

# **RADIO OPERATING Questions and Answers**

Twelfth Edition

A new edition of a basic radio operator's license manual, based on the latest FCC requirements, with complete revisions of Elements 1 and 2, and all other most recent changes

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# Radio Operating Questions and Answers

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## Preface

The twelfth edition of this book is needed to keep pace with advances in the radio art. Since the last revision, color television broadcasts compatible with the existing monochrome system have been authorized by FCC; the transistor in all its forms has come out of the laboratory and is engaged in everyday work; and microwave techniques are becoming increasingly useful and important.

In its latest study guide for commercial radio operators, the Federal Communications Commission has very wisely included questions that demand a knowledge of these subjects and of the latest radio rules and regulations.

The authors have endeavored to furnish sufficient material so that the candidate for examination may quickly brush up on his previous knowledge. However, both the transistor art and that of color television are so relatively complex that it may be necessary for the prospective operator to study these and other subjects at some length before he can avail himself of the summaries represented in this book.

For reasons of economy and publishing speed, the additional questions and answers for Elements 3, 4, and 6 have been gathered at the back of the book in the form of an Addendum.

Other changes (particularly those in Elements 1 and 2) have been incorporated in their proper places in the body of the book. Because of some last-minute deletions in the FCC guide, this book will be found to contain more than the minimum review material with which to prepare for the examinations.

The reader is urged to consult the following section, "How To Use This Book," for detailed directions covering each type of commercial examination.

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Instructions for the technique of artificial respiration, together with illustrations, were furnished by American National Red Cross, Washington, D.C.

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## How to Use This Book

This book has been written to furnish concise, quick answers to questions that appear in the most recent revision of the booklet "Study Guide and Reference Material for Commercial Radio Operator Examinations," published by the Federal Communications Commission and available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

The "Study Chart" that follows indicates the page location of questions and answers in this book about subjects upon which the various commercial license examinations are based. To avoid confusion about what elements are necessary, the study chart shows exactly which pages to read for each class of license or endorsement.

The FCC numbering of questions within each element, although essentially meaningless, has been retained to some extent. However, in this book the questions and their answers have been grouped according to categories or subjects, such as laws, power supplies, and theory.

Schools and individual students alike have found that this kind of presentation makes it much easier to concentrate upon one aspect of the examination material at a time. If a teacher wishes to restore the questions to their original random state for review purposes, he has only to refer to the Index to Question Numbers in the back of the book.

The Index of Subjects makes it possible for the student to find specific information on the topic or topics in which he is interested.

It is strongly recommended that the student or commercial operator purchase from the Superintendent of Documents a copy of "Part 13—Rules Governing Radio Operators." When this material is received, he

## Study Chart

Class of License	Examination Elements						What to Study
	1	2	3	4	5	6	
Radiotelegraph First	x	x			x	x	Pages 3-33 Pages 54-82 Pages 240-337 Pages 371-391 Pages 552-554
Radiotelegraph Second	x	x			x	x	Pages 3-33 Pages 54-82 Pages 240-337 Pages 371-391 Pages 552-554
Radiotelegraph Third Permit	x	x			x		Pages 3-33 Pages 54-61
Radiotelephone First	x	x	x	x			Pages 3-53 Pages 85-239 Pages 341-370 Pages 541-552
Radiotelephone Second	x	x	x				Pages 3-41 Pages 85-184 Pages 341-364 Pages 541-547
Radiotelephone Third Permit	x	x					Pages 3-33
Restricted Radiotelephone Permit	No oral or written examination						
Aircraft Radiotelegraph Endorsement	First- and second-class radiotelegraph operators only by examination in Element 7						Pages 395-463
Ship Radar Endorsement	First- and second-class radiotelegraph or radiotelephone operators by examination in Element 8						Pages 464-486

should then fill out the attached coupon and send it to the address specified. Thereafter he will receive official notice of changes in operator requirements directly from the FCC. Other parts of the radio law may be similarly obtained.

The student must remember that the actual examination questions are quite different from the suggested study questions given here. Examinations are now entirely of the multiple-choice type. It is therefore insufficient for the student merely to learn these answers by heart. He must understand the reasons for them in order to pass the examination.



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RADIO LAWS, REGULATIONS,  
AND OPERATING PRACTICES

[Elements: 1, 2, 3, 4, 5, 6]



## **Element 1**

### **Basic Law**

#### **1.1 Where and how is an operator license or permit obtained?**

*Answer.* An operator license or permit is obtained by application and/or examination at a Field Engineering Office of the Federal Communications Commission.

#### **1.2 Must a person designated to operate a radiotelephone station post his operator license or permit and if so, where?**

*Answer.* Generally, the operator of a radiotelephone station must post his license at the place where he is on duty.

#### **1.3 Must a person who receives a notice of violation from FCC reply?**

*Answer.* Within three days from receipt of such notice (or such other period as may be specified therein) the licensee must send a written answer direct to the Federal Communications Commission at Washington, D.C., and a copy to the office, if any, from which the official notice originated. Specific and full answers must be given.

#### **1.4 How soon does the FCC require a response to a notice of violation?**

*Answer.* The FCC requires an answer to be sent within three days.

#### **1.5 If a person cannot respond to a notice of violation in the time prescribed by the FCC is it necessary to explain the reasons for any delay?**

*Answer.* Yes. If the answer must be delayed, owing to illness or other unavoidable circumstances, the answer must be sent as soon as possible with a full and satisfactory explanation for the delay.

**1.6 Should the answer to each notice of violation be complete and should reference be made to remedial action, if any specific remedial steps are necessary?**

*Answer.* Yes. The answer to each notice must be complete and not abbreviated by reference to other communications. If the notice relates to violations resulting from a defective transmitter, the answer must state what steps have been taken to prevent a recurrence.

**1.7 To whom is a response to a notice of violation addressed?**

*Answer.* Responses are sent to Federal Communications Commission, Washington, D.C.

**1.8 May the FCC suspend an operator license or permit for due cause?**

*Answer.* Yes. The FCC may suspend an operator's license for violations, failure to carry out orders, willful damage to equipment, transmission of improper signals, or fraud.

**1.9 Can suspension of an operator license or permit take effect prior to notification?**

*Answer.* No. Suspension becomes effective 15 days after written notice has been given to the operator.

**1.10 How soon after receiving notification of suspension of an operator license or permit does a suspension order become effective?**

*Answer.* It does not become effective for 15 days and may be held in abeyance for a much longer time pending, and during, a hearing.

**1.11 May a person who has received an order of suspension of operator license or permit request a hearing?**

*Answer.* The licensee receiving a suspension notice may make written application for a hearing during the 15-day period following his receipt of the notice.

**1.12 Is it prohibited by law to transmit unnecessary and superfluous signals? Is profane and obscene language prohibited?**

*Answer.* Unnecessary and superfluous signals are forbidden under international agreement. No person shall utter any obscene, indecent, or profane language by means of radio communication.

**1.13 Does the government have authority to impose fines for failure to comply with the rules and regulations governing the use of radio on compulsorily equipped ships?**

*Answer.* Yes. Any person who knowingly violates the Communications Act will be punished, after conviction, by a fine of not more than \$500 for every day such offense occurs.

**1.14 What must a person do whose operator license or permit has been lost, mutilated, or destroyed?**

*Answer.* He must notify the Commission immediately and make proper application for a duplicate license.

**1.15 In applying for a duplicate operator license or permit, what documentary evidence must be submitted along with an application?**

*Answer.* The operator must furnish documentary evidence or a statement, under oath, of service obtained under the original license or permit.

**1.16 Is it permissible to operate pending receipt of a duplicate operator license or permit after application has been made for reissue?**

*Answer.* Yes. Nothing in the rules indicates that a duly licensed operator shall lose his operating privileges by physical loss, mutilation, or destruction of his license. His duty of immediately notifying the Commission is, however, clearly indicated.

**1.17 What provision is made for operation without an actual operator license or permit pending receipt of a duplicate?**

*Answer.* The operator must exhibit a signed copy of the application he has submitted to the Commission in place of the license he has lost.

**1.18 Is the holder of a radiotelephone third-class operator permit authorized to make technical adjustments to the transmitter he operates?**

*Answer.* No. He is not authorized to make adjustments to his transmitter unless they are of a type that will not result in improper operation. If competent to do so, he may make any adjustment under the supervision and responsibility of a first- or second-class radiotelephone operator. This prohibition applies also to adjustment of ship or aircraft radiotelephone stations when the unmodulated carrier power in the antenna exceeds 100 watts.

**1.19 Should a radio station that is required to be operated by a licensed radio operator be a licensed radio station?**

*Answer.* Yes. There is no provision of the Communications Act for operating any radio transmitting apparatus without a license. The Act provides further that certain classes of stations must always be operated by licensed operators.

**1.20 Are communications bearing upon distress situations subject to the secrecy provisions of law?**

*Answer.* No. Radio communications relating to ships in distress are not subject to the secrecy provisions of the Communications Act.

**1.21 What penalty is provided by law for willful and knowing violation of regulations imposed by the FCC and of radio treaties?**

*Answer.* Such offender shall, in addition to any other penalties, be punished, upon conviction, by a fine of not more than \$500 for each and every day during which such offense occurs.

**1.22 What penalty is provided by law for willful and knowing violation of the radio laws?**

*Answer.* An offender can be punished by a fine of not more than \$10,000 or imprisonment for not more than a year or both. A person previously convicted may be fined not more than \$10,000 or imprisoned for not more than two years or both.

**1.23 Are radio stations subject to inspection by the FCC?**

*Answer.* Yes. The FCC has authority to inspect all radio installations to insure that they conform to Commission rules and regulations.

**1.24 In radiotelephony, what are the distress, urgency, and safety signals?**

*Answer.* In radiotelephony, the distress call is MAYDAY spoken three times. The urgency signal is PAN, repeated three times. The word SECURITY (pronounced as the French word *sécurité*) repeated three times is used for the safety signal.

**1.25 In radio communication, what does the transmission of the distress, urgency, and safety signals signify, respectively?**

*Answer.* Transmission of the distress signal indicates that the station sending it is threatened by grave and imminent danger and requests immediate assistance. The distress message follows the signal.

The urgency signal indicates that the calling station has a very urgent message to transmit concerning the safety of a ship, aircraft, or other vehicle or of some person on board or within sight.

The safety signal precedes transmission of a message concerning safety of navigation or important meteorological warnings.

### 1.26 What information must be contained in a distress message?

*Answer.* The distress message comprises: distress call; name of ship, aircraft, or vehicle in distress; particulars of its position; nature of the distress and kind of assistance desired; any other information to facilitate rescue.

As a general rule, a ship signals its position in latitude and longitude (Greenwich) using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST. The signal  $\cdot - \cdot - \cdot -$  is used to separate the degrees from the minutes. When practicable, the true bearing and distance in nautical miles from a known geographical point may be given.

As a general rule, and if time permits, an aircraft shall transmit in its distress message the following information:

1. Estimated position and time of the estimate.
2. True heading and indicated air speed.
3. Altitude.
4. Type of aircraft.
5. Nature of distress.
6. Intention of person in command (such as forced alighting on the sea or crash landing).

As a general rule, an aircraft in flight signals its position if possible by latitude and longitude (Greenwich) using figures for the degrees and minutes, together with one of the words NORTH or SOUTH and one of the words EAST or WEST; or by the name of the nearest place, and its approximate distance in relation thereto, together with one of the words NORTH, SOUTH, EAST, or WEST, as the case may be, or when practicable, by words indicating intermediate directions.

### 1.27 Under what conditions may a mobile radio station send a distress message for another mobile station in distress?

*Answer.* One mobile station may transmit the distress message for another if the station in distress cannot transmit it or if the master of the intervening station believes that further help is necessary.

**1.28 If a mobile radio station is in distress, what station is responsible for the control of distress message traffic?**

*Answer.* Control of distress traffic is the responsibility of the station in distress or of the mobile station assisting handling of the distress message. Either of these stations may delegate control to another station.

**1.29 What does the distress call consist of when sent by radiotelephony?**

*Answer.* The radiotelephone distress call is MAYDAY, spoken three times, then the words THIS IS, followed by the mobile station identification, the whole being repeated three times. The distress call is generally preceded by the signal ···— — —··· produced by a whistle or any other suitable means.

**1.30 How may necessary corrections to the log record be made?**

*Answer.* A necessary correction to a log may be made only by the person who originally made the entry. He must strike out (not erase) the erroneous portion, initial the correction made, and date the correction.

**1.31 How soon before expiration of an operator license or permit should application be made for renewal?**

*Answer.* Application for renewal of an operator license may be filed at any time during the final year of the license term or during a one-year period of grace after expiration of the license.

**1.32 Is it prohibited by law to transmit false or fraudulent signals of distress?**

*Answer.* Yes. No person shall knowingly transmit such signals or communications relating thereto.

**1.33 What is the priority of the urgency signal?**

*Answer.* The urgency signal has priority over all types of communications except distress calls, distress messages, and distress traffic.

## Element 2

# Basic Operating Practice (Law)

### GENERAL

**2.101** If a radiotelephone operator desires to make a brief test of a transmitter, what would be a good choice of words to use in the test?

*Answer.* Such a phrase as THIS IS KM2359 TESTING. Tests should be as brief as possible.

**2.102** Why is it important to avoid unnecessary calls by radio communication?

*Answer.* Only necessary calls should be made by radio because other stations sharing the frequency deserve consideration. Unnecessary calls may also contribute to interference at a distance, even beyond the range of useful communication.

**2.103** Is it required that a person listen on a channel before transmitting?

*Answer.* Yes. The operator should always listen to hear if the communications channel is in use before transmitting. He should listen either on his own transmitting frequency or on an associated receiving channel, whichever is appropriate.

**2.104** Why is it advisable to listen on a channel before transmitting?

*Answer.* Unless the operator listens before transmitting, he cannot know whether or not the channel is already in use. If it is in use, his transmission will usually result in interference without any possi-

bility of getting his message through and consequent delay in clearing the channel for other messages.

**2.105 Why should a trial of the radiotelephone installation be made every day?**

*Answer.* Daily tests will reveal any defect or malfunction of either the transmitter or receiver that would otherwise not be discovered until practical use of the equipment was required. Repairs or readjustments can then be made without delaying communications.

**2.106 How can the radiotelephone installation be tested?**

*Answer.* A radiotelephone installation can be tested by several methods. The transmitter operation can be checked by grid- and plate-current meter readings and by listening to its signal on a monitor receiver. The receiver can likewise be tested by connecting a signal generator input to its antenna or input and measuring the receiver output. In most practical cases, especially in the field, the equipment is tested by actual communication with another station.

**2.107 Before placing the transmitting apparatus of a radio station in operation for a test, what precautions must be taken?**

*Answer.* Before testing a radio transmitter with its radiating antenna connected, the frequency channel must be monitored to ensure that the testing operation does not interfere with communications already in progress.

**2.108 What is the correct form for transmitting a distress call by radiotelephony?**

*Answer.* The radiotelephone distress call is the distress signal MAYDAY spoken three times, the words THIS IS followed by station identification, the whole repeated three times. The distress signal would generally be preceded by the signal · · · — — — · · · produced by a whistle or similar means.

**2.109 Why is it a good policy to be brief in radiotelephone conversations?**

*Answer.* Radiotelephone conversations must be brief to allow time for transmission of other messages on the same channel. Sometimes, at the end of a long transmission, an operator finds that interference or

fading has prevented the operator at the other station from hearing much of the message. Short transmissions speed message handling.

**2.110 What is the significance of the word CLEAR when transmitted at the end of a radiotelephone communication?**

*Answer.* The word CLEAR at the end of a communication means that the particular business has ended and the station is now going off the air, leaving the channel clear.

**2.111 Are there any ill effects to radio communication if the operator shouts into the microphone?**

*Answer.* Yes. His voice will probably become unintelligible, and occasionally some damage may be done to the equipment. Often spurious frequencies generated cause adjacent-channel interference.

**2.112 Is it a good practice to shield the microphone with the hands when speaking into a microphone in a noisy location?**

*Answer.* Yes. Cupping the hands around the microphone will reduce much of the noise, leaving the voice relatively stronger.

**2.113 In radiotelephone communications, why should the operator use well-known words and phrases and simple language as much as possible?**

*Answer.* Most radiotelephone circuits are limited to a top audio frequency of about 3,000 cycles. The lowest frequency transmitted may be about 300 cycles. Therefore, only a simulation of the speaker's voice is received, and his words may not be easy to understand. Simple, well-known words and phrases are most easily understood.

**2.114 What is the operator's responsibility upon hearing the word SECURITY repeated three times?**

*Answer.* An operator who hears the safety signal SECURITY must continue listening on its frequency until sure that the message does not concern his station. He must not make any transmissions likely to interfere with the message.

**2.115 What must the operator do if he is told that he is interfering with a distress call?**

*Answer.* An operator who hears the distress call must continue listening until he hears the distress message, after which he must acknowledge its receipt. Any station hearing the distress call must cease any transmission likely to interfere with distress traffic.

**2.116 What is the significance of the word OVER when transmitted at the end of a radiotelephone communication?**

*Answer.* The word OVER is commonly used at the end of a transmission to indicate that the listening station may now transmit.

**2.117 What is indicated by the word OUT when transmitted at the end of a radiotelephone communication?**

*Answer.* The word OUT following a transmission indicates that the sending station has completed its business and does not intend to make immediate further transmissions to the receiving station.

**2.118 Can a radio operator always consider his radiotelephone conversation completely confidential and not heard by other persons?**

*Answer.* No. Radio signals may be heard by anyone with suitable receiving equipment. Signals often travel over great distances, far beyond the station to which they are specifically transmitted.

**2.119 In calling a station by radiotelephony, how many times does the calling station generally repeat the call sign or name of the calling station in each calling transmission?**

*Answer.* In establishing communication, the call sign or name of the calling station should generally not be repeated more than three times in each transmission. After communication is established, it is seldom necessary to use the call more than once in each transmission.

**2.120 Would you listen on a shared channel before transmitting? Why?**

*Answer.* Yes. If users of a shared channel fail to listen before transmitting, interference will be caused and messages delayed.

**2.121 Under normal conditions would a transmission on a calling frequency be proper if the receiver for that frequency was inoperative?**

*Answer.* No. Normally the calling station must be able to monitor

the frequency to find out whether it is in use. Otherwise, serious interference may result.

**2.122 What is the difference between calling and working frequencies?**

*Answer.* A calling frequency is used to establish contact with one of many stations sharing the common calling channel. As soon as contact has been established, transmission of messages is effected on another working frequency. One calling frequency may be used in connection with many different working frequencies.

**2.123 Why is it important to give the station call clearly?**

*Answer.* The station call sign must be given clearly to speed communications between stations and as a means of identifying the station as one legally permitted to operate.

**2.124 Should a test of the radiotelephone equipment be made each day?**

*Answer.* Yes. Radiotelephone equipment not in regular use should be tested each day.

**2.125 Should messages bearing upon safety, including weather information, be given priority over business messages?**

*Answer.* Messages preceded by the safety signal take priority over all other messages except distress transmissions and those preceded by the urgency signal.

**2.126 If a station is required by law to listen on a calling and distress frequency, when may the listening be discontinued?**

*Answer.* In general, safety watches must be kept on 500 kc during 8 hours of any day by a qualified radiotelegraph operator. At the end of this time the autoalarm may be turned on as substitute for safety watch. However, every passenger ship, as well as cargo ships in excess of 5,500 tons, if not fitted with autoalarm, must keep continuous watch.

**2.127 Why should a radiotelephone transmitter be kept off the air when voice transmissions are not in progress?**

*Answer.* As long as the carrier of a radiotelephone transmitter is on the air, the equipment is capable of causing interference and block-

ing use of the channel. The carrier should be off at all times except while the operator is talking.

**2.128 Why is it beneficial for the transmitter of a radio station to be in constant readiness for making a call?**

*Answer.* Unless a radio transmitter is able to function, it is useless, particularly in an emergency, when it is most urgently required.

**2.129 If a station is required to maintain effective listening on a distress frequency, why is it desirable for the equipment to return automatically to reception on the distress frequency immediately after completing use of the equipment on another frequency?**

*Answer.* Automatic return of the equipment to the distress frequency ensures that distress calls will be heard without delay, even if the operator neglects to retune immediately for this purpose.

**2.130 Why is rapid frequency change of the transmitter and receiver desirable?**

*Answer.* Rapid frequency change of transmitter and receiver makes it possible to shift quickly between calling and working frequencies. Such operation speeds communications and cuts down the time during which interference is caused to other stations sharing the channels.

**2.131 What would you do as radiotelephone operator if you were told that your voice was distorting?**

*Answer.* An operator receiving a report that the speech signal from his station is distorted should first speak in a softer tone, checking his modulation by whatever meter or other indicator is provided. If such control is available, he might adjust his modulation level.

If distortion continues, another microphone can be tried, and, finally, the speech circuits and tubes in the transmitter should be checked.

**2.132 What is the correct form for transmitting a distress call by radiotelephone?**

*Answer.* The distress call comprises the word MAYDAY repeated three times followed by the words THIS IS and then the station identification. The whole sequence is repeated three times.

**2.133 Under what conditions may a radiotelephone station employ a calling frequency as contrasted to a working frequency?**

*Answer.* The frequency 2,182 kc used for distress calls and traffic by radiotelephone and also for urgency and safety signals or messages can be used for call and reply between ship and coast stations when duly authorized by the government and so indicated on the list of coast and ship stations.

**2.134** In calling a station by radiotelephony, should the calling station repeat the call sign or name of the called station in each calling transmission more than three times?

*Answer.* No. It is unnecessary to give the call sign more than three times.

**2.135** Why should stations using a shared frequency leave an interval between calls?

*Answer.* A station sharing a frequency with others must leave an interval between calls so that other stations can call or be called.

**2.136** Under what conditions may it be desirable to repeat important words by radiotelephony?

*Answer.* It may be desirable to repeat important words by radiotelephony when the words are unusual, such as proper names or foreign words, when they are phonetically similar to other words, or when receiving conditions are poor.

**2.137** What is the operator's responsibility upon hearing a distress call in the mobile services?

*Answer.* It is the duty of the operator to acknowledge receipt of the distress message immediately if the mobile station transmitting it is in his vicinity and to report the fact to the person in charge of his craft.

If the distress message appears to come from a mobile station not in the vicinity, the operator must allow a short interval before replying to permit nearer stations to answer without interference.

**2.138** Is it good practice to listen on the working frequency to be later used before making an initial call on the calling frequency?

*Answer.* An operator should listen on the working frequency to ensure that it is not presently in use, then listen on the calling frequency to make sure that it is free. This procedure permits a maximum of calls without interference.

**2.139 Why is it necessary to avoid unnecessary calls by radio-communication?**

*Answer.* Unnecessary or overly long calls reduce the time available for all stations sharing the same frequency assignments.

**2.140 State why station identification should be clearly made by a radio transmitting station.**

*Answer.* Station identification must be clearly made to speed communications and show that the station is legally entitled to transmit.

**2.141 When routine radio communications are unreliable due to static or fading, should the operator continue transmitting or wait for more favorable conditions?**

*Answer.* Except in emergencies, an operator who encounters bad static or fading should generally wait for more favorable conditions to complete communications. Continued useless transmissions only serve to deny others the use of the channel.

**2.142 What is the order of priority for radiotelephone communications?**

*Answer.* The order of priority of communications in the mobile service (see Appendix for official phrasing) is as follows:

1. Distress calls (MAYDAY), distress messages, distress traffic.
2. Communications preceded by the urgency signal (PAN).
3. Communications preceded by the safety signal (SECURITY).
4. Radio direction finding.
5. Navigation and safe movement of aircraft.
6. Navigation, movement, and needs of ships; weather observations for an official meteorological service.
7. Priority government radiotelegrams.
8. Service messages.
9. All other communications.

#### SUPPLEMENTARY—SHIP

**2.201 In making a ship-to-ship contact, except in an emergency involving safety, how long may a ship radiotelephone station continue calling in each instance?**

*Answer.* Calling must not continue for more than 30 sec in each instance.

**2.202** Except in an emergency involving safety, if a ship radiotelephone station does not receive a reply after calling, how long must it wait before calling again?

*Answer.* If the called station does not reply or is not heard, it must not be called again until 1 min has elapsed.

**2.203** What types of communications may be transmitted by ship stations on the ship-to-ship frequencies between 2,000 and 3,000 kc?

*Answer.* Such communications include calls, answers, operating signals, and conversation pertaining to safety.

**2.204** In regions of heavy traffic, how long may the ship-to-ship radiotelephone frequencies between 2,000 and 3,000 kc be used for any one exchange of communications (other than distress and emergency communications)?

*Answer.* Any one exchange of communications shall not exceed 5 min after contact has been established by calling and answering.

**2.205** How is a ship radiotelephone station required to be identified in connection with its operation?

*Answer.* The assigned call sign shall be transmitted in the English language by voice or by tone-modulated telegraphy in the International Morse Code, either by a properly licensed radiotelegraph operator or by an automatic device approved for the purpose.

Identification must be made at the beginning and conclusion of each transmission, at the beginning and completion of each communication, and at intervals not exceeding 15 min.

When an official call sign has not been assigned, the name of the ship and of the licensee must be given in the English language.

**2.206** Do public coast stations normally charge for forwarding messages reporting dangers to navigation?

*Answer.* No charge shall be made by any station for the transmission, receipt or relay of information concerning dangers to navigation.

**2.207** How does the licensed operator of a ship radiotelephone station exhibit his authority to operate this station?

*Answer.* The operator is required to post his original license in a conspicuous place at the principal location on board ship at which the station is operated.

**2.208** If a radiotelephone installation provided on board ship for safety purposes, in accordance with treaty, becomes defective, what action must the licensed operator take?

*Answer.* The operator must notify the master of the vessel, and this fact, as well as the details of the defect, must be entered in an appropriate log record.

**2.209** Who signs the radio log of a ship radiotelephone station certifying to entries made therein?

*Answer.* The log must be signed by the licensed operator who is responsible for operation of the radiotelephone transmitting apparatus.

**2.210** What are the requirements with respect to listening watch in a ship radiotelephone station during its hours of service in the 2,000–3,000-kc band?

*Answer.* Each station must, during its hours of service for radiotelephony, maintain an efficient watch for reception of class A3 emission on 2,182 kc whenever the station is not being used for transmission on that channel or for communication on other radio channels.

**2.211** Who may operate the radiotelephone set aboard a vessel?

*Answer.* Although anyone authorized by the master of a vessel may speak into the station microphone, only a properly licensed operator may actually operate the radio equipment and must exercise necessary control to ensure proper operation of the station.

**2.212** Is it necessary for all vessels having knowledge of distress traffic to follow the traffic even if they do not take part in it?

*Answer.* Yes. Such stations must refrain from transmitting on the frequencies on which distress traffic is being handled and must refrain from using class B (spark) transmissions. However, after distress traffic is well established, a station in the mobile service that is capable of continuing normal service while monitoring distress traffic may do so provided it does not interfere.

**2.213** What is the proper form to use in acknowledging a distress message?

*Answer.* Acknowledgment of receipt of a distress message must take the following form:

1. Call sign of the mobile station in distress (three times).
2. The word DE.
3. Call sign of the station acknowledging (three times).
4. RRR.
5. Distress signal.

**2.214 What information is required to be sent following acknowledgement of a distress message?**

*Answer.* Information must be sent in this order: name of the mobile station answering and its position, as shown below. A ship generally signals its position in latitude and longitude using figures for degrees and minutes with the words NORTH or SOUTH and one of the words EAST or WEST. The signal · — · — · — is used to separate the degrees from the minutes. True bearing and distance in nautical miles from a known place are given when this is possible.

As a rule, an aircraft in flight should furnish the same type of information, except that it may identify its position in relation to the nearest place, using words to indicate direction. Finally, the mobile station should give the speed at which it is proceeding towards the ship, aircraft, or other vehicle in distress.

Before sending the message, the station must be sure that it will not interfere with transmissions from other stations better situated to render assistance.

**2.215 Is it necessary that the authority of the master or person responsible for the vessel be obtained prior to sending information required following acknowledgement of a distress call?**

*Answer.* Yes. Such messages are sent only on the order of the master or person responsible.

**2.216 Is it desirable that care be taken to ensure that an acknowledgment to a distress message will not interfere with other acknowledgments from vessels better able to assist?**

*Answer.* Yes. If there is no doubt that the vessel in distress is not in the vicinity, a mobile station must wait a short interval of time before acknowledgment of the distress message to permit stations nearer to answer and acknowledge receipt without interference.

**2.217 Is a vessel that hears a distress message but is not in a posi-**

Alternatively, the name of the ship and the shore-station location may be used together with channel designations known to both stations.

**2.226 Is it permissible to communicate with coast stations or any other station on 2,182 kc except for safety purposes?**

*Answer.* Yes. The frequency of 2,182 kc is specified for calls, answers, and operating signals as well as conversation relating to safety. Except for distress or emergency messages, a single exchange of communications shall not exceed 3 min. Generally, 2,182 kc is used to establish communications that are continued on another designated frequency.

The frequency 2,182 kc can also be used for brief radio-operating signals and brief test signals. When the frequency is used for other than distress calls and distress traffic and urgency and safety signals and messages, the mean antenna power of the unmodulated carrier wave shall not exceed 100 watts.

**2.227 Give a typical procedure you might use to call a vessel when its identity is not known.**

*Answer.* The vessel should be called on 2,182 kc using some means of identification recognizable to the operator of the vessel called. The call sign of the calling vessel must be given.

*Example:* THIS IS WZ9199 CALLING THE VESSEL THAT JUST SIGNED OFF WITH KAA or THIS IS WZ9199 CALLING THE VESSEL AT ANCHOR NEAR BUOY SEVEN or THIS IS THE INCHCLIFFE CASTLE CALLING THE VESSEL PASSING BENEATH THE WILLIAMSBURG BRIDGE. COME IN PLEASE.

### SUPPLEMENTARY—COAST

**2.301 What daily attention should be given to the antenna tower lights at a radio station?**

*Answer.* A daily check on the operation of tower lights must be made not later than one hour after local sunset. The check can be made visually or by viewing an automatic indicator.

**2.302 What should be done in case of failure of the antenna tower lights at a radio station?**

*Answer.* If the tower lights have failed and the failure is not corrected within 30 min, report by telephone or telegraph immediately to the nearest Airways Communication Station or office of the Civil Aeronautics Administration. Further notification is required immediately upon resumption of normal illumination.

**2.303 How should station identification be made at a coast station using radiotelephony?**

*Answer.* Upon completion of each communication with any other station and at beginning and end of any other transmission, station identification by voice transmission in the English language must be made using the assigned call sign or a geographical location approved by FCC (such as BOSTON MARINE OPERATOR).

The call sign may be sent by tone-modulated Morse code by a licensed radiotelegraph operator or approved automatic device.

**2.304 If a licensed radio operator at the controls of a coast station observes obscene language being spoken by another person and transmitted through the facilities of the station, what action should he take?**

*Answer.* It is the duty of the operator to prevent transmission of obscene language. He must cut off modulation, warn the person speaking against this illegal use of radio facilities, and file a report with his employer giving details of any occurrence of such transmission.

**2.305 If a coast station hears a distress call from a mobile station, what action, if any, should the operator on duty take?**

*Answer.* When a coast station hears a distress call from a mobile station, it must cease all transmission that might interfere and listen for the distress message.

**2.306 Under what circumstances should a public coast station employing radiotelephony use a calling frequency in establishing a communication circuit with a ship or aircraft?**

*Answer.* A public coast radiotelephone station may use a calling frequency to establish a communication circuit with ship or aircraft stations when use of a different carrier frequency appears impracticable by reason of operating or equipment limitations of the mobile station.

**2.307 What type of radiotelephone communications must be handled free by a public coast station which normally charges for its service?**

*Answer.* No charge shall be made for transmission of distress messages and replies, relaying information about dangers to navigation, or messages in connection with safety of life and property at sea.

**2.308** When calling a mobile radiotelephone station but receiving no immediate reply, how often may a coast station using radiotelephony repeat the call?

*Answer.* Calling shall not continue for a period of more than 1 min in each instance. If the called station does not reply, it shall not be called again until after an interval of 3 min, except in an emergency.

**2.309** What is meant by "safety communication" in the maritime mobile service?

*Answer.* A safety communication is transmission or reception of distress, alarm, urgency or safety signals or any communication preceded by these signals or any radiocommunication which, if delayed, may adversely affect life or property. It is also an occasional test transmission necessary to determine if the radio equipment is in good working condition.

**2.310** What are the requirements with respect to log keeping at a coast station using radiotelephony?

*Answer.* A public coast station must maintain an accurate record containing such information as page number, date, call sign, operator signatures, time of making entries, time of watches, details of distress communications, names or call signs of vessels, reports of harmful interference, time checks, equipment failures, maintenance performed, and operation of tower lights, if any.

**2.311** Under what conditions may a coast station intervene in a distress situation?

*Answer.* A land station receiving a distress message must advise rescue authorities without delay. If it cannot render assistance, it must attract the attention of other stations that may be in a position to help. With approval of the authority responsible for the station, it may also transmit the autoalarm signal, the distress call, and the distress message.

**2.312** To what extent may a coast station using radiotelephony communicate with stations other than ship stations?

*Answer.* A coast station may communicate with any land station for the purpose of aiding safety communications to ship or aircraft stations. It may, upon application, transmit meteorological and marine navigational information to a designated fixed location when it is also

transmitting this information primarily to ship stations or may communicate with certain remote, isolated, fixed stations.

### SUPPLEMENTARY—AIRCRAFT

**2.401** What is indicated by the use of the word **BREAK** in a radiotelephone conversation?

*Answer.* The word **BREAK** indicates a separation between portions of a message.

**2.402** What is indicated by the word **ROGER** as a reply to a radiotelephone communication?

*Answer.* The word **ROGER** indicates that the entire preceding transmission has been received.

**2.403** What is indicated by the expression **WORDS TWICE** when transmitted by radiotelephone?

*Answer.* The expression **WORDS TWICE** is used to request the sending station to send every phrase or important word twice.

**2.404** What is indicated by the use of the words **READ BACK** in a radiotelephone communication?

*Answer.* The expression **READ BACK** is a request to repeat the message to the sending station to ensure that the receiving station has understood it word for word.

**2.405** For what purpose is the frequency 121.5 mc authorized to be used by an aircraft radio station?

*Answer.* The frequency 121.5 mc is a universal simplex channel for emergency and distress communications. It is available for emergency direction finding and is a means of establishing air-to-ground contact with lost aircraft.

**2.406** What is the national calling and working frequency for air-carrier aircraft?

*Answer.* The national calling and working frequency for air-carrier aircraft is 3,117.5 kc.

**2.407** In lieu of using a call sign, how may an aircraft telephone station be identified in the course of operation?

*Answer.* Air-carrier aircraft may use registration number or com-

pany flight identification instead of assigned radio call letters on radiotelephony. Private aircraft may use registration number; the ground station, after the first call, may initiate the practice of using only the last three characters of the full registration number.

**2.408 What types of communications or messages is an aircraft radiotelephone station authorized to transmit?**

*Answer.* Communications are limited at an aircraft station to the necessities of safe aircraft operation.

**2.409 When must an aircraft radio station and maintenance record be made available for inspection?**

*Answer.* Records must be made available upon request of an authorized representative of the FCC.

**2.410 How is the communication range of an aircraft radio station on a very-high frequency dependent upon the altitude of the aircraft?**

*Answer.* Communication range at VHF depends upon height above ground of the transmitter and receiver. For example, at 2,000 ft an airplane might be able to talk to a ground station about 60 miles away; at 8,000 ft the distance would be doubled, or about 120 miles.

**2.411 Why should an aircraft station avoid making unnecessary on-the-air tests?**

*Answer.* An aircraft station, especially in the air, should avoid unnecessary signals because it may thereby interfere with communications at a considerable distance. For instance, using VHF radio, an aircraft 100 miles east of a receiving station and flying at high altitude might completely obliterate signals from a lower-flying craft 60 miles to the west of the receiver.

**2.412 What is the normal calling procedure of a private aircraft for contacting a control tower?**

*Answer.* A private aircraft desiring to contact an airport control tower would usually address the desired tower on an appropriate frequency giving its registration number as identification. The procedure might be: TETERBORO TOWER. BEECHCRAFT 81769. DO YOU READ ME? OVER; to which the tower might reply, BEECHCRAFT 769, THIS IS TETERBORO. I READ YOU LOUD AND CLEAR. OVER.

**2.413** How should an air-carrier aircraft radiotelephone station normally be identified in operation in lieu of using the call sign?

*Answer.* An air-carrier aircraft may use its official aircraft registration number instead of call letters. Or it may use company flight identification if adequate records are kept to permit identification of individual aircraft.

**2.414** What is meant by a phonetic alphabet in radiotelephone communication?

*Answer.* A phonetic alphabet used in radiotelephone communication is a set of standard words, each of which represents one letter. The number NINE might be spelled NAN ITEM NAN EASY. See the Appendix for several phonetic alphabets in common use.

#### SUPPLEMENTARY—UNSPECIALIZED

**2.501** In making a ship-to-ship contact, except in an emergency involving safety, how long may a ship radiotelephone station continue calling in each instance?

*Answer.* Calling must not continue for more than 30 sec in each instance.

**2.502** Except in an emergency involving safety, if a ship radiotelephone station does not receive a reply after calling, how long must it wait before calling again?

*Answer.* The station must not be called again until 1 min has elapsed.

**2.503** How is a ship radiotelephone station required to be identified in connection with its operation?

*Answer.* By a call sign in the English language or by tone-modulated telegraphy either from an automatic device or keyed by a licensed radiotelegraph operator.

**2.504** Do public coast stations normally charge for forwarding messages reporting dangers to navigation?

*Answer.* No charges are to be made for handling messages concerning dangers to navigation.

**2.505** What are the requirements with respect to listening watch in a ship radiotelephone station during its hours of service in the 2,000–3,000-kc band?

*Answer.* Such a ship station must, during its hours of service, maintain watch for reception of class A3 emission on 2,182 kc whenever the station is not communicating on that or other channels.

**2.506** Is it necessary for all vessels having knowledge of distress traffic to follow the traffic even if they do not take part in it?

*Answer.* Yes. Moreover, such stations must not transmit on distress frequencies, but if able to follow distress traffic and still continue normal service without interfering with distress traffic, may do so.

**2.507** What is the proper form to use in acknowledging a distress message?

*Answer.* See 2.213 for the exact form.

**2.508** Is it necessary that the authority of the master or person responsible for the vessel be obtained prior to sending information required following acknowledgement of a distress call?

*Answer.* Yes. Every mobile station acknowledging receipt of a distress message must, on the order of the master or person responsible for the ship, aircraft, or other vehicle, transmit, as soon as possible, its name, its position, and the speed at which it is proceeding towards the vehicle in distress.

**2.509** Is a vessel which hears a distress message but is not in a position to assist required to take all possible steps to attract the attention of stations that might be in a position to assist?

*Answer.* Yes. Every possible effort must be made to obtain assistance.

**2.510** What radio channel or channels are used by ships for communicating by radiotelephone with the U.S. Coast Guard?

*Answer.* The frequency 2,182 kc is the international radiotelephone distress frequency for the maritime mobile service and is the only distress frequency to be used in the Great Lakes region. In the event of distress only, U.S. Coast Guard stations may be called on the government frequency 2,670 kc.

**2.511** Is it general practice for a ship to use 2,182 kc for establishing contact prior to communicating with a coast station on an appropriate public correspondence channel?

*Answer.* No. Although use of 2,182 kc is authorized, ships generally call on ship-shore channels authorized primarily for working.

**2.512 How often should station identification be made at a base or land radiotelephone station?**

*Answer.* Stations in the Public Safety Radio services are required to be identified by the assigned call signal. Each station identifies at the end of each transmission period or every 30 min, as desired. Mobile stations operating on the frequency of the base station need not identify; where base and mobile stations do not share a common frequency, one mobile station in each geographical area may transmit identification for the group.

**2.513 What entries must be made in the logs or records of radio stations required to have antenna tower lights?**

*Answer.* Entries must be made of the time lights are turned on and off manually; time of daily check if automatic alarm is not provided; nature of any failure with date and time it was noted; date, time, and nature of adjustments, repairs, or replacements; identification of CAA station notified; date and time notice of resumption of required illumination was given to CAA; date of trimonthly inspection of lighting system; and nature of adjustments or repairs.

**2.514 What attention should be given periodically to the antenna tower lights and associated apparatus at a radio station?**

*Answer.* Observe tower lights visually or by means of an indicator every 24 hours; inspect at least every three months all control devices, indicators, and alarm systems to ensure that such apparatus is functioning properly.

**2.515 What should be done in case of failure of the antenna tower lights at a radio station?**

*Answer.* If trouble is not corrected in 30 min, a report must be made by telephone or telegraph to the nearest CAA office or communications station immediately. Further notification must be given by similar means immediately upon resumption of required illumination.

**2.516 If a licensed radio operator at the controls of a radio station observes obscene or indecent language being spoken by another person and transmitted through the facilities of the station, what action should he take?**

*Answer.* It is the duty of the operator to prohibit such language by removing modulation or shutting off the carrier. He should warn the person speaking, citing the law against such language, and make a written report of the incident to the proper authority.

**2.517** If a coast station hears a distress call from a mobile station what action, if any, should the operator on duty take?

*Answer.* Immediately cease any transmission that might interfere and listen on the frequency of the distress call.

**2.518** Under what circumstances should a public coast station employing radiotelephony use a calling frequency in establishing a communication circuit with a ship or aircraft?

*Answer.* A public coast station may use the general calling frequency 2,182 kc for distress traffic; urgent messages concerning safety of a ship or person; safety messages particularly concerning navigation or meteorological warnings; calls and brief replies only when necessary to reach a mobile station; brief announcements of communications to be transmitted on another channel; and brief test signals.

**2.519** What type of radiotelephone communications must be handled free by a public coast station which normally charges for its service?

*Answer.* No charge may be made for distress messages and replies having to do with safety of life and property at sea or for transmission of information about dangers to navigation.

**2.520** When calling a mobile radiotelephone station but receiving no immediate reply, how often may a coast station using radiotelephony repeat the call?

*Answer.* Calling time shall not exceed 1 min, and the coast station must wait 3 min before calling again.

**2.521** What is meant by "safety communication" in the maritime mobile service?

*Answer.* A safety communication is one involving use of distress, alarm, urgent, or safety signals or one which, if delayed, may adversely affect safety of life or property. Also included are occasional test transmission or reception.

**2.522** What are the requirements with respect to log keeping at a coast station using radiotelephony?

*Answer.* Logs must contain entries covering page number, date, operator's name, time (GMT for all but Great Lakes and inland waters), time of safety watch, distress communications (including text of messages), all calls transmitted or received, interference reports, test

emissions, time check, equipment failures, installation and maintenance work, and operation of tower lights.

**2.523 Under what conditions may a coast station intervene in a distress situation?**

*Answer.* A land station receiving a distress message must immediately advise the rescue-operation agencies. Any station unable to help directly, but which has heard an unanswered distress message, must attract the attention of stations able to help.

**2.524 To what extent may a coast station using radiotelephony communicate with stations other than ship stations?**

*Answer.* Such station may communicate with any land station to facilitate safety communications to or from ship or aircraft stations. If it operates below 4,000 kc, it may communicate with marine fixed stations. It may handle public correspondence with certain aircraft stations. On occasion, it may be authorized to communicate with a designated remote station.

**2.525 What is indicated by the use of the word BREAK in a radiotelephone conversation?**

*Answer.* The word BREAK indicates a separation between parts of a message.

**2.526 What is indicated by the use of the word ROGER as a reply to a radiotelephone communication?**

*Answer.* The word ROGER means I HAVE COMPLETELY RECEIVED YOUR LAST TRANSMISSION.

**2.527 What is indicated by the expression WORDS TWICE when transmitted by radiotelephone?**

*Answer.* The expression WORDS TWICE is a request that each word or phrase be repeated twice.

**2.528 What is indicated by the use of the words READ BACK in a radiotelephone communication?**

*Answer.* The request READ BACK ensures that the receiving station exactly understands the message, since he must repeat it to the sending station.

**2.529 For what purpose is the frequency 121.5 mc authorized to be used by an aircraft radio station?**

*Answer.* The frequency 121.5 mc is the universal simplex channel for emergency and distress communications and is an emergency means of establishing air-to-ground contact with lost aircraft. It is not assigned, however, unless other similar frequencies are also available for normal communications.

**2.530 What is the national calling and working frequency for air-carrier aircraft?**

*Answer.* The national calling and working frequency for air-carrier aircraft is 3,117.5 kc.

**2.531 In lieu of using a call sign, how may an aircraft radiotelephone station be identified in the course of operation?**

*Answer.* Air-carrier aircraft may use radio call letters, aircraft registration number, or company flight identification. Private aircraft may use only radio call letters or aircraft registration number. An aeronautical public service station may use the aircraft station identification or an assigned telephone number.

**2.532 What types of communications or messages is an aircraft radiotelephone station authorized to transmit?**

*Answer.* Aircraft stations must limit themselves to communications concerning necessities of safe aircraft operation.

**2.533 When must an aircraft radio station and maintenance records be made available for inspection?**

*Answer.* All aviation-service stations must be made available for inspection, together with their records, upon request of authorized FCC representatives.

**2.534 Why should an aircraft station avoid making unnecessary on-the-air tests?**

*Answer.* Transmissions from aircraft on the ground using frequencies between 3 and 6 mc are likely to be received at great distances and may cause interference. On frequencies above 100 mc, transmissions made while the craft is airborne may interfere over shorter distances with signals from aircraft at lower altitudes even though the latter may be nearer the receiving station.

**2.535 What is the normal calling procedure of a private aircraft for contacting a control tower?**

*Answer.* A private aircraft would normally call the control tower on either 3,023.5 kc or a very-high frequency such as 122.5, 122.7, or 122.9 mc. The call would be addressed to the tower by name, and the registration number of the aircraft would probably be used as identification. In addition, the aircraft pilot would probably identify his plane as to type or make to aid visual identification by the tower operator.

**2.536 How should an air-carrier aircraft radiotelephone station normally be identified in operation in lieu of using the call sign?**

*Answer.* By aircraft registration number or company flight identification.

**2.537 What is meant by a phonetic alphabet in radiotelephone communication?**

*Answer.* A phonetic alphabet is a list of words each of which identifies a letter of the alphabet. (See Appendix.)

**2.538 For what purposes may the frequency 2,182 kc be used?**

*Answer.* The frequency 2,182 kc is the international radiotelephone distress frequency for the maritime mobile service. It may be used, preferably with A3 emission, for distress calls and traffic by ship and aircraft stations. It may also be used for the urgency and safety signals and appropriate messages following them, for brief radio operating signals and brief test signals, and as a calling frequency (mandatory on the Great Lakes) between ships.

**2.539 What precautions should be taken when a radio station is left unattended in a public place?**

*Answer.* An unattended radio station in a public place must be safeguarded by locks and/or enclosures to prevent unauthorized operation or danger of electrical shock or other injury. A radio station in an automobile, for example, should be turned off and the car locked up.

**2.540 What radio channel or channels are used by ships for communication by radiotelephone with the U.S. Coast Guard?**

*Answer.* Ships will normally call the Coast Guard on 2,182 kc. However, until this frequency is effectively guarded for distress calls in areas other than the Great Lakes, the government frequency 2,670 kc may be used.

## Element 3

# Basic Radiotelephone (Law)

**3.460** List four classes of stations which may be operated by a person holding a radiotelephone second-class license.

*Answer.*

1. Experimental (including experimental broadcast) using frequencies above 300 mc.
2. Remote pickup broadcast.
3. Studio-transmitter broadcast.
4. Noncommercial educational FM broadcast under 10 watts output.
5. Ship station telephone under 100 watts.
6. Coastal telephone.
7. Coastal harbor telephone.
8. Aircraft station telephone.

**3.461** List four classes of broadcast stations which may be operated by the holder of a radiotelephone second-class operator license.

*Answer.* See first four answers to 3.460.

**3.462** May the holder of a radiotelephone second-class operator license adjust and service or supervise the adjustment and servicing of any class of police radio station?

*Answer.* Yes, as long as such station is using type A3 or F3 emission.

**3.463** List four classes of stations, the equipment of which may be adjusted and serviced by the holder of a radiotelephone second-class operator license.

*Answer.*

1. Experimental using frequencies above 300 mc.
2. Noncommercial educational FM broadcast under 10 watts.
3. Police and Fire Radio Service.
4. Domestic Land Mobile Service.

**3.464** List three classes of stations which may not be serviced or adjusted by the holder of a radiotelephone second-class operator licensee.

*Answer.*

1. Commercial television broadcast.
2. Standard broadcast including FM.
3. Ship telegraph.
4. International broadcast.

**3.465** If an operator is employed at more than one station, how may the requirements of the Rules and Regulations of the FCC be met with respect to the posting of operator licensee?

*Answer.* The holder of an operator license who operates any station in which the posting of an operator license is not required may, upon filing application in duplicate accompanied by his license, obtain a verification card. This card may be carried on the person of the operator in lieu of the original operator license, provided the license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

The original license of each station operator shall be posted at the (principal) place where he is on duty or kept in his possession in the manner specified in the regulations governing the class of station concerned.

**3.466** Is it necessary that the original operator license be posted at an aeronautical station? An aircraft station? An airport station? A broadcast station? A ship station?

*Answer.* The original license of each station operator shall be conspicuously posted at the place he is on duty, or in the case of mobile units, either the license or verification card must be kept in his personal possession.

**3.467** What is a "verification card," and under what circumstances may it be used?

*Answer.* The holder of an operator license who operates any station in which the posting of an operator license is not required may, upon filing application in duplicate accompanied by his license, obtain a "verification card." This card may be carried on the person of the operator in lieu of the original operator license, provided the license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

**3.468** If a ship-telephone station is assigned the frequency of 2,738 kc, and the maximum tolerance is 0.02 per cent, what are the highest and lowest frequencies within the tolerance limits?

*Answer.* 2,738.55 and 2,739.45 kc.

**3.469** If an aircraft station is assigned the frequency of 3,117.5 kc, and the maximum tolerance is 0.01 per cent, what are the highest and lowest frequencies within the tolerance limits?

*Answer.* 3,117.81 and 3,117.19 kc.

**3.470** If a heterodyne frequency meter, having a calibrated range of 1,000 to 5,000 kc, is used to measure the frequency of a transmitter operating on approximately 500 kc by measurement of the second harmonic of this transmitter, and the indicated measurement was 1,008 kc, what is the actual frequency of the transmitter output?

*Answer.* 504 kc.

**3.471** Define the following types of emission: A0, A1, A2, A3, A4, A5.

*Answer.* Type A0. Waves the successive oscillations of which are identical under fixed conditions. (Standard frequency transmission.)

Type A1. Telegraphy on pure continuous waves which are keyed according to a telegraph code.

Type A2. Modulated telegraph. A carrier wave modulated at one or more audible frequencies, the audible frequency or frequencies or their combination with the carrier wave being keyed according to a telegraph code.

Type A3. Telephony. Waves resulting from the modulation of a carrier wave by frequencies corresponding to the voice, to music, or to other sounds.

Type A4. Facsimile. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of a fixed image with a view to its reproduction in a permanent form.

Type A5. Television. Waves resulting from the modulation of a carrier wave by frequencies produced at the time of the scanning of fixed or moving objects.

In addition to the continuous-wave emissions, which are classed as type A, there is type B emission (prohibited) composed of successive series of oscillations, the amplitude of which, after attaining a maximum, decreases gradually, the wave trains being keyed according to a telegraph code. (See also the Appendix.)

**3.472 In the adjustment of a radiotelephone transmitter, what precautions should be observed?**

*Answer.* Tests and experiments are permitted to certain stations provided they do not interfere with services of other stations. The operator should make certain before each test or adjustment that such interference will not take place.

**3.473 Explain the relation between the signal frequency, the oscillator frequency, and the image frequency in a superheterodyne receiver.**

*Answer.* The image frequency is as far above the oscillator frequency as the signal frequency is below the oscillator frequency or vice versa. The difference between the oscillator frequency and the signal frequency equals the intermediate frequency. The difference between the oscillator frequency and the image frequency also equals the intermediate frequency.

**3.474 What means are used to prevent interaction between the stages of a multistage audio-frequency amplifier?**

*Answer.* Adequate filters or a decoupling network ( $R$  and  $C$ ) must be provided where necessary, and the various components oriented to the optimum position for minimum reaction between components. Iron shields are useful in keeping down this reaction. It is sometimes useful to ground the shields.

**3.475 For what period of time must a log containing distress entries be retained?**

*Answer.* Logs containing distress entries shall be retained by the licensee until specifically authorized in writing by the FCC to destroy them.

**3.529** In accordance with the Rules and Regulations of the FCC, what is the primary standard for radio-frequency measurements of radio stations in the various services?

*Answer.* The primary standard of frequency for radio-frequency measurements shall be the national standard of frequency maintained by the National Bureau of Standards, Department of Commerce, Washington, D.C. The operating frequency of all radio stations will be determined by comparison with this standard or the standard signals of station WWV of the NBS. A table of frequencies and times of transmission is included in the Appendix.

**3.530** What is meant by carrier frequency? Carrier wave?

*Answer.* Carrier frequency is the frequency of the transmitter output when the modulation is zero. The carrier wave of a frequency-stabilized system is a wave generated at a point in the transmitting system and subsequently modulated by the signal intelligence.

**3.531** Define land station; base station; mobile station; experimental station; domestic fixed service; public correspondence; facsimile; fixed service; Industrial Radio Services; Industrial, Scientific, and Medical Equipment; Land Transportation Radio Services; Public Safety Radio Services; and Citizens Radio Service.

*Answer.* A "land station" (FL) is a station in the mobile service not intended for operation while in motion.

A "base station" (FB) is a land station in the land mobile service carrying on a service with land mobile stations.

A "mobile station" (MOZ) is any mobile station other than a television pickup station.

An "experimental station" (EX) is a station utilizing Hertzian waves in experiments, with a view to the development of science or technique. This definition does not include amateur stations.

"Domestic fixed service" is a fixed service intended for the transmission of information between points, all of which lie within the 48 states and the District of Columbia, except for the domestic haul of international traffic.

“Public correspondence” is any telecommunication that the offices and stations, by reason of their being at the disposal of the public, must accept for transmission.

“Facsimile” is a system of telecommunication for the transmission of fixed images, with a view to their reception in a permanent form.

“Fixed service” is a service of radiocommunication between specified fixed points.

“Industrial Radio Services” are any service of radiocommunication essentially operated by, and for the sole use of, those enterprises which for purposes of safety or other necessity require radiocommunication in order to function efficiently; the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

“Industrial, Scientific, and Medical Equipment” is radio transmitting equipment or other devices employing Hertzian waves for industrial, scientific, or medical purposes, including the transfer of energy by radio, and which are not intended to be used for radio communication.

“Land Transportation Radio Services” are any service of radio communication operated by, and for the sole use of, certain land transportation carriers; the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

“Public Safety Radio Service” is any service of radiocommunication essential to either the discharge of nonfederal governmental functions relating to public-safety responsibilities or the alleviation of an emergency endangering life or property; the radio transmitting facilities of which are defined as fixed, land, or mobile stations.

“Citizens Radio Service” is a radio communication service of fixed, land, or mobile stations, or combination thereof, intended for use by citizens of the United States for private or personal radiocommunication (including radio signalling, control of objects by radio, and other purposes).

**3.532** What are the frequency ranges included in the following frequency subdivisions: MF (medium frequency), HF (high frequency), VHF (very high frequency), UHF (ultrahigh frequency), and SHF (superhigh frequency)?

*Answer.* The frequency ranges, together with their abbreviations, are shown in the Appendix. They extend from VLF (very low frequency) to EHF (extremely high frequency)—10 kc to 300 kmc, respectively.

**3.533 Explain what is meant by the following types of emission: F0, F1, F2, F3, F4, and P0.**

*Answer.* Type F emissions are frequency or phase modulated, and type P emissions are pulsed. Type A emissions indicate amplitude modulation. The complete list of the various combinations is shown in the Appendix.

**3.534 What are the requirements for posting of operator license for (a) the operator performing duties other than, or in addition to, service or maintenance, at two or more stations, and (b) the operator performing service or maintenance duties at one or more stations?**

*Answer.* In the first case (a), the operator must post his license or permit of the diploma form at one such station and must post a verification card, Form 759, at all other such stations. An operator performing maintenance (b) must either post his license or have on his person a verification Form 758F, if the transmitter on which he is working is actually in operation. If the maintenance operator also performs operating duties, he must, of course, comply with the requirements for (a) above.

**3.535 If service or maintenance logs are required to be kept at a radio station, what entries are required to be entered in the log?**

*Answer.* Where a log or service records are required and when service is performed that may affect the proper operation of the station, the responsible operator must sign and date an entry in the log or maintenance record. The entries consist of details of work performed; his name and address; class, serial number, and expiration date of his license. If the operator is regularly employed at the station full time, it is required only that he give the details of the work performed.

**3.536 In communication services such as the Public Safety Radio Services, (a) what percentage of modulation is normally required when amplitude modulation is used for radiotelephony, and (b) what maximum frequency deviation arising from modulation is permitted when phase or frequency modulation is used for radiotelephony?**

*Answer.* For amplitude modulation (a), the percentage must normally be maintained about 70, but not to exceed, 100 per cent; for phase or frequency modulation (b), the maximum deviation must not exceed  $\pm 15$  kc from the unmodulated carrier.

**3.537** In communication services such as the Public Safety Radio Services, how often should (a) transmitter frequencies be measured, (b) transmitter power be measured, and (c) percentage of modulation be measured? What entries relative to technical measurements are required to be entered in station records?

*Answer.* The transmitter frequency (a) must be measured at initial installation; when any change is made that may cause a change in frequency or stability; at least every six months for crystal-controlled transmitters; and at intervals not over a month for transmitters without crystal control. Transmitter power (b) must be measured at initial installation; when any change is made that might increase power input; and at intervals not to exceed six months. The percentage of modulation (c) must be measured at initial installation; when any change is made that might affect the modulation and at intervals not to exceed six months.

The station records must contain a notation of these various check measurements and must show whether the plate current or cathode current has been used to determine input power. The name of a qualified measurement service, together with address and the name of the person making the measurement, must be shown. Power and percentage of modulation can be determined at a test bench, provided the load conditions are the same as in actual service. If this is done, it is also necessary to make a receiving test after the transmitter has been reinstalled to ensure that it is working properly.

## Element 4

# Advanced Radiotelephone (Law)

**4.130 Under what conditions may a broadcast station be operated at a reduced power other than specified in the station license?**

*Answer.* The license of a broadcast station shall maintain the operating power of the station within the prescribed limits of the licensed power at all times, except that, in an emergency when, owing to causes beyond the control of the licensee, it becomes impossible to operate with the full licensed power, the station may be operated at reduced power for a period of not to exceed 10 days, provided that the FCC and the inspector in charge shall be notified in writing immediately after the emergency develops.

**4.131 When the transmitter of a regular broadcast station is operated at 85-per cent modulation, what is the maximum permissible combined audio-harmonic output?**

*Answer.* When the transmitter is operated with 85 per cent modulation, not over 10-per cent combined audio-frequency harmonics shall be generated by the transmitter.

**4.132 How frequently must the auxiliary transmitter of a regular broadcast station be tested?**

*Answer.* The auxiliary transmitter shall be tested at least once each week to determine that it is in proper operating condition and that it is adjusted to the proper frequency, except that in case of operation in accordance with paragraph (c) of section 3.63, Rules & Regulations of the FCC, during any week, the test in that week may be omitted provided the operation under paragraph (c) is satisfactory. A record shall be kept of the time and result of each test operating under

paragraph (c). Tests shall be conducted between midnight and 9 A.M., local standard time. Paragraph (c) reads as follows:

c. The auxiliary transmitter shall be maintained so that it may be put into immediate operation at any time for the following purposes:

1. The transmission of the regular programs upon the failure of the main transmitter.
2. The transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed five days.
3. Upon request by a duly authorized representative of the FCC.

**4.133 For what purpose is an auxiliary transmitter maintained?**

*Answer.* An auxiliary transmitter is maintained for the following reasons:

1. For the transmission of the regular programs upon the failure of the main transmitter.
2. For the transmission of regular programs during maintenance or modification work on the main transmitter, necessitating discontinuance of its operation for a period not to exceed five days.

**4.134 If the plate ammeter in the last stage of a broadcast transmitter burned out, what should be done?**

*Answer.* No instrument indicating the plate current or plate voltage of the last radio stage, the antenna current, or the transmission-line current shall be changed or replaced without written authority of the FCC, except by instruments of the same make, type, maximum scale reading, and accuracy. Requests for authority to change an instrument may be made by letter or telegram giving the manufacturer's name, type number, serial number, and full-scale reading of the proposed instrument and the values of current or voltage the instrument will be employed to indicate. Requests for temporary authority to operate without an instrument or with a substitute instrument may be made by letter or telegram stating the necessity therefor and the period involved.

**4.135 The currents in the elements of a directive broadcast antenna must be held to what percentage of their licensed value?**

*Answer.* Five per cent.

**4.136** What are the permissible tolerances of power of a standard broadcast station?

*Answer.* From +5 to -10 per cent.

**4.137** What is meant by "equipment," "program," and "service" tests where these are mentioned in the Rules and Regulations of the FCC?

*Answer.* Upon completion of construction of a radio station in exact accordance with the terms of the construction permit, the technical provisions of the application therefor, and the rules and regulations governing the class of station concerned, but prior to filing of application for license, the permittee is authorized to test the equipment during the experimental period (12 midnight to local sunrise) as long as the construction permit remains valid. An informal application for such authority must be filed with the FCC at least two days prior to the equipment test.

When construction and equipment tests are completed in exact accordance with the terms of the construction permit, the technical provisions of the application therefor, and the rules and regulations governing the class of station concerned, and after an application for station license has been filed with the FCC showing the transmitter to be in satisfactory operating condition, the permittee is authorized to conduct service or program tests in exact accordance with the terms of the construction permit.

Request for authorization must be filed with the FCC at least ten days before beginning such program tests. The engineer in charge of the district in which the station is located shall also be notified. Program tests may usually continue until definitive action has been taken by the Commission on the application for station license.

**4.138** At broadcast stations using the direct method of computing output power, at what point in the antenna system must the antenna current be measured?

*Answer.* At the point of maximum current, which is as close to the ground as possible.

**4.139** For what purpose may a standard broadcast station, licensed to operate during daytime or specified hours, operate during the experimental period without specific authorization?

*Answer.* The term "experimental period" means that period of time between 12 midnight and local sunrise. This period may be used for experimental purposes in testing and maintaining apparatus by the licensee of any standard broadcast station, on its assigned frequency and with its authorized power, provided no interference is caused to other stations maintaining a regular operating schedule within such period. No station licensed for daytime or specified hours of operation may broadcast any regular or scheduled program during the experimental period.

**4.140** What is the allowable frequency deviation, in percentage, for a broadcast station operating on 1,000 kc?

*Answer.* Allowable deviation is 0.002 per cent at 1,000 kc. Since January 1, 1942, standard broadcast transmitters must not deviate more than 20 cycles above or below assigned frequency. Therefore at 1,000 kc;

$$\frac{20}{1,000 \times 10^3} = \frac{20}{10^6} = 20 \times 10^{-8} = 0.00002 = 0.002 \text{ per cent}$$

**4.141** What is the last audio-frequency amplifier stage which modulates the radio-frequency stage termed?

*Answer.* The last audio-frequency amplifier stage which modulates a radio-frequency stage is called the modulator stage.

**4.142** How frequently must a remote-reading ammeter be checked against a regular antenna ammeter?

*Answer.* Calibration shall be checked against the regular meter at least once a week.

**4.143** What factors enter into the determination of power of a broadcast station which employs the indirect method of measurement?

*Answer.* The operating power determined by indirect measurement from the plate-input power of the last radio stage is the product of the plate voltage ( $E_p$ ), the total plate current of the last radio stage ( $I_p$ ), and the proper factor ( $F$ ) as given by the following formula:

$$\text{Operating power} = E_p \times I_p \times F$$

The factor  $F$  varies from 0.25 to 0.80, depending on the type of modulation, class of amplifier, or type of tube used.

**4.144** What is the power that is actually transmitted by a regular broadcast station termed?

*Answer.* "Operating power." This refers to the power that is actually supplied to the radio station antenna.

**4.145** Are the antenna current, plate current, etc., as used in the Rules and Regulations of the FCC modulated or unmodulated values?

*Answer.* Unmodulated. "Plate-input power" means the product of the direct-plate voltage applied to the tubes in the last radio stage and the total direct current flowing to the plates of these tubes, measured without modulation. "Antenna current" means the radio-frequency current in the antenna with no modulation.

**4.146** With reference to broadcast stations, what is meant by the "experimental period"?

*Answer.* See 4.139.

**4.147** What percentage of modulation capability is required of a broadcast station?

*Answer.* A licensee of a broadcast station will not be authorized to operate a transmitter unless it is capable of delivering satisfactorily the authorized power with a modulation of at least 85 per cent. When the transmitter is operated with 85-per cent modulation, not over 10 per cent combined audio-frequency harmonics shall be generated by the transmitter.

**4.148** Define the "maximum-rated carrier power" of a broadcast station transmitter.

*Answer.* "Maximum-rated carrier power" is the maximum power at which the transmitter can be operated satisfactorily and is determined by the design of the transmitter and the type and number of vacuum tubes used in the last radio stage.

**4.149** Define the "plate-input power" of a broadcast station transmitter.

*Answer.* "Plate-input power" means the product of the direct-current plate voltage applied to the tubes in the last radio stage and the total direct current flowing to the plates of these tubes, measured without modulation. "Antenna current" means the radio-frequency current in the antenna with no modulation.

**4.150 Define "high-level" and "low-level" modulation.**

*Answer.* "High-level" modulation is modulation produced in the last radio stage of the system. "Low-level" modulation is modulation produced in an earlier radio stage than the final.

**4.151 What is the tolerance that is applied to the antenna currents in the various elements of a directional array?**

*Answer.* Five per cent.

**4.152 What is the frequency tolerance which must be maintained at the present time by a standard broadcast station?**

*Answer.* See 4.140.

**4.153 What is the frequency tolerance allowed an International broadcast station?**

*Answer.* 0.005 per cent.

**4.154 What is the required full-scale accuracy required in the ammeters and voltmeters associated with the final radio stage of a broadcast transmitter?**

*Answer.* Accuracy shall be at least 2 per cent of the full-scale reading.

**4.155 If a broadcast transmitter employs seven tubes of a particular type, how many spare tubes of the same type are required to be kept on hand in accordance with FCC regulations?**

*Answer.* Three, in accordance with the following schedule:

<i>Number of Tubes of Each Type Employed</i>	<i>Spares Required</i>
1 or 2	1
3 to 5	2
6 to 8	3
9 or more	4

**4.156** Describe the various methods by which a broadcast station may compute its operating power, and state the conditions under which each method may be employed.

*Answer.* After July 1, 1940, all broadcast stations shall employ the *direct-measurement method* of determining operating power. With this method, the antenna-input power (operating power) is determined by multiplying the antenna resistance by the square of the antenna current, both being measured at the base of the antenna, the point of maximum current.

