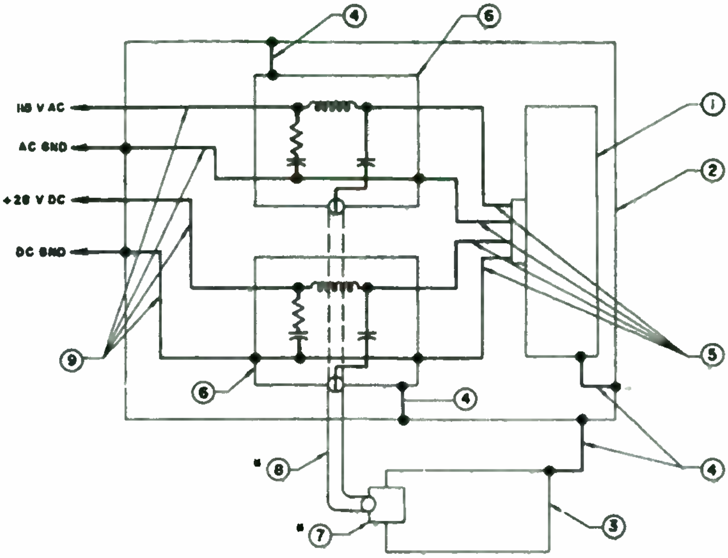


Figure 7.- Dipole antenna orientation and positioning.



(1) EQUIPMENT UNDER TEST (NOISE SOURCE)

(2) GROUND PLANE (TABLE TOP) SEE 4.4.2

(3) RADIO INTERFERENCE MEASURING INSTRUMENT

(4) BONDING STRAPS. SEE 4.4.2.4

(5) TEST SAMPLE POWER LEADS. SEE 4.1.2

(6) LINE STABILIZATION NETWORK. SEE 4.1.3

(7) MATCHING CONNECTOR. FOR FERRIS METER SEE FIG. 9 AND 16; FOR STODDARD AN/PRM-1 METER SEE FIG. 9 (CU/197).

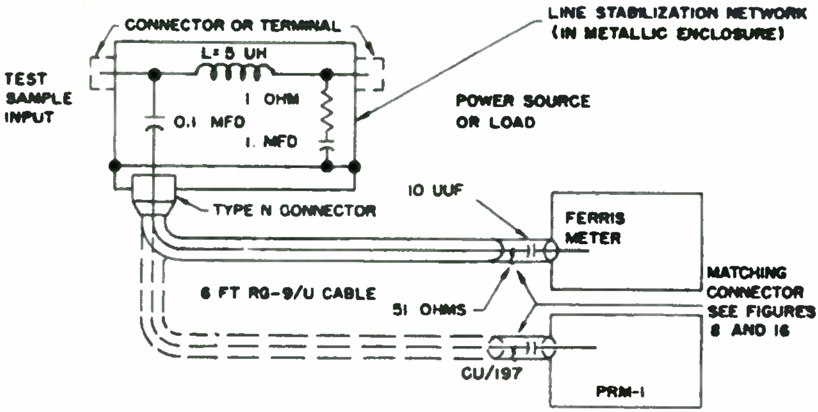
(8) SIX FEET OF RG-9/U CABLE TERMINATED IN TYPE N CONNECTORS

(9) FILTERED POWER INPUT LEADS.

*ITEMS 7 AND 8 ARE OMITTED WHEN MAKING RADIATED INTERFERENCE TESTS.

TYPICAL TEST SETUP FOR RADIO INTERFERENCE TESTS

Figure 8



COIL DATA (50 AMPS.)-

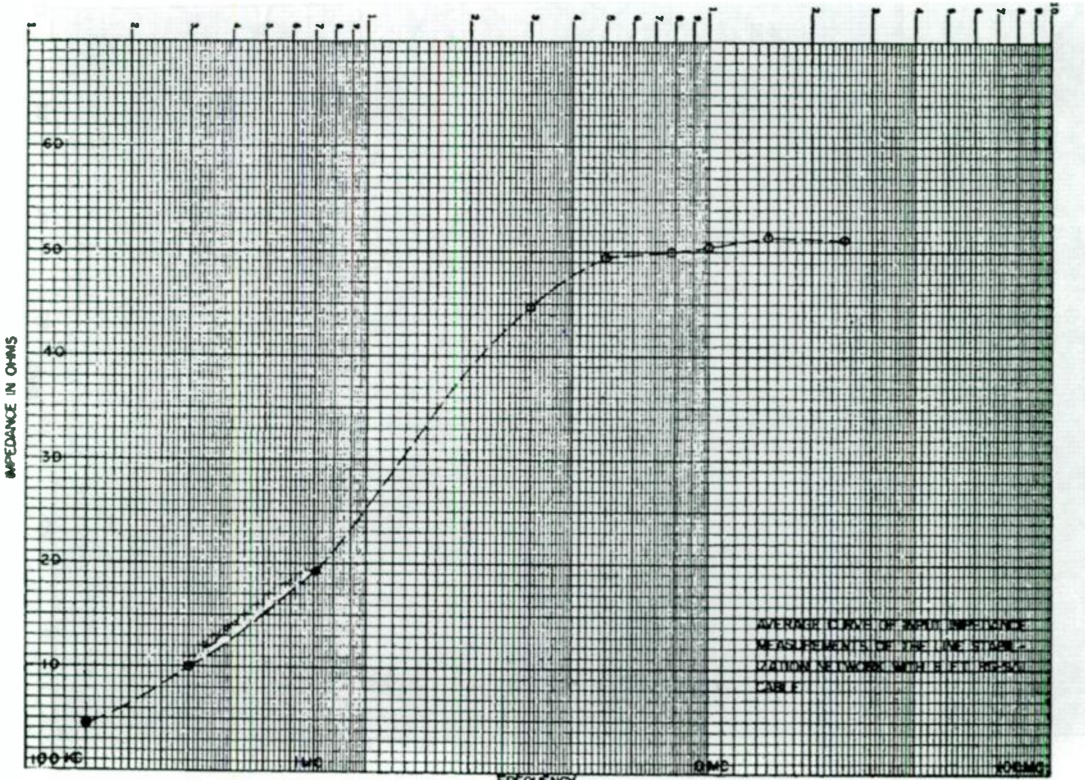
1. L=4.9 MICROHENRYS AT 1.0 MC.
2. 18 TURNS NO 10 WIRE, HEAVY INSULATED.
3. BAKELITE TUBING 1-5/8 INCHES DIAMETER.

NOTE:

1. FOR USE ABOVE 50 AMPERES, REPLACE COIL WITH 5 MICROHENRY COIL OF SUITABLE DIMENSIONS CAPABLE OF CARRYING DESIRED CURRENT.
2. THE VALUES GIVEN FOR THE COMPONENT PARTS OF THE NETWORK ARE NOMINAL. REGARDLESS OF CONSTRUCTION OR DEVIATION FROM NOMINAL VALUES, THE NETWORK MUST HAVE AN INPUT IMPEDANCE TO WITHIN 10% OF THAT GIVEN IN FIGURE 10.

LINE STABILIZATION NETWORK AND TYPICAL METER CONNECTION FOR CONDUCTED MEASUREMENTS

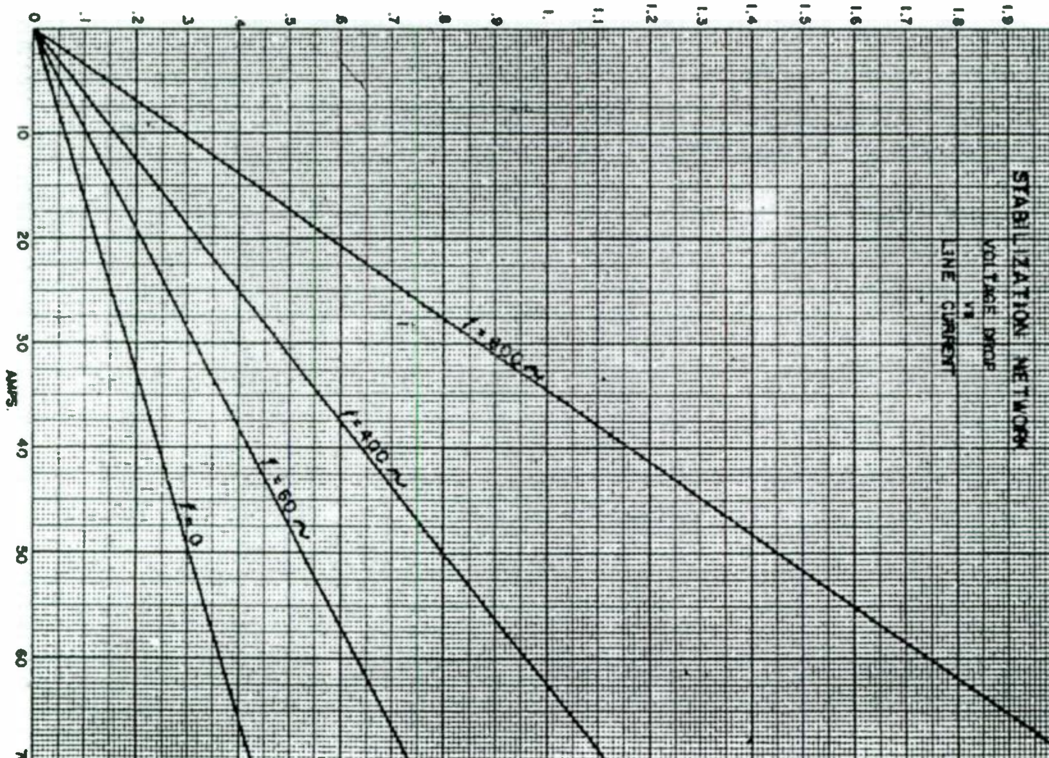
Figure 9



FREQUENCY

Figure 10

Figure 11. - VOLTAGE DROP ACROSS STABILIZATION NETWORK



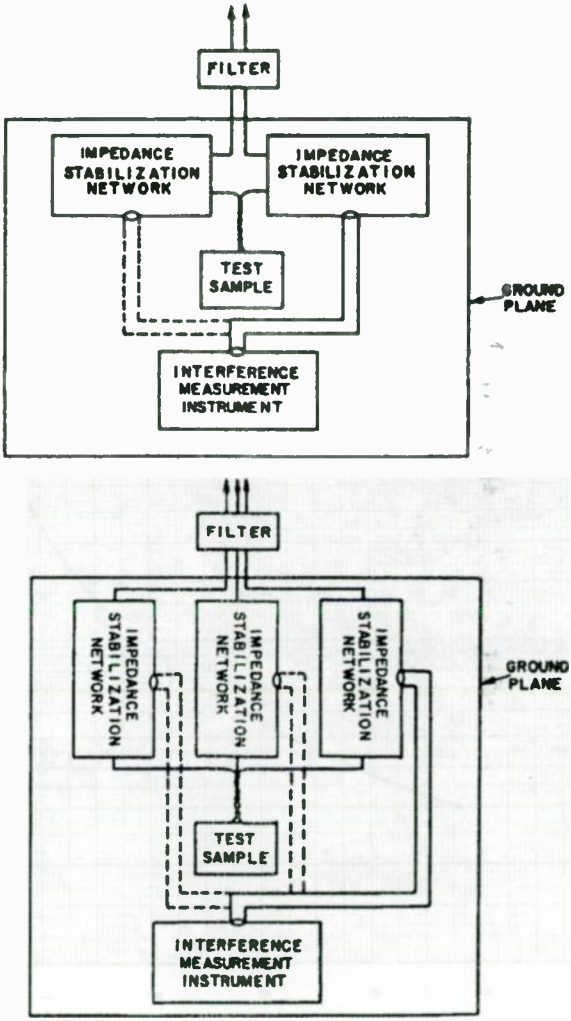
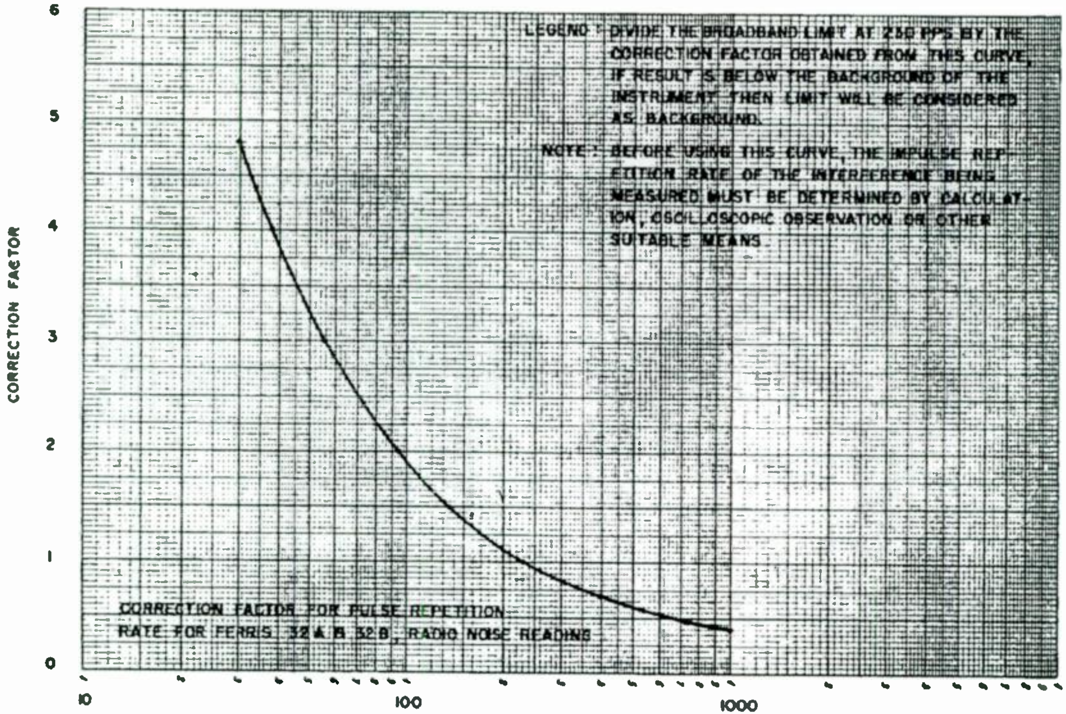


Figure 12. - Procedure for use of line and load impedance stabilization network.


LEGEND: DIVIDE THE BROADBAND LIMIT AT 250 PPS BY THE CORRECTION FACTOR OBTAINED FROM THIS CURVE, IF RESULT IS BELOW THE BACKGROUND OF THE INSTRUMENT THEN LIMIT WILL BE CONSIDERED AS BACKGROUND.
NOTE: BEFORE USING THIS CURVE, THE IMPULSE REPETITION RATE OF THE INTERFERENCE BEING MEASURED MUST BE DETERMINED BY CALCULATION, OSCILLOSCOPIC OBSERVATION OR OTHER SUITABLE MEANS
CORRECTION FACTOR FOR PULSE REPETITION RATE FOR FERRIS 32 A & 32 B, RADIO NOISE READINGS
CORRECTION FACTOR
0
1
2
3
4
5
6
10
100
1000
IMPULSE REPETITON RATE (P.P.S.)
Figure 13

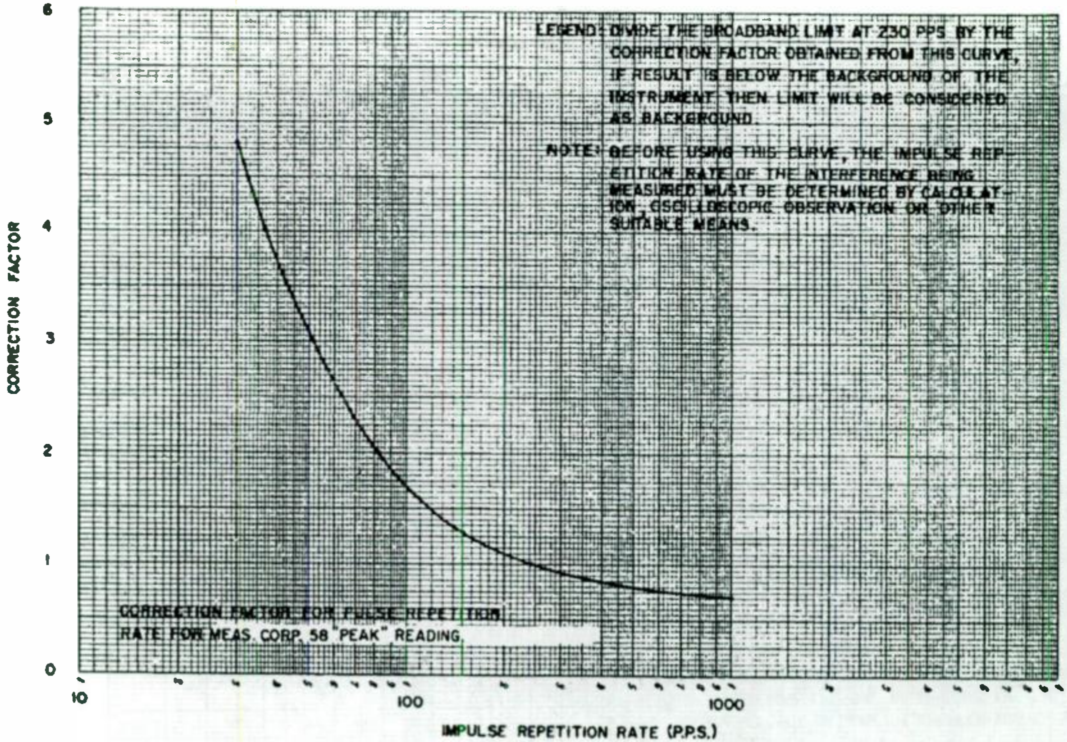

LEGEND: DIVIDE THE BROADBAND LIMIT AT 230 PPS BY THE CORRECTION FACTOR OBTAINED FROM THIS CURVE, IF RESULT IS BELOW THE BACKGROUND OF THE INSTRUMENT THEN LIMIT WILL BE CONSIDERED AS BACKGROUND.
NOTE: BEFORE USING THIS CURVE, THE IMPULSE REPETITION RATE OF THE INTERFERENCE BEING MEASURED MUST BE DETERMINED BY CALCULATION, OSCILLOSCOPIC OBSERVATION OR OTHER SUITABLE MEANS.
CORRECTION FACTOR FOR PULSE REPETITION RATE FOR MEAS. CORP. 58 "PEAK" READING.
CORRECTION FACTOR
0
1
2
3
4
5
6
10
100
1000
IMPULSE REPETITION RATE (P.P.S.)