In case of an emergency where the licensed antenna has been damaged or destroyed by storm or other cause beyond the control of the licensee, or pending completion of authorized changes in the antenna system, the *indirect measurement method* of determining operating power may be employed. With this method, the plate-input power to the last radio stage is taken as the operating power. (See 4.143.)

**4.157** What portion of the scale of an antenna ammeter having a square-law scale is considered as having acceptable accuracy for use at a broadcast station?

*Answer.* No scale division above one-third full-scale reading (in amperes) shall be greater than one-thirtieth of the full-scale reading.

*Example:* An ammeter meeting standard requirements and having a full-scale reading of 6 amperes is acceptable for reading currents from 2 to 6 amperes provided no scale division between 2 and 6 amperes is greater than  $\frac{1}{30}$  of 6 amperes, that is, greater than 0.2 ampere.

**4.159** Define "auxiliary broadcast transmitter" and state the conditions under which it may be used.

*Answer.* "Auxiliary transmitter" means a transmitter maintained only for transmitting the regular programs of a station in case of failure of or work on the main transmitter.

**4.160** What is the purpose of using a frequency standard or service independent of the transmitter-frequency monitor or control?

*Answer.* To assure that the transmitter is on the assigned frequency and within tolerance limits. It also permits a check upon the station monitor.

**4.163** When the authorized nighttime power of a standard broadcast station is different from the daytime power and the operating

power is determined by the "indirect" method, which of the efficiency factors established by FCC rules is used?

*Answer.* Use the efficiency factor given for the maximum licensed power of the station.

**4.242** How is the operating power of an FM broadcast station determined?

*Answer.* The operating power of FM broadcast stations shall be determined by the indirect method. This is the product of the plate voltage ( $E_b$ ) and the plate current ( $I_b$ ) of the final radio-frequency stage, and the efficiency. The efficiency is defined by the FCC as a factor  $F$ , which shall be established by the specific transmitter manufacturer.

$$\text{Operating power} = E_b \times I_b \times F$$

The  $F$  factor is generally in the vicinity of 65 per cent.

**4.243** If an FM broadcast station uses a total of five tubes of a given type at the transmitter, what is the minimum number of spare tubes of this type required at the transmitter?

*Answer.* A minimum of two will be required. The spare tube requirements specified by the FCC are shown in 4.155.

**4.244** What is the required frequency range of the indicating device on the frequency monitor at an FM broadcast station?

*Answer.* The range of the indicating device on an FM frequency monitor shall be at least from 2,000 cycles below to 2,000 cycles above the assigned center frequency.

**4.245** What is the audio-frequency range that an FM broadcast station is required to be capable of transmitting?

*Answer.* From 50 to 15,000 cycles per second.

**4.246** How wide is an FM broadcast channel?

*Answer.* The total bandwidth of a frequency channel is 200 kc. Channels for FM broadcast stations begin at 88.1 mc and continue in successive steps of 200 kc to and including 107.9 mc.

**4.247** What frequency swing is defined as 100 per cent modulation for an FM broadcast station?

*Answer.* A frequency swing of  $\pm 75$  kc is defined as 100 per cent modulation in an FM broadcast transmitter.

**4.248 What is the tolerance in operating power of FM broadcast stations?**

*Answer.* The operating power tolerance in an FM broadcast station according to FCC standards is +5 per cent - 10 per cent.

Standard power ratings and operating power range of FM broadcast transmitters must be according to the table below.

<i>Standard Power Rating</i>	<i>Operating Power Range</i>
250 watts	250 watts or less
1 kw	250 watts to 1 kw
3 kw	1-3 kw
10 kw	3-10 kw
25 kw	10-25 kw
50 kw	10-50 kw
100 kw	50-100 kw

**4.249 What is the meaning of the term "center frequency" in reference to FM broadcasting?**

*Answer.* Center frequency is referred to in FM broadcasting as the assigned unmodulated radio-frequency wave. It is analogous to the unmodulated carrier frequency in AM transmitters. It may also be defined as the "average frequency" of the emitted wave when modulated by a sinusoidal signal.

**4.250 Exclusive of monitors, what indicating instruments are required in the transmitting system at an FM broadcast station?**

*Answer.* Accurate indicating instruments to measure plate voltage, plate current, transmission-line currents, and antenna currents. Recording instruments for plotting plate-current and plate-voltage graphs are sometimes used. The indicating instruments required to fulfill the above conditions are as follows:

1. A-C and d-c voltmeters.
2. A-C and d-c ammeters.
3. D-C milliammeters.
4. Radio-frequency ammeters (thermocouple types).

**4.251 What is the required accuracy of instruments indicating the plate current and the plate voltage of the last radio stage or the transmission-line current or voltage at an FM broadcast station?**

*Answer.* Instruments indicating plate current or plate voltage shall have linear scales and those indicating transmission-line current or voltage shall meet the following specifications:

1. Instruments having linear scales shall meet the requirements specified in 4.215 and 4.217.

2. Instruments having logarithmic or square-law scales shall meet the following requirements:

- a. The length of the scale shall be not less than  $2\frac{3}{10}$  inches, as for linear scale instruments.
- b. Accuracy shall be at least 2 per cent of the full-scale reading, as for linear scale instruments.
- c. Full-scale reading shall not be greater than three times the minimum normal indication.
- d. No scale division above one-third full-scale reading (in amperes) shall be greater than one-thirtieth of the full-scale reading.

3. Radio-frequency instruments having expanded scales.

- a. Shall meet requirements 2(a) and 2(b) above.
- b. Full-scale reading shall not be greater than five times the minimum normal indication.
- c. No scale division above one-fifth full-scale reading (in amperes) shall be greater than one-fiftieth of the full-scale reading.
- d. The meter face shall be marked with the words "expanded scale" or the abbreviation thereof (E.S.).

**4.252** What is the frequency tolerance of an FM broadcast station?

*Answer.* A frequency tolerance of  $\pm 2,000$  cycles of the assigned center frequency is allowed.

**4.253** What is the meaning of the term "frequency swing" in reference to FM broadcast stations?

*Answer.* "Frequency swing" is the term applied to the instantaneous departure of the frequency of the transmitted wave from the center frequency during the process of modulation, as defined by FCC. Engineers prefer to call this "deviation" and refer to the total deviation each side of the carrier as "swing." For example, deviation of an FM broadcast station is  $\pm 75$  kc, the swing is 150 kc.

**4.278** If standard broadcast emissions are classified as A3 emission, what is the classification of television broadcast video emissions?

*Answer.* Television broadcast emissions are classified as type A5.

**4.279** What is the range of audio frequencies that the aural transmitter of a television broadcast station is required to be capable of transmitting?

*Answer.* A band of audio frequencies from 50 to 15,000 cycles.

**4.280** What is meant by 100 per cent modulation of the aural transmitter at a television broadcast station?

*Answer.* A frequency swing of  $\pm 25$  kc is considered 100 per cent modulation.

**4.281** What is the frequency tolerance for broadcast STL stations?

*Answer.* The licensee of each broadcast STL (studio-to-transmitter link) or FM intercity relay station must maintain the operating frequency of the station within  $\pm 0.005$  per cent of the assigned frequency.

**4.282** What are the licensed operator requirements for a television broadcast station? For a frequency-modulated broadcast station? For a 5-kw nighttime directional standard broadcast station?

*Answer.* The operator of a television broadcast station must hold a radiotelephone first-class license and must be on duty at the transmitter and in actual charge of it.

A first-class radiotelephone operator must be in actual charge of an FM broadcast station at the transmitter location or remote control point. However, stations authorized for 10-kw output or less may be operated by a person holding any commercial radio-operator license except an aircraft radiotelephone or temporary limited radiotelegraph second-class. The equipment must be ordinarily incapable of off-frequency operation by misadjustment of operating controls. Adjustment of equipment must be under immediate supervision of a first-class radiotelephone operator.

A 5-kw nighttime directional standard broadcast station requires a radiotelephone first-class operator in actual charge at the transmitter location or remote control point.

**4.283 Under what conditions may a standard broadcast station be operated by remote control?**

*Answer.* A station authorized for nondirectional operation with power of 10 kw or less may, by authorization of FCC, be operated by remote control.

Equipment must be installed and protected to prevent operation by unauthorized persons. It must be designed so that faults will automatically shut down the transmitter. An operator at either the transmitter or the control point must be able to perform all functions required by FCC rules.

**4.284 Within what limits is the operating power of a television aural or visual transmitter required to be maintained?**

*Answer.* Except in emergencies, the operating power of these transmitters shall be maintained at authorized power and never more than 10 per cent above or 20 per cent below authorized power.

## Element 5

# Radiotelegraph (Law)

**5.01 List three classes of stations which may not be operated by the holder of a radiotelegraph third-class operator permit.**

*Answer.* A radiotelegraph operator third class may not operate broadcast stations, ship stations licensed to use A3 or F3 emission for communication with coastal telephone stations, radiotelegraph stations on board vessels required to be equipped by treaty or statute, or coastal telegraph or marine-relay stations open to public correspondence.

**5.02 Is the holder of a radiotelegraph third-class operator permit authorized to make technical adjustments to a radiotelephone transmitter? To a radiotelegraph transmitter?**

*Answer.* Such operator may make only operational adjustments to a radiotelephone transmitter that will not result in improper operation or any unauthorized radiation. He may not make technical adjustments to a radiotelegraph transmitter. Needed adjustments are made in the presence of or by an operator holding a first-class or second-class license.

**5.03 Where should the operator on duty at a manually operated radiotelegraph station normally post his operator license or permit?**

*Answer.* He must post it at the transmitter, or at the operating position if that is at a different location.

**5.04 What are the requirements for station identification at radiotelegraph stations in the Public Safety Radio Services?**

*Answer.* Each station in these services must transmit its call signal at the end of each transmission (or exchange of transmissions), or once each fifteen minutes. Mobile units communicating with a base

station on the same frequency may use a unit identifying signal (like "car 15" or "pumper 4") each time if such identifier is on file at the base station. Mobile units on a different frequency may use an identifier during each exchange, together with the assigned call of either the base station or the mobile unit. Automatic stations are usually exempted from this requirement on request.

**5.05 What is the radiotelegraph distress signal? Urgency signal? Safety signal?**

*Answer.* The distress signal is  $\overline{SOS}$ , sent as one character. The urgency signal is XXX. The safety signal is TTT.

**5.06 The speed of radiotelegraph code transmission in cases of distress, urgency, or safety must not, in general, exceed what speed?**

*Answer.* In general, such messages should not be sent at a speed exceeding 16 words per minute.

**5.07 What radiotelegraph signal is generally used in a call "to all stations?"**

*Answer.* The call to all stations is CQ.

**5.08 What is meant by the following radiotelegraph operating signals?**

R,  $\overline{AS}$ ,  $\overline{IMI}$ , C,  $\overline{BT}$ , K,  $\overline{AR}$ ,  $\overline{VA}$ , DE

*Answer.* R means "understood" or "received ok."

$\overline{AS}$  means "wait."

$\overline{IMI}$  is a question mark or indication that something is not understood (when used after a Q signal, it asks a question).

C means "yes."

$\overline{BT}$  is a break or space.

K is an invitation to transmit, usually following a call sign or end-of-message operating signal.

$\overline{AR}$  indicates the end of a message, even though more messages may be coming during the whole transmission.

$\overline{VA}$  is the end of a transmission or series of them, sometimes termed the "Signoff."

DE comes from the French meaning "from" and is used between the call letters of the called station and the calling station.

**5.09** If a radiotelegraph operator makes an error in transmitting message text, how does he indicate that an error has been made?

*Answer.* By sending a series of dots, officially eight, although the number may vary in actual practice.

**5.10** When testing a radiotelegraph transmitter, what signals are generally transmitted?

*Answer.* Usually a series of V's, three groups of three, followed by the station call letters three times.

**5.11** In order to avoid confusion in transmitting numbers involving a fraction, how should such numbers be transmitted? Give an example of such a number, showing how it should be transmitted.

*Answer.* The ordinary fraction bar is sent as  $\overline{\text{TF}}$ . When a fraction and whole number must be sent, the hyphen  $\overline{\text{BA}}$  is used. For example,  $1\frac{3}{2}$  is sent as

$$1\overline{\text{BA}}3\overline{\text{TF}}32$$

**5.12** What is meant by the preamble in a radiotelegraph message? What information is usually given in the preamble?

*Answer.* The preamble of a radiotelegraph message is that part that precedes the actual message itself. The preamble usually includes a prefix denoting the type of message, the serial number, the check or word count, the office of origin and its call letters, the time of filing, the day of the month on which it was filed, and routing instructions. The sender is charged only for the part of the telegram that comes after the preamble.

**5.13** In addition to the preamble, what parts does a radiotelegraph message contain?

*Answer.* A complete message is made up of preamble, address, text, and signature.

**5.14** What is meant by a service prefix or indicator in a radiotelegraph message?

*Answer.* A service prefix, like RP or OBS, indicates the type of message and the handling it must be given.

**5.15** What does "word count," or "check," mean in a radiotelegraph message?

*Answer.* Word count, or check, as given in the preamble, indicates the number of words that are charged for in the part of the message after the preamble. When certain service indicators showing how the message is to be handled appear in the preamble, they are also subject to charge.

**5.16** At what time, or times, does the serial numbering of radio messages begin? Does the period of numbering vary in some services?

*Answer.* Messages are numbered beginning with Nr 1 at 0000 midnight, GMT. In a purely local service, message numbering may begin at midnight, local standard time.

**5.17** Code or cipher groups are often used in radiotelegraph messages for what purpose?

*Answer.* Code or cipher groups are used sometimes for purposes of secrecy, to conserve charges in transmitting intelligence that would otherwise require a greater amount of plain language, or, as in the weather code, to reduce the amount of time necessary to disseminate essential public information.

**5.18** Immediately following the transmission of a radiotelegraph message containing figures or odd symbols, why are such figures sometimes collated?

*Answer.* The amount of information in figures and odd symbols is usually greater than that in plain language, and errors are less easily detected. For this reason, such symbols are collated or confirmed to ensure accuracy.

**5.19** If receiving conditions are bad and you desire that the transmitting station send each word or group twice to facilitate reception, what operating signal would be appropriate to use?

*Answer.* Transmit each word or group twice; QSZ.

**5.20** In general, what is the purpose of a service message in radiotelegraph communication?

*Answer.* A service message (SVC) is one that is sent from one station to another and concerns a message already initiated, such as reporting that a message cannot be delivered or requesting further information on it.

**5.21 Why are Q signals or other arbitrary selected procedure signals used in radiotelegraph communications?**

*Answer.* By their shortness and universal use, these special signals save a great deal of operating time. They are also distinctive and cannot be confused with message content.

**5.22 What is meant by the following signals: QRA, QRM, QRN, QRT, QRZ, QSA, QSV, QUM, QRL?**

*Answer.* As questions, these signals are followed by a query signal IMI. Without, they mean, respectively: the name of my station is \_\_\_\_; I am being interfered with; I am troubled by static; stop transmission; you are being called by \_\_\_\_; the strength of your signals is \_\_\_\_ (1 to 5); transmit a series of V's; distress traffic is ended; I am busy. (See also the complete list of Q signals in the Appendix.)

**5.23 If the signal strength of a radiotelegraph signal is reported on a scale of 1, 2, 3, 4, 5, what scale number would indicate a very strong signal? What scale number would indicate a very weak signal?**

*Answer.* High numbers indicate strong signals; QSA 5 is the strongest. Low numbers indicate weak signals; QSA 1 means a scarcely perceptible signal.

**5.24 If, upon being called by another station, a called station is busy with other traffic, what should the operator of the called station do?**

*Answer.* He should so indicate (QRL) and also ask the calling station to wait (QRX) or (AS) a specified number of minutes or until a specified time. Distress or urgent calls take precedence over other operations.

**5.25 Describe a procedure of radiotelegraph transmission in which one station calls another. Give an example.**

*Answer.* If WLKH is calling KNIV, the calling procedure would be as follows:

KNIV, KNIV, KNIV DE WLKH, WLKH, WLKH K

**5.26 Describe a procedure of radiotelegraph transmission in which one station answers the call of another. Give an example.**

*Answer.* If KNIV hears the call of WLKH, he answers as follows:

WLKH, WLKH, WLKH DE KNIV, KNIV, KNIV R K

**5.27** What is meant by the statement: "A station is open to public correspondence?"

*Answer.* Such a station, being at the disposal of the public, must accept suitable messages for transmission.

**5.28** Should the speed of transmission of radiotelegraph signals be in accordance with the desire of the transmitting or receiving operator?

*Answer.* The transmitting operator must adjust his speed of transmission in accord with the desire of the receiving operator.

**5.29** After long periods of listening to a CW telegraph signal of constant tone, what adjustment can the operator make to a radio receiver to relieve hearing fatigue?

*Answer.* He can adjust the setting of the beat-frequency oscillator to give a different or more pleasing pitch, or he can slightly detune a tuned-radio-frequency (TRF) receiver to accomplish the same effect. Retuning a superheterodyne instead of adjusting the beat oscillator will accomplish the effect but may result in a slight loss in sensitivity.

**5.30** What is meant by break-in operation at a radiotelegraph station?

*Answer.* Break-in operation means an arrangement of equipment so that the operator can hear signals from the other station between letters or even between the intraletter spacings. If the other station wishes to break the sending, he can therefore do so without waiting for the conclusion of a transmission.

**5.31** How should the automatic volume-control switch be set for reception of CW radiotelegraph signals on a communications receiver designed for both radiotelephone and radiotelegraph reception?

*Answer.* It is generally desirable to turn the automatic volume-control switch off when receiving CW signals and maintain the radio-frequency gain manually. On some receivers, the AVC can be left

on, but the receiver will block on strong local signals, particularly if the gain control is set high.

**5.32 Explain the use of the crystal-filter switch on a communications receiver.**

*Answer.* A crystal filter is often provided on a communications receiver to narrow the passband of the receiver, thereby reducing the effects of noise and interfering signals on adjacent frequencies. When it is desired to use the crystal filter, the switch is turned on and the desired signal tuned in until it is at maximum strength. If the pitch of the signal is not satisfactory at maximum signal strength, the beat-frequency oscillator is then adjusted to obtain the proper pitch. The tuning at maximum signal is very critical. A phasing control is often furnished with the crystal filter. When this control is manipulated, it is often possible to get a better ratio of desired-to-undesired signal strength.

**5.33 What adjustment should be made to a radiotelegraph receiver if the receiver "blocks" on the reception of strong signals?**

*Answer.* The automatic volume control should be turned off and the radio-frequency gain reduced until the signal is received without blocking.

**5.34 Describe how to adjust a communications radio receiver for the reception of weak CW signals.**

*Answer.* Most operators find that it is desirable to increase the audio-amplifier gain to maximum and raise the radio-frequency gain to sufficient level to copy the weak CW signals. The beat-frequency oscillator must be on and the AVC off.

**5.35 How should a radiotelegraph receiver be adjusted for the reception of type A2 emissions?**

*Answer.* Although the beat-frequency oscillator can often be left on, it is generally more satisfactory to turn it off when receiving tone-modulated (A2) telegraph signals. In other respects, the receiver is generally adjusted as it would be for reception of radiotelephone signals. If there is danger of blocking, especially from the local transmitter during break-in, the AVC should be turned off.

**5.36** Sometimes a given radiotelegraph transmitting station can be heard at more than one place on the tuning dial of a receiver. Is this always an indication that the station is transmitting on more than one frequency?

*Answer.* No. The transmitter signal may be beating with some locally generated oscillation in the receiver. Images, having a frequency for which the receiver is tuned, plus twice the intermediate frequency, are a most frequent source of unwanted signal in superheterodyne receivers.

**5.37** How should a manual radiotelegraph transmitting key be adjusted for good operation? Is the adjustment always the same for slow as it is for high speed?

*Answer.* The adjustment of a transmitting key is mostly a matter of operator preference. However, it should generally be adjusted so that the contacts are about  $\frac{1}{32}$  in. apart and have sufficient tension to break the contact sharply, but not so much as to tire the hand. Although the adjustments are essentially the same for all sending speeds, some fast operators tend to keep the contacts close together and the spring tension light so as to have the key more flexible to manipulate. They tend to depress and raise the key manually rather than to punch it and allow the spring to return it.

**5.38** Describe how an automatic key, or "bug," should be properly adjusted to send good readable radiotelegraph signals.

*Answer.* A bug key has a multiplicity of adjustments, most of them interdependent. For best readability, the bug should be adjusted for the speed at which most sending is to be done. The main consideration is to transmit dots and dashes in such a relationship that the dash is equal to three dots. The adjustable weight on the dot-forming arm has the greatest effect upon dot speed. The length of the dot is determined both by the arc of swing of the arm and upon the dot-contact adjustment. At slow speeds, the dots should ideally be longer in length than they are at high speeds. The various tension, travel, and contact adjustments for the dash portion should then be adjusted until the operator has no trouble forming perfect characters at the chosen speed. A bug adjusted for high speed will sound choppy at slow speed, making it difficult for inexperienced receiving operators. A slow bug at high speed will send dashes that are nearly the same length as the dots and will similarly cause copying difficulties.

## Element 6

# Advanced Radiotelegraph (Law)

**6.511** What is the definition of "type B" emission?

*Answer.* The "type B wave" may be defined as a damped wave. A damped wave is one in which the energy decreases progressively with each oscillation until the wave train dies out. It is the type of wave generated by the spark-gap radio transmitter.

**6.512** Define type A1, A2, A3, and A4 emission.

*Answer.* See 3.471, 6.629 and table in the Appendix.

**6.513** In the aeronautical mobile service, what is the maximum period of time that operation of 333 kc is permitted?

*Answer.* In no case, in the aeronautical mobile service, must the work on 333 kc, (900 meters) exceed 5 min.

**6.514** Who may authorize tests or experiments by other than mobile stations?

*Answer.* The FCC inspector in charge of the district in which the transmitter is located.

**6.515** What is the maximum period of time during which test V's may be transmitted for purposes of adjusting a transmitter?

*Answer.* When it is necessary to make test signals, either for the adjustment of a transmitter before transmitting the call or for the adjustment of a receiver, these signals must not last more than 10 sec, and they must be composed of a series of V's followed by the call signal of the station transmitting for the tests.

**6.516** In all cases other than those in which the transmitter output must be maintained at a fixed value, what amount of power should be employed for routine communications?

*Answer.* In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

**6.517** What is the radiotelegraph urgency signal?

*Answer.* In radiotelegraph, the urgency signal shall consist of the group XXX transmitted three times, with the letters of each group, as well as the consecutive groups, well separated; it shall be sent before the call.

**6.518** What is the urgency signal for radiotelegraph use in the aeronautical service?

*Answer.* In the aeronautical service, the urgency signal XXX shall be used in radiotelegraphy and PAN in radiotelephony to indicate that the aircraft transmitting it is in trouble and is forced to land but that it is not in need of immediate help. These signals should, as far as possible, be followed by a message giving additional information.

**6.519** What is the meaning of the spoken expression MAYDAY?

*Answer.* In radiotelephony, the distress signal shall consist of the spoken expression MAYDAY (corresponding to the French pronunciation of the expression *m'aider*).

**6.520** In radiotelegraphy, what is the safety signal?

*Answer.* In radiotelegraphy, the safety signal shall consist of the group TTT, transmitted three times, with the letters of each group, as well as the consecutive groups, well separated. This signal shall be followed by the word DE and three transmissions of the call signal of the station sending it. It announces that this station is about to transmit a message concerning the safety of navigation or giving important meteorological warnings.

**6.521** What is the maximum transmission speed to be used in connection with distress, emergency, or safety transmissions?

*Answer.* When distress, emergency, or safety is involved, the telegraph transmission speed, in general, must not exceed 16 words per minute.

**6.522 What is the general call "to all" stations?**

*Answer.* Two types of call signals "to all" shall be recognized:

1. The CQ call followed by the letter K.
2. The CQ call not followed by the letter K.

**6.523 What is the radiotelephone urgency signal?**

*Answer.* In radiotelephony, the urgency signal shall consist of three transmissions of the expression PAN (corresponding to the French pronunciation of the word *panne*); it shall be transmitted before the call.

**6.524 What is the radiotelegraph distress signal?**

*Answer.* In radiotelegraphy, the distress signal shall consist of the group  $\dots - - - \dots$  (SOS) transmitted as one signal, in which the dashes must be emphasized so as to be distinguished clearly from the dots.

**6.525 What classes of stations may be operated by the holder of a third-class radiotelegraph license?**

*Answer.* Any station while using type B, A0, A1, A2, A3, or A4 emission, provided that, in the case of equipment designed for and using type A3 or A4 emission,

1. Such operator is prohibited from making adjustments that may result in improper transmitter operation.
2. The equipment is so designed that none of the operation necessary to be performed during the course of normal rendition of service may cause off-frequency operation or result in any unauthorized radiation.
3. Any needed adjustments of the transmitter which may affect proper operation of the station are regularly made by or in the presence of an operator holding a first- or second-class license, either telephone or telegraph, who shall be responsible for the proper operation of the equipment.

*Exceptions:*

1. The permit is not valid for the operation of any of the various classes of broadcast stations other than a relay broadcast station.

2. The permit is not valid for the operation of a ship station licensed to use type A3 emission for communication with coastal telephone stations.

3. The license is not valid for the operation of a radiotelegraph station on board a vessel required by treaty or statute to be equipped with a radio installation.

4. The license is not valid for the operation of any ship telegraph, coastal telegraph, or marine-relay station open to public correspondence.

**6.526 For what period of time must a station log, which contains entries incident to a disaster, be retained?**

*Answer.* Logs containing distress entries shall be retained by the licensee until specifically authorized by the FCC to destroy them.

**6.527 What is the meaning of "frequency tolerance"?**

*Answer.* The amount of frequency variation allowed under the regulations of the FCC for the particular class of station.

**6.528 Under what circumstances may a station be operated by an unlicensed person?**

*Answer.* The actual operation of all licensed transmitting apparatus must be carried on by a licensed operator. However, it is provided that the FCC, if it finds that the public interest, convenience, or necessity will be served thereby, may waive or modify the provisions requiring the licensed operator, except for stations where licensed operators are required by international agreement and for safety; broadcast stations; and stations operated as common carriers below 30 mc.

**6.529 If an operator is employed at more than one station, how may he comply with the rule requiring the posting of operator licenses?**

*Answer.* The holder of an operator license who operates any station in which the posting of an operator license is not required may, upon filing application in duplicate, accompanied by his license, obtain a verification card. This card may be carried on the person of the operator in lieu of the original operator license, provided the license is readily accessible within a reasonable time for inspection upon demand by an authorized Government representative.

**6.530** If, upon being called by another station, a called station is unable to proceed with the acceptance of traffic, what should the operator of the called station do?

*Answer.* If the station called is prevented from receiving, it shall reply to the call as indicated in the Regulations, but it shall replace the letter K by the signal  $\cdot - \cdot \cdot \cdot$  (wait), followed by a number indicating in minutes the probable duration of the wait. If this probable duration exceeds 10 min (5 min in the aeronautical mobile service), a reason must be given therefor.

**6.531** What is the definition of a "station open to public service"?

*Answer.* A station open to public correspondence at published rates, that is, a paid or toll message service. Such a station may transmit either by radiotelegraph or radiotelephone.

**6.532** Under what circumstances may the FCC authorize the remote control of a radiotelegraph transmitter, with the operator at a point other than the location of the transmitter proper?

*Answer.* The FCC may modify the rule requiring an operator on duty at the place where the transmitter is located, provided that, upon proper application, a showing is made that such operator or operators may be on duty at the control station in lieu of the place where the transmitting apparatus is located.

In the case of two or more stations, except amateur and broadcast, using frequencies above 30,000 kc only, a licensed radio operator of any class, except amateur or holder of restricted radiotelephone or radiotelegraph operator permit, who has the stations within his effective control, may be on duty at any point within the communication range of such stations in lieu of the transmitter location or control point during the actual operation of the transmitting apparatus.

**6.533** How is an experimental station restricted with regard to message traffic?

*Answer.* Experimental stations shall not be used to conduct general message traffic of any kind, to demonstrate equipment for prospective sales purposes, to transmit programs for direct entertainment, to transmit the programs of any other station, except in conjunction with experimental programs, or to render any commercial communication

service or communications involving advertising, either directly or indirectly, subject to specific limitations and restrictions which will be prescribed in individual cases by the FCC. This authority will be granted only for special reasons to obtain information or data which give promise of being of benefit to the radio art.

**6.534 Describe the procedure of a radiotelegraph transmission in which one station calls another.**

*Answer.* The call shall consist of the following:

1. The call signal of the station called transmitted not more than three times.
2. The word DE.
3. The call signal of the calling station transmitted not more than three times.

**6.541 Who may authorize tests or experiments by stations other than mobile stations?**

*Answer.* See 6.514.

**6.600 What is the primary standard of frequency for radio-frequency measurements for all licensed radio stations?**

*Answer.* The primary standard of frequency for radio-frequency measurements shall be the national standard of frequency maintained by the NBS, Washington, D.C. The operating frequency of all stations will be determined by comparison with the NBS standard signal station WWV. A schedule of the various standard frequency transmissions and their times is given in the Appendix.

**6.767 The time indications of what zone shall be used in making log entries with respect to the observance of the international silent period?**

*Answer.* The time of making an entry shall be shown opposite the entry and shall be expressed in Greenwich mean time (GMT, counted from 00:00 to 24:00 o'clock, beginning at midnight). The first entry in each hour shall consist of four figures; additional entries in the same hour may be expressed in two figures by omitting the hour designation. The abbreviation "GMT" shall be marked at the head of the column in which the time is entered.

*Examples:*

Local time (EST)	EST by 24-hr notation	Corresponding GMT
12 midnight.....	0000	0500
12:30 A.M.....	0030	0530
6:00 A.M.....	0600	1100
12:00 noon.....	1200	1700
1:00 P.M.....	1300	1800
4:00 P.M.....	1600	2100
11:59 P.M.....	2359	0459 (next day)

**6.768 Under what circumstances must log entries be made regarding the observance of the International Silent Period?**

*Answer.* During the period a watch is maintained by an operator, an entry shall be made twice per hour stating whether or not the international silent period was observed. In addition, entries shall be made indicating any signals or communications heard on 500 kc (410 kc on the Great Lakes) during this period. If no signals are heard on 500 kc (410 kc on the Great Lakes), an entry to that effect shall be made. The use of rubber stamps for making entries to show observation of the silent period is not authorized.

**6.769 At what time(s) are routine transmissions forbidden in the bands of 480 to 520 kc?**

*Answer.* In order to increase safety of life at sea (ships), and over the sea (aircraft), all the stations of the maritime mobile service which normally listen on the waves of the authorized bands between 405 and 535 kc (736 and 539 meters) must, during their working hours, make the necessary provisions to ensure the watch on the distress wave, 500 kc (600 meters), twice per hour, for three minutes, beginning at XX15 and at XX45 GMT.

**6.770 At what time(s) must the international silent period be observed?**

*Answer.* See 6.769.

**6.771 After a distress call has been transmitted, every distress-traffic radiotelegram shall contain what symbol in the preamble?**

*Answer.* Every distress-traffic radiotelegram must include the distress signal preceding the call and repeated at the beginning of the preamble.

**6.772 Under what conditions may a mobile station, the service of which is not continuous, close?**

*Answer.* Ship stations, the service of which is not continuous, may close after having:

1. Finished all operations called for by a distress call.

2. Exchanged, as far as possible, all radiotelegrams originating in or destined to land stations which are within their range, and mobile stations which, being within their range, have signaled their presence before the effective cessation of work.

A mobile station which has no fixed working hours must advise the land station with which it is in communication of the closing and reopening hours of its service.

Any mobile station which arrives in a port and the service of which is accordingly about to close, must so advise the nearest land station and, if necessary, the other land stations with which it generally communicates. It must not close until it has cleared all traffic on hand, unless prohibited by the regulations of the country where it calls. At the time of its departure, it must advise the interested land station or stations of its reopening, as soon as such reopening is permitted by the regulations in force within the country in which the port of departure is located.

**6.773 How long must mobile stations listen after hearing an urgency signal?**

*Answer.* Mobile stations hearing the urgency signal must listen for at least 3 min. After this interval, and if no urgent message has been heard, they may resume their normal service.

**6.774 What space of time should elapse between the transmission of the international autoalarm signal and the distress call?**

*Answer.* When circumstances permit, the transmission of the distress call shall be separated from the end of the alarm signal by a two-minute silence.

**6.775 What exceptions are permitted to the regulation which states that a mobile station, which has no fixed working hours, must advise the land station with which it is in communication of the closing and reopening hours?**

*Answer.* If the regulations of the country where the ship calls pro-

hibit the use of the ship's radio transmitter while the ship is within the territorial waters of that country, the mobile station is not required by international law to report its closing to the nearest land station.

**6.776 How frequently must an entry be made in the marine radio log while a radio watch is being maintained?**

*Answer.* Once every 15 min.

**6.777 During what periods must a distress message be repeated, following the initial transmission?**

*Answer.* The distress message must be repeated at intervals until an answer has been received, and especially during the periods of silence.

**6.778 Upon what bodies of water is the frequency of 500 kc not utilized as the international calling and distress frequency?**

*Answer.* The Great Lakes.

**6.779 What station shall be in control of distress traffic?**

*Answer.* The control of distress traffic shall devolve upon the mobile station in distress or upon the mobile station which has sent the distress call. These stations may delegate the control of the distress traffic to another station.

**6.780 What transmission should precede the transmission of the distress call?**

*Answer.* The distress call, when sent in radiotelegraphy on 500 kc (600 meters) shall, as a general rule, be immediately preceded by the autoalarm signal.

**6.781 Describe how a distress call should be made.**

*Answer.* The distress call shall include:

1. The autoalarm signals.
2. The distress signal transmitted three times.
3. The word DE.
4. The call signal of the mobile station in distress transmitted three times.

**6.782 Under what circumstances, and by whom, may the international autoalarm signal be transmitted to announce an urgent cyclone warning?**

*Answer.* The only purpose of this special signal is to set into operation the automatic apparatus used to give the alarm. It must only be used either to announce that a distress call or message is to follow, or to announce the transmission of an urgent cyclone warning; in the latter case it can only be used by coast stations duly authorized by their government.

**6.783** While a vessel is at sea, how frequently must the autoalarm be tested?

*Answer.* While the ship is being navigated outside a harbor or port, the autoalarm shall be tested at least once every 24 hr by means of the testing device supplied as part of the alarm, the timing of the dashes to be made by reference to the second hand of the ship-station clock. A statement that the foregoing requirement has been fulfilled must be inserted in the radio-station log daily.

**6.784** Describe the number of dashes, or dots, and spaces which compose the international autoalarm signal and indicate the time intervals involved.

*Answer.* The alarm signal shall consist of a series of 12 dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two dashes, one second. It can be transmitted by hand or by means of an automatic instrument. Any ship station working in the band of 405 to 535 kc (736 to 557 meters), and which is not provided with an automatic apparatus for the transmission of the autoalarm signal must be permanently equipped with a clock distinctly marking the seconds, preferably by means of a moving hand completing one revolution per minute. This clock, with a face not less than 5 in. in diameter, must be placed at a point sufficiently visible from the keying table so that the operator may, by watching it, easily and correctly time the different elements of the alarm signal. See also the Appendix.

**6.785** Describe the safety signal.

*Answer.* In radiotelegraphy, the safety signal shall consist of the group TTT, transmitted three times, with the letters of each group, as well as the consecutive groups, well separated. This signal shall be followed by the word DE and three transmissions of the call signal of the station sending it. It announces that this station is about to trans-

mit a message concerning the safety of navigation or giving important meteorological warnings.

In radiotelephony, the word SECURITY (corresponding to the French pronunciation of the word *sécurité*) repeated three times, shall be used as the safety signal.

**6.786 During what periods must the safety signal be transmitted?**

*Answer.* In the maritime mobile service, apart from messages transmitted according to a schedule, the safety signal must be transmitted toward the end of the first ensuing period of silence, and the message shall be transmitted immediately after the period of silence.

**6.787 Indicate the order of priority of the various types of radio communications.**

*Answer.* The general order of priority of radio communications in the mobile service is shown below. See Appendix for exact order.

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by the urgency signal.
3. Communications preceded by the safety signal.
4. Radio direction finding.
5. Radiotelegrams relative to navigation and safe movement of aircraft; navigation, movement, and needs of ships; weather observations; government messages.
6. Service messages and, finally, all other communications.

**6.788 Upon hearing a safety signal, what should the operator at the receiving station do?**

*Answer.* Hearing the safety signal, the operator must continue listening on the frequency on which the safety signal has been sent until the message so announced has been completed; he must, moreover, keep silence on all frequencies likely to interfere with the message.

**6.789 When the autoalarm bell rings, what should the operator do?**

*Answer.* The alarm bell may be caused to ring for one or the other of the following reasons:

1. Receipt of true alarm signal from a distant station.
2. Failure of equipment in autoalarm installation.

If the alarm rings, the operator must first determine if the bells are caused to ring by a failure in the autoalarm equipment. He can do this

by pressing the release button provided for this purpose. If the alarm bell *does not stop* when this button is pressed, there is trouble with the autoalarm equipment. The operator must take the proper action to correct the trouble.

If the alarm bell *does stop* ringing when the release button is pressed, this signifies that a true alarm has been received. Under these conditions, the operator must go on watch immediately and listen in on the distress frequency for the distress call, distress message, or meteorological warning which should follow the alarm signal within two minutes. (See also 6.774 and 6.792.)

**6.790** If you received a distress call signed by a call signal composed of five letters, could you determine the type of craft which transmitted the signal?

*Answer.* The answer can be deduced from the following:

1. Land stations have three-letter call signals.
2. Ship stations have four-letter call signals.
3. Aircraft stations have five-letter call signals.

**6.791** You intercept CQ CQ WSV TFC QSY 735 AS. What does this mean?

*Answer.* CQ means general call "to all."

WSV is the call letter of a shore station.

TFC means "traffic."

QSY 735 means "shift to transmission on 735 meters."

AS means "wait" or "stand by for shift."

Hence, the above communication reads:

"All (ship) stations shift to 735 meters and listen to see if your call is included in the traffic list, signed WSV." (Consult the Appendix for further abbreviations.)

**6.792** Upon hearing an SOS, what should an operator do?

*Answer.* This call shall have absolute priority over all other transmissions. All stations hearing it must immediately cease all transmission capable of interfering with the distress traffic and must listen on the wave used for the distress call. This call must not be sent to any particular station and shall not require an acknowledgment of receipt.

**6.793** On a vessel of the United States equipped with an approved autoalarm where is the control button, which silences the warning bells, located?

*Answer.* Only one switch for stopping the audible warning apparatus from functioning is authorized, and this shall be located in the main radiotelegraph operating room and shall be capable of manual operation only.

**6.794** What is the radiotelegraph urgency signal?

*Answer.* In radiotelegraphy, the urgency signal shall consist of the group XXX transmitted three times, with the letters of each group, as well as the consecutive groups, well separated; it shall be sent before the call.

**6.795** With what type(s) of emission and upon what frequency should a transmitter be adjusted to transmit a distress call?

*Answer.* In case of distress, the wave to be used shall be the international distress frequency, that is, 500 kc (600 meters), preferably using type A2 emission. Ship stations which cannot transmit on the international distress frequency shall use their normal calling frequencies.

**6.796** Upon what band of radio frequencies must an approved autoalarm receiver function?

*Answer.* From 492 to 508 kc.

**6.797** Upon compulsorily equipped vessels, which are required to have an accurate clock in the radio room, how frequently must this clock be adjusted and compared with standard time?

*Answer.* At least once every 24 hr. For this purpose, authentic radio time signals received from land or fixed stations shall be acceptable as standard time.

**6.798** Within what frequency-band limits do all U.S. marine radio-beacon stations operate?

*Answer.* From 285 to 325 kc.

**6.799** Upon what frequency should a Navy direction-finding station be called to obtain a radio bearing?

*Answer.* 410 kc.

6.800 Upon what band, in addition to the 350- to 515-kc band, must a main receiver on a compulsorily equipped U.S. ship be capable of operation? What is the purpose of this additional band?

*Answer.* From 90 to 160 kc. To provide long-wave radiotelegraph long-distance communication.

6.801 While a vessel is in port, how frequently should the emergency equipment be tested?

*Answer.* Not at all, except just prior to departure.

6.802 How frequently must the quantity of fuel in the supply tank for use with an oil- or gas-driven emergency generator be checked, while the vessel is in the open sea?

*Answer.* Once each day.

6.803 While the vessel is in the open sea, how frequently must the specific gravity of the emergency battery be taken?

*Answer.* Once each day.

6.804 While the vessel is in the open sea, how frequently must the emergency equipment be tested?

*Answer.* Once each day.

6.805 What is the principal port of the United States, on the Pacific Coast, at which navigation lines terminate?

*Answer.* San Francisco.

6.806 In what city is the major telecommunication center of the United States located?

*Answer.* New York City.

6.807 What is the approximate latitude of Colon, Republic of Panama?

*Answer.* This can be found in the table below.

Port	Approximate	
	Latitude	Longitude
Colon, Panama.....	9.4°N	80°W
Los Angeles, Calif.....	34°N	118°W
New Orleans, La.....	30°N	90°W
New York, N.Y.....	41°N	74°W
San Francisco, Calif.....	38°N	122.5°W

**6.808** In what ocean is the island of Guam located?

*Answer.* Pacific Ocean.

**6.809** To what continent do the greatest number of telecommunication channels from the United States extend?

*Answer.* Europe.

**6.810** What is the principal Atlantic Coast port of the United States at which navigation lines terminate?

*Answer.* New York City.

**6.822** Under what circumstances is a station in the mobile service not required to listen to distress traffic?

*Answer.* A station of the mobile service which, while following distress traffic of which it is aware, is able to continue its normal service, may do so, when the distress traffic is well established, under the following conditions:

1. The use of the distress wave, 500 kc (600 meters), or the wave on which the distress traffic is taking place and type B waves shall be forbidden.

2. The use of type A1 waves, with the exception of those which might interfere with the distress traffic, shall be permitted.

**6.823** What interval of time must elapse between the end of the autoalarm signal and an urgent cyclone warning?

*Answer.* Two minutes.

**6.824** Describe the international autoalarm signal.

*Answer.* See 6.784.

**6.825** What is the international distress frequency for stations in the mobile service?

*Answer.* 500 kc.

**6.882** What is the GMT time and the day of the week in Shanghai when it is Wednesday noon in New York City?

*Answer.* Wednesday, 1700 GMT (Greenwich Meridian Time). New York standard time is five hours slower than GMT; therefore New York noon is 1700 GMT all over the world.

To figure local time, it is helpful to remember that when traveling west across the international date line it is necessary to add a day. Therefore, Wednesday, 12 noon (1700 GMT) in New York is the same as Thursday, 0100 (1 A.M.) by Shanghai local time (Wednesday, 1700 GMT).

**6.883 Explain the use and meaning of the following indicators or prefixes on radiotelegrams and describe the difference in handling of the various types of radiotelegrams: RP, TC, PC, FS, PR, TR, MSG, CDE, OBS, PDH, CODH.**

*Answer.* The indicators and their meanings are listed below:

**RP**—Radiotelegram with prepaid reply. Reply-paid messages are transmitted with the indicator RP as the first word preceding the address, followed by the amount the sender wishes to prepay, for example, "RP\$3.40." The whole expression is counted and charged for as one word.

**TC**—Collation or repeat back. For collation, the sender pays an additional charge equal to one half the charge for an ordinary radiotelegram of the same length for the same destination by the same route. The service indicator appears before the address where it is counted and charged for as one word.

**PC**—This indicator is used on radiotelegrams to ships filed ashore when the sender wishes to be advised by the shore station that his message has been sent. The indicator which precedes the name is charged for, and an additional charge for a six-word ordinary telegram delivery advice back to the sender is made.

**FS**—Use of this indicator before the address shows that the telegram is to follow the addressee, assuming that he has left a forwarding address. The indicator is counted and charged for.

**PR**—This indicator shows that the radiotelegram is to be delivered by registered mail. Both the indicator appearing before the address and the registered postage must be paid for.

**TR**—A ship's position report to a coastal station is prefixed TR and no charge is made for the message.

**MSG**—All messages to and from the master of the ship except distress and emergency traffic must be put in message form. When these messages pertain to ship's business, they should be prefixed MSG. There is no ship charge for this service. Inquiries from other ships as to the position of your ship must be addressed to the master; such inquiry and the reply must be in message form signed by the master.

**CDE**—A code radiotelegram carries in the preamble the service indicator CDE which is neither counted nor charged for. A code message uses either artificial words or real words with a meaning other than that normally assigned. Radiotelegrams containing combinations, abbreviations, contractions, or mutilations of real words are not admissible as CDE.

**OBS**—A meteorological radiotelegram is a weather or forecast message sent by an official meteorological service or by a mobile station in official relation to such a service. The service indicator OBS appears in the preamble and again preceding the address. The latter is charged as one word.

**PDH**—When the sender of a radiotelegram presents a frank issued by a company other than the one operating the radiotelegraph service, as, for instance, a wire telegraph line, the prefix PDH is used. In addition, the message must bear the number of the frank in the preamble, but this information is neither counted nor charged for. All charges except those covered by the frank must be paid for.

**CODH**—A business message from a radio operator to a designated official of his company requesting information, relief, or repairs is customarily sent to a coastal station, prefixed CODH.

**6.884 Explain cable count and the use of standard service abbreviations, and show the difference between cable count and domestic word count.**

*Answer.* Cable count refers to the procedure of determining the tolls to be charged for a message transmitted either by cable or by radio to or from points outside the boundaries of the United States. A charge is normally made for each word that the sender of the message puts down, including the name and address as well as his own signature. The paid service indicators, such as RP and TC are also charged for. Routing instructions and standard service abbreviations employed by the operator are not charged for. For example, GA meaning to resume sending, and AS indicating a wait are not part of a message, although both are likely to be used during the transmission of messages.

In domestic word count, only the text of the message itself is charged for. No charge is made for the address and signature as in cable count. Domestic word count is used in land-wire telegrams or messages sent by point-to-point radio circuits within the limits of the United States and Canada.

The cable-count system of counting the check is used for radiograms. This system provides that all words in the address, text, and signature must be counted and charged for. In this system, messages are divided into two classes, namely,

1. Plain language.
2. Code language.

*Plain-language* messages must be written entirely in plain language. Words are counted on the basis of 15 characters to the word. Any fractional part of 15 characters is also counted as one word. Numbers up to five in a group would be counted as one word, over five as two words.

*Examples:* Gymnasium (one word); 7,583 (one word); intellectualization (two words); 37,463 (one word); unconstitutional (two words); 987,641 (two words); Constantinople (one word).

*Code language* is made up of pronounceable words of no direct meaning not to exceed five characters in length. If a code word exceeds five characters in length it is counted as two words, and this is noted in the check. Words in which the meaning has been concealed by reversing the order of the letters or syllables will not be accepted as code words.

*Examples:* JELHI, one word (code language); X-ray, two words (plain language); XQNOW, not accepted (unpronounceable).

When a message is written in mixed language, a careful checkup under the following rules must be made:

*Code and plain language:* Maximum length of words chargeable is 10 characters. The words street, road, park, or square are always counted as one word aside from their designator in the address. Hyphenated or compound words are counted as so many separate words depending on the number of parts.

Names of places, such as New York, New London, or Frankfurt am Main, are counted as one word in the address and two words in the text.

If New York is written Newyork or New London is written New-london and like examples, they are counted as one word in the text and so charged for. They should be written as two separate words in the address, but as the names of all cities count as one word in the address, they are charged for as one word. See Appendix for standard abbreviations.

**6.885** Construct a plain language telegram and indicate what portions comprise (a) the preamble, (b) the address, (c) the text, and (d) the signature.

*Answer.* The following is a representative message:

*Preamble:* P NR 5 CK 17 SS AMERICA WEDI 2220 GMT 21  
VIA WSC

*Address:* KENNETH THAYER  
457 DYER DRIVE  
NEW YORK CITY

*Text:* LEAVING FOR ANNUAL CRATHIE VISIT WILL RETURN SOMETIME IN AUGUST

*Signature:* GARTH

The preamble contains the prefix (P) denoting a personal message; the serial number (NR 5) of the message for the day; the check or word count (CK 17, using cable count); the office of origin and call letters (SS AMERICA, WEDI); time the radiotelegram was filed (2220 GMT); the day of the month in which the message was filed (21); the routing instructions (VIA WSC). The sender is charged only for the part of the telegram that comes after the preamble.

**6.889** For how long a period of continuous operation should the emergency power supply on a compulsorily equipped ship station be capable of energizing the emergency radiotelegraph installation?

*Answer.* The emergency power supply must be in complete readiness at all times and must be capable of operating an emergency transmitter for a continuous period of six hours.

**6.890** Why is the clock on a compulsorily equipped ship radiotelegraph station required to have a sweep second hand?

*Answer.* A sweep second hand is required in a ship radiotelegraph station to facilitate accurate time adjustments to United States and foreign government time signals. An accurate adjustment of the ship's clock to standard time signals permits the ship's deck officers to check the accuracy of the ship's chronometer to the exact second. The station clock must also be accurate to the second to provide for correct time entries into the operator's log and also to observe at all times the International Silent Period. The law also requires that all intermediate ship stations operating on frequencies below 515 kc be provided with

a clock containing a sweep second hand, an hour dial of not less than 5 in. in diameter and capable of operation for at least eight days on one winding for manually operating and timing of the international auto-alarm signals.

**6.891 Between what points on a ship, compulsorily equipped with a radiotelegraph installation, is a reliable intercommunication system required?**

*Answer.* The law requires that a reliable communication system be provided between the radio room and the navigating bridge, and between direction finder and bridge.

**6.892 What is the purpose of an automatic-alarm-signal keying device on a compulsorily equipped ship?**

*Answer.* This device must be capable of automatically keying the radiotelegraph transmitter or transmitters so as to send out the automatic alarm signal that will set into operation the automatic apparatus used to give the alarm. It is used only to announce either that a distress call or message is to follow, or to announce the transmission of an urgent cyclone warning; in the latter case, it can only be used by coast stations duly authorized by their government.

The automatic alarm signal consists of a series of 12 dashes sent in one minute, the duration of each dash being four seconds and the duration of the interval between two dashes, one second. It can be transmitted by hand or by means of an automatic instrument.

**6.893 What experience is the holder of a first- or second-class radiotelegraph operator license required to have before he is permitted to act as chief or sole operator on a compulsorily radio-equipped cargo ship?**

*Answer.* He must have had at least six months of satisfactory service in the aggregate as a qualified radiotelegraph operator on a ship or ships of the United States.

**6.894 Are there any age requirements that a person must meet before he can be issued a radiotelegraph operator license?**

*Answer.* An applicant for the radiotelegraph first-class operator license must be at least 21 years of age at the time the license is issued and shall have had an aggregate of one year of satisfactory service as a

radiotelegraph operator manipulating the key of a manually operated radiotelegraph station on board a ship or in a manually operated coastal telegraph station.

**6.895** What action if any should a radio operator take when he observes a ship station flagrantly violating the international radio regulations and causing harmful interference to other stations?

*Answer.* Whenever a radiocommunication is already in progress between two ship stations or between a ship and a coastal station and it appears to be interfered with by a subsequent transmission from another ship station, the latter must cease transmitting at the first request of either of the other two except as priority may be otherwise determined. The station requesting the cessation must indicate the approximate length of the wait imposed upon the ship station whose transmission is suspended. The order of priority in the maritime mobile service is: distress, urgency, safety, direction finding, Government (for which priority has not been waived), all other communications.

If in the judgment of a radio operator another station seems to be violating international radio regulations, he should report to the FCC, usually through channels provided by his company or employer. His report must be countersigned by the master of the ship or aircraft, or by the chief of the land station. He must provide such specific information as the following: a statement that the station interfered with actually uses the frequency assigned to it; that it uses modern receiving equipment equal to the best available for the service; its call letters, nationality, and approximate position; and he must describe the nature of the interference, its frequency, the time, date, and the call letters, and nationality if known, of the interfering station. He must also indicate name and call letters of the station in communication with the station committing the violation.

Whenever harmful interference is experienced, an entry shall be made to that effect, stating the source of the interference, if known, in the ship station log. Excerpts from the ship log shall be used to document the report to the FCC.

GENERAL THEORY,  
TRANSMITTERS, RECEIVERS

[Elements: 3, 4, 6]



## Element 3

# Basic Radiotelephone (Theory)

**3.01\*** By what other expression may a "difference of potential" be described?

*Answer.* Difference of potential may be defined in any one of the following forms: emf, voltage,  $IR$  drop, voltage drop, electrical pressure, or fall of potential.

**3.02** By what other expression may an "electric current flow" be described?

*Answer.* Electric current may be described as a flow of electricity, a flow or periodic displacement of electrons in a circuit, or, simply, the *amperes* flowing in a circuit.

**3.03** Which factors determine the amplitude of the emf induced in a conductor which is cutting magnetic lines of force?

*Answer.* The rate or speed of cutting, the density of the magnetic flux, the angular relationship between the conductor, and the field lines of force.

**3.04** Name four methods by which an electrical potential may be generated.

*Answer.* A voltaic cell or battery (chemical), generator (mechanical), photoelectric cell (light), thermocouple (heat), microphone (sound-mechanical), crystal (piezoelectric).

**3.05** If the diameter of a conductor of given length is doubled, how will the resistance be affected?

\*Note that questions 6.01 through 6.311 are the same as 3.01 through 3.311 but are shown only under the latter numbers.

*Answer.* The resistance will be decreased. This is due to the fact that the resistance of a wire varies inversely with its cross-sectional area.

**3.06** If the value of a resistance, to which a constant emf is applied, is halved, what will be the resultant proportional power dissipation?

*Answer.* The rate in which energy is dissipated (power) will be doubled.

$$\text{Power} = I^2R = \frac{E^2}{R} = E \times I \text{ watts}$$

**3.07** What method of connection should be used to obtain the maximum no-load output voltage from a group of similar cells in a storage battery?

*Answer.* The cells must be connected in series.

**3.08** What is the sum of all voltage drops around a simple d-c series circuit, including the source?

*Answer.* Zero. The algebraic sum of all the voltage drops around the circuit, including the source, is zero.

**3.09** What method of connection should be used to obtain the maximum short-circuit current from a group of similar cells in a storage battery?

*Answer.* The cells must be connected in parallel.

**3.10** If the value of a resistance, across which a constant emf is applied, is doubled, what will be the resultant proportional power dissipation?

*Answer.* The power dissipation will be halved. (See 3.06.)

**3.11** Name four materials which are good insulators at radio frequencies. Name four materials which are not good insulators at radio frequencies, but which are satisfactory for use at commercial power frequencies.

*Answer.* Good radio-frequency insulators are quartz, stabilized polyethylene, mica, polystyrene, isolantite, Steatite, Nonex, Pyrex, and Mycalex.

Good commercial power-frequency insulators are glazed porcelain, glass, slate, Micarta, fiber, hard rubber, and asbestos.

3.12 Explain the factors which influence the resistance of a conductor.

*Answer.* The resistance of a conductor is dependent primarily upon the character of the material, the length of the conductor, and its cross-sectional area. Excessive current flow and surrounding temperature also affect the resistivity.

3.13 What effect does the cross-sectional area of a conductor have upon its resistance per unit length?

*Answer.* See 3.05.

3.14 Name four conducting materials in the order of their conductivity.

*Answer.* Silver, copper, aluminum, Duralumin, tungsten, and zinc.

3.15 What effect does a change in the dielectric constant of a capacitor dielectric material have upon the capacitance of a capacitor?

*Answer.* The capacitance of the capacitor will vary directly as the dielectric constant.

3.16 Explain the effect of increasing the number of plates upon the capacitance of a capacitor.

*Answer.* Increasing the number of plates increases the area and consequently its capacitance.

3.17 If the specific inductive capacity of a capacitor dielectric material between the capacitor plates were changed from 1 to 2, what would be the resultant change in capacitance?

*Answer.* The capacitance would be doubled.

3.18 State the formula for determining the quantity or charge of a capacitor and the energy stored in a capacitor.

*Answer.*

$$Q = CE \quad E = \frac{Q}{C}$$

$$W = \frac{1}{2} CE^2 = \frac{Q^2}{2C}$$

where  $C$  is in farads

$E$  in volts

$Q$  in coulombs

$W$  in joules.

**3.19 Neglecting temperature coefficient of resistance and using the same gage of wire and the same applied voltage in each case, what would be the effect, upon the field strength of a single-layer solenoid, of a small increase in the number of turns?**

*Answer.* The field strength will remain practically unchanged. The slight increase in turns will introduce a small increase in resistance thereby decreasing the current flow. This will *approximately* reestablish the original conditions.

**3.20 How will a magnetic compass be affected when placed within a coil carrying an electric current?**

*Answer.* Within the coil the compass will align itself at right angles to the current flow with its north-seeking pole pointing toward the north pole of the coil.

**3.21 Which factors influence the direction of magnetic lines of force generated by an electromagnet?**

*Answer.* The magnetic lines of force generated by an electromagnet will take a direction determined by the direction of the windings of the solenoid and the direction of current flow through the coil.

**3.22 Define the term "permeability."**

*Answer.* "Permeability" may be defined as the ratio of the magnetic induction  $B$  in the substance and the strength of the magnetizing field to which it is subjected, field  $H$ . Simply stated, it is an expression of the ease with which a magnetic material will conduct lines of force as compared with air. The permeability ratio  $\mu$  of air is unity.

**3.23 What unit is used in expressing the a-c impedance of a circuit?**

*Answer.* The ohm ( $Z$ ).

**3.24 What is the unit of resistance?**

*Answer.* The ohm ( $R$ ).

**3.25 Explain the meaning of the prefix in "micromicrofarad."**

*Answer.* The prefix "micromicro" means one-trillionth, or  $10^{-12}$  farad.

**3.26 What is the unit of capacitance?**

*Answer.* The standardized unit is the farad. The capacitance is generally expressed in millifarads, microfarads, or micromicrofarads.

**3.27 What single instrument may be used to measure (a) Electrical resistance? (b) Electrical power? (c) Electrical current? (d) Electromotive force?**

*Answer.*

1. Electrical resistance can be measured by using a voltmeter and a standard resistor (ohmmeter). Resistance may also be measured, but less accurately, by using a voltmeter whose resistance is known and applying the formula

$$R = \frac{E_1 - E_2}{E_2} \times R_m$$

where  $E_1$  is the voltage without the unknown resistor in the circuit.

$E_2$  is the voltage with the unknown resistor in the circuit.

$R_m$  is the resistance of the voltmeter.

2. Electrical power is measured by a wattmeter.
3. Electrical current is measured by an ammeter.
4. Electromotive force is measured by a voltmeter.

**3.28 Define the term "residual magnetism."**

*Answer.* "Residual magnetism" refers to the magnetic field which remains in a magnetic material after the magnetizing force is removed.

**3.29 What is the unit of electrical power?**

*Answer.* The watt.

**3.30 What is the unit of conductance?**

*Answer.* The mho.

**3.31 What is the unit of inductance?**

*Answer.* The standardized unit of inductance is the henry. Fractional parts of this unit are generally expressed in millihenrys (mh) and microhenrys ( $\mu\text{h}$ ) ( $10^{-3}$  or  $10^{-6}$  henry, respectively).

**3.32 What is the meaning of the prefix "kilo"?**

*Answer.* "Kilo" as a prefix means one thousand; thus, when compounded with other words, it means multiply by one thousand.

**3.33 What is the meaning of the prefix "micro"?**

*Answer.* "Micro" as a prefix means one-millionth; thus, when compounded with other words, it means one-millionth part of the whole.

**3.34 What is the meaning of "power factor"?**

*Answer.* "Power factor" in an alternating-current circuit is the ratio of the true watts expended in the circuit to the apparent watts expended in the circuit. It is an expression of the ratio of power consumed in a pure resistance to that returned to the source by the reactive component of the circuit. Power factor is always less than unity and is found by any of the following formulas:

$$\text{Power factor} = \cos \theta = \frac{P}{EI} = \frac{\text{real watts}}{\text{apparent watts}}$$

where  $P$  is the true power as indicated by a wattmeter, and  $EI$  is the product of the voltmeter and the ammeter readings in the a-c circuit.

**3.35 What is the meaning of the prefix "meg"?**

*Answer.* "Meg" from the Greek word *mega* means one million. For example, 1 megohm = 1,000,000 ohms.

**3.36 Define the term "conductance."**

*Answer.* "Conductance" is the reciprocal of the resistance in d-c circuits. In a-c circuits, conductance is the ratio of the resistance to the impedance squared, expressed in mhos.

**3.37 What instrument is used to measure current flow?**

*Answer.* Electrical current flow is measured by an ammeter, a milliammeter or a microammeter.

**3.38 Define the term "decibel."**

*Answer.* The "decibel" (db) is the unit used for expressing the ratio between two quantities, of either electrical or sound energy. The unit decibel is a relative measurement of electrical or sound energy levels

and does not specify any definite current, voltage, or power. Using conventional symbols, the formulas for the decibel are as follows:

$$\text{db} = 10 \log_{10} \frac{P_1}{P_2} \quad \text{db} = 20 \log_{10} \frac{E_1}{E_2} \quad \text{db} = 20 \log_{10} \frac{I_1}{I_2}$$

### 3.39 What is meant by "ampere turns"?

*Answer.* "Ampere turns" is the product of the number of turns times the current through them.

### 3.40 Define the term "inductance."

*Answer.* "Inductance" is that property of a coil or circuit to store up energy in an electromagnetic form. The inductance of a coil or circuit is one henry if a counter emf due to self-induction of one volt is developed when the current in the circuit changes at the rate of one ampere per second.

### 3.41 Define the term "coulomb."

*Answer.* The unit of quantity of electricity passing a given point in a conductor in one second when one ampere is flowing is called a "coulomb." One coulomb is also the amount of electricity contained in a capacitor having a capacitance of one farad when charged to a potential of one volt.

### 3.42 State the three ordinary mathematical forms of Ohm's law.

*Answer.*

$$E = I \times R \quad R = \frac{E}{I} \quad I = \frac{E}{R}$$

### 3.43 State Ohm's law.

*Answer.* The current in an electric circuit varies directly as the emf producing it and inversely as the resistance of the conductor.

### 3.44 If a vacuum tube having a filament rated at $\frac{1}{4}$ ampere and 5 volts is to be operated from a 6-volt battery, what is the value of the necessary series resistor?

*Answer.* The voltage drop across the filament is 5 volts. Therefore, the voltage drop across the resistor must be 1 volt. Applying Ohm's

law, we find that the necessary resistance is 4 ohms, calculated as follows:

$$R = \frac{E}{I} = \frac{1}{0.25} = 4 \text{ ohms}$$

**3.45** If the voltage applied to a circuit is doubled and the resistance of the circuit is increased to three times its former value, what will be the final current value?

*Answer.* Assuming the initial conditions are as follows: emf = 1 volt,  $R = 1$  ohm; then the current flow is 1 ampere. If, then, the voltage is doubled to 2 volts and the resistance increased to 3 ohms, the current, according to Ohm's law, will be

$$I = \frac{E}{R} = \frac{2}{3} \text{ ampere}$$

or two-thirds of the initial value.

**3.46** What should be the minimum power dissipation rating of a resistor of 20,000 ohms to be connected across a potential of 500 volts?

*Answer.* Theoretically, a 12.5-watt resistor would do. In practice, at least a 25-watt resistor would be used. The computations are as follows:

*Solution:*

$$\text{Power} = \frac{E^2}{R} = \frac{500^2}{20,000} = 12.5 \text{ watts}$$

**3.47** If resistors of 5, 3, and 15 ohms are connected in parallel, what is the total resistance?

*Answer.* 1.66 ohms, computed as follows:

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{5} + \frac{1}{3} + \frac{1}{15}} = \frac{15}{9} = 1.66 \text{ ohms}$$

**3.48** What is the maximum rated current-carrying capacity of a resistor marked "5,000 ohms, 200 watts"?

*Answer.* 200 milliamperes, computed as follows:

$$I = \sqrt{W/R} = \sqrt{0.04} = 0.2 \text{ ampere}$$

3.49 A milliammeter with a full-scale deflection of 1 milliampere and having a resistance of 25 ohms was used to measure an unknown current by shunting the meter with a 4-ohm resistor. It then read 0.4 milliampere. What was the unknown current value?

*Answer.* Let  $I_1$  equal full-scale current through meter without shunt;  $I_2$  equal full-scale current through shunt;  $R_1$  equal resistance of meter;  $R_2$ , equal resistance of shunt. Then

$$I_1 = R_2 \quad (\text{Let } I_2 = x)$$

$$I_2 = R_1$$

$$\frac{1}{x} = \frac{4}{25}$$

$$x = 6.25 = I_2$$

Total current through the meter and shunt equals 7.25 milliamperes with full-scale deflection. With 0.4 deflection, the actual current is

$$0.4 \times 7.25 = 2.9 \text{ milliamperes}$$

3.50 What will be the heat dissipation, in watts, of a resistor of 20 ohms having a current of  $\frac{1}{4}$  ampere passing through it?

*Answer.*

$$\begin{aligned} \text{Power} &= I^2R \text{ watts} \\ &= \left(\frac{1}{4}\right)^2 \times 20 \\ &= \frac{1}{16} \times 20 = 1.25 \text{ watts} \end{aligned}$$

3.51 If two 10-watt 500-ohm resistors are connected in parallel, what are the power dissipation capabilities of the combination?

*Answer.* 20 watts.

3.52 What is the formula used to determine the total capacitance of three or more capacitances connected in series?

*Answer.*

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots}$$

where  $C$  is in the same units, farads or microfarads, as are used to express  $C_1$ ,  $C_2$ ,  $C_3$ , etc.

**3.53** If capacitors of 1, 3, and 5 microfarads are connected in parallel, what is the total capacitance?

*Answer.*

$$C = C_1 + C_2 + C_3 = 1 + 3 + 5 = 9 \mu\text{f}$$

**3.54** If capacitors of 5, 3, and 7  $\mu\text{f}$  are connected in series, what is the total capacitance?

*Answer.* The total capacitance is 1.48  $\mu\text{f}$ , computed as follows:

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} = \frac{1}{\frac{1}{5} + \frac{1}{3} + \frac{1}{7}} = \frac{1}{0.676} = 1.48\mu\text{f}$$

**3.55** The charge in a capacitor is stored in what portion of the capacitor?

*Answer.* On the surface of the dielectric in the form of electrostatic lines of force.

**3.56** Having available a number of capacitors rated at 400 volts and 2  $\mu\text{f}$  each, how many of these capacitors would be necessary to obtain a combination rated at 1,600 volts 1.5  $\mu\text{f}$ ?

*Answer.* Twelve capacitors connected into three series banks of four capacitors each, the series banks then being connected in parallel.

**3.57** Calculate the voltage drop across an individual capacitor of a group connected in series.

*Answer.* Let  $C_t$  equal the total capacitance,  $\left(\text{where } C_t = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}\right)$

$C_1$  equal the capacitance of one of the capacitors,  $E_t$  equal the potential across the group, and  $E_1$  the potential across  $C_1$ . Then the voltage across  $C_1$  can be found by

$$\frac{E_1}{E_t} = \frac{C_t}{C_1} \quad \text{and} \quad E_1 = E_t \times \frac{C_t}{C_1}$$

**3.58** What factors determine the charge stored in a capacitor?

*Answer.* The charging voltage and the capacitor capacitance. (See 3.18.)

**3.59** Given two identical mica capacitors of  $0.1 \mu\text{f}$  capacitance, each. One of these is charged to a potential of 125 volts and disconnected from the charging circuit. The charged capacitor is then connected in parallel with the uncharged capacitor. What voltage will appear across the two capacitors connected in parallel?

*Answer.* 62.5 volts.

**3.60** What is the effect of an iron core in an inductance?

*Answer.* The inductance value will increase. In a-c circuits the iron core will increase the inductive reactance of the inductance coil.

**3.61** What will be the effect of a short-circuited turn in an inductance?

*Answer.* A short-circuited turn will decrease the inductance.

**3.62** What is the relationship between the number of turns and the inductance of a coil?

*Answer.* Inductance varies as the square of the number of turns, provided the length of the coil is the same. This holds true regardless of the character of the wire used.

**3.63** Define the term "reluctance."

*Answer.* "Reluctance" is the opposition offered to a magnetic path in a magnetic circuit. Reluctance is directly proportional to its magnetic path length and inversely to its cross section.

**3.64** State the formula for determining the resonant frequency of a circuit when the inductance and capacitance are known.

*Answer.*

$$f = \frac{1}{2\pi \sqrt{LC}} \text{ cycles per second}$$

where  $L$  is in henrys, and  $C$  is in farads.

**3.65** What is the formula for determining the power in a d-c circuit when the voltage and resistance are known?

*Answer.*

$$P = I \times E = \frac{E}{R} \times E = \frac{E^2}{R}$$

Hence,

$$P = \frac{E^2}{R} \text{ watts}$$

**3.66** What is the formula for determining the power in a d-c circuit when the current and resistance are known?

*Answer.*

$$P = I^2R \text{ watts}$$

**3.67** What is the formula for determining the power in a d-c circuit when the current and voltage are known?

*Answer.*

$$P = EI \text{ watts}$$

**3.68** What is the formula for determining the wavelength when the frequency, in kilocycles, is known?

*Answer.*

$$\lambda = \frac{3 \times 10^8}{f_1} = \frac{300,000}{f_2} \text{ meters}$$

where  $f_1$  is in cycles, and  $f_2$  is in kilocycles.

**3.69** What is the frequency corresponding to a wavelength of 375 meters?

*Answer.* 800 kc, computed according to the formula

$$f = \frac{v}{\lambda}$$

where  $v$  = velocity of radio wave,  $3 \times 10^8$  meters per sec,

$\lambda$  = wavelength in meters.

$f$  = frequency in cycles per sec.

**3.70** State Ohm's law for a-c circuits.

*Answer.* Expressed mathematically Ohm's law adapted to a-c circuits reads

$$E = IZ \quad I = \frac{E}{Z} \quad Z = \frac{E}{I}$$

Stated in words these formulas show that the current  $I$  varies directly as the emf  $E$  and inversely as the impedance  $Z$ .

3.71 Draw a simple schematic diagram showing a tuned-plate tuned-grid oscillator with series-fed plate. Indicate polarity of supply voltages.

Answer. See Fig. 3-1.

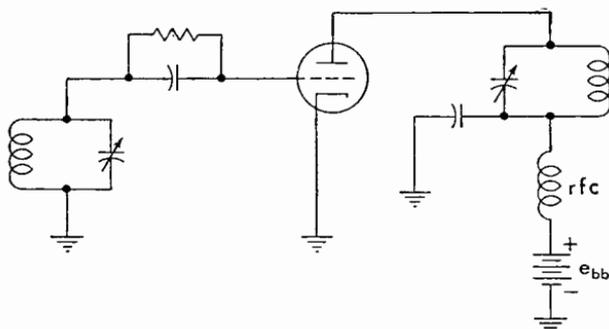


FIG. 3-1. Tuned-plate tuned-grid series-fed oscillator.

3.72 Draw a simple schematic diagram showing a Hartley triode oscillator with shunt-fed plate. Indicate power-supply polarity.

Answer. See Fig. 3-2.

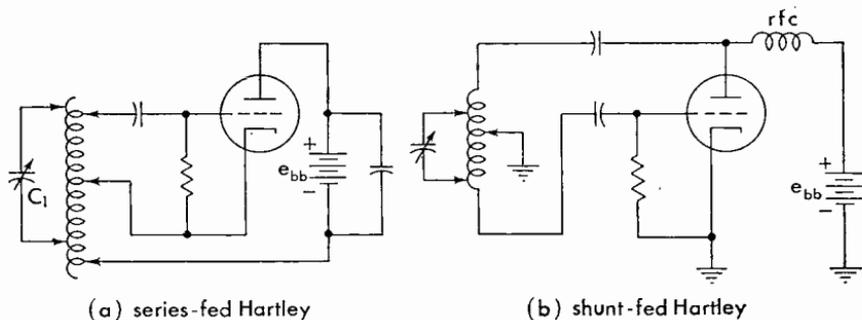


FIG. 3-2. Hartley oscillators.

**3.73** Draw a simple schematic diagram showing a tuned-grid Armstrong triode oscillator, with shunt-fed plate. Indicate power-supply polarity.

*Answer.* See Fig. 3-3.

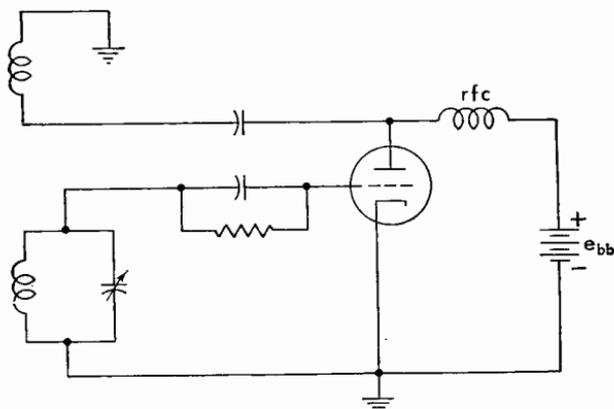


FIG. 3-3. Armstrong tuned-grid shunt-fed oscillator.

**3.74** Draw a simple schematic diagram showing a tuned-plate tuned-grid triode oscillator with shunt-fed plate. Indicate polarity of supply voltages.

*Answer.* See Fig. 3-4.

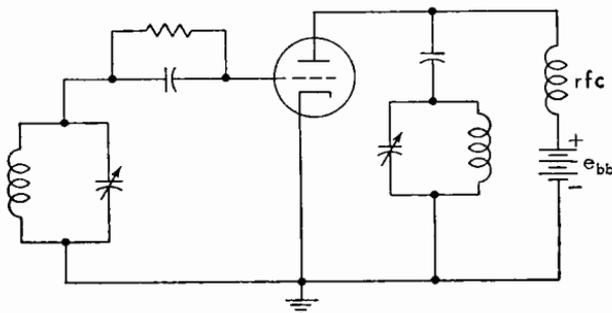


FIG. 3-4. Tuned-plate, tuned-grid, shunt-fed oscillator.

3.75 Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator. Indicate power-supply polarity.

*Answer.* See Fig. 3-5.

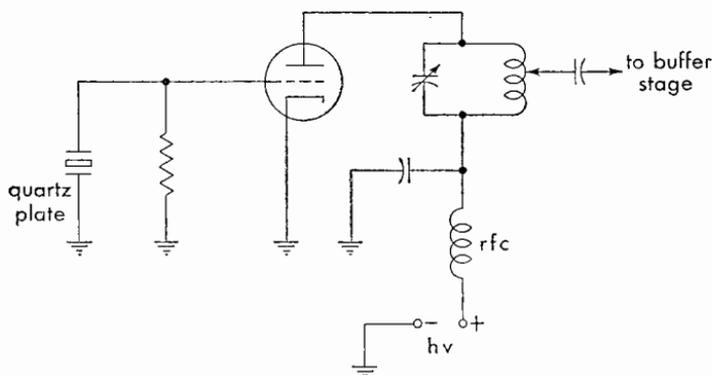


FIG. 3-5. Triode-type crystal-controlled oscillator.

3.76 Draw a simple schematic diagram showing a Colpitts triode oscillator, with shunt-fed plate. Indicate power-supply polarity.

*Answer.* See Fig. 3-6.

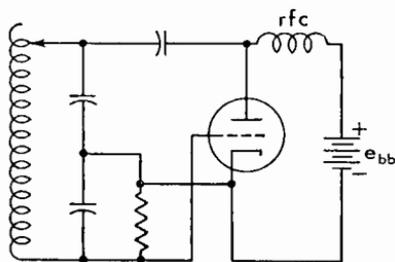


FIG. 3-6. Colpitts shunt-fed oscillator.

3.77 Draw a simple schematic diagram showing a tuned-grid Armstrong triode oscillator, with series-fed plate. Indicate power-supply polarity.

*Answer.* See Fig. 3-7.

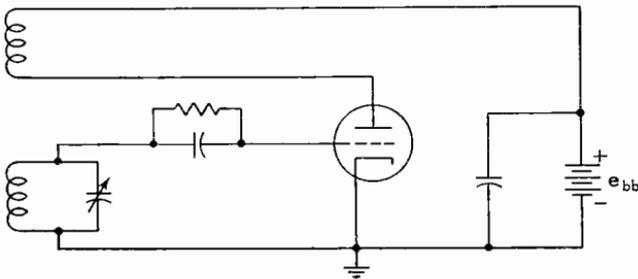


FIG. 3-7. Armstrong series-fed oscillator.

3.78 Draw a simple schematic diagram of an electron-coupled oscillator, indicating power-supply polarities where necessary.

*Answer.* See Fig. 3-8.

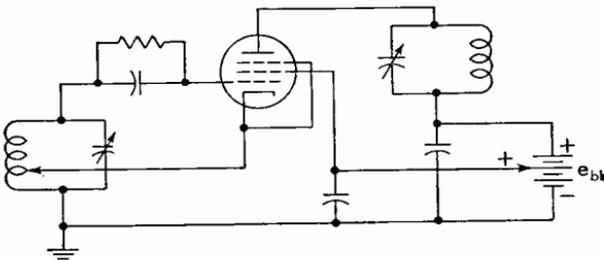


FIG. 3-8. Electron-coupled oscillator.

3.79 Draw a simple schematic diagram of a pentode tube used as a crystal-controlled oscillator, indicating power-supply polarities.

Answer. See Fig. 3-9.

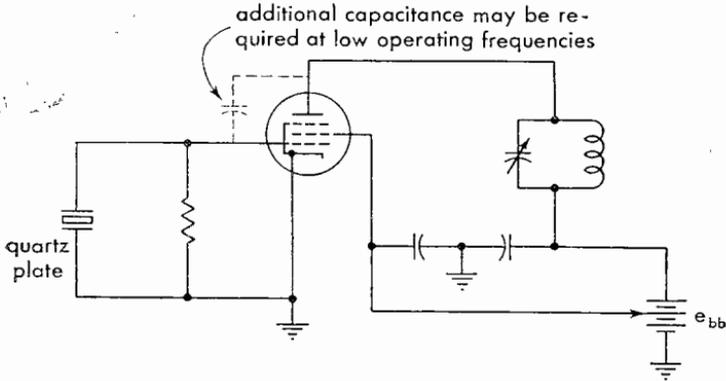


FIG. 3-9. Pentode-type crystal-controlled oscillator.

3.80 Draw a simple schematic circuit showing a method of coupling a high-impedance loudspeaker to an audio-frequency amplifier tube without flow of tube plate current through the speaker windings, and without the use of a transformer.

Answer. See Fig. 3-10.

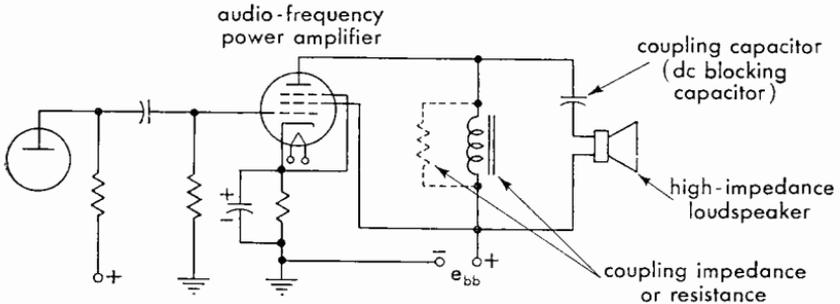


FIG. 3-10. Parallel-fed loudspeaker coupling system.

3.81 Draw a simple schematic diagram of a triode vacuum-tube audio-frequency amplifier inductively coupled to a loudspeaker.

*Answer.* See Fig. 3-11.

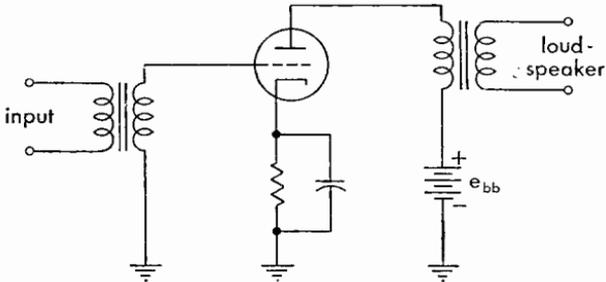


FIG. 3-11. Loudspeaker coupling arrangement.

3.82 Draw a simple schematic circuit showing a method of resistance coupling between two triode vacuum tubes in an audio-frequency amplifier.

*Answer.* See Fig. 3-12.

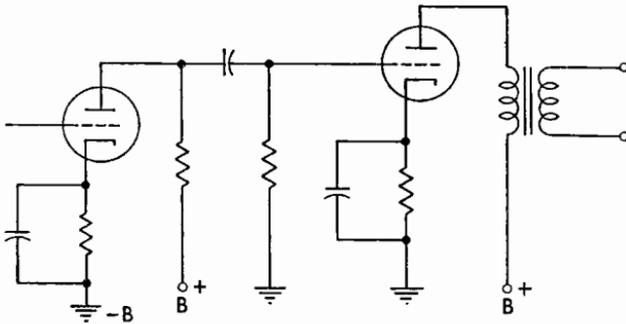


FIG. 3-12. Resistance coupling.

3.83 Draw a simple schematic diagram showing a method of transformer coupling between two triode vacuum tubes in an audio-frequency amplifier.

*Answer.* See Fig. 3-13.

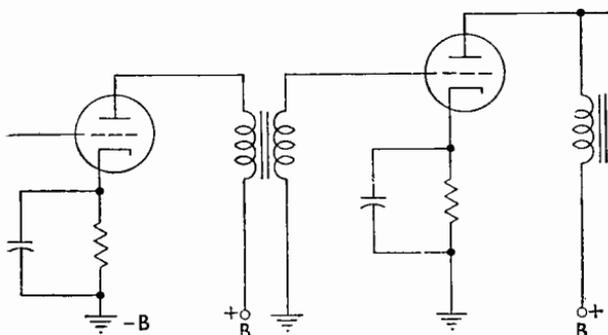


FIG. 3-13. Inductive or transformer coupling.

3.84 Draw a simple schematic diagram of a method of impedance coupling between two vacuum tubes in an audio-frequency amplifier.

*Answer.* See Fig. 3-14.

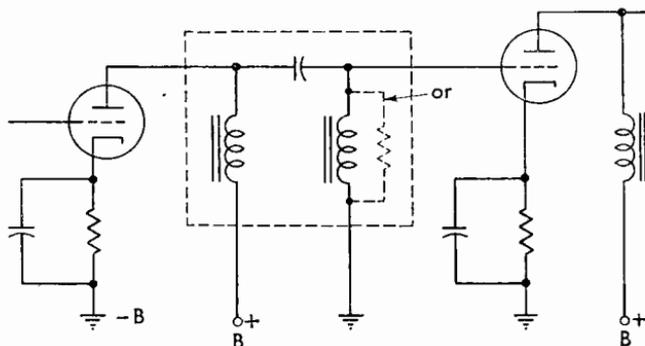


FIG. 3-14. Impedance coupling.

3.85 Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power-amplifier stage of a transmitter to an antenna.

*Answer.* See Fig. 3-15.

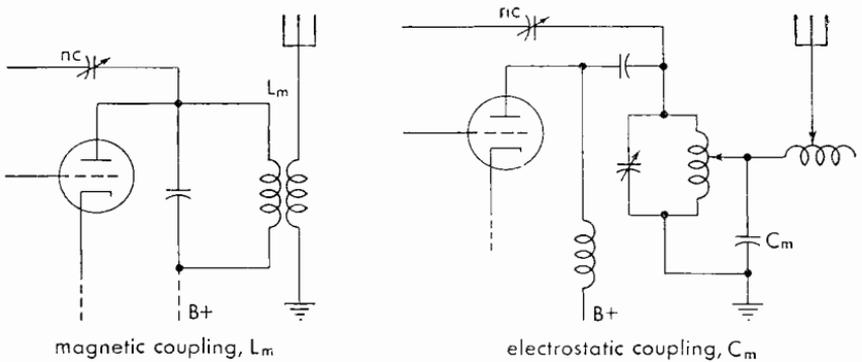


FIG. 3-15. Antenna coupling systems.

3.86 Draw a simple schematic diagram showing a method of coupling between two tetrode vacuum tubes in a tuned radio-frequency amplifier.

*Answer.* See Fig. 3-16.

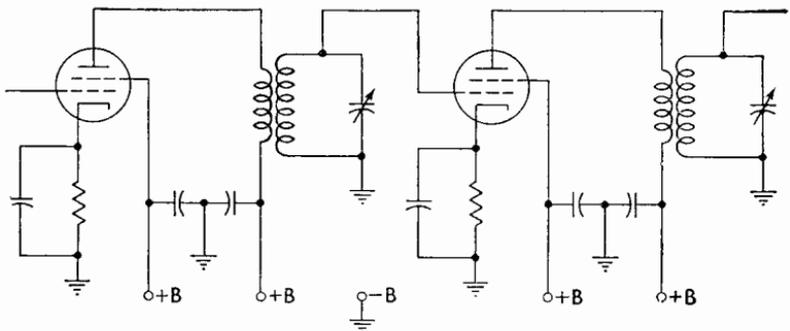


FIG. 3-16. Interstage coupling system.

3.87 Draw a simple schematic diagram showing a method of coupling between two triode vacuum tubes in a tuned radio-frequency amplifier, and a method of neutralizing to prevent oscillation.

*Answer.* See Fig. 3-17.

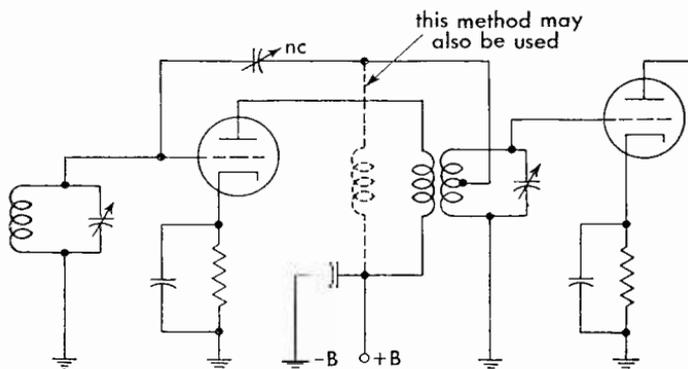
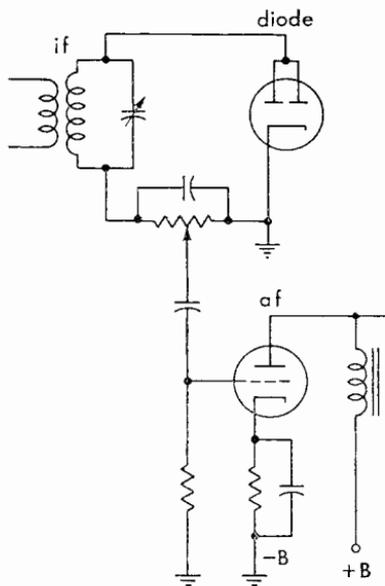


FIG. 3-17. Interstage coupling and neutralization.



3.88 Draw a simple schematic diagram of a diode vacuum tube connected for diode detection, and showing a method of coupling to an audio amplifier.

*Answer.* See Fig. 3-18.

FIG. 3-18. Diode detector and audio-frequency amplifier.

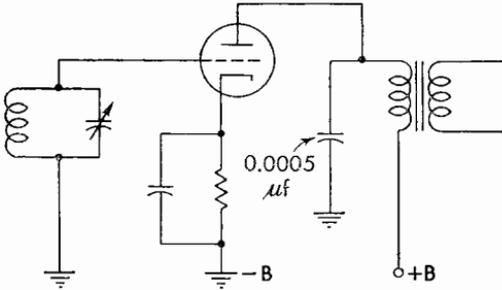


FIG. 3-19. Power or plate detection system.

3.89 Draw a simple schematic diagram of a triode vacuum tube connected for plate or power detection.  
*Answer.* See Fig. 3-19.

3.90 Draw a simple schematic diagram of a triode tube connected for grid-leak detection.  
*Answer.* See Fig. 3-20.

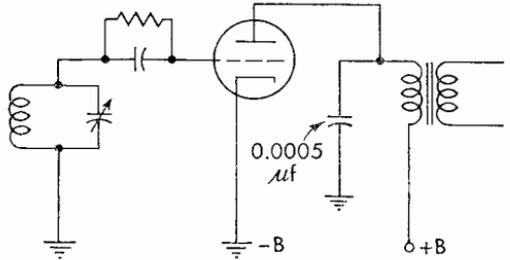


FIG. 3-20. Grid-leak detector.

3.91 Draw a simple schematic circuit of a regenerative detector.  
*Answer.* See Fig. 3-21.

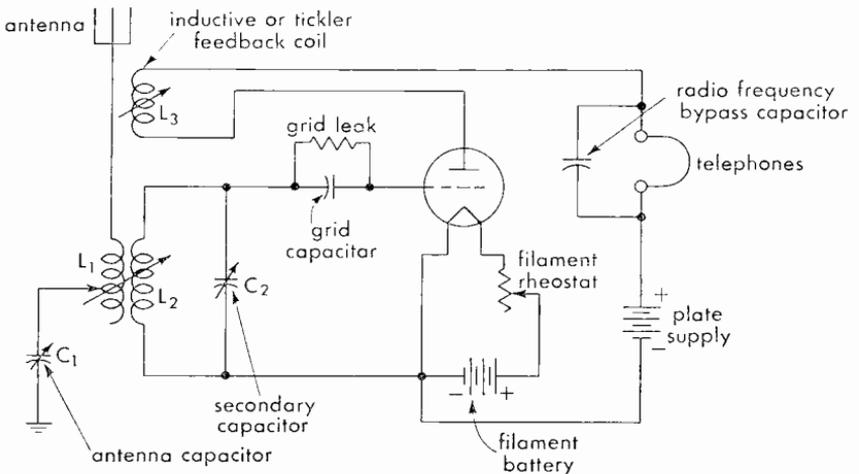


FIG. 3-21. Regenerative detector.

3.92 Draw a simple schematic circuit of a radio-frequency doubler stage, indicating any pertinent points which will distinguish this circuit as that of a frequency doubler.

*Answer.* See Figs. 3-22 and 6-4. The doubler illustrated in Fig. 3-22 is identified only by its operating characteristics. The adjustment of

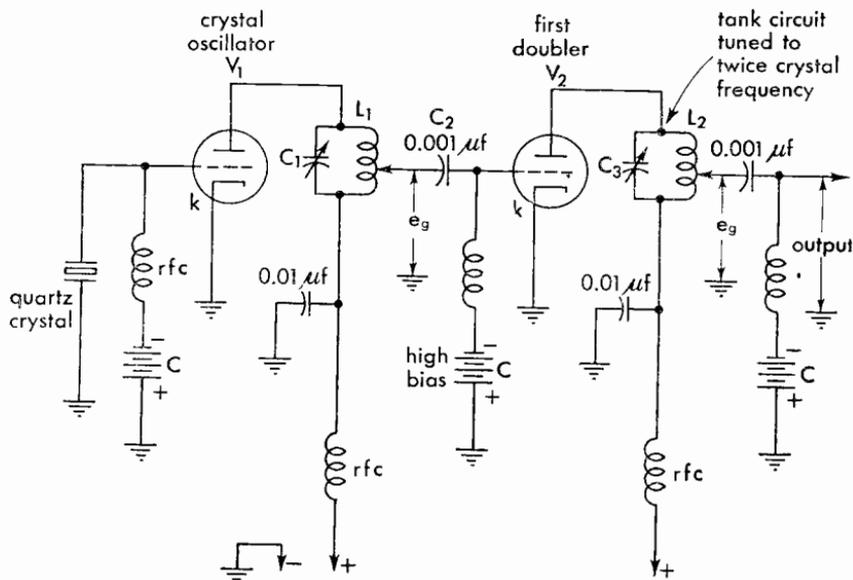


FIG. 3-22. Radio-frequency doubler stage.

the doubler circuit to obtain rich harmonic outputs is dependent upon grid bias, plate voltage, and output tuning. The tube should be operated at reasonably high plate potential, high grid bias (class C), and the plate-tank circuit tuned to the second or third harmonic of the input frequency, as required.

3.93 Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be two-thirds the resistance of one unit.

*Answer.* See Fig. 3-23.

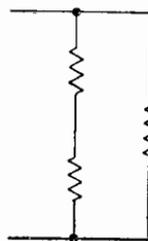


FIG. 3-23. Parallel-resistance combination.

3.94 Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be  $1\frac{1}{2}$  times the resistance of one unit.

*Answer.* See Fig. 3-24.

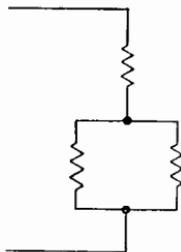


FIG. 3-24. Series-parallel resistance combination.

3.95 Draw a simple schematic diagram showing the method of connecting the three resistors of equal value so that the total resistance will be one-third of one unit.

*Answer.* See Fig. 3-25.

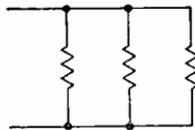


FIG. 3-25. Parallel resistance combination.

3.96 Draw a simple schematic diagram showing the method of connecting three resistors of equal value so that the total resistance will be three times the resistance of one unit.

*Answer.* See Fig. 3-26.

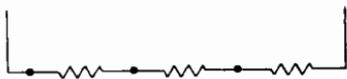


FIG. 3-26. Series resistance combination.

**3.97** Draw a diagram of a single-button carbon-microphone circuit, including the microphone transformer and source of power.

*Answer.* See Fig. 3-27.

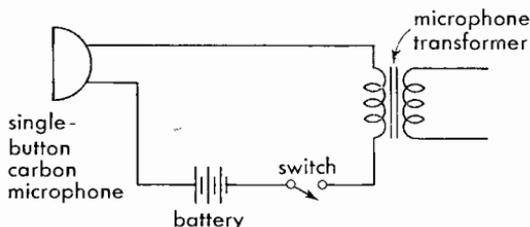


FIG. 3-27. Carbon-microphone circuit arrangement.

**3.98** What is meant by a “soft” vacuum tube?

*Answer.* A tube containing a small amount of gas which was not thoroughly exhausted during the manufacturing process.

**3.99** Describe the physical structures of the triode, tetrode, and pentode on a comparative basis.

*Answer.* The triode has three elements; cathode, control grid, and plate. The tetrode has four elements, namely, cathode, control grid, screen grid, and plate. The pentode has five elements, including all those mentioned for the tetrode, and in addition, a fifth element called the suppressor grid. The suppressor grid is generally (but not always) connected directly to the cathode. Therefore, it assumes a negative potential with respect to the plate and retards secondary emission.

**3.100** Describe the electrical characteristics of the pentode, tetrode, and triode on a comparative basis.

*Answer.* The pentode is a five-element tube, the distinctive feature of which is a suppressor grid usually directly connected to the cathode and serving to prevent secondary emission. When the pentode is used as a power-output amplifier, the suppressor makes possible a large power output with high gain, because the plate swing can be made very large. When the pentode is used as a radio-frequency amplifier, high-voltage amplification is possible using moderate values of plate voltage. Because the pentode also has a screen grid, interelement capacitance is minimized and an external system of neutralization is generally unnecessary when the tube is used as a radio-frequency amplifier.

The tetrode is a four-element tube, the distinctive feature of which is a screen grid located between the control grid and the plate. The screen grid serves to neutralize or reduce the grid-to-plate capacitance, thus making the tube suitable for use in most types of radio-frequency amplifier circuits without the application of special neutralizing methods.

The screen grid is operated at a positive voltage lower than that of the plate. A desirable result achieved is that the screen grid makes plate current practically independent of plate voltage within limits. Because the screen grid is charged with a positive potential, it serves as an extra force for pulling electrons through the space charge. Because the plate current in the tetrode is independent of the plate voltage, a much higher gain per stage is possible with a tetrode than with a triode, other conditions being equal.

The triode is a three-element tube, consisting of cathode, grid, and plate. The purpose of the grid is to control the flow of electrons from the filament to the plate. When the tube is used as an amplifier, the grid is usually operated with a negative bias. A negative charge on the grid tends to reduce plate current while a positive charge on the grid tends to increase plate current. Therefore, when an alternating signal voltage is applied to the grid, the plate current varies in accordance with the applied signal voltage. Because there is electrostatic capacitance between the grid and the plate, allowing a feedback of radio-frequency energy between these elements, it is necessary to compensate this interelement capacitance by an external system of neutralization.

### **3.101 What are the visible indications of a "soft" tube?**

*Answer.* A "soft" tube may be detected by an excessive or erratic flow of plate current. If the plate voltage is sufficiently high to ionize the gas, a light-blue haze will be apparent between the cathode and the plate.

### **3.102 Describe the physical structure of a triode vacuum tube.**

*Answer.* A triode is a three-element vacuum tube, containing a cathode and filament heater or a filament alone, a control grid surrounding the cathode or filament, and a plate enveloping the grid and cathode elements. The filament or cathode may be of tungsten, thoriated tungsten, or oxide. The grid is composed of small-spaced wire

laterals or spirals. The plate is generally a solid rectangle or cylinder. Grid and plate materials are usually of metal or metallized structures of molybdenum, nickel, iron, carbonized nickel, or manganese-nickel alloys.

### 3.103 Describe the physical structure of a tetrode vacuum tube.

*Answer.* A tetrode is a four-element tube, containing the same elements as the triode but with the addition of a second grid spiral called a screen or shield grid. This screen grid is placed between the control grid and the plate of the tube. Unlike the control grid, the screen grid is generally at positive potential with respect to the cathode. Its primary function is to reduce the internal-control grid-to-plate capacitance and to increase the over-all voltage amplification as compared with a triode. (The amplification properties are also dependent upon the output load impedance into which the tube functions.) Frequently, as in the case of wide-band amplifiers, the load impedance may be of such value as to give very little gain, the objective being primarily to improve the bandwidth of the amplifier.

The control grid in a tetrode vacuum tube is shielded internally to reduce the capacitance between it and the plate.

### 3.104 Does a pentode vacuum tube usually require neutralization when used as a radio-frequency amplifier?

*Answer.* No. The reduced grid-to-plate capacitance minimizes the possibility of feedback. However, its use in very high-frequency circuits may necessitate neutralization.

### 3.105 What is the meaning of "secondary emission"?

*Answer.* When primary electrons from the filament are drawn to the plate of a vacuum tube with such force that they, in turn, dislodge electrons from the surface of the plate by their impact force, the electrons so dislodged are called "secondary electrons." The emission of these electrons from the plate is called "secondary emission" to differentiate it from the primary emission from the filament. Secondary emission opposes and reduces the normal plate-current flow.

### 3.106 What is the meaning of "electron emission"?

*Answer.* "Electron emission" is the liberation of electrons from a material when it is heated to a point at which electrons break through the surface of the material.

**3.107 Describe the characteristics of a vacuum tube operating as a class C amplifier.**

*Answer.* This type of amplifier is very efficient because plate-current pulses flow only during brief periods; these pulses are of a duration appreciably less than one-half of each positive cycle. Although efficiency may be made as high as 95 per cent, output then falls off, so the amplifier is generally operated between 60 and 80 per cent efficiency. The grid-bias adjustment of a class C amplifier is generally between  $1\frac{1}{2}$  and 4 times the cutoff bias value. The plate power varies approximately as the square of the plate voltage. High power outputs can be obtained in properly adjusted class C amplifiers. They are used for radiotelegraph and similar types of signals.

**3.108 During what portion of the excitation voltage cycle does plate current flow when a tube is used as a class C amplifier?**

*Answer.* See 3.107.

**3.109 Describe the characteristics of a vacuum tube operating as a class A amplifier.**

*Answer.* The characteristics of a class A amplifier are that the output wave shape is essentially a linear reproduction of the grid voltage. The ratio of voltage amplification is high, but the efficiency of the tube as an amplifier is low. Plate current flows during the entire excitation cycle.

**3.110 Describe the characteristics of a vacuum tube operating as a class B amplifier.**

*Answer.* The output power of a class B amplifier is proportional to the square of the excitation voltage. The practical operating efficiency is approximately  $33\frac{1}{3}$  per cent. Grid-bias adjustment is at or near the plate-current cutoff value.

This type of amplifier is frequently referred to as a "linear" amplifier owing to its excellent output characteristics.

**3.111 During what portion of the excitation voltage cycle does plate current flow when a tube is used as a class B amplifier?**

*Answer.* Plate current flows in a class B amplifier for a period of approximately one-half of the grid excitation cycle.

**3.112 Does a properly operated class A audio amplifier produce serious modification of the input wave form?**

*Answer.* No. Its operation is essentially linear.

**3.113 What is the meaning of the term "maximum plate dissipation"?**

*Answer.* "Plate dissipation" refers to the quantity of power lost at the plate of the tube in heat radiation. Maximum dissipation is the amount of heat that can safely be accommodated at the plate without injury to the tube ( $e_b \times i_b$ ).

**3.114 What is meant by a "blocked grid"?**

*Answer.* A tube has a "blocked grid" when the grid bias is of such a value as to shut off plate current.

**3.115 What is meant by the "load" on a vacuum tube?**

*Answer.* The resistance or impedance into which the output of the tube is fed.

**3.116 What circuit and electron-tube factors influence the voltage gain of a triode audio-frequency amplifier stage?**

*Answer.* The amplification factor of the tube, the value of load resistance or impedance  $R_L$ , the alternating current or plate resistance of the tube  $r_p$ , and the turns ratio of the coupling transformer, if used.

$$\text{Voltage gain (triode)} = \frac{\mu R_L}{r_p + R_L},$$

**3.117 What is the purpose of a bias voltage on the grid of an audio-frequency amplifier tube?**

*Answer.* The purpose of the biasing voltage on a class A audio-frequency amplifier tube is to operate the tube at the center of the straight portion of the characteristic curve to obtain a symmetrical reproduction of the grid swing in the plate circuit. If the signal is restricted within the straight portion of the curve, distortion will be negligible.

In a class B amplifier the grid bias ensures operation at or near the cutoff point of the tube and also limits the grid-current flow to the required value. It also permits considerably higher excitation as compared with a class A amplifier.

**3.118** What is the primary purpose of a screen grid in a vacuum tube?

*Answer.* See 3.100, 3.103, and 3.104.

**3.119** What is the primary purpose of a suppressor grid in a multi-element vacuum tube?

*Answer.* To retard the emission of secondary electrons from the plate, which otherwise would flow to the screen grid, reducing plate current and limiting permissible plate swing.

**3.120** What is the meaning of the term "plate saturation"?

*Answer.* "Plate saturation" is the condition present when practically all the electrons which are emitted from the filament of the tube reach the plate for the filament voltage applied.

**3.121** What is the most desirable factor in the choice of a vacuum tube to be used as a voltage amplifier?

*Answer.* The most desirable factor in a voltage amplifier tube is a high mutual conductance ( $g_m$ ).

**3.122** What is the principal advantage of a tetrode over a triode as a radio-frequency amplifier?

*Answer.* A tetrode does not require capacitance neutralization unless used in ultrahigh- or very high-frequency circuits. A tetrode in general also gives a higher voltage amplification than a triode tube owing to its relatively higher mutual conductance and amplification factor.

**3.123** What is the principal advantage of the tetrode as compared to the triode, when used in a radio receiver?

*Answer.* See 3.122.

**3.124** What is the principal advantage in the use of a diode detector instead of a grid-leak triode detector?

*Answer.* The diode detector will give less distortion, particularly on strong or high-percentage modulated signals.

**3.125** Draw a grid-voltage-plate-current characteristic curve of a vacuum tube and indicate the operating points for class A, class B, and class C amplifier operation.

Answer. See Fig. 3-28.

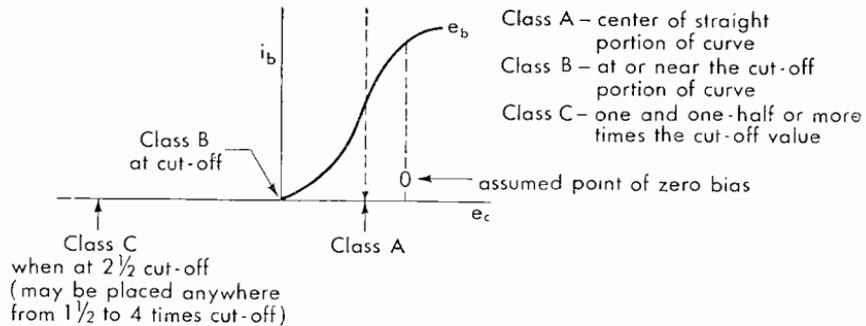


FIG. 3-28. Vacuum-tube operating-curve adjustments for class A, class B and class C amplification.

### 3.126 What operating conditions determine that a tube is being used as a power detector?

Answer. Power detection or large-signal detection may be obtained by either a diode, grid-leak, or plate-current cutoff detector under certain operating conditions. The most frequently used types of power detectors in receivers are the grid-leak large-signal detector and the diode detector. The operating conditions of power detection in general require a relatively lower impedance in the detector load circuit as compared with ordinary detectors. For example, in the grid-leak or diode large-signal detector the grid-leak resistance and diode load resistance are generally between 100,000 and 500,000 ohms as compared with 1 to 10 megohms in the ordinary weak-signal grid-leak detector. (See also 3.134.)

### 3.127 Why is it desirable to use an a-c filament supply for vacuum tubes?

Answer. The use of alternating current on the filaments of vacuum tubes eliminates the necessity for cumbersome filament batteries and charging apparatus or rectifier units and filters for supplying direct current from an alternating-current line. In general, the entire operation of the system is simplified because filament power can be taken directly from the a-c line through a step-down transformer. (See 3.128.)

### 3.128 Why is it advisable periodically to reverse the polarity of the filament potential of high-power vacuum tubes when a d-c filament supply is used?

*Answer.* It is advisable periodically to reverse the polarity of the filament potential in order to lengthen the life of the filament. The electronic emission is not uniform over the entire length of the filament since the variable space current present all along the filament causes a difference in the temperature of the filament at various points along its length. Hence, the resistance of the filament is altered with a consequent change in the filament's potential gradient. All of these effects taken together, if allowed to operate without variation on a filament, will tend to shorten its life. By reversing the filament potential at regular intervals, this strain is periodically redistributed on the filament and its life lengthened.

**3.129 Why is it important to maintain transmitting-tube filaments at recommended voltages?**

*Answer.* If the filament voltage is above normal, the life of the tube is shortened. If the filament voltage is below normal, the tube will not give optimum results because of a deficiency in its electron-emitting qualities. Hence, it is important to keep the filament voltage at the rated value.

**3.130 When an a-c filament supply is used, why is a filament center tap usually provided for the vacuum-tube plate and grid return circuits?**

*Answer.* If the filament return circuits were connected to one side of the filament, the bias on the grid would be varied by an amount equal to the filament voltage at each reversal of filament polarity. This action would cause audio-frequency modulation in the tube and a hum in the circuit.

**3.131 Explain the operation of a grid-leak detector.**

*Answer.* Grid-leak or square-law detection as illustrated in Fig. 3-20 operates upon the principle of diode rectification in the grid circuit with the exception that the rectified component is amplified in the plate circuit. It is in reality a diode rectifier and audio-frequency amplifier all in one.

When a modulated radio-frequency wave is applied to the grid circuit and between the cathode and grid of the triode tube, electrons will be attracted to the grid during the positive halves of the incoming cycle. The electrons will flow through the grid-leak resistance, which will develop an  $IR$  drop across it and make the grid negative with

respect to the cathode. Hence, there is developed across the grid-leak resistance a d-c voltage drop which varies in accordance with the amplitude changes of the modulated radio-frequency wave. Since the effect of the increase in grid current due to rectification is to increase the  $IR$  drop across the grid leak, the average grid voltage increases in a negative direction as the modulated signal increases in amplitude. The average plate current therefore decreases during these grid peak periods. If therefore the input radio-frequency signal in the grid circuit is amplitude-modulated, the resultant decrease in plate current fluctuates at an audio-frequency rate, producing an amplified audio-frequency voltage across the plate-circuit load.

**3.132 List and explain the characteristics of a square-law vacuum-tube detector.**

*Answer.* The grid-leak-and-capacitor detector is a square-law detector, the output waveshape varying as the square of the signal input voltage. This results in a detector which is very sensitive but has a high percentage of harmonic distortion. The square-law detector responds only to a modulated signal input on its grid circuit. Hence, the square-law detector cannot respond to continuous-wave (type A1) emission applied to its grid circuit.

**3.133 Explain the operation of a diode detector.**

*Answer.* The operation of the diode detector is precisely the same as the grid-leak detector explained in 3.131 with the exception that the diode load is connected in the cathode return. The audio-frequency voltages developed across the diode load (Fig. 3-18) are then fed to the grid of an audio-frequency amplifier.

**3.134 Explain the operation of a power or plate rectification vacuum-tube detector.**

*Answer.* In power or plate rectification the grid is biased almost to the cutoff point. Hence, plate current flows only during the positive alternation of the signal voltage impressed on the grid, causing a consequent rise in plate current. The output waveshape conforms to that of the modulated radio-frequency signal voltage.

**3.135 Is a grid-leak detector more or less sensitive than a power detector (plate rectification)? Why?**

*Answer.* The weak-signal grid-leak or square-law detector is the more sensitive because it operates at zero bias at which point the

mutual conductance is maximum. The plate detector operates near cutoff at which point the mutual conductance is minimum.

**3.136 Describe what is meant by a class A amplifier.**

*Answer.* A class A amplifier operates in such a manner that the plate-output waveform is essentially the same as the excitation grid voltage. Plate current flows during the entire excitation cycle. The grid must usually not go positive on excitation peaks, and the plate current must not fall low enough at its minimum to cause distortion. (Adapted from IRE Standards definitions.)

**3.137 What are the characteristics of a class A audio amplifier?**

*Answer.* A relatively high voltage gain, low efficiency with linear output, and a constant d-c plate component. Low harmonic distortion if properly adjusted and operating into a load impedance of at least  $2r_p$ .

**3.138 What will be the effect of incorrect grid bias in a class A audio amplifier?**

*Answer.* An incorrect grid bias may cause nonsymmetry with consequent distortion of the output waveform.

**3.139 What are the factors which determine the bias voltage for the grid of a vacuum tube?**

*Answer.* The efficiency to be achieved, the class of amplifier operation, the excitation voltage available, the plate potential to be used, the permissible swing of the a-c component, and the second-harmonic content allowed are all factors which affect the final selection of bias voltage for the grid of a vacuum tube.

**3.140 Why are tubes operated as class C amplifiers not suited for audio-frequency amplification?**

*Answer.* Class C amplifiers are not suited to audio-frequency amplification primarily because of the high grid excitation, grid bias, and plate-voltage requirements, also because the distortion content as compared with a properly operated class A amplifier is considerably greater.

**3.141 Draw a circuit of a frequency doubler and explain its operation.**

*Answer.* See Fig. 3-22 for diagram. The tube is biased beyond the cutoff point. This produces a distorted plate-current waveshape which contains a large percentage of harmonics. The plate  $LC$  circuit is tuned to twice the input frequency (second harmonic).

In Fig. 6-4 frequency doubling is accomplished as follows: The two grids are excited alternately 180 deg out of phase. When one grid is positive, the plate-tank circuit is shocked into oscillation, since both plates are connected in parallel. Owing to the flywheel action of the tank circuit, a complete cycle is developed in the tank circuit for each excitation pulse. Hence, since a grid excitation frequency of, say, 1 megacycle is developed in the grid circuit, the plate circuit will oscillate at 2 megacycles. The parallel-resonant adjustment of the plate-tank circuit must be tuned to twice the frequency of the grid excitation frequency under these conditions.

### 3.142 For what purpose is a doubler amplifier stage used?

*Answer.* The doubler amplifier is used when an output frequency greater than the maximum safe operating frequency of a crystal oscillator is desired, and also, in the case of ordinary oscillators, to obtain better frequency stability by operating the oscillator at a lower frequency.

### 3.143 Describe what is meant by "link coupling" and for what purpose(s) is it used?

*Answer.* "Link coupling" is the term applied to the coupling provided between two major circuits by an intermediate link circuit, which may, in turn, be defined as two inductors joined by a relatively short transmission line and inductively coupled to the major circuits. (See Fig. 3-29.)

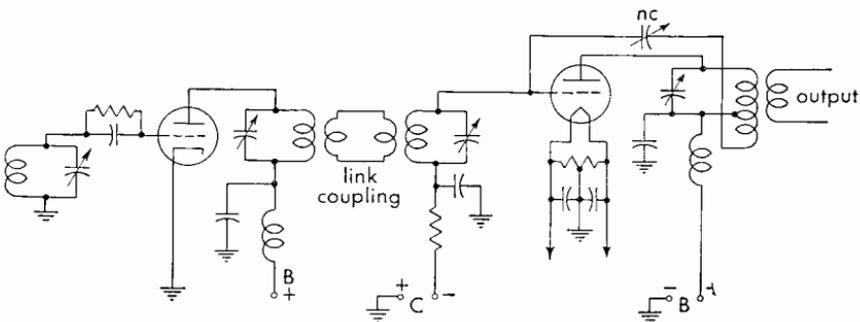


FIG. 3-29. Link-coupling arrangement.

**3.144 What factors may cause low plate current in a vacuum-tube amplifier?**

*Answer.* Low plate current may be caused by defective tubes, excessive grid bias, or defective filter or bypass capacitors, low operating voltages, insufficient grid excitation in a class B or C amplifier.

**3.145 Given the following electron-tube constants:  $E_b = 1,000$  volts,  $I_b = 150$  milliamperes,  $I_g = 10$  milliamperes, and grid leak = 5,000 ohms, what would be the value of d-c grid-bias voltage?**

*Answer.* 50 volts.  $E = IR = 0.01 \times 5,000 = 50$  volts

**3.146 Explain how you would determine the value of cathode-bias resistance necessary to provide correct grid bias for any particular amplifier.**

*Answer.* The correct value of resistance may be determined by reference to the static characteristics of the tube plate, screen-grid currents. The desired bias voltage required  $E_c$  for a given value of plate voltage.

$$R_{\text{bias}} = \frac{E \text{ (bias voltage required)}}{I \text{ (total cathode resistor currents)}}$$

**3.202 What effects might be caused by a short-circuited grid capacitor in a three-circuit regenerative receiver?**

*Answer.* A short-circuited grid capacitor in a three-circuit regenerative receiver would prevent rectification (detection) of the modulated signal. The automatic grid-biasing action due to the grid capacitor and grid-leak combination would be eliminated. No regeneration or rectification would result unless a small amount of cathode bias is present in the circuit.

**3.203 What would be the effect of a short-circuited coupling capacitor in a conventional resistance-coupled audio amplifier?**

*Answer.* The effect of a short-circuited coupling capacitor in a conventional resistance-coupled audio amplifier would be to allow the grid of the following tube to become positively biased, causing heavy grid and plate currents to flow. Under these conditions a continuous grid current and heavy plate current will flow, which completely alters the linearity of the operating curve and which results in severe distortion. In addition, the heavy  $IR$  drops in the plate circuit will result in a great decrease in plate potential and volume.

**3.204 What might be the cause of low sensitivity of a three-circuit regenerative receiver?**

*Answer.* This condition may be the result of low plate voltage, reversed feedback coil winding, incorrect value or change in grid-leak resistance, leaky grid capacitor, low filament potential, or defective tube.

**3.217 Why are high-reactance head telephones generally more satisfactory for use with radio receivers than low-reactance types?**

*Answer.* High-reactance or high-impedance telephones possess a greater ampere-turns ratio as compared with low-reactance types especially as related to weak-signal current flow. Hence they possess a greater sensitivity to weak signals. High-impedance telephones also provide a better load-impedance match to the output of an audio-frequency amplifier or detector tube.

**3.218 What may cause packing of the carbon granules in a carbon button microphone?**

*Answer.* Excessive carbon current, jarring with current on.

**3.219 Why should polarity be observed in connecting head telephones directly in the plate circuit of a vacuum tube?**

*Answer.* When the head telephones are connected directly in the plate circuit of a vacuum tube, direct current flows through their magnet windings. Unless the direction of this current is correct, this current will serve to demagnetize these magnets and render the head telephones insensitive. On the other hand, if the direction of this current is proper, the magnetic strength of the magnets will be kept up to normal.

**3.220 What precautions should be observed in the use of a double-button carbon microphone?**

*Answer.* The current should be balanced in each button and should not exceed 30 milliamperes. The microphone should not be handled with the current on. The sound level impressed on the diaphragm of the microphone should not be high enough to cause "blasting." This type of microphone should be kept dry and free from exposure to moisture.

**3.221** If low-impedance head telephones of the order of 75 ohms are to be connected to the output of a vacuum-tube amplifier, how may this be done to permit most satisfactory operation?

*Answer.* To do this satisfactorily, an output transformer must be used. The input side of this transformer must have an impedance equal to at least twice the tube's plate resistance. The output must be designed to make the head telephones' load reflect the desired impedance to the tube. This is done by using the proper turns ratio  $N$ , where  $N = \sqrt{R_p/R_L}$  (approximately), where  $R_p$  is the plate resistance and  $R_L$  is the load resistance.

**3.222** What is the effect on the resonant frequency of adding an inductor in series with an antenna?

*Answer.* The resonant frequency of the antenna system will be decreased.

**3.223** What is the effect on the resonant frequency of adding a capacitor in series with an antenna?

*Answer.* The resonant frequency of the antenna system will be increased.

**3.224** What is the velocity of propagation of radio-frequency waves in space?

*Answer.* 300,000,000 meters per sec or 186,000 miles per sec.

**3.225** What is the relationship between the electrical and physical length of a Hertz antenna?

*Answer.* A Hertz antenna will radiate a wave equal to approximately twice its physical length.

**3.226** If you desire to operate on a frequency lower than the resonant frequency of an available Marconi antenna, how may this be accomplished?

*Answer.* This may be accomplished by adding an inductance in series with the antenna. This will make the antenna resonant at a lower frequency.

**3.227** What will be the effect upon the resonant frequency if the physical length of a Hertz antenna is reduced?

*Answer.* The resonant frequency of the antenna will be higher.

**3.228** Which type of antenna has a minimum of directional characteristics in the horizontal plane?

*Answer.* The single-radiator vertical antenna.

**3.229** What factors determine the resonant frequency of any particular antenna?

*Answer.* The physical length of the antenna determines the resonant frequency, depending upon the type of antenna used, that is, whether it is grounded or ungrounded. The wavelength of the grounded antenna is approximately 4.2 to 4.5 times its physical length. The Hertz ungrounded antenna has a wavelength of twice its physical length.

**3.230** If the resistance and the current at the base of a Marconi antenna are known, what formula can be used to determine the power in the antenna?

*Answer.* The formula used would be  $I^2R$ , where  $I$  is the current at the base of the antenna and  $R$  is the radiation resistance.

**3.231** Does the resistance of a copper conductor vary with variations in temperature and if so, in what manner?

*Answer.* The resistance of a copper conductor varies directly with any change in temperature; that is, as the heat increases, the resistance increases and vice versa.

**3.232** What type of insulator is best suited for use as an antenna-strain insulator which is exposed to the elements?

*Answer.* Electrical glazed porcelain is best suited for use as an antenna-strain insulator.

**3.233** What material is frequently used for relay contacts? Why?

*Answer.* Silver, because it has low resistance, exhibits a minimum amount of corrosion and does not pit easily. Tungsten is also commonly used.

**3.234** Describe the operation of a crystal detector (rectifier).

*Answer.* A simple radio receiver using a crystal detector is comprised of a radio-frequency transformer, a variable-tuning capacitor, a galena or silicon crystal, and a pair of high-resistance telephones (2,000 to 8,000 ohms) shunted by a small radio-frequency bypass capacitor (0.0001 to 0.0005  $\mu\text{f}$ ).

The unilateral conductivity of the crystal permits a current to flow through it in one direction only and thereby makes it possible to "detect" a modulated radio-frequency wave and produce an audible response in the telephones.

The operation is as follows: When the tuned circuit is adjusted to resonance for a given modulated signal frequency, an alternating high-frequency voltage, which is varying in amplitude in accordance with the modulating frequency, is developed across the tuned circuit. Owing to the rectifying action of the crystal, the low-frequency and high-frequency components of the signal pass through the circuit in one direction only. The rectified radio-frequency pulses pass through the bypass capacitor, and the low-frequency tonal groups pass through the telephones. The high impedance of the small bypass capacitor to the audio frequencies enables the full audio-frequency voltage of the rectified modulated signal to act across the high-impedance telephones. Thus, a series of low-frequency pulses actuates the diaphragm through the telephone windings to produce an audible response. The detecting action is therefore simply a process of changing the high-frequency signal to a low-frequency signal by the crystal rectifying action.

### 3.235 Define a "damped wave."

*Answer.* A "damped wave" may be defined as an oscillatory wave train, the energy of which gradually decreases with time until the wave is damped out. It may also be defined as a series of pulses in which the successive amplitude of each peak of a pulse group gradually diminishes or decays.

### 3.236 Why is rosin used as soldering flux in radio construction work?

*Answer.* In soldering, any acid will in time cause corrosion, thus increasing the resistance of the electrical connection. Pure rosin when used as a flux produces no corrosion and is, therefore, used in all high-grade radio work.

### 3.237 What is meant by a "harmonic"?

*Answer.* A "harmonic frequency" is a multiple of the fundamental frequency. In radio work, the initial frequency is regarded as the first harmonic, the second multiple of this frequency being the second harmonic, the third multiple of this frequency the third harmonic, and so forth.

**3.238 Why should all exposed metal parts of a transmitter be grounded?**

*Answer.* To protect the operator from coming in contact with a high voltage, thus protecting him against serious or fatal shock. It is also employed to minimize electrostatic coupling of components with respect to ground.

**3.239 What is the difference between electrical power and electrical energy?**

*Answer.* Energy is defined as work. The fundamental practical unit of work is the *joule* or *watt-second*. Power is the rate of doing work, or the rate at which energy is expended. The practical unit is the *watt*.

**3.240 How can the direction of flow of d-c electricity in a conductor be determined?**

*Answer.* The direction of flow of d-c electricity can be determined by any one of the following means:

1. A d-c ammeter.
2. Determining the polarity of the source emf. The electron flow will be in the direction of the positive point of potential or away from the negative point in a closed electric circuit.
3. A compass needle placed near a conductor carrying a d-c flow. Application of Fleming's right-hand rule and positioning of the compass needle with known polarity will determine the direction of current flow.
4. Passing the current through a saline solution.

**3.241 What instrument measures electric power?**

*Answer.* The wattmeter.

**3.242 What instrument measures electrical energy?**

*Answer.* The watthour meter.

**3.243 What is an electron? An ion?**

*Answer.* An *electron* is a negatively charged particle of electricity. An *ion* is a positively or negatively charged atom or group of atoms. An atom that has lost or gained one or more of its electrons is referred to in chemistry as a positive or a negative ion, respectively.

With gas-filled tubes the bombardment of electrons with gas atoms causes the atoms to lose one or more of their electrons. In this case only positive ionization occurs.

**3.244 With respect to electrons, what is the difference between conductors and nonconductors?**

*Answer.* A conductor is a material in which the total atomic structure contains many *free* electrons. A nonconductor or insulator is a material in which the total atomic structure is lacking in the number of free electrons.

**3.245 Describe an electrolyte.**

*Answer.* An electrolyte is a water solution of an acid, alkali, or a salt of sufficient concentration to carry an electric current. In such a solution the molecules break down to form ions that are the carriers of the current.

**3.246 What is an A battery? B battery? C battery?**

*Answer.* The terms "A," "B," and "C" batteries are used to denote the filament voltage, plate voltage, and grid-biasing supply voltages, respectively, for vacuum tubes.

An A battery is a battery for heating the filaments of vacuum tubes.

A B battery is a battery for supplying positive potentials to the plate, screen grid, and occasionally other electrodes of vacuum tubes with respect to the cathodes or filaments.

A C battery is a battery for supplying negative grid voltage (bias) to vacuum tubes with respect to the cathodes or filaments.

**3.247 What are the lowest radio frequencies useful in radio communication?**

*Answer.* Frequencies between 10 and 30 kc. These frequencies are called VLF or very-low radio frequencies.

**3.248 What radio frequencies are useful for long-distance communications requiring continuous operation?**

*Answer.* Frequencies in the VLF (10 to 30 kc) range are commonly employed for long-distance point-to-point communications.

**3.249** What frequencies have substantially straight-line propagation characteristics analogous to those of light waves and unaffected by the ionosphere?

*Answer.* Frequencies above about 100 mc possess substantially straight-line propagation characteristics. This range of frequencies is classified into three groups:

VHF (very-high radio frequencies) 30 to 300 mc.

UHF (ultrahigh radio frequencies) 300 to 3,000 mc.

SHF (superhigh radio frequencies) 3,000 to 30,000 mc.

**3.250** What effects do sunspots and aurora borealis have on radio communications?

*Answer.* Sunspots and aurora borealis may produce severe fading and absorption of radio signals. Long-distance transmissions that depend upon the ionosphere for reflections may be completely blanketed during magnetic storms caused by aurora borealis or sunspots.

**3.251** What type of modulation is largely contained in "static" and "lightning" radio waves?

*Answer.* A highly damped (broad response) wave of amplitude-modulation characteristic.

**3.252** What type of radio receiver does not respond to static interference?

*Answer.* Receivers employing the principle of frequency modulation.

**3.253** What crystalline substance is widely used in crystal oscillators?

*Answer.* Crystal slabs cut from natural quartz.

**3.254** Why is the crystal in some oscillators operated at constant temperature?

*Answer.* Some crystals require constant-temperature control to hold the frequency of the crystal to its assigned value. This is because certain types of crystals have a positive temperature coefficient while others have a negative temperature coefficient. (See also 3.421.)

**3.255** What is meant by "negative temperature coefficient" of a quartz crystal when used in an oscillator?

*Answer.* See Ques. 3.424.

**3.256** What is the seventh harmonic of 360 kc?

*Answer.* 2,520 kc.

*Solution:*

$$360 \times 7 = 2,520$$

**3.257** Describe the directional characteristics of the following types of antenna:

1. Horizontal Hertz antenna.
2. Vertical Hertz antenna.
3. Vertical loop antenna.
4. Horizontal loop antenna.
5. Vertical Marconi antenna.

*Answer.*

1. Omnidirectional at 90 deg to antenna.
2. Omnidirectional characteristic, vertically polarized.
3. Bidirectional, 90 deg to plane of loop.
4. Bidirectional, 90 deg to plane of loop.
5. Omnidirectional in horizontal plane, like (2).

**3.258** What is meant by the "efficiency" of a radio device?

*Answer.* The efficiency of any radio device is the ratio of the work performed to the energy supplied to it. It is a measure, usually expressed in percentage, of the ratio of the output to the input of any device, with both output and input expressed in the same unit of power or energy.

$$\text{Per cent efficiency } (n) = \frac{\text{output}}{\text{input}} \times 100$$

**3.259** What form of energy is contained in a sound wave?

*Answer.* Sound is composed of mechanical vibrations (acoustic energy) lying within the frequency range of human audibility.

**3.260** What characteristic determines the pitch of a sound?

*Answer.* The pitch of a pure tone is primarily dependent upon the frequency or number of vibrations per second and to a slight degree upon the sound intensity.

**3.261** How many micromicrofarads are there in one microfarad?

*Answer.* One microfarad contains 1,000,000 or  $10^6$  micromicrofarads. A micro unit is a millionth part of one.

**3.262** What is the difference between a milliwatt and a kilowatt?

*Answer.* Milli = one-thousandth part of 1 or 0.001. Kilo = 1,000.

A milliwatt is one-thousandth part of 1 watt or 0.001 watt. A kilowatt is equal to 1,000 watts.

**3.263** What precaution should be observed when electrolytic capacitors are connected in a circuit?

*Answer.* The correct polarity must be observed, since the electrolytic type of capacitor functions as a capacitor only when its positive terminal is connected to the corresponding potential point in the circuit.

**3.267** If the period of one complete cycle of a radio wave is 0.000001 second, what is the wavelength?

*Answer.* 300 meters.

*Solution:*

$$\text{Frequency } (f) = \frac{1}{T} = \frac{1}{0.000001} = 10^6 \text{ cycles}$$

$$\text{Wavelength } (\lambda) = \frac{v}{f} = \frac{300,000,000}{10^6} = 300 \text{ meters}$$

- where  $f$  = frequency in cycles per second.
- $T$  = time period of one cycle in seconds.
- $\lambda$  = wavelength in meters per second.
- $v$  = velocity of light.

**3.268** Compare the selectivity and sensitivity of the following types of receivers: (a) tuned radio-frequency receiver, (b) superregenerative receiver, (c) superheterodyne receiver.

*Answer.* The comparative selectivity and sensitivity of tuned radio-frequency, superregenerative, and superheterodyne receivers are classified as follows:

<i>Receiver</i>	<i>Sensitivity</i>	<i>Selectivity</i>
Superheterodyne.....	Excellent	Excellent
Tuned radio-frequency.....	Good	Good
Superregenerative.....	Good	Poor

**3.269** What type of radio receiver contains intermediate-frequency transformers?

*Answer.* The superheterodyne receiver.

**3.270** What type of radio receiver is subject to image interference?

*Answer.* The superheterodyne receiver.

**3.271** What type of radiotelephone receiver using vacuum tubes does not require an oscillator?

*Answer.* The tuned radio-frequency receiver.

**3.272** Describe the operation of a regenerative receiver.

*Answer.* The theoretical operation of this type of receiver is based upon the principle of inductive or capacitive feedback of radio-frequency energy from the plate to the grid circuit. (See also Fig. 3-21 and 6.646.)

**3.273** How may a regenerative receiver be adjusted for maximum sensitivity?

*Answer.* See 6.646.

**3.274** What effect does the reception of modulated signals have on the plate current of a grid-leak-grid-capacitor detector? On a grid-bias detector?

*Answer.* The plate current pulses will decrease when a modulated signal is applied to the grid circuit of a grid-leak detector.

In the grid-bias detector the opposite holds true, since the grid is biased almost to the point of plate current cutoff when no signal is applied. An incoming modulated signal, therefore, will cause the negative bias to decrease, resulting in a rise in plate current. (See also 3.131, 6.356-6.358.)

**3.275** What is meant by double detection in a receiver?

*Answer.* Double detection is the name applied when demodulation (detection) occurs in two circuits of the same receiver. The superheterodyne receiver uses this principle. The first detector is the stage in which the mixing action necessary to produce the intermediate frequency takes place. The second detector follows the last inter-

mediate-frequency stage and converts the modulated signal into the audio-frequency component. (See also 6.387.)

**3.276 What is the purpose of a wave trap in a radio receiver?**

*Answer.* A wave trap is employed in a radio receiver to reject undesired signals. In practice, a series wave trap is sometimes shunted across the input terminals of a superheterodyne radio receiver to eliminate code interference. Wave traps are also employed in certain wide-band receivers to isolate certain frequency bands.

**3.277 What is the purpose of an oscillator in a receiver operating on a frequency near the intermediate frequency of the receiver?**

*Answer.* An oscillator operating near the intermediate frequency of a superheterodyne receiver is used for producing a beat frequency. This would permit the receiver to respond to continuous-wave signals for code reception or for continuous-wave calibration purposes in standard-frequency transmissions. (See also 4.111.)

**3.278 Explain the purpose and operation of the first detector in a superheterodyne receiver.**

*Answer.* See 6.387.

**3.279 What is a "getter" in a vacuum tube?**

*Answer.* A "getter" in a vacuum tube is a small trough-shaped metal or ribbon made of barium or tantalum. This device is inserted in all types of vacuum tubes to remove stray gases that remain after the process of evacuation.

**3.280 What is "space charge" in a vacuum tube?**

*Answer.* "Space charge" is the term used for the accumulation or field of electrons around the hot filament or cathode of a vacuum tube.

**3.281 Explain the operation of a triode vacuum tube as an amplifier.**

*Answer.* Amplification is the process of increasing the amplitude of a signal through the control by signal input of power supplied from a local source to the output circuit. The amplification of a signal is the ratio of the signal output amplitude to the signal input amplitude, both expressed in the same terms.

The ability of a triode vacuum tube to amplify is based upon the fundamental fact that a small change in grid voltage applied between the grid and the cathode of such a tube will produce large changes of plate current. This is due to the effective control of the negative space charge by the grid because of its close proximity to the cathode. Hence, when small signal voltages are applied to the grid, the normal plate current is varied in accordance with the signal swing. This results in relatively larger voltages being developed across the plate load impedance or resistance.

The amplifying action of a triode, therefore, depends upon the geometry of the tube and its circuit relations.

$$\text{Amplification} = \frac{\mu R_L}{R_p + R_L}$$

where  $\mu$  = amplification factor of the tube.

$R_L$  = plate-load resistance or impedance.

$R_p$  = plate resistance of the tube.

(See also 4.127.)

**3.282 What is the approximate efficiency of a class A vacuum-tube amplifier? Of a class B? Of a class C?**

*Answer.* The approximate practical plate efficiencies of the three main classes of amplifiers are

1. Class A, 20 to 40 per cent.
2. Class B, 50 to 65 per cent.
3. Class C, 60 to 80 per cent.

**3.283 Does direct-current grid current normally flow in a class A amplifier employing one tube?**

*Answer.* No. If the signal voltage swing is maintained within the straight portion of the  $I_B$ - $E_C$  characteristic curve and does not exceed the fixed biasing voltage during positive peaks, no grid current will flow.

**3.284 Why must some radio-frequency amplifiers be neutralized?**

*Answer.* In general, triode radio-frequency amplifiers must be neutralized to prevent self-oscillation due to the possibility of feedback through the internal grid-plate capacitance of the tube. (See also 3.312.)

**3.285 Describe how a vacuum tube oscillates in a circuit.**

*Answer.* A vacuum tube used in conjunction with an oscillatory circuit produces continuous oscillations if the plate-circuit energy is coupled either magnetically or electrostatically to the grid circuit, provided that the feedback energy is of proper amplitude and phase relationship. The grid must be out of phase with the plate by 180 deg. The vacuum-tube oscillator is in reality a self-excited amplifier in which the feedback voltages supply the inherent grid-circuit losses.

**3.286 Is the d-c bias normally positive or negative in a class A amplifier?**

*Answer.* The d-c bias in a class A amplifier is normally negative. The bias is generally maintained at a value that permits operation at the center of the straight portion of the  $I_B-E_C$  characteristic curve. This operation permits the symmetrical reproduction of the input waveform in the plate circuit.