Figure 14

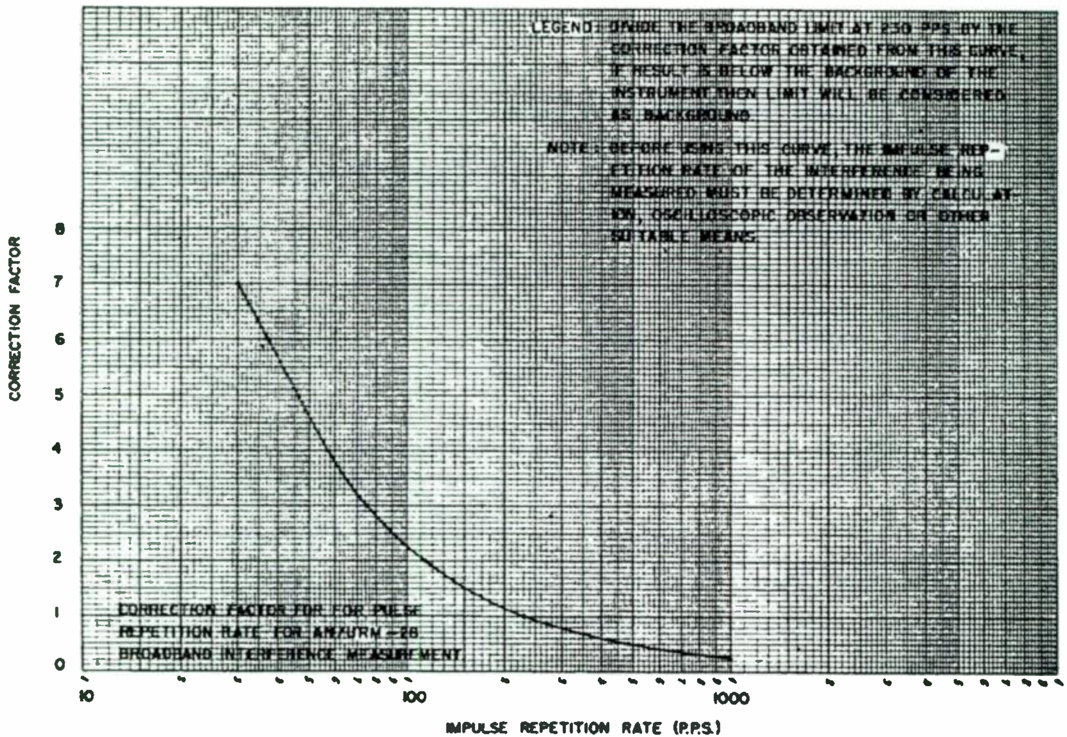

LEGEND: DIVIDE THE BROADBAND LIMIT AT 230 PPS BY THE CORRECTION FACTOR OBTAINED FROM THIS CURVE, IF RESULT IS BELOW THE BACKGROUND OF THE INSTRUMENT THEN LIMIT WILL BE CONSIDERED AS BACKGROUND.
NOTE: BEFORE USING THIS CURVE, THE IMPULSE REPETITION RATE OF THE INTERFERENCE BEING MEASURED MUST BE DETERMINED BY CALCULATION, OSCILLOSCOPIC OBSERVATION OR OTHER SUITABLE MEANS.
CORRECTION FACTOR FOR FOR PULSE REPETITION RATE FOR AN/URM-28 BROADBAND INTERFERENCE MEASUREMENT
CORRECTION FACTOR
0
1
2
3
4
5
6
7
8
10
100
1000
IMPULSE REPETITION RATE (P.P.S.)

Figure 15

MILITARY SPECIFICATION

INTERFERENCE LIMITS AND TESTS FOR MODIFIED OR RECONDITIONED AIRCRAFT

1. SCOPE

1.1 This specification covers interference limits applicable to aircraft being modified or reconditioned.

2. APPLICABLE DOCUMENTS

2.1 The following specification of the issue in effect on the date of invitation for bids forms part of this specification:

SPECIFICATIONS

Military

MIL-F-15733 Filters, Radio Interference

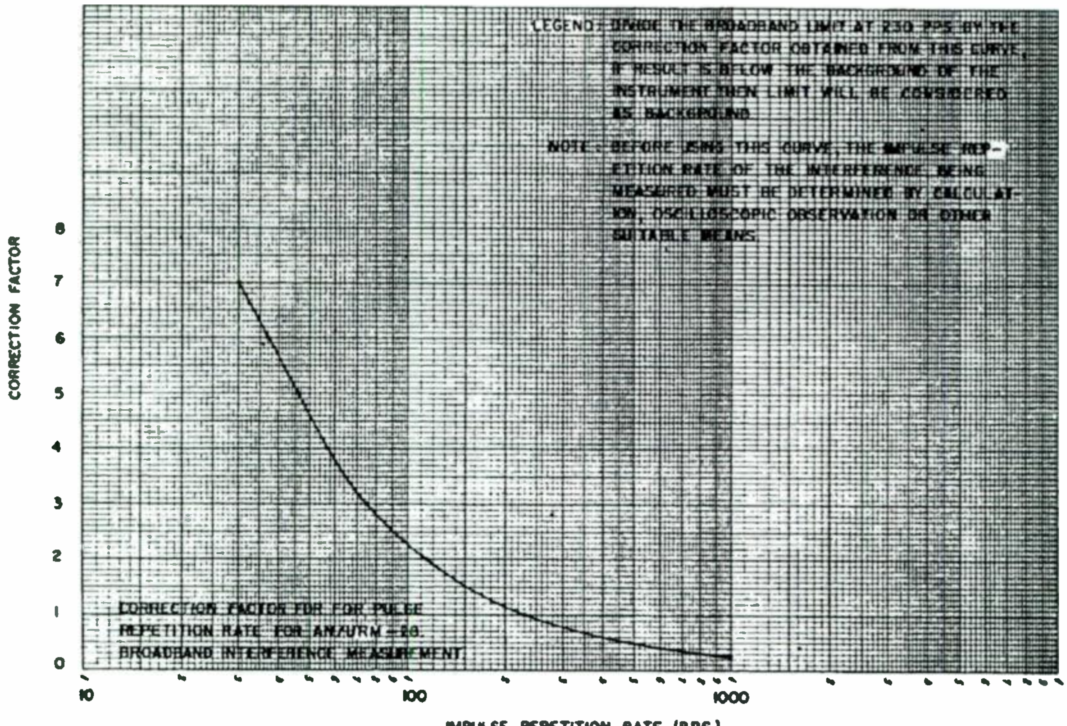
(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General. - The modifying activity, contractor, or repairing activity shall be responsible for the installation engineering of all equipment to achieve an interference-free aircraft.

3.1.1 Failure to meet Requirements. - Where it can be demonstrated to Government representative that interference caused by a certain component cannot be eliminated by means within the contractors control, including reasonable external application of shielding or filtering, the procuring activity shall be notified immediately.

3.2 Performance. - There shall be no undesirable response from electronic receivers above the area noise level, or malfunctioning of other electronic equipment, due to radio interference produced by any or all electrical, electronic, and other equipment of the aircraft, when


LEGEND: DIVIDE THE BROADBAND LIMIT AT 230 PPS BY THE CORRECTION FACTOR OBTAINED FROM THIS CURVE, IF RESULT IS BELOW THE BACKGROUND OF THE INSTRUMENT THEN LIMIT WILL BE CONSIDERED AS BACKGROUND
NOTE: BEFORE USING THIS CURVE, THE IMPULSE REPETITION RATE OF THE INTERFERENCE BEING MEASURED MUST BE DETERMINED BY CALCULATION, OSCILLOSCOPIC OBSERVATION OR OTHER SUITABLE MEANS.
CORRECTION FACTOR FOR FOR PULSE REPETITION RATE FOR AN/URM-20 BROADBAND INTERFERENCE MEASUREMENT
CORRECTION FACTOR
0
1
2
3
4
5
6
7
8
10
100
1000
IMPULSE REPETITION RATE (P.P.S.)
Figure 15

MIL-I-25171(USAF)
15 March 1955

MILITARY SPECIFICATION

INTERFERENCE LIMITS AND TESTS FOR MODIFIED OR RECONDITIONED AIRCRAFT

1. SCOPE

1.1 This specification covers interference limits applicable to aircraft being modified or reconditioned.

2. APPLICABLE DOCUMENTS

2.1 The following specification of the issue in effect on the date of invitation for bids forms part of this specification:

SPECIFICATIONS

Military

MIL-F-15733 Filters, Radio Interference

(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General. - The modifying activity, contractor, or repairing activity shall be responsible for the installation engineering of all equipment to achieve an interference-free aircraft.

3.1.1 Failure to meet Requirements. - Where it can be demonstrated to Government representative that interference caused by a certain component cannot be eliminated by means within the contractors control, including reasonable external application of shielding or filtering, the procuring activity shall be notified immediately.

3.2 Performance. - There shall be no undesirable response from electronic receivers above the area noise level, or malfunctioning of other electronic equipment, due to radio interference produced by any or all electrical, electronic, and other equipment of the aircraft, when tested as specified herein. This requirement applies to the entire frequency range of all installed electronic equipment and to the entire frequency range of all electronic equipment for which complete installation provisions have been made.

3.3 Transient Responses. - Undesirable transient responses are exempted from the requirements specified herein if they cause no malfunctioning and occur only during ground engine starting, or if they cause no malfunctioning, are less than 1 second in duration and do not recur during normal operation more frequently than once every three minutes. Undesirable aural transient responses are further exempted if their duration is less than three seconds and they do not occur more than once per flight.

3.4 Method and Material. - The method and material used to accomplish suppression or elimination of radio interference, such as the installation of filtering, bonding, and shielding, shall be in accordance with good engineering practice. Where a proposed method has not been previously approved for U.S. Air Force use, the contractor shall forward, with the proposal, substantiating engineering data for its use.

3.4.1 Filters. - Filters shall be in accordance with the requirements of Specification MIL-F-15733 and shall be installed only when it is demonstrated to the procuring activity that they are necessary to insure compliance with this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Identification Of Tests. - The two tests outlined herein are identified as follows:

a. Interference Compliance Test
b. General Acceptance Test

4.2 Interference Compliance Test. -

4.2.1 Aircraft To Be Tested. - Each aircraft being modified or reconditioned shall be submitted to an interference compliance test.

4.2.2 Test Equipment. -

4.2.2.1 Electronic Receivers. - Electronic receivers for conducting tests under this specification shall be taken from stock equipment of the aircraft, shall meet the sensitivity requirements for the individual equipment, and shall be acceptable to the procuring activity.

4.2.2.2 Output Meter. - An alternating current output meter of at least 1000 ohms per volt input impedance, with a damping factor not more than 0.7 (critical), and capable of measuring audio outputs at -10 db below one milliwatt at 600 ohms, shall be used for measuring audio outputs of receivers when conducting radio interference tests in aircraft.

4.2.2.2.1 Electronic Voltmeter. - During tests of aircraft utilizing Interphone Equipment AN/AIC-10, an electronic voltmeter capable of indicating signal levels of one millivolt shall be used to measure the interphone output.

4.2.2.3 Headsets. - Standard low-impedance headsets, such as HS-33-A or HS-38-A, shall be used for detecting interference in the audio output of receivers, except, when the output of AN/AIC-10 interphone equipment is being monitored, in which case, Headset-Microphone H-78/AIC-10 or other equivalent headset shall be used. When special headsets are required for a special equipment, they shall be used with that equipment during the tests.

4.2.3 Test Conditions and Procedures. -

4.2.3.1 Installation. - Prior to test, all electronic and electrical equipment shall be properly installed in the aircraft.

4.2.3.2. Test Locations. - For all tests, locations shall be chosen where area noise level is at a minimum. In instances where the area noise level exceeds the receiver system background level by 8 db appropriate measures shall be taken to insure that the area noise does not "mask" the interference from electronic or electrical devices being tested. For receivers having unshielded lead-ins, utilizing the frequency range below 20 mcs, the following procedure is considered a satisfactory method to overcome the effect of high area noise level:

4.2.3.2.1 Adjustments of Receivers. - All electronic receivers for conducting tests (below 20 mcs) shall be adjusted for maximum performance with antenna disconnected at the point of entry of the aircraft and the receiver lead-in connected, in series with an appropriate capacitor, to the inside skin of the aircraft at a point as near as practicable to the feed through insulator. In order to reduce the coupling of external signals and interference to the lead-in the external antenna shall be disconnected and removed from the vicinity of the feed through insulator for this test.

4.2.3.2.2 Excessive Noise Levels. - In case area noise levels are encountered which exceed 8 db above the receiver noise, on receivers above 20 mcs, the tests shall be delayed until such time as the area noise is within this limit or the airplane shall be moved to another area, or tested during flight within an area not exceeding the 8 db limit.

4.2.3.3 Power Source. - During all tests, the power source voltages shall be maintained within the limits normally available in the aircraft.

4.2.3.4 Controls. - All electronic receivers for conducting tests shall be adjusted for maximum performance. Where provided, external gain controls shall be "full on", squelch circuits inoperative, modulated continuous wave (MCW) reception employed, and all external antenna trimmers adjusted for maximum sensitivity at a mid-frequency of the range covered. No internal modification shall be made unless specified in the contract or modification specification for the aircraft.

4.2.3.5 Aural Output Measurement. - Electronic equipment which provides an aural output shall have a headset and an output meter connected in parallel at the normal operating positions. The jack box or control panel gain control shall be "full on", and all other jack boxes or control panels shall be set on a position other than the position on which the test is being accomplished. In an electronic system where any receiver output is normally fed into a radio-interphone amplifier, the headset and output meter shall be connected in the amplifier output circuit. The controls for the radio-interphone amplifier shall be adjusted for the conditions of normal system operation.

4.2.3.6 Test Frequencies. - Tests for the presence of radio interference in the output of each electronic receiver shall be made at a representative number of frequencies within the range of the equipment while all other equipments and systems which are potential sources of radio interference are in operation. Whenever possible, test frequencies shall be selected on the basis of listening tests covering the entire frequency range. Acceptable demonstration by the contractor or modifying activity at a limited number of frequencies shall not be construed as a waiver of the requirements for interference free operation throughout the frequency range.

4.3 General Acceptance Test.

4.3.1 Aircraft to be Tested. - A general acceptance test will be performed on all aircraft in which an aircraft component, which is a potential source of radio-interference, has been exchanged, installed, or modified. This requirement does not apply where the aircraft component exchange, installation, repair, or modification has been accomplished prior to an interference compliance test.

4.3.2 Test Conditions and Procedures. - The test conditions and procedures for the general acceptance test shall be as specified for the interference compliance test, except that no output meter need be used, and quantitative measurements are not required.

5. NOTES

5.1 Use. - The purpose of this specification is to obtain radio-interference-free performance of electronic installations in modified or reconditioned aircraft by providing interference limits and methods of test for a complete aircraft.

5.2. Definitions.

5.2.1 Receiver Noise Level. - Receiver noise level is defined as the "hiss", in cases of equipments with aural outputs, "grass" or "snow" in visual types, which is inherent to the equipment. This may be measured in aural output equipment by placement of the equipment with the antenna terminal terminated by a suitable phantom antenna in a radio-shielded room and measuring the output under those conditions. Noise level of a location is the noise audible from a receiver or seen on a visual type receptor with no radio signal input.

5.2.2 Radio Interference. - Radio interference to any electronic equipment is defined as any disturbance or disturbances which cause undesirable response or malfunctioning of any electronic equipment.

5.2.3 Malfunctioning. - Malfunctioning is defined as that type of output which departs from normal due to interference, in such a manner that the operator or actuating mechanism is unable to differentiate operationally between desired and undesired signals. Examples are the undesired actuating of an auto-pilot, and the introduction of a fixed target on a radar scope.

5.2.4 Undesirable Response. - Undesirable response is defined as a recognizable interruption to the normal output which introduces no malfunctioning. Examples are snow on a radar scope, and static in headsets.

5.2.5 Rework. - Rework is defined as any modification or change in the aircraft or its components, or in assembly procedure, other than the replacement of defective parts, performed as a result of the aircraft failing to meet any test specified herein.

5.3 Phantom Antennas. - Ground tests may facilitate the locating of the interference sources and the coupling paths into the receivers. For such tests, usual area interference and other interference externally coupled via the antenna can be eliminated by terminating receiver antenna lead-ins at the skin of the aircraft, using suitable phantom antennas.

MIL-I-26600(USAF)
AMENDMENT 2
9 May 1960
Superseding
AMENDMENT 1
17 June 1959

MILITARY SPECIFICATION

INTERFERENCE CONTROL REQUIREMENTS, AERONAUTICAL EQUIPMENT

This amendment forms a part of Military Specification MIL-I-26600(USAF) dated 2 June 1958

Page 1, paragraph 2.1: Add "MIL-I-6181 Interference Control Requirements, Aircraft Equipment."

Page 4, paragraph 3.5.1: Delete and substitute:

"3.5.1 Class I. - Class I equipment is electrical or electronic equipment including special purpose test equipment installed in or closely associated with airborne weapons systems. This class shall be subdivided into two subclasses, defined as follows:

"3.5.1.1 Class Ia. - This subclass applies to equipment and subsystems intended for installation in manned aircraft that do not carry missiles as operational combat armament. The interference control requirements for this class shall be in accordance with MIL-I-6181.

"3.5.1.2 Class Ib. - Class Ib equipment shall be all class I equipment (see 3.5.1) other than that included in class Ia (see 3.5.1.1). Requirements and tests for class Ib shall be in accordance with figure 1. Class Ib specifically includes the following equipments:

a. Ground support equipment.

b. Air vehicles carrying missiles as operational combat armament.

c. All missiles."

Page 5, Figure 1, delete "Class I" heading and substitute "Class Ib."

Page 15, Add new paragraph:

"3.5.4 Class IV. - Class IV equipment consists of machine tools and electrically powered portable hand tools. Examples are:

a. Machine tools such as lathes, drill presses, shapers, table saws, stamping presses, handsaws, grinders, etc.

b. Hand tools such as drills, sabre saws, circular saws, riveting guns, polishers, vacuum cleaners, impact wrenches, screwdrivers, etc.

"3.5.4.1 Class IV Limits. - A 40 db relaxation or increase in limits applies to figure 8 for radiated limits and to figures 3 and 5 for conducted limits. Figures 2, 4, 6, 7 and 9 do not apply to class IV equipment. Radiated interference shall be measured at 3 feet over the frequency range of 0.15 to 400 mc. Conducted interference shall be measured over the frequency range of 0.15 to 25 mc. No measurements are required above 400 mc and no susceptibility tests shall be made."

Page 44, paragraph 6.2.4: Delete and substitute:

"6.2.4 Antenna System Correction. - The antenna system correction factor should be specified by the interference measurement instrument manufacturer."

Page 46, paragraph 6.6: Add the following: "Nonadjustable antennas are available in certain frequency ranges that can be used in lieu of the tuned dipole. The purpose of these antennas is to reduce measurement time by eliminating time spent in adjusting the dipoles. Only nonadjustable antennas, furnished by interference instrument manufacturers and approved for use by the procuring activity, should be used. Information as to which antennas have been approved should be obtained from the instrument manufacturer and not the procuring activity."

WWDPER-2
ALP/nd

MIL-I-26600(USAF)
2 June 1958
Superseding
MIL-I-006181C(USAF)
6 June 1957

MILITARY SPECIFICATION

INTERFERENCE CONTROL REQUIREMENTS, AERONAUTICAL EQUIPMENT

1. SCOPE

1.1 This specification covers design requirements, interference test procedures and limits for electrical and electronic aeronautical equipment, including ignition systems, to be installed in or associated with weapon systems or support systems.

1.2 Classification. - The test procedures which are specified cover the following types of tests:

a. Interference Tests: Conducted and radiated tests which measure the magnitude of the interference signals emanating from the equipment under test.

b. Susceptibility Tests: Conducted, radiated, intermodulation and front-end rejection tests which determine whether an equipment will operate satisfactorily when exposed to external interference signals.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification:

SPECIFICATIONS

Military

MIL-I-6051	Interference Limits and Methods of Measurements, Electrical and Electronic Installation in Airborne Weapons Systems and Associated Equipment
MIL-T-9107	Test Reports, Preparation Of
MIL-S-10379	Suppression, Radio Interference, General Requirements for Vehicles (and Vehicular Subassemblies)

FSC-None

(Copies of documents required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General

3.1.1 Operation. - Electrical and electronic equipment shall operate satisfactorily, not only independently but also in conjunction with other such equipment which may be placed nearby. This requires that the operation of all such equipment shall not be adversely affected by interference voltages and fields reaching it from external sources, and also requires that such equipment shall not, in itself, be a source of interference which might adversely affect the operation of other equipments. The limits specified herein are established to ensure that the weapons system will meet the requirements of MIL-I-6051 or other applicable system specification.

3.1.2 Short Duration Interference. - Interference resulting from manual operation of switches, but not including any electrical or electromechanical operations resulting from the manual switching, may deviate from the limits as indicated below. Ignition components used only during engine starting may deviate from the limits by 20 db. Other short duration interference may deviate from the limits as indicated below. Approval shall be obtained from the procuring activity before using these deviations.

Maximum Duration	Maximum Recurrence	Deviation Permitted
1 second	Once in 3 minutes	20 db
3 seconds	Twice per normal operational period	No limitation

3.1.2.1 The deviations permitted for short-duration interference shall not apply to equipments which are intended for use in unmanned weapons systems unless specifically authorized by the procuring activity.

3.2 Design

3.2.1 Interference-Free Design. - Interference control shall be considered in the basic design of all electronic and electrical equipment, components, assemblies, and systems. This design shall be such that, before interference control components are applied, the amount of interference inherently generated and propagated is the minimum achievable. The application of interference control components that must be used, such as filtering, shielding, and bonding, shall conform to good engineering practice and, whenever possible, shall be an integral part of the system. Whenever additional interference control components are necessary, the use of miniaturized components is preferred.

3.2.2 Susceptibility. - The equipment shall be designed to minimize susceptibility to interference from other sources. The enclosing case construction shall be designed not only to minimize interference propagation, but also to minimize interference pickup from external sources. Where conducted energy on the power leads or any external leads might cause interference, the leads shall be isolated from other leads to avoid coupling, and, where necessary, shall have line filters at their entry into the enclosing case. Receiving antenna inputs, or any other low-level signal circuits shall be low impedance, or of balanced design, so that coaxial or other shielded transmission lines can be used to insure an interference-free installation. Routing of receiving antenna input or any low-level signal circuit within the equipment shall be so designed and installed that interference is not picked up from power or control leads due to circuit coupling. Antenna or low-level signal circuit return paths or ground paths shall be so arranged that interference will not occur due to common conductive paths with other circuits, or with the enclosing case grounding path.

3.2.3 Case Shielding. - The number of mechanical discontinuities in the case (such as covers, inspection plates, and joints) shall be kept to a minimum. All necessary mechanical discontinuities in the case shall be electrically continuous across the interface of the discontinuity so as to provide low impedance current path. Multiple-point spring-located contacts are suggested as a desirable method of obtaining low impedance continuity. Ventilation openings shall be designed to permit conformance to the radiated interference limits. Electrical bonding shall be provided where access doors or cover plates form a part of the shielding. Hinges, in themselves, are not considered satisfactory conductive paths.

3.2.4 Chassis, Case, and Mounting Continuity. - The mating surface of the chassis, case, and mounting shall be free of all insulating finishes in order to provide a continuous electrical bond between these items and to enable the installing activity to accomplish bonding contact to the basic structure. Such surfaces shall be covered with removable protective coating to prevent corrosion prior to assembly. This requirement shall take precedence over any conflicting requirements in specifications on finishes.

3.2.5 Component Placement. - Components shall be placed and circuitry arranged to obtain minimum undesired coupling and to require a minimum number of filter components.

3.2.6 Line Shielding. - It is preferred that interference reduction be accomplished inside the equipment when such means give results equal to or better than the use of a shielded line. Any line shielding used shall be approved by the procuring activity and shall be prescribed as an installation requirement.

3.2.6.1 Under no condition shall line shielding be used for primary power leads to equipment.

3.2.6.2 Equipment requiring antennas, but not employing waveguides, shall be designed to utilize shielded coaxial cable as lead-in. When it has been determined that a single braid shield is not adequate, a double or triple braid or a solid shield shall be used as required.

3.2.7 Interference Control Components. - When additional interference control components are required after careful design in accordance with the foregoing paragraphs, components shall be used that conform to the environmental requirements for the equipment. Hermetically sealed interference control components shall be used even though the equipment is not hermetically sealed. Separately installed and external components shall not be used unless specifically authorized by the procuring activity.

3.2.8 Vehicles and Vehicular Subassemblies. - The requirements of MIL-S-10379 shall be applicable in lieu of the requirements of this specification for vehicles and vehicular subassemblies. This applies only to the equipment necessary for operation of the vehicle itself; any electronic equipment or ground support equipment installed or used in the vehicle and all equipment installed or used in trailers, vans et cetera, shall meet the requirements of this specification.

3.3 Subsystems. - When the procuring activity requires that this specification be applied to a group of units or equipments that are designed to operate together, the group shall be tested as a subsystem, and each individual item does not have to be tested separately.

3.4 Interference Control Plan. - The contractor shall submit a detailed plan describing his interference control program and the engineering design aspects of the interference control program shall be emphasized. Such information shall be included as the circuits to be shielded and filtered, methods of eliminating spurious emanations and responses, methods of eliminating spurious resonances, method of obtaining continuous shielding on equipment using pressure or hermetic seals, thickness of case material required to provide adequate shielding on high power r-f equipment, selection of interference-free components to be used on equipment, and any other pertinent information. This plan shall be submitted to the procuring activity within 90 days after the award of a contract.

3.5 Interference Control Requirements. - All equipment tested for compliance with this specification shall conform to the interference control requirements set forth in figure 1 for the appropriate equipment class. For the purposes of this specification, all unwanted signals shall be considered as continuous wave (cw), pulsed cw, or broadband impulsive interference.

3.5.1 Class I. - Class I equipment is electrical or electronic equipment including special purpose test equipment, installed in or closely associated with airborne weapons systems.

3.5.2 Class II. - Class II equipment is a collection of electronic and electrical devices which operate together as a support system and is intended to directly support airborne weapons systems; examples are early warning systems, guidance systems, control and communications systems, and tracking systems. These systems are usually installed in buildings, shelters, vans, et cetera.

3.5.3 Class III. - Class III equipment is the individual electrical and electronic equipment which is used with a surface system. Included are:

a. Electronic equipment such as receivers, transmitters, teletypewriters, countermeasures equipment, navigation and identification, wire terminal equipment, radio relay equipment, modulators, and associated power supplies and subassemblies.

b. Electrical equipment used in conjunction with electronic systems such as heaters, air conditioning units, lighting equipment, et cetera.

c. Electrical power equipment such as generators, converters, rectifiers used to furnish power to electronic equipment.

3.6 Interference Measuring Instruments. - The instruments used to perform the measurements required by this specification shall be the best commercial equipment available that are capable of peak and field intensity measurements. All suitable commercially available instruments approved by the Air

TEST	INTERFERENCE TESTS AND LIMITS					
	CLASS I		CLASS II		CLASS III	
	PARAGRAPH	FIGURE	PARAGRAPH	FIGURE	PARAGRAPH	FIGURE
a. CONDUCTED						
1. STABILIZATION NETWORK	4.3.1.1	2,3	4.3.1.1	2,3	4.3.1.1	2,3
2. CURRENT PROBE	4.3.1.2	4,5	4.3.1.2	4,5	4.3.1.2	4,5
b. RADIATED						
1. MEASURED AT 1 FOOT	4.3.2	6,7,8,9	NOT REQUIRED		NOT REQUIRED	
2. MEASURED AT 3 FEET	NOT REQUIRED		NOT REQUIRED		4.3.2	6,7,8,9
3. MEASURED AT 25 FEET	NOT REQUIRED		4.3.2	6,7,8,9	NOT REQUIRED	
c. ANTENNA CONDUCTED						
1. TRANSMITTER KEY-UP OR RECEIVER	4.3.3.1		NOT REQUIRED		4.3.3.1	
2. TRANSMITTER KEY-DOWN	4.3.3.2		NOT REQUIRED		4.3.3.2	
d. SUSCEPTIBILITY						
1. RADIO FREQUENCY CONDUCTED	4.3.4.1.1		NOT REQUIRED		4.3.4.1.1	
2. AUDIO FREQUENCY CONDUCTED	4.3.4.1.2		NOT REQUIRED		4.3.4.1.2	
3. RADIO FREQUENCY RADIATED	4.3.4.2		NOT REQUIRED		4.3.4.2	
4. INTERMODULATION	4.3.4.3		NOT REQUIRED		4.3.4.3	
5. FRONT END REJECTION	4.3.4.4	10	NOT REQUIRED		4.3.4.4	10

FIGURE 1. INTERFERENCE CONTROL REQUIREMENTS

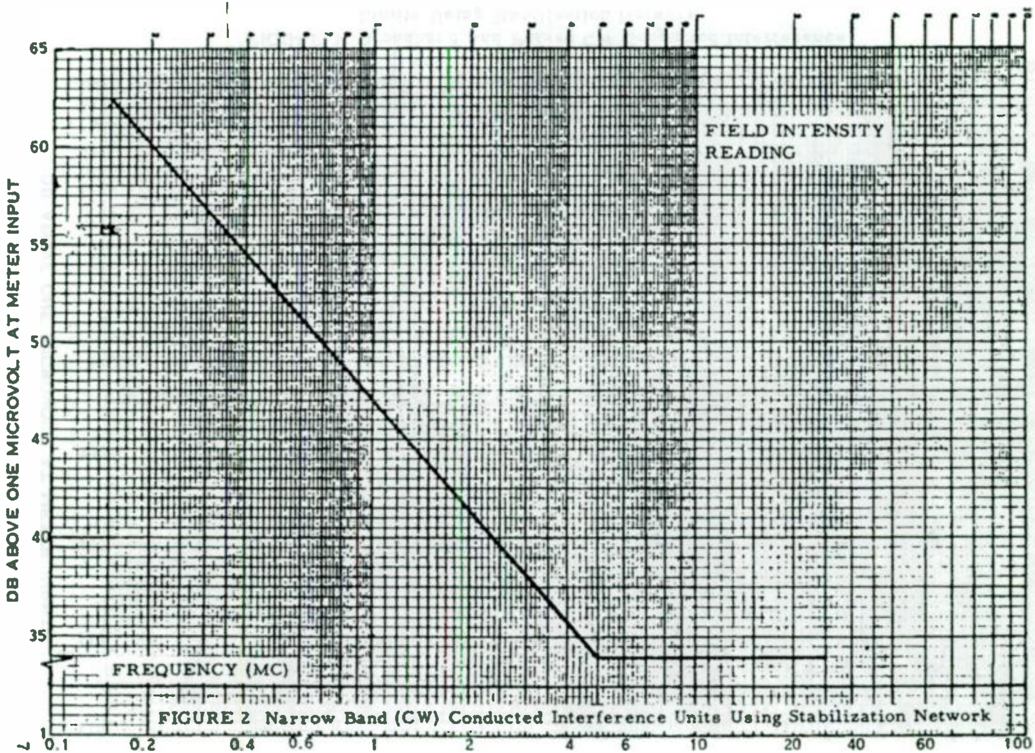


FIGURE 2 Narrow Band (CW) Conducted Interference Units Using Stabilization Network

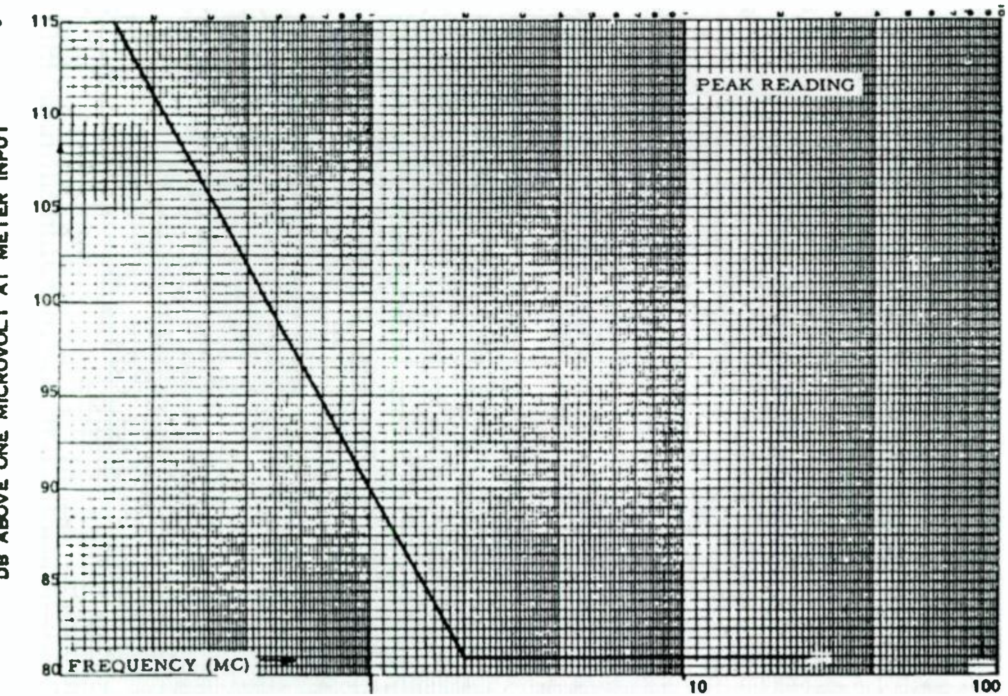


FIGURE 3 Broadband And Pulsed CW Conducted Interference Limits Using Stabilization Network