**3.287 What is the composition of filaments, heaters, and cathodes in vacuum tubes?**

*Answer.* Thoriated tungsten and oxide-coated metals are the most commonly used cathode and filament-emitting materials. The base is generally of tungsten, nickel, or Konal alloy coated with thorium or barium carbonates.

**3.288 What is the direction of electronic flow in the plate and grid circuits of vacuum-tube amplifiers?**

*Answer.* Electrons in the plate circuit of a vacuum tube flow from the cathode to the plate and return to the cathode through the plate-supply circuit. Electrons flow in the grid circuit from the cathode to the grid and through the grid return circuit to the cathode. Grid-current flow in general takes place only during periods in which the positive peaks of the grid-signal voltage exceed the negative grid-bias voltage.

**3.289 Draw a diagram showing a method of obtaining grid bias to an indirectly heated cathode vacuum tube by use of a resistance in the cathode circuit of the tube.**

Answer. See Fig. 3-30.

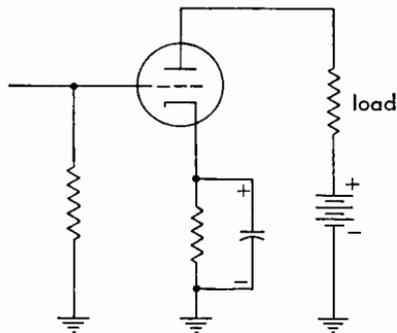


FIG. 3-30. Grid bias by cathode resistor.

3.290 Draw a diagram showing a method of obtaining grid bias to a filament vacuum tube by use of a resistance in the plate circuit of the tube.

Answer. See Fig. 3-31.

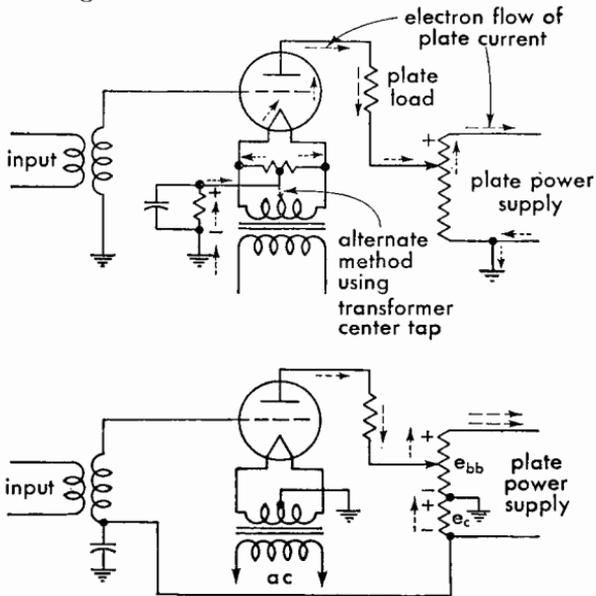


FIG. 3-31. Grid bias by plate-circuit resistor.

3.291 What is the impedance of a solenoid if its resistance is 5 ohms and 0.3 ampere flows through the winding when 110 volts at 60 cycles is applied to the solenoid?

*Answer.* The impedance of the solenoid is  $366\frac{2}{3}$  ohms.

*Solution:*

$$Z = \frac{E}{I} = \frac{110}{0.3} = 366\frac{2}{3} \text{ ohms}$$

**3.292** What is the conductance of a circuit if a current of 6 amperes flows when 12 volts direct current is applied to the circuit?

*Answer.* The conductance  $G$  is 0.5 mho.

*Solution<sub>1</sub>*

$$R = \frac{E}{I} = \frac{12}{6} = 2 \text{ ohms}$$

$$G = \frac{1}{R} = \frac{1}{2} = 0.5 \text{ mho}$$

or

$$G = \frac{I}{E} = \frac{6}{12} = 0.5 \text{ mho}$$

(See also 3.36.)

**3.293** What is the relationship between the effective value of a radio-frequency current and the heating value of the current?

*Answer.* The effective value of an alternating current may be defined as that value which will produce the same heating effect as a direct current of the same amount. The heating effect of a current is proportional to the square of the current,  $I^2R$ .

**3.294** What safety precautions should a person observe when making internal adjustments to a television receiver to avoid personal injury?

*Answer.* The following safety precautions must be observed when making internal adjustments on *any* type of high-voltage equipment:

**DON'T BE CARELESS. IT MAY COST YOU YOUR LIFE!**

1. Make certain that the interlock switch is open.

2. Remove the high-voltage power-supply fuse before testing the circuit. Complete all tests on low-voltage power-supply circuits. If trouble in the high-voltage circuit is apparent and a test other than simple point-to-point resistance tests *must* be made, reinsert the high-voltage fuse and close the interlock switch but observe the following precautions:

3. Make voltage checks using only one hand. Keep the other hand in your pocket.

4. Do not allow any part of body to touch the chassis or other metal objects.

5. Use long insulated tools and test prods.

6. Exercise great care in the handling of the cathode-ray tube in a television receiver or transmitter. Careless handling may result in a serious implosion. Gloves and goggles provide an additional safety factor.

Installation: Keep antennas and leadin wires away from all high-tension power circuits. Insulate all exposed wires wherever possible.

**3.295** With measuring equipment that is widely available, is it possible to measure a frequency of 10,000,000 cycles to within 1 cycle of the exact frequency?

*Answer.* No. Specially designed precision equipment is required for this high degree of accuracy.

**3.296** Do oscillators operating on adjacent frequencies have a tendency to synchronize oscillation or drift apart in frequency?

*Answer.* Coupled oscillators tend to lock together in frequency.

**3.298** What precaution should be observed when using and storing crystal microphones?

*Answer.* A crystal microphone must be handled with care owing to the fact that physical shock or mechanical vibration may cause the voltages generated by both sides of the microphone to be out of phase. The crystal microphone is also very sensitive to moisture and temperature changes. It should be stored in a dry moistureproof wrapping or hood and not subjected to temperatures in excess of about 120 deg Fahrenheit.

It is also desirable to avoid using a gain control between the crystal microphone and its associated amplifier, since such a control will seriously impair the low-frequency response.

**3.299** If a 1,500-kc radio wave is modulated by a 2,000-cycle sine-wave tone, what frequencies are contained in the modulated wave?

*Answer.* In amplitude-modulation systems the sideband and carrier frequencies of 1,498, 1,502, and 1,500 kc will be contained in the modulated wave. (See also 6.628.)

**3.300 Why are laminated iron cores used in audio and power transformers?**

*Answer.* To reduce eddy-current losses.

**3.301 What are cathode rays?**

*Answer.* Cathode rays are composed of a stream of negatively-charged particles or electrons generally in the form of a circular beam and traveling at high velocities.

**3.302 Why is a high ratio of capacitance to inductance employed in the grid circuit of some oscillators?**

*Answer.*

1. To supply sufficient stored energy to meet grid-circuit requirements.
2. To increase oscillator frequency stability.
3. To reduce harmonics.
4. To increase the tank circuit Q.

**3.303 What is the purpose of a buffer-amplifier stage in a transmitter?**

*Answer.* The buffer amplifier in a transmitter is used to isolate the oscillator stage from the succeeding amplifier stages. It is an effective medium for preventing succeeding amplifier load changes from reacting upon the oscillator circuit. The buffer amplifier thereby minimizes frequency drift in the oscillator.

An efficient buffer stage is biased with sufficient negative voltage to prevent grid-current flow during the excitation cycle.

**3.304 What determines the speed of a synchronous motor? An induction motor? A d-c series motor?**

*Answer.* The speed of a synchronous motor and an induction motor is determined primarily by the frequency of the source voltage. The speed of a d-c series motor is dependent upon the source voltage and the loading. An increase in line voltage will raise its speed, while an increase in loading results in a decrease in speed. (See also 4.178.)

**3.305 What is the total resistance of a parallel circuit consisting of one branch of 10 ohms resistance and one branch of 25 ohms resistance?**

*Answer.* 7.143 ohms.

*Solution:*

$$R_{\text{eff}} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{250}{35} = 7.143 \text{ ohms}$$

3.306 Draw a diagram of a resistance load connected in the plate circuit of a vacuum tube, and indicate the direction of electronic flow in this load.

*Answer.* See Fig. 3-31.

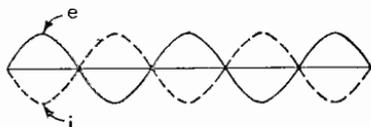


FIG. 3-32. Sine wave of voltage, and current displacement.

3.307 Indicate by a drawing a sine wave of voltage displaced 180 deg from a sine wave of current.

*Answer.* See Fig. 3-32.

3.308 Show by a diagram how a voltmeter and an ammeter should be connected to measure power in a d-c circuit.

*Answer.* See Fig. 3-33.

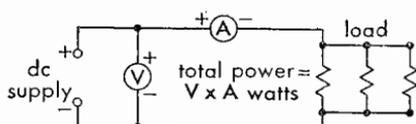


FIG. 3-33. Measuring power in parallel resistors.

3.309 Indicate by a diagram how the total current in three branches of a parallel circuit can be measured by one ammeter.

*Answer.* See Fig. 3-33.

3.310 Draw a graph indicating how the plate current in a vacuum tube varies with plate voltage, the grid bias remaining constant.

*Answer.* See Fig. 3-34.

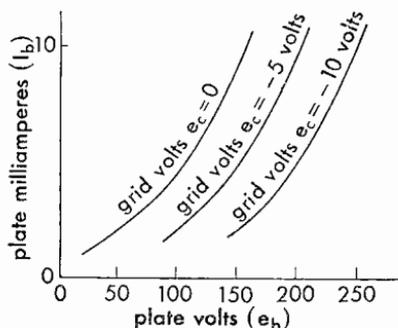


FIG. 3-34. Vacuum-tube characteristic curve.

3.311 Indicate by a drawing two cycles of a radio-frequency wave, and indicate one wavelength thereof.

*Answer.* See Fig. 3-35.

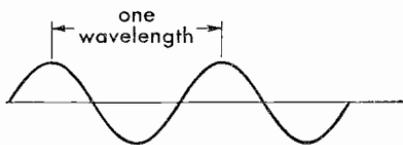


FIG. 3-35. Sine wave illustrating one wavelength.

3.312 Explain the purposes and methods of neutralization in radio-frequency amplifiers.

*Answer.* Neutralization of radio-frequency amplifiers is generally required in triode and, in some cases, tetrode amplifiers to prevent self-oscillation due to feedback through the grid-plate capacitance of the vacuum tube. Figures 3-29 and 3-36 illustrate two commonly

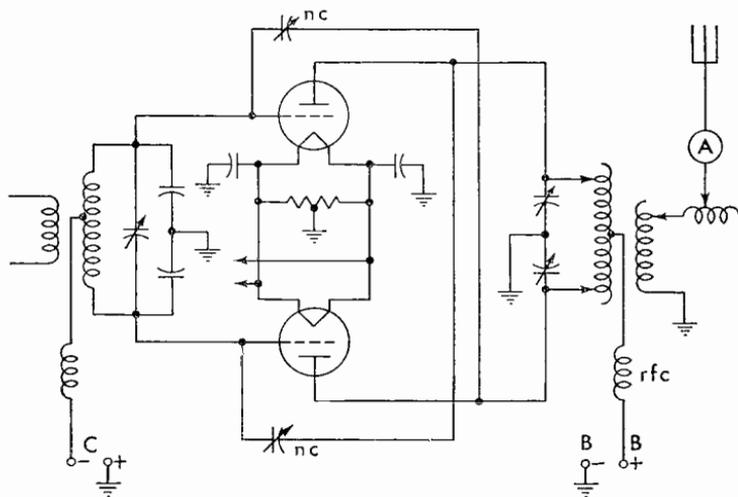


FIG. 3-36. Push-pull neutralized radio-frequency amplifier.

used methods of grid-plate capacitance neutralization. (See also 6.409 for the operating procedure in neutralizing a radio-frequency amplifier.)

3.313 In a circuit consisting of an inductance having a reactance value of 100 ohms and a resistance of 100 ohms, what will be the phase angle of the current with reference to the voltage?

*Answer.* The phase angle will be 45 deg.

$$\tan \theta = \frac{\omega L}{IR} = \frac{X_L}{R} = \frac{100}{100} = 1.000$$

From a table of trigonometric functions,  $1.0 = 45$  deg.

**3.314** What is the effective value of a sine wave in relation to its peak value?

*Answer.* Effective value = peak value  $\times$  0.707

**3.315** What is the meaning of "phase difference"?

*Answer.* Phase difference denotes the time displacement of one sine wave from another at the same frequency. For example, in an a-c circuit containing inductance the maximum current lags behind the maximum voltage, whereas in a circuit containing only pure resistance these maxima coincide in time.

Phase difference is generally expressed as an angle of lag or lead, of which the cosine, in per cent, is the power factor.

**3.316** What factors must be known in order to determine the power factor of an a-c circuit?

*Answer.* The true watts, as indicated by the wattmeter, and the volts and amperes in the circuit, as indicated by a voltmeter and ammeter.

$$\text{Power factor} = \cos \theta = \frac{W}{EI} \quad \frac{(\text{real watts})}{(\text{apparent watts})}$$

The ratio  $\frac{R}{Z}$  can also be used.

**3.317** What are the properties of a series capacitor acting alone in an a-c circuit?

*Answer.* A series capacitor acting alone in an a-c circuit will cause the current to lead the voltage by 90 deg. The reactance of the capacitor will vary inversely as the frequency varies.

**3.318** What is the reactance value of a capacitor of 0.005  $\mu\text{f}$  at a frequency of 1,000 kc?

*Answer.* The reactance value is 31.8 ohms, computed as follows:

$$X_c = \frac{10^6}{2\pi fC} \text{ ohms}$$

**3.319** State the mathematical formula for the energy stored in the magnetic field surrounding an inductance carrying an electric current.

*Answer.*

$$W = \frac{1}{2}LI^2 \text{ joules}$$

where  $L$  is in henrys, and  $I$  is in amperes.

**3.320** What is the current and voltage relationship when inductive reactance predominates in an a-c circuit?

*Answer.* When an inductive reactance predominates in an a-c circuit, the current lags the voltage.

**3.321** Given a series circuit consisting of a resistance of 4 ohms, an inductive reactance of 4 ohms and a capacitive reactance of 1 ohm; the applied circuit alternating emf is 50 volts. What is the voltage drop across the inductance?

*Answer.* The voltage drop across the inductance is 40 volts.

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{25} = 5 \text{ ohms}$$

$$I = \frac{E}{Z} = \frac{50}{5} = 10 \text{ amperes}$$

Therefore  $E_L = IX_L = 10 \times 4 = 40 \text{ volts}$

**3.322** What would be the effect if direct current were applied to the primary of an a-c transformer?

*Answer.* The current in the primary would be limited only by the d-c resistance of the circuit. Unless the applied voltage was very small, the current would either blow the fuses or burn out the transformer in a few seconds.

**3.323** If a power transformer having a voltage step-up ratio of 1:5 is placed under load, what will be the approximate ratio of primary to secondary current?

*Answer.* 5:1.

**3.324** What is the meaning of "skin effect" in conductors of radio-frequency energy?

*Answer.* The tendency of high-frequency currents to travel on the surface of a conductor is known as "skin effect." This effect is caused

by the varying density of the electric field in the conductor, which acts to produce the lowest reactance path on the surface of the conductor.

**3.325** Neglecting distributed capacitance, what is the reactance of a 5-millihenry choke coil at a frequency of 1,000 kc?

*Answer.* The reactance is 31,400 ohms.

$$X_L = 2\pi fL = 6.28 \times 10^6 \times 0.005 = 31,400 \text{ ohms}$$

**3.326** What is meant by the term "radiation resistance"?

*Answer.* The term "radiation resistance" is analogous to the effective increase of a circuit resistance due to the heat dissipation in a wire or circuit. In antenna radiating systems, it is the ratio of the power radiated by the antenna to the squared effective value of the antenna current measured at the point where the power is supplied to the radiating system.

**3.327** What is the value of total reactance in a series-resonant circuit at the resonant frequency?

*Answer.* Zero. The inductive and capacitive reactances are equal and opposite in sign and therefore cancel out in a series-resonant circuit at the resonant frequency.

**3.328** What is the value of reactance across the terminals of the capacitor of a parallel resonant circuit, at the resonant frequency, and assuming zero resistance in both legs of the circuit?

*Answer.* The reactance is zero, and impedance is infinite under these conditions.

$$X = X_L - X_c = 0$$

$$Z = \frac{X_L^2}{R} = \infty \text{ (infinity)}$$

**3.329** Given a series-resonant circuit consisting of a resistance of 6.5 ohms and equal inductive and capacitive reactances of 175 ohms, what is the voltage drop across the resistance, assuming the applied circuit potential is 260 volts?

*Answer.* 260 volts. Since  $X_L$  and  $X_c$  are equal, their effects cancel out of the series-resonant frequency. Hence, the entire source voltage of 260 volts appears across the 6.5-ohm resistance.

3.330 Given a series-resonant circuit consisting of a resistance of 6.5 ohms and equal inductive and capacitive reactances of 175 ohms, what is the voltage drop across the inductance when the applied circuit potential is 260 volts?

*Answer.* 7,000 volts.

$$I = \frac{E}{R} = \frac{260}{6.5} = 40$$

$$E_L = IX_L = 40 \times 175 = 7,000 \text{ volts}$$

3.331 Under what conditions will the voltage drop across a parallel-tuned circuit be a maximum?

*Answer.* At resonance, when  $X_L = X_c$  and ohmic resistance is small (when the admittance of the two branches is equal).

3.332 Draw a simple schematic diagram showing a method of coupling a modulator tube to a radio-frequency power-amplifier tube to produce plate modulation of the amplified radio-frequency energy.

*Answer.* See Fig. 3-37.

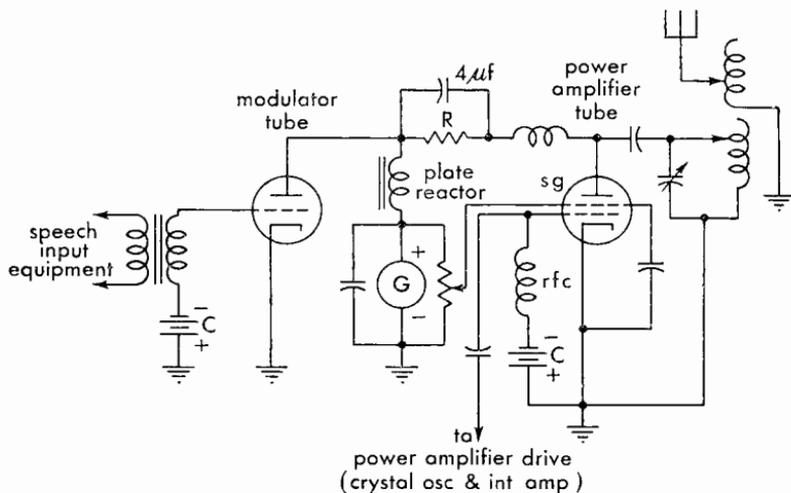


FIG. 3-37. Basic plate-modulation system.

3.333 Draw a diagram of a carrier-wave envelope when modulated 50 per cent by a sinusoidal wave. Indicate on the diagram the dimensions from which the percentage of modulation is determined.

*Answer.* See Fig. 3-38.

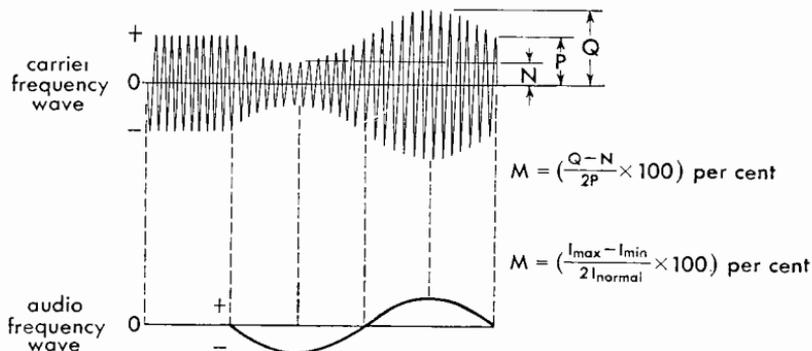


FIG. 3-38. Carrier wave and modulation envelope.

3.334 Draw a diagram of a microphone circuit complete with two stages of audio amplification.

*Answer.* See Fig. 3-39.

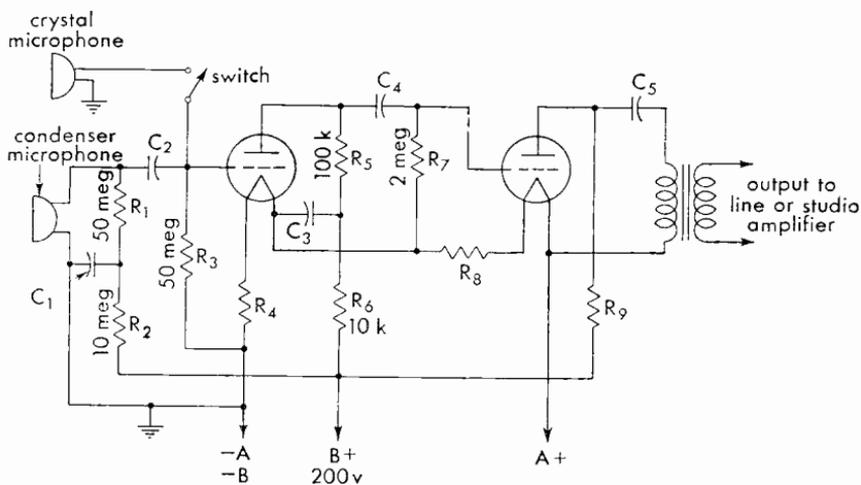


FIG. 3-39. Microphone amplifier.

3.335 Draw a simple schematic diagram showing a Heising-modulation system capable of producing 100-per cent modulation. Indicate power-supply polarity where necessary.

*Answer.* See Fig. 3-37.



**3.338** What is meant by "frequency shift" or "dynamic instability" with reference to a modulated radio-frequency emission?

*Answer.* "Frequency shift," "dynamic instability," or "carrier shift" is that condition in a modulated radio-frequency amplifier when the *average* value of the radio-frequency voltage envelope shifts in a positive or negative direction during modulation. If for any reason this average changes, then distortion is introduced, since the amplitude variation is no longer constant. An increase in the average is known as *positive carrier shift*, while a decrease is known as *negative carrier shift*.

**3.339** What is meant by "high-level" modulation?

*Answer.* "High-level" modulation is modulation produced in the last radio-frequency stage of the transmitter.

**3.340** What is meant by "grid modulation"? By "plate modulation"?

*Answer.* By "grid modulation" is meant modulation produced by the introduction of the modulating wave into any of the grid circuits of any tube in which the carrier-frequency wave is present. "Plate modulation" is modulation produced by the introduction of the modulating wave into the plate circuit of any tube in which the carrier-frequency wave is present.

**3.341** What is meant by "low-level" modulation?

*Answer.* "Low-level" modulation is modulation produced in a radio-frequency stage preceding the final radio-frequency stage.

**3.342** Describe the construction and characteristics of a crystal microphone.

*Answer.* The crystal microphone employs a piezoelectric crystal as its actuating unit, which is coupled to the diaphragm through a lever arrangement. The conventional crystal microphone is made up of several crystal cells arranged so that each cell aids the others to increase the over-all sensitivity. The microphone is affected very little by temperature changes. The output is approximately -85 db. Owing to the high impedance of the crystal, the output may be worked directly into the grid of the amplifier tube. The frequency response is excellent over the whole audio spectrum.

**3.343 Describe the construction and characteristics of a carbon-button microphone.**

*Answer.* A single-button carbon microphone consists of a tightly stretched diaphragm fixed in front of a metal cup filled with carbon granules, the cup assembly being called a "button." The natural frequency of the diaphragm is well above 5,000 cycles. The diaphragm is damped by an air cushion to improve its frequency response, which extends approximately from 60 to 5,000 cycles. A hiss is noticeable unless the sound level is high. This is the most sensitive microphone.

**3.344 What might be the cause of variations in plate current of a class B modulator?**

*Answer.* Under normal conditions with complex modulation the plate current of a class B modulator is constantly varying, depending upon the amplitude of the speech input wave.

**3.345 What is the relationship between the average power output of the modulator and the modulated-amplifier plate-circuit input under 100 per cent sinusoidal plate modulation?**

*Answer.* The correct ratio is 1:2, or 50 per cent. (See 6.626 for detailed explanation.)

**3.346 What would be the effect of a short-circuited turn in a class B modulation transformer? In a class A modulation transformer?**

*Answer.* A short-circuited turn in both the class A and B modulation transformer would result in serious overheating and may cause the shorted primary section to burn out. In the class B amplifier one tube only would be inoperative and serious distortion would result. The class A amplifier using a single modulator tube would be entirely inoperative if the plate winding burned out. In both cases, however, the initial symptom is manifest in serious distortion due to the impedance mismatch.

**3.347 Why is a high percentage of modulation desirable?**

*Answer.* High-percentage amplitude modulation in telephone transmitters increases the useful service range of the transmitter owing to the relatively higher ratio of modulated carrier-frequency power to the normal carrier-frequency power. The peak power in 100 per cent modulated systems is four times the normal carrier power. The use of high-percentage modulation systems increases the plate efficiency

of the amplifiers, increases the ratio of useful power in the receiver system, and decreases carrier interference at remote points. Interference between stations on adjacent channels is also minimized.

**3.348 What are some of the possible results of overmodulation?**

*Answer.* Overmodulation results in a widening of the frequency band causing interference on adjacent channels. Overmodulation also causes distortion in the audio components of the radiated wave. Since the continuity of the carrier is interrupted, it means that there are harmonics radiated and that the transmission occupies a band which is wider than necessary, causing interference on adjacent channels.

**3.349 What might cause frequency modulation in an AM radiotelephone transmitter?**

*Answer.* Phase or frequency shifts in the oscillator or amplifier circuits produced by excessive tube or load circuit changes. Poor voltage regulation.

**3.350 What percentage of antenna-current increase should be expected between unmodulated conditions and 100 per cent sinusoidal modulation?**

*Answer.* The antenna current will rise approximately 22.5 per cent if the modulating wave has a sinusoidal characteristic. In practical broadcasting, owing to the unsymmetrical nature of the modulated wave, this increase in antenna current cannot be depended upon to indicate 100 per cent modulation.

**3.351 What might be the cause of a decrease in antenna current of a high-level AM radiotelephone transmitter when modulation is applied?**

*Answer.* Overmodulation, improper neutralization, incorrect grid bias, low filament emission, poor regulation, open filter capacitor in power supply, or improperly tuned antenna system.

**3.352 If a regenerative receiver oscillates too freely with minimum tickler coupling, what adjustment would reduce the feedback?**

*Answer.* A reduction in plate or filament potential.

**3.353 Why is it necessary to use an oscillating detector for reception of an unmodulated carrier?**

*Answer.* An oscillating detector is required for the reception of continuous-wave signals to produce an audible "beat" or "heterodyne" tone response in the telephones or loudspeaker.

**3.354** What is the purpose of shielding in a multistage radio receiver?

*Answer.* Shielding is required to prevent self-oscillation in radio-frequency amplifiers.

**3.355** Explain what circuit conditions are necessary in a regenerative receiver for maximum response to a modulated signal.

*Answer.* The regenerative feedback control must be adjusted critically to a point on the verge of oscillation.

**3.356** What feedback conditions must be satisfied in a regenerative detector for most stable operation of the detector circuit in an oscillating condition?

*Answer.* Stabilized oscillation is obtained when the feedback control is adjusted to an oscillating condition beyond the critical point at which oscillations begin. Practically, this condition is obtained when the feedback coupling is a maximum, the filament voltage is normal, and the plate voltage is near the maximum operating limits. A high tank circuit  $Q$  or low  $L/C$  ratio is also desirable.

**3.357** What are the advantages to be obtained from adding a tuned radio-frequency amplifier stage ahead of the first detector (converter) stage of a superheterodyne receiver?

*Answer.* A preselector stage increases the over-all circuit selectivity and sensitivity and tends to eliminate image frequency interference. It also serves to prevent possible reradiation which might be caused by the coupling of the converter and oscillator circuits directly to the antenna system.

**3.358** What feedback conditions must be satisfied in a regenerative detector in order to obtain sustained oscillations?

*Answer.* See 3.356.

**3.359** How is automatic volume control accomplished in a radio receiver?

*Answer.* See 4.214.

**3.360** If a superheterodyne receiver is tuned to a desired signal at 1,000 kc and its conversion oscillator is operating at 1,300 kc, what would be the frequency of an incoming signal which would possibly cause "image" reception?

*Answer.* It is evident that the intermediate frequency is 300 kc. Hence, at frequency of 1,600 kc, the grid of the converter tube will produce an intermediate frequency of 300 kc if the conversion oscillator is tuned to 1,300 kc. Hence, 1,600 kc is the image.

**3.361** If a tube in the only radio-frequency stage of your receiver burned out, how could temporary repairs or modifications be made to permit operation of the receiver if no spare tube is available?

*Answer.* The antenna could be connected to the grid of the succeeding tube or preferably to the plate prong of the burned-out tube through a 0.0005- $\mu$ f coupling capacitor.

**3.362** What are the characteristics of plate detection?

*Answer.* The plate-current flow increases during signal reception. When no signal is received, the plate current is low, since the tube is operating near the plate-current cutoff point of the characteristic. The primary characteristic of plate detection is a good linear output response with strong signal input voltages.

**3.363** What is the purpose of a radio-frequency choke?

*Answer.* To prevent radio-frequency current flow through the power-supply circuit and also to improve the bypassing efficiency of the radio-frequency bypass capacitor. It is an effective high-impedance filter or isolating device.

**3.364** What would be the effect upon a radio receiver if the vacuum-tube plate potential were reversed in polarity?

*Answer.* The receiver would not operate.

**3.365** What would be the effect upon the operation of a receiver if the grid return is connected to the positive rather than the negative terminal of the filament battery?

*Answer.* The circuit sensitivity and selectivity will be decreased. The grid voltage may become slightly positive, causing a grid current to flow and a corresponding increase in plate current. Circuit linearity is impaired, and signal distortion will occur.

3.366 Draw a simple schematic diagram of a system of coupling a single electron tube employed as a radio-frequency amplifier to a Hertz antenna.

*Answer.* See Fig. 3-42.

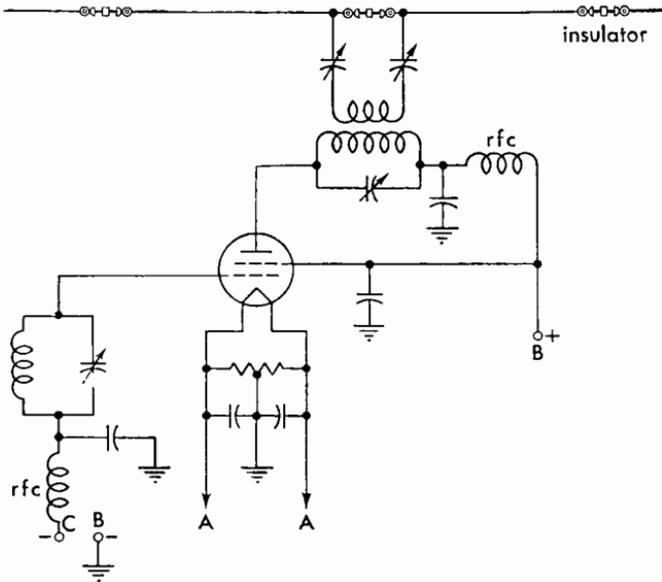


FIG. 3-42. Hertz-radiator coupling system.

3.367 Draw a simple schematic diagram indicating a link coupling system between a tuned-grid-tuned-plate oscillator stage and a single electron tube, neutralized amplifier.

*Answer.* See Fig. 3-29.

3.368 Draw a simple schematic diagram of a push-pull, neutralized radio-frequency amplifier stage, coupled to a Marconi antenna system.

*Answer.* See Fig. 3-36.

3.369 Draw a simple schematic diagram of a system of neutralizing the grid-plate capacitance of a single electron tube employed as a radio-frequency amplifier.

*Answer.* See Fig. 3-29.

**3.370** Draw a simple schematic diagram showing the proper method of obtaining d-c screen-grid voltage from the plate supply in the case of a plate-modulated pentode, class C amplifier.

*Answer.* See Fig. 3-43.

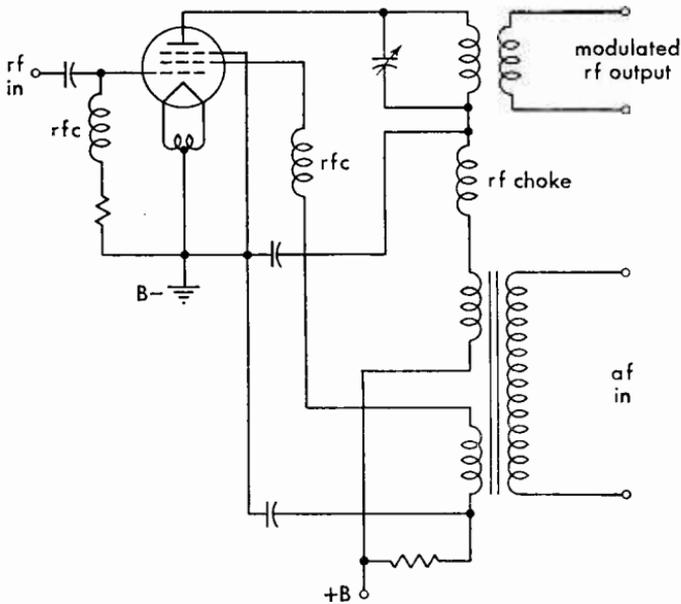


FIG. 3-43. Plate and screen-grid modulation system.

**3.371** What is the purpose of a buffer amplifier?

*Answer.* A buffer amplifier is essentially a frequency stabilizer. It serves as a voltage amplifier stage(s) to isolate the crystal oscillator from the radio-frequency amplifier circuits. It prevents circuit reactions and load changes from the power-amplifier stages from affecting the frequency stability of the oscillator.

**3.372** What is a "frequency doubler" stage?

*Answer.* A "frequency doubler" stage is a radio-frequency amplifier, the output frequency of which is double that of the input frequency. A frequency doubler is often used in connection with a crystal oscillator when the desired output frequency exceeds the safe operating limits of crystal plates.

**3.373 What are the advantages of a master-oscillator power-amplifier transmitter as compared with a simple oscillator transmitter?**

*Answer.* Improved frequency stability. An ordinary oscillator will be subject to frequency changes when coupled directly to an antenna system. Phase shift and reactance changes are therefore considerably reduced in the master-oscillator power-amplifier system.

**3.374 What are the differences between Colpitts and Hartley oscillators?**

*Answer.* In the Colpitts oscillator the grid circuit receives its excitation from a split tank capacitor. In the Hartley oscillator, the grid receives its excitation from a split tank inductance. (See Fig. 3-2 and Fig. 3-6 for circuit diagrams.)

**3.375 What is the primary purpose of a grid leak in a vacuum-tube transmitter?**

*Answer.* A grid leak is used primarily to develop operating bias. It also serves to maintain a constant load on an amplifier to minimize overloading when the grid of a given stage is driven positive during excitation.

**3.376 By what means is feedback coupling obtained in a tuned-grid-tuned-plate oscillator?**

*Answer.* Through the grid-to-plate capacitance of the tube.

**3.377 What may be the result of parasitic oscillations?**

*Answer.* Parasitic oscillations may result in an erratic behavior and a heavy increase in plate current, which may cause serious overheating of the tube. The plate milliammeter or radio-frequency choke coil may burn out. Normal output power on the operating frequency will also be decreased.

**3.378 How may the production of harmonic energy by a vacuum-tube radio-frequency amplifier be minimized?**

*Answer.* See 3.302 and 3.447.

**3.379 What is a definition of "parasitic oscillations"?**

*Answer.* "Parasitic oscillations" are undesired oscillations developed in a radio-frequency amplifier circuit at some frequency higher than the normal operating frequency. They are principally due to feedback

resulting from the connecting lead capacitive and inductive effects when tubes are operated in parallel or push-pull. Parasitics are eliminated by introducing circuit losses to these spurious frequencies by the insertion of small radio-frequency choke coils shunted by a non-inductive resistance in each plate and/or grid lead of the parallel-connected tubes. Parasitic oscillations are not necessarily a harmonic component of the fundamental frequency.

**3.380 What is the purpose of a Faraday screen between the final tank inductance of a transmitter and the antenna inductance?**

*Answer.* The purpose of a Faraday screen is to minimize the radiation of harmonic frequencies. This it does by reducing the capacitive coupling between the amplifier and antenna circuits, by which the harmonics are chiefly transmitted.

**3.381 How may the distortion effects caused by class B operation of a radio-frequency amplifier be minimized?**

*Answer.* Distortion effects are minimized by operating the amplifier tubes in a push-pull arrangement, a reasonably high tank-circuit impedance, proper grid bias, a high Q tank circuit, and balanced tubes and by restricting the grid excitation voltage to the normal linear range of the amplifier. Proper tuning and loading adjustments are other important prerequisites.

**3.382 What is the effect of carrier shift in a plate-modulated class C amplifier?**

*Answer.* Carrier shift causes unwanted harmonics and additional sideband frequencies, resulting in interference with other stations on adjacent frequencies. (See 6.642.)

**3.383 What are some possible indications of a defective transmitting vacuum tube?**

*Answer.* Some possible indications of a defective transmitting vacuum tube are

1. Burned-out filament (dark tube).
2. Low emission as indicated by no reading or a low reading on the plate-current meter accompanied by a slightly high voltage reading.
3. A gassy tube, as indicated by a blue haze, red-hot plate, and/or fluctuations in plate current or by excessive grid-current flow.

**3.384** What would be possible indications that a vacuum tube in a transmitter has subnormal filament emission?

*Answer.* The general symptom is indicated by a low plate-current indication in the defective tube. Decreased excitation and radiation and low plate temperature (plate color) in power-amplifier tubes are other possible symptoms.

**3.385** What are possible causes of negative carrier shift in a linear radio-frequency amplifier?

*Answer.* A negative carrier shift is one in which the upward excursion of a modulated radio-frequency wave is not so great as the downward excursion when averaged over the modulation cycle. Circuit conditions which may produce a negative carrier shift are as follows: overmodulation, excessive radio-frequency excitation, poor filter circuit, or poor regulation.

**3.386** In a modulated class C radio-frequency amplifier, what is the effect of insufficient excitation?

*Answer.* Decreased radiation, low plate efficiency, decreased tank and plate currents, distortion, and carrier shift may develop owing to insufficient excitation.

**3.387** What is the purpose of a dummy antenna?

*Answer.* A dummy antenna is used to load a transmitter for testing purposes without radiation. The dummy antenna may consist of a bank of lamps or other equal resistors. The resistance of the dummy antenna must be equivalent to that of the working antenna.

**3.388** In a class C radio-frequency amplifier stage of a transmitter, if plate current continued to flow and radio-frequency energy was still present in the antenna circuit after grid excitation was removed, what defect would be indicated?

*Answer.* On a radiotelegraph transmitter, this would indicate defective keying, usually a failure of the keying bias to block the tubes when the key is up. In a radiotelephone transmitter, a continuous flow of plate current and antenna current may be due to a short-circuited bias supply or self-oscillation resulting from improper neutralization. Parasitic oscillations may also produce this effect.

**3.389** If the transmitter filament voltmeter should cease to operate, how may the approximately correct filament rheostat adjustment be found?

*Answer.* By observing the color of the filaments and by noting other meter readings to see that they are normal.

**3.390** What are some possible causes of overheating vacuum-tube plates?

*Answer.* Overheating may be due to any one of the following causes: parasitic oscillations, excessive drive, insufficient grid bias, plate-tank circuit improperly tuned (off resonance), gassy tube, self-oscillation due to improper neutralization, and excessive filament or plate voltage.

**3.391** Should the plate current of a modulated class C amplifier stage vary or remain constant under modulation conditions? Why?

*Answer.* The plate current should remain constant during sinusoidal modulation, since the average value of the d-c component is essentially zero under these conditions.

**3.392** What is the effect of a swinging antenna upon the output of a simple oscillator?

*Answer.* Inasmuch as the antenna circuit is coupled directly to the plate circuit of a simple oscillator, any variation in antenna capacitance, such as might be caused by a swinging antenna, would be reflected into the tube's plate circuit. This action would be equivalent to placing a fluctuating load on the oscillator and would result in frequency instability.

**3.418** Draw a simple schematic diagram of a quartz-crystal-controlled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* See Fig. 3-5.

**3.419** Draw a simple schematic diagram of a dynatron oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* Fig. 3-44 illustrates a dynatron oscillator. Capacitors  $C$  and  $C_1$  are used to bandspread and tune; capacitors  $C_2$  and  $C_3$  are used for radio-frequency bypassing.

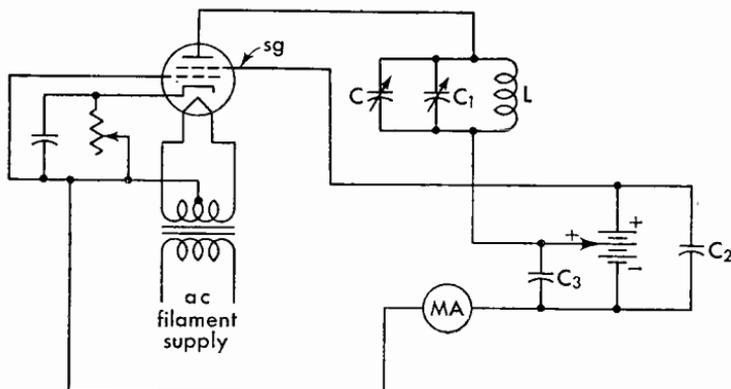


FIG. 3-44. Dynatron oscillator.

3.420 Draw a simple schematic diagram of an electron-coupled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* See Fig. 3-8. In this type of circuit the plate element acts only as an output-coupling medium while the screen-grid element serves as the actual oscillator plate.

3.421 What does the expression "positive temperature coefficient" mean as applied to a quartz crystal?

*Answer.* The expression "positive temperature coefficient" means that the frequency of the crystal varies directly with the temperature; that is, when the temperature increases, the frequency of the crystal increases.

3.422 Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator using a pentode tube. Indicate power-supply polarity where necessary.

*Answer.* See Fig. 3-9.

3.423 What will result if a d-c potential is applied between the two parallel surfaces of a quartz crystal?

*Answer.* The parallel surfaces of a quartz crystal will either expand or contract, depending upon the polarity of the applied voltage. The crystal will not oscillate with a d-c potential applied. If the applied potential is great enough in voltage value, the crystal will crack or split.

**3.424** What does the expression "negative temperature coefficient" mean as applied to a quartz crystal?

*Answer.* The expression "negative temperature coefficient" means that the frequency of the crystal varies indirectly with the temperature; that is, when the temperature increases, the frequency of the crystal decreases.

**3.425** What does the expression "low temperature coefficient" mean as applied to a quartz crystal?

*Answer.* The expression "low temperature coefficient" means that the frequency of the crystal varies very little with a change in temperature.

**3.426** What is the function of a quartz crystal in a radio transmitter?

*Answer.* The function of a quartz crystal in a radio transmitter is to keep the transmitter on its assigned frequency within the allowed frequency tolerances; that is, the quartz crystal functions as a frequency stabilizer.

**3.427** What may result if a high degree of coupling exists between the plate and grid circuits of a crystal-controlled oscillator?

*Answer.* A high degree of coupling between the plate and grid circuits of a crystal-controlled oscillator might result in excessive feedback with the danger of cracking the crystal.

**3.428** What is the purpose in maintaining the temperature of a quartz crystal as constant as possible?

*Answer.* It is necessary to keep the temperature of a quartz crystal constant in order to keep its oscillating frequency stable within limits.

**3.429** Why is a separate source of plate power desirable for a crystal-oscillator stage in a radio transmitter?

*Answer.* A separate source of plate power is desirable in order that the crystal-oscillator stage may operate with a maximum stability. If the crystal stage takes its power from the same source as the rest of the transmitter and the regulation of the power supply is not up to the required standard for crystal stability owing to variable load conditions in the power amplifier, the dynamic stability of the crystal frequency will be poor.

**3.430** What are the principal advantages of crystal control over tuned-circuit oscillators?

*Answer.* High-frequency stability, highly selective tuning properties (high  $Q$ ), and critical control of fundamental frequency and harmonics by temperature adjustments.

**3.431** What is the approximate range of temperature coefficients to be encountered with X-cut quartz crystals?

*Answer.* From  $-10$  to  $-25$  parts per million (ppm) per degree centigrade.

**3.432** Is it necessary or desirable that the surfaces of a quartz crystal be clean? If so, what cleaning agents may be used which will not adversely affect the operation of the crystal?

*Answer.* Yes, it is necessary to keep the surfaces of a quartz crystal clean. This may best be done by using soap and water or carbon tetrachloride.

**3.433** List the characteristics of a dynatron oscillator.

*Answer.* The characteristics of a dynatron oscillator are as follows:

1. A well-designed dynatron has a frequency stability which compares favorably with that of the crystal oscillator without temperature control.

2. Its efficiency is low.

3. It can be used in a heterodyne wavemeter. When so used, the sharpness of indication of the meter is increased because the dynatron neutralizes the positive resistance of the wavemeter circuit. This it does by virtue of the negative resistance of the tube operating as a dynatron.

**3.434** List the characteristics of an electron-coupled oscillator.

*Answer.* The characteristics of an electron-coupled oscillator are as follows: In the electron-coupled oscillator, the plate circuit is isolated from its load. Hence, changes in load-circuit impedance do not affect the  $LC$  value in the oscillator circuit. Therefore, frequency stability is good. Modern practice is to use the electron-coupled oscillator in frequency meters because of its excellent frequency stability.

**3.435** Upon what characteristic of an electron tube does a dynatron oscillator depend?

*Answer.* Secondary emission.

**3.436 What is a multivibrator and what are its uses?**

*Answer.* The multivibrator or relaxation oscillator is a two-tube resistance-coupled oscillator in which the voltage developed by the output of the second tube is applied to the input of the first tube. The principle of operation is based upon the fact that the tubes invert the waveform. The output wave is nonsinusoidal in character. This type of oscillator may be used for any of the following purposes:

1. Master oscillator timer.
2. To produce rectangular control pulses of certain lengths, synchronized with excitation trigger pulses.
3. To introduce delay between input trigger pulses and a second circuit.
4. Frequency division. To synchronize or lock circuits at other than 1:1 ratio. (See Fig. 4-11 for circuit diagram.)

**3.437 If a frequency meter, having an over-all error proportional to the wavelength, is accurate to 10 cycles when set at 600 kc, what is its error in cycles when set at 1,110 kc?**

*Answer.* The error is 18.5 cycles, computed as follows:

$$10:600 = x:1,110 \quad x = 18.5$$

**3.438 What precautions should be taken before using a heterodyne frequency meter?**

*Answer.* The following precautions should be observed:

1. See that the filaments are operating at the proper voltage.
2. Be sure all high-potential voltages are correct.
3. Be certain all holding screws on the cabinet are tight before checking or using the instrument. Any looseness involves capacitance changes in the circuit, which will introduce errors in the calibration.
4. Make certain the meter has been recently checked against a calibrated test oscillator for frequency accuracy.
5. Let tubes warm up.

**3.439 What is the meaning of "zero beat" as used in connection with frequency-measuring equipment?**

*Answer.* "Zero beat" means zero-beat frequency, which is the condition achieved when the frequency of the frequency-meter oscillator and that of the oscillations under measurement are equal. Hence, if

the frequency of the frequency-meter oscillator is ascertainable on a calibrated dial, then at "zero beat" the frequency of the oscillations being measured is that indicated on the calibrated dial.

Zero beat might also be defined as the condition under which maximum and minimum values of two different frequencies occur at the same instant.

**3.440** What precautions should be observed in using an absorption-type frequency meter to measure the frequency of a self-excited oscillator? Explain your reasons.

*Answer.* Place the instrument as far as workably possible from the circuit being measured to avoid mutual coupling reactions, which would alter the output frequency of the circuit being measured.

**3.441** If the first speech amplifier tube of a radiotelephone transmitter were overexcited, but the percentage modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output of the transmitter?

*Answer.* Excessive distortion would result in the modulated amplifier and, consequently, in the radiated wave.

**3.442** What is the purpose of a preamplifier?

*Answer.* A preamplifier is used with certain low-output microphones such as a condenser microphone chiefly for two purposes: (a) to avoid cable loss ahead of the first stage of amplification thereby improving signal-to-noise ratio, (b) to isolate the impedance of the cable and load from the microphone.

**3.443** What are the advantages of using two tubes in push-pull as compared with the use of the same tubes in parallel in an audio-frequency amplifier?

*Answer.* By operating two tubes in push-pull rather than in parallel a more symmetrical output waveform is secured, which conforms periodically to both sides of the excitation cycle, resulting in a neutralization of even harmonics.

**3.444** List four causes of distortion in a class A audio-frequency amplifier.

*Answer.* The following will cause distortion in a class A audio-frequency amplifier:

1. Too much excitation voltage.
2. Improper operating potentials.
3. Improper load impedance.
4. Leaky bypass or coupling capacitors.
5. Improper bias.
6. Parasitic oscillations (singing).

**3.445 What is the purpose of bypass capacitors connected across audio-frequency amplifier cathode-bias resistors?**

*Answer.* The purpose of the bypass capacitors is to provide a low-impedance path for the audio-frequency components of the plate current to increase low-frequency response and signal amplitude.

**3.446 What are the advantages of using a resistor in series with the cathode of a class C radio-frequency amplifier tube to provide bias?**

*Answer.* When this method is used, the tube is safeguarded against the removal of bias in the event of the failure of the independent bias supply. With this method, as long as a plate current flows, a bias is provided. If the bias supply should be short-circuited from a class C radio-frequency amplifier tube not provided with a resistor, the plate current would immediately rise and possibly damage the tube.

**3.447 How may the generation of even harmonic energy in a radio-frequency amplifier stage be minimized?**

*Answer.* The generation of even harmonic energy may be minimized by the use of the following:

1. Push-pull circuits with matched tubes.
2. Faraday screen.
3. Optimum ratio of volt-amperes to watts in the tank circuit.

**3.448 What tests will determine if a radio-frequency power-amplifier stage is properly neutralized?**

*Answer.* Plate voltages only are removed from the tube, leaving the tube in its proper position in the circuit. Then test for the presence of radio-frequency current in the plate-tank circuit of the tube whose neutralization is being tested. To do this, the preceding amplifier must be operating and an indicator of radio-frequency current, such

as the thermocouple meter attached to a very small loop of wire, a neon bulb, or a low-power carbon-filament lamp, must be brought close to the tank circuit. If no radio-frequency current is present in the tank circuit, the tube is properly neutralized. If the presence of radio-frequency current is indicated in the tank circuit, the neutralizing capacitor should be varied until it is indicated that this radio-frequency current in the tank circuit is at a minimum.

Excessive plate current in an amplifier stage might indicate improper neutralization. Therefore, a proper reading on the plate-current ammeter would indicate proper neutralization of that stage. (See 3.455 and 6.409.)

**3.449 Why is the plate-circuit efficiency of a radio-frequency amplifier tube operating as class C higher than that of the same tube operating as class B? If the statement above is false, explain your reasons for such a conclusion.**

*Answer.* The statement is true. The reason is that plate current flows only on the positive peaks of the excitation voltage at the instant when the voltage drop across the tube is low. Under these conditions, the largest portion of the plate power will be absorbed by the tuned plate circuit and transferred from there as useful output. (See 3.107.)

**3.450 Why does a class B audio-frequency amplifier stage require considerably greater driving power than a class A amplifier?**

*Answer.* Because the grid of the class B amplifier is driven positive on the crest of each cycle and the grid input resistance of the tube is low. To avoid severe distortion the grid resistance must be very small so that the load on the driver does not change greatly when the grid goes positive. The low-resistance grid circuit consumes a relatively large amount of power. By contrast, the class A amplifier presents a high resistance at all times to the driver. Hence, it requires less driving power.

**3.451 Discuss the input circuit requirements for a class B audio-frequency amplifier grid circuit.**

*Answer.* The most important consideration in the requirements of a class B amplifier is the proper design of the input circuit. The input to the grids of a class B audio-frequency amplifier is generally a balanced class A amplifier with a high load-impedance primary. The secondary

winding which feeds the grids of the class B stage is of low impedance and low resistance to handle the heavy grid-current swings. The heavy power demands also require a well-regulated plate and bias supply to keep distortion at a minimum.

**3.452** When a signal is impressed on the grid of a properly adjusted and operated class A audio-frequency amplifier, what change in average value of plate current will take place?

*Answer.* There will be no change in the average value of the plate current.

**3.453** If the value of capacitance of a coupling capacitor in a resistance-coupled audio amplifier is increased, what effect may be noted?

*Answer.* If the capacitance of the coupling capacitor is increased, the low-frequency response will be improved, but if the capacitance is increased to an excessive value, "motorboating" or distortion may occur owing to a change in the time constants of the circuit.

**3.454** Why does a screen-grid tube normally require no neutralization when used as a radio-frequency amplifier?

*Answer.* Because the screen grid reduces the grid-to-plate capacitance of the tube, which decreases the amount of feedback energy reaching the grid, thus preventing self-oscillation.

**3.455** What instruments or devices may be used to adjust and determine that an amplifier stage is properly neutralized?

*Answer.* Any of the following combinations may be used: a wavemeter in conjunction with a thermocouple galvanometer, a sensitive thermocouple galvanometer connected in series with a small pick-up loop, a neon bulb or a low-power carbon-filament lamp connected in series with a pickup loop. In modern broadcast transmitters it is generally unnecessary to use the above devices, since each transmitter is equipped with an extra "sensitive" thermocouple shunt. This sensitive thermocouple is part of the regular tank-circuit radio-frequency ammeter. A pair of metal links are provided to switch the ammeter from the high-current thermocouple to the sensitive couple for neutralizing purposes.

Great care must be exercised that the sensitive thermocouple is not connected in the tank circuit during the period in which the plate voltages are applied, since it will burn out immediately.

**3.456 What is meant by the term "unity coupling"?**

*Answer.* When all the lines of force of one coil cut the windings of a second coil coupled to it and vice versa, the coefficient of coupling is said to equal unity. A formula for coefficient of coupling is

$$k^2 = \frac{M^2}{L_p L_s}$$

where  $M$  is the mutual induction between the coils, and  $L$  is the inductance value.

Under ordinary conditions, the value of  $k$  can approach, but never exceed, the value of unity. However, by the use of an iron core,  $k$  can be made almost equal to unity. Unity coupling is the condition when  $k$  equals unity or one.

**3.457 Draw a diagram illustrating "capacitive" coupling between two tuned radio-frequency circuits.**

*Answer.* See Fig. 3-45.

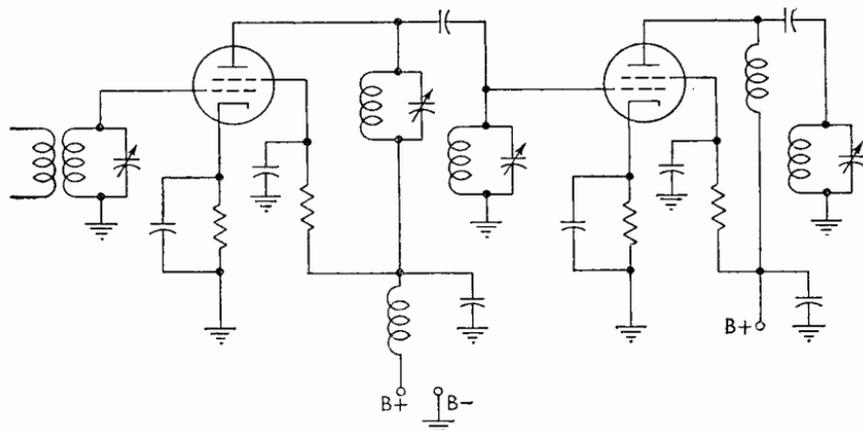


FIG. 3-45. Capacitive coupling system.

**3.458 Draw a diagram illustrating inductive coupling between two tuned radio-frequency circuits.**

*Answer.* See Fig. 3-16.

3.459 Draw a diagram illustrating direct or Loftin-White coupling between two stages of audio-frequency amplification.

*Answer.* See Fig. 3-46.

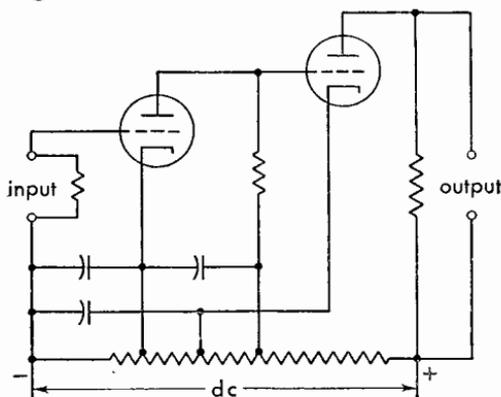


FIG. 3-46. Loftin-White direct-coupled amplifier.

3.476 What effect, if any, does modulation have on the amplitude of the antenna current of an FM transmitter?

*Answer.* In FM transmitters the amplitude of the antenna current remains essentially constant during the process of modulation.

3.477 Why is a high percentage of modulation desirable in AM transmitters?

*Answer.* See 3.347.

3.478 How would loss of radio-frequency excitation affect a class C modulated amplifier when using grid-leak bias only?

*Answer.* A decrease in radio-frequency excitation will result in decreased value of grid-biasing voltage. The modulated amplifier would no longer operate as an efficient class C amplifier. Complete loss of excitation would result in excessive plate dissipation and probable damage to the modulated amplifier tube or tubes. (See also 6.371 and 6.757.)

3.479 What is the purpose of a center-tap connection on a filament transformer?

*Answer.* A center-tap connection is provided on a filament transformer to provide a balanced grid and plate circuit return to the fila-

ment of a directly heated vacuum tube; to maintain constant equipotential relations between the grid, plate, and filament of the tube; and to equalize the plate current drain from both sides of the filament.

**3.480** What would be the result of a short circuit of the plate radio-frequency choke coil in a radio-frequency amplifier?

*Answer.* In a parallel-fed radio-frequency amplifier a short-circuited choke coil will effectively ground the radio-frequency plate potential. No radio-frequency energy will be supplied to the plate-tank circuit. The possibility of a radio-frequency current flow through the defective choke may burn out the d-c plate ammeter if not suitably protected by a radio-frequency bypass capacitor.

**3.481** What are the advantages of push-pull operation compared to single tube operation in amplifiers?

*Answer.* See 3.443, 6.365, 6.464.

**3.482** What class of amplifier is appropriate to use in a radio-frequency doubler stage?

*Answer.* A class C amplifier is most suitable in a radio-frequency doubler stage.

**3.483** What is the ratio of modulator power output to modulated amplifier plate power input for 100 per cent amplitude modulation?

*Answer.* A ratio of 1:2. (See also 6.626.)

**3.484** Draw a diagram of a Hartley oscillator. A Colpitts oscillator.

*Answer.* See Fig. 3-2 and Fig. 3-6.

**3.485** Describe the construction and characteristics of (a) a beam-power tube, (b) a thyratron tube, and (c) a battery-charging rectifier tube.

*Answer.* The beam-power tube is composed of a cathode, a control grid, a screen grid, a suppressor grid (optional), and a plate. A beam tube designed without an actual suppressor grid contains specially designed beam-forming parabolic plates connected to the cathode. This plate structure produces an electron beam effect and also prevents stray electrons from the plate from returning to the screen outside of

the normal beam path. The screen and control grids are spiral-wound wires arranged so that each turn of the screen grid is shaded from the cathode by one of the grid wires. The plate characteristics are similar to those of the pentode except that the constant-current portion is reached at lower plate voltage.

The thyratron or gas-filled triode tube is similar to a standard triode vacuum tube with the exception that it contains mercury vapor or an inert gas of helium, argon, or neon. The cathode is generally of the cylindrical indirect heater type. The grid is a relatively large cylindrical sleeve with large perforations that completely shields the cathode from the plate. The plate is usually a button-shaped metallic disk and serves merely as a simple collector for the electrons.

A typical battery charger rectifier is the Tungar diode rectifier tube. This tube contains a tungsten filament and a button-shaped graphite plate. In the bulb there is an inert argon gas at low pressure.

The characteristics of the (a) beam-power, (b) thyratron, and (c) battery rectifier tubes are briefly as follows:

- a. High power output, high power sensitivity, and high efficiency.
  - b. The grid serves as a critical electronic means for starting current flow. It cannot stop the flow as in the nongaseous types. The thyratron possesses rapid deionization time.
  - c. Low voltage, high current flow.
- (See also 6.819.)

**3.486** What kinds of vacuum tubes respond to filament reactivation, and how is reactivation accomplished?

*Answer.* The thoriated-tungsten type of vacuum tube. Reactivation is accomplished by a series of short-period flash tests of 30 to 60 sec at voltages approximately twice that of the normal filament operating potential. This should be followed with a seasoning test over a period of several hours at a slightly higher than normal operating potential. The plate voltage must be disconnected during these tests.

**3.487** What is the purpose of a bleeder resistor in the filter of a high-voltage d-c power supply?

*Answer.*

1. Provide a suitable discharge path for the high-voltage capacitors in the filter system after the power supply is cut off.
2. Improves voltage regulation.

3. Reduces surge transients.
4. Equalizes the filter-capacitor voltages.
5. Minimizes filter-capacitor breakdown due to momentary peak surges with changing loads.  
(See also 6.433.)

**3.488** How much energy is consumed in 20 hr by a radio receiver rated at 60 watts?

*Answer.* 1,200 watthours or 1.2 kilowatthours. Energy in watt-hours = watts  $\times$  hours =  $60 \times 20 = 1,200$  watthours. Expressed in joules, 1 watthour = 360 joules.

$$1,200 \text{ watthours} = 360 \times 1,200 = 432 \times 10^3 \text{ joules}$$

The fundamental unit of work, or energy, is the "erg"; for practical purposes, the joule or watt-second is used. The watt-second is equivalent to the energy requirements of an electrical circuit in which one watt is supplied for one second. This is equal to  $10^7$  ergs.

**3.489** How does the value of resistance in the grid leak of a regenerative detector affect the sensitivity of the detector?

*Answer.* The grid leak of a capacitor-resistance combination in a regenerative detector regulates the time constant of this network. This in turn controls the automatic grid bias developed during input signal or feedback voltages. With weak-signal input the sensitivity of the circuit will be improved if a large value of grid leak (1 to 10 megohms) and a small capacitor of 0.0001 to 0.00025  $\mu\text{f}$  are employed. The larger the value of  $R$  and the smaller the capacitor capacitance the greater will be the circuit sensitivity for weak-signal-input voltages. (See also 3.204, 6.356.)

**3.490** Compare the design and operating characteristics of class A, class B, and class C amplifiers.

*Answer.* See 3.107, 3.112, 3.136, 6.402, 6.472.

**3.491** What are the causes of downward fluctuation of antenna current at an AM transmitter when the transmitter is modulated?

*Answer.* See 3.351, 4.51, 4.123.

**3.492** What may cause upward fluctuation of the antenna current at an AM transmitter when the transmitter is modulated?

*Answer.* The antenna current will normally rise during the process of modulation owing to the additive audio-frequency power delivered to the carrier. (See also 3.350 and 6.406.)

**3.493** Explain how grid-bias voltage is developed by the grid leak in an oscillator.

*Answer.* The feedback voltages applied to the grid circuit from the plate develop alternate positive and negative emf's between the grid and the cathode of the oscillator tube. If a suitable value of grid capacitor and grid leak is connected, as illustrated in Fig. 3-3, the grid will attract electrons during the positive half of the excitation cycle. The blocking action of the series-grid capacitor will force the electrons to flow through the grid-leak resistance, resulting in a voltage drop across the resistance. Hence, since electrons will continuously flow through the resistance from the grid to the cathode, the grid will be maintained negatively with respect to the cathode during the period in which the tube circuit oscillates. (See also 6.361.)

**3.494** Explain why radio-frequency chokes are sometimes placed in the power leads between a motor-generator power supply and a high-powered radio transmitter.

*Answer.* Radio-frequency chokes are sometimes connected in this manner to prevent possible high-frequency high-power current surges from burning out one or more of the generator armature coils. They are also provided to filter out commutator transients.

**3.495** What effect does inductive reactance in an a-c circuit have on the power factor of the circuit?

*Answer.* An inductive reactance in an a-c circuit introduces a lagging power factor. It will decrease the power factor below unity by a value depending upon the reactance value of the inductance. (See also 3.34.)

**3.496** In which circuits of a radio station are three-phase circuits sometimes employed?

*Answer.* In the rectifier high-voltage power-supply circuits. The high-voltage transformer in these high-power three-phase installations is generally of the delta-Y type.

### 3.497 Explain the operation of a vacuum-tube rectifier power supply and filter.

*Answer.* Figure 3-47 illustrates a typical full-wave vacuum-tube rectifier and power-supply system. The theoretical operation of this type of circuit is briefly as follows:

The a-c power-supply voltage is raised through the step-up action from the primary to the secondary winding on the transformer in accordance with the laws of induction as related to transformer theory. A step-down winding is also provided to supply the filament voltage for the rectifier tubes.

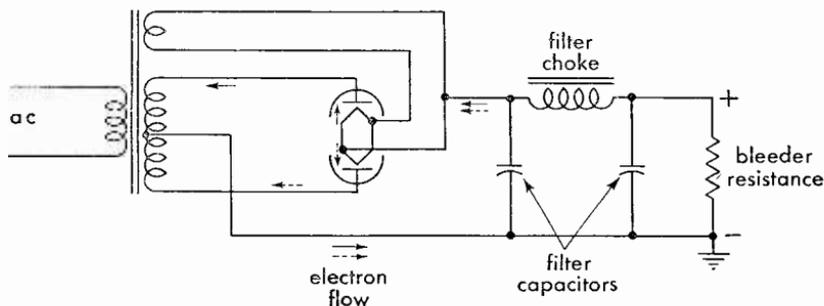


FIG. 3-47. Full-wave vacuum-tube rectifier.

When an alternating current flows in the primary winding, the filaments of the rectifier tubes are heated and electrons are emitted from the rectifier-tube filaments. The alternating voltage induced in the high-voltage secondary winding alternately charges the plates of the rectifier tubes positive with respect to the filaments. When the plate of one tube is positive, electrons will flow from the filament to the plate of that tube through one-half section of the high-voltage winding and through the voltage divider resistance and the choke coils, thus returning to the filament to complete the circuit. The complete flow is in the form of a half-wave pulsation.

When the alternating cycle reverses, the other tube will conduct a current flow through the other half of the high-voltage winding and the circuit components. Another half-wave pulsation is developed which completes two pulsations for the one cycle of alternating voltage.

The pulsations passing through the choke coils are partly smoothed but not sufficiently to develop a pure direct current. The filter capacitors serve to fill in the slight irregularities or troughs of the pulsations in a sort of reservoir action to improve filtering further. The input

filter capacitor also tends to boost the voltage output developed across the voltage divider resistance.

The complete power-supply and vacuum-tube rectifier system is essentially a device for changing the alternating line voltage to a direct voltage of greater amplitude.

**3.498 What are the merits of an FM communication system compared to the merits of an AM communication system?**

*Answer.* The primary advantage of an FM communication system is the improvement shown in signal-to-noise ratio. A properly adjusted FM receiver is practically devoid of man-made noise and static disturbances.