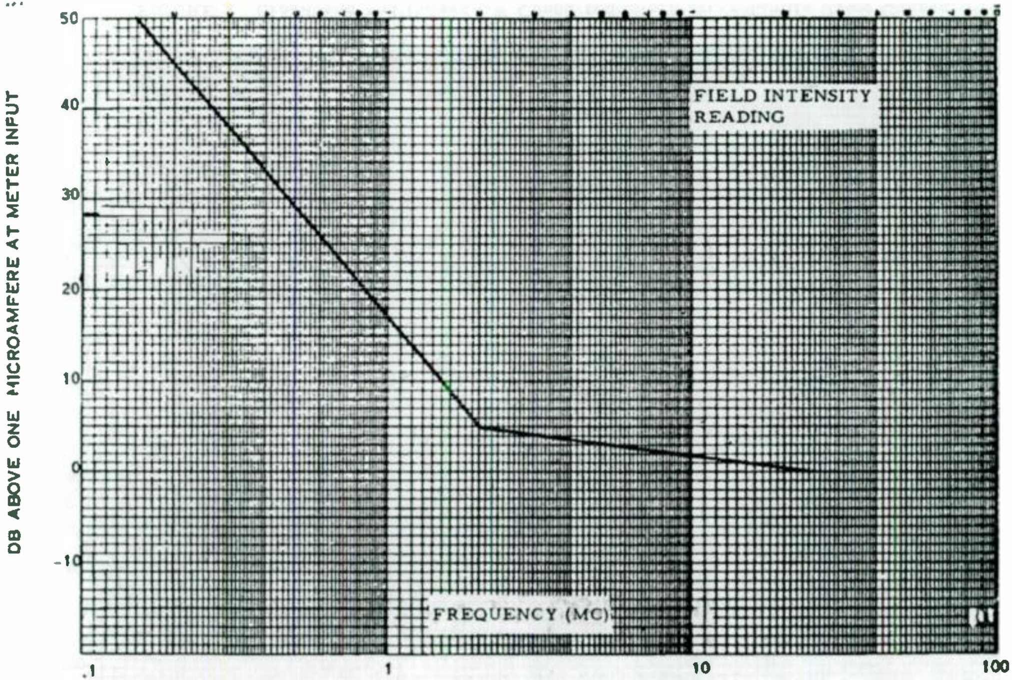


FIGURE 4 Narrow Band (CW) Conducted Interference Limits Using Current Probe

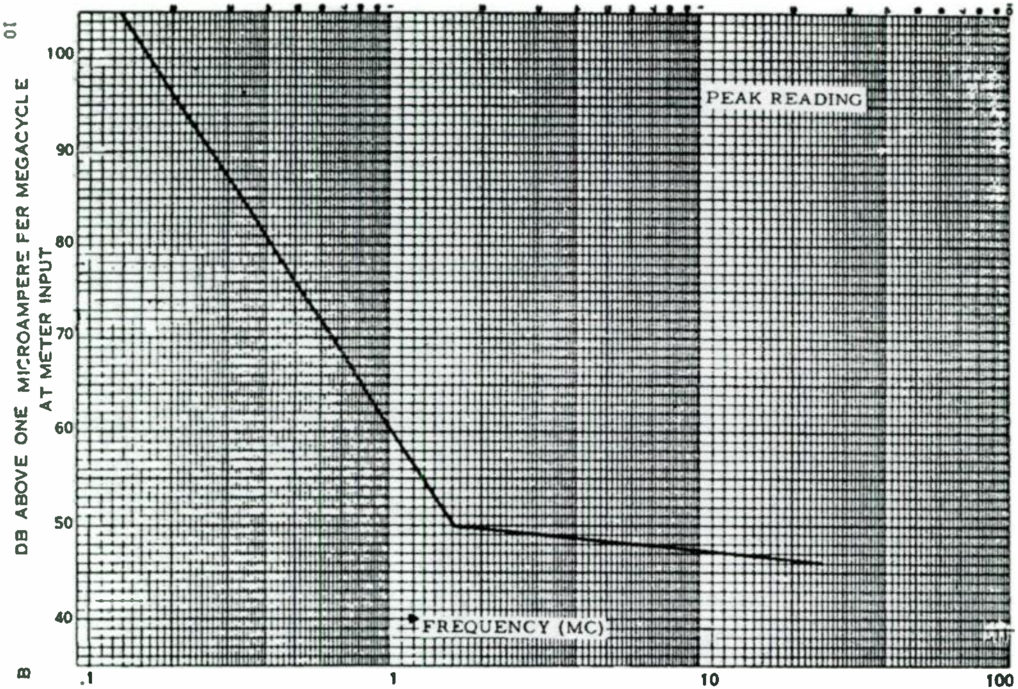


FIGURE 5 Broadband And Pulsed CW Conducted Interference Limits Using Current Probe

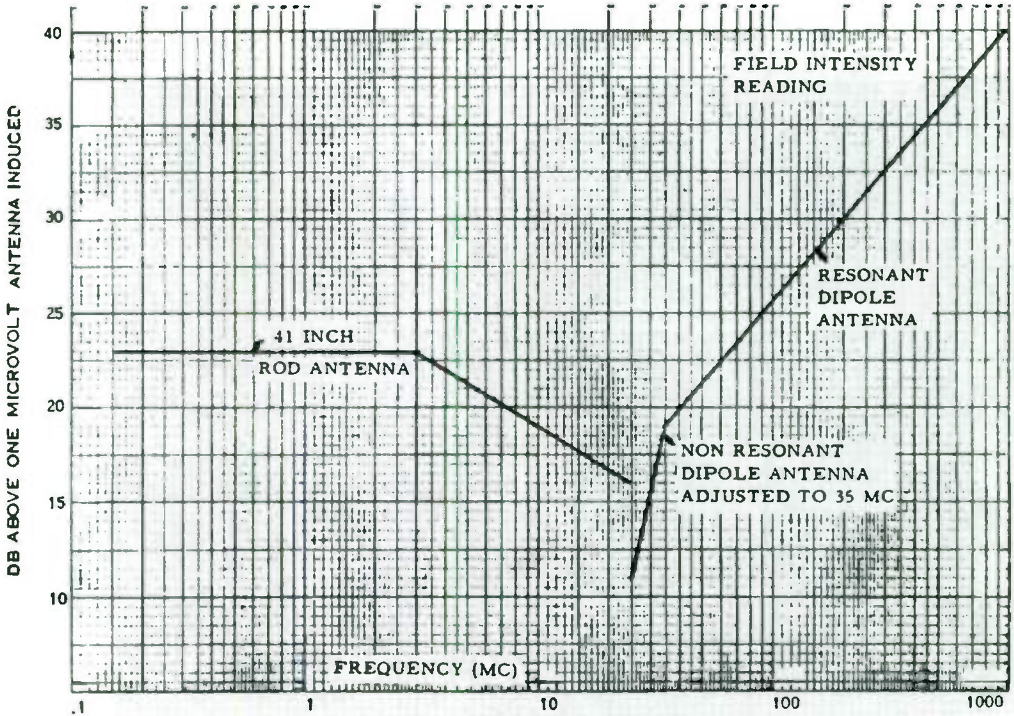


FIGURE 6 Narrow Band (CW) Radiated Interference Limits

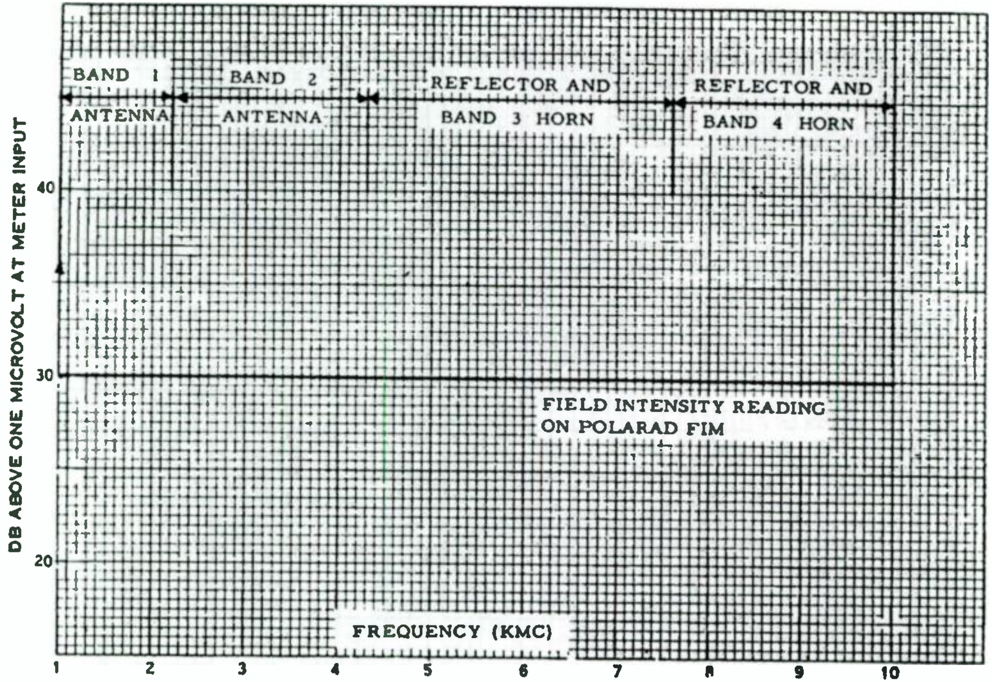


FIGURE 7 - Narrow Band (CW) Radiated Limits

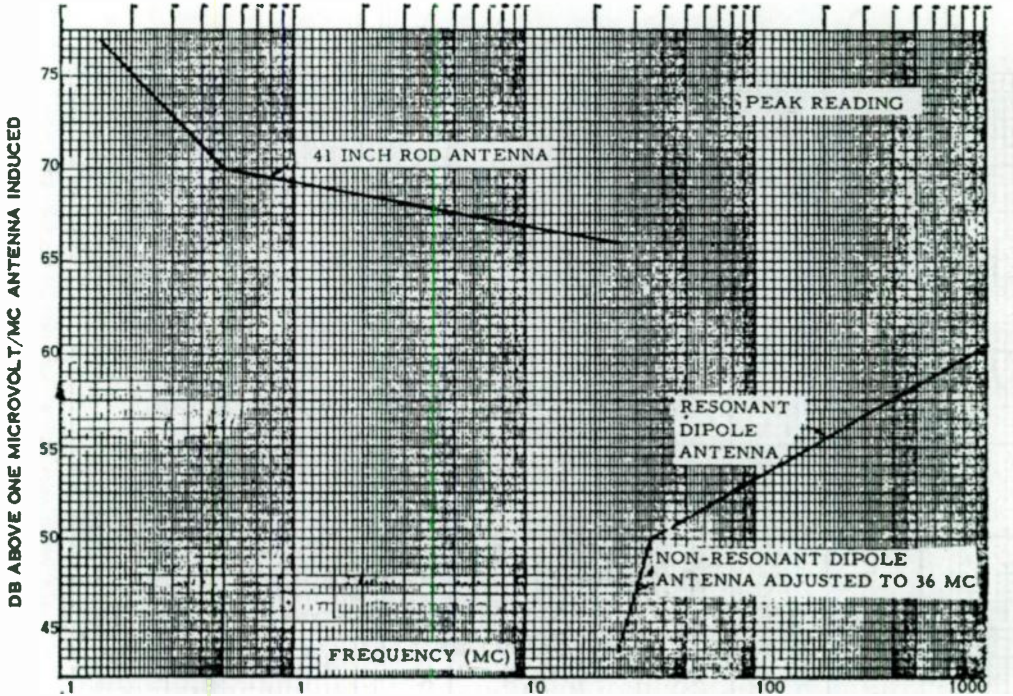


FIGURE 8 Broad Band and Pulsed CW Radiated Interference Limits

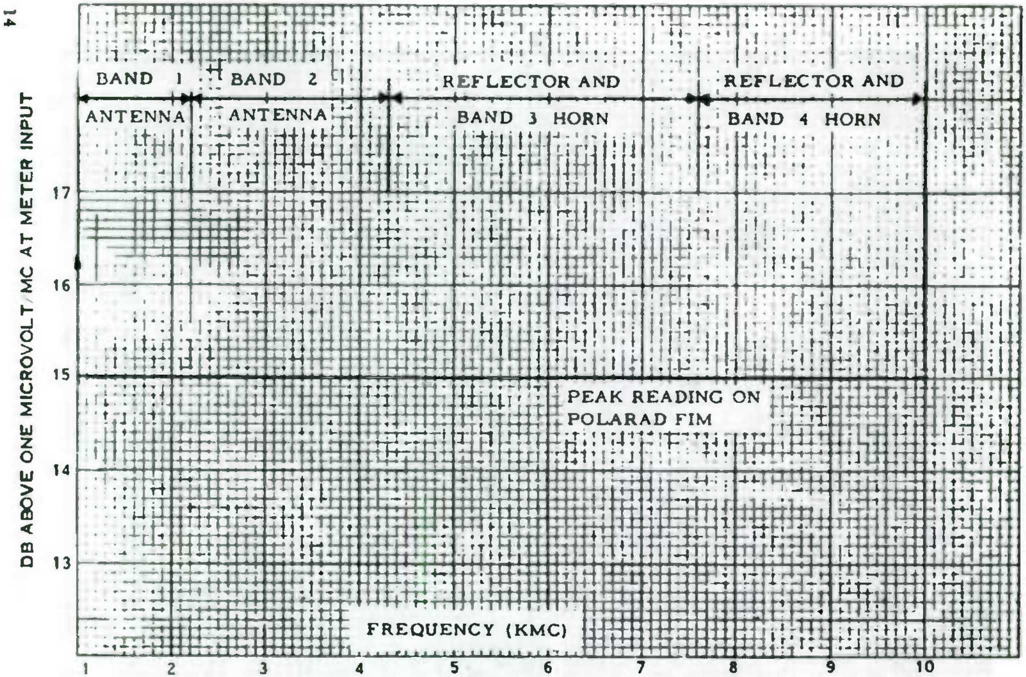


FIGURE 9 Broadband And Pulsed CW Radiated Limits

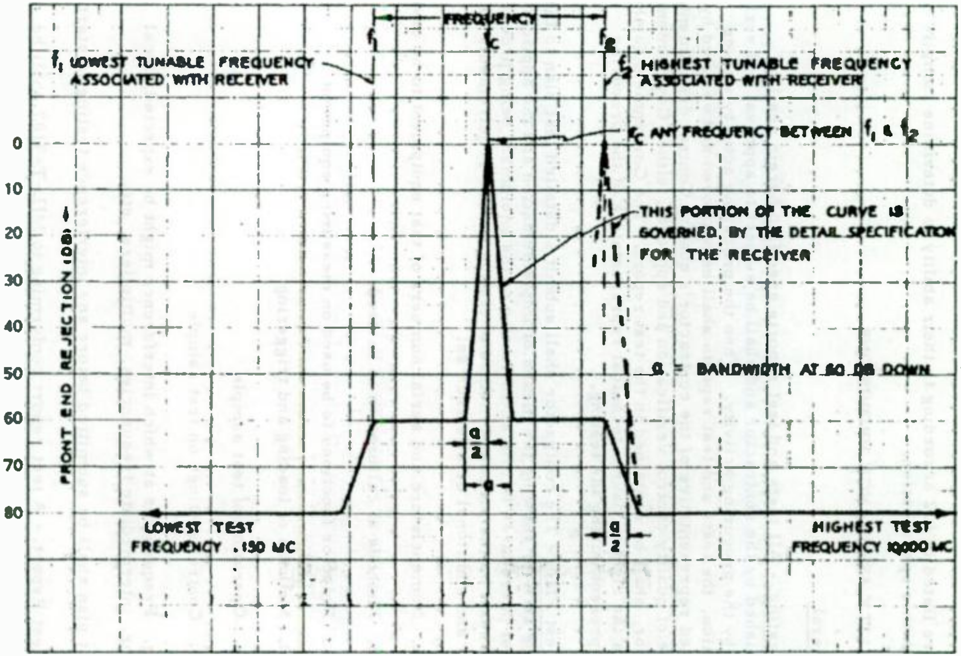


FIGURE 10 Receiver Front End Rejection

Force are listed in 6.2 according to their ability to determine compliance with this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 General

4.1.1 Testing. - All tests and test reports specified herein shall be accomplished by the contractor and shall be subject to approval and verification by the procuring activity. When the procuring activity waives verification, the tests and test reports shall be approved and verified by a qualified representative of the contractor's quality Control department. Evidence of quality control verification and approval, either Government or contractor, shall be contained in the test report. The Government further reserves the right to have a technical representative of the procuring activity present during the testing.

4.1.2 Test Plan. - The contractor shall submit a detailed test plan to the procuring activity showing the means of implementation and the application of the test procedures in this specification to the equipment being procured. Included shall be the proposed method of testing for the requirements in figure 1, and additional details such as:

a. Nomenclature and serial numbers of test equipment to be used

b. Methods of calibration to be used

c. Detector functions to be used on measuring equipment

d. Methods of loading and triggering

e. Operation of test sample

f. Control settings on test sample

g. Frequencies at which interference might be expected, local oscillator, intermediate frequencies, multipliers, etc.

This test plan shall be submitted before any interference testing is started.

4.1.3 Test Report. - A test report conforming to MIL-T-9107 shall be submitted to the procuring activity prior to submission of the preproduction model for acceptance. In addition to the requirements in MIL-T-9107, the test report shall include such details of testing as:

a. Nomenclature of interference measuring equipment

b. Serial number of interference measuring equipment

c. Date of last calibration of interference measuring equipment

d. Detector functions used on interference measuring equipment

e. Internal noise level of instrument used on detector function at each test frequency

f. Descriptions of procedures used (methods of loading and triggering, etc, operation of and control settings on test sample, etc.)

g. Measured line voltages to test sample

h. Test frequencies

i. Method of selection of test frequencies

j. Type of interference measured

k. Measured level of interference at each test frequency

l. Specification limit at each test frequency

m. Graphs showing items e, h, k, and l

n. Photographs of the test setup and test sample

o. Sample calculations (showing how item k was obtained for all antennas used).

p. Description and size of screened enclosure

q. Ground plane used if test is not performed in screened enclosures

r. Description of open space area, if used

s. Ambient interference levels

t. Measured impedance of line stabilization network.