Frequency-modulated transmission also provides a more uniform service area. This is due to the fact that the signal-to-noise ratio remains high until the field intensity reaches a low value. Decreased interchannel interference and relatively lower power requirements are other important advantages of FM over AM systems.

**3.499 What is meant by horizontal and vertical polarization of a radio wave?**

*Answer.* The polarization of radio waves or light waves is the effect of these waves to exhibit different properties in different directions at right angles to the line of propagation. A vertically polarized wave is one in which all the lines of electric force lie in planes perpendicular to the ground plane. In a horizontally polarized wave, the lines of force are parallel to the ground plane.

In general, an antenna that is vertical with respect to the earth radiates a vertically polarized wave while a horizontal antenna radiates a horizontally polarized wave.

**3.500 How should a transmitting antenna be designed if a vertically polarized wave is to be radiated, and how should the receiving antenna be designed for best performance in receiving the ground wave from this transmitting antenna?**

*Answer.* The antenna should be designed to stand in a vertical position with respect to the earth and close to the ground. Vertically polarized waves so constructed produce a stronger signal close to the earth than do horizontally polarized waves. Vertical polarization, therefore, depends upon the physical position of the antenna.

In general, vertically erected antennas, grounded or ungrounded, of a dimension from one-eighth to one full wavelength, are ideally suited for the transmission of vertically polarized waves close to the ground. In any event, the receiving antenna should conform exactly with the position and ground relationship of the transmitting antenna.

**3.501 Draw a block diagram of an FM receiver and explain its principle of operation.**

*Answer.* See Fig. 3-48.

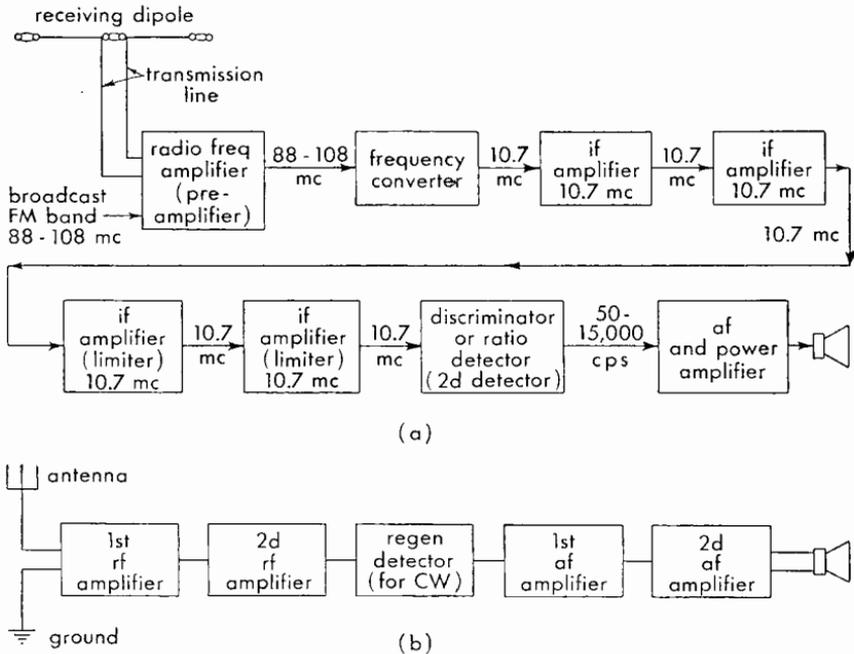


FIG. 3-48. Block diagram of FM receiver (a) and TRF receiver (b).

The radio-frequency components of an FM superheterodyne receiver are essentially the same as in the conventional AM receivers. The primary difference lies in the increased bandwidth (50 to 15,000 cps) requirements, input signal clipping (limiter action), and the demodulation (detection) of the FM wave.

A comparison of Figs. 3-48 and 3-52 illustrates the basic changes in the FM receiver as compared with a typical AM type.

In the FM system, the transmitted carrier frequency is practically of constant amplitude but varies in width during the process of modulation.

When the transmitted signal is picked up by the receiver dipole antenna, FM signals will pass through the tuned radio-frequency amplifier into the frequency converter. Here the local oscillator and signal frequencies are combined in typical superheterodyne fashion to produce the desired heterodyne beat at the designated intermediate frequency. The signals are then amplified by the successive intermediate-frequency amplifiers and limiter stages.

The limiter stage(s) serve to clip off any amplitude variations of the signal input, thereby making its output constant to the discriminator or ratio detector system. The detector in an FM receiver must be so designed that its output varies with the input frequency. This is obtained in the discriminator-detecting system by feeding the signal from the final limiter intermediate stage to a balanced diode rectifier. The radio-frequency signal to the diodes is fed from the limiter stage into a double-tuned circuit (one for each diode) at two frequencies: one above the intermediate-frequency center frequency and the other below it. Hence, as the frequency of the carrier frequency swings because of the modulating frequency, the output across the diode load resistance varies in accordance with the audio frequency modulating the carrier. This audio frequency is then amplified in the usual manner by the audio-frequency voltage and the power-amplifier tubes.

**3.502 Draw a block diagram of an FM transmitter and indicate the center frequency of the master oscillator and the center frequency radiated by the antenna.**

*Answer.* See Fig. 3-49.

It is assumed in this example that an output center frequency of 108 mc is required, this output in turn to be frequency-modulated to produce a frequency deviation during the process of modulation of 75 kc. Furthermore, since the primary or master oscillators in many FM transmitters are in the vicinity of 6 mc, this latter frequency was chosen to represent the controlled master-oscillator frequency.

Hence, to satisfy these conditions, it will be necessary to obtain a multiplication of eighteen times ( $3 \times 3 \times 2$ ) by means of two tripler and one doubler amplifier stage to increase the frequency from 6 to 108 mc.

$$F = 18F_1 = 18 \times 6 = 108 \text{ mc}$$

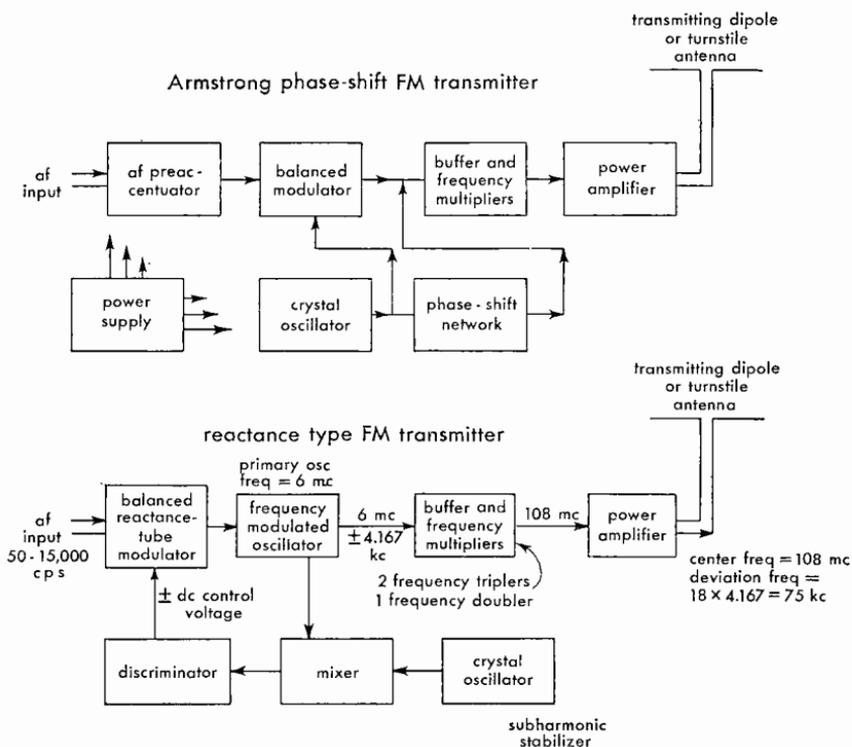


FIG. 3-49. Frequency-modulation transmitters.

However, to satisfy the conditions of modulation, the master oscillator must have a corresponding maximum permissible swing of  $\frac{75}{18}$ , or 4.167 kc. This deviation of the master oscillator frequency when multiplied by 18 (tripler and doubler stages) will yield a maximum swing of  $\pm 75$  kc.

**3.503** In an FM radio communication system what is the meaning of modulation index? Of deviation ratio? What values of deviation ratio are used in an FM radio communication system?

*Answer.* Modulation index is defined as the ratio of the FM carrier frequency swing to the modulating (audio) frequency.

$$m = \frac{\text{maximum frequency swing}}{\text{frequency of signal voltage}}$$

The term "deviation ratio" relates more specifically to the ratio of a frequency swing of 75 kc (100 per cent modulation) to the maximum

audio frequency transmitted. The maximum audio frequency is standardized at 15 kc. Hence, for broadcast transmitters the maximum deviation ratio is  $75,000/15,000 = 5$ . In radio communication systems the deviation ratio is generally between 1 and 3.

**3.504 Why is narrowband frequency modulation rather than wide-band frequency modulation used in radio communication systems?**

*Answer.*

1. Improves signal-to-noise ratio.
2. Provides maximum coverage for a given amount of power.
3. Reduces interchannel interference.
4. Accommodates more stations in a given spectrum.
5. Does not require high fidelity for code and voice transmissions.
6. Gives simplified transmitter and antenna design.

**3.505 What is the purpose of a squelch circuit in a radio communication receiver?**

*Answer.* A squelch circuit in a communications receiver is used to reduce the inherent noise developed in the receiver during the period in which no signal frequency is present.

**3.506 Discuss methods whereby interference to a radio receiver can be reduced.**

*Answer.* The reduction of interference to a radio receiver can be improved by one or more of the following suggestions:

1. Thorough grounding of all metal components of the receiver.
2. Inserting shielded radio-frequency choke coils and bypass capacitors in the power-supply input to the receiver.
3. Directional antennas.
4. Balanced transmission lines or coaxial cables.
5. Shielded antenna leadin wire. (Reduces normal signal gain to the receiver.)
6. Series-resonant trap circuit across receiver input. (Adjust to the interfering signal frequency.)
7. Parallel-resonant wave trap circuit in series with the antenna. (Adjust to the interfering signal.)
8. Insertion of a pretuner stage to the receiver input terminals. (See also 6.649 and 6.655.)

### 3.507 Draw a diagram of an absorption wavemeter and explain its principle of operation.

*Answer.* Figure 3-50 illustrates a typical circuit diagram of an absorption wavemeter. The coil of the wavemeter is loosely coupled to the circuit under measurement. The tuning capacitor is varied until resonance is indicated by a maximum deflection on the radio-frequency ammeter.

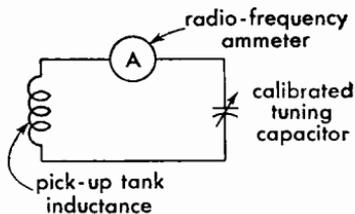


FIG. 3-50. Absorption-type wavemeter.

The frequency or wavelength at resonance is determined by a direct reading on the scale of the capacitor or by reference to the instrument calibration chart. (See also 3.440.)

### 3.508 Draw a diagram of an ohmmeter and explain its principle of operation.

*Answer.* Figure 3-51 illustrates a simple type of ohmmeter. In this instrument, small battery cells are used to supply the voltage to operate a calibrated 1-milliamperere meter when the external terminals to an unknown resistor are closed. Two standard calibrated resistors are employed. One resistor  $R_1$  is of fixed value, and the other  $R_2$  is of the variable type to compensate for battery voltage changes.

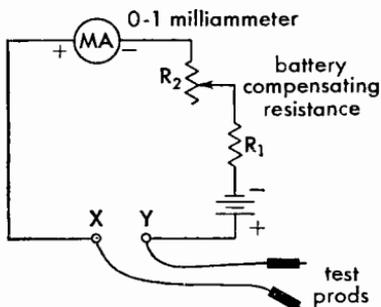


FIG. 3-51. Simple ohmmeter.

Adjustment of the meter is accomplished by short-circuiting the terminals  $X$ - $Y$  and varying  $R_2$  until the milliammeter indicates a full-scale deflection (zero ohms on the calibrated scale).

When an unknown resistance is connected across the terminals, the current flow through the meter will decrease in proportion to the amount of the unknown resistance applied. Thus, since the scale is calibrated directly in ohms, the reading will give the value of the unknown resistance. Zero ohms are indicated at the extreme right, and maximum ohms are shown on the extreme left in this simple type of ohmmeter.

**3.509 Discuss Lecher wires; their properties and use.**

*Answer.* Lecher wires are short-wavelength two-wire transmission lines. Two short parallel lengths of line are frequently used in ultra-high-frequency vacuum-tube oscillators to provide the necessary oscillatory constants for the circuit. Lecher wires are generally a quarter wavelength long or some multiple of a quarter wavelength, depending upon the frequency required.

Lecher wires present an excellent means for studying the phenomena of ultrahigh-frequency transmission particularly as related to the measurements of standing waves and nodes on a transmission line.

**3.510 If a 0-1 d-c milliammeter is to be converted into a voltmeter with full-scale calibration 100 volts, what value of series resistance should be connected in series with the milliammeter?**

*Answer.* 100,000 ohms.

*Solution:*

$$R = \frac{E}{I} = \frac{100}{0.001} = 100,000 \text{ ohms}$$

**3.511 What are wave guides? Cavity resonators?**

*Answer.* A wave guide is a metallic pipe of rectangular or circular construction. It is used as a transmission line to guide or transfer electromagnetic waves in the microwave-frequency spectrum between a generating source and an output device, such as a parabolic antenna system. Wave guides are used almost exclusively in the transmission of microwave frequencies between 1 and 10 centimeters in wavelength (10,000 to 3,000 mc).

A cavity resonator is a closed metallic chamber, either round or rectangular in cross section. These resonant cavities develop standing-wave reflections which build up in the cavity and reinforce each other at some resonant frequency depending upon the physical construction of the cavity chamber.

The cavity resonator is to the microwave field what the conventional lumped inductance and capacitance are to the lower radio-frequency field of high, medium, and low radio-frequency circuits.

**3.512 In what range of frequencies do magnetron and klystron oscillators find application?**

*Answer.* Magnetron and klystron oscillators are used almost exclusively in the microwave and very high-frequency ranges between 1,000 and 30,000 mc.

**3.513 What is the purpose of a diversity antenna receiving system?**

*Answer.* The diversity antenna system is extensively used in trans-oceanic telegraphy and telephone installations to reduce signal fading.

**3.514 Why are insulators sometimes placed in antenna guy wires?**

*Answer.* Insulators are sometimes placed in antenna guy wires to prevent absorption and reradiation. If the physical length of a certain guy wire approaches a resonant relationship to some multiple of the normal antenna frequency, harmonic radiation and serious interference may result. Series insulators connected in the guy wires help to break up these resonant properties and prevent harmonic radiation.

**3.515 Discuss the construction and operation of dynamotors.**

*Answer.* A dynamotor is a special type of motor-generator with a single field winding (or common permanent magnet) and a rotor with two armatures and two commutators. The low-voltage armature is generally supplied with 6, 12 or 24 volts d-c. The high-voltage or generator armature usually delivers from 300 to 500 volts. Although only about 50 per cent efficient, the dynamotor is useful in mobile equipment and can be made to deliver up to 500 watts.

**3.516 Discuss the cause and prevention of interference to radio receivers installed in motor vehicles.**

*Answer.* Although interference is caused principally by the ignition system in motor vehicles, it may also arise from the generator brushes, intermittent contact in the voltage regulator, from loose hub caps or static charges built up between tube and tire.

Special spark plugs or suppressors should be used. If necessary, shield ignition wires. A 0.5- $\mu$ f bypass capacitor can be connected across distributor points and dashboard ammeter. Generator brushes and regulator contacts should be bypassed with a capacitor and small resistor in series. Spring contactors are available for use between hub caps and axles. Conducting powder should be sprinkled in tire casings.

The leadin cable between antenna and receiver should be shielded,

with the sheath grounded. All other metal-sheathed cables should be bonded and grounded. Wires to dome lights should be bypassed.

**3.517 Explain the process of neutralizing a triode radio-frequency amplifier.**

*Answer.* See 6.409.

**3.518 A relay with a coil resistance of 500 ohms is designed to operate when 0.2 ampere flows through the coil. What value of resistance must be connected in series with the coil if operation is to be made from a 110-volt d-c line?**

*Answer.* A resistance of 50 ohms will be required to drop the voltage across the relay to the desired 100 volts.

*Solution:*

$$E = IR = 0.2 \times 500 = 100 \text{ volts}$$

$$R_{\text{series}} = \frac{E}{I} = \frac{110 - 100}{0.2} = 50 \text{ ohms}$$

**3.519 What value of resistance should be connected in series with a 6-volt battery that is to be charged at a 3-ampere rate from a 115-volt d-c line?**

*Answer.*  $36\frac{1}{3}$  ohms.

*Solution:*

$$R = \frac{E - e}{I} = \frac{115 - 6}{3} = 36\frac{1}{3} \text{ ohms}$$

**3.520 What may cause self-oscillation in an audio amplifier?**

*Answer.* Self-oscillation or motorboating in an audio-frequency amplifier may be caused by any of the following defects:

1. Open output filter capacitors in the power-supply system.
2. Open grid leaks.
3. Improper *RC* time constant in resistance-capacitance coupled audio-frequency amplifiers.

**3.521 Why are pairs of wires carrying alternating heater currents in audio amplifiers twisted together?**

*Answer.* Filament wires carrying alternating current are twisted in order that the 60-cycle magnetic fields around them will cancel out. This reduces the possibility of hum pickup in adjacent circuits.

3.522 Draw a block diagram of a superheterodyne receiver capable of receiving AM signals and indicate the frequencies present in the various stages when the receiver is tuned to 2,450 kc. What is the frequency of a station that might cause image interference to the receiver when tuned to 2,450 kc?

Answer. See Fig. 3-52.

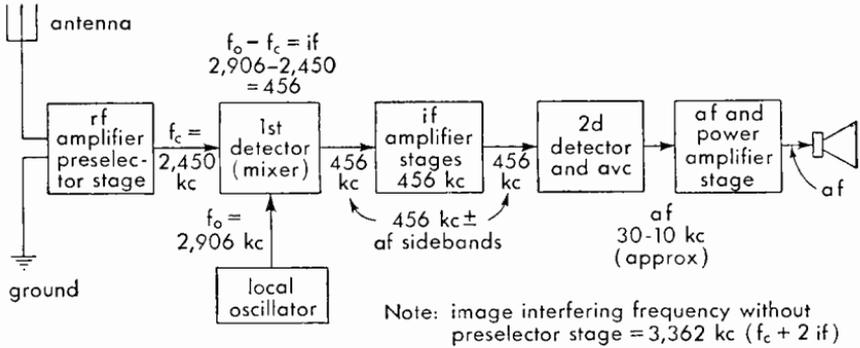


FIG. 3-52. Block diagram of superheterodyne receiver for amplitude-modulation reception.

3.523 Show by a diagram how to connect a wave trap in the antenna circuit of a radio receiver to attenuate an interfering signal.

Answer. See Fig. 3-53.

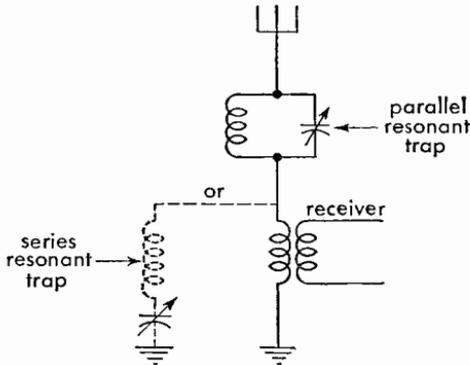


FIG. 3-53. Wave-trap arrangements.

3.524 Draw a diagram of a tuned radio-frequency radio receiver.

*Answer.* See Fig. 3-54.

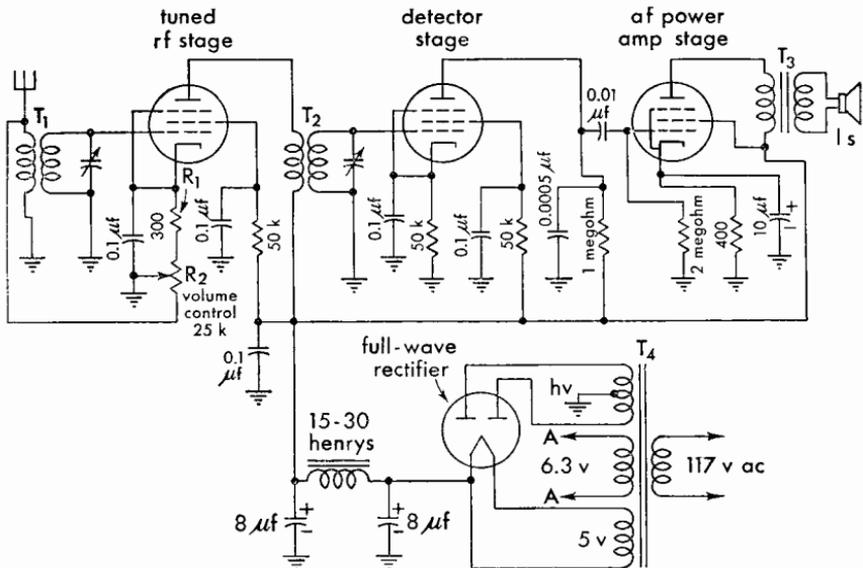


FIG. 3-54. Tuned-radio-frequency receiver.

3.525 What would be the effects of connecting 110 volts at 25 cycles to the primary of a transformer rated at 110 volts and 60 cycles?

*Answer.* The inductive reactance of the 110-volt 60-cycle primary winding will be lowered when the transformer is connected to a 25-cycle frequency source. The current flow through the primary winding will be more than double its normal value and may result in serious overheating and ultimate damage to the winding.

3.526 Draw a diagram of a one-tube audio oscillator using an iron-core choke.

Answer. See Fig. 3-55.

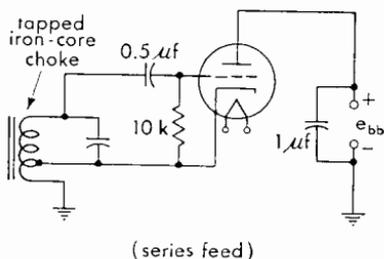
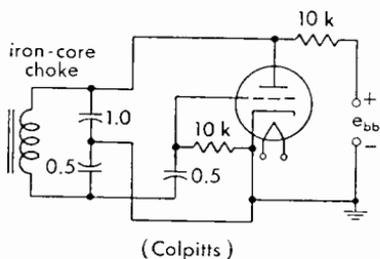
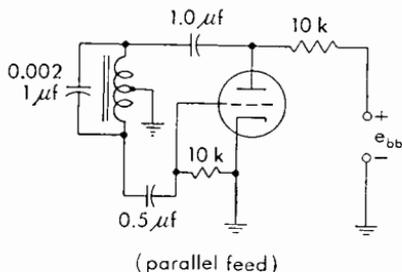


FIG. 3-55. Iron-core coil audio-frequency oscillators.

3.527 Show by a diagram how a two-wire radio-frequency transmission line may be connected to feed a Hertz antenna.

Answer. See Fig. 3-56.

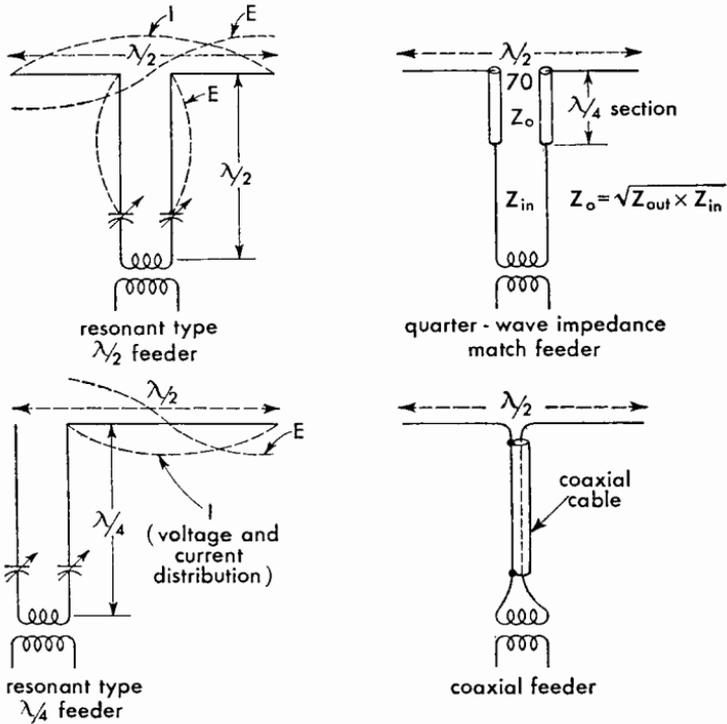


FIG. 3-56. Half-wave antenna systems.

3.528 Draw a diagram of a synchronous vibrator power supply. A nonsynchronous vibrator power supply.

Answer. See Fig. 3-57.

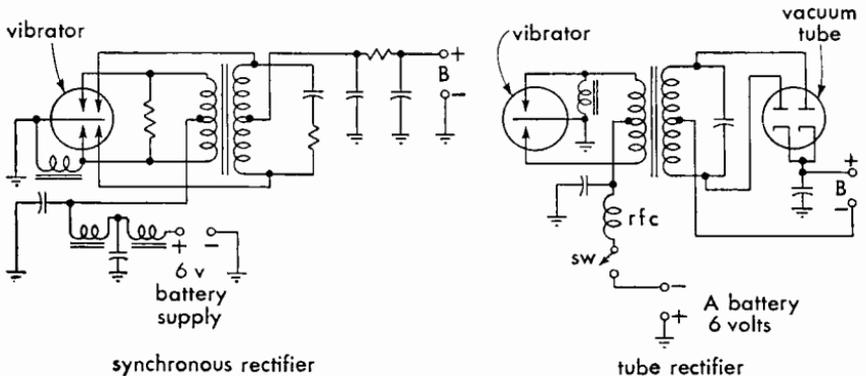


FIG. 3-57. Vibrator high-voltage supplies.

## Element 4

# Advanced Radiotelephone (Theory)

4.01 A parallel circuit is made up of five branches, three of the branches being pure resistances of 7, 11, and 14 ohms, respectively. The fourth branch has an inductive reactance value of 500 ohms. The fifth branch has a capacitive reactance of 900 ohms. What is the total impedance of the network? If a voltage is impressed across the parallel network, which branch will dissipate the greatest amount of heat?

*Answer.* The first step in a problem of this character is to reduce the three parallel resistances to their effective or singular equivalent value.

$$R_{\text{eff}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = 3.27 \text{ ohms}$$

Thus, a single resistance equivalent of 3.27 ohms is connected in parallel to an inductive reactance value of 500 ohms and a capacitive reactance of 900 ohms. Obviously, this low value of resistance in shunt to the two higher reactances will make the circuit impedance somewhere in the vicinity of 3+ ohms. To prove this contention, however, let us apply some arbitrary value of voltage to this combination of, say, 900 volts. The currents through the various branches may then be readily determined by Ohm's law,  $I = E/R$ ,  $I = E/X_L$ ,  $I = E/X_C$ . The total line current may then be obtained by the equation,

$$I_{\text{line}} = \sqrt{I_R^2 + (I_L - I_C)^2} = 276 \text{ amperes}$$

Thus,

$$Z = \frac{E}{I} = \frac{900}{276} = 3.26 \text{ ohms}$$

The greatest amount of heat will be dissipated by the 7-ohm unit.

4.02 What is the reactance of a capacitor at the frequency of 1,200 kc if its reactance is 300 ohms at 680 kc?

*Answer.* The correct answer is 170 ohms.

*Solution:*

$$\begin{aligned}\frac{X_{c_1}}{X_{c_2}} &= \frac{f_2}{f_1} \\ \frac{300}{X_{c_2}} &= \frac{1,200}{680} \\ X_{c_2} &= 170 \text{ ohms}\end{aligned}$$

4.03 If the mutual inductance between two coils is 0.1 henry, and the coils have inductances of 0.2 and 0.8 henry, respectively, what is the coefficient of coupling?

*Answer.* The coefficient of coupling is 0.25.

*Solution:*

$$k = \frac{M}{\sqrt{L_1 \times L_2}} = \frac{0.1}{\sqrt{0.2 \times 0.8}} = 0.25 \text{ (25 per cent)}$$

4.04 If, in a given a-c series circuit, the resistance, inductive reactance, and capacitive reactances are of equal magnitude of 11 ohms, and the frequency is reduced to 0.411 of its value at resonance, what is the resultant impedance of the circuit at the new frequency?

*Answer.* The resultant impedance of the circuit at the new frequency is 24.8 ohms.

*Solution:*

$$\begin{aligned}X_L &= 11 & X_c &= 11 & R &= 11 \\ X'_L &= 0.411 \times 11 = 4.52 \\ X'_c &= \frac{11}{0.411} = 26.76 & \text{New } X &= X'_c - X'_L = 22.24 \text{ ohms} \\ Z' &= \sqrt{R^2 + X^2} = 24.8 \text{ ohms}\end{aligned}$$

4.05 If an alternating current of 5 amperes flows in a series circuit composed of 12 ohms resistance, 15 ohms inductive reactance, and 40 ohms capacitive reactance, what is the voltage across the circuit?

*Answer.* The voltage across the circuit is 138.7 volts.

*Solution:*

$$E_A = \sqrt{E_R^2 + (E_c - E_L)^2} = \sqrt{3,600 + 15,625} = 138.7 \text{ volts}$$

$$E_R = IR = 5 \times 12 = 60 \text{ volts}$$

$$E_c = IX_c = 5 \times 40 = 200 \text{ volts}$$

$$E_L = IX_L = 5 \times 15 = 75 \text{ volts}$$

**4.06** A series circuit contains resistance, inductive reactance, capacitive reactance. The resistance is 7 ohms, the inductive reactance is 8 ohms, and the capacitive reactance is unknown. What value must this capacitor have in order that the total circuit impedance be 13 ohms?

*Answer.* The capacitive reactance value must be 18.96 ohms.

*Solutions:*

$$Z = \sqrt{R^2 + X^2} = \sqrt{169} = \sqrt{49 + X^2} \quad X^2 = 120$$

$$X = \pm 10.96$$

but  $X = X_L - X_c$

$$\therefore \pm 10.96 = 8 - X_c \quad X_c = 8 + 10.96 = 18.96$$

*Proof:*

$$Z = \sqrt{R^2 + (X_c - X_L)^2} = \sqrt{49 + 120} = \sqrt{169} = 13 \text{ ohms}$$

**4.07** What is the total reactance of two inductances connected in series with zero mutual inductance?

*Answer.* The total reactance with zero mutual inductance is the sum of the two individual reactances,  $X_1 + X_2$ .

**4.08** If an alternating voltage of 115 volts is connected across a parallel circuit made up of a resistance of 30 ohms, an inductive reactance of 17 ohms, and a capacitive reactance of 19 ohms, what is the total circuit-current drain from the source?

*Answer.* The total current drain is 3.9 amperes.

*Solution:*

$$I_{\text{line}} = \sqrt{I_R^2 + (I_L - I_c)^2} = \sqrt{14.7 + .5} = 3.9 \text{ amperes}$$

$$I_R = \frac{E}{R} = 3.83 \text{ amperes} \quad I_L = \frac{E}{X_L} = 6.76 \text{ amperes}$$

$$I_c = \frac{E}{X_c} = 6 \text{ amperes}$$

**4.09** When two coils, of equal inductance, are connected in series, with unity coefficient of coupling and their fields in phase, what is the total inductance of the two coils?

*Answer.* The total inductance is the sum of the two equal inductances plus the product of  $2M$ , or  $4 \times L_1$  or  $4 \times L_2$ .

*Solution:*

$$M = \sqrt{L_1 \times L_2} \quad L_x = L_1 + L_2 + 2M$$

**4.10** If a power transformer has a primary voltage of 4,400 volts and a secondary voltage of 220 volts, and the transformer has an efficiency of 98 per cent when delivering 23 amperes of secondary current, what is the value of primary current?

*Answer.* The current flow at 98 per cent efficiency is approximately 1.17 amperes.

*Solution:*

$$I_p = \frac{E_s \times I_s}{E_p} = 1.15 \text{ amperes at 100 per cent efficiency}$$

$$P_p = \frac{220 \times 23}{0.98}$$

$$I_p = \frac{P_p}{E_p} = \frac{5,170}{4,400} = 1.175 \text{ amperes}$$

Thus, at 98 per cent efficiency the value of primary current is 1.17 amperes.

**4.11** Three single-phase transformers, each with a ratio of 220:2,200 volts, are connected across a 220-volt three-phase line, primaries in delta. If the secondaries are connected in Y, what is the secondary line voltage?

*Answer.* In a delta-Y-connected transformer system the output voltage across the secondary may be computed from the formula

$$E_s = E_p T_r \times 1.732$$

where  $E_s$  = secondary voltage.

$T_r$  = transformation ratio.

$E_p$  = primary voltage.

Thus, in this example, the secondary voltage is 3,810 volts.

**4.12 What factors determine core losses in a transformer?**

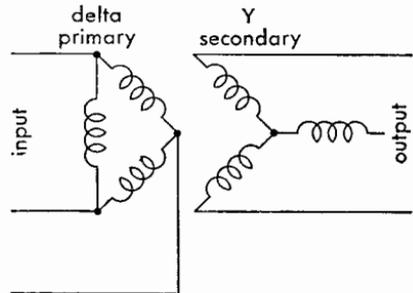
*Answer.* The character of the core material and the physical structure of the core material. The core losses in transformers are mainly due to molecular friction or hysteresis and eddy currents. These are minimized by the use of special core material, such as silicon steel, and the arrangement of the core into sheets or laminations.

**4.13 What circuit constants determine the copper losses of a transformer?**

*Answer.* The copper losses are primarily dependent upon the circuit load. These losses are generally expressed as the  $IR$  losses. The proper size of wire for given load conditions is essential to keep these losses at a minimum.

**4.14 Draw a schematic wiring diagram of a three-phase transformer with delta-connected primary and Y-connected secondary.**

*Answer.* Figure 4-1 illustrates a delta-Y-connected transformer.



**4.15 What factor(s) determine the ratio of impedances which a given transformer can match?**

*Answer.* The turns ratio.

$$\text{Turns ratio} = \sqrt{\frac{Z_p}{Z_s}}$$

FIG. 4-1. Delta-star (or-Y) transformer.

**4.16 If a transformer, having a turns ratio of 10:1, working into a load impedance of 2,000 ohms and out of a circuit having an impedance of 15 ohms, what value of resistance may be connected across the load to effect an impedance match?**

*Answer.* A load resistance of 6,000 ohms will effect an approximate match.

*Solution:*

$$\begin{aligned} \frac{n_1}{n_2} &= \sqrt{\frac{Z_1}{Z_2}} & \left(\frac{n_2}{n_1}\right)^2 &= \frac{Z_2}{Z_1} \\ 100 &= \frac{Z_2}{15} \\ 1,500 &= Z_2 \end{aligned}$$

Therefore  $R_x$  must be of such value as to give 1,500 ohms when in parallel with 2,000 ohms.

**4.17** In a class C radio-frequency amplifier, what ratio of load impedance to dynamic plate impedance will give the greatest plate efficiency?

*Answer.* The theoretical ratio is infinity to one. For practical purposes this ratio is generally 1:1.

**4.18** If a lamp, rated at 100 watts and 115 volts, is connected in series with an inductive reactance of 355 ohms and a capacitive reactance of 130 ohms across a voltage of 220 volts, what is the current value through the lamp?

*Answer.* The current flow through the lamp is approximately 0.86 ampere.

*Solution:*

$$R_{\text{lamp}} = 132 \text{ ohms (approx.)}$$

$$I = \frac{E}{Z} = \frac{220}{\sqrt{R^2 + (X_L - X_C)^2}} = 0.86 \text{ ampere (approx.)}$$

**4.19** If an a-c series circuit has a resistance of 12 ohms, an inductive reactance of 7 ohms, and capacitive reactance of 7 ohms, at the resonant frequency, what will be the total impedance at twice the resonant frequency?

*Answer.* The impedance will be approximately 15.9 ohms.

*Solution:*

$$\begin{aligned} 2X_L &= 14 \text{ ohms} \\ \frac{1}{2}X_C &= 3.5 \text{ ohms} \\ Z &= \sqrt{R^2 + (X_L - X_C)^2} = 15.9 \text{ ohms} \end{aligned}$$

**4.20** In a parallel circuit composed of an inductance of 150 microhenrys and a capacitance of 160  $\mu\mu\text{f}$ , what is the resonant frequency?

*Answer.* The resonant frequency is 1,028 kc.

*Solution:*

$$f_r = \frac{10^6}{2\pi \sqrt{LC}} = 1,028 \text{ kc}$$

**4.21** What value of capacitance must be shunted across a coil having an inductance of 56 microhenrys in order that the circuit resonate at 5,000 kc?

*Answer.* Approximately 18  $\mu\text{mf}$ .

*Solution:*

$$C_{\text{inrads}} = \frac{1}{4\pi^2 f^2 L} = 18 \mu\text{mf}$$

**4.22** Why should impedances be matched in speech-input equipment?

*Answer.* Impedances should be matched to effect a maximum energy transfer and minimum line reflections. Improper impedance matching in speech-amplifier circuits not only might decrease the volume but might seriously affect the quality of reproduction. A piece of cable that is electrically short and is terminated in a resistance higher than its characteristic resistance is equivalent to a shunt capacitance.

**4.23** What are the purposes of H- or T-pad attenuators?

*Answer.* Attenuators of the H- and T-pad variety effect proper impedance matching with desired attenuation.

**4.24** Why are grounded center-tap transformers frequently used to terminate program lines?

*Answer.* They effect a proper balance to ground. This will cause a reduction in stray field pickup and also balance out unwanted line noises. The frequency response is also improved.

**4.25** What is the purpose of a line pad?

*Answer.* A line pad serves to introduce a proper amount of attenuation and at the same time effect an impedance match.

**4.26** Why are electrostatic shields used between windings in coupling transformers?

*Answer.* Electrostatic shields between windings in coupling transformers reduce the capacitive coupling between coils.

**4.27** Why is it preferable to isolate the direct current from the primary winding of an audio transformer working out of a single vacuum tube?

*Answer.* To prevent transformer core saturation. A saturated core will lower the primary inductance and seriously impair the quality of transmission. Heavy distortion will occur.

**4.28 Why are preamplifiers used ahead of mixing systems?**

*Answer.* Mixing systems introduce a signal loss because they are attenuating networks and consequently require a preamplifier to compensate for these losses.

**4.29 What is the purpose of a variable attenuator in a speech-input system?**

*Answer.* Variable attenuators are used to control the voltage gain of an amplifier. They permit the proper degree of adjustment for variable signal-input levels.

**4.30 In a low-level amplifier using degenerative feedback, at a nominal mid-frequency, what is the phase relationship between the feedback voltage and the input voltage?**

*Answer.* Degenerative feedback, or feedback without the generation of sustained oscillations, is that condition in a vacuum-tube amplifying circuit in which energy from the plate circuit to the grid circuit causes the feedback voltage at a nominal mid-band frequency to be 180 deg out of phase with the input voltage.

**4.31 Under what circumstances will the gain per stage be equal to the voltage amplification factor of the vacuum tube employed?**

*Answer.* The gain per stage in a resistance-coupled amplifier is equal to the voltage-amplification factor of the vacuum tube employed. To achieve maximum gain from the tube, the load impedance into which the tube works must be high.

**4.32 Why is a high-level amplifier, feeding a program transmission line, generally isolated from the line by means of a pad?**

*Answer.* This is done to prevent overloading the line and also to reduce the possibility of line reflections back to the final stage. Proper impedance relations are also maintained.

**4.33** What is the result of deliberately introduced degenerative feedback in audio amplifiers?

*Answer.* This will result in a decrease in the gain of the amplifier but will greatly improve the frequency characteristic of the amplifier.

**4.34** What unit has been adopted by leading program transmission organizations as a volume unit and to what power is this unit equivalent?

*Answer.* The volume unit, or *VU*. It has a power equivalent of 0.001 watt (600 ohms). It is indicated by a meter with definite characteristics.

**4.35** What is the purpose of a line equalizer?

*Answer.* A line equalizer as used in telephone lines serves to compensate for the higher audio-frequency signal loss through the distributed capacitance in the lines. It enables the output of the line to present a "flatter" frequency characteristic.

**4.36** Draw a diagram of an equalizer circuit most commonly used for equalizing wire-line circuits

*Answer.* Fig. 4-2 illustrates a typical line equalizer.

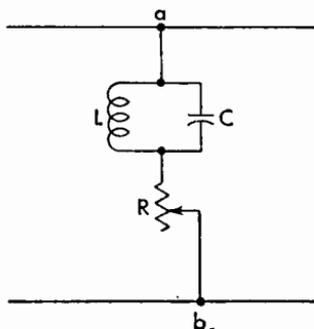


FIG. 4-2. Line equalizer.

**4.37** What type of microphone employs a coil of wire, attached to a diaphragm, which moves in a magnetic field as a result of impinging sound waves?

*Answer.* The dynamic microphone.

4.38 What is the most serious disadvantage of using carbon microphones with high-fidelity amplifiers?

*Answer.* The possibility of carbon noises or "hissing."

4.39 Why are the diaphragms of certain types of microphones stretched?

*Answer.* The diaphragms of certain types of microphones are stretched in order to obtain uniform response particularly at the high audio frequencies. The stretching increases the resonant frequency of the diaphragm.

4.40 Draw a simple schematic diagram of a grid-bias modulation system, including the modulated radio-frequency stage.

*Answer.* Fig. 4-3 illustrates a simple schematic of a grid-bias modulated radio-frequency stage.

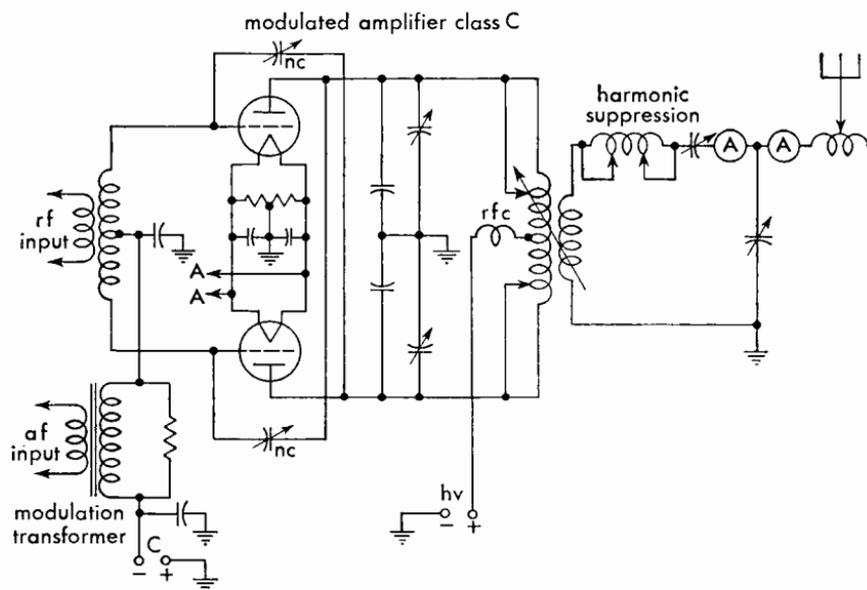


FIG. 4-3. Grid-bias modulated class C radio-frequency amplifier with inductive coupling to the antenna.

4.41 Draw a simple schematic diagram of a class B audio high-level modulation system, including the modulated radio-frequency stage.

*Answer.* Figure 4-4 illustrates a simple schematic of a class B modulated radio-frequency stage.

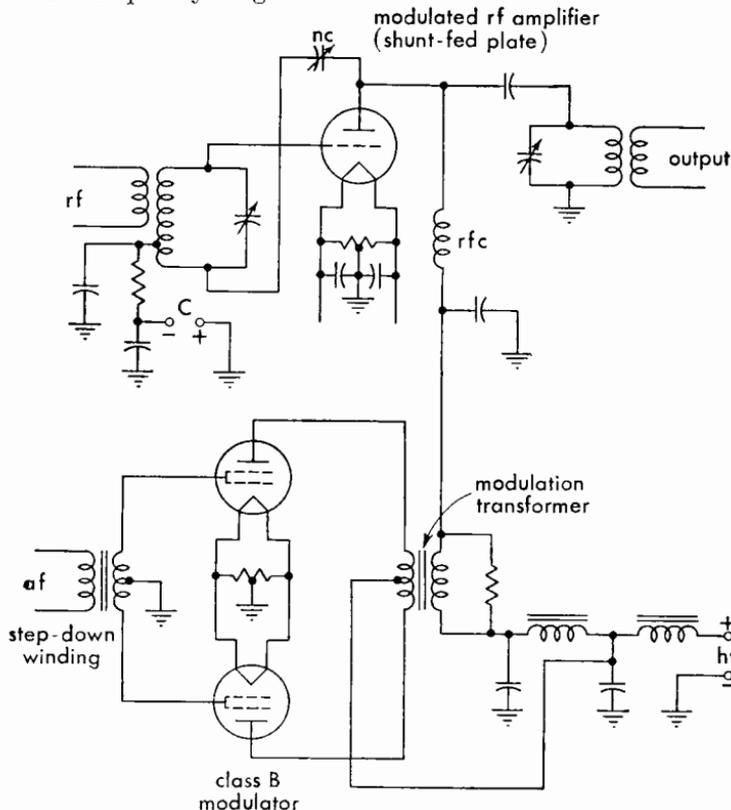


FIG. 4-4. Class B modulation system.

4.42 Draw a simple sketch of the trapezoidal pattern on a cathode-ray oscilloscope screen indicating low per cent modulation without distortion.

*Answer.* Figure 4-5 illustrates a trapezoidal pattern as indicated on the screen of a cathode-ray tube under the conditions of low percentage of modulation without distortion. The pattern for complete modulation and excessive modulation is also shown, for comparison.

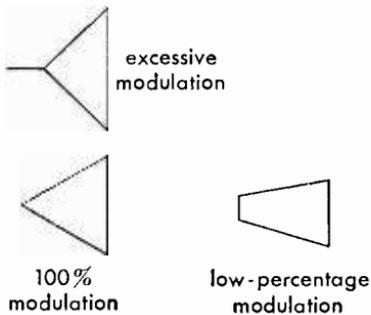


FIG. 4-5. Cathode-ray trapezoidal modulation pattern.

**4.43 During 100 per cent modulation, what percentage of the average output power is in the sidebands?**

*Answer.* At 100 per cent modulation the percentage of total side-band power is equal to 33.3 per cent of the total output power.

**4.44 Draw a schematic diagram of test equipment which may be used to detect carrier shift of a radiotelephone transmitter output.**

*Answer.* Figure 4-6 illustrates an arrangement for determining carrier shift of a radiotelephone transmitter. Movement of the milliammeter needle indicates a shift in the carrier frequency.

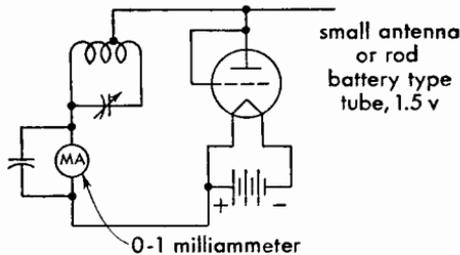


FIG. 4-6. Simple carrier-shift indicator.

**4.45 What are the advantages and disadvantages of class B modulators?**

*Answer.* The class B system of modulation provides greater efficiency compared with the distortionless class A system. Class B, however, introduces a relatively greater degree of distortion than the class A system. In addition to the higher plate efficiency, the class B modulator provides lower power consumption, since plate current flows only during the grid-excitation periods.

**4.46 Why is frequency modulation undesirable in the standard broadcast band?**

*Answer.* High-fidelity frequency modulation requires a wider band than amplitude modulation, which would restrict the number of stations operating in this band.

**4.47 What is meant by "low-level" modulation?**

*Answer.* "Low-level" modulation is the term applied to systems in which the modulated radio-frequency stage precedes the final power-amplifier stage.

4.48 If a preamplifier, having a 600-ohm output, is connected to a microphone so that the power output is  $-40$  db, and assuming the mixer system to have a loss of  $10$  db, what must be the voltage amplification necessary in the line amplifier to feed  $+10$  db into the transmitter line?

*Answer.* The necessary voltage amplification to satisfy these conditions must be 1,000.

*Solution* (assuming 600-ohm terminations):

Input is  $-50$  db at 600 ohms

Output is  $+10$  db at ? ohms.

$$\text{db} = 20 \log \frac{E_1 \sqrt{R_2}}{E_2 \sqrt{R_1}}$$

Decibel gain, therefore, is 60.

$$60 = 20 \log \frac{E_1 \sqrt{600}}{E_2 \sqrt{600}}$$

If

$$\log \frac{E_1}{E_2} = 3$$

then,

$$\frac{E_1}{E_2} = 1,000$$

4.49 If the power output of a modulator is decreased from 1,000 watts to 10 watts, how is the power loss expressed in decibels?

*Answer.* Gain or loss in decibels =  $10 \log \frac{P_1}{P_2} = 20$  db

*Solution:*

$$10 \log \frac{P_1}{P_2} = 10 \log 100$$

$$\log 100 = 2$$

$$\text{db} = 20$$

Since the power has been decreased, this is a 20-db loss, or  $-20$  db.

4.50 In a modulated amplifier, under what circumstances will the plate current vary as read on a d-c meter?

*Answer.* Under normal conditions, the *average* value of the voltage on either side of the carrier frequency (d-c component) remains constant throughout the modulating cycle. However, if during modulation the plate current varies, it is an indication that the average during the modulating cycle is being shifted up or down in accordance with the circuit defects (carrier shift).

The following are the most probable causes for these variations: overmodulation, parasitic oscillations, improper neutralization, defective tube(s), poor regulation, low or excessive radio-frequency excitation, improper grid bias or plate-impedance adjustments.

**4.51 What could cause downward deflection of the antenna current of a transmitter when modulation is applied?**

*Answer.* The most common causes of downward deflection of the antenna ammeter are low filament voltage or defective tubes in the modulating or power-amplifier stages, open filter capacitor in the power supply, improper neutralization, improper load-impedance adjustment, overmodulation, and low radio-frequency excitation in the modulating or power-amplifier stages.

**4.52 If tests indicate that the positive modulation peaks are greater than the negative peaks in a transmitter employing a class B audio modulator, what steps should be taken to determine the cause?**

*Answer.* Decrease the audio-frequency excitation to ascertain if the excessive positive peaks are caused by a high gain-control setting. Check the balance of the modulator tubes for equality of emission. Check the neutralization of the modulated amplifier. Increase the tank-circuit capacitance and retune to resonance, as an insufficient C will also produce this result. Check the grid-bias adjustments. (See 6.642.)

**4.53 In a properly adjusted grid-bias modulated radio-frequency amplifier, under what circumstances will the plate current vary as read on a d-c meter?**

*Answer.* If *all* adjustments are assumed to be correct, the plate current as indicated on the d-c ammeter will vary with excessive audio-frequency excitation to the amplifier grids (overmodulation).

**4.54** What percentage increase in average output power is obtained under 100 per cent sinusoidal modulation as compared with average unmodulated carrier power?

*Answer.* A 50 per cent increase in output power will be obtained.

**4.55** In a class C radio-frequency amplifier stage feeding an antenna system, if there is a positive shift in carrier under modulation conditions, what may be the trouble?

*Answer.* This may be due to insufficient tank-circuit capacitance, antenna or tank circuits out of tune, insufficient excitation, improper neutralization, or overmodulation. (See 6.642.)

**4.56** Name four causes of distortion in a modulated-amplifier stage output.

*Answer.* Four causes of distortion in a modulated-amplifier output are

1. Overmodulation.
2. Excessive radio-frequency drive.
3. Insufficient load impedance adjustment.
4. Improper neutralization (self-oscillation or regeneration).
5. Parasitic oscillations.

**4.57** If you decrease the percentage of modulation from 100 per cent to 50 per cent, by what percentage have you decreased the power in the sidebands?

*Answer.* The sideband power will be decreased 75 per cent.

*Solution:* Assuming a 100-watt completely modulated carrier, we get

$$P_{sb} = \frac{m^2 P_c}{2} = \frac{1 \times 100}{2} = 50 \text{ watts}$$

If modulation is reduced to 50 per cent, we get, by the same formula,

$$\frac{0.5^2 \times 100}{2} = 0.25 \times 50 = 12.5 \text{ watts}$$

a reduction of 75 per cent.

**4.58** If a certain audio-frequency amplifier has an over-all gain of 40 db and the output is 6 watts, what is the input?

*Answer.* The input will be 0.0006 watt or 0.6 milliwatt.

*Solution:*

$$\text{db} = 10 \log \frac{P_1}{P_2} \quad 40 = 10 \log \frac{6}{x} \quad 10,000 = \frac{6}{x}$$

$$x = \frac{6}{10,000} = 0.0006 \text{ watt}$$

**NOTE:** 40 db equals a power ratio of 10,000.

**4.59** If the field intensity of 25 millivolts per meter develops 2.7 volts in a certain antenna, what is the effective height?

*Answer.* The effective height will be 108 meters.

*Proof:* A height of 1 meter will develop 0.025 volt.

**4.60** Draw a schematic diagram of a final amplifier with capacitance coupling to the antenna which will discriminate against the transfer of harmonics.

*Answer.* Figure 4-7 illustrates a capacitive coupling system.

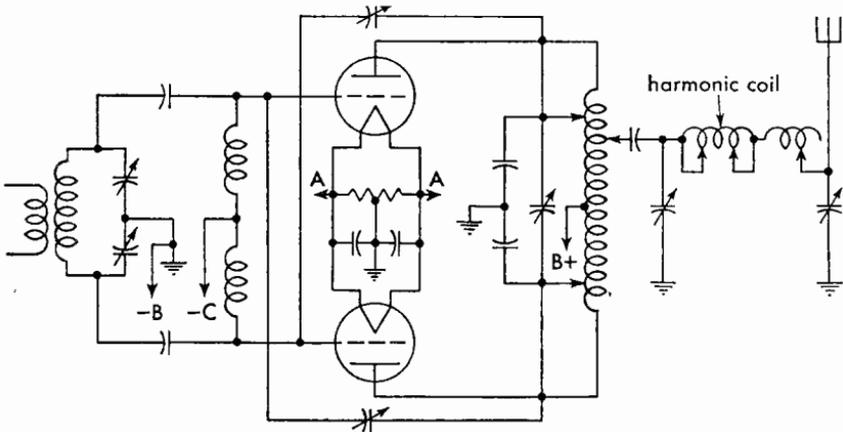


FIG. 4-7. Capacitive coupling and harmonic suppression arrangement.

**4.61** In what units is the field intensity of a broadcast station normally measured?

*Answer.* Field intensity is generally measured in millivolts or microvolts per meter.

4.62 Draw a simple schematic diagram showing a method of coupling the radio-frequency output of the final power-amplifier stage of a transmitter to a two-wire transmission line, with a method of suppression of second- and third-harmonic energy.

*Answer.* Figure 4-7 and 4-8 illustrate a schematic arrangement of a final power-amplifier stage with transmission-line coupling and harmonic-suppression circuit.

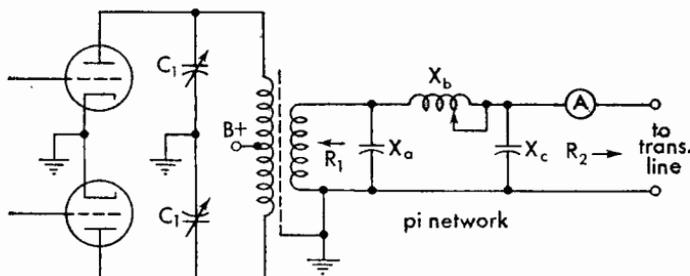


FIG. 4-8. Transmission-line coupling system.

4.63 An antenna is being fed by a properly terminated two-wire transmission line. The current in the line at the output end is 3 amperes. The surge impedance of the line is 500 ohms. How much power is being supplied to the line?

*Answer.*  $P = I^2R = 9 \times 500 = 4,500$  watts

4.64 If the daytime transmission-line current of a 10-kilowatt transmitter is 12 amperes, and the transmitter is required to reduce to 5 kilowatts at sunset, what is the new value of transmission-line current?

*Answer.* The new value of current is 8.4 amperes.

*Solution:*

$$R = \frac{P}{I^2} = \frac{10,000}{144} = 70 \text{ ohms}$$

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{5,000}{70}} = 8.4 \text{ amperes}$$

4.65 If the antenna current is 9.7 amperes for 5 kilowatts, what is the current necessary for a power of 1 kilowatt?

*Answer.* For a power of 1 kilowatt the current necessary will be 4.3 amperes, computed as in the preceding answer.

**4.66** What is the antenna current when a transmitter is delivering 900 watts into an antenna having a resistance of 16 ohms?

*Answer.*

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{900}{16}} = 7.5 \text{ amperes}$$

**4.67** If the day input power to a certain broadcast-station antenna having a resistance of 20 ohms is 2,000 watts, what would be the night input power if the antenna current were cut in half?

*Answer.* The night input power would be 500 watts.

*Solution:*

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{2,000}{20}} = \sqrt{100} = 10 \text{ amperes}$$

$$\frac{10}{2} = 5 \text{ amperes}$$

$$P = I^2R = 25 \times 20 = 500 \text{ watts}$$

**4.68** The d-c input power to the final amplifier stage is exactly 1,500 volts and 700 milliamperes. The antenna resistance is 8.2 ohms and the antenna current is 9 amperes. What is the plate efficiency of the final amplifier?

*Answer.* The plate efficiency is 63.25 per cent.

*Solution:*

$$\text{Efficiency} = \frac{P_o}{P_i} = \frac{664.2}{1,050} = 0.6325 \text{ or } 63.25 \text{ per cent}$$

**4.69** If the power output of a broadcast station is quadrupled, what effect will this have upon the field intensity at a given point?

*Answer.* The field intensity at a given point will be doubled.

*Solution:* An increase of power to 4 times will result in a current increase of 2 times. The field intensity, therefore, will increase in direct proportion.

**4.70** The ammeter connected at the base of a Marconi antenna has a certain reading. If this reading is increased 2.77 times, what is the increase in output power?

*Answer.* The increase in output power will be 7.67 times greater.

*Solution:*

$$P = I^2R \text{ watts}$$

If the current is increased by 2.77 times, then the power must increase  $2.77^2$  times.

**4.71** If the power of a broadcast station has been increased so that the field intensity at a given point is doubled, what increase has taken place in the antenna current?

*Answer.* The antenna current under these conditions has been doubled.

*Solution:* Field power is proportional to antenna power which is proportional to antenna current squared. Field power is also proportional to field intensity squared. Therefore, field intensity is proportional to antenna current. If the field intensity is doubled, the antenna current was also doubled.

**4.72** If a transmitter is modulated 100 per cent by a sinusoidal tone, what percentage increase in antenna current will occur?

*Answer.* The antenna current will increase 1.225 times the unmodulated current or 22.5 per cent.

*Solution:*

$$I_{\text{eff}} = \sqrt{1 + \frac{m^2}{2}}$$

$$\text{At 100 per cent } I_{\text{eff}} = \sqrt{1.5} = 1.225$$

**4.73** What is the ratio between the currents at the opposite ends of a transmission line,  $\frac{1}{4}$  wavelength long, and terminated in an impedance equal to its surge impedance?

*Answer.* The current readings at the input and output ends of the line will be equal.

**4.74** The power input to a 72-ohm concentric transmission line is 5,000 watts. What is the rms voltage between the inner conductor and the sheath?

*Answer.* The rms voltage is 600 volts, and the peak voltage is 848.4 volts.

*Solution:*

$$E = \sqrt{PR} = \sqrt{5,000 \times 72} = \sqrt{360,000} = 600$$

$$E_{\text{peak}} = E_{\text{eff}} \times 1.414 = 848.4 \text{ volts}$$

4.75 A long transmission line delivers 10 kilowatts into an antenna; at the transmitter end the line current is 5 amperes and at the coupling house it is 4.8 amperes. Assuming the line to be properly terminated and the losses in the coupling system negligible, what is the power lost in the line?

*Answer.* The power lost in the line is 850 watts.

*Solution:*

$$R = \frac{P}{I^2} = \frac{10,000}{4.8^2} = 434$$

$$\text{Power lost} = 5^2 \times 434 - 10,000 = 850 \text{ watts}$$

4.76 The power input to a 72-ohm concentric line is 5,000 watts. What is the current flowing in it?

*Answer.* The current flow is 8.35 amperes.

*Solution:*

$$I = \sqrt{\frac{P}{R}} = 8.35 \text{ amperes}$$

4.77 What is the primary reason for terminating a transmission line in an impedance equal to the characteristic impedance of the line?

*Answer.* Proper termination of a transmission line prevents standing waves and resultant line radiations. A maximum transfer of power to the radiating system also results. Harmonic radiation is minimized.

4.78 If a vertical antenna is 405 ft high and is operated at 1,250 kc, what is its physical height, expressed in wavelengths? (1 meter = 3.28 ft.)

*Answer.* The physical wavelength is 0.515 wavelength.

4.79 What must be the length of a vertical radiator  $\frac{1}{2}$  wavelength high if the operating frequency is 1,100 kc?

*Answer.* The height must be 136.2 meters.

#### 4.80 Draw a diagram of a crystal oscillator.

*Answer.* Figure 4-9 illustrates a crystal oscillator with temperature-control chamber coupled to one stage of radio-frequency amplification.

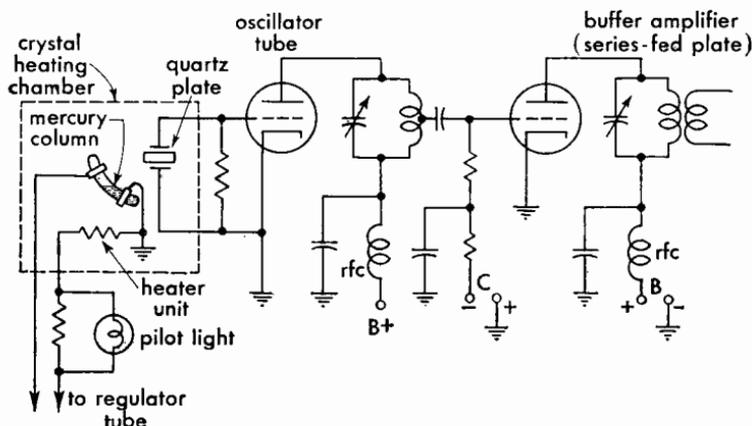


FIG. 4-9. Crystal-controlled oscillator with elementary temperature-control unit and radio-frequency amplifier.

#### 4.81 Draw a diagram of a class B push-pull linear amplifier using triode tubes. Include a complete antenna coupling circuit and antenna circuit. Indicate points at which the various voltages will be connected.

*Answer.* Figure 4-7 illustrates a class B linear amplifier in push-pull arrangement coupled to an antenna system.

#### 4.82 Draw a diagram of a complete class B modulation system, including the modulated radio-frequency amplifier stage. Indicate points where the various voltages will be connected.

*Answer.* See Fig. 4-4.

4.83 A certain transmitter has an output of 100 watts. The efficiency of the final, modulated-amplifier stage is 50 per cent. Assuming that the modulator has an efficiency of 66 per cent, what plate input to the modulator is necessary for 100 per cent modulation of this transmitter? Assuming that the modulator output is sinusoidal.

*Answer.* The plate-input power to the modulator is 151.5 watts. On the basis of 100-watt carrier requirements and an efficiency of 50 per cent the modulated amplifier must have an input power of 200

watts. At 100 per cent modulation the total of the load power and the plate dissipation will be increased by 50 per cent. Hence the modulator must supply 100 watts of audio-frequency power, and since it is operating at an efficiency of 66 per cent, the power input to the modulator must be 151.5 watts.

*Solution:*

$$\frac{P_o}{\text{eff}} = \frac{100}{0.66} = 151.5 \text{ watts}$$

where  $P_o$  is the power output required and eff the efficiency.

**4.84** If an oscillatory circuit consists of two identical tubes, the grids connected in push-pull and the plates in parallel, what relationship will hold between the input and output frequencies?

*Answer.* This arrangement may be used as a frequency-doubling system provided that the plate circuit is tuned to twice the input frequency. (See Fig. 6-4.)

**4.85** What undesirable effects result from overmodulation of a broadcast transmitter?

*Answer.* Overmodulation may cause serious interference on channels adjacent to that on which the transmitter may be operating. Overmodulation in a frequency-modulated transmitter or amplitude-modulated transmitter will also cause distortion of the output wave.

**4.86** What do variations in the final amplifier plate current of a transmitter employing low-level modulation usually indicate?

*Answer.* An abnormal variation may indicate a defective tube, improper load adjustment, improper radio-frequency excitation, or excessive modulation. Improper adjustments of the grid-biasing voltage in the modulating or final power amplifier may also result in excessive variations.

**4.87** If, upon tuning the plate circuit of a triode radio-frequency amplifier, the grid current undergoes variations, what defect is indicated?

*Answer.* Variation in grid current is normal during the tuning process due to the load impedance changes in the plate tank circuit. However, in triode amplifiers, excessive variations during tuning may indicate the presence of parasitics or improper neutralization.

**4.88** A 50-kilowatt transmitter employs six tubes in push-pull parallel in the final class B linear stage, operating with a 50-kilo-watt output and an efficiency of 33 per cent. Assuming that all of the heat radiation is transferred to the water-cooling system, what amount of power must be dissipated from each tube?

*Answer.* The power input to all of the tubes is

$$\frac{P_o}{\text{eff}} = \frac{50,000}{0.33} = 151,515 \text{ watts} \quad P_i - P_o = 101,515 \text{ watts}$$

Each tube will therefore dissipate 16,919 watts, or 16.92 kilowatts.

**4.95** Why is it not advisable to operate a filter reactance in excess of its rated current value?

*Answer.* An excessive current flow through a filter reactance may increase the possibility of core saturation and additional  $IR$  drop. Both conditions would affect the output regulation as well as the filtering. The inductance of any iron-core reactor will drop as the core becomes saturated.

**4.96** What is a low-pass filter? A high-pass filter?

*Answer.* The low-pass filter is used in any circuit where it is desired to attenuate all frequencies above a definite cutoff frequency and to pass without attenuation all frequencies below this point. A high-pass filter reduces frequencies below its cutoff design point and allows the higher frequencies to pass essentially without attenuation.

**4.97** Draw a diagram of a simple low-pass filter.

*Answer.* See Fig. 4-10. The high-pass filter is also shown, for comparison.

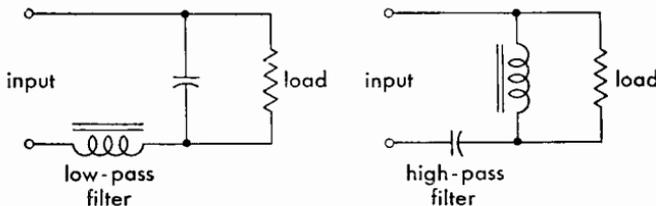


FIG. 4-10. Filter networks.

4.98 If a power supply has a regulation of 11 per cent when the output voltage at full load is 240 volts, what is the output voltage at no load?