4.1.3.1 Examples of Sample Calculation

a.

Interference measuring equipment	NF-105
Frequency of cw measurement	460 mc
Antenna factor (DM Antenna)	+8 db
Cable loss correction factor at 460 mc	+3 db
Meter reading	+40 db

Interference level = meter reading + cable loss + antenna factor = 40 + 3

+ 8 = 51 db

b.

Interference measuring equipment	NM-20B
Frequency of broadband radiated measurement	500 kc
Antenna factor	0 db or 1
Cable loss correction factor	0 db or 1
Meter reading	9 microvolts
Effective random bandwidth	3400 cps

Impulse bandwidth = 1.4 x 3400 = 4760 cps = 4760 kc

$$\text{Interference level} = \frac{\text{meter reading + antenna factor + cable loss}}{\text{impulse bandwidth}}$$

$$= \frac{9 \times 1 \times 1}{4.76} = 1.89 \ \frac{\text{Antenna induced microvolts}}{\text{kc}}$$

= 65.5 db above 1 microvolt per mc (antenna induced)

4.1.3.2 Identification of Test Sample. - The test sample shall be completely identified in the test report with complete nomenclature, manufacturer, and serial number. All suppression work performed on the test sample during the interference tests shall be fully described in words as well as by the test data in the test report.

4.1.4 Operation of Measuring Instruments. - For both conducted and radiated interference measurements, the instruments used shall be calibrated and operated as indicated in their respective instruction manuals, unless otherwise permitted by this specification.

4.1.4.1 Calibration. - Interference measuring instrumentation shall be maintained in a known condition of accuracy. Periodic checks on the calibration accuracy shall be made with laboratory generators. Recalibration shall be accomplished when the standardized gain setting fails to reflect a meter reading within plus or minus 20 percent of the known input signal. Substitution type measurements can be used in lieu of the calibrated method.

4.1.4.2 Generator Accuracy. - Laboratory-type signal generators and impulse generators capable of an output voltage accuracy of at least 20 percent shall be used to calibrate interference measuring instruments and for substitution measurements.

4.1.4.3 Broadband Interference Measurement. - Broadband interference shall be measured by using an impulse generator with the substitution technique, or by calibrating the interference measuring instrument so that it reads directly in decibels above one microvolt per unit bandwidth. The peak detector function on the interference measuring instruments shall be used for broadband and pulsed cw measurements.

4.1.4.4 CW Interference Measurements. - CW interference shall be measured by calibrating the interference measuring instrument so that it reads directly in decibels above one microvolt or by using a signal generator with a substitution technique.

4.1.4.5 Pulsed CW Interference Measurements. - Pulsed cw shall be measured in accordance with the procedures and limits used for broadband interference.

4.1.5 Bonding Measuring Instrument. - Interference measuring instruments utilizing dipole antennas shall be bonded to the ground plane or shielded enclosure with the ground clip on the power cord. Instruments used for conducted measurements shall not be bonded to the ground plane except through the interconnecting coaxial cable.

4.1.5.1 The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise. This applies to rod antennas utilizing the interference measuring instrument as a counterpoise, and to rod antennas mounted on a separate counterpoise.

4.1.5.2 The interference measuring instruments shall be physically grounded with only one connection. If the copper strap is used, neither the ground clip, the ground terminals, nor the power supply shall be connected to ground.

4.1.6 Monitoring. - The interference measuring instrument shall be monitored with a headset, loudspeaker, oscilloscope, or other indicating devices, during all measurements. Precaution shall be taken to ensure that the monitoring does not influence the meter reading on the interference measuring equipment.

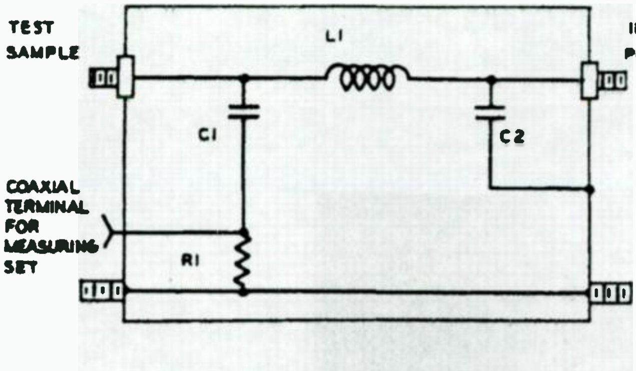
4.1.7 Test Frequencies. - The interference measuring instrument shall be slowly turned through each frequency octave and the frequencies at which maximum interference or susceptibility is obtained shall be selected as test frequencies. Test frequencies shall not be selected prior to the interference test. The witnessing official or Government representative shall certify in the test report that the test frequencies were selected after each octave was scanned. A minimum of three measurements shall be made in each frequency octave.

4.1.8 Tuning. - The interference measuring instrument shall be tuned to and measurements made at the fundamental frequency and all harmonics of equipment containing oscillator circuits. Additional checks shall be made by scanning for and measuring any signal or spurious response that can be anticipated.

4.1.9 Power Line Stabilization Network. - The power line stabilization network is shown in figure 11. One each network shall be inserted in each ungrounded power supply lead supplying power to the test sample, and shall be used for the complete radio interference tests. The network enclosure shall be bonded to the ground plane.

4.1.9.1 Performance Characteristics. - The current carrying capacity of the network shown is 50 amperes dc to 800 cycles ac. The maximum voltage drop at 50 amperes is not over 2 percent of the supply voltage. The performance characteristics of this device will permit measurements of test items at the following maximum voltage ratings:

dc	600 volts
60 cycles	440 volts
400 cycles	230 volts
800 cycles	115 volts



7-RESISTOR DATA: R_1= 1000 OHM, 1 WATT CARBON

6 CAPACITOR DATA: C_1 = .1 UF, 600 VOLT DC, BATHTUB
C_2 = 1 UF, 600 VOLT DC, BATHTUB

5 CAPACITORS SHALL BE MOUNTED ON 1-INCH INSULATING BLOCKS

4 COIL DATA: L1 = 5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4-IN WINDING LENGTH

3-WIRE DATA: AWG 6, 600 VOLT, .310 INCH DIA (OD)

2 FORM DATA: 5 1/4-IN LENGTH, 3-IN DIA. (OD), .125-IN WALL
DRILL 3/8-IN HOLE 7/16-INCH FROM EACH END.

1 ENCLOSURE DATA: 14 GAUGE (B&S) ALUMINUM
SUGGESTED SIZE 9 3/8-IN. x 4-IN. x 4-IN.

FIGURE 11 POWER LINE STABILIZATION NETWORK SCHEMATIC DIAGRAM

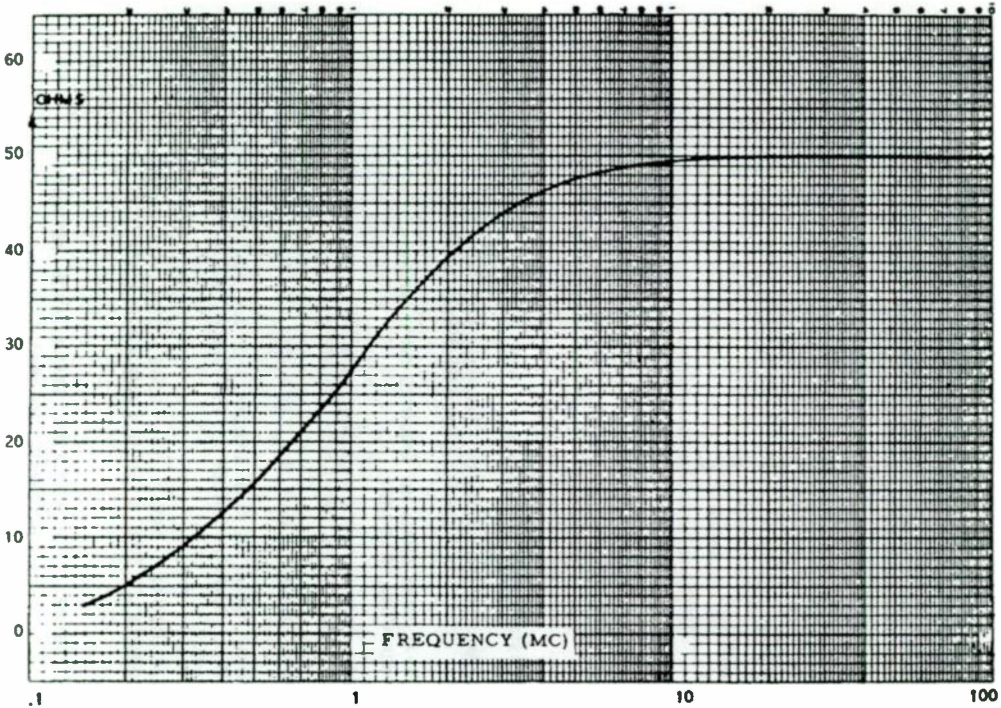


FIGURE 12 INPUT IMPEDANCE OF LINE STABILIZATION NETWORK

4.1.9.2 Design of Typical Network. - Working data and an electrical schematic drawing of this device are included in figure 11. The network shall have a nominal impedance, looking into the test sample terminal, within plus or minus 10 percent of that given in figure 12 when the power line terminal is open circuited, and when a 50-ohm termination is connected to the noise meter terminal. This is a network for currents up to 50 amperes; it is not anticipated that networks with a higher rating will be required since another measurement method using a current probe is available.

4.2 Test Conditions

4.2.1 Ambient Interference Level. - It is desirable that the ambient interference level during testing, measured with the test sample deenergized, be at least 6 db below the allowable specified interference limit. However, in the event that at the time of measurement the levels of ambient interference plus test item interference are not above the specified limit, the test item, etc. This requirement shall apply equally to both radiated and conducted ambient interference levels. A shielded enclosure can be used if necessary or desired. If a shielded enclosure is used, the minimum length shall be such that a 35-mc tuned dipole can be placed in the room with at least 12 inches clearance between the antenna extremities and the shielded enclosure.

4.2.2. Ground Plane. - A copper or brass ground plane, 0.01 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12 square feet or more in area with a minimum width of 30 inches, shall be used. In a screen room the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet and at both ends of the ground plane. The ground plane and screen room walls may be considered equivalent to an aircraft fuselage for purposes of simulating a normal installation. For large equipment systems mounted on a metal test stand, the test stand may be considered, for testing purposes, to be a part of the ground plane and shall be bonded accordingly. When a shielded room is not used, the measuring equipment may be placed on a solid support for operation. The support may be solid earth, steel or iron flooring, metal bedplate, metal-covered planking, or the like.

4.2.3 Bonding. - Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment case and mount, together or to the ground plane. Where bonding straps are required to complete the test setup, they shall have a length not greater than 5 times the width, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid. Connections made with such bond straps shall have clean metal-to-metal contact.

4.2.3.1 Shock and Vibration Isolators. - Test samples shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. Where mounting bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

4.2.3.2 External Ground Terminal. - When an external terminal or connector pin is available for a ground connection on the test sample, this terminal shall be connected to the ground plane if the terminal is normally grounded in the installation. If the installation conditions are unknown, the terminal shall not be grounded.

4.2.3.3 Portable Equipment. - Portable equipment shall be tested while it is bonded to the ground plane and also when it is not bonded to the ground plane. Portable equipments that are intended to be grounded through a power cord shall not be bonded to the ground plane by other means.

4.2.4 Power Supply Voltage. - The power supply voltages shall be within the tolerance specified in the detail specification for the test sample. The voltages shall be measured at the power line terminals on the line stabilization networks. The test sample shall be operated at the line voltage, within the above tolerance, which causes maximum conducted interference or susceptibility at 0.5 mc.

4.2.5 Arrangement and Operating Conditions. - The general arrangement of equipment, interconnecting cable assemblies, and supporting structures shall be such as to simulate actual installation and usage insofar as practicable. The front surface of each unit shall be located 4 inches ± 1/2 inch from the edge of the ground plane; interconnecting cables shall be routed between the units and the edge of the ground plane. In those cases where equipment size exceeds the ground plane dimensions, or where more than two line stabilization networks are required, the above instructions shall be adhered to as closely as possible.

4.2.5.1 Dummy Antennas. - Any dummy antenna used shall have electrical characteristics which closely simulate those of the normal antenna, and should be shielded where possible. The dummy antenna shall be capable of handling the power required and shall contain any unusual components which are used in the normal antenna (such as filters, crystal diodes, etc). When the nominal antenna impedance is 50 ohms, a 50-ohm (± 20 percent from 0.15-1000 mc) dummy antenna shall be used.

4.2.5.1.1 A 5-foot length of double shielded coaxial cable shall be used between a transmitter and its dummy antenna.

4.2.5.2 Test Sample Leads. - The test sample leads to the power line stabilization network shall be 24 inches ± 1 inch in length and shall be so arranged that the distance between the leads and from each lead to ground or grounded enclosure is approximately 2 inches. In those cases where more than two power line stabilization networks are required, the above instructions shall be adhered to as closely as possible.

4.2.5.2.1 Interconnecting Leads. - Interconnecting leads between boxes comprising a test sample shall not be less than 2 feet and not more than 5 feet long. Leads between the test sample and external leads shall be 5 feet long.

4.2.6 Antenna Orientation and Positioning in Shielded Enclosures. - Those interference measuring instruments which use a rod antenna shall be so placed that the rod antenna is in a vertical position and the instrument panel or counterpoise is 6 inches below the level of the ground plane. The rod antenna shall be located at the point where maximum interference or susceptibility indications are obtained when it is moved along a line parallel with the edge of the ground plane. Those interference measuring instruments which use a resonant dipole antenna shall have the dipole positioned parallel with the front edge of the ground plane. Its height shall be 12 inches ± 1 inch above the level of the ground plane and its center shall be adjacent to the geometrical center of the units under test. The rod or the dipole antenna shall be located at the distance from the test sample specified in figure 1, and the typical test setups. When the dimensions of the dipole or directive antenna become smaller than the test layout, the antenna shall be moved parallel to the edge of the ground plane to keep its sensitive elements adjacent to the point of maximum leakage or susceptibility. At frequencies from 25 up to and including 35 megacycles, the measurements shall be taken with the dipole antenna adjusted to 35 mc. The dipole antenna shall be adjusted to the proper length at all frequencies above 35 mc.

4.2.7 Antenna Orientation and Positioning (Free Space). - Those interference measuring instruments which use a rod antenna shall be so placed that the rod antenna is in a vertical position. Those interference measuring instruments which use a dipole antenna shall be so placed that the antenna is parallel with the test sample and on the same level as the midpoint of the test sample. The antenna shall be at the distance from the test sample specified in figure 1. The antenna shall be located at a point around the perimeter of the test sample where maximum interference signal is received.

4.2.8 Loads. - The equipment under test shall be loaded with the full mechanical and electrical load, or equivalent, for which it is designed. This requirement specifically includes electrical loading of the contacts of mechanisms which are designed to control electrical loads even though such loads are physically separate from the equipment under test. Operation of voltage regulators and other circuits which operate intermittently is required. The loads used shall simulate the resistance, inductance, and capacitance of the actual load.

4.3 Test Methods

4.3.1 Conducted Interference. - Radio interference voltages, in the frequency range of 0.15 to 25 mc, generated by the equipment or system in excess of the values indicated in figures 2, 3, 4, and 5 shall not appear on any conductor, external to the system, which could conduct interference to other equipment. Typical test setups for these measurements are shown in figures 13 and 14. Measurements may be omitted on leads deemed incapable of conducting interference into other equipment by the procuring activity.

4.3.1.1 Conducted Interference Using Stabilization Network. - Conducted interference measurements on input power leads, 50 amperes and under shall be made by connecting the interference measuring instrument to the noise meter terminal on the line stabilization network with a 6-foot length of 50-ohm double-shield coaxial cable.

4.3.1.2 Conducted Interference Using Current Probe. - Conducted interference measurements on power lines over 50 amperes and other lines shall be made with a clamp-on interference current measuring device. Examples of cases where this requirement applies are measurement on electrical load lines, inverter output lines, high current (over 50 amperes) power lines, etc. Measurements might be required on shielded leads in some cases.

4.3.1.2.1 Position of Probe. - The current probe shall be positioned at the point of maximum interference on the lead to be tested. This maximum interference point shall be located at each test frequency. The location of the current probe shall be fully described in the test report.

4.3.2 Radiated Interference. - Radiated interference fields in excess of the values given in figures 6, 7, 8, and 9 shall not radiate from any unit, cable (including control, pulse, IF, video, antenna transmission and power cables), or interconnecting wiring over the frequency range of 0.15

to 10,000 mc for cw and pulsed cw interference and 0.15 to 400 mc for broadband impulsive interference. This requirement includes the transmitter fundamental spurious radiation, oscillator radiation, other spurious emanations, and broadband interference. This does not include radiation emanating from antennas. Test setups are illustrated in figures 15, 16, 17, 18, 19, 20, 21, 22, and 23. Equipments which do not utilize electronic circuits and which are incapable of producing oscillations, either intentional or unintentional, are exempt from measurements above 400 mc.

4.3.3 Antenna-Conducted Spurious Emanations

4.3.3.1 Transmitter Keyup or Receiver. - The rf output of any transmitter keyup or receiver shall not exceed 40 db above 1 microvolt for cw or 60 db above 1 microvolt per mc for impulse interference at any frequency between 0.15 and 10,000 mc. Measurements above 1000 mc will not be required providing the contractor can furnish satisfactory evidence to the procuring activity that such measurements do not result in any significant data.