*Answer.* The no-load output voltage is 266.4 volts.

*Solution:*

$$E_{NL} = 240 \times 1.11 = 266.4 \text{ volts}$$

*Proof:*

$$\frac{E_{NL} - 240}{E_{FL}} = 0.108 \text{ or } 11 \text{ per cent}$$

4.99 How is the inverse peak voltage, to which the tubes of a full-wave rectifier will be subject, determined from the known secondary voltages of the power transformer? Explain.

*Answer.* The inverse peak voltage is obtained by multiplying the known effective end-to-end secondary alternating voltage by 1.414 and subtracting the drop in the idle tube.

4.100 If a power supply has an output voltage of 140 volts at no load and the regulation at full load is 15 per cent, what is the output voltage at full load?

*Answer.* The output voltage at full-load conditions is 121.7 volts.

*Solution:*

$$140 \div 1.15 = 121.7$$

4.103 If a frequency-doubler stage has an input frequency of 1,000 kc, and the plate inductance is 60 microhenrys, what value of plate capacitance is necessary for resonance, neglecting stray capacitances?

*Answer.* If the input frequency of a doubler system is 1,000 kc, the output circuit must be tuned to 2,000 kc. Hence, the capacitance required would be 105  $\mu\text{mf}$ . Computed according to the formula

$$C = \frac{1}{4\pi^2 f^2 L} \quad \text{farads}$$

4.104 Draw a simple schematic diagram of a multivibrator oscillatory circuit.

*Answer.* Figure 4-11 illustrates a simple schematic of a multivibrator circuit. (See also 4.182.)

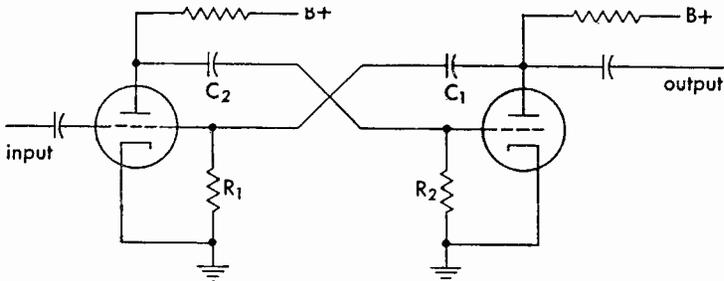


FIG. 4-11. Multivibrator oscillator.

**4.105** What precautions should be taken to ensure that a crystal oscillator will function at one frequency only?

*Answer.*

1. The temperature must be kept constant.
2. The crystal mounting must be proper and maintain correct pressure.
3. The crystal must be accurately ground.
4. The crystal must be perfectly clean, although coatings are sometimes used to change the frequency deliberately.
5. The power-supply voltage must be kept constant.
6. The load must be kept constant by use of a buffer amplifier.

**4.106** What are the advantages of mercury thermostats as compared with bimetallic thermostats.

*Answer.* Mercury thermostats ensure better electrical contacts and more accurate temperature control.

**4.107** A 600-kc X-cut crystal, calibrated at 50 deg centigrade and having a temperature coefficient of  $-20$  parts per million per degree, will oscillate at what frequency when its temperature is 60 deg centigrade?

*Answer.* 599,880 cycles.

**4.108** Why are crystals usually operated in temperature-controlled ovens?

*Answer.* Crystals are usually operated in temperature-controlled ovens because they possess a temperature coefficient. A change in temperature will produce a change in frequency. A fixed value of temperature will hold the crystal at a precise frequency.

**4.109** What is the device called which is used to derive a standard frequency of 10 kc from a standard-frequency oscillator operating on 100 kc?

*Answer.* The device is called a multivibrator.

**4.110** What procedure should be adopted if it is found necessary to replace a tube in a heterodyne frequency meter?

*Answer.* The frequency meter must be rechecked against a standard calibrator for zero beats in accordance with the exact frequency calibrations. If a standard calibrator is not available, the plate currents and filament voltages of the replaced tubes should be carefully checked as compared with the previous readings, and any necessary voltages and current changes made so that the old and new readings correspond.

**4.111** If a frequency of 500 cycles is beat with a frequency of 550 kc, what will be the resultant frequencies?

*Answer.* The resultant frequencies are  $f_m$ ,  $f_o$ ,  $f_1$ , and  $f_2$ , or 500 cycles, 550, 550.5, and 549.5 kc, respectively.

**4.112** In what part of a broadcast-station system are phase monitors sometimes found? What is the function of this instrument?

*Answer.* Phase monitors are sometimes found in transmission systems where two or more directive transmission-line antennas are employed. This is generally known as the Adcock principle and operates through the use of two or more vertical radiators excited from a common source but in such a manner that the two vertical antennas receive voltages 180 deg out of phase with each other, so that the current flowing in each vertical antenna is in an opposite direction to that of the other antenna. This system is particularly applicable to cases in which energy is to be transmitted in the vertical plane only. The actual amount of phase departure between antennas may be accurately determined by a meter or so-called "phase monitor" which reads the actual angular variation in degrees. A mutual-inductance bridge, such as is sometimes used in line amplifiers for determining the phase shift on an artificial line or filter system, may also be called

a phase monitor although this is more aptly called a phase-measuring device.

**4.113** If a broadcast station receives a frequency-measurement report indicating that the station frequency was 45 cycles low at a certain time, and the transmitter log for the same time shows the measured frequency to be 5 cycles high, what is the error in the station-frequency monitor?

*Answer.* The error in the reading of the station frequency meter is 50 cycles.

**4.114** If a heterodyne frequency meter, having a straight-line relation between frequency and dial reading, has a dial reading of 31.7 for a frequency of 1,390 kc, and a dial reading of 44.5 for a frequency of 1,400 kc, what is the frequency of the ninth harmonic of the frequency corresponding to a scale reading of 41.2?

*Answer.* The frequency of the ninth harmonic of the frequency corresponding to a scale reading of 41.2 is 12,577 kc.

**4.115** What is the reason why certain broadcast-station frequency monitors must receive their energy from an unmodulated stage of the transmitter?

*Answer.* To ensure that the frequency monitor shall not be affected by sideband frequencies.

**4.116** In what part of a broadcast-station system are limiting devices usually employed? What are their functions?

*Answer.* Limiting devices are used at the transmitter end of a broadcast-station system in conjunction with the speech-input equipment to the transmitter. They are used to prevent overmodulation on voice or music peaks and allow a generally higher average modulation percentage with resultant improved station coverage.

**4.117** What are the results of using an audio-peak limiter?

*Answer.* Audio-peak limiters prevent the modulation percentage of the transmitter from being exceeded. They are adjusted so that any degree of modulation peaks may be supplied to the transmitter and will not allow the percentage of modulation to exceed the preadjusted value regardless of the peak amplitude of the incoming audio-frequency wave.

4.118 How is the load on a modulator, which modulates the plate circuit of a class C radio-frequency stage, determined?

*Answer.* See 4.83.

4.119 Given a class C amplifier with a plate voltage of 1,000 volts and a plate current of 150 milliamperes which is to be modulated by a class A amplifier with a plate voltage of 2,000 volts, plate current of 200 milliamperes, and a plate impedance of 15,000 ohms. What is the proper turns ratio for the coupling transformer?

*Answer.* The calculation of the turns ratio for the coupling transformer is based upon the assumption that a class A amplifier for distortionless power output must work into a load impedance of twice the a-c plate resistance  $R_p$ . Class A tube,

$$15,000 \text{ ohms} = R_p \quad \therefore 2R_p = 30,000 \text{ ohms} = Z_1$$

Class C tube,

$$Z_2 = \frac{E}{I} = \frac{1,000}{0.15} = 6,667 \text{ ohms}$$

Hence,

$$\text{Turns ratio} = \sqrt{\frac{Z_1}{Z_2}} = \sqrt{\frac{30,000}{6,670}} = 2.12:1$$

The turns ratio, therefore, is 2.12:1.

4.120 Indicate, by a simple diagram, the shunt-fed plate circuit of a radio-frequency amplifier.

*Answer.* Figure 4-12 illustrates a simple shunt-fed plate radio-frequency amplifier.

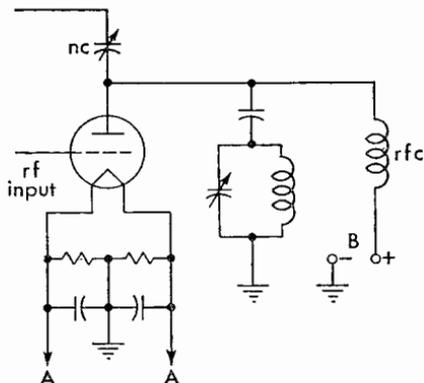


FIG. 4-12. Simple shunt-fed plate arrangement.

4.121 Indicate, by a simple diagram, the series-fed plate circuit of a radio-frequency amplifier.

*Answer.* Figure 4-13 illustrates a simple series-fed plate radio-frequency amplifier.

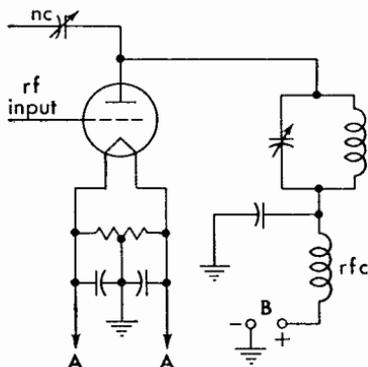


FIG. 4-13. Simple series-fed plate arrangement.

4.122 With respect to the unmodulated values, doubling the excitation voltage of a class B linear radio-frequency amplifier will result in what increase in radio-frequency power output?

*Answer.* The radio-frequency power output will be increased four times if the excitation voltage is doubled, assuming steady carrier values.

4.123 What may be the cause of a decrease in antenna current during modulation of a class B linear radio-frequency amplifier?

*Answer.* Downward deflection during modulation may be due to the following causes: poor tube, low-filament voltage, excessive value of load-impedance adjustment, open-filter capacitor in power supply, improper excitation, or overloading.

4.124 In adjusting the plate-tank circuit of a radio-frequency amplifier, should minimum or maximum plate current indicate resonance?

*Answer.* The d-c plate milliammeter should show a minimum reading at the critical resonant point.

4.125 What is the formula for determining the decibel loss or gain in a circuit?

*Answer.*

$$\text{Voltage gain or loss} = 20 \log_{10} \frac{E_1}{E_2} \text{ db}$$

$$\text{Power gain or loss} = 10 \log_{10} \frac{P_1}{P_2} \text{ db}$$

**4.126 What will occur if one tube is removed from a push-pull class A audio-frequency amplifier stage?**

*Answer.* The second harmonic content, which is normally balanced out in a push-pull amplifier, will reappear. Distortion will occur, and the output power will be reduced. The hum component of the plate circuit will also be increased.

If a high-permeability core material is used in the audio-frequency transformer, core saturation may result. This condition could seriously lower the inductance of the transformer and permanently damage it.

**4.127 What is the stage amplification obtained with a single triode operating with the following constants: plate voltage 250, plate current 20 milliamperes, plate impedance 5,000 ohms, load impedance 10,000 ohms, grid bias 4.5 volts, amplification factor 24.**

*Answer.* The stage amplification will be 16.

*Solution:*

$$\text{Voltage gain} = \frac{\mu Z_0}{R_p + Z_0} = \frac{24,000}{15,000} = 16$$

**4.128 Under what circumstances is neutralization of a triode radio-frequency amplifier not required?**

*Answer.* Neutralization is not generally required in triode radio-frequency amplifiers when they are used as frequency doublers.

**4.129 Why is it necessary or advisable to remove the plate voltage from the tube being neutralized?**

*Answer.* It is generally advisable to remove the plate voltage when neutralizing a radio-frequency amplifier, since the presence of the high plate-current flow may cause self-oscillation the moment power is applied. This may damage the tube even before neutralizing adjustments are begun. More critical adjustments of balance and less danger from shock make the disconnection of high-voltage supply advisable.

**4.158 Define: "amplifier gain," "percentage deviation," "stage amplification," and "percentage of modulation." Explain how each is determined.**

*Answer.* "Amplifier gain" is the ratio of output to input signal amplitude (voltage gain) or the ratio of output to input signal power (power gain). This ratio may be expressed in decibels.

"Percentage deviation" is the percentage which a carrier frequency varies from its stable frequency value.

"Stage amplification" is the ratio of the output to input voltage or power of a single amplifier tube with its associated input- and output-coupling system. This ratio is also expressed in decibels gain.

"Percentage of modulation" is the term applied when the modulation factor is expressed as a percentage, and is the ratio of the maximum departure, positive or negative, of the envelope of a modulated wave from its unmodulated value. (IRE Standards definition, 1938.)

**4.161 Discuss the characteristics of a modulated class C amplifier.**

*Answer.* The class C amplifier has very high efficiency. It is generally operated in the vicinity of 60 per cent efficiency for modulated stages. It operates with a grid-bias adjustment of approximately twice the cutoff value and a tank-circuit impedance of three or four times the tube impedance. These adjustments permit a fairly linear adjustment between the tank current and plate voltage. The continuous power output with 100-per cent modulation is 1.5 times the power at zero modulation. It undergoes a power variation of from 0 to 4 times the carrier power under 100 per cent modulation.

**4.162 What is the purpose of neutralizing a radio-frequency amplifier stage?**

*Answer.* To prevent the amplifier from going into self-oscillation and to avoid serious overloading.

**4.164 Describe the technique used in frequency measurements employing a 100-kc oscillator, a 10-kc multivibrator, a heterodyne frequency meter of known accuracy, a suitable receiver, and standard-frequency transmission.**

*Answer.* The principle involved in all primary-frequency standards is based upon the zero-beat method. In the primary method, employing a 100-kc oscillator of stabilized frequency, is a series of multivibrators

that operates a clock in synchronism with the oscillator frequency. Now, if a secondary-frequency measuring system employing a heterodyne frequency meter is adjusted to zero beat with a receiver tuned to a standard-frequency transmission station, these frequencies may be intercoupled for any degree of calibration desired. In this manner primary- and secondary-frequency standards may readily be obtained.

**4.165** What is the power specified in the instrument of authorization for a standard broadcast station called?

*Answer.* "Authorized power" or "licensed power."

**4.166** What is the effect of 10,000-cycle modulation of a standard broadcast station on adjacent channel reception?

*Answer.* This will cause strong interference, since it produces a sideband at the frequency of the carrier of the adjacent channel. A 10,000-cycle single-tone modulation frequency will result in a total bandwidth of 20,000 cycles. The permissible bandwidth for AM stations is 10,000 cycles.

**4.167** What system of connections for a three-phase, three-transformer bank will provide maximum secondary voltage?

*Answer.* The delta-Y connection, where the primary is connected in delta and the secondary in "Y" as illustrated in Fig. 4-1.

**4.168** Draw a diagram and describe the electrical characteristics of an electron-coupled oscillator circuit.

*Answer.* Figure 3-8 illustrates a simple electron-coupled oscillator. The cathode, grid, and screen grid operate as a Hartley triode oscillator. The circuit is very little affected by variations in plate-circuit impedance, since the current in a tetrode or pentode is nearly independent of plate voltage. Power, however, is delivered from the oscillator circuit to the plate circuit by the flow of electrons to the plate. The frequency stability of the oscillator is very good.

**4.169** In frequency measurements using the heterodyne zero-beat method, what is the best ratio of signal emf to calibrated heterodyne oscillator emf?

*Answer.* An approximate 1:1 ratio is desirable in order that the resultant beat note shall be strong compared with the weaker beat notes also present.

**4.170** What is meant by the "Q" of a radio-frequency inductance coil?

*Answer.* The Q of a coil is an expression of the "figure of merit" of any coil carrying an alternating current. It defines the degree of selectivity or sharpness of tuning in a circuit containing an inductance. The Q of a coil is determined by the ratio  $X_L/R$  where  $X_L$  is the reactance to an alternating current expressed in ohms, and  $R$  is the combined d-c and radio-frequency resistance of the coil.

**4.171** What effect does a loading resistance have on a tuned radio-frequency circuit?

*Answer.* A loading resistance reduces the effective Q of a tuned radio-frequency circuit. This results in increased damping of the oscillatory circuit. The circuit thus tunes less sharply, resulting in a broadened frequency response or wider bandwidth.

**4.172** What is meant by the "time constant" of a resistance-capacitance circuit?

*Answer.* The "time constant" of a resistance-capacitance circuit is the time in seconds required for the capacitance to reach 63.2 per cent of its full charge after a voltage is applied, or for the capacitance to discharge through the resistor to 36.8 per cent of its charged value when the circuit is short-circuited. This time constant is found by multiplying the resistance in ohms by the capacitance in farads ( $T = RC$ ). (See 8.56.)

**4.173** A potential of 110 volts is applied to a series circuit containing an inductive reactance of 25 ohms, a capacitive reactance of 10 ohms, and a resistance of 15 ohms. What is the phase relationship between the applied voltage and the current flowing in this circuit?

*Answer.* The phase relationship or phase angle is 45 deg.

$$\tan \theta = \frac{X}{R} = \frac{X_L - X_C}{R} = \frac{24 - 10}{15} = 1$$

Therefore,

$$\theta = 45 \text{ degrees}$$

**4.174** What does the term "power factor" mean in reference to electric power circuits?

*Answer.* "Power factor" is a numerical expression ranging between zero and unity and denotes the ratio of the true power consumed in an a-c circuit divided by the product of the voltage and the current in the circuit.

$$\text{Power factor} = \cos \theta = \frac{\text{watts}}{E \times I}$$

**4.175** What is the predominant ripple frequency in the output of a single-phase full-wave rectifier when the primary source of power is 110 volts at 60 cycles?

*Answer.* 120 cycles.

**4.181** Why is degenerative feedback sometimes used in an audio amplifier?

*Answer.* Degenerative feedback is sometimes employed in an audio-frequency amplifier to improve the frequency response of the amplifier and reduce the over-all amplifier distortion.

**4.182** What determines the fundamental operating frequency range of a multivibrator oscillator?

*Answer.* The fundamental operating frequency is determined by the resistance and capacitor values of the grid leak and grid capacitor of each tube.

$$f = \frac{0.6}{R_1 C_1 + R_2 C_2} \text{ cycles per second}$$

**4.183** Draw a diagram of an audio amplifier with inverse feedback.

*Answer.* Figure 4-14 illustrates a method of applying inverse feedback to an audio-frequency amplifier tube.

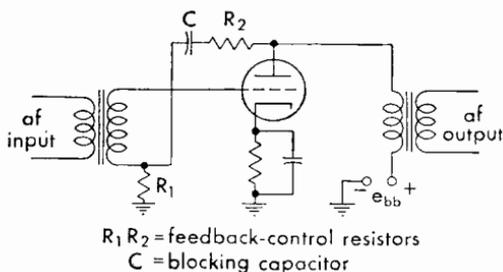


FIG. 4-14. Inverse feedback arrangement.

**4.184** What is the meaning of "mutual conductance" and "amplification factor" in reference to vacuum tubes?

*Answer.* "Mutual conductance,"  $g_m$ , is defined as the ratio of a change in plate current to a change in grid voltage that will produce that plate-current change (plate voltage held constant). The practical unit of mutual conductance is the micromho =  $10^{-6}$  mho.

$$g_m = \frac{\Delta I_b \times 10^3}{\Delta E_c} \text{ micromhos} \quad (E_b = \text{constant})$$

where  $I_b$  is in milliamperes.

Amplification factor,  $mu$  or  $\mu$ , is defined as the ratio of a change in plate voltage to a change in grid voltage in the opposite direction that will maintain the plate-current constant.

$$\mu = \frac{\Delta E_b}{\Delta E_c} \quad (I_b \text{ constant})$$

**4.185** What is the purpose of a screen grid in a vacuum tube?

*Answer.* The screen grid in a vacuum tube serves as an electrostatic shield between the grid and the plate elements of the tube. This reduces the internal capacitance of the tube between these two elements. (See also 3.118.)

**4.186** What is meant by secondary emission in a vacuum tube?

*Answer.* Secondary emission of electrons in a vacuum tube is that phenomenon which takes place when the electrons emitted from the hot cathode or filament strike the plate during the normal plate-current flow. These primary electrons striking the plate at high velocity release electrons from the plate, and it is this effect which is called "secondary" emission.

**4.187** Why are grounded-grid amplifiers sometimes used at very high frequencies?

*Answer.* The grounded-grid amplifier using a triode vacuum tube is sometimes used at very high and ultrahigh frequencies (VHF, UHF) because of its excellent stability. The low feedback capacitance between the plate and the cathode due to the grounded grid prevents self-oscillation at these frequencies and therefore makes neutralization unnecessary.

**4.188** What material is used in shields to prevent stray magnetic fields in the vicinity of radio-frequency circuits?

*Answer.* Tin, copper, and aluminum are the most commonly used materials.

**4.189** For maximum stability, should the tuned circuit of a crystal oscillator be tuned to exact crystal frequency?

*Answer.* No. The plate-circuit load is generally inductive and must, therefore, be tuned so that its resonant frequency is slightly higher than that of the crystal.

**4.190** What is the principal advantage of a class C amplifier?

*Answer.* High plate efficiency. The class C amplifier may develop an efficiency of nearly 100 per cent if the current duration is limited to a very small value. For practical purposes, the efficiency of class C amplifiers generally ranges between 60 and 80 per cent. Output power is small at higher efficiencies.

**4.191** Draw a diagram of a grounded-grid amplifier.

*Answer.* Figure 4-15 illustrates a circuit arrangement of a typical grounded-grid amplifier.

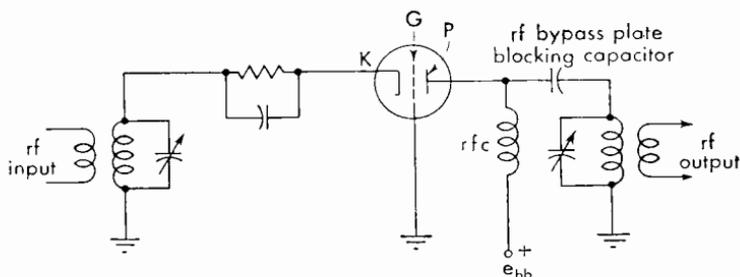


FIG. 4-15. Grounded-grid amplifier.

**4.194** What is the power output of an audio amplifier if the voltage across the load resistance of 500 ohms is 40 volts?

*Answer.* 3.2 watts.

$$P = \frac{E^2}{R} = \frac{40^2}{500} = \frac{1,600}{500} = 3.2 \text{ watts}$$

**4.195** What type of meter is suitable for measuring peak alternating voltage?

*Answer.* Any standard a-c voltmeter is suitable for measuring peak sine-wave alternating voltage, provided the meter reading is multiplied by 1.414, which is the conversion factor from effective to peak voltage. Vacuum-tube voltmeters may also be used. The peak reading types will read peak voltages directly on their scales.

**4.196** What type of meter is suitable for measuring the automatic-volume-control voltage in a standard broadcast receiver?

*Answer.* Any standard d-c voltmeter that has an internal resistance of at least 20,000 ohms per volt.

**4.197** What type of meter is suitable for measuring radio-frequency currents?

*Answer.* A thermocouple or hot-wire radio-frequency ammeter.

**4.198** What type of voltmeter absorbs no power from the circuit under test?

*Answer.* Certain types of vacuum-tube voltmeters, notably the plate detection type. Although the diode vacuum-tube voltmeter absorbs some power from the circuit under test, this power is generally small compared with that taken by a standard voltmeter.

**4.199** What type of voltmeter is appropriate to measure peak a-c voltages?

*Answer.* The electronic or vacuum-tube voltmeter (VTVM). A direct reading of a-c peak voltages may also be accurately obtained by the use of a calibrated scale on a cathode-ray oscilloscope.

**4.200** If the spacing of the conductors in a two-wire radio-frequency transmission line is doubled, what change takes place in the surge impedance of the line?

*Answer.* The characteristic or surge impedance  $Z_0$  of the two-wire transmission line will be increased by the factor  $276(\log_{10} 2)$ .

$$Z_0 = 276 \log_{10} \frac{2D}{d}$$

where  $Z_0$  = surge impedance.

$D$  = separation of the conductors from center to center.

$d$  = diameter of the conductors.

Let us assume a two-wire transmission line in which the separation  $D$  is 5 in. and the diameter  $d$  is 1 in.

$$Z_0 = 276 \log_{10} \frac{2D}{d} \quad \log \frac{2D}{d} = \frac{10}{1} = 1.0$$

$$Z_0 = 276 \times 1.0 = 276 \text{ ohms}$$

Doubling the spacing of the two conductors yields,

$$Z_0 = 276 \log_{10} \frac{2D}{d} \quad \log \frac{2D}{d} = \frac{20}{1} = 1.301$$

$$Z_0 = 276 \times 1.301 = 359 \text{ ohms}$$

**4.201** If the conductors in a two-wire radio-frequency transmission line are replaced by larger conductors, how is the surge impedance affected, assuming no change in the center-to-center spacing of the conductor?

*Answer.* Increasing the diameter of the conductors will decrease the surge impedance.

*Example* (refer to example of 4.200):

$$Z_0 = 276 \log_{10} \frac{2D}{d}$$

When  $D = 10$  inches and  $d = 1$  inch,  $Z_0 = 350$  ohms. Increasing  $d$  to 2 inches, we obtain

$$Z_0 = 276 \log_{10} 2\frac{1}{2} \quad \log 2\frac{1}{2} = 1.0$$

$$Z_0 = 276 \times 1.0 = 276 \text{ ohms}$$

**4.202** Why is an inert gas sometimes placed within concentric radio-frequency transmission cables?

*Answer.* An inert nitrogen gas or dry air is generally kept under slight pressure within concentric radio-frequency transmission lines to prevent the entrance of moisture into the inner conductor area. This reduces dielectric losses, insulation breakdown, and arcing.

**4.203** What is the direction of maximum radiation from two vertical antennas spaced 180 deg and having equal currents in phase?

*Answer.* Two vertical antennas spaced one-half wavelength (180 deg) apart and having equal currents in phase will produce a bidirectional field pattern. The radiation will lie in a plane perpendicular to the array.

#### 4.204 Explain the properties of a quarter-wave section of a radio-frequency transmission line.

*Answer.* A quarter-wave section of a radio-frequency transmission line has the property of "inverting" the load as viewed from the input or source. This inverting property of a quarter-wave section can be used to match one impedance to another impedance of different value. For example, a 300-ohm line of any length can be matched to a terminating impedance of 72 ohms by the insertion of a quarter-wave transformer or matching section (also called "Q" section or "Q" bar) as illustrated in Fig. 3-56.

$$Z_0 = \sqrt{Z_s Z_L}$$

where  $Z_0$  = characteristic impedance of the quarter-wave matching section.

$Z_s$  = 300-ohm line impedance.

$Z_L$  = 72-ohm terminating impedance.

Thus,

$$\begin{aligned} Z_0 &= \sqrt{300 \times 72} = \sqrt{21,600} \\ &= 147 \text{ ohms} \end{aligned}$$

A quarter-wave line, with one end open-circuited and the other end connected across a source of emf, appears as a series-resonant circuit and presents a low impedance to the source emf at the resonant frequency of the line. A quarter-wave line with one end short-circuited appears as a parallel-resonant circuit and presents a high impedance to the source emf at the resonant frequency of the line.

#### 4.205 How does the field strength of a standard broadcast station vary with distance from the antenna?

*Answer.* The field strength of the waves radiated from a standard broadcast transmitting antenna is inversely proportional to the distance from the antenna or approximately  $1/d$  and is based on the assumption that there is zero ground-wave attenuation.

Maximum radiation from broadcast antennas takes place at or near the ground and travels directly to the receiving antenna also

located near the ground, namely, at a height very low compared with a full wavelength at broadcast frequencies. Under these conditions, the field intensity at any point is directly proportional to the antenna current and inversely proportional to the distance from the transmitter.

**4.206 What pattern on a cathode-ray oscilloscope indicates over-modulation of a standard broadcast station?**

*Answer.* The trapezoidal pattern for overmodulation is shown in Fig. 4-5. A modulated-envelope pattern of complex modulation shows a series of bright dots in the center of the screen during overmodulation.

**4.207 What is the Doherty amplifier?**

*Answer.* The Doherty amplifier is a high-efficiency linear radio-frequency amplifier circuit designed to give increased output efficiency as compared with the conventional class B and class C types. Average all-day working efficiency of the Doherty system is approximately 63 per cent at 100 per cent modulation as compared with  $33\frac{1}{3}$  per cent for conventional types.

The Doherty high-efficiency circuit uses a new principle in which the normal or carrier power is delivered at high radio-frequency voltage and hence high efficiency by one tube alone, and the additional voltage required for modulation peaks is supplied by a second tube.

**4.208 Why do some standard broadcast stations use top-loaded antennas?**

*Answer.* The most important factors are

1. Improvement in the horizontal radiation pattern.
2. Increased antenna-terminal resistance.
3. Lower antenna capacitive reactance.
4. Increased antenna-radiation resistance.
5. Improved radiation efficiency.
6. Economy made possible through reduction in physical height.

Top loading in a vertical radiating system is generally in the form of uniformly spaced umbrella wires connected at the ends with a wire hoop and placed at the top of the vertical antenna tower.

**4.209 How may a standard broadcast antenna ammeter be protected from lightning?**

*Answer.* A standard broadcast antenna ammeter should be protected from lightning by connecting a short-circuiting switch across the terminals of the meter. The meter case must be shielded and properly grounded. (See also 6.412.)

**4.210** What is the ratio of unmodulated carrier power to instantaneous peak power, at 100 per cent modulation at a standard broadcast station?

*Answer.* Instantaneous peak power is four times the unmodulated carrier power and eight times the effective power of the carrier.

**4.211** What effect do broken ground conductors have on a standard broadcast antenna?

*Answer.* Broken ground conductors decrease the total earth currents and may seriously reduce the antenna-radiated field intensity. An efficient ground system for practically all types of vertical antennas is generally one consisting of approximately 120 buried radial wires, each one-half wavelength long, placed directly under the antennas. Thus, a break in any of these ground wires will affect the field pattern and the ground resistance.

**4.212** What may cause nonsymmetrical modulation of a standard broadcast transmitter?

*Answer.* Assuming proper  $E_b$ ,  $E_c$ , and  $E_g$  relations, nonsymmetrical modulation of a carrier envelope may be due to one or more of the following causes:

1. Improper tube balance in the modulator or modulating amplifier.
2. Improper circuit balance in the grid or plate circuit of the modulating amplifier.
3. Improper linearity due to insufficient plate-load impedance.
4. Poor power-supply regulation.
5. Amplitude and phase distortion during modulation due to improper tuning of amplifier resonant circuits to the excitation carrier frequency.
6. Insufficient grid excitation due to low grid drive to the class C modulated amplifier stage.
7. Microphone polarity effects.

**4.213** If the two towers of a 950-kc directional antenna are separated by 120 electrical deg, what is the tower separation in feet?

*Answer.* The tower separation is approximately 345.25 ft.

*Solution:*

$$\begin{aligned} 950 \text{ kc per sec} &= 315.79 \text{ meters } (\lambda) \\ 120^\circ &= \lambda/3 \end{aligned}$$

A separation of one-third wavelength between towers at 950 kc is

$$\frac{1}{3} \times 315.79 = 105.26 \text{ meters}$$

$$1 \text{ meter} = 3.28 \text{ ft}$$

$$105.26 \times 3.28 = 345.25 \text{ ft, the spacing between towers}$$

4.214 Draw a diagram showing how automatic volume control is accomplished in a standard broadcast receiver.

*Answer.* Figure 4-16 illustrates typical automatic-volume-control (AVC) systems used in modern broadcast receivers.

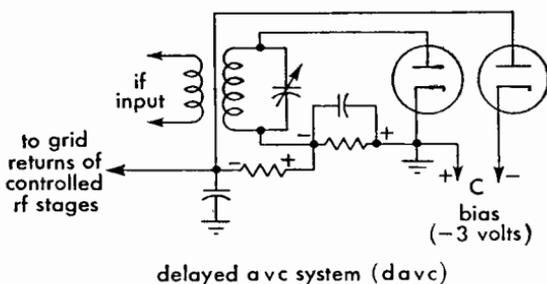
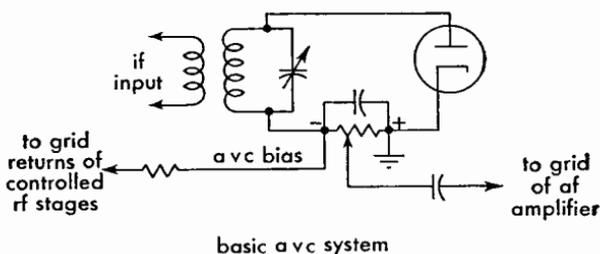


FIG. 4-16. Automatic-volume-control systems.

4.215 What is the required full-scale accuracy of the plate ammeter and plate voltmeter of the final radio stage of a standard broadcast transmitter?

*Answer.* A full-scale accuracy of 2 per cent is required.

**4.216** What is the maximum carrier shift permissible at a standard broadcast station?

*Answer.* 20 cycles.

**4.217** In accordance with the FCC standards of good engineering practice, what determines the maximum permissible full-scale reading of indicating instruments required in the last radio stage of a standard broadcast transmitter?

*Answer.* The FCC standards relating to maximum permissible full-scale reading of indicating instruments are as follows:

1. Length of the scale shall not be less than  $2\frac{3}{10}$  in.
2. Accuracy shall be at least 2 per cent of the full-scale reading.
3. The scale shall have at least 40 divisions.
4. Full-scale reading shall not be greater than five times the minimum normal indication.
5. Maximum rating to be such that the meter does not read off scale during modulation.

**4.218** When an X- or a Y-cut crystal is employed in the automatic-frequency-control equipment at a standard broadcast station, what is the maximum permitted temperature variation at the crystal from the normal operating temperature?

*Answer.* A temperature variation not to exceed  $\pm 0.1$  deg centigrade at the mid-band broadcast frequency of 1,000 kc. This variation will maintain the assigned carrier frequency to within the required 20-cycle deviation.

The normal oven temperature in modern broadcast transmitters is generally maintained between 60 and 70 deg centigrade depending upon the type of crystal cut used and the specific operating frequency.

**4.219** What is the purpose of a discriminator in an FM broadcast receiver?

*Answer.* The discriminator or demodulator in an FM receiver is a circuit designed to convert the FM radio-frequency responses into amplitude variations at audio frequency. It is in reality the signal detector of an FM receiver. (See Fig. 4-17).

**4.220** Explain why high-gain antennas are used at FM broadcast stations.

*Answer.* The transmission of FM signals in the very-high-frequency spectrum requires specially constructed high-gain antennas to produce a radiation pattern that has circular symmetry in the horizontal plane and also to concentrate the signal strength toward the horizon.

Frequencies above 50 mc follow the line-of-sight characteristics which, in general, restrict their effectiveness to a limited area. The antenna design, therefore, must be such as to distribute a maximum signal intensity over the useful area in which the relatively smaller receiving antennas are located.

High-gain antennas provide more efficient utilization of power.

**4.221 What is the frequency swing of an FM broadcast transmitter when modulated 60 per cent?**

*Answer.*  $\pm 45$  kc. For FM broadcast stations, a frequency swing of  $\pm 75$  kc is defined as 100 per cent modulation. Hence a 60 per cent modulated FM signal will produce a frequency swing of  $0.6 \times 75$  kc, or  $\pm 45$  kc.

**4.222 An FM broadcast transmitter is modulated 50 per cent by a 7,000-cycle test tone. When the frequency of the test tone is changed to 5,000 cycles and the percentage of modulation is unchanged, what is the transmitter frequency swing?**

*Answer.*  $\pm 37.5$  kc. Since the carrier-frequency swing is independent of the modulating frequency, the frequency swing for 50 per cent modulation will be  $\pm 75$  kc  $\times 0.5 = \pm 37.5$  kc.

**4.223 What is a common method of obtaining frequency modulation in an FM broadcast transmitter?**

*Answer.* There are two common methods of obtaining frequency modulation in an FM transmitter: (a) the Armstrong phase-shift system using balanced modulators or the Day "Serrasoid" phase-shift circuit, and (b) the reactance-tube method. A third system uses a specially designed modulator tube called the "phasitron."

**4.224 What is meant by "pre-emphasis" in an FM broadcast transmitter?**

*Answer.* This term is applied to the preamplification of audio frequencies above approximately 2,000 cycles. A special pre-emphasis

circuit is placed in the transmitter audio-frequency channel to reduce the noise effects at the higher audio frequencies. The pre-emphasis circuit effectively accentuates the higher range of audio frequencies and thereby decreases the over-all transmitted noise-to-signal ratio.

**4.225** What is the purpose of a de-emphasis circuit in an FM broadcast receiver?

*Answer.* The de-emphasis circuit in an FM receiver acts to reduce the amplitude of signals above approximately 2,000 cycles. The combined action of pre-emphasis at the transmitter and de-emphasis at the receiver restores the over-all response of the received energy with a resultant decrease in noise level.

**4.226** An FM broadcast transmitter operating on 98.1 mc has a reactance-tube modulated oscillator operating on a frequency of 4,905 kc. What is the oscillator frequency swing when the transmitter is modulated 100 per cent by a 2,500-cycle tone?

*Answer.* Plus or minus 3.75 kc.

*Solution:* For 100 per cent modulation the carrier frequency varies from

$$98.1 \text{ mc} - 0.075 \text{ mc to } 98.1 \text{ mc} + 0.075 \text{ mc} = 98.025 \text{ mc to } 98.175 \text{ mc}$$

$$\frac{f(\text{carrier})}{f(\text{oscillator})} = \text{frequency multiplication}$$

$$\frac{98.1}{4.905} = 20$$

The oscillator frequency swing will be  $\pm 7\frac{1}{2}\% = \pm 3.75$  kc.

**4.227** What characteristic of an audio tone determines the percentage of modulation of an FM broadcast transmitter?

*Answer.* The amplitude of an audio tone determines the percentage of modulation in an FM broadcast transmitter.

**4.228** What determines the rate of frequency swing of an FM broadcast transmitter?

*Answer.* The rate of frequency swing in an FM transmitter is determined by the *audio frequency* applied to the modulating amplifier stage.

**4.229** How wide a frequency band must the intermediate-frequency amplifier of an FM broadcast receiver pass?

*Answer.* A bandwidth of 200 kc. The ideal requirement is a maximum over-all flat frequency response of 100 kc above and 100 kc below the frequency-modulation carrier or center frequency.

**4.230** An FM broadcast transmitter is modulated 40 per cent by a 5,000-cycle test tone. When the percentage of modulation is doubled, what is the frequency swing of the transmitter?

*Answer.* Plus or minus 60 kc. Doubling the modulation percentage from 40 per cent results in 80 per cent modulation. Since  $\pm 75$  kc swing represents 100 per cent modulation, the swing at 80 per cent modulation is

$$\pm 75 \times 0.8 = 60 \text{ kc}$$

**4.231** If an FM transmitter employs one doubler, one tripler, and one quadrupler, what is the carrier frequency swing when the oscillator frequency swing is 2 kc?

*Answer.* A frequency swing of 48 kc.

$$2 \times 2 \times 3 \times 4 = 48 \text{ kc}$$

**4.232** What is the purpose of a "reactance tube" in an FM broadcast transmitter?

*Answer.* A reactance tube is commonly used as a modulator in FM systems. Its basic function is to vary the FM oscillator frequency in accordance with the applied audio-frequency tone voltage.

**4.233** At 100 per cent modulation, what is the ratio of unmodulated power output to modulated power output of an FM broadcast station?

*Answer.* A ratio of 1:1. In frequency or phase modulation the peak amplitude of the composite signal remains practically constant during the process of modulation. The audio tone frequency is imparted to the carrier by a variation of the phase as a function of time.

**4.234** What is a ratio detector?

*Answer.* Figure 4-17 illustrates two typical detector circuits used in frequency modulation and television receivers; (a) the discriminator

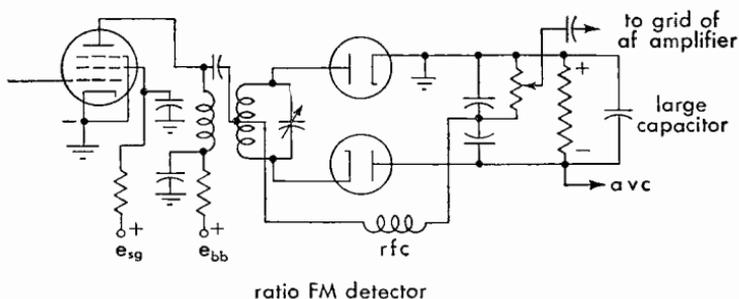
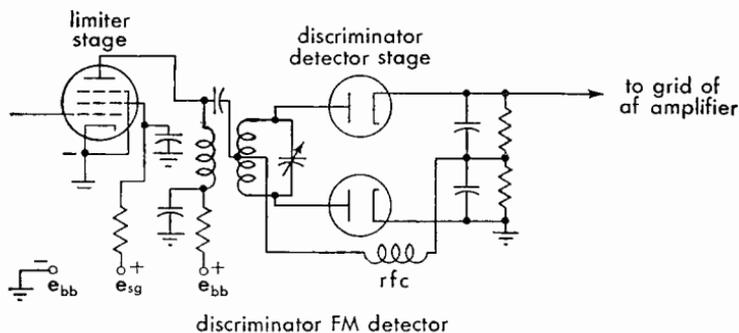


FIG. 4-17. Frequency-modulation detectors.

and (b) the ratio detector. The transformer connections for the ratio detector are essentially those of the so-called Foster-Seeley phase-shift discriminator. However, the diodes instead of being connected push-pull are in series. The circuit of the ratio-detector is characterized by a large capacitor across the load so that it acts like an audio bypass and thus wipes out amplitude-modulation effects. The diodes of the ratio detector essentially both limit and rectify, so that for many applications the intermediate-frequency tube preceding does not have to be connected as a limiter.

**4.235** How does the amount of audio power required to modulate a 1,000-watt FM transmitter compare with the amount of audio power required to modulate a 1,000-watt standard broadcast transmitter to the same percentage of modulation?

*Answer.* The audio-frequency power requirements in an FM transmitter are small as compared with those in AM systems. This is due

to the fact that the modulator tubes serve merely as a device to vary the frequency of the oscillator in step with the audio frequency or tone voltage.

**4.236** What is the purpose of a limiter stage in an FM broadcast receiver?

*Answer.* The limiter stage in an FM receiver precedes the discriminator and is necessary to ensure that all variations in the carrier amplitude due to noise and interference are removed and that a carrier of constant amplitude is maintained.

**4.237** If the transmission-line current of an FM broadcast transmitter is 8.5 amperes without modulation, what is the transmission-line current when the percentage of modulation is 90 per cent?

*Answer.* 8.5 amperes. The transmission-line current will remain constant during the process of modulation.

**4.238** An FM broadcast transmitter has 370 watts plate-power input to the last radio-frequency stage and an antenna field gain of 1.3. The efficiency of the last radio-frequency stage is 65 per cent, and the efficiency of the antenna transmission line is 75 per cent. What is the effective radiated power?

*Answer.* The effective radiated power is approximately 304.83 watts.

*Solution:*

$$\begin{aligned} \text{Effective radiated power} &= \text{output power} - \text{losses} \\ &\qquad \qquad \qquad \times \text{antenna field gain squared} \\ \text{Power output (operating power)} &= \text{power input} \times \text{efficiency} \\ &= 370 \times 0.65 \\ &= 240.5 \text{ watts} \end{aligned}$$

A transmission-line loss of 25 per cent decreases the power reaching the antenna 60.125 watts or a total of

$$240.5 - 60.125 = 180.375 \text{ watts}$$

An antenna gain of 1.3 will raise the *effective* radiated power to  $1.3^2 \times 180.375$ , or 304.8337 watts.

**4.239** Draw a diagram of an FM broadcast receiver-detector circuit.

*Answer.* Figure 4-17 illustrates two typical FM broadcast receiver-detector circuits.

4.240 Draw a diagram of a means of modulation of an FM broadcast station.

*Answer.* Figure 4-18 illustrates reactance-tube modulation commonly used in FM transmitters.

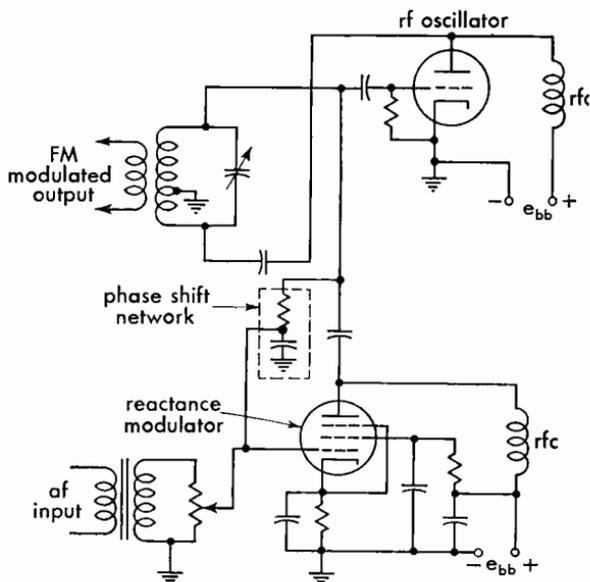


FIG. 4-18. Elementary frequency-modulation transmitter.

4.241 Draw a diagram of a limiter stage in an FM broadcast transmitter.

*Answer.* Figure 4-19 shows a typical limiter stage used in FM receivers.

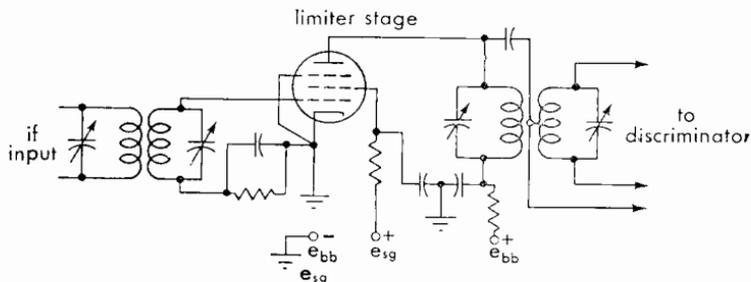


FIG. 4-19. Limiter stage.

**4.254 Why is a scanning technique known as "interlacing" used in television broadcasting?**

*Answer.* Interlaced scanning is universally employed in standard television broadcasting to reduce the *flicker* effect caused by the persistence of vision. This system of scanning may be summarized briefly as a method in which the picture-repetition rate is either mechanically or electronically doubled. Technically, the term "interlaced scanning" is defined as a process of scanning in which successively scanned lines are spaced an integral number of line widths and in which the adjacent lines are scanned during successive cycles of the field scanning frequency.

**4.255 Does the video transmitter at a television broadcast station employ frequency or amplitude modulation?**

*Answer.* Amplitude modulation.

**4.256 Does the sound transmitter at a television broadcast station employ frequency or amplitude modulation?**

*Answer.* Frequency modulation.

**4.257 What is a monitor picture tube at a television broadcast station?**

*Answer.* The monitor picture tube is an image-reproducer cathode-ray tube generally used in conjunction with a cathode-ray oscilloscope. This combination is connected at the output circuit of the transmitter video line amplifier and also at the output of the studio control booth. The monitor permits a critical analysis of picture faults at several points between the picture transmitter and the various camera chains.

**4.258 Describe scanning as used by television broadcast stations. Describe the manner in which the scanning beam moves across the picture in the receiver.**

*Answer.* Scanning in modern television is the process of analyzing successively the light values of picture elements constituting the total picture area.

In modern television stations the scanning of an image is obtained by an electronic process in which a narrow circular beam of electrons in a specially designed cathode-ray tube (iconoscope or image orthicon) is projected against a photosensitive screen within the tube. This beam

is deflected back and forth across the screen in horizontal motion by electromagnetic coils around the neck of the tube controlled by a current variation which is in the form of a saw-tooth-shaped wave. As the wave rises diagonally on the time-base axis, the beam sweeps across the face of the tube almost horizontally from top left to right. When the peak of the saw tooth is reached, the beam reaches the extreme right of the screen and completes one scanning line. Now as the peak of the saw-tooth wave is reached, it will drop sharply to the zero axis of the time base and cause the beam to retrace back to the top left-hand portion of the picture screen but slightly below the first scanning line by a width separation of one line. As the wave again rises diagonally on the time base axis, the beam sweeps across the face of the tube parallel with the first beam trace. This process continues to the bottom of the picture at which time its positioning is again directed to the top of the picture. The return of the beam to the top, however, is now directed to a position in between the first and second lines. This is referred to as "interlaced scanning" or the process in which successively scanned lines are spaced an integral number of line widths and in which adjacent lines are scanned during successive cycles of the field-scanning frequency.

Thus, when a suitably illuminated image is passed through the optical lines of the camera tube to the photosensitive screen inside the tube, the photoelectric effect transforms the optical image into an electrical image corresponding to the light changes impressed upon the sensitive element of the tube.

The scanning beam in the receiver image-reproducing tube is caused to move in the same manner as and in proper time relation with the beam of electrons in the camera tube in the transmitting studio. The beam moves across the face of the tube from left to right almost horizontally with a slight vertical tilt in a downward direction in two series of alternate or interlaced lines. Each set of lines is referred to as the "field" frequency and the total series as the "frame" frequency.

The total number of scanning lines has been standardized at 525 lines, interlaced 2 to 1. The frame frequency shall be 30 per sec, and the field frequency 60 per sec.

#### 4.259 What is a mosaic plate in a television camera?

*Answer.* The mosaic in the camera tube on which the image is focused takes the place of the film in the ordinary camera. The mosaic

plate in a television camera tube usually consists of a sheet of mica on one side of which a large number of photoelectric-producing chemicals have been deposited and the other side of which is a conducting metallic film.

When the mosaic particles are illuminated, electrons will be emitted in an amount depending upon the degree of illumination. This leaves an excess of positive charges on the mosaic particles, which will vary in accordance with the degree of illumination. Thus, when the narrow circular electron beam from the hot cathode of the camera tube strikes the screen, a change in voltage results at this point between each mosaic particle and the metallic plate.

**4.260 What is the purpose of synchronizing pulses in a television broadcast signal?**

*Answer.* Synchronizing pulses are used to maintain the proper time relationship of the scanning process between the transmitter and the receiver. These pulses are sent out by the transmitter as an integral part of the video carrier frequency between successive scanning lines and fields.

A horizontal pulse is sent out at the end of each scanning line to restore the beam to the left side of the screen, and a vertical pulse is sent out at the end of each field scan to return the beam to the top of the screen. (See the Appendix for television waveforms.)

**4.261 What is the effective radiated power of a television broadcast station if the output of the transmitter is 1,000 watts, antenna transmission-line loss is 50 watts, and the antenna power gain is 3?**

*Answer.* 2,850 watts.

*Solution:*

$$\begin{aligned} \text{Effective radiated power} &= \text{power output} - \text{losses} \\ &\qquad\qquad\qquad \times \text{antenna power gain} \\ (1,000 - 50) \times 3 &= 2,850 \text{ watts or } 2.85 \text{ kilowatts} \end{aligned}$$

**4.262 Besides the camera signal, what other signals and pulses are included in a complete television broadcast signal?**

*Answer.*

1. FM sound carrier and sidebands.
2. Video carrier frequency.
3. Horizontal synchronizing pulses.

4. Vertical synchronizing pulses.
5. Horizontal blanking pulses.
6. Vertical blanking pulses.
7. Equalizing pulses.

**4.263 What are synchronizing pulses in a television broadcasting and receiving system?**

*Answer.* Synchronizing pulses are short, accurately timed pulses employed for controlling the local scanning generator at the transmitter and receivers, thereby establishing the proper position of the scanning beam.

**4.264 What are blanking pulses in a television broadcasting and receiving system?**

*Answer.* Blanking pulses developed by the synchronizing generator in a television system are pulses used for the purpose of cutting off the electron beam at the transmitter and the receiver during the horizontal and vertical retrace periods. Hence the blanking pulses are transmitted along with the video signal in order that the beam in the image-reproducer tube is cut off simultaneously with that in the camera tube.

**4.265 For what purpose is a voltage of saw-tooth waveform used in a television broadcast receiver?**

*Answer.* A saw-tooth wave is generated to produce the sweep and retrace of the electron beam in the cathode-ray reproducing tube. It produces a linear motion of the scanning beam.

**4.266 In television broadcasting, what is the meaning of the term "aspect ratio"?**

*Answer.* The numerical ratio of the frame width to the frame height as transmitted (4:3).

**4.267 How many frames per second do television broadcast stations transmit?**

*Answer.* Thirty complete frames or pictures per second.

**4.268 In television broadcasting, why is the field frequency made equal to the frequency of the commercial power supply?**

*Answer.* To permit the picture-repetition or frame frequency to coincide accurately with the 60- or 120-cycle ripple frequency developed by the rectified power supply. This is of particular importance, since the scanning and synchronizing circuits of a television system are controlled by the rectified power supply. Hence, if some ripple frequency is present because of inadequate filtering, no difficulty will be experienced, since the field frequency and the power frequency coincide at every cycle. Thus, the ripple will not drift across the screen. It is assumed that both transmitter and receiver operate from the same, or synchronized, power lines.

**4.269** If the cathode-ray tube in a television receiver is replaced by a larger tube such that the size of the picture is changed from 4 by 3 in. to 8 by 6 in., what change if any is made in the number of scanning lines per frame?

*Answer.* No change.

**4.270** If a television broadcast station transmits the video signals in channel No. 6 (82 to 88 mc), what is the center frequency of the aural transmitter?

*Answer.* 87.75 mc. Transmission standards specify that the aural center frequency shall be located 0.25 mc lower than the upper frequency limit of the channel.

**4.271** What is the field frequency of a television broadcast transmitter?

*Answer.* The field frequency is the number of times per second the frame or picture area is fractionally scanned by the interlaced-scanning method. The field frequency in modern television has been standardized at 60 per second and represents the scanning time of half the number of total lines ( $262\frac{1}{2}$ ).

**4.272** How is the operating power of the aural transmitter of a television broadcast station determined?

*Answer.* The operating power of an aural transmitter is determined by the indirect method.

$$\text{Operating power} = E_b \times I_b \times \text{efficiency}$$

**4.273 Numerically, what is the aspect ratio of a picture as transmitted by a television broadcast station?**

*Answer.* The aspect ratio of the transmitted picture shall be four units horizontally to three units vertically.

**4.274 What is meant by "vestigial sideband transmission" of a television broadcast station?**

*Answer.* This term refers to a system of sideband transmission in which one of the generated sidebands is partly attenuated at the transmitter and radiated only in part.

**4.275 What is the frequency tolerance of television broadcast transmitters?**

*Answer.* The carrier-frequency tolerance for visual transmitters shall be automatically maintained within 1 kc of the authorized frequency. Aural transmitters must be automatically maintained 4.5 mc above visual carrier frequency within 5 kc.

**4.276 What is meant by "antenna field gain" of a television broadcast antenna?**

*Answer.* Antenna field gain of a television antenna is defined as the ratio of the effective free-space field intensity produced at one mile in the horizontal plane expressed in millivolts per meter for a one-kilowatt antenna input power to 137.6 millivolts per meter.

**4.277 How wide is a television broadcast channel?**

*Answer.* A total bandwidth of 6 mc per sec.

## Element 6

# Advanced Radiotelegraph (Theory)

### 6.312\* What is the meaning of "ampere turns"?

*Answer.* The magnetomotive force produced by the flow of an electric current in a coil is proportional to the total quantity of charge circling the coil in one second. Thus, it is proportional to the product of the current in each turn and the total number of turns in the coil. The magnetomotive force can be conveniently expressed in ampere turns which are computed by the formula,

$$\text{ampere turns} = N \times I$$

where  $N$  is the number of turns and  $I$  the current flowing.

### 6.313 What is the meaning of "electrolyte"? List four types of radio equipment in which it may be used.

*Answer.* "Electrolyte" may be defined as an acid or alkaline solution. Electrolyte is used in the following radio equipment:

1. Storage battery.
2. Electrolytic capacitor.
3. Electrolytic rectifier.
4. Electrolytic interrupter.
5. Electrolytic detector.

### 6.314 Name at least five pieces of radio equipment which make use of electromagnets.

\* Questions numbered 6.01 to 6.311 inclusive are the same as Questions 3.01 to 3.311 inclusive.

*Answer.* Electromagnets are used in the following pieces of radio equipment:

1. Overload and underload circuit breakers.
2. Headphones.
3. Relays.
4. Meters.
5. Motors.
6. Generators.
7. Loudspeakers.

**6.315** How many watts equal one horsepower?

*Answer.* 746 watts.

**6.316** What is the meaning of "residual magnetism"?

*Answer.* The magnetism which still remains in temporary magnets after the magnetizing current has been removed.

**6.317** If two 10-watt 500-ohm resistors are connected in series, what is the total power-dissipation capability?

*Answer.* Each resistance has a capability of 10 watts dissipation, thus the total power-dissipation capability will be 20 watts.

**6.318** A milliammeter with a full-scale deflection of 1 milliamperere and having an internal resistance of 25 ohms is used to measure an unknown current, by shunting it with a 4-ohm resistance. When the meter reads 0.4 milliamperere, what is the actual value of current?

*Answer.*  $I = 2.9$  milliampereres, or 0.0029 ampere. (See 3.49 for details.)

*Solution:*

$$I = I_M \left( 1 + \frac{R_M}{R_S} \right) = 0.4 \left( 1 + \frac{25}{4} \right) = 2.9 \text{ milliampereres}$$

where  $I_M$  = meter reading.

$R_M$  = resistance of the meter.

$R_S$  = resistance of the shunt.

**6.319** If two 10-watt 500-ohm resistors are connected in parallel, what is the total power-dissipation capability?

*Answer.* The total power-dissipation capability will be 20 watts.

6.320 What is the maximum current-carrying capacity of a resistor marked "5,000 ohms, 200 watts"?

*Answer.*

$$I = \sqrt{\frac{P}{R}} = 0.2 \text{ ampere}$$

6.321 What factors determine the heat generated in a conductor carrying an electric current?

*Answer.* The current-flow-squared value and the resistance.  $P = I^2R$  watts.

6.322 Two resistances of 18 and 15 ohms are connected in parallel; in series with this combination is connected a 36-ohm resistance; in parallel with this total combination is connected a 22-ohm resistance. The total current flowing through the combination is 5 amperes. What is the current value in the 15-ohm resistance?

*Answer.* The current flow through the 15-ohm resistance will be 0.9+ amperes. To solve this problem by simple arithmetic and Ohm's law proceed as follows:

1. Reduce the parallel combination of the 15- and 18-ohm resistances to the effective resistance,

$$R_{\text{eff}} = \frac{R \times R}{R + R} = 8.18+ \text{ ohms}$$

2. Add the effective resistance to the 36-ohm series resistance, 44.18 ohms.

3. Obtain the total effective resistance of the 44.18-ohm and the 22-ohm parallel combination,

$$R_{\text{eff}} = \frac{R \times R}{R + R} = 14.68+ \text{ ohms}$$

4. Determine the applied voltage across the entire combination,  $E_a = IR = 5 \times 14.68 = 73.4$  volts.

5. Find the current flow through the 22-ohm resistance.

$$I = \frac{E}{R} = 3.341 \text{ amperes}$$

6. Find the current through the remaining branch.

$$5 - 3.341 = 1.659 \text{ amperes}$$

7. Find the voltage developed across the 15- and 18-ohm effective combination of 8.18+ ohms.

$$E = IR = 1.659 \times 8.18+ = 13+ \text{ volts}$$

8. Thus the current through the 15-ohm resistance is found.

$$I = \frac{E}{R} = \frac{13+}{15} = 0.9+ \text{ ampere}$$

**6.323** What method is used to obtain more than one value of voltage from a fixed-voltage d-c source?

*Answer.* By the use of a voltage-divider resistance or potentiometer.

**6.324** Two resistors are connected in series. The current through these resistors is 3 amperes. Resistance one has a value of 50 ohms; resistance two has a voltage drop of 50 volts across its terminals. What is the total impressed emf?

*Answer.* The total impressed emf is 200 volts. The current through the 50-ohm resistor is  $I = E/R$  or,  $E = IR = 3 \times 50 = 150$  volts. Since a 50-volt drop is known to be present across resistance two, the total or impressed emf must be the sum of the two  $IR$  drops or 200 volts.

**6.325** A circuit is passing a current of 3 amperes. The internal resistance of the source is 2 ohms. The total external resistance is 50 ohms. What is the terminal voltage of the source?

*Answer.* The terminal voltage of a source is always less than the open circuited voltage by an amount  $I \times R$  (internal resistance). Thus the terminal voltage in this circuit is 150 volts.

*Proof:*

$$E = IR = 3 \times 50 = 150 \text{ volts.}$$

**6.326** A 10,000-ohm 100-watt resistor, a 40,000-ohm 50-watt resistor, and a 5,000-ohm 10-watt resistor are connected in parallel. What is the maximum value of total current through this parallel combination which will not exceed the wattage rating of any of the resistors?

*Answer.* The maximum value of current flow through this combination is 0.07 ampere. The power dissipated in each resistance,  $E^2/R$ , must not exceed the rating of the resistance. Since all of the resistances

are in parallel, it is obvious that the calculations are based upon the 5,000-ohm 10-watt resistor. Hence, we must determine what value of current flow through this resistor will not exceed 10 watts of power dissipation. Thus, we find the current value through this resistance by the equation,  $I = \sqrt{P/R} = \sqrt{10/5,000} = 0.0447$  ampere.

*Proof:*

$$P = I^2 \times R = 0.0447^2 \times 5,000 = 10 \text{ watts}$$

The applied voltage may now readily be determined

$$E_a = I \times R = 0.0447 \times 5,000 = 223.5 \text{ volts}$$

and

$$P = E^2/R = 50,000/5,000 = 10 \text{ watts}$$

The current flow through each of the remaining resistors is then obtained by Ohm's law,

$$I_2 = 223.5/40,000 \text{ amperes} \quad \text{and} \quad I_1 = 223.5/10,000 \text{ amperes}$$

The sum of all the branch currents is, therefore, the total current, or 0.07 ampere.

**6.327** What is the ratio of peak to effective voltage values of a sine wave?

*Answer.* The ratio is  $1/0.707 = 1.414:1$

**6.328** If a d-c voltmeter is used to measure effective alternating voltages by the use of a bridge-type full-wave rectifier of negligible resistance, by what factor must the meter readings be multiplied to give corrected readings?

*Answer.* The meter reading must be multiplied by 1.11 to obtain corrected readings.

**6.329** By what factor must the voltage of an a-c circuit, as indicated on the scale of an a-c voltmeter, be multiplied in order to obtain the average voltage value?

*Answer.* Since the meter reading is an effective value indication it will be necessary to multiply the scale reading by 0.9 in order to obtain average values.

$$E_{av} = E_{eff} \times 0.9$$

**6.330** By what factor must the voltage of an a-c circuit, as indicated on the scale of an a-c voltmeter, be multiplied in order to obtain the peak value?

*Answer.* The meter reading must be multiplied by 1.414 to obtain peak values.

**6.331** What is the ratio of peak to average value of a sine wave?

*Answer.* The ratio is  $1/0.637 = 1.57:1$

**6.332** What is the meaning of the term "phase difference"?

*Answer.* Phase difference is a measure of the time displacement of one sine wave from another at the same frequency. It is usually expressed in electrical degrees, of which there are 360 in each sinusoidal cycle.

**6.333** What is the meaning of the term "leading power factor"?

*Answer.* The power in an a-c circuit is equal to the product of voltage and current and the cosine of the angle between them. Power factor is the cosine of the phase angle expressed in per cent. The cosine of the angle is equal to the ratio of the resistance to the impedance  $R/Z$ . A "leading power factor" is an expression of that condition in an a-c circuit where capacitive reactance predominates since the current in that type of circuit is leading the voltage between zero and 90 deg. (See also 3.34 and 3.316 for practical formulas.)

**6.334** The Product of the readings of an a-c voltmeter and ammeter in an a-c circuit is called what?

*Answer.* This product is referred to as the "apparent power" or "volt-amperes."

**6.335** In what units is an alternator output ordinarily rated?

*Answer.* Preferably in volt-amperes, but radio manufacturers invariably rate output in watts.

**6.336** Define "power factor."

*Answer.* See 3.34, 3.316, and 6.333.

**6.337** What is the total inductance of two coils, connected in series, but without any mutual coupling?

*Answer.*  $L_{\text{eff}} = L_1 + L_2 \pm 2M$ . In this case, therefore, the total inductance is the sum of the two inductances expressed in henrys.

**6.338** What is the total inductance of two coils connected in parallel but without any mutual coupling?

*Answer.* When the coils are so far apart that mutual inductances are negligible, inductances in parallel are combined like resistances in parallel.

**6.339** A series inductance, acting alone in an a-c circuit has what properties?

*Answer.* It has the properties of generating a counter emf, developing kinetic energy, and causing the current to lag behind the voltage by 90 deg. It acts as an a-c resistance and is known as inductive reactance,  $X_L$ . The reactance value varies directly with frequency. The series inductance also has a smoothing effect on circuit variations and tends to improve the regulation.

**6.340** What is the total reactance of a series a-c circuit containing no resistance, and equal values of inductive and capacitive reactance?

*Answer.* The total reactance is zero.

**6.341** What is meant by the "flywheel" effect of a tank circuit?

*Answer.* The circuit inertia set up by the kinetic energy of the inductance tending to keep the circuit oscillating. The capacitor discharges through the inductance and the energy developed by the inductance in the collapsing field recharges the capacitor in the opposite direction.

**6.342** What may be the effects of shielding applied to radio-frequency inductances?

*Answer.* The inductance of the coil decreases. The capacitance of the coil increases. The Q of the coil decreases.

**6.343** What is the effect on the resonant frequency of connecting a capacitance in series with an antenna?

*Answer.* The effective capacitance of the entire antenna system is reduced. The resonant frequency increases as the capacitive reactance increases, that is, as the size of the series capacitance is reduced.

**6.344** What is the total impedance of a capacitance and inductance having equal values of reactance, when connected in parallel?

*Answer.* The total reactance will be zero, and the impedance across the combination will be theoretically infinite.

**6.345** What factors determine the efficiency of a power transformer?

*Answer.* The core structure, the character of the core material, the size of the wire used, and flux leakage. The amount of loading.

**6.346** What factors determine the no-load voltage ratio of a power transformer?

*Answer.* The turns ratio  $N$ .

$$N = \frac{E_P}{E_S} = \frac{N_P}{N_S}$$

$$E_S = \frac{N_S}{N_P} \times E_P$$

**6.347** What factors determine the ratios of primary and secondary currents in a power transformer?

*Answer.* The currents in the primary and the secondary of a power transformer are approximately in the inverse ratio of the corresponding turns.

$$I_P/I_S = N_S/N_P$$

The size of wire also affects the current ratio.

**6.348** A radio receiver has a power transformer and rectifier designed to supply plate voltage to the vacuum tubes at 250 volts when operating from a 110-volt 60-cycle supply. What will be the effect if this transformer primary is connected to a 110-volt d-c source?

*Answer.* The primary winding will seriously overheat and burn out unless adequately protected by fuses.

**6.349** What is the relationship between the turns ratio and the impedance ratio of the windings of a transformer?

*Answer.*

$$\text{Turns ratio} = \sqrt{Z_P/Z_S}$$

where  $Z_P$  is the primary impedance, and  $Z_S$  is the secondary impedance.