4.3.3.2 Transmitter Keydown. - The transmitter shall be operated into a dummy load. A suitable coupling device shall be used to sample the transmitter output and protect the measuring equipment. Bridge "T" rejection networks, filter rejection network, or other adequate devices shall have the approval of the procuring activity. Attention should be given to oscillator frequency and harmonics, outputs from frequency multipliers and crystal saver circuits, beat frequency oscillator outputs, etc. External filters shall not be used unless approval is obtained from the procuring activity. Spurious emanations shall be below the fundamental power by the value obtained from the following formula at any frequency between 0.15 and 10,000 mc: Requirements in decibels below the fundamental = 80 + 10 log (transmitter power in watts). Measurements above 1000 mc will not be required providing the contractor can furnish satisfactory evidence to the procuring activity that such measurements do not result in any significant data.

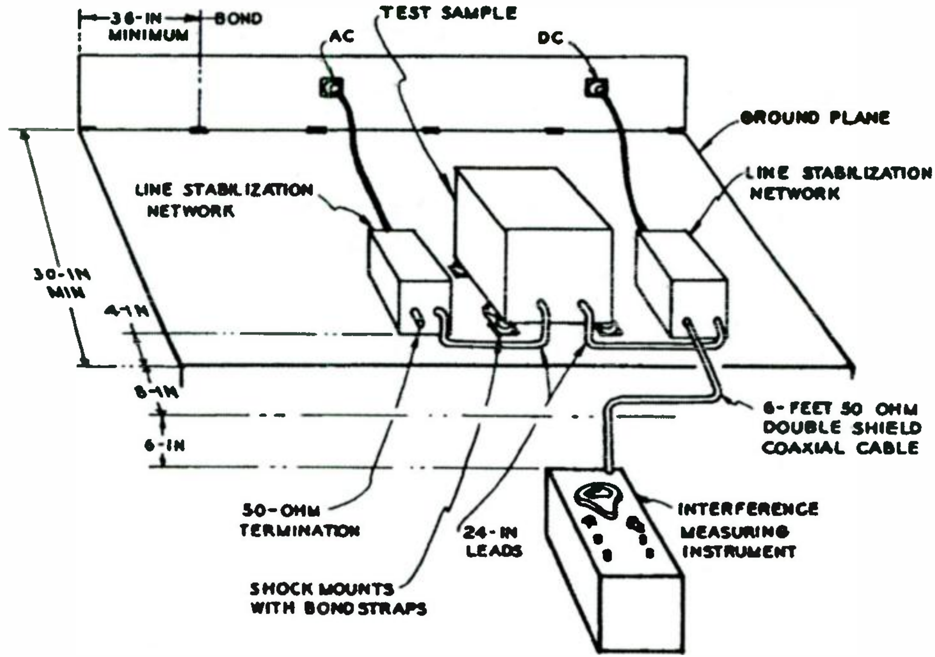


FIGURE 13. TYPICAL TEST SETUP FOR CONDUCTED INTERFERENCE MEASUREMENTS

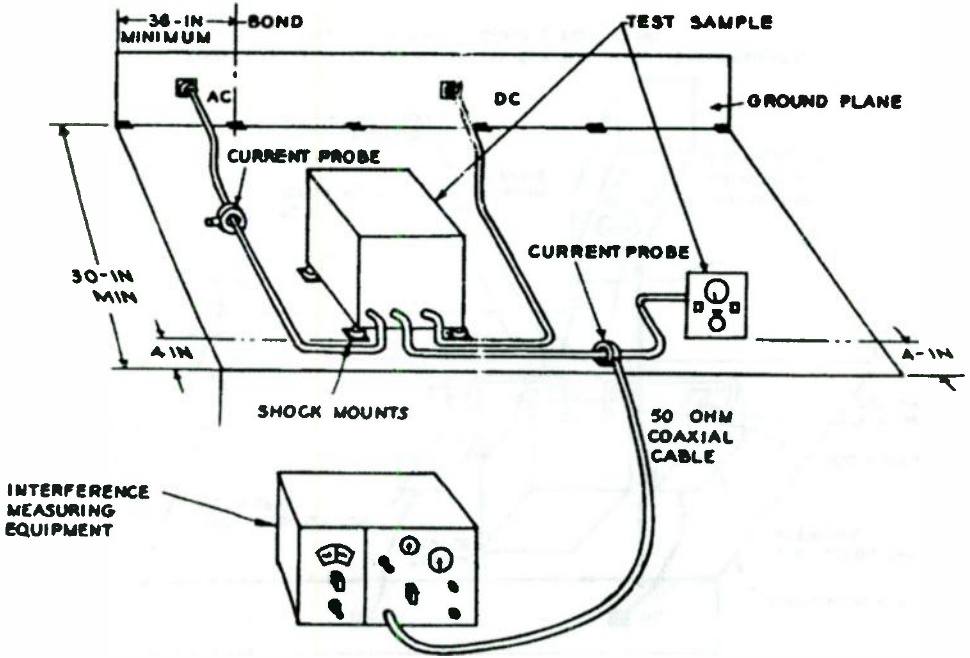


FIGURE 14 TYPICAL TEST SETUP FOR CONDUCTED INTERFERENCE MEASUREMENTS USING CURRENT PROBE

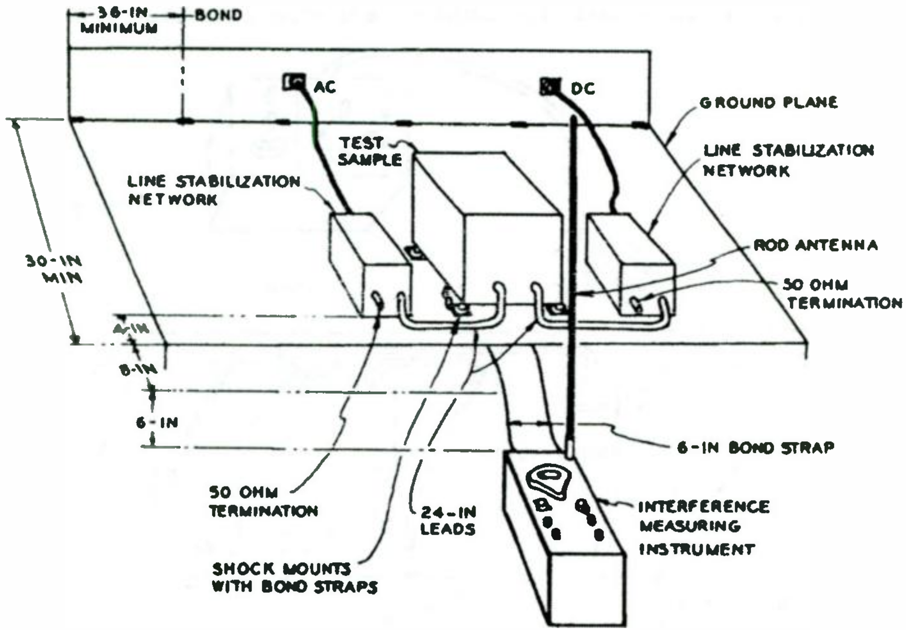


FIGURE 15 TYPICAL TEST SET-UP FOR RADIATED MEASUREMENTS (ROD ANTENNA) CLASS I EQUIPMENT

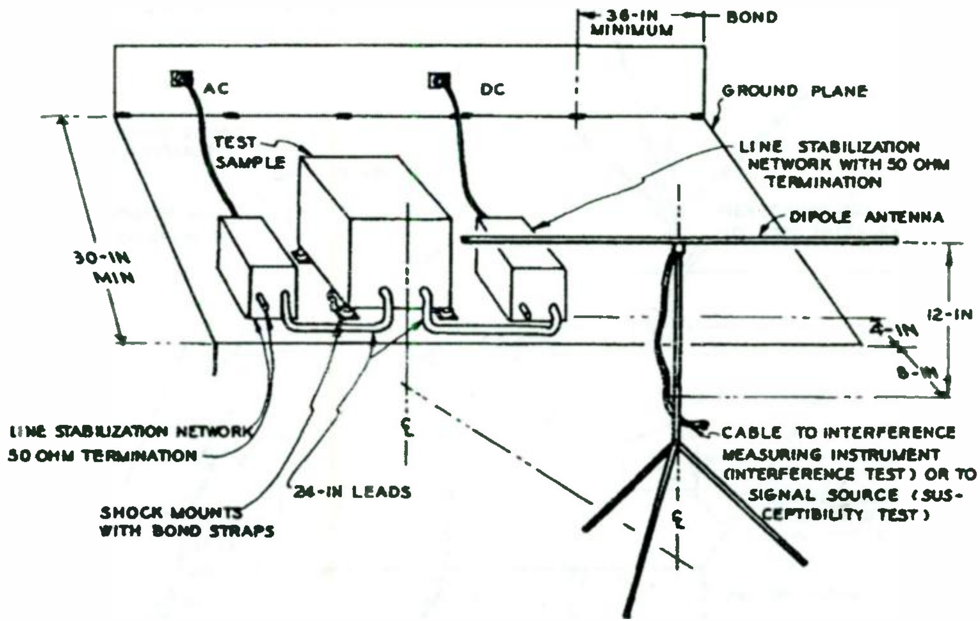


FIGURE 16 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (DIPOLE ANTENNA)
CLASS I EQUIPMENT

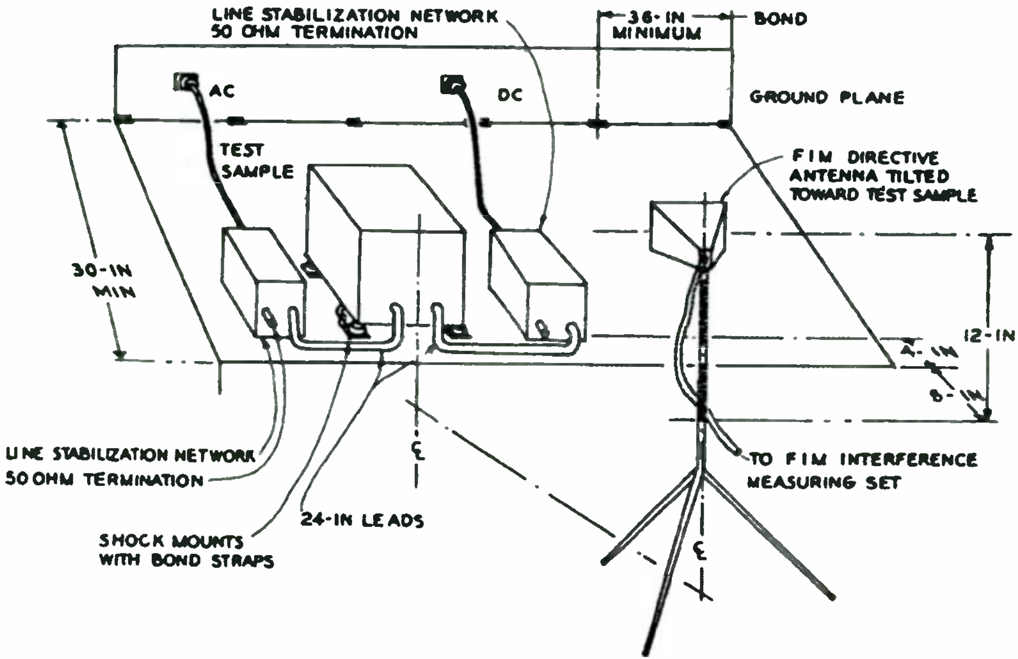


FIGURE 17 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (MICROWAVE-DIRECTIVE ANTENNA) CLASS I EQUIPMENT

CLASS II EQUIPMENT

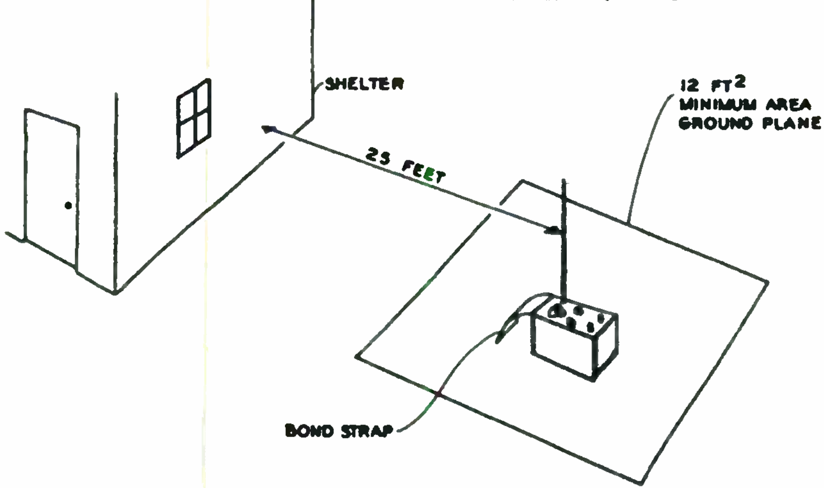


FIGURE 18 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS
(ROD ANTENNA)

CLASS II EQUIPMENT

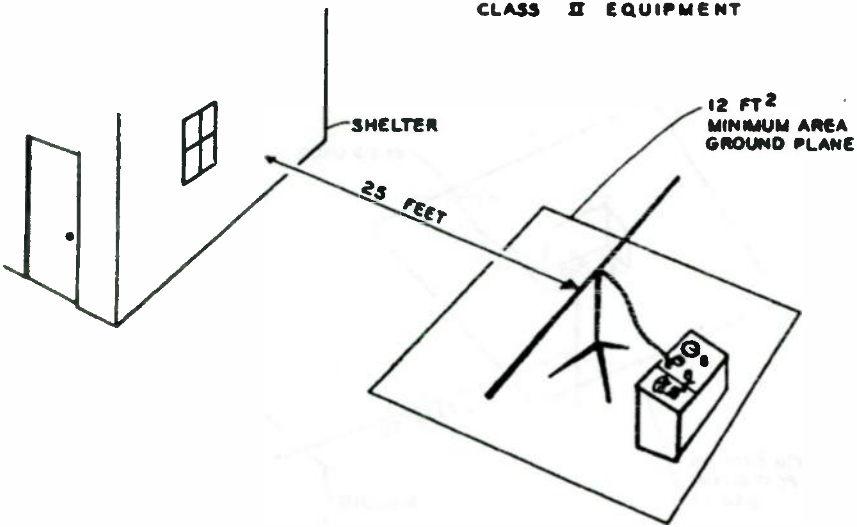


FIGURE 19 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (DIPOLE ANTENNA)

CLASS II EQUIPMENT

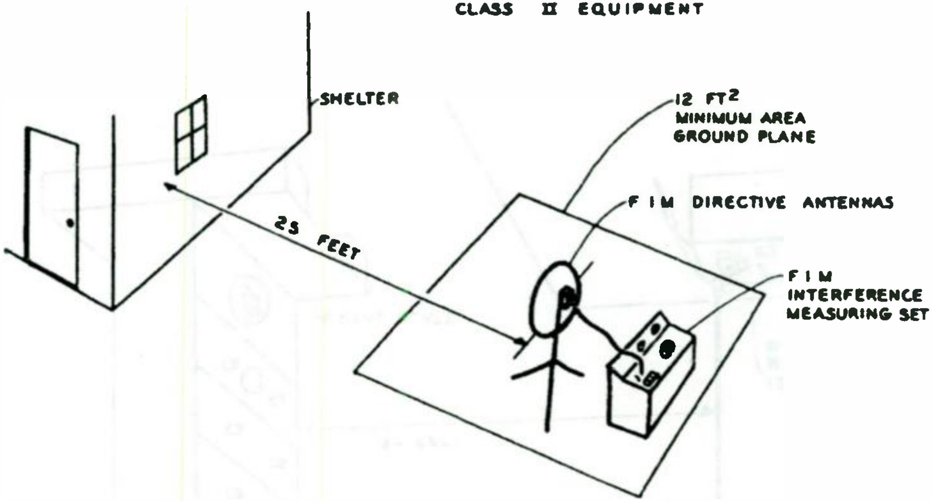


FIGURE 20 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (MICROWAVE DIRECTIVE ANTENNAS)

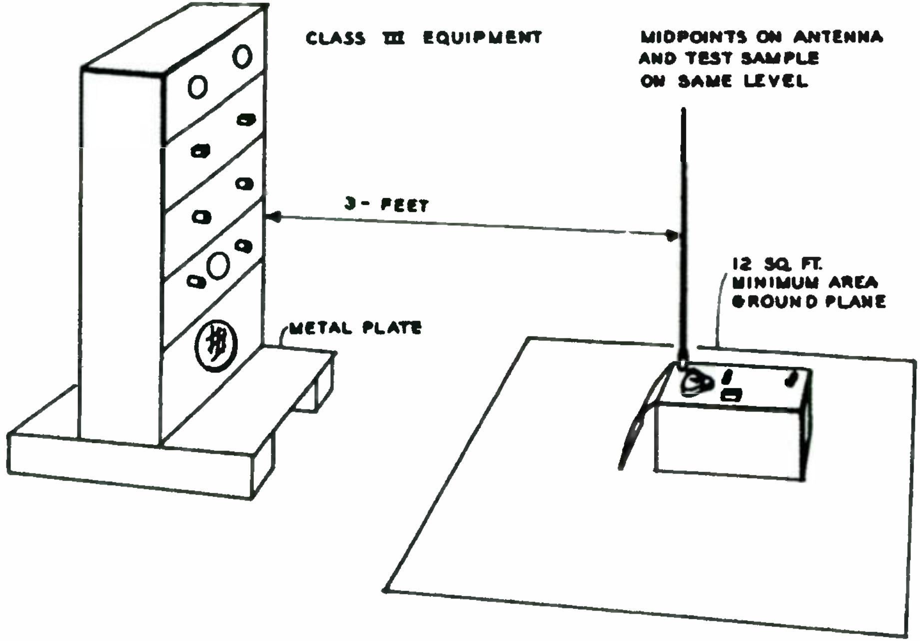


FIGURE 21 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (ROD ANTENNA)

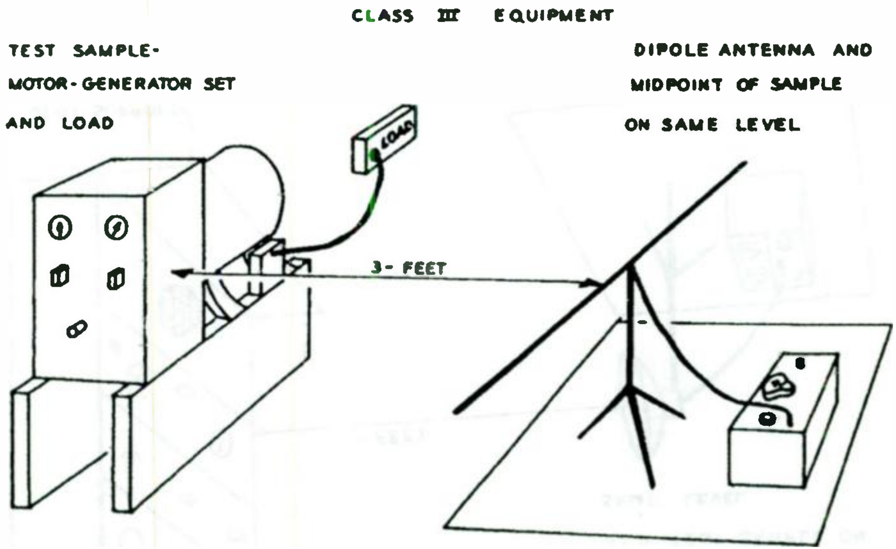


FIGURE 22 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS (DIPOLE ANTENNA)

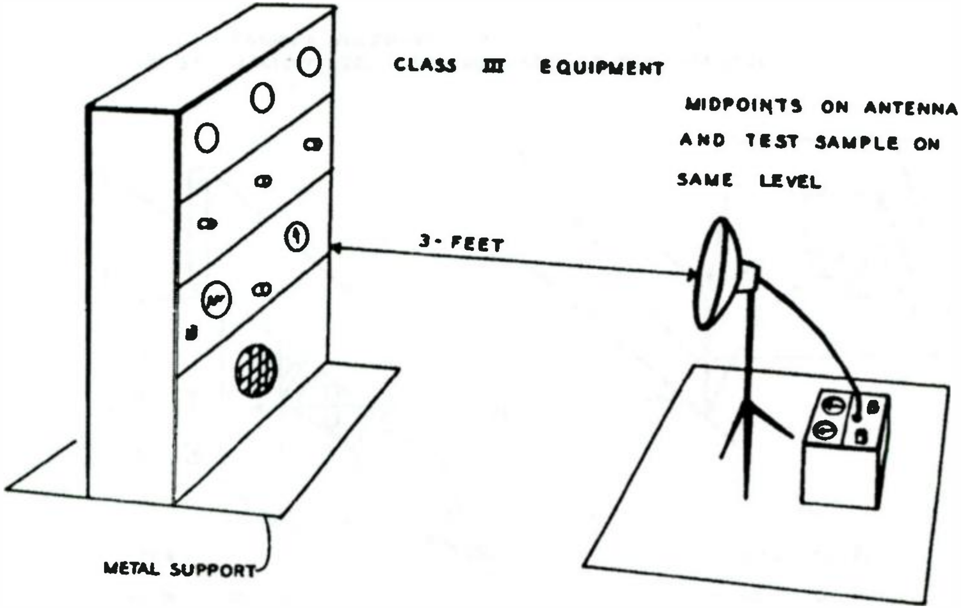


FIGURE 23 TYPICAL TEST SETUP FOR RADIATED MEASUREMENTS
(MICROWAVE DIRECTIVE ANTENNA)

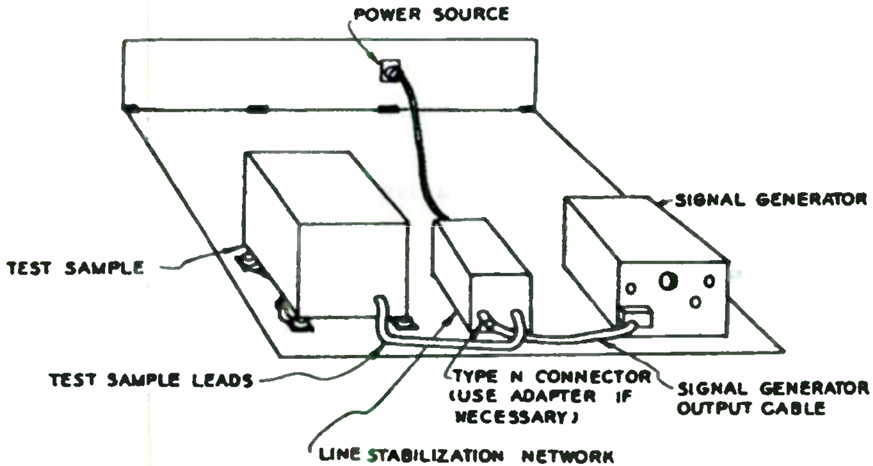
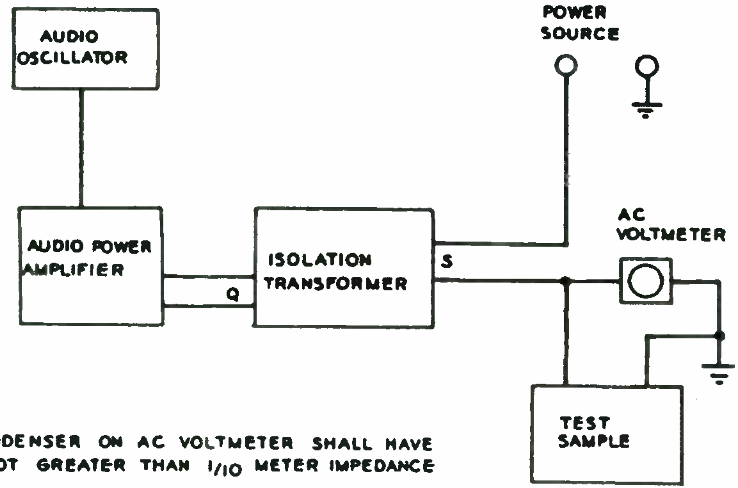


FIGURE 24 RF SUSCEPTIBILITY TEST SETUP (CONDUCTED)



3. SERVES CONDENSER ON AC VOLTMETER SHALL HAVE REACTANCE NOT GREATER THAN 1/10 METER IMPEDANCE

2. TRANSFORMER SHALL CARRY ALL CURRENTS WITHOUT SATURATION. TURNS RATIO $\frac{\text{PRIMARY}}{\text{SECONDARY}} = \frac{2}{1}$

1. AUDIO AMPLIFIER SHALL BE 30-50 WATTS AND SHALL HAVE A LOW IMPEDANCE OUTPUT OF 5 OHMS OR LESS

FIGURE 25 AF SUSCEPTIBILITY TEST SET UP

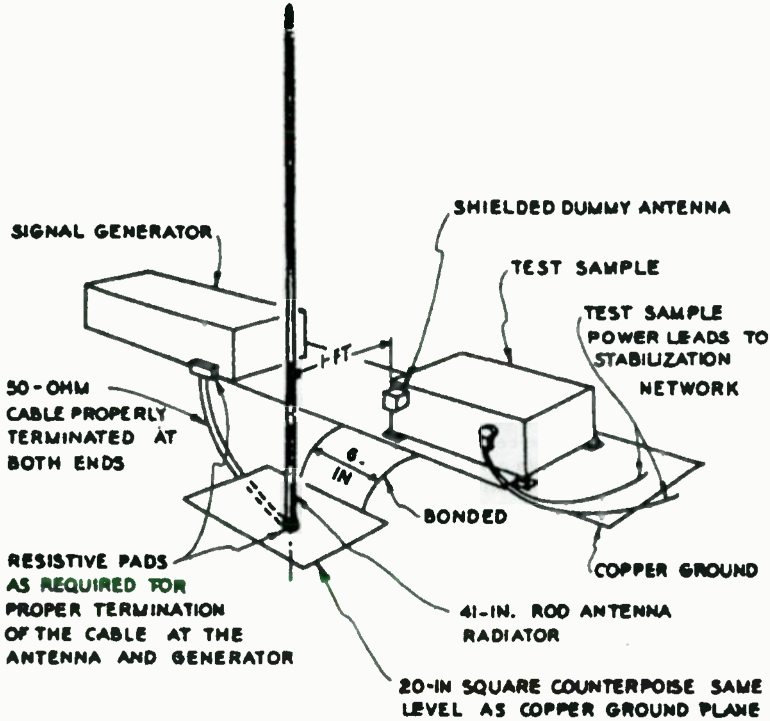


FIGURE 16 SHOWS TYPICAL TEST SET UP USING DIPOLE ANTENNA

FIGURE 26 SUSCEPTIBILITY RADIATED TEST SETUP
(ROD ANTENNA)

4.3.4 Susceptibility. - Equipment, such as navigation light flashers, windshield wipers, fuel pump motors, etc, deemed incapable by the procuring activity of being affected by the applied extraneous signals are exempt from susceptibility requirements. On receivers, all external and internal controls shall be set for maximum signal plus noise to noise ratio. All external or internal controls for squelch or limiting shall be set to give minimum limiting action. On other equipment all external and internal controls shall be set for maximum indication of susceptibility, or, if this causes an equipment to malfunction or to become inoperable as a result of such a control setting, the critical control shall be adjusted as directed in the instruction manual. The radio frequency signal shall be modulated 30 percent, 400 or 1000 cps, on equipments that are not designed for other modulation frequencies or for special forms of modulation. When testing other equipment, the modulation frequency or any other special form of modulation shall be used to modulate the radio frequency.

4.3.4.1 Conducted Susceptibility. - The voltages specified shall be those voltages which are calculated to exist across the output terminals of the signal source when no load other than that necessary to meet the requirements as to source impedance is connected to the signal generator. A matching network suitable for use at required test frequencies and voltages shall be used to obtain the proper source impedance. Blocking capacitors having neglibible impedance at the test frequency may be inserted in the leads from the signal source to the equipment under test if required for the protection of the signal source.

4.3.4.1.1 Radio Frequency Conducted. - No change in indication, malfunctioning, or degradation of performance shall be produced in any equipment when an rf signal of 100,000 microvolts, from a source having an impedance of 50 ohms is applied to the test sample as shown in figure 24. Tests shall be made over the frequency range of 0.150 mc to 10,000 mc.

4.3.4.1.2 Audio Frequency Conducted. - No change in indication, malfunction, or degradation of performance shall be produced in any equipment when a sine wave audio frequency signal of 3 volts rms is applied between each ungrounded power lead and ground as shown in figure 25. Measurements shall be made over a frequency range of 50 to 15,000 cps.

4.3.4.2 Radio Frequency Radiated. - No change in indications, malfunction, or degradation of performance shall be produced when the equipment is subjected to a radio frequency field. This field shall be established with a signal generator driving the antenna listed below.

Care shall be taken to use matching networks, when required. The voltages specified are those calculated to exist across the antenna terminals. The test setup is shown in figure 26 for the rod antenna and is similar to figures 16 and 17 for the other antennas, with the signal source replacing the interference meter.

Frequency	Microvolts	Antenna
0.10 to 25 mc	100,000	41 inch rod
25 to 35 mc	100,000	35 mc dipole
35 to 1000 mc	100,000	tuned dipole
1000 to 10,000 mc	100,000	nondirective antennas

4.3.4.3 Intermodulation. - Receivers, preamplifiers, or antenna couplers shall not produce an output indication when two sine wave signals, representing undesired signals, are connected to the input terminals of the test sample. The two frequencies shall be chosen so that their sum or difference is equal to the test frequency and so that neither will give an output when applied alone. The magnitude of each shall be at least 100 db above 1 microvolt at the test sample terminal; one shall be modulated 30 percent with a 1000 cycle signal, and the other 30 percent with a 400 cycle signal. Impedance matching networks shall be used as required.

4.3.4.4 Receiver Front End Rejection. - Front end rejection of receivers shall be equal to or greater than the limit shown in figure 10 except that image frequencies outside the tuning range of the receiver shall be 60 db. This requirement shall apply to each tuning unit on receivers with plug-in or separate tuning units. Dimension a in figure 10 shall not be greater than 20 percent of fc. This test shall be performed with any signal generators equipped with an accurate attenuator and capable of a signal output at least 80 db greater than the minimum signal perceptible at the tuned frequency of the particular receiver being tested. If necessary, matching networks shall be used to obtain a 50-ohm (± 20 percent) output. All measurements shall be corrected to account for any changes in output voltages due to addition of matching networks and shall be equal to the open circuit voltage at the output terminals. With the signal generator and receiver connected with a 50-ohm coaxial cable and tuned to the same frequency, the generator setting which gives the minimum perceptible reading above the receiver background noise shall be noted. Modulation may be used in conjunction with an output meter if the receiver is not equipped to give meter indications of cw signals. The frequency range between 150 kc and 10,000 mc shall then be scanned with the generator output preferably set at least 80 db above the output originally noted. Those frequencies at which output signals are obtained shall be investigated to obtain the generator reading which corresponds to the original receiver output signal. Since all signal generators emit a substantial amount of harmonics, care should be taken that the receiver is not erroneously rejected because of such spurious signal content. Front end rejection is calculated with the following formula:

$$\text{Front end rejection} = 20 \log V_2/V_1$$

V_1 = Signal generator voltage required for minimum perceptible receiver output on channel or frequency under test.

V_2 = Signal generator voltage required for minimum perceptible receiver output at all other frequencies.

When this test cannot be accomplished due to the possibility of crystal burnout or for other reasons, the test signals shall be injected into the test sample by using a suitable antenna fed from a signal generator. The test procedure to be used shall be included in the test plan.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable to this specification.

6. NOTES

6.1 Intended Use. - The test procedures and limits specified herein are intended to insure that aeronautical, electrical, and electronic equipments will operate properly in service use when subjected to certain radio and audio interference voltages, and will not cause the malfunction of other equipments by generation of interference voltages. This specification applies to components or systems as specified by the procuring activity or by the detail specification.

6.2 Instrumentation. - The applicable interference measuring instruments which are currently commercially available are listed in table I according to their compliance with this specification. Instruments that have been modified to meet category A requirements should not be used unless a distinctive non-removable label has been attached by the instrument manufacturer; any restrictions on the usage of the modified instrument, or associated accessories, should be indicated on the label.

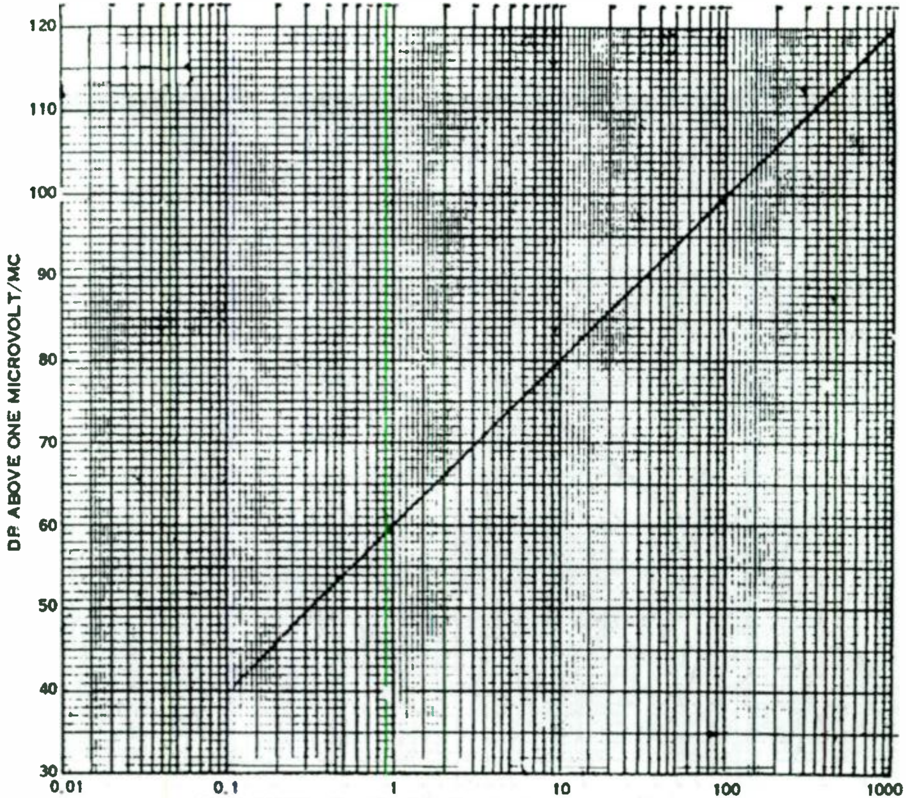


FIGURE 27 Conversion Chart - Microvolts KC to DBMC

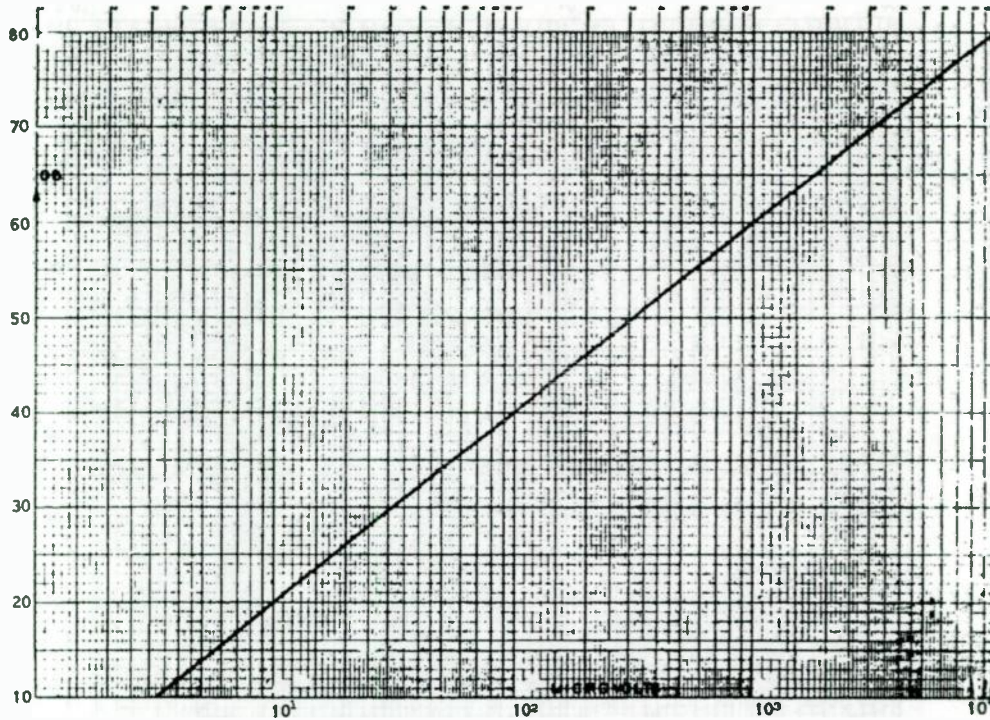


FIGURE 28 Conversion Chart - Microvolts to DB

6.2.1 Category A. - Category A instruments are those interference measuring instruments which adequately measure the parameters of interference signals as required by this specification and which are approved by the Air Force. Any combination of category A instruments may be used for the required measurements.