**6.350** Why should the cathode of an indirectly heated vacuum tube be maintained at nearly the same potential as the heater circuit?

*Answer.* To prevent cathode leakage which might be caused by voltage breakdown between the cathode and the filament. Also to reduce stray fields existing between the cathode and the filament.

**6.351** Why is it impracticable to reactivate oxide-coated filament vacuum tubes?

*Answer.* Because the oxide coating is nearly all on the surface of the filament. The reactivation process here applied would merely decrease the degree of oxide.

**6.352** What types of vacuum-tube emitting surfaces respond to reactivation?

*Answer.* Thoriated-tungsten filaments.

**6.353** Describe how reactivation may be accomplished?

*Answer.* The filament is subjected to a momentary voltage surge of a higher value than the normal operating voltage and then to a slightly lower voltage, but for a longer period of time. It is important that the plate potential be disconnected during this operation. (See also 3.486.)

**6.354** Is a tungsten filament operated at higher or lower temperatures than a thoriated filament? Why?

*Answer.* The tungsten filament is operated at a higher filament temperature because the electron-emission characteristic is considerably lower.

**6.355** What is indicated when a blue glow is noticed within a vacuum-tube envelope?

*Answer.* If the glow occurs between the plate and filament elements this indicates the presence of gas.

**6.356** What is the function of the grid leak in a grid-leak detector?

*Answer.* In a grid-leak detector, the grid and cathode act as a diode rectifier. The grid leak serves as a load resistance across which the modulation (signal) voltage is developed and applied to the grid of

the tube which then operates as an audio-frequency amplifier. Operating bias is developed automatically by rectification of the signal and is zero in the absence of the signal. Since for small signals the bias is small, the  $g_m$  of the tube is maximum and the gain of the stage is high.

**6.357** What effect does an incoming signal have upon the value of plate current of a grid-leak detector vacuum tube?

*Answer.* The automatic bias action decreases the plate current.

**6.358** What effect does an incoming signal have upon the value of plate current of a power detector tube?

*Answer.* The plate current rises during the signal periods.

**6.359** Why is it sometimes necessary to provide a radio-frequency filter in the plate circuit of a detector tube?

*Answer.* To bypass the plate radio-frequency variations around the high impedance of the audio-transformer primary or headphones. This filter may be used to peak the 500-cycle audio beat note by effecting a parallel resonant condition.

**6.360** Explain how power detection is accomplished.

*Answer.* Power detection, or more accurately, linear detection, is accomplished by operating the detector tube with a large value of grid bias almost to the point of plate-current cutoff. The plate voltage is of a considerably higher value than normal. The name "power detection" is used because it generally operates with large applied signal voltages.

**6.361** Explain how grid-leak detection is accomplished.

*Answer.* Grid-leak detection is accomplished by the insertion of a grid capacitor and shunt resistance connected in series with the grid. Operating bias is developed across the grid resistance by the flow of rectified grid current.

**6.362** Explain how diode detection is accomplished.

*Answer.* Diode detection is accomplished by using either a triode or special diode tube. In the case of the former, the grid is used as the diode element while the plate is connected to cathode or ground. The

grid is then connected to one end of the radio-frequency input transformer while the other end of the transformer is connected through a high resistance (500,000 ohms) to the cathode of the tube. A small radio-frequency bypass capacitor of approximately 0.0001  $\mu\text{f}$  is connected in shunt with the resistance. The audio-frequency voltage developed across the resistance by rectification is then applied to the grid of an audio-frequency amplifier tube. With the diode tube the diode plate or plates are connected together and then connected as the grid was in the preceding explanation.

**6.363** What is the principal advantage of transformer coupling compared to resistance coupling, as used in audio-frequency amplifiers?

*Answer.* Higher amplification may be obtained owing to the primary-to-secondary step-up ratios. Voltage step-up ratios with transformers range between 1:1.5 to 1:10. Resistance ratios are 1:1.

**6.364** Why is it necessary to use two tubes in a class B audio amplifier?

*Answer.* Since this type of amplifier operates at cutoff, a single tube would amplify only one-half of the signal cycle and serious distortion would result. Two tubes complete the cycle.

**6.365** What are the advantages of push-pull amplification as compared to single-ended amplification?

*Answer.* Push-pull amplification reduces harmonic distortion caused by the second harmonic, reduces hum, eliminates core saturation, and develops a more symmetrical reproduction of the input wave form than the single-ended amplifier.

**6.366** Why is it not feasible to employ a vacuum-tube operated class C as an audio amplifier, either singly or in push-pull?

*Answer.* Because there is too much distortion present in the output of the class C amplifier to make it feasible for use on audio frequencies. Hence, class C amplifiers are used primarily in the amplification of the unmodulated radio-frequency carrier wave in radio transmitters. Note that in radio-frequency circuits the plate tank circuit provides a "flywheel" action that would permit single-tube operation in a class C amplifier with minimum distortion.

**6.367** Why is an audio transformer seldom employed as the output device to be used in the plate circuit of a tetrode audio-amplifier stage?

*Answer.* The plate impedance of a tetrode ranges between 300,000 and 1,000,000 ohms. To satisfy load conditions, the transformer would require a primary inductance value of 300 to 500 or more henrys. This would necessitate a transformer with large physical dimension as well as one difficult to construct with a flat-frequency response. Another reason is that the tetrode possesses a large voltage amplification factor and, therefore, does not require large output step-up ratios.

**6.368** If a final radio-frequency amplifier, operated as class B linear, were excited to saturation with no modulation, what would be the effects when undergoing modulation?

*Answer.* The amplifier plate current would be unable to increase as it should on modulation peaks but would decrease on the troughs. This would result in serious audio-frequency distortion and a downward deflection of the plate-current meter.

**6.369** Under what class of amplification are the vacuum tubes in a linear radio-frequency amplifier stage, following the modulated stage, operated?

*Answer.* Class B.

**6.370** What class of amplifier should be employed in the final amplifier stage of a radiotelegraph transmitter for maximum plate efficiency?

*Answer.* Class C.

**6.371** Discuss the effects of insufficient radio-frequency excitation on a class C modulated radio-frequency amplifier in so far as the output signal waveform is concerned.

*Answer.* The negative peaks of the modulation envelope will be flattened. A positive carrier shift will result.

**6.372** What factors are most important in the operation of the vacuum tube as a frequency doubler?

*Answer.* The most important factors are:

1. Very large value of grid-bias adjustment.
2. High plate voltages.

3. High radio-frequency voltage excitation.
4. Low C-tank circuit value.
5. Proper adjustment of the doubler plate circuit to the harmonic of the frequency applied to its grid.

**6.373** What is the primary purpose of the suppressor grid of a pentode tube?

*Answer.* To reduce *secondary emission* and improve the linearity of the plate characteristics.

**6.374** What is the primary purpose of the screen grid of a tetrode?

*Answer.* The primary purpose is to act as an electrostatic shield. It serves to reduce the interelectrode grid-plate capacitance and raise the electron acceleration to the plate. Greater plate resistance and increased circuit stability are resultant contributing factors.

**6.375** What is the primary purpose of the control grid of a triode?

*Answer.* The control grid provides a means by which the signal voltage can vary the plate current while drawing little or no current from the signal source.

**6.376** A triode transmitting tube, operating with plate voltage of 1,250 volts, has filament voltage of 10, filament current of 3.25 amperes, and plate current of 150 milliamperes. The amplification factor is 25. What value of control grid bias must be used for operation as a class C stage?

*Answer.* A grid bias of approximately  $-125$  volts. For class C amplification the ratio  $(E_b/\mu) \times 2.5$  may be used for determining grid bias with fairly accurate results.

**6.377** Name four materials which can be used as crystal detectors.

*Answer.* Carborundum, galena, iron pyrites, silicon, germanium, and zincite-bornite.

**6.378** Why do headphone receivers have high impedance windings?

*Answer.* As radio headphones are sometimes called upon to act as the load on the final audio-amplifier tube, it is desirable that their resistance approach the impedance-match condition for distortionless amplification, which is twice the tube's plate resistance. Generally speaking, therefore, radio headphones should have a d-c resistance of

2,000 ohms or more. Their a-c impedance would, of course, exceed this value owing to the reactance effect in the magnet windings.

**6.379** What are the objections to the operation of a regenerative, oscillating-detector receiver, when directly coupled to an antenna?

*Answer.* An oscillating detector is in reality a miniature transmitter. Heterodyne interference in nearby receivers will be produced. In addition, the frequency stability of the receiver will be affected by physical changes in the position of the antenna, as in a strong wind.

**6.380** What controls determine the selectivity of a three-circuit receiver?

*Answer.* The regenerative feedback control, the secondary tuning capacitor, the antenna series capacitor, and the antenna coupling coil.

**6.381** A superheterodyne receiver is adjusted to 2,738 kc. The intermediate frequency is 475 kc; what is the frequency to which the grid circuit of the second detector must be tuned?

*Answer.* 475 kc.

**6.382** Explain the reasons why a superheterodyne receiver may not be successfully used for reception of frequencies very near the frequency of the intermediate-frequency amplifier.

*Answer.* Frequencies near the intermediate-frequency range would pass through without any mixing effect. In other words, the intermediate frequency would function as a simple untuned radio-frequency amplifier to these frequencies. At the same time the mixer oscillator may cause a continuous squeal in the output.

**6.383** A superheterodyne receiver, having an intermediate frequency of 465 kc and tuned to a broadcast station on 1,450 kc, is receiving severe interference from an "image" signal. What is the frequency of the interfering station?

*Answer.* 2,380 kc.

**6.384** A superheterodyne receiver is tuned to 1,712 kc and the intermediate frequency is 456 kc. What is the frequency of the mixer oscillator?

*Answer.* 2,168 kc.

**6.385 Describe a "superregenerative" receiver.**

*Answer.* The superregenerative receiver is essentially the same as a three-circuit regenerative receiver with the exception that a local generating frequency of, say, 25,000 cycles is coupled to the plate circuit. The purpose of this local oscillator is to increase the regenerative effect beyond the point in which the receiver would normally go into self-oscillation. In other words, the local oscillator supplies a *quench* frequency which continuously interrupts the oscillation frequency and, therefore, the degree of regeneration can be built up to tremendous proportions.

**6.386 Why are the unused portions of inductances in receivers usually short-circuited?**

*Answer.* To eliminate "dead end" losses.

**6.387 What is the "mixer" tube in a superheterodyne?**

*Answer.* The "mixer" tube or first detector is that tube in which the combining of the signal frequency and the local oscillator frequency takes place. It is in the mixer tube that the intermediate-beat frequency is generated.

**6.388 What is the purpose of a tuned radio-frequency amplifier stage ahead of the mixer stage of a superheterodyne receiver?**

*Answer.* It serves as a preselector stage to eliminate image interference. It improves the signal-to-noise ratio in the lower frequency bands.

**6.389 What is the advantage of using iron cores of special construction in radio-frequency transformers and inductances?**

*Answer.* This type of transformer permits more effective bandwidth adjustments in receivers thereby providing better high-fidelity response. They also make for better circuit stability in the reception of unstable frequencies particularly in the ultrahigh-frequency bands. Some types are adjustable for variable selectivity.

**6.390 If signals are heard with the headphones plugged into the detector plate circuit of a receiver, but no signals are heard when phones are plugged into the first audio-frequency amplifier-stage plate circuit, what might be the cause and how could it be remedied?**

*Answer.* The primary or secondary winding of the audio transformer may have opened. Substitute resistance coupling for the opened section.

**6.391 Name three causes of an audio "howl" in a regenerative receiver.**

*Answer.* Howling might be caused by a microphonic detector tube, too much regeneration, acoustic feedback, open grid leak.

**6.392 Name four reasons why a regenerative receiver is prevented from oscillating.**

*Answer.* Open plate bypass capacitor, open grid capacitor, insufficient plate voltage, low filament emission, coil losses resulting from moisture absorption, reversed tickler winding or short-circuited grid capacitor.

**6.393 What is the advantage of heterodyne reception as compared with autodyne reception?**

*Answer.* The heterodyne method of beat reception has the advantage over autodyne beat reception in slightly greater sensitivity and wider range of beat production.

**6.394 How is automatic volume control accomplished in a receiver?**

*Answer.* Automatic volume-control action is generally developed in the diode load section of the diode detector. The rectified signal voltage developed across this load produces a direct voltage component which makes one end of the resistance negative with respect to the cathode. By connecting to the negative end through a filter resistor and a bypass capacitor this voltage is fed to the return lead of the variable- $\mu$  radio-frequency tube(s) to be controlled. The grid voltage of the radio-frequency amplifier is, therefore, reinforced by the d-c potential developed across the diode load, and the radio-frequency signal peaks are diminished.

**6.395 What is a "crystal filter" as used in a superheterodyne receiver?**

*Answer.* The "crystal filter" is a quartz-plate resonant circuit which has very high Q characteristics (very sharp tuning). This plate is

generally connected between the mixer and first intermediate stages to effect extremely sharp tuning or give so-called "single-signal reception."

**6.396 How may image response be minimized in a superheterodyne receiver?**

*Answer.* Image response may be minimized by the introduction of specially designed trap circuits or by adding a preselector stage before the mixer tube.

**6.397 Discuss the advantages and disadvantages of self-excited oscillator and master-oscillator power-amplifier transmitters.**

*Answer.* The advantage of the self-excited oscillator transmitter is that only a single tube is required. The great disadvantage compared to the master-oscillator power-amplifier (MOPA) type is the frequency instability of the self-excited oscillator. Antenna-load changes produce variations in output frequency to such a degree that the output frequency may drift over thousands of cycles.

**6.398 Draw a simple schematic diagram of a dynatron oscillator using a tetrode, indicating polarity of power-supply voltages.**

*Answer.* Figure 3-44 illustrates a schematic diagram of a dynatron oscillator.

**6.399 What is the meaning of "carrier shift"?**

*Answer.* "Carrier shift" is the unequal relationship of the positive and negative peaks of the modulated wave, which results in a carrier shift. It is due to the lack of symmetry of the modulation envelope, which causes a change in the average amplitude of the modulated wave. (See 6.642.)

**6.400 What effect upon the plate current of the final amplifier stage will be observed as the antenna circuit is brought into resonance?**

*Answer.* The d-c plate milliammeter will show an increased reading.

**6.401 What will be the effect of a swinging antenna upon the output of a self-excited oscillator transmitter? A master-oscillator power-amplifier transmitter?**

*Answer.* A swinging antenna will cause frequency instability in a self-excited oscillator. When a master-oscillator power-amplifier transmitter is used a swinging antenna will not affect the frequency of the transmitter because the antenna-capacitance changes are not reflected back to the oscillator circuit. The radio-frequency power amplifier serves to isolate the oscillator from the antenna circuit. Hence, any capacitance changes in the antenna cannot affect the frequency of the oscillator.

**6.402** Discuss the advantages and disadvantages of operating an amplifier as a class C stage.

*Answer.* The advantage is high efficiency. The efficiency of a class C amplifier may be brought up as high as 85 per cent in practice. Perhaps the only disadvantage of this type of amplifier is the relatively larger excitation voltages required to overcome the large grid-bias voltage used. Also its output is not so linear as class B.

**6.403** What is the crystal frequency of a transmitter having three doubler stages and an output frequency of 16,880 kc?

*Answer.* Three doubler stages will raise the crystal frequency 8 times; therefore the fundamental crystal frequency must be  $\frac{1}{8}$  of 16,880, or 2,110 kc.

**6.404** What is the ratio of the frequencies of the output and input circuits of a single-phase full-wave rectifier?

*Answer.* The ripple ratio is 2:1. (The 60-cycle input is raised to a 120-cycle output.)

**6.405** What is meant by "shock excitation" of a circuit?

*Answer.* The generation of highly damped oscillations by pulse excitation of an oscillatory circuit.

**6.406** What increase in antenna current will be noted when a transmitter is modulated 100 per cent by a sinusoidal audio frequency?

*Answer.* An increase of 1.225 times.

**6.407** What may be the reasons why a zero reading is not obtained on the neutralizing indicator while neutralizing a radio-frequency amplifier stage?

*Answer.* This may be due to some tube losses thereby preventing an exact phase balance. A series resistance is sometimes inserted in series with the neutralizing capacitor in order to obtain an exact balance or a phase angle of 90 deg. Stray couplings between the circuit may also be the cause.

**6.408 What precautions should be observed in tuning a transmitter?**

*Answer.* Care should be exercised in adjusting all high-voltage circuits to avoid shock. The high-voltage switch must be opened whenever making coil-tap or capacitor-section changes. Filter capacitors not shunted by a resistor should be discharged by short-circuiting with an insulated-handle screwdriver or grounding stick.

**6.409 Describe a procedure which would be satisfactory in neutralizing a radio-frequency amplifier stage.**

*Answer.* Open the plate-supply switch to the radio-frequency stage to be neutralized. Open up the main power switch to all tubes, and discharge all high-voltage capacitors. Insert a thermocouple galvanometer into the low-potential side of the plate-tank circuit of the stage to be neutralized. Engage the neutralizing capacitor about one-third position. Close the main power switch but leave the plate-supply switch of the amplifier open. Increase the radio-frequency drive gradually and tune all circuits to resonance. Observe the reading on the thermocouple galvanometer and vary the neutralizing capacitor until this reading is a minimum or, preferably, zero. Remove the thermocouple galvanometer and insert the regular ammeter. Close the high-voltage plate-supply switch to the radio-frequency amplifier just neutralized. Carefully recheck and balance all circuits to minimum plate-current dips.

**6.410 Name three instruments which may be used as indicating devices in neutralizing a radio-frequency amplifier stage of a transmitter.**

*Answer.* A thermogalvanometer, a sensitive hot-wire ammeter, a cathode-ray oscilloscope, a neon tube, or a wavemeter.

**6.411 Describe a means of reducing sparking at the contacts of a key used with a radiotelegraph transmitter.**

*Answer.* A capacitor shunted across the contacts. A capacitor with series resistance shunted across the contacts or a choke coil in series with a capacitor shunted across the contacts. See Figs. 6-1, 6-2.

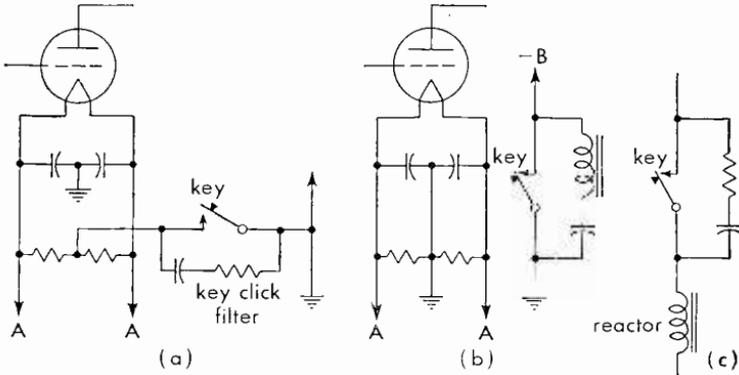


FIG. 6-1. Key-click filters.

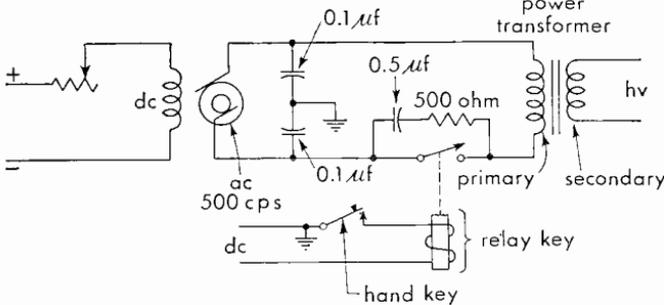


FIG. 6-2. Transformer-primary keying system.

**6.412** How may instruments used to indicate various direct currents and voltages in a transmitter be protected against damage due to stray radio-frequency energy?

*Answer.* Instruments may be protected by grounding the cases (if metal), shielding the leads and grounding, shunting a small radio-frequency bypass capacitor across them, inserting small radio-frequency chokes and bypass capacitors in the leads, and by placing the meters (ammeters) in the low-potential side of the circuit.

**6.413** What is the purpose of a choke coil?

*Answer.* The choke coil in d-c circuits serves to filter the power supply. The choke coil in radio-frequency circuits serves to isolate the

radio-frequency currents from the power-supply circuits. The primary function of a choke coil is to filter or smooth out current variations.

**6.414** What currents will be indicated by a milliammeter connected between the center tap of the filament transformer of a tetrode and negative high voltage (ground)?

*Answer.* The milliammeter in this position will read the combined plate and screen-grid currents.

**6.416** Name four indications of a defective vacuum tube in a transmitter.

*Answer.* Low plate currents under normal filament- and plate-operating voltages, low tank currents, low antenna currents, blue glow inside envelope between grid and plate, and filament not lighting.

**6.432** Explain the principle of operation of an electrolytic capacitor.

*Answer.* The electrolytic capacitor functions upon the principle of unilateral conductivity, that is, the capacitor offers a very high resistance to current flow in one direction and low resistance to the flow of current in an opposite direction. This type of capacitor depends for its operation upon the fact that certain metals when used as anodes in certain electrolytes become coated with a very thin film of insulation, caused by polarization. This film acts as a dielectric separating the two electrodes constituting the capacitor.

**6.435** What factors determine the breakdown voltage rating of a capacitor?

*Answer.* The character of the dielectric and the thickness of the dielectric.

**6.441** What precautions should be used when an absorption frequency meter is used to measure the output of a self-excited oscillator?

*Answer.* Place the instrument as far as possible from the circuit being measured to avoid mutual coupling reactions which would alter the output frequency.

**6.442** What is the meaning of "zero beat" as used in connection with frequency-measuring equipment?

*Answer.* "Zero beat" is that condition which prevails when two radio-frequency oscillators are coupled to each other and adjusted to exactly the same frequency. An audible output circuit, such as headphones, would produce no response under this condition.

**6.443** What precautions should be taken before using a heterodyne frequency meter?

*Answer.* The heterodyne frequency meter should be placed as far as possible from the circuit being checked. The calibration should be checked against a known standard-frequency calibrator. Allow meter time to warm up.

**6.444** If a wavemeter, having an error proportional to the frequency, is accurate to 20 cycles when set at 1,000 kc, what is its error when set at 1,250 kc?

*Answer.* The error at 1,250 kc will be 25 cycles.

**6.445** What cleaning agents may be used to clean the surfaces of a quartz crystal? Is such cleaning ever necessary? Explain.

*Answer.* The best cleaning agent is plain soap and water. Carbon tetrachloride or alcohol may also be used. All unmounted quartz-crystal plates should be cleaned whenever handled because any oily deposit or grit may prevent the unit from oscillating on the desired frequency, or at all. Note that carbon tetrachloride fumes are toxic.

**6.446** Name four advantages of crystal-control over tuned-circuit oscillators.

*Answer.*

1. Maximum frequency stability.
2. Minimizes dynamic instability.
3. Gives better tone signal for radiotelegraphy.
4. Reduces necessary bandwidth.
5. Simplifies grid circuit.
6. Reduces beat frequency between stations on same carrier frequency.

**6.447** Why is a separate source of power desirable for the crystal-oscillator unit of a transmitter?

*Answer.* Common power supply for crystal- and power-amplifier units would produce frequency modulation and consequent serious frequency instability and distortion. This is due to load changes upon the oscillator plate circuit which in turn are caused by modulation or power-amplifier plate-load changes.

**6.448** Why is the temperature of a quartz crystal usually maintained constant?

*Answer.* Because the crystal possesses a temperature coefficient. Temperature changes will cause drifting of the crystal frequency.

**6.449** What will be the effect of a high degree of coupling between the plate and grid circuits of a quartz-crystal oscillator?

*Answer.* Excessive strain may be applied to the crystal and a possible cracking or chipping may result.

**6.450** What is the function of a quartz crystal in a radio transmitter?

*Answer.* The crystal serves as the frequency controlling unit of the oscillator to maintain a station at an assigned frequency. It is the frequency stabilizer of the transmitting system.

**6.451** What does the expression "low temperature-coefficient crystal" mean?

*Answer.* This term means that the variation in crystal frequency with positive and negative change in temperature is practically zero.

**6.452** What does the expression "the temperature coefficient of an X-cut crystal is negative" mean?

*Answer.* "A negative-coefficient characteristic" is one in which the crystal frequency decreases as the temperature is raised.

**6.453** What will be the effect of applying a d-c potential to the opposite plane surfaces of a quartz crystal?

*Answer.* The crystal will change in shape, the amount and direction of the change depending upon the cut of the crystal. A high voltage will crack the crystal.

**6.454** What does the expression "the temperature coefficient of a Y-cut crystal is positive" mean?

*Answer.* "A positive-coefficient characteristic" is one in which the crystal frequency increases as the temperature is raised.

**6.455** Draw a simple schematic diagram of a crystal-controlled vacuum-tube oscillator using a tetrode tube. Indicate power-supply polarity where necessary.

*Answer.* Figure 3-9 illustrates a schematic diagram of a tetrode crystal oscillator. The basic circuit is the same as that using a pentode tube with the exception that the suppressor grid (next to the plate) is omitted.

**6.456** What is a "multivibrator"? Explain its principle of operation.

*Answer.* The multivibrator or relaxation oscillator is a two-tube resistance-coupled oscillator in which the voltage developed by the output of the second tube is applied to the input of the first tube. The principle of operation is based upon the fact that the tubes invert the waveform. The output wave is nonsinusoidal in character. This type of oscillator may be used for any of the following purposes:

1. Master oscillator timer.
2. To produce rectangular control pulses of certain lengths, synchronized with excitation trigger pulses.
3. To introduce delay between input trigger pulses and a second circuit.
4. Frequency division. To synchronize or lock circuits at other than 1:1 ratio.

**6.457** What is a "dynatron oscillator"? Explain its principle of operation.

*Answer.* A dynatron oscillator is a tetrode oscillator in which the screen-grid voltage is operated at a critical point above the plate-voltage potential. It operates upon the principle of the *negative-resistance* characteristic used in regeneration and oscillatory circuits. As the plate voltage is gradually raised, the plate-to-cathode current is reduced, owing to a neutralizing effect at some critical point between the normal emission from the cathode and the secondary emission from the plate. When this particular point is reached, the plate-to-filament resistance will indicate a negative-resistance characteristic and the plate-tank circuit will continue to oscillate.

6.458 What is an "electron-coupled oscillator"? Explain its principle of operation.

*Answer.* The electron-coupled oscillator is a tetrode oscillator in which the control grid, cathode, and screen grid serve as the triode section of an oscillator. The screen grid serves as the oscillator plate. The regular plate is coupled through the tube capacitance to the triode elements. The variation of the space charge is controlled by the triode grid, and these variations in turn energize the plate circuit and its load impedance.

6.459 Explain the principle of generation of radio-frequency energy by means of a spark discharge.

*Answer.* See 6.851.

6.460 Draw a simple schematic diagram of a crystal-controlled oscillator and means of coupling to the following radio-frequency amplifier stage, showing power-supply polarities.

*Answer.* See Fig. 4-9.

6.461 Draw a simple schematic diagram of an oscillatory circuit involving the use of a spark-gap discharge, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* See Fig. 6-3.

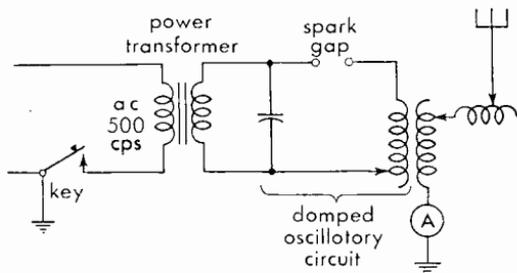


FIG. 6-3. Fundamental spark transmitter.

6.462 Draw a simple schematic diagram of an electron-coupled oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* See Fig. 3-8.

**6.463** Draw a simple schematic diagram of a dynatron oscillator, indicating the circuit elements necessary to identify this form of oscillatory circuit.

*Answer.* See Fig. 3-44.

**6.464** Why is a push-pull audio-frequency amplifier preferable to a single-tube stage?

*Answer.* A push-pull audio-frequency amplifier is preferable to a single-tube stage because by means of the push-pull circuit the even harmonics in the output are neutralized. A greater power output is also secured from a push-pull amplifier than is secured from a single-tube amplifier. It prevents core saturation in high-permeability cores and balances out any d-c hum component.

**6.465** Name four applications for vacuum tubes operating as class A audio amplifiers.

*Answer.* Several applications of vacuum tubes operating as class A audio amplifiers are as follows:

1. Audio-frequency voltage amplifiers in receivers.
2. Audio-frequency voltage amplifiers in speech input equipment.
3. Modulators.
4. Line amplifiers.
5. Microphone preamplifiers.
6. Audio-frequency power amplifiers in receivers.

**6.466** What is the chief advantage of class A audio operation as compared with other classes of audio-frequency amplifiers?

*Answer.* The chief advantage of class A audio operation is that the output is essentially linear, and distortion is reduced to a minimum. Also, it may be operated with a single-tube.

**6.467** Why is correct grid bias important in an audio-frequency amplifier?

*Answer.* The correct grid bias is important because it serves to locate the operating point of the tube at the proper location on the characteristic curve for the desired operating conditions.

**6.468** How may even harmonic energy be reduced in the output of an audio-frequency amplifier?

*Answer.* Harmonic energy may be reduced in the output of an audio-frequency amplifier by operating the tube with a limited grid-voltage swing so that the plate current is never driven off the straight-line portion of the characteristic. In addition, even harmonic energy may be reduced by working the tubes in a push-pull circuit, thus canceling out the even harmonics.

**6.469** Why are class A audio amplifiers not as critical, in so far as grid-drive requirements are concerned, as class B audio amplifiers?

*Answer.* Because plate current flows during the entire excitation cycle. Therefore, as long as an excitation voltage is present, an output component will be secured. On the other hand, with a class B audio amplifier the excitation voltage must be of the correct value within limits to cause the tube to operate on the desired portion of the grid-voltage plate-current characteristic. See also 6.536.

**6.470** Name at least two uses of a class C radio-frequency amplifier in modern radiotelegraph and radiotelephone transmitters.

*Answer.* A class C radio-frequency amplifier may be used in the transmitting circuit as follows:

1. As a buffer amplifier.
2. As a power amplifier for class C telegraphy.
3. As a frequency multiplier (usually a doubler).
4. As a modulated radio-frequency amplifier.

**6.471** Name four causes of excessive plate current in a radio-frequency amplifier.

*Answer.* Excessive plate current may be caused in the radio-frequency amplifier by any of the following:

1. Plate circuit not tuned to resonance.
2. Parasitic oscillations.
3. Improper neutralization.
4. Excessive excitation voltage.
5. Defective vacuum tube.
6. Insufficient bias.

**6.472** What is the chief advantage of a class B radio-frequency amplifier, and for what is this type of amplifier commonly employed?

*Answer.* The chief advantage of a class B radio-frequency amplifier is its linearity of operation. It is, therefore, commonly used as a final power radio-frequency amplifier or as a power amplifier following a modulated class C amplifier.

**6.473** What class of amplifier should be used following a modulated radio-frequency amplifier?

*Answer.* A linear class B radio-frequency power amplifier.

**6.474** Define a class C amplifier.

*Answer.* A class C amplifier operates with a grid bias, which is appreciably greater than the cutoff value. The plate current in each tube is zero when no alternating grid voltage is applied. The plate current in a specific tube flows for appreciably less than one-half of each cycle when an alternating grid voltage is applied. (IRE Standards definition, 1938.)

**6.475** Why are bypass capacitors used across the cathode bias resistors of a radio-frequency amplifier?

*Answer.* Bypass capacitors are used across the cathode bias resistors of a radio-frequency amplifier to provide a low reactance path for the alternating plate component to return to the filament. This reduces degeneration and increases the stage gain.

**6.476** What is the main advantage of a tuned audio-frequency amplifier in a receiver used for the reception of radiotelegraph signals?

*Answer.* The main advantage of a tuned audio-frequency amplifier in a receiver used for CW reception is that with a tuned audio-frequency amplifier the receiver will respond to only one frequency. It is possible, therefore, to decrease interference by filtering out unwanted signals near the frequency to which the receiver is tuned. The receiver will then respond to signals having an audio beat at the frequency to which the audio system is peaked.

**6.477** What is the purpose of decoupling networks in the plate circuits of a multistage audio amplifier?

*Answer.* When the plate voltage for several tubes of a high-gain amplifier is obtained from a single source, decoupling networks are used to prevent the internal resistance of the power source from acting as a coupling between stages. These circuits also prevent the coupling of the stages through bleeder-circuit resistors when screen voltage for two or more tubes is taken from a common tap or through a bias resistor common to the control-grid circuits of several tubes.

**6.478** What is a "buffer" amplifier and what are its applications?

*Answer.* The purpose of the buffer amplifier is to isolate the oscillator from the succeeding stages of radio-frequency amplification. This prevents any reaction between the modulated radio-frequency amplifiers and the oscillator, which might cause frequency instability.

**6.479** For what purpose is a frequency-doubler stage used in a transmitter?

*Answer.* The doubler amplifier is used when an output frequency greater than the maximum stable operating frequency of a crystal oscillator is desired. It is also used to obtain sufficient carrier-frequency swing from a reactance-tube or phase-shift modulator in an FM transmitter.

**6.480** Describe the operation of a frequency-doubler stage.

*Answer.* See Fig. 3-22 for diagram. The tube is biased beyond the cutoff point. This causes a distorted waveshape in the plate circuit. The plate *LC* circuit is tuned to twice the input frequency with the result that strong harmonic voltages are set up in it by the distorted wave.

Circuit adjustments in frequency-doubler stages (harmonic or distortion generators) must fulfill the typical class C-amplifier requirements such as high grid bias, high plate voltage, and large grid-driving power. The distortion characteristics are produced by the single-tube plate-circuit pulses which are rich in harmonics. The plate-tank circuit is then adjusted to the desired harmonic of the fundamental frequency pulses.

Another type of frequency doubler is illustrated in Fig. 6-4. In this circuit the grids are excited in push-pull and the plates in parallel. Hence, if the plate tank is tuned to twice the input frequency, the output frequency is doubled.

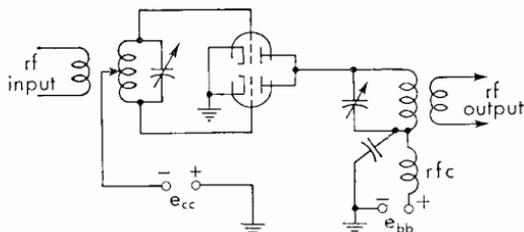


FIG. 6-4. Frequency doubler.

**6.481 Why is neutralization often necessary in a radio-frequency amplifier?**

*Answer.* Neutralization is generally necessary in a radio-frequency amplifier to prevent erratic operation of the circuit which would occur if the amplifier went into self-oscillation owing to positive feedback. Neutralization is essentially negative feedback.

**6.482 What is the purpose of shielding between radio-frequency amplifier stages?**

*Answer.* The purpose of shielding in a multistage radio receiver is to prevent electrical interaction between the various receiver components, which interaction would disturb their normal operation and may result in regeneration or self-oscillation. Shielding prevents the lines of force surrounding the shielded component from leaving the area within the shield. Shielding also prevents any outside lines of force from entering the shielded compartment.

**6.483 Describe how a radio-frequency amplifier stage may be neutralized.**

*Answer.* See 6.409.

**6.484 In neutralizing a radio-frequency amplifier stage of a transmitter, using a thermocouple galvanometer as indicator, what precautions must be observed?**

*Answer.* When a thermocouple meter is used as an indicator, care must be taken not to burn the meter out. To prevent this, the thermocouple should be inserted in a pick-up loop, which, in turn, can be loosely coupled to the tank circuit of the amplifier stage being neutralized.

**6.485** Draw a complete schematic diagram of a system of inductive coupling between the output of a radio-frequency amplifier and an antenna system.

*Answer.* See Fig. 4-8.

**6.486** Draw a simple schematic diagram showing a method of link coupling between two radio-frequency amplifier stages.

*Answer.* See Fig. 3-29.

**6.487** Draw a simple schematic diagram showing a method of direct coupling between two stages of an audio-frequency amplifier.

*Answer.* See Figs. 3-14 and 3-46.

**6.488** Draw a simple schematic diagram showing a method of impedance coupling between two stages of a radio-frequency amplifier.

*Answer.* See Fig. 3-14.

**6.489** Draw a simple schematic diagram showing a method of inductive or transformer coupling between two stages of a radio-frequency amplifier.

*Answer.* See Fig. 3-16.

**6.490** Discuss the characteristics of a dynatron oscillator.

*Answer.* The characteristics of a dynatron oscillator are as follows:

1. A well-designed dynatron has a frequency stability which compares favorably with that of the crystal oscillator without temperature control.

2. Its efficiency is low.

3. It can be used in a heterodyne wavemeter. When so used, the sharpness of indication of the meter is increased because the dynatron

neutralizes the positive resistance of the wavemeter circuit. This it does by virtue of the negative resistance of the tube operating as a dynatron.

**6.491** What type of oscillator depends upon secondary emission from the anode for its operation?

*Answer.* The dynatron oscillator.

**6.492** What is the primary reason for the suppression of radio-frequency harmonics in the output of a transmitter?

*Answer.* To prevent interference on other channels, which are in harmonic relation to the fundamental frequency being transmitted.

**6.493** In a radiotelegraph transmitter employing a d-c generator as a source of plate voltage, an a-c generator as filament supply and grid-bias keying, if it is noted that when the key contacts are open the emission continues, what could be the trouble?

*Answer.* This would indicate that no blocking bias is being applied to the tubes. This might be caused by a burned-out bias resistor or a defect in the bias circuit. It might also be due to a short-circuited key-click capacitor, the relay key contacts may have stuck, or the relay key may be defective.

**6.494** What is the purpose of an electrostatic shield?

*Answer.* An electrostatic shield, also known as a Faraday screen, is used between the plate-tank coil of the final radio-frequency power amplifier and the antenna coil coupled to it. The purpose of this shield is to reduce the radiation of harmonic energy. This it does by effectively loosening the coupling between the two coils and providing a low-reactance path to ground for the harmonic frequencies.

**6.495** What is the advantage of link coupling between radio-frequency amplifier stages?

*Answer.* Link coupling reduces the radiation of harmonic frequencies. Another advantage of link coupling is that it permits the construction of the various amplifier stages as separate units, these units being effectively coupled by a low-impedance line with coupling loops, consisting of one or two turns of wire, at each end, known as the link circuit.

6.496 Draw a simple schematic diagram showing how a radio-telegraph transmitter may be keyed by the grid-blocking method.

*Answer.* See Fig. 6-5.

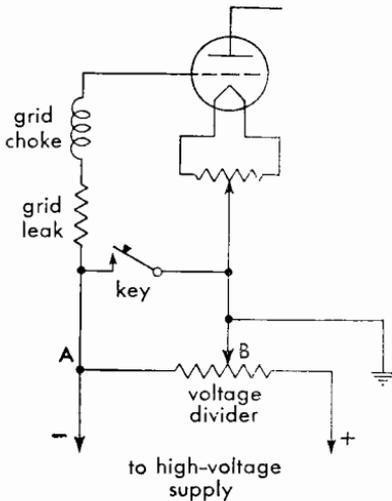


FIG. 6-5. Grid-blocking keying system.

Another system is the grid-choke method. In this system a choke heavy enough to stop oscillation of the tube is placed in the grid of the oscillator tube and known as a "keying choke." This choke is short-circuited when the key or keying-relay contacts are closed which permits the tube to oscillate; hence, keying is accomplished.

In connection with crystal-controlled transmitters, it is generally undesirable to key the oscillator or the buffer amplifier, as to do so would disturb the frequency stability of the transmitter. The practice with these transmitters is to key the stages following the buffer amplifier, usually by the grid-blocking system.

6.498 What is meant by "grid-block keying"?

*Answer.* See 6.497 and Fig. 6-5.

6.499 Draw a simple schematic diagram of a key-click filter suitable for use when a vacuum-tube transmitter is keyed in the negative high-voltage circuit.

*Answer.* See Fig. 6-1.

6.497 Discuss methods of keying a high-power radiotelegraph transmitter.

*Answer.* The most satisfactory means of keying a high-power radio-telegraph transmitter is by the so-called "grid-blocking" system. With this system a grid bias sufficient to block the power amplifier is applied when the key is up. The key is connected to shunt the bias resistor, thus removing the bias when the key is down. When the bias is removed, the signal wave is emitted by the transmitter.

**6.500** Draw a simple schematic diagram of a system of keying in the primary of the transformer supplying high voltage to a vacuum-tube transmitter. Indicate any values of inductance, resistance, capacitance which may be deemed necessary to fully understand the correct operation of this type of keying.

*Answer.* See Fig. 6-2.

**6.501** A transmitter is operating on 5,000 kc, using a 1,000-kc crystal with a temperature coefficient of  $-4$  cycles per megacycle per degree centigrade. If the crystal temperature increases 6 deg centigrade, what is the change in the output frequency of the transmitter?

*Answer.* 4,999.88 kc is the new frequency.

**6.502** What may cause a positive carrier shift in a linear radio-frequency amplifier output?

*Answer.* Some possible causes of positive carrier shift are

1. Improper neutralization.
2. Excessive grid bias.
3. Improper value of load impedance.
4. Overmodulation.
5. Insufficient excitation of modulated tube(s).

(See 6.642.)

**6.503** What is the second harmonic of 380 meters?

*Answer.* 190 meters.

**6.504** What is the effect of excessive coupling between the output circuit of a simple oscillator and an antenna?

*Answer.* Excessive coupling will cause what is known as a "split tuning." The load impedance coupled to the oscillator is an equivalent impedance which is the resultant of the impedances of the closed- and open-oscillatory circuits. It is impossible to keep both of these impedances exactly alike. Changes in tube constants during operation vary the impedance of the closed-oscillatory circuit, while changes in antenna capacitance, caused by antenna movement, vary the impedance of the open-oscillatory circuit. If the coupling is tight, the difference between these two impedances is enough to present a broad or "two humped" load-impedance characteristic to the tube. However, it

chooses the lowest impedance. If the lowest value shifts from one circuit to the other, the frequency jumps with the shift. Split tuning can be avoided by using a loose coupling adjustment, although it must be borne in mind that loosening the coupling also reduces the radiated power. The plate current will rise and may seriously overheat the tube if coupling is too tight.

**6.505** A station has an assigned frequency of 8,000 kc and a frequency tolerance of  $\pm 0.04$  per cent. The oscillator operates at one-eighth of the output frequency. What is the maximum permitted deviation of the oscillator frequency, in cycles, which will not exceed the tolerance?

*Answer.*  $\pm 400$  cycles, computed as follows:

$$3.2:8,000 = X:1,000 \quad X = 0.4 \text{ kc} \quad X = \pm 400 \text{ cycles};$$

or, simply,  $\pm 0.0004 \times 1,000 = \pm 0.4 \text{ kc} = \pm 400 \text{ cps}$ .

**6.506** What is meant by "self-wiping" contacts as used in connection with relays?

*Answer.* "Self-wiping" contacts are contacts which slide together instead of butt together. All modern relays are constructed with self-wiping contacts.

**6.507** Why are permanent magnets used in head telephones? In d-c meters?

*Answer.* To polarize the headphones so that positive current peaks deflect the diaphragm in one direction while negative peaks deflect it in the opposite direction.

Permanent magnets are used in d-c meters to ensure the operation of the meter according to the polarity markings on its terminals. Permanent magnets, as used in d-c meters, serve to increase the accuracy of the meter and provide a fixed field which produces a torque in the moving coil in proportion to the current flowing in the coil.

**6.508** What devices may be used as indicators of radio-frequency energy?

*Answer.* The following devices may be used as indicators of radio-frequency energy:

1. Thermocouple galvanometer.
2. Hot-wire ammeter.

3. Neon or argon bulb.
4. Incandescent lamp.
5. Fluorescent tube.

**6.509** What is the correct value of negative grid bias, for operation as a class B amplifier, for a vacuum tube of the following characteristics: plate voltage 1,000, plate current 127 milliamperes, filament voltage 4 volts, filament current 5.4 amperes, mutual conductance 8,000 micromhos, and amplification factor 25?

*Answer.* 42 volts, computed as follows:

Cutoff point =  $E_b/\mu = 1,000/25 = 40$  volts plus one-half the filament voltage equals 42 volts.

**6.510** Is an oscillator ever neutralized? Discuss.

*Answer.* No. Neutralization is used for the purpose of preventing oscillation and the feedback of energy between the plate and grid circuits. As the primary purpose of an oscillator is to oscillate, and as the feedback of energy from the plate to the grid circuit is necessary for oscillation, the oscillator, obviously, is never neutralized.

**6.535** What is the total reactance when two capacitances of equal value are connected in series?

*Answer.* The reactance value in ohms is doubled.

**6.536** What are the effects of overexcitation of a class B amplifier grid circuit?

*Answer.* Overexcitation of the amplifier grid may cause an excessive value of grid current to flow which may seriously overload the tube and possibly ruin it. The regulation and plate-circuit linearity will be completely lost owing to the loading effect upon the plate current. The plate efficiency will be greatly reduced and the power output correspondingly lowered. Plate dissipation may rise to abnormal values. Harmonic distortion will also be caused by overexcitation. (See also 6.368.)

**6.537** Name four devices that could be used to indicate oscillation in a crystal oscillator.

*Answer.* A d-c milliammeter in series with the grid leak of the oscillator; the plate d-c milliammeter; radio-frequency ammeter in the plate-tank circuit; radio-frequency galvanometer in the grid circuit; a neon tube placed near the grid or plate oscillatory leads; a wavemeter and lamp indicator placed near to the plate-tank circuit.

**6.538 What is the effect of loose laminations in a filter choke?**

*Answer.* Loose laminations may produce a chattering or hum. The inductance may also be affected.

**6.539 What is a desirable feature of an electrolytic capacitor as compared with other types?**

*Answer.* Much greater capacitance is obtainable with smaller physical dimensions as compared with other types. A wet electrolytic capacitor also possesses self-healing properties.

**6.540 Why is an additional plate-grid feedback capacitor sometimes necessary in a crystal oscillator?**

*Answer.* The feedback capacitor is sometimes employed to supply sufficient increment to start the crystal oscillating. This is particularly true where the internal grid-plate capacitance of a tube is low, such as with the screen-grid types of tubes. The capacitor must, however, be very small since excessive voltage surges to the quartz plate may fracture it.

**6.558 Why do some superheterodyne receivers employ a crystal oscillator in the first detector?**

*Answer.* Superheterodyne receivers in certain types of military and mobile as well as fixed service are designed to receive on only one frequency or on relatively few channels. In order to ensure communication on the channel monitored, the receiver is provided with one or several crystal-controlled high-frequency first oscillators that can be switched into service. In this way, the operator can always be sure that he is tuned as exactly as possible to the frequency of the desired transmitting station.

**6.559 Draw a block diagram of a superheterodyne receiver capable of receiving continuous-wave radiotelegraph signals**

*Answer.* See Fig. 6-6.

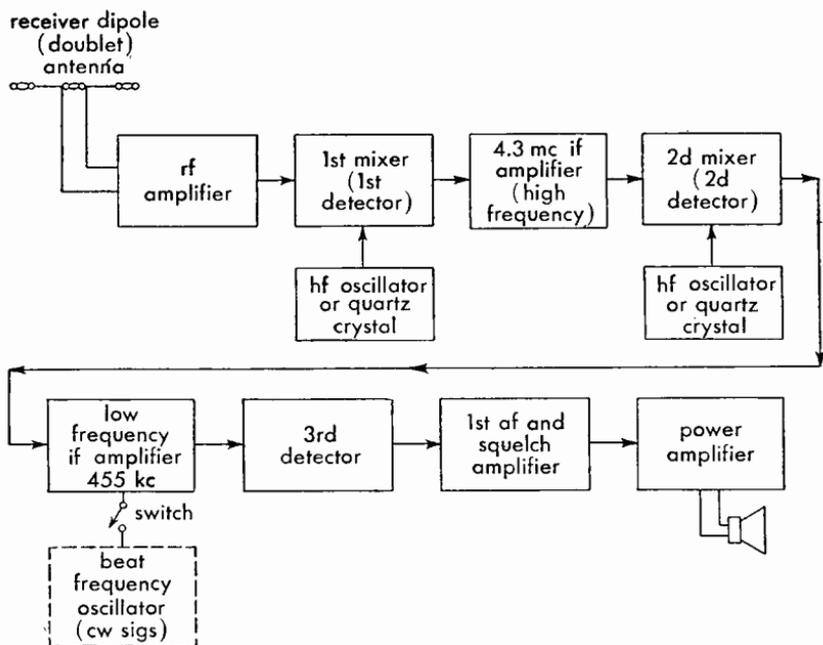


FIG. 6-6. Triple-detection superheterodyne receiver for mobile, land, and ship communication.

6.560 Draw a block diagram of a superheterodyne receiver designed for reception of FM signals.

*Answer.* See Fig. 3-48(a).

6.561 Draw a block diagram of a tuned radio-frequency receiver.

*Answer.* See Fig. 3-48(b).

6.562 How should a superheterodyne communications receiver be adjusted for maximum response to weak CW signals? To strong CW signals?

*Answer.* The radio-frequency gain of a communications receiver should be advanced to the maximum and the audio-frequency gain reduced only as much as necessary when receiving weak CW signals. When receiving strong CW signals that tend to block the receiver, the operator will find it most convenient to advance audio-frequency gain to maximum and advance radio-frequency gain only enough to maintain the signal at the desired level. In general, the AVC should be turned off.

**6.563** What is the purpose of a crystal filter in the intermediate-frequency stage of a superheterodyne communications receiver? Under what conditions is this filter used?

*Answer.* A crystal filter is used in one arm of a bridge circuit in the intermediate-frequency stage of a superheterodyne receiver to sharpen the selectivity. A variable phasing capacitor that is customarily employed in another arm of the bridge is set to neutralize the capacitance of the crystal holder. At other adjustments the phasing control acts with the holder capacitance as a parallel-resonant rejection circuit against signals on frequencies slightly removed from that being received with maximum selectivity. The filter is switched into use by the operator under conditions of interference by stations on adjacent frequencies. (See also 6.395.)

**6.564** Draw a simple schematic diagram of an FM receiver discriminator.

*Answer.* See Fig. 4-17.

**6.565** After long periods of listening to a CW telegraph signal of constant tone, what adjustment can the operator make to a radio receiver to relieve hearing fatigue?

*Answer.* The operator should make fairly frequent readjustments to the beat-frequency oscillator of his receiver to vary the pitch of the tone. The sense of hearing becomes fatigued by a constant pitch, and under certain circumstances the signal will actually seem to fade.

**6.566** Draw a simple schematic diagram of a diode detector.

*Answer.* See Figs. 3-18 and 4-16.

**6.567** Draw a simple schematic diagram of a two-stage audio amplifier.

*Answer.* See Fig. 3-13.

**6.568** Describe the construction of a pentode vacuum tube. A beam-power vacuum tube. In what types of circuits do these tubes find application?

*Answer.* (See 3.485.) Pentode tubes find their application primarily as radio-frequency voltage and power amplifiers in transmitting and receiving circuits.

Beam-power tubes are extensively used as class A power amplifiers in audio-frequency systems. They also find wide application as class B and class C radio-frequency amplifiers in marine and broadcast transmitting systems.

6.569 Draw a simple circuit diagram showing the principle of operation of an ohmmeter.

*Answer.* See 3.508.

6.570 In the operation of a class B audio-amplifier stage, should the plate current fluctuate or should it remain at a steady value?

*Answer.* The plate current will fluctuate during signal input. The plate current during zero signal input is very nearly zero because of the cutoff bias adjustment. However, as soon as the grid receives an input voltage the plate current will rise with the positive halves of the grid excitation cycle.

6.571 What is the function of a grid leak in a class C amplifier?

*Answer.* The grid-leak resistor in a class C amplifier provides grid-bias voltage for the tube. It is a convenient means of obtaining this voltage because as the direct grid current increases through the resistor the bias voltage is automatically increased. The leak resistor must be bypassed for radio-frequency voltages. A tube biased by the grid-leak method alone is likely to be damaged if the grid-drive voltage is removed and the plate current is allowed to rise to high values.

6.572 Draw a simple schematic diagram of a Hartley oscillator. A Pierce oscillator. A Colpitts oscillator.

*Answer.* See Figs. 3-2, 3-6, and 6-7.

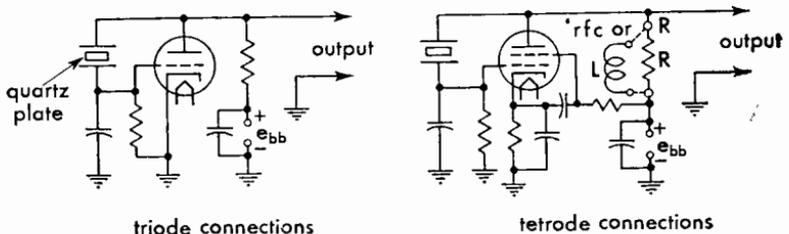


FIG. 6-7. Pierce crystal oscillator.

6.573 In a series-fed plate circuit of a vacuum-tube amplifier, what would be the result of a short circuit of the plate bypass capacitor?

*Answer.* The power supply would be short-circuited, and a heavy current drain would flow in the power-supply circuit. The rectifier tube, choke coil, or plate milliammeter may burn out as a result.

6.574 In a shunt-fed plate-circuit of a vacuum-tube amplifier what would be the result of a short circuit of the plate radio-frequency choke coil?

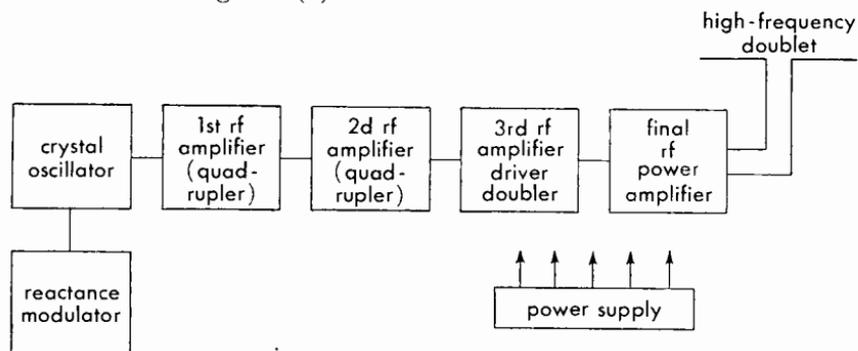
*Answer.* See 3.480.

6.575 What determines the fundamental operating frequency of a multivibrator oscillator?

*Answer.* See 4.182.

6.576 Draw a block diagram of a MOPA radiotelegraph transmitter with the master oscillator operating on 2017.5 kc and the transmitter output on 8,070 kc.

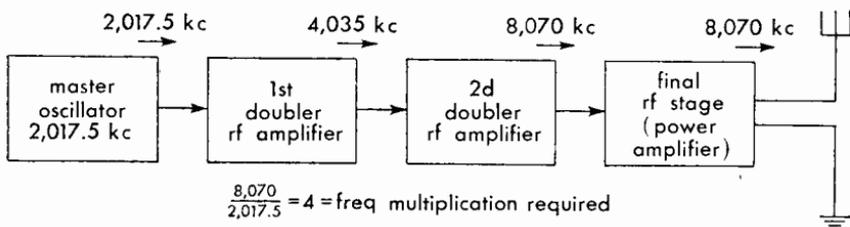
*Answer.* See Fig. 6-8 (b).



assuming:

an operating freq of 34.1 mc, the crystal  
freq requirements would be 1,065.625 kc  
( $4 \times 4 \times 2 = 32 = \text{freq multiplication required}$ )

(a)



(b)

FIG. 6-8. Block diagram of FM transmitter (a) and MOPA radiotelegraph transmitter (b).

**6.577** Does the code speed or number of words per minute transmitted have any effect on the bandwidth of the emission from a radiotelegraph transmitter?

*Answer.* The bandwidth required for the transmission of a radiotelegraph signal increases directly with the number of keying cycles in a given time. According to international agreement, bandwidth in cycles is equal to the product of  $B$  and  $K$  for A1, CW telegraphy. The symbol  $B$  represents the speed in bauds and is equal to the speed in words per minute times 0.8. The factor  $K$  (for fading circuits) is equal to 5. For example, the bandwidth for 25 words per minute is  $25 \times 0.8 \times 5 = 100$  cycles per second; for 20 wpm it is

$$20 \times 0.8 \times 5 = 80 \text{ cps.}$$

**6.578** In the transmission of the International Morse code what are the relative time lengths of dashes, dots, and spaces?

*Answer.* In the International Morse code, the relative lengths of dashes, dots, and spaces are three, one, and three. The space between the parts that make up a single letter is equal to one dot. The space between two words is equal to five dots.

**6.579** Draw a block diagram of an FM transmitter.

*Answer.* See Fig. 6-8 (a).

**6.580** Show by a diagram how a radiotelegraph transmitter can be keyed by the use of a keying relay.

*Answer.* See Figs. 6-1, 6-2, and 6-5.

**6.581** If a transmitter is adjusted for maximum power output for telegraph operation, why must the plate voltage be reduced if the transmitter is to be amplitude-modulated?

*Answer.* For 100 per cent modulation the power input to the tube is increased by 50 per cent, resulting from the audio power supplied by the modulator. This additional power input is worked on by the same tube efficiency as in the telegraph case. The power dissipated at the plate increases as does the radio-frequency power handled by the plate-tank circuit. If the transmitter components are already operating at their maximum voltages for telegraph, power input (and plate voltage) must be reduced before introducing amplitude modulation. No such

reduction in power input or plate voltage would be necessary with frequency modulation. (See also 6.626.)

**6.582** List the various points in a radiotelegraph transmitter where keying can be accomplished.

*Answer.* Keying in a radiotelegraph transmitter can be done in the high-voltage lead to the final stage, in the cathode or filament center-tap of the final, or by removal of a blocking bias voltage on the grid. Other methods are suppressor, screen-grid, and primary keying. Any of these keying methods can be employed in a driver stage, provided that the biases on the grids of all the succeeding amplifier tubes are sufficient to cut off the tubes when they are not receiving radio-frequency driving voltage. In all these methods of keying, the hand key is normally and most safely used in a low-voltage circuit to operate an electromechanical relay or an electronic keying tube that actually makes and breaks the high voltage or medium-high voltage. (See also 6.496–6.499.)

**6.583** A certain keying relay coil has a resistance of 500 ohms and is designed to operate on 125 milliamperes. If the relay is to operate from a 110-volt d-c source, what value of resistance should be connected in series with the relay coil?

*Answer.* A 500-ohm relay coil of these specifications would require a series resistance of 380 ohms.

*Solution:*

$$E_{\text{relay}} = IR = 0.125 \times 500 = 62.5 \text{ volts}$$

$$(110 - 62.5 = 47.5 \text{ volts})$$

$$R_s = \frac{E}{I} = \frac{47.5}{0.125} = 380 \text{ ohms}$$

**6.584** What is meant by break-in operation at a radiotelegraph station, and how is it accomplished?

*Answer.* Break-in operation is a technique by which the station receiving a message can almost immediately signal the sending station even though both their transmitters operate on the same or in some cases, closely adjacent frequencies. In order to accomplish break-in, the receivers at both stations must be well shielded and provided with electromechanical or electronic relays such that when the transmitter

is keyed on, the receiver is disconnected from its receiving antenna and otherwise made insensitive to the local transmitter signal. A common antenna is often used for both transmitter and receiver, being properly connected through a relay. The receiver must not be "blocked" so that it remains insensitive after the transmitting key has been released. If these conditions are met at each station, it will be possible for either operator to hear incoming signals on his own transmitting frequency, between transmitted letters. Break-in achieves more efficient communication and allows the quick stopping of traffic in emergencies.

**6.585 What is meant by frequency-shift keying and how is it accomplished?**

*Answer.* Frequency-shift keying is a kind of telegraph frequency modulation in which the mark signals are transmitted by varying the frequency to one side and the space signals by varying it to the other side of a center frequency. Although this system requires a considerably greater bandwidth than normal on-off keying, it has a greater discrimination against interference and noise and is therefore advantageous. One fairly simple means of accomplishing frequency-shift keying is the use of a reactance tube shunted across the frequency-control circuit. The reactance tube shifts the frequency when a keyed signal is applied to it.

**6.586 Why does harmonic radiation from a transmitter sometimes cause interference at distances from a transmitter where the fundamental signal cannot be heard?**

*Answer.* Under favorable conditions, high-frequency radio signals of low power are frequently reflected to great distances by the ionosphere. At the same time, medium-frequency signals of the same power may be reflected only to much shorter distances. A signal at 2 mc might be copied at 500 miles over water and less than 150 miles over land during the day. Yet the fourth harmonic, 8 mc, even though weaker at the transmitter might be copied at several thousand miles. This phenomenon is known as "skip."

**6.587 What is meant by polarization of a radio wave? How does polarization affect the transmission and reception of a radio wave?**

*Answer.* Polarization of a radio wave refers to the direction of the lines of force of the electrostatic, or electric, field. A vertically polar-

ized wave is one in which the lines of force are vertical or at right angles to the earth. The electromagnetic lines of force, or the magnetic flux, is at right angles to the electrostatic field. In order to propagate a true ground wave at medium frequencies over sea water, it is highly desirable to employ vertical polarization. If horizontal polarization is attempted, the high conductivity of the sea water tends to short circuit the electric component, resulting in a reduced range. The polarization of a radio wave is particularly important in communication at frequencies that do not use reflections from the ionosphere. Transmissions at VHF and higher make extensive use of the fact that a horizontally (or vertically) polarized transmission is received much more efficiently on a receiving antenna that is properly oriented than on one that has the wrong polarization. Although there seems to be but a slight advantage in horizontal polarization, there is enough evidence to standardize on this type for FM and television broadcasting. Because of the simpler omnidirectional antennas for vertical polarization, most of the mobile VHF services use vertical polarization. In general, a radio wave that has been reflected from the ionosphere loses its pure polarization. For this reason, aside from point-to-point communication, there is little need for elaborately polarized receiving antennas for reflected waves. Transmitting antennas, on the other hand, can be profitably arranged so as to give the wave the best possible start for the desired reflection angle. (See also 3.499 and 3.500.)

**6.588 What is meant by harmonic radiation?**

*Answer.* Harmonic radiation from a transmitter refers to the signal radiated at twice, three, or more, times that of the desired fundamental frequency. (See also 3.237.)

**6.589 How may harmonic radiation of a transmitter be prevented?**

*Answer.* Harmonic radiation of a transmitter can usually be avoided by proper transmitter design and reasonably careful adjustment. Even harmonics are greatly reduced by the use of push-pull amplifiers that are carefully balanced. A plate-tank circuit with a high  $Q$  is desirable for suppressing harmonics, since the selectivity increases with  $Q$ . However, in order to achieve a reasonable tank-circuit efficiency, a loaded  $Q$  of about 12 is customary. The grid-tank circuit of the final amplifier should have a fairly high  $Q$ . A Faraday shield prevents electrostatic coupling (which is a low-impedance path for the high

frequencies) between output tank and antenna circuit, without disturbing the electromagnetic coupling. Overdriving a class C amplifier tends to generate harmonics. Keying transients cause harmonic radiation. They should be avoided by keying circuits that allow a relatively slow build-up and decay of power when the transmitter is keyed. Square-keying impulses should be avoided. (See also Figs. 4-7 and 4-8.)

**6.590** Draw a diagram showing how current varies along a half-wavelength Hertz antenna.

*Answer.* See Fig. 3-56.

**6.591** What is the difference between a Hertz and a Marconi antenna?

*Answer.* The Hertz antenna is a half-wave ungrounded radiator or dipole. The Marconi antenna is a quarter-wave grounded antenna of the inverted variety.

**6.592** Why is an artificial antenna sometimes used in testing a transmitter? By what other names is this instrument known?

*Answer.* An artificial antenna is a device that matches in every characteristic the resistance and reactance of a transmitting antenna normally used with a transmitter. It must be capable, in addition, of dissipating the full or test power of the transmitter. By its use, unnecessary radiation of test signals is avoided during periods of adjustment or maintenance. An artificial antenna is sometimes known as a "dummy antenna" or "dummy load."

**6.593** Draw a simple schematic diagram of a wave trap in an antenna circuit for attenuating an interfering signal.

*Answer.* See Fig. 3-53 and 3.276.

**6.594** What are the advantages and disadvantages of using an absorption wavemeter in comparison to other types of frequency meters?

*Answer.* The advantage of the absorption wavemeter is simplicity of operation. However, since it is generally placed near the transmitter and is a power-absorbing device, it is not very selective and usually has an accuracy of only 2 per cent. Care must also be exercised to

prevent burning out the galvanometer or lamp indicator when testing transmitters.

**6.595** Draw a simple schematic diagram of an absorption wave-meter.

*Answer.* See Fig. 3-50.

**6.596** What are cavity resonators, and in what type of radio circuit do they find application?

*Answer.* See 3.511.

**6.597** What are wave guides, and in what type of radio circuit do they find application?

*Answer.* See 3.511.

**6.598** What determines the operating frequency of a magnetron oscillator? A klystron oscillator?

*Answer.* The operating frequency of a magnetron is primarily dependent upon its physical structure and its associated powerful permanent magnet. The magnetron's physical structure is in the form of a cylinder of copper with holes, or cavities, and a cathode, inside. The holes are called the *resonant cavities*, because they are capable of sustaining a definite frequency. The cavity "tuning" depends upon the size and shape of the holes. The smaller the cavity the higher the frequency.

Other factors which affect the operating frequency are the pulse voltage, the strength of the magnetic field, the cathode voltage, the anode potential, and the radio-frequency tuning adjustments. Split-anode magnetrons use either two-wire resonant lines with movable short-circuiting bars or small tank circuits of  $L$  and  $C$  to vary the frequency.

The klystron oscillator also operates upon the principle of cavity resonance. Unlike the magnetron, however, the reflex klystron has an accelerating grid, a repeller plate, and two main grids connected to a split cavity or resonant chamber. The frequency is determined primarily by varying the volume of the resonant cavity.

The repeller voltage may also be varied over a narrow range to provide minor adjustments in operating frequency. Some tubes use an

external cavity with screw plugs for tuning, while others have means for varying the grid spacings.

**6.599 In what radio circuits do klystron and magnetron oscillators find application?**

*Answer.* The magnetron finds application in the field of pulse techniques such as radar as a generator of superhigh-frequency oscillations (microwaves) and also for continuous telegraph-wave transmissions at these or lower frequencies.

The magnetron is used almost exclusively where extremely high power transmission is required at microwave frequencies between 1 and 10 centimeters in wavelength.

The klystron finds its application in the microwave field as a local oscillator in a superheterodyne receiver, a precision heterodyne frequency meter, a low-power oscillator transmitter, or a frequency multiplier for precision-control applications and primary frequency standard measurements. The klystron is frequently used in the frequency spectrum of 1,000 through 30,000 mc.

**6.601 What are the ratios between the average, effective, and peak values of a sinusoidal wave?**

*Answer.* The various ratios are as follows:

$$\begin{aligned}\text{Peak to effective} &= 1/0.707 = 1.414:1 \\ \text{Peak to average} &= 1/0.637 = 1.57:1 \\ \text{Effective to average} &= 0.707/0.637 = 1.11:1\end{aligned}$$

Any of these values may readily be transposed for another desired ratio.