6.2.2 Category B. - Category B instruments are those existing instruments which are in use but which do not adequately measure the parameters of interference signals as required by this specification. Use of these instruments is permissible until conditions permit their replacement by category A instruments, if: (a) the category B instrument was procured prior to 29 May 1953, and the instrument is listed in the table; or (b) if a category A instrument is not commercially available in the same frequency range.

6.2.3 Category C. - Category C instruments should not be used unless specifically authorized by the procuring activity.

6.2.3.1 Category C-1. - Category C-1 instruments are those which have recently been developed to meet category A requirements that have not been evaluated by the Air Force.

6.2.3.2 Category C-2. - Category C-2 instruments are those which have been recently developed but do not meet category A requirements, and which can presumably be modified by the manufacturer to attain a category A rating.

TABLE I[1]

Category	Frequency Range	Commercial Nomenclature	Manufacturer
A	0.15 to 25 mc	NM-20A, B	Stoddart
	0.15 to 30 mc	T-A/NF-105[2]	Empire
	20 to 400 mc	NM-30A[3] (Ser No. 191-1 or higher)	Stoddart
	20 to 200 mc	T-1/NF-105	Empire
	200 to 400 mc	T-2/NF-105	Empire
	400 to 1000 mc	T-3/NF-105[4]	Empire
	375 to 1000 mc	NM-50A[5] (Ser No. 222-1 and higher)	Stoddart
	1000 to 10,000 mc	FIM	Polarad
B	375 to 1000 mc	NM-50A[5] (Ser No. 190-50 and below)	Stoddart
C-1	375 to 1000 mc	NM-50B	Stoddart
C-2	0.15 to 30 mc	T-A/NF-105[6]	Empire
	20 to 400 mc	NM-30A[5] (lower than Ser. No. 191-1)	Stoddart
	400 to 1000 mc	T-3/NF-105 [7]	Empire

(1) This table is subject to change upon reasonable notice to include new instruments having superior performance characteristics and to change the category of older instruments which have become obsolete.

(2) This category applies only to tuning units purchased after 11 March 1957

(3) This category applies only when power supply 91226-1 is used.

(4) This category applies to instruments purchased after 9 May 1956.

(5) These instruments can be modified to category A requirements by the manufacturer.

(6) This category applies to instruments purchased prior to 11 March 1957. The manufacturer can supply information on the changes necessary to modify the tuning units to category A requirements.

(7) This category applies to instruments purchased prior to 9 May 1956. These instruments can be modified to category A requirements by the instrument manufacturer.

6.2.4 Antenna System Correction. - The following factors when added to the reading that is obtained on the interference measuring instrument, convert to antenna induced microvolts and compensate for mismatch, input impedance, et cetera. The instrument reading, before the addition of this factor, is that voltage which is calculated to be at the input of the coaxial cable or input connector.

Instrument	Antenna System Correction (DB)
NM-20A, B	0
NM-30A (90833-2 antenna)	8
NM-30A (90832-2 antenna)	14
NM-50A	8
NF-105 (DA antennas)	11
NF-105 (DM antennas)	8

6.3 Bonding. - The requirements of MIL-B-5087 are recommended for study as a guide toward design for compliance with the bonding requirements of this specification.

6.4 Additional Information. - The information contained in the handbook, "Design Techniques for Interference-Free Operation of Airborne Electronic Equipment," is recommended as a guide towards design for compliance with this specification. Organizations with a military contract can obtain the handbook, at no cost, from ASTIA, Publication No. ATI-159699. Organizations without a military contract can order the handbook as Report No. P.B. 111051 from the Department of Commerce, Office of Technical Services, Washington 25, D. C. A check for $11.50, payable to the Treasurer of the United States, must accompany the order.

6.5 Definitions

6.5.1 Interference. - Interference is defined as any electrical or electromagnetic disturbance, phenomenon, signal or emission, manmade or natural, which causes or can cause undesired response, malfunctioning or degradation of performance of electrical and electronic equipment, or premature and undesired location, detection or discovery by enemy forces, except deliberately generated interference (electronic countermeasures).

6.5.2 Susceptibility. - As used herein, susceptibility is defined as that characteristic which causes an equipment to malfunction or exhibit an undesirable response when its case or any external lead or circuit, excepting antennas, is subjected to the specified radio or audio frequency voltage or field.

6.5.3 Ambient Interference. - Ambient interference, for the purpose of this specification, is the interference level emanating from sources other than the test sample, including the internal background noise of the interference measuring equipment.

6.5.4 Antenna Induced Microvolts. - Antenna induced microvolts is that voltage which exists across the open-circuited antenna terminals.

6.5.5 Impulsive Interference. - For the purposes of this specification, all broadband noise, including random noise, is considered to be impulsive interference.

6.5.6 Octave. - An octave is a frequency ratio of 1 to 2, i.e., from 1 to 2 mc, 2 to 4 mc, 500 to 1000 mc et cetera.

6.5.7 Microvolts per MC. - The nearest approach to a standard unit of measurement of broadband radio interference is in terms of microvolts per megacycle. Interference intensity in microvolts per megacycle is equal to the number of root mean square sine wave microvolts (unmodulated) applied to the input of the measuring circuit at its center frequency that will result in detector peak response in the circuit equal to that resulting from the interference pulse being measured, divided by the impulse bandwidth of the circuit in megacycles. The impulse bandwidth is the area divided by the height of the voltage response versus radio frequency selectivity curve from antenna through the peak detector. Impulse bandwidth is approximately equivalent to the bandwidth between the 0.45 voltage points on the selectivity curve.

6.5.8 Impulse Bandwidth. - The impulse noise bandwidth of the interference measuring instrument should be used in calculations involving broadband noise. Effective (random) bandwidth should not be used.

6.5.9 Radio Receiver Front End Rejection. - Front-end rejection is the measured capability of a receiver, expressed in decibels, in rejecting signals at the antenna terminals that are outside the channel, or frequency, to which the receiver is tuned.

6.5.10 Weapon System. - A weapons system is an instrument of combat, such as an air vehicle, together with all related equipment, both airborne and ground based, the skills necessary to operate the equipment, and the supporting facilities and services required to enable the instrument of combat to be a single unit of striking power in its operating environment.

6.5.11 Supporting Systems. - A supporting system is a system composed of techniques, skills, and equipment, the composite of which is not an instrument of combat but which is in support of an operational role or mission.

6.5.12 Aeronautical Equipment. - Aeronautical equipment, for the purpose of this specification, is equipment, either airborne or ground based, that is used in conjunction with weapons or supporting systems and is under the cognizance of the Air Services.

6.5.13 Open Space. - The term open space, as used in this specification, is intended to designate an ideal site for radiated interference measurements. This ideal site should be open, flat terrain at a considerable distance (100 feet or more) from buildings, electric power lines, fences, trees, underground cables, and pipe lines. This site should have a sufficiently low ambient level of radiated interference to permit testing to the governing radiated interference limit at any test frequency selected.

6.6 Standard Antennas. - Because of the nonuniformity of the electromagnetic field which usually exists close to a test sample, it is imperative that tests for radiated interference be conducted with antennas identical to those specified. Attempts to correlate results obtained with other antennas by reducing the results to microvolts per meter, based upon plane wave calculations and antenna effective height, may be erroneous and will not be accepted as indicating compliance with this specification.

6.7 Operator and Observer Positions. - In those cases where the operator's or observer's location seems to vary a measurement reading, a minimum distance of 3 feet should be maintained between his body and the antenna; the operator should change position slightly until a maximum reading is obtained. In all cases, as few observers as possible should be present in the screen room during the radiated measurements.

6.8 Impulse Generators. - Satisfactory impulse generators can be obtained from Empire Devices Products Corporation, 38-15 Bell Boulevard, Bayside 61, New York, and from Stoddart Aircraft Radio Company, 6644 Santa Monica Boulevard, Hollywood 38, California.

6.9 Current Probes. - Current probes are available from Stoddart Aircraft Radio Company.

6.10. Conversion Charts. - Figure 27 provides a convenient method for converting microvolts per kilocycle bandwidth to decibels above 1 microvolt per megacycle. Figure 28 converts microvolts to decibels above 1 microvolt.

6.11 Coaxial Switches. - Coaxial switches can be used to advantage for measurements where many manipulations of coaxial cables are required during tests.

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MILITARY SPECIFICATION

CALIBRATION SYSTEM REQUIREMENTS

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification provides for the establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment used to assure that supplies and services presented to the Government for acceptance are in conformance with prescribed technical requirements.

1.2 Applicability. This specification applies to all contracts under which the contractor is required to maintain measuring and test equipment in support of contract requirements.

1.3 Significance. This specification and any procedure or document executed in implementation thereof shall be in addition to and not in derogation of other contract requirements.

2. APPLICABLE DOCUMENTS (None.)

3. REQUIREMENTS

3.1 General. The contractor shall establish or adapt and maintain a system for the calibration of all measuring and test equipment used in fulfillment of his contractual requirements. The calibration system shall be coordinated with his Inspection or Quality Control Systems and shall be designed to provide adequate accuracy in use of measuring and test equipment. All measuring and test equipment applicable to the contract, whether used in the contractor's plant or at another source, shall be subject to such control as is necessary to assure conformance of supplies and services to contractual requirements. The calibration system shall provide for the prevention of inaccuracy by ready detection of dificiencies and timely positive action for their correction. The contractor shall make objective evidence of accuracy conformance readily available to the Government representative.

3.2 Description. The contractor shall provide and maintain a written description of his calibration system covering measuring and test equipment and measurement standards. The portion dealing with measuring and test equipment shall prescribe calibration intervals and sources and may be main-

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tained on the documents normally used by the contractor to define his inspection operations. The description for calibration of measurement standards shall consist essentially of a listing of the applicable measurement standards, both reference and transfer, and shall provide nomenclature, identification number, calibration interval and source, and environmental conditions under which the measurement standards will be applied and calibrated. The description of the calibration system and applicable procedures and reports of calibration shall be available to the Government representative.

3.2.1 *Adequacy of standards.* Standards established by the contractor for calibrating the measuring and test equipment used in controlling product quality shall have the capabilities for accuracy, stability, and range required for the intended use.

3.2.2 *Environmental controls.* Measuring and test equipment and measurement standards shall be calibrated and utilized in an environment controlled to the extent necessary to assure continued measurements of required accuracy giving due consideration to temperature, humidity, vibration, cleanliness, and other controllable factors affecting precision measurement. When applicable, compensating corrections shall be applied to calibration results obtained in an environment which departs from standard conditions.

3.2.3 *Intervals of calibration.* Measuring and test equipment and measurement standards shall be calibrated at periodic intervals established on the basis of stability, purpose, and degree of usage. Intervals shall be shortened as required to assure continued accuracy as evidenced by the results of preceeding calibrations and may be lengthened only when the results of previous calibrations provide definite indications that such action will not adversely affect the accuracy of the system.

3.2.4 *Calibration procedures.* Written procedures shall be prepared or provided and utilized for calibration of all measuring and test equipment and measurement standards used to assure the accuracy of measurements involved in establishing product conformance. The procedures may be a compilation of published standard practices or manufacturer's written instructions and need not be rewritten to satisfy the requirements of this specification. Th procedure shall require that calibration be performed by comparison with higher accuracy level standards.

3.2.5 *Calibration source.*

3.2.5.1 *Domestic contracts.* Measuring and test equipment shall be calibrated by the contractor or a commercial facility utilizing reference standards (or interim standards) whose calibration is certified as being traceable to the National Bureau of Standards, has been derived from accepted values of natural physical constants, or has been derived by the ratio type of self-calibration techniques. Reference standards requiring calibration by a higher level standards laboratory shall be calibrated by a commercial facility capable of providing the required service, a Government Laboratory under arrangements made by the Contracting Officer, or by the National Bureau of Standards. All reference standards used in the calibration system shall be supported by certificates, reports, or data sheets attesting to the date, accuracy, and conditions under which the results furnished were obtained. All subordinate standards and measuring and test equipment shall be supported by like data when such information is essential to achieving the accuracy control required by this specification. In those cases where no date is required, a suitably annotated calibration label on the item shall be sufficient to satisfy the support data requirements of this paragraph. Certificates or reports from other than the National Bureau of Standards or Government Laboratory shall attest to the fact that the Standards used in obtaining the results have been compared at planned intervals with the National Standard either directly or through a controlled system utilizing the methods outlined above. The contractor shall be responsible for assuring that the sources providing calibration services, other than the National Bureau of Standards or a Government Laboratory, are in fact capable of performing the required service to the satisfaction of this specification. All certificates and reports shall be available for inspection by authorized Government representatives.

3.2.5.2 *Foreign contracts*. The provisions in paragraph 3.2.5.1 shall apply with the exception that the National Standards Laboratories of countries whose standards are compared with International or U. S. National Standards may be utilized in lieu of the U. S. National Bureau of Standards.

3.2.6 *Application and records*. The application of the above requirements will be supported by records designed to assure that established schedules and procedures are followed to maintain the accuracy of all measuring and test equipment, and supporting standards. The records shall include a suitably identified individual record of calibration or other means of control for each item of measuring and test equipment and measurement standards, providing calibration interval and date of certification of results of last calibration. In addition, the individual record of any item whose accuracy must be reported via a calibration report or certificate will quote the report or certificate number for ready reference. These records shall be available for review by authorized Government personnel.

3.2.7 *Calibration labelling*. Measuring and test equipment and measurement standards shall be labeled to indicate the date of last calibration, by whom it was calibrated, and when the next calibration is due. When the size or functional characteristics limit the application of labels, an identifying code shall be applied to the item to reflect serviceability and due date for next calibration. When neither labeling or coding is practical the system shall provide suitable procedures for monitoring of recall records to assure adherence to calibration schedules. Labels, codes, or recall records for items which are not required to be used to their full capabilities, or items which require functional check only shall indicate the applicable condition.

3.2.8 *Control of subcontractor calibration*. The contractor shall be responsible for assuring that his subcontractors have a calibration system which essentially meets the requirements of this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Government verification. All operations performed by the contractor in compliance with this specification will be subject to Government verification at unscheduled intervals. Verification will include but not be limited to the following:

(a) Surveillance of calibration operation for conformance to the established system.

(b) Review of calibration results as necessary to assure accuracy of the system.

5. PREPARATION FOR DELIVERY

(None.)

6. NOTES

6.1 Intended use. This specification is to be used as a part of contractual documents, by reference in the contract, as a basis for the establishment of workable system within the contractor's facility and between the contractor and his subcontractors for the control of accuracy of measuring and test equipment and standards used in support of contract requirements.

6.2 Definitions.

6.2.1 *Calibration*. Comparison of a measurement standard or instrument of known accuracy with another standard or instrument to detect, correlate, report, or eliminate by adjustment, any variation in the accuracy of the item being compared.

6.2.2 *Measuring and test equipment.* All devices used to measure, gage, test, inspect, or otherwise examine items to determine compliance with specifications.

6.2.3 *Measurement standard (reference).* Standards of the highest accuracy order in a calibration system which establish the basic accuracy values for that system.

6.2.4 *Measurement standard (transfer).* Designated measuring equipment used in a calibration system as a medium for transferring the basic value of reference standards to lower echelon transfer standards or measuring and test equipment.

6.2.5 *Interim standard.* An instrument used as a standard until an authorized standard is established.

6.3 Supersession and ordering.

6.3.1 *Amendments and revisions.* Whenever this specification is amended or revised subsequent to its contractually effective date, the contractor may follow or authorize his subcontractor to follow the amended or revised specification provided no increase in price or fee is involved. The contractor shall not be required to follow the amended or revised specification except as a change in the contract. If the contractor elects to follow the amended or revised specification, he shall notify the Government representative in writing of this election.

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