**6.602 Define the following terms: "hysteresis," "permeability," "eddy currents."**

*Answer.* "Hysteresis" is the molecular friction produced by the a-c reversals in a magnetic-core material. It is the lagging effect of the magnetic flux with respect to the magnetizing force that produces it.

"Permeability" is the ease of magnetic conduction through a magnetic material as compared to air. It is the measure of the relative conductivity of iron or any magnetic material compared with air.

"Eddy currents" are the circulation of small currents through the

interior of a solid mass of conducting material. These currents are caused by the generation of small emfs owing to the movement of a magnetic field near a material or the movement of the material itself in a magnetic field. These currents as set up are similar to swirls of water in their motion with respect to the flow of water which is causing them. Hence the term "eddy currents."

**6.603** What is the total impedance of a series a-c circuit having an inductive reactance of 14 ohms, a resistance of 6 ohms, and a capacitive reactance of 6 ohms?

*Answer.* The impedance is 10 ohms.

**6.604** What is the total impedance of a series a-c circuit having a resistance of 3 ohms, an inductive reactance of 7 ohms, and zero capacitive reactance.

*Answer.* The total impedance is 7.62 ohms.

**6.605** What changes in circuit constants will double the resonant frequency of a resonant circuit?

*Answer.* By halving the inductance and the capacitance values or dividing the  $LC$  value by 4.

**6.606** How may the  $Q$  of a parallel resonant circuit be increased?

*Answer.* The  $Q$  of a parallel resonant circuit is determined by the ratio,  $2\pi fL/R$ . Increasing the  $Q$  is generally accomplished practically by reducing the resistance and absorption losses of the coil and circuit by reducing the radio-frequency resistance of the coil and leads. In addition, by the use of special low-loss dielectric supporting forms made from materials such as quartz, Isolantite, Mycalex, for both coils and tuning capacitors. These are the general considerations for increasing the  $Q$  of oscillatory circuits although such factors as core material and mutual coupling must also be considered in changing the  $Q$ , the figure of merit for efficiency.

**6.607** If a parallel circuit, resonant at 1,000 kc, has its values of inductance halved and capacitance doubled, what will be the resultant resonant frequency?

*Answer.* 1,000 kc.

**6.608** Assume a resistance of 8 ohms in parallel with a resistance of 6 ohms; in series with this combination is a resistance of 77 ohms. What is the total resistance of the combination?

*Answer.* Reducing the parallel combination to its effective resistance we obtain,  $R_{\text{eff}} = \frac{R_1 \times R_2}{R_1 + R_2} = 3.42$  ohms.

Thus,  $R_3 + R_{\text{eff}} = 80.42$  ohms

**6.609** Assume an inductance of 5 henrys in parallel with a capacitance of 1  $\mu\text{f}$ . If there is no resistance in either leg of this circuit, what is the equivalent impedance of the parallel network at resonance?

*Answer.* The impedance looking into the network at resonance will be theoretically infinite. This may be seen from the parallel-resonance impedance equation,

$$Z = X_L^2/R \text{ ohms}$$

As the denominator in the equation is reduced, the impedance rises. The impedance of the combination inside the circulating network will, on the other hand, be zero.

**6.610** Why are iron cores, of the type used in audio-frequency transformers, not used in radio-frequency transformers?

*Answer.* There are two primary reasons why this is not done:

1. The iron cores as used in audio-frequency transformers would present hysteresis and eddy-current losses of too high a value to allow practical efficiencies. Dust cores of iron and alloys have been successfully used at low radio frequencies.

2. Radio-frequency transformers generally respond to a narrow band of radio frequencies. They must possess selective qualities in order to effect sharp tuning. Large iron cores would defeat this purpose. The iron cores such as are used in audio transformers permit a broad-frequency response to enable the passage of the speech and musical frequencies. This range for the average audio-frequency transformer is between 30 and 6,000 cycles per second and for the higher grade types between 25 and 10,000 cps.

**6.611** Why should the metallic case of a high-voltage transformer be grounded?

*Answer.* The metallic case of a high-voltage transformer is grounded to prevent build-up of an electric field between the case and nearby objects. Grounding also ensures greater safety to personnel in the event of a voltage breakdown between the primary or secondary and the case. In most instances it will help to eliminate a source of radio noise.

**6.612** What turns ratio should a transformer have which is to be used to match a source impedance of 500 ohms to a load of 10 ohms?

*Answer.* A turns ratio of 7.1 to 1. It can be determined by the equation

$$\frac{T_p}{T_s} = \sqrt{\frac{Z_p}{Z_s}} = \sqrt{\frac{500}{10}} = \frac{7.1}{1}$$

where  $T_p$  and  $T_s$  are the primary and secondary turns respectively, and  $Z_p$  and  $Z_s$  are the primary and secondary impedances in ohms.

**6.613** What would happen if a transformer, designed for operation on 60 cycles, were connected to a 120-cycle source of the same voltage?

*Answer.* Its higher impedance at the higher frequency would decrease current in the primary. Although there would probably be no resultant damage, the power-handling capabilities of the transformer would be seriously impaired during its use at the higher frequency.

**6.614** What would happen if a transformer, designed for operation on 500 cycles, were connected to a 60-cycle source of the same voltage?

*Answer.* Its lower impedance at the decreased frequency would result in heavy current flow, overheating the primary and eventually burning it out.

**6.625** A ship's transmitter has an antenna current of 8 amperes using A1 emission. What would be the antenna current when this transmitter is 100 per cent modulated by sinusoidal modulation?

*Answer.* When a continuous-wave transmitter is modulated by 100-per cent sinusoidal modulation the increase in antenna current will be 22.5 per cent. An increase of 22.5 per cent may be calculated by multiplying the unmodulated antenna current by 1.225; thus  $8 \times 1.225 = 9.8$  amperes.

**6.626** The d-c plate input to a modulated class C amplifier, with an efficiency of 60 per cent, is 200 watts. What value of sinusoidal audio power is required in order to ensure 100 per cent modulation? 50 per cent modulation?

*Answer.* For 100 per cent modulation, the modulator tube must supply audio-frequency power equal to 50 per cent of the unmodulated carrier plus 50 per cent of the power dissipated in the modulated amplifier plate when unmodulated. Thus the audio-frequency power supplied by the modulator is,

$$P_{\text{mod}} = m^2 P_0 / 2n$$

where  $m$  = modulation factor.

$n$  = estimated efficiency of the class C amplifier.

$P_0$  = unmodulated carrier power.

Since the input power in this example is 200 watts and the plate dissipation at 60 per cent efficiency is 80 watts the output power will be 120 watts. Thus the audio-frequency power required at 100 per cent modulation may be found by the equation,

$$\frac{1^2 \times 120}{2 \times n} = 100 \text{ watts}$$

Now since the modulation factor for 100 per cent modulation is equal to 1, the modulation factor for 50 per cent modulation will be 0.5 (modulation factor  $\times 100$  = percentage of modulation). Thus, for 50 per cent modulation the audio-frequency power required will be

$$\frac{0.5^2 \times 120}{2 \times n} = \frac{0.25 \times 120}{1.2} = 25 \text{ watts}$$

**6.627** What increase in antenna current will be observed when a radiotelephone transmitter is 100 per cent modulated by a sinusoidal waveform?

*Answer.* The antenna current when modulated 100 per cent will show an increase of 22.5 per cent over the unmodulated value assuming single-tone sinusoidal excitation.

**6.628** What is the total bandwidth of a transmitter using A2 emission with a modulating frequency of 800 cycles and a carrier frequency of 500 kc?

*Answer.* The bandwidth of a 500-kc radio-frequency wave modulated at a modulating frequency of 800 cycles is 1,600 cycles or 1.6 kc. The

bandwidth is computed on the basis of the upper and lower sideband frequencies,  $500,000 + 800$ ,  $500,000 - 800$ . The width of the band, therefore, is the algebraic difference between the upper and lower sidebands.

**6.629** What are the general characteristics of the emission of a radiotelegraph transmitter which uses a chopper to obtain A2 emission?

*Answer.* Figure 6-9 illustrates all types of emissions.

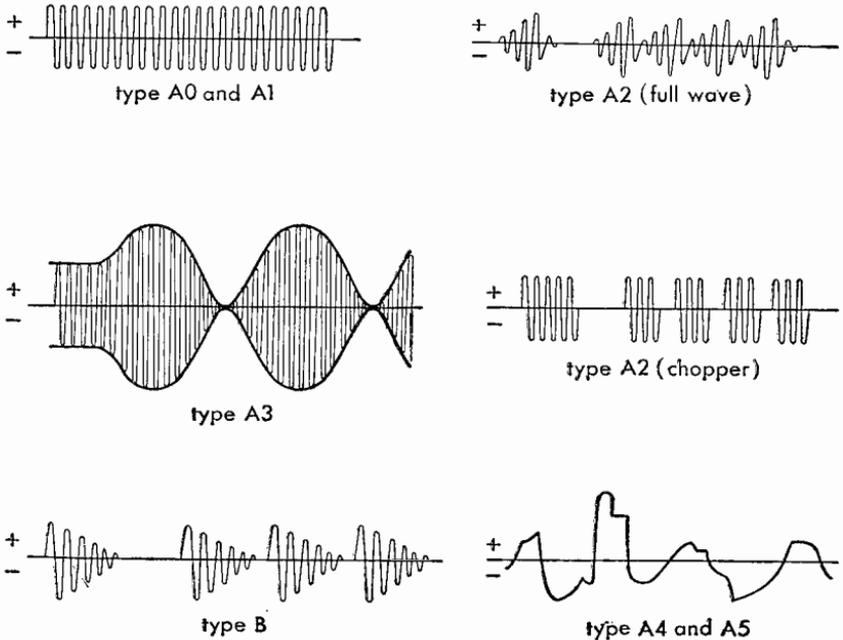


FIG. 6-9. Types of radio-wave emissions.

**6.630** How should the bias of a grid-modulated radio-frequency stage be adjusted?

*Answer.* The bias of a grid-modulated radio-frequency stage should be adjusted to a voltage value  $1\frac{1}{2}$  to 4 times the plate-current cutoff value.

**6.631** Compare the characteristics of plate-voltage and grid-bias modulation.

*Answer.* In the plate-voltage modulation (constant plate impedance) system the audio-frequency voltage is applied directly to the plate circuit of the radio-frequency stage to be modulated. In this system of modulation the source of signal voltage must supply a large part of the power supplied to the plate circuit. The operating efficiency is about 65 per cent.

In the grid-bias modulation (variable plate impedance) system the audio-frequency voltage, as well as the carrier voltage, is applied to the grid circuit. This system has the advantage over the plate-modulation system in that it requires much lower exciting audio-frequency grid voltage, but gives a slight amount of increase in distortion. Efficiency is about 33 per cent.

Linear plate- and grid-modulation systems produce much less distortion compared with most systems at high modulation percentages. In addition, they are excellent for use in high-power transmission because of their high ratio of useful power output to the total power supplied to the plate circuit. The grid-bias adjustment in the modulated radio-frequency stage is  $1\frac{1}{2}$  to 4 times plate current cutoff in both systems.

**6.632 Is a high degree of modulation desirable in connection with a self-excited type of transmitter? Explain.**

*Answer.* No. There are several very important reasons why a self-excited oscillator should not be modulated at a high degree of modulation. These are itemized as follows:

1. Frequency instability caused by power-supply load changes.
2. Frequency instability caused by changes in antenna constants, such as a swinging antenna, and humidity changes.
3. Rapid changes in frequency and amplitude, particularly with high percentages of modulation, will cause heavy changes in the output carrier frequency.
4. Poor quality of transmission.
5. Broader tuning response at the receiving station which may result in adjacent-station interference.

**6.633 What is meant by "low-level modulation"?**

*Answer.* The term "low-level modulation" is applied to those types of radiotelephone transmitters in which the audio-frequency signal is applied to some one of the radio-frequency amplifier stages preceding the final power-amplifier stage.

**6.634** Why is a series resistor used in the d-c plate supply of a modulated radio-frequency amplifier, between the amplifier and the modulator, in a Heising-modulation system?

*Answer.* The series dropping resistor is used in order that the radio-frequency amplifier will operate at a d-c plate voltage lower than that of the modulator. This is necessary in order that the radio-frequency amplifier stage will be completely modulated. In other words, if the radio-frequency amplifier voltage is one-third less than that of the modulator, the radio-frequency amplifier will be completely modulated when the modulator develops a peak output voltage of two-thirds the d-c plate potential.

**6.635** Should the efficiency of a grid-bias modulated stage be maximum at complete modulation or zero modulation? Explain.

*Answer.* The efficiency of a grid-bias modulated stage should be a maximum at complete modulation. This is so because the efficiency of plate-power conversion will be higher at complete modulation because some d-c grid current will be drawn at modulation peaks. It is, of course, important that the grid-current flow be not excessive, since that condition would introduce distortion. If the grid bias on a grid-modulated system is adjusted so that no grid current flows even on high peaks poor economy will result.

**6.636** What is the purpose of a plate choke as used in Heising modulation?

*Answer.* The primary purpose of the plate choke, or plate reactor as it is commonly called, is to maintain a constant current in the modulator and modulated-amplifier plate circuits. The Heising system of modulation is often called the "constant current system" of modulation owing to the action of the plate reactor. The action of the choke may be more clearly understood from the following explanation: since the plate reactor is connected in the positive lead of the d-c power supply and feeds simultaneously the voltage to the plates of both the modulator and the modulated-amplifier tubes any changes in the current flow in either plate circuit will be affected by the self-inductance of the coil. That is to say, when the grid of the modulator tube swings positive the plate current in this stage will increase. Owing to the large inductance of the reactor, however, the rise in current will change the polarity in accordance with the laws of induction. Thus the

voltage developed across it by the expanding magnetic field will be 180 deg out of phase with the direct voltage. This results in a decrease in the voltage on the plate of the modulated-amplifier tube owing to the bucking effect of the plate reactor upon the d-c generator. When the grid of the modulator swings negative on the next half of the audio-frequency cycle the modulator plate current decreases. This causes the magnetic field around the plate reactor to contract, thereby putting the reactor voltage in phase with the supply generator and increasing the voltage upon the plate of the modulated power-amplifier tube. This complete action varies the modulated amplifier voltage in accordance with the modulator changes and consequently varies the amplitude of the carrier frequency at an audio frequency.

**6.637** Does grid current flow in the conventional grid-bias modulated stage of a radiotelephone transmitter, under modulated conditions?

*Answer.* Yes. Grid current flows in slight amounts during the positive peaks of the audio-frequency excitation cycle. (See also 6.635.)

**6.638** If the first speech-amplifier tube of a radiotelephone transmitter were overexcited, but the percentage-modulation capabilities of the transmitter were not exceeded, what would be the effect upon the output?

*Answer.* Overexcitation of the first tube in the speech input equipment would produce nonlinear distortion (amplitude distortion) in the plate circuit of the first tube which would be greatly amplified in each of the succeeding stages. Obviously this would badly distort the waveform of the modulated carrier and resulting transmission. The effect of amplitude distortion is generally referred to as *overloading* in the case of overexcitation.

**6.639** What types of microphones have a high-impedance output?

*Answer.* Condenser microphones and piezoelectric (crystal) microphones have a large output impedance. All microphones which operate upon the electrostatic principle are of the high-output impedance variety. Carbon microphones have a high-output impedance as compared with the low-impedance variety such as the dynamic or velocity types, but their impedance is low compared to the condenser and crystal types.

**6.640 What are the advantages of the single-button carbon microphone?**

*Answer.* The main advantage of the single-button carbon microphone is that it does not require the careful adjustment of button balance since only a one-button current flows through the output transformer winding. In the double-button types the two currents in the respective halves must be carefully balanced for proper symmetry. Other advantages of the single button microphone are its relatively low cost, very high output, and low current consumption.

**6.641 Why is a speech amplifier used?**

*Answer.* Speech amplifiers are used to build up the voltages developed by the microphones to higher voltage amplitudes. High-audio-voltage amplitudes are required to transmit speech and musical frequencies to the modulating circuits, line circuits, and reproducers. Speech amplifiers are generally referred to as "voltage" or "gain" amplifiers. In any case where it is required to increase the audio-frequency voltage output of feeble generating (a-c) sources, a voltage or speech amplifier may be used.

**6.642 What might be the causes of a positive shift in carrier amplitude during modulation?**

*Answer.* Carrier shift is that condition in a modulated wave in which the *average* value of the transmitted wave is changed in an upward or downward direction. Any situation which will change the average d-c plate reading of the linear power-amplifier stage upward during modulation produces a positive carrier shift, and if downward, a negative carrier shift. In other words, any upset in the plate-circuit symmetry may cause a shift. Overmodulation *may* be the cause of either a positive or a negative carrier shift. Some other causes for a positive carrier shift are: excessive grid bias, poor bias-supply regulation, insufficient radio-frequency excitation. Negative carrier shift may be caused by: poor plate-supply regulation, insufficient grid bias, or excessive radio-frequency excitation which causes grid current to flow.

**6.643 What is the ratio between the d-c power input of the plate circuit of the stage being plate modulated, and the output audio power of the modulator for 100 per cent sinusoidal modulation?**

*Answer.* For distortionless 100 per cent modulation capabilities the d-c power input to the modulated radio-frequency amplifier stage should be twice the modulator's undistorted audio-frequency power output.

**6.644** At 100 per cent amplitude modulation, what is the ratio of peak antenna current to unmodulated antenna current?

*Answer.* The ratio of peak antenna current to unmodulated antenna current at 100 per cent modulation is 2:1, the peak modulated value rising to double the unmodulated value.

**6.645** At 100 per cent amplitude modulation, what is the ratio of peak antenna power to unmodulated antenna current?

*Answer.* The ratio is 4:1. Assuming unity current without modulation, the peak current for 100 per cent modulation will be twice that. Since the power varies as the square of the current, it will be four times the value of the unmodulated current.

**6.646** Using a regenerative receiver, without radio-frequency amplifier stages, describe how you would adjust to receive radio-telegraph signals through interference.

*Answer.* To increase the selectivity of a regenerative receiver so as to reduce interference to a minimum, reduce the coupling between the primary and the secondary of the tuner and carefully retune the circuit to resonance by varying the secondary tuning capacitor. Gradually increase the regeneration control to the point just before where self-oscillation is produced. Repeat the process critically by varying each of the tuning adjustments; namely, antenna series capacitor, secondary tuning capacitor, and the regeneration feedback control. Various degrees of loose-coupling values should be chosen until the proper degree of selectivity is obtained. It is important to remember however that each time the coupling is varied the circuit must be entirely retuned.

For continuous-wave reception the process is the same, with the exception that the regeneration control is increased to the point of self-oscillation so that an audible beat note may be produced.

**6.647** What is the effect upon the sound of received type B emission if the receiver detector is oscillating?

*Answer.* The tone frequency of the damped wave becomes badly distorted and it has a "mushy" tone characteristic.

**6.648** What effect does an incoming signal have upon the plate current of a triode detector of the grid-leak type?

*Answer.* The plate current will decrease. This is due to the fact that the grid-capacitor blocking action causes a negative building up process or grid bias upon the grid with respect to the cathode. In other words, the grid leak develops an automatic grid bias during the periods in which the incoming signals prevail, thereby reducing the plate current.

**6.649** If broadcast signals interfered with your reception of signals on 500 kc while aboard ship, how would you reduce or eliminate such interference?

*Answer.* The interference may be reduced or eliminated by the use of a tunable wave trap connected in the antenna circuit. The trap circuit is then tuned to the undesired frequency. See Fig. 3-53.

**6.650** Describe how you could test a regenerative receiver to determine if the detector were in an oscillating condition?

*Answer.* One of the simplest tests to ascertain if the detector is in an oscillating condition is to touch the finger to the grid of the tube. A loud "cluck" or "plop" should be heard in the telephones if the receiver is oscillating and another "plop" when the finger is removed. Another simple test would be to bring the regeneration control up slowly from its minimum position towards maximum until a similar "plop" is heard. This will indicate that the circuit has gone into oscillation.

**6.651** Discuss the relative advantages and disadvantages of a stage of radio-frequency amplification as compared with a stage of audio-frequency amplification, for use in connection with a regenerative receiver.

*Answer.* The relative advantages of a stage of radio-frequency amplification in connection with a regenerative receiver are as follows:

1. Provides an increase in sensitivity.
2. Increases the circuit selectivity.
3. Eliminates reradiation from the oscillating detector into the antenna system.

4. Reduces the possibility of "dead spot" points when the oscillating detector is resonated with the antenna circuit.

The disadvantages of a stage of radio-frequency amplification before the oscillating detector are as follows:

1. A stage of radio-frequency amplification does not give so much audio-frequency volume as does one stage of audio-frequency amplification. This is particularly true if high step-up ratio audio-frequency transformers are used.

2. A radio-frequency stage requires careful shielding and filtering of all component parts to ensure circuit stability. Design considerations are more exacting.

3. It generally requires an additional tuning stage.

4. It may require neutralization of interelectrode grid-plate capacitance to prevent amplifier self-oscillation.

**6.652** If a ship's regenerative receiver failed to oscillate when the regeneration control was advanced, explain the possible causes and remedies.

*Answer.* The following are the common causes for failure of a regenerative receiver to oscillate:

1. Low filament-supply potential.
2. Deactivated filament. (Poor filament emission.)
3. Run-down plate-supply batteries.
4. Open plate bypass capacitor.
5. Open grid-coupling capacitor.
6. Open grid leak.

7. High resistance contacts in some portion of the circuit. The remedies in each case are obvious.

**6.653** Explain how you would test the various components of a receiver of the three-circuit regenerative type in trouble shooting.

*Answer.* Two basic tests are essential in trouble shooting a three-circuit regenerative receiver, namely:

1. Point-to-point continuity test with an ohmmeter or a pair of telephones with a battery in series.

2. Voltmeter test.

The first step in servicing a receiver is to replace the old tubes with new ones to eliminate this common source of trouble. Then proceed as follows:

1. Test the voltages of the filament supply and plate supply across the filament terminals and plate to filament respectively with the voltmeter.

2. If the voltmeter indicates a reading when it is connected between the plate and the cathode at the socket terminals, it is evident that the entire plate circuit is continuous.

3. Test the circuit continuity with the ohmmeter or battery-telephone combination from the control grid to the cathode.

4. Test the continuity of the antenna coil by the same method.

5. Test all capacitors for leaks or shorts.

**6.654** What is the effect of connecting a high value of resistance in parallel with the primary of an audio transformer in a regenerative receiver?

*Answer.* A high resistance connected across the primary winding of an audio-frequency transformer in a regenerative receiver prevents the annoying condition known as "fringe howl." The value of resistance should be in the order of 100,000 ohms.

**6.655** Why should a superheterodyne receiver, used for reception of A1 signals, be equipped with at least one stage of radio-frequency amplification ahead of the first detector?

*Answer.* A stage of radio-frequency amplification before the first detector serves as a preselector and reduces the possibility of image interference.

**6.656** What is the chief advantage to be gained in the utilization of high intermediate frequencies in a superheterodyne receiver?

*Answer.* The chief advantage to be gained in using high intermediate frequencies in a superheterodyne receiver is the reduction of image-frequency interference.

**6.657** If a superheterodyne receiver is receiving a signal on 1,000 kc and the mixing oscillator is tuned to 1,500 kc, what is the intermediate frequency?

*Answer.* The intermediate frequency is the difference between the incoming signal and the mixing oscillator frequency or, 500 kc.

**6.658** Why are diode detectors usually employed in modern radio receivers?

*Answer.* Diode detectors are used in most modern receivers because they more closely approach the ideal detecting or signal-rectifying characteristics. In other words, a detection characteristic is obtained which resembles a straight line or linear character and, as a result, develops an audio signal of minimum distortion.

**6.659** What is the purpose of an auxiliary receiving antenna installed on a compulsorily equipped vessel, which is also fitted with a direction finder?

*Answer.* On a vessel required by law to maintain a watch by a qualified operator or operators, an effective auxiliary antenna or other approved arrangement shall be provided whenever deemed necessary by the FCC to avoid unauthorized interruption of this watch during use of a radio direction finder on board the same vessel.

**6.660** What is the primary purpose of the "break-in" relay associated with a radiotelegraph transmitter?

*Answer.* A break-in relay permits rapid interruption of the sequence of transmission by the receiving station in the event of interference or a break in the copying of the message. (See 6.584.)

**6.661** When an antenna is erected, why should precautions be taken to prevent the wire from kinking?

*Answer.* The kinking of the wire weakens its physical structure at the point of the kink. If the wire is subjected to strain and constant swaying, it may eventually break. Another possibility, particularly at very high radio frequencies, would be a loss of energy due to an increase in the high-frequency resistance because of sharp bends or kinks.

**6.662** What may be the causes of noisy operation of a regenerative, three-circuit receiver having two stages of audio-frequency amplification?

*Answer.* Tube noises caused by a high degree of amplification, excessive or critical regeneration adjustment, defective regeneration control (potentiometer type), defective grid leak, run-down plate-supply or filament batteries, high-resistance contacts, or poor grounding.

**6.663** How may the frequency of the antenna circuit of a shipboard receiver be lowered?

*Answer.* By decreasing the natural resonant frequency of the antenna circuit. This is accomplished by "loading" the antenna with a series inductance or loading coil.

**6.664** How may the frequency of the antenna circuit of a ship-board receiver be increased?

*Answer.* By decreasing the loading inductance value at the taps or by inserting an antenna series capacitor.

**6.665** What is the directional reception pattern of a loop antenna?

*Answer.* Figure 6-10 illustrates the directional pattern of a loop antenna.

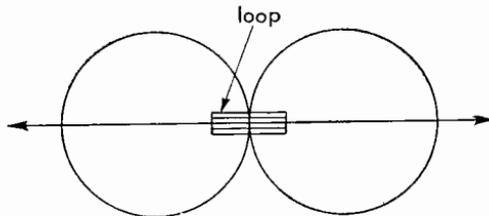


FIG. 6-10. Directional pattern of a loop antenna.

**6.666** What is the directional reception pattern of a vertical antenna?

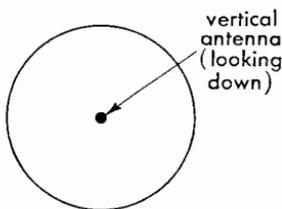


FIG. 6-11. Directional pattern of a vertical antenna.

*Answer.* Figure 6-11 illustrates the directional pattern of a vertical antenna.

**6.667** What is meant by "split tuning"?

*Answer.* Split tuning refers to the double-peaked characteristic obtained with tight coupling. (See 6.504.)

**6.668** Why should a transmitter be adjusted at reduced power?

*Answer.* To protect the transmitter and avoid excessive interference.

**6.669** How is the power output of a marine vacuum-tube radiotelegraph transmitter ordinarily adjusted?

*Answer.* By varying the resistance of the generator-field rheostat, thereby increasing or decreasing the output plate voltage.

**6.670** A marine transmitter uses 500-cycle alternating current for plate supply. It is rectified by a full-wave rectifier circuit but is not filtered. How would the emission be classified?

*Answer.* This type of emission is classified as A2 (ICW). (See Fig. 6-9.)

**6.671** In general, what advantages may be expected by the use of high frequencies in radio communication?

*Answer.* Transmission over vastly greater distances with a relatively smaller amount of input power. Greater compactness of component parts.

**6.672** How is the antenna aboard ship changed most rapidly from the transmitter to the receiver during the course of communication?

*Answer.* By the use of a break-in relay system.

**6.673** How can you determine the optimum coupling between the closed circuit of a spark transmitter and the antenna circuit?

*Answer.* Optimum coupling may be determined by the antenna radio-frequency ammeter when the maximum deflection is obtained. The optimum coupling position for most spark transmitters should be somewhere in the vicinity of  $2\frac{1}{2}$  in. between the primary and secondary coils, depending upon the power used. A peak antenna current should be indicated at the resonant point which falls off rapidly as the coupling is either tightened or loosened from the optimum coupling point.

**6.674** What are the primary factors which determine the frequency of emission of a spark transmitter?

*Answer.* The group or spark frequency of a spark transmitter is determined primarily by the speed of the alternator (power-transformer input frequency) and by the type of spark gap used. The radio-frequency emission is dependent upon the closed-circuit oscillatory constants of  $L$  and  $C$ .

**6.675** What is the best method of reducing the power output of a spark transmitter?

*Answer.* By reducing the generator output voltage. This is accomplished by increasing the resistance of the generator-field rheostat. It is also necessary to reduce the spark gap.

**6.676** Why are protective capacitors connected across the low potential a-c circuit of a spark transmitter?

*Answer.* To prevent possible damage to the alternator armature, motor armature, alternator field, motor field, primary of the power transformer, and line equipment, which might be caused by high-frequency kick-back surges.

**6.677** Upon what factor(s) does the spark, or note frequency, of a spark transmitter depend?

*Answer.* The spark or note frequency depends primarily upon the a-c generator frequency and the gap-interrupting frequency. The latter can vary the tonal frequency when a rotary spark gap is used. The frequency of the generator is, however, the most important determinant and is dependent upon the speed of the a-c armature and the number of field poles and the time factor, thus

$$\text{Frequency} = \frac{N \times S}{2 \times 60} \text{ cycles per sec}$$

where  $N$  is the number of field poles, and  $S$  is the speed in revolutions per minute.

**6.678** What factors determine the output frequency of a marine arc radiotelegraph transmitter?

*Answer.* The output frequency of a marine-arc transmitter is dependent upon the antenna capacitance, antenna inductance, and the antenna series-loading inductance.

**6.679** Why is it essential that pure water be used in the cooling system associated with an arc transmitter?

*Answer.* Since the water passes through the positive electrode pure water must be used to prevent grounding or short-circuiting the high-voltage generator. Pure water has high dielectric or insulating properties and is, therefore, a poor conductor.

**6.680** What is the purpose of the hydrogen gas, liberated from the injected alcohol, in the arc chamber?

*Answer.* The purpose of burning an arc in an atmosphere of hydrogen is to increase the degree of ionization to assist in the reduction of

the arc resistance. This increase in arc conduction manifests itself in the following:

1. Makes possible the generation of radio frequencies.
2. Increases the output radio-frequency energy.
3. Makes the arc burn more steadily (produces a "fatter" arc).
4. Ensures a more stable radiated frequency.
5. Makes for quicker ignition.

**6.681 Describe the back-shunt method of keying an arc transmitter.**

*Answer.* Figure 6-12 illustrates the back-shunt system of arc keying. The back-shunt relay is actuated by a solenoid excited from the ship's

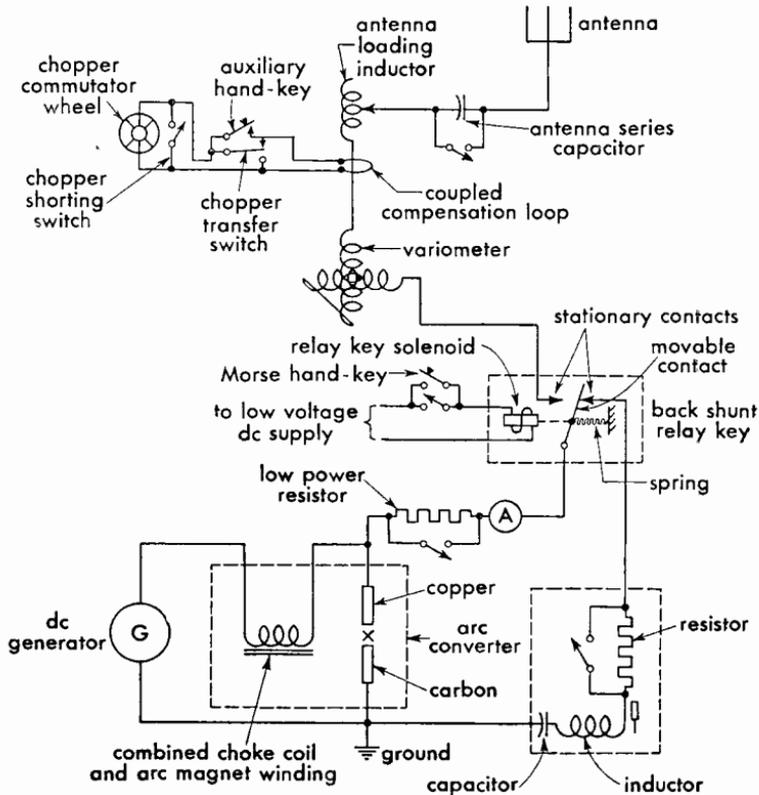


FIG. 6-12. Arc back-shunt signaling system.

direct current and controlled by a small Morse hand key in series with the solenoid. When the key is open, the back-shunt relay arm is con-

nected to a closed absorption circuit into which the arc oscillates. When the key is closed, the arc is transferred to the antenna oscillatory system. This results in a uniwave signal emission, enables the operator to adjust the arc for maximum stability when the key is open, and eliminates unnecessary adjustment interference.

**6.682** Of what material is the anode of a marine arc transmitter composed?

*Answer.* Copper.

**6.683** Compare the advantages and disadvantages of a modern marine vacuum-tube transmitter and a marine spark transmitter.

*Answer.* The modern marine vacuum-tube transmitter has several very important advantages over the spark transmitter, namely:

1. Greater transmission coverage.
2. Creates less interference.
3. Lower frequency deviation (greater stability).
4. Requires less adjustment.
5. Lower power consumption (relatively).
6. Tunes over a greater frequency band.
7. Permits large variation of tonal frequency.
8. Permits simpler antenna design (physical).
9. Possesses greater flexibility.
10. Efficient on low and high powers.

The spark transmitter has an advantage only in that it does not require replacements, such as tubes. It transmits a relatively broader wave, which is desirable for distress transmissions only. It has less component parts to go out of order. It is useless for high-frequency (short-wave) transmission. It has very poor efficiency.

**6.684** What is meant by a "self-rectified" circuit, as employed in marine vacuum-tube radiotelegraph transmitters?

*Answer.* Figure 6-13 illustrates a typical marine "self-rectifying" circuit. The plates of the tubes receive their voltage supply from the secondary winding of a high-voltage transformer. Since the plates are excited by an alternating voltage each tube is conductive only on alternate portions of the charging cycle, hence the name of self-rectification. If one tube is used in the oscillatory circuit, and the a-c plate frequency from the power transformer is 500 cycles, the tone frequency

of the radiated wave will be 500 cycles. If two tubes are used, full-wave self-rectification will result and the tonal frequency will be 1,000 cycles.

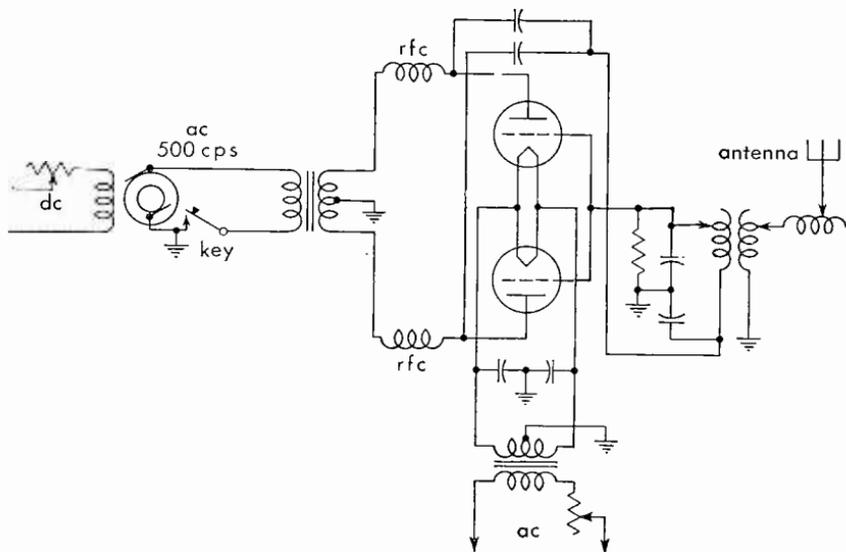


FIG. 6-13. Marine self-rectifying transmitter circuit.

**6.685** What is the principal advantage to be gained by the use of a crystal-controlled oscillator in a marine radiotelegraph transmitter?

*Answer.* The crystal-controlled oscillator reduces frequency drifting to a minimum and, therefore, ensures more stabilized transmission.

**6.686** Discuss the advantages and disadvantages of self-excited as compared to master-oscillator power-amplifier transmitters?

*Answer.* The self-excited oscillator has one important advantage over the master-oscillator power-amplifier system in that it requires only one tube. Greater power output can be obtained with a minimum of tubes. Less component parts are required and, therefore, simpler tuning is obtained. One of the great disadvantages, however, is the inability of this type of oscillating system to maintain a steady carrier frequency. Frequency variations are produced by circuit-load changes, particularly the antenna system. Changes in the antenna constants, caused by swinging, and varying humidity and temperature greatly affect the carrier frequency. Certain systems in which the self-excited

oscillator is also modulated causes considerable frequency fluttering and distortion. Broad tuning and interference may result. All of these disadvantages are overcome by the master-oscillator power-amplifier system.

**6.709** What factors determine the setting of the sensitivity control of an autoalarm receiver approved for installation on a vessel of the United States?

*Answer.* Optimum sensitivity and the prevention of receiver blocking by heavy static.

**6.710** If you were a radio operator on a vessel of the United States, equipped with an approved autoalarm which employs a linear detector and an electronic selector, what factors would cause the bell to sound? The warning lights to operate?

*Answer.* The bells would be caused to ring by any of the following:

1. Receipt of an autoalarm signal.
2. Receipt of a false-alarm signal caused by a combined static and keying interference (rare).
3. Failure of ship's line voltage or junction-box fuse.
4. Burned-out tube filament.
5. Failure of the 6-volt battery supply.

The warning lights may be caused to glow by any of the following:

1. Reception of signals where the key is depressed for a period considerably greater than 4.5 sec.
2. Sensitivity control set too high for the prevailing noise level.

Warning lights may glow intermittently because of:

1. Occasional long bursts of static.
2. Keying interference due to dashes in excess of 3.5 sec.
3. Heavy 500-kc interference due to simultaneous transmission of several radiotelegraph transmitters.

**6.711** If you were a radio operator on a vessel of the United States, equipped with an approved autoalarm which employs a linear detector and an electronic selector, what would result upon failure of a vacuum-tube filament?

*Answer.* The bells would ring.

**6.712** With an autoalarm of the type which employs a linear detector and an electronic selector, what is the most probable cause of the intermittent ringing of the bells?

*Answer.* This would probably be caused by a fluctuating line voltage beyond certain limits.

**6.713** With an autoalarm of the type which employs a square-law detector and a mechanical selector, what factors cause the bell to sound? The warning lights to operate?

*Answer.* The bell will ring upon:

1. Receipt of true-alarm signal.
2. Receipt of false-alarm signal.
3. Failure of equipment in autoalarm, such as
  - a. Failure of any heater.
  - b. Storage-battery voltage too low.
  - c. Selector fuse on battery charger blown or 24-volt circuit open.
  - d. Motor stopped or running too slow.
  - e. Heater circuit or 24-volt circuit to receiver open.
  - f. Ground on alarm-bell circuit.

The warning lights will operate upon the reception of a long dash or because of strong local noise or static conditions. The remedy is to reduce the sensitivity control. The warning lights also operate when the ship's d-c power fails or falls below 70 volts, thereby switching in the auxiliary B batteries.

**6.714** If an autoalarm bell rings, and upon pressing the release button it does not stop, what could be the cause(s)?

*Answer.* Since the button is designed to break the bell circuit (in series) it is evident that the bells are electrically grounded or the relay arm is stuck in the closing position.

**6.715** If an autoalarm bell rings, and upon pressing the release button it stops, what could be the cause(s) of the ringing?

*Answer.* Receipt of alarm signal, true or false. This condition may also be caused by the closing of the selector relay and is brought about by a break after a series of four dashes has been received.

**6.716** With an autoalarm of the type which employs a square-law detector and a mechanical selector, why does this alarm receiver not respond to type A1 emission?

*Answer.* Type A1 emission is a continuous wave of constant amplitude; hence it cannot produce detector action when impressed on the grid of the square-law detector.

**6.717** From how many simultaneous directions is a direction finder capable of receiving signals if adjusted to take unilateral bearings through 360 deg?

*Answer.* From one direction only.

**6.718** What figure represents the reception pattern of a properly adjusted unilateral direction finder?

*Answer.* A cardioid (heart-shaped) figure as shown in Fig. 6-14, the heavy-line curve being the cardioid.

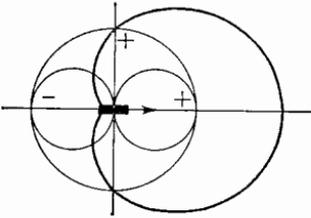


FIG. 6-14. Loop antenna unilateral characteristic.

**6.719** What is the principal function of a vertical antenna, associated with a unilateral direction finder?

*Answer.* To determine definitely the "sense" of direction.

**6.720** What is the principal function of the vertical antenna associated with the bilateral radio direction finder?

*Answer.* To provide proper balance and thereby minimize distortion of local field by nearby metal objects.

**6.721** Why are loop antennas, associated with direction finders, metallically shielded?

*Answer.* Metallic shielding minimizes the so-called "antenna effect." It reduces deviation due to capacitance effects with the ground.

**6.722** What is a "compensator" as used with direction finders, and what is its purpose?

*Answer.* A "compensator" as used in direction finders is a device attached to the loop shaft which mechanically compensates the error on the compass indicator for the deviation caused by antenna effect owing to the presence of nearby metallic objects. This mechanical compensator automatically causes the compass indicator to lag or lead the plane of the direction-finder loop by the necessary amount to assure correct compensation.

**6.723** How is the unilateral effect obtained in a direction finder?

*Answer.* By the use of a small vertical antenna coupled to the loop

direction finder. If a small vertical antenna is coupled to the loop antenna and both are tuned to resonance, the two voltages at the input grid will have either a 0- or 180-deg phase relationship. A cardioid pattern such as illustrated in Fig. 6-14 will be obtained.

**6.724** On shipboard, what factors may affect the accuracy of a direction finder, after it has been properly installed, calibrated, and compensated?

*Answer.* Antenna effect. This is generally due to direct pickup from nearby metallic objects, but these may be minimized by proper compensating adjustments. If all adjustments are properly made, the trouble is generally due to an erratic variation of the sky wave at night compared with ground waves. This is known as "night effect."

**6.725** What is indicated by the bearing obtained by the use of a bilateral radio direction finder?

*Answer.* The line of direction along which the signal is traveling.

**6.726** What is indicated by the bearing obtained by the use of a unilateral direction finder?

*Answer.* The sense of direction from which the signal emanates.

**6.727** If the vacuum-tube heater burns out, in an approved autoalarm, what causes the warning bells to ring?

*Answer.* The operation of a special relay in the receiver. This relay is in series with the heaters and controls the bell circuit.

**6.728** What is the function of the balancing capacitor in a direction finder?

*Answer.* To provide the proper loop balance; that is, to balance out the stray capacitance and inductive effects existing between the loop and ground. It permits the obtaining of a sharper null point.

**6.729** What signal will cause an approved autoalarm receiver to ring the warning bell?

*Answer.*

1. Receipt of true-alarm signal.
2. Receipt of false-alarm signal.
3. Failure of equipment in autoalarm.

The following equipment troubles will cause the bell to sound:

1. Failure of any heater.
2. Storage-battery voltage too low.
3. Selector fuse on battery charger blown.
4. Motor stopped or running too slow.
5. Vacuum-tube heater circuit or 24-volt circuit to receiver open.
6. Ground on alarm-bell circuit.

**6.730** To what frequency, or band of frequencies, is an approved autoalarm receiver tuned?

*Answer.* A band of frequencies ranging from 492 to 508 kc.

**6.731** What is the maximum permissible rms (root-mean-square) value of audio voltage which can be applied to the grid of a class A audio amplifier which has a grid-bias value of 10 volts?

*Answer.* Since the peak value must not exceed the 10-volt grid bias, the rms value of the audio signal must not exceed 7.07 volts.

$$E_{\text{rms}} = E_{\text{peak}} \times 0.707$$

**6.732** What is the effect of leakage in the coupling capacitor in an impedance or resistance-coupled audio-frequency amplifier?

*Answer.* Serious distortion will occur. This is so because the control grid of the succeeding tube will be positive with respect to cathode. A heavy rise in plate current and lowering in the plate voltage will occur, thereby seriously altering the plate  $I_p$ - $E_g$  curve.

**6.733** What is the d-c plate voltage of a resistance-coupled amplifier stage which has a plate-supply voltage of 260 volts, a plate current of 1 milliamperere, and a plate-load resistance of 100,000 ohms?

*Answer.* The potential difference between the plate and the cathode of the tube will be 160 volts.

$$E = IR = 100,000 \times 0.001 = 100 \text{ volts}$$

$$260 - 100 = 160 \text{ volts}$$

**6.734** List four causes of distortion in a class A audio amplifier.

*Answer.*

1. Excessive grid excitation.
2. Improper grid-bias adjustment.

3. Improper plate-supply voltage adjustment.
4. Improper value of load impedance.

**6.735** In a self-biased radio-frequency amplifier stage having a plate voltage of 1,250 volts, a plate current of 150 milliamperes, a grid current of 15 milliamperes, and a grid-leak resistance of 4,000 ohms, what is the value of the operating grid bias?

*Answer.*  $E = IR = 0.015 \times 4,000 = 60$  volts

**6.736** In a radio-frequency amplifier, employing fixed bias, as the plate circuit is varied in adjustment from a point below resonance to a point above resonance, what effect will be observed on the grid current?

*Answer.* The grid current will normally rise slightly as the plate-tank circuit is tuned through resonance.

**6.737** What is the primary function of the power-amplifier stage of a marine radiotelegraph transmitter?

*Answer.* To develop the power input for the antenna system and to provide the suitable coupling transfer. It also permits better frequency stability by isolating the oscillator from the antenna.

**6.738** In a series-fed plate circuit of a vacuum-tube amplifier, what would be the effect of a short circuit of the plate-supply bypass capacitor?

*Answer.* It would short-circuit the power supply.

**6.739** In a shunt-fed plate circuit of a vacuum-tube amplifier, what would be the effect of an open circuit in the plate radio-frequency choke?

*Answer.* The plate voltage would be removed from the tube plates.

**6.740** What is the function of a dummy antenna?

*Answer.* The dummy antenna is a noninductive resistance which serves as a substitute for the antenna or transmission-line resistance in making transmitter-circuit adjustments without the use of an antenna. Or it may comprise a resistance and suitable reactance to simulate the characteristics of an electrically similar antenna. It permits making power-amplifier output adjustments without creating unnecessary interference.

**6.741** What is the primary advantage to be obtained by shunting a high-resistance fixed resistor across each unit of a high-voltage series capacitor bank in the power-supply filter circuit of a transmitter?

*Answer.* To equalize the voltage drop across each capacitor, distribute the strain, and to discharge the capacitors after shutdown.

**6.742** What is the effect of an inductance connected in series with the antenna circuit?

*Answer.* It increases the fundamental wavelength of the antenna; that is, it decreases the antenna resonant frequency.

**6.743** If a vacuum tube in the only radio-frequency stage in your receiver burned out, how could you make temporary repairs to permit operation of the receiver if no spare vacuum tube was available?

*Answer.* The plate winding of the radio-frequency transformer may be used as the antenna primary coil. A coupling capacitor from the antenna to the plate side of the radio-frequency tube socket may be used.

**6.744** What is the meaning of "high-level" modulation?

*Answer.* "High-level" modulation is that system in which the modulated-amplifier stage is also the final power-amplifier stage.

**6.745** What is the meaning of "low-level" modulation?

*Answer.* "Low-level" modulation is that system in which the modulated radio-frequency-amplifier stage precedes the final power-amplifier stage.

**6.746** If the plate current of the final radio-frequency amplifier in a transmitter suddenly increased and radiation decreased, although the antenna circuit is in good order, what would be the possible causes?

*Answer.* This may be due to a short-circuited turn in the secondary of the output-coupling transformer, a short-circuited secondary-shunt tuning capacitor, poor neutralization, or a gassy tube.

**6.747** A master-oscillator power-amplifier transmitter has been operating normally. Suddenly the antenna ammeter reads zero,

although all filaments are burning and plate and grid meters are indicating normal voltages and currents. What would be the possible cause(s)?

*Answer.* This would be due to an open- or short-circuited ammeter movement, assuming that the associated shunt is unaffected. It might also be caused by a defective thermocouple.

**6.748** What could cause abnormally low voltage at the input power terminals of a lifeboat radiotelegraph transmitter, while it is in operation?

*Answer.* This may be due to a low state of charge of the supply battery or excessive overloading.

**6.749** What is the result of excessive coupling between the antenna and output circuits of a self-excited vacuum-tube transmitter?

*Answer.* Erratic operation, tube overloading, and frequency instability. (See 6.504.)

**6.750** What is the purpose of the iron compound cylinders which are found in the inductances of certain marine radiotelegraph transmitters? The position of the cylinders, with respect to the inductances, is adjustable for what purpose?

*Answer.* These are provided for variable reactance tuning. They are adjustable so that the inductance value may be changed, thus effecting a change in frequency adjustment.

**6.751** What is the most common cause of split tuning?

*Answer.* Improper adjustment of mutual coupling.

**6.752** Should the antenna circuit of a master-oscillator, power-amplifier transmitter be adjusted to the resonant frequency before the plate-tank circuit of the final stage? Give the reason(s) for your answer.

*Answer.* No. The tank circuit should first be resonated to the excitation frequency for a minimum plate-current indication on the d-c milliammeter. The antenna circuit is then tuned to resonance and the plate circuit readjusted to compensate for the antenna-loading effect. The minimum plate-current reading when the antenna is tuned to resonance with the plate-tank circuit will be higher than with untuned

antenna conditions, and the tuning for minimum current will be broader. Another reason for tuning the power amplifier first is that this stage must be neutralized before any antenna-transfer adjustments are made.

**6.753** In a transmitter involving a master oscillator, intermediate amplifier and final amplifier, describe the order in which circuits should be adjusted in placing this transmitter in operation.

*Answer.* From the master oscillator toward the antenna circuit.

**6.754** What is a "frequency-doubler" stage?

*Answer.* This is an amplifier in which the plate circuit is tuned to a harmonic of the grid-excitation frequency. It is generally adjusted to double that of the input frequency.

**6.755** Define "parasitic oscillations."

*Answer.* Spurious audio- or radio-frequency oscillations independent of the normal circuit frequency. They are commonly brought about by coupling between leads through parallel connecting of tubes.

**6.756** What is the effect of parasitic oscillations?

*Answer.* Erratic operation, circuit instability, spurious signals, possible serious overheating of the tubes, overloading, and decreased efficiency.

**6.757** What may cause a radio-frequency amplifier tube to have excessive plate current?

*Answer.* Improper neutralization, parasitic oscillation, excessive radio-frequency drive, insufficient load impedance, insufficient grid bias, excessive plate voltage, improper output tuning, incorrect voltmeter or ammeter, gassy tube.

**6.758** What are some of the indications of a defective vacuum tube in a transmitter?

*Answer.* Low plate-current readings if the trouble is due to low-filament emission, or excessive plate current if the tube has developed gas. Unstable readings during operation will result.

**6.759** At what point on a shipboard antenna system will the maximum potential be noted?

*Answer.* At the insulators, particularly at the one farthest away from the leadin. This is generally referred to as the free or high-potential end.

**6.760** What is the effect upon a transmitter of dirty or salt-encrusted antenna insulation?

*Answer.* Decreased radiation, erratic antenna, and plate milliammeter readings; increased corona or brush discharge losses; increased leakage losses.

**6.761** Why do many marine transmitters employ variometers rather than variable capacitors as the tuning adjustments?

*Answer.* Because, in order to maintain a proper  $Q$  for various frequencies, the inductance rather than the capacitance of the oscillatory circuit must be varied. The use of variometers also permits constant  $LC$  ratio.

**6.762** What is the relationship between the antenna current and radiated power of an antenna?

*Answer.* The antenna-current-squared value times the antenna resistance gives a true measure of radiated power, at any given frequency. It is assumed that the current is measured at a current loop. If it is not, the actual radiated power may be different, and the apparent current will vary with the same input power at different frequencies.

**6.763** Why is a self-excited oscillator transmitter undesirable for shipboard service?

*Answer.* Because of its frequency instability.

**6.764** What is the fundamental difference(s) between the Hartley and Colpitts oscillators?

*Answer.* Both circuits obtain grid excitation directly from the resonant circuit, the Hartley from a portion of the tank coil, which is split for this purpose, and the Colpitts from a portion of the tank capacitance through a split-capacitor arrangement.

**6.765** How is the keying of a simple oscillator emergency marine transmitter usually accomplished?

*Answer.* Transformer primary keying is generally used.

**6.766** If you found that it was impossible to keep the receiver-storage A battery charged and at the same time, maintain the required watch period, what remedy may be found?

*Answer.* The emergency power supply on board a cargo vessel (on which a separate main and emergency installation is not provided), subject to Title III, Part II of the Communications Act, while being navigated in the open sea, is authorized to be used only for emergency communication except that it may be used for routine communication for a period not to exceed one hour per day in the aggregate. However, a storage battery which is the emergency power supply or a part thereof, may be used at any time to maintain a watch for safety purposes if such use will not reduce the ability of the emergency power supply to energize the emergency installation for a period of at least six consecutive hours.

**6.811** List four principles by which an emf may be generated by sound waves.

*Answer.*

1. Resistance variation (carbon microphone).
2. Electromagnetic (dynamic, or ribbon microphone).
3. Piezoelectric (crystal microphone).
4. Electrostatic (condenser microphone).

**6.812** What is indicated in a radiotelephone transmitter by an increase in antenna current without carrier shift?

*Answer.* Modulation must be taking place.

**6.813** What methods may be used to reduce fringe howl in a regenerative receiver?

*Answer.* Fringe howl may be eliminated by shunting a 100,000-ohm resistance across the primary winding of the detector audio-frequency transformer, or more usually, across the secondary.

**6.814** Knowing the intermediate frequency and the signal to which a superheterodyne receiver is tuned, how would you determine the most probable frequency on which "image" reception would occur?

*Answer.* Any complement of frequencies other than the one to which the receiver is tuned which will give the value of the intermediate

frequency. In other words, the sum of the desired signal frequency and twice the value of the intermediate frequency is the "image" frequency.

**6.815** How is the degree of coupling varied in a pi network used to transfer energy from a vacuum-tube plate circuit to an antenna?

*Answer.* A pi network is shown in Fig. 4-8. The coupling is usually varied by adjusting the series inductance. To increase coupling decrease inductance, and vice versa.

**6.816** What means are usually provided to prevent operation of the ship's transmitter when the autoalarm receiver is in use?

*Answer.* The transmitter key-relay power-supply circuit is opened when the autoalarm receiver is in use.

**6.817** Explain how you would determine the value of the cathode-bias resistor for a specific amplifier stage.

*Answer.* By referring to the tube characteristic chart for the proper operating voltages and currents, the bias resistor may be calculated by the formula

$$R_{\text{bias}} = E_c / I$$

where  $I$  is the total return currents flowing to the cathode, namely, the plate and screen-grid currents.

**6.818** In a class A audio-frequency amplifier, what is the main advantage obtained through the use of two triodes in push-pull as compared to parallel operation?

*Answer.* Balancing out of the second harmonic component, hum, and subsequent distortion. Greater power output and prevention of core saturation in the transformer plate winding.

**6.819** Explain briefly the construction and characteristics of a beam power tube.

*Answer.* The basic structure of the beam tube is practically the same as for any pentode with the exception that an extra reflecting or beam-forming plate is placed near the plate so that the electrons are uniform in their progress towards the plate. This concentration of the

electron stream towards the plate gives rise to a perfectly uniform distribution of the space charge. The control and screen grids are so aligned that the wires of the latter fall in the shadow of the former. Far greater power-output capabilities are achieved.

**6.820** Explain the operating procedure employed in neutralizing a radio-frequency power amplifier, using a thermocouple ammeter as an indicating device.

*Answer.* Open the plate-supply switch to the radio-frequency stage to be neutralized. Open up the main power switch to all tubes and discharge all high-voltage capacitors. Insert a thermocouple galvanometer into the low-potential side of the plate-tank circuit of the stage to be neutralized. Engage the neutralizing capacitor about one-third position. Close the main power switch but leave the plate-supply switch of the amplifier open. Increase the radio-frequency drive gradually and tune all circuits to resonance. Observe the reading on the thermocouple galvanometer and vary the neutralizing capacitor until this reading is a minimum or, preferably, zero. Remove the thermocouple galvanometer and insert the regular ammeter. Close the high-voltage plate-supply switch to the radio-frequency amplifier just neutralized. Carefully recheck and balance all circuits to minimum plate-current dips.

**6.821** For what purposes are decoupling networks used in audio-frequency amplifiers?

*Answer.* Decoupling networks are employed to stabilize amplifier operation. These networks reduce the common impedance coupling relations between circuits and thereby prevent regenerative effects and self-oscillation. Distortion is reduced and quality of reproduction is greatly improved.

**6.844** What is meant by the "time constant" of certain electric circuits containing resistance and capacitance?

*Answer.* See 4.172.

**6.845** What is the reactance of a 0.01- $\mu$ f capacitor at a frequency of 3,000 cycles? What is the reactance of a 2-henry choke coil at the same frequency?

*Answer.* A capacitive reactance of 5,308 and an inductive reactance of 37,680 ohms.

$$X_c = \frac{1,000,000}{2\pi fC} = 5,308 \text{ ohms}$$

$$X_L = 2\pi fL = 37,680 \text{ ohms}$$

**6.846** What is the resonant frequency of a tuned circuit consisting of a capacitor of 500  $\mu\mu\text{f}$ , a tuning coil of 150 microhenrys, and a resistance of 10 ohms?

*Answer.* 581 kc.

$$f_{\text{cps}} = \frac{1}{2\pi \sqrt{LC}} = \frac{10^6}{1.72} = 581,000 \text{ cps or } 581 \text{ kc}$$

**6.847** Draw a diagram of a crystal-detector receiver and explain its principle of operation. Name two substances that can be used as the crystal in such a receiver.

*Answer.* See 3.234 and 6.377.

**6.848** In the operation of a regenerative receiver how is oscillation of the detector indicated?

*Answer.* The plate-current flow as indicated by a milliammeter in the detector circuit will show a sharp decrease when the detector goes into oscillation. (See also 6.650.)

**6.849** Draw a diagram of a superheterodyne receiver with automatic volume control, and explain the principle of operation.

*Answer.* Figure 6-15 illustrates a basic superheterodyne receiver with automatic volume control.

The operation of this circuit is briefly as follows: An incoming modulated signal impressed across the grid and cathode of the first detector, or mixer tube, develops a radio-frequency signal component in the plate circuit. The oscillator develops a similar plate-current variation in the same plate circuit but of a higher frequency. The two plate-current components develop a resultant "beat" or "intermediate frequency" which alone passes through the intermediate-frequency amplifier. This signal is amplified through one or more of these stages and is then rectified in the diode detector circuit. The rectified or audible signal is then further amplified in the audio-frequency amplifier circuit.

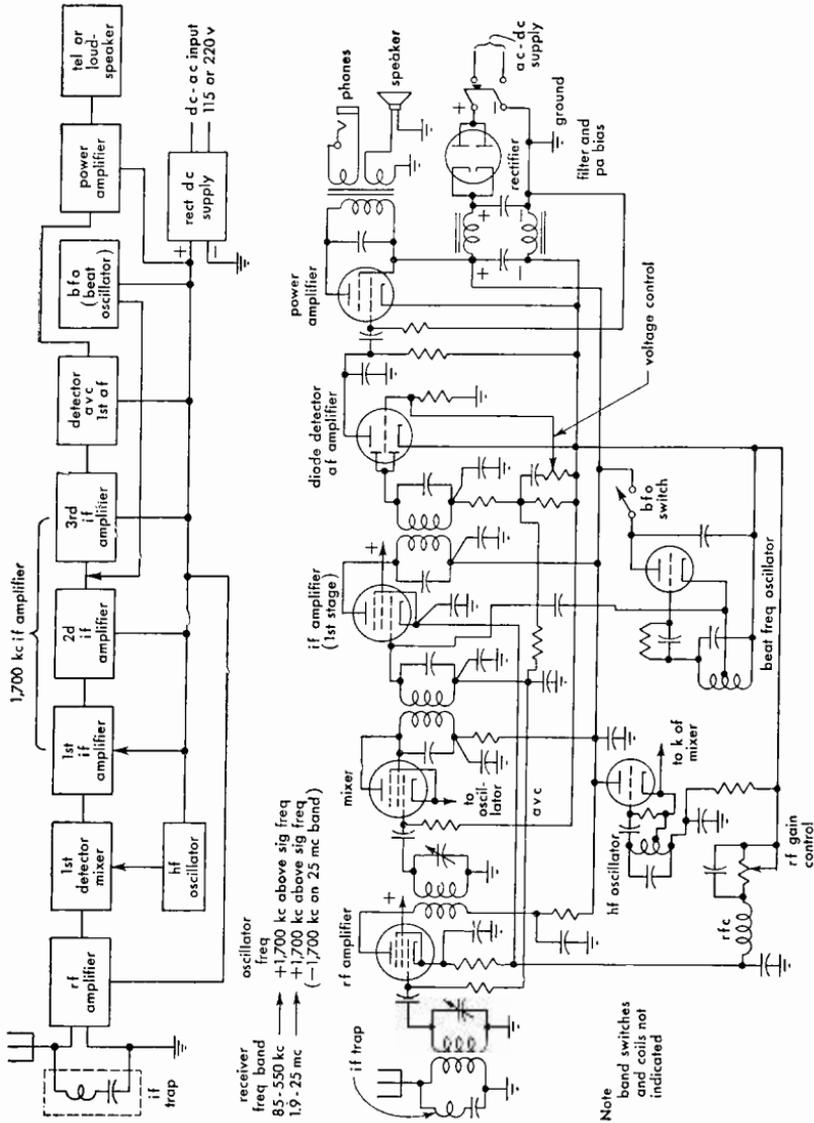


Fig. 6-15. Block and schematic diagrams of marine-type superheterodyne receiver.

A portion of the rectified signal is used to develop a negative voltage with respect to the diode cathode to apply an additional negative voltage to the grids of the intermediate-frequency amplifier tubes. This voltage varies in accordance with the signal amplitude and, when strong signals are applied, produces a control or throttling effect on very strong peak signal voltages. This leveling action is referred to as automatic volume control.

**6.850 Define the following terms in reference to vacuum tubes: amplification factor, plate resistance, mutual conductance, and maximum inverse plate voltage.**

$$\text{Answer. Amplification factor} = \mu = \frac{de_p}{de_g} (i_p \text{ constant})$$

$$\text{Plate resistance } r_p = \frac{de_p}{di_p} (e_g \text{ constant})$$

$$\text{Mutual conductance } g_m = \frac{di_p}{de_g} (e_p \text{ constant})$$

Plate resistance or plate impedance (a-c resistance),  $r_p$ , is expressed as the plate-voltage change divided by the resulting plate-current change in a vacuum tube, all other conditions being fixed. This must not be confused with the d-c plate resistance, which is merely the steady plate voltage divided by the steady plate current flowing in the tube.

Maximum inverse plate voltage refers to the conduction ability of a gas or vacuum tube to conduct in the reverse direction at certain potentials. The maximum inverse plate voltage is approximately three to four times the normal d-c output voltage. It is essentially the maximum voltage a rectifier tube will withstand across its plate cathode during the nonconducting portion of the rectified cycle without flash-back. (See also 4.93.)

**6.851 Draw a simple schematic diagram of a spark transmitter, and explain its principle of operation.**

*Answer.* The spark-discharge oscillatory circuit consists of a transformer, which supplies power to the capacitor of an oscillatory circuit consisting of a capacitor, a spark gap, and an inductor in series. An analysis of the supply-line low-frequency charging cycle applied to the capacitor would show that, from 0 to 90 deg of the charging cycle, the capacitor charges. Electrostatic lines of force around the capacitor ear gradually increasing. As the charging cycle approaches 90 deg, an

excessive electrostatic strain is manifested between the points of the spark gap. When the potential difference across the spark gap reaches the rupture point, there is a breaking up of air particles between the electrodes into ions. This is called ionization of the spark gap.

From 90 to 180 deg on the charging cycle, the capacitor discharges through the gap and the inductance, converting the electrostatic energy in the capacitor into electromagnetic energy. Because of the "flywheel" effect of the oscillatory circuit, this energy charges the capacitor in the opposite direction but to a decreased amplitude. The loss in energy is that caused by the dissipation of energy in the form of heat when the capacitor made its first discharge through the gap and the inductance.

From 180 to 270 deg, the same action as from 0 to 90 deg takes place with the exception that the charge on the capacitor is reversed owing to the reversal of the charging emf. The energy involved has continued to decrease owing to heat and light losses.

From 270 to 360 deg, the same action as from 90 to 180 deg takes place. These cycles of discharge continue back and forth until all of the energy is dissipated in heat.

It can be seen from this explanation that the spark gap functions as a trigger or valve, and therefore, if the coil is inductively coupled to a secondary coil connected in series with an open radiating circuit and both circuits are in tune, then the alternating field about the primary coil will cut the secondary and induce into it an emf, which will set the antenna into oscillation and radiate damped waves. If the proper discharge is to be obtained, the gap spacing must be carefully adjusted.

If the gap electrodes are too close, the capacitor will not receive a full charge and may discharge before 90 deg of the charging cycle. On the other hand, if the gap electrodes are too far apart, then the capacitor dielectric will be subjected to abnormal strain which will result in a puncture of the dielectric.

The period of damping in a circuit of this type is another important factor. For example, if the type of gap used does not radiate the heat quickly (deionize), then the oscillations will not die out very rapidly (low damping) and, consequently, will not permit a wave of low decrement to be emitted from the antenna system. This is due to reaction of the primary and secondary circuits on account of the high conductivity of the gap circuit.

Hence, for every discharge of the capacitor through the spark gap and the inductance, the electrostatic energy is converted into electromagnetic energy about the inductance and the connecting wires, and since the oscillations are of a high-frequency character and of a constantly changing polarity, the magnetic field about the inductance will be rising and falling at a definite frequency depending upon the values of the inductance and the capacitance in the circuit. Thus radio-frequency oscillations will be generated. (See Fig. 6-3.)

**6.852** Draw a simple circuit diagram of a transmitter using an oscillator coupled to the antenna, with the oscillator using a self-rectifying circuit for operation directly from an a-c generator.

*Answer.* See Fig. 6-13.

**6.853** Draw a circuit diagram showing the principle of operation of a telegraph keying relay.

*Answer.* See Fig. 6-5.

**6.854** If the power of a 500-kc transmitter is increased from 150 watts to 300 watts, what would be the percentage change in field intensity at a given distance from the transmitter? What would be the decibel change in field intensity?

*Answer.* (a) Approximately 41 per cent. (b) 3 db.

(a) Field intensity or field strength is proportional to antenna current. Hence if the power is doubled, the antenna current will increase 1.414 times ( $\sqrt{2}$ ) the initial value, or 41.4 per cent. An increase of power to four times will increase the antenna current and field strength to twice ( $\sqrt{4}$ ) the initial value.

(b) The decibel change in field intensity may be computed as follows:

$$\begin{aligned} \text{Gain in db} &= 20 \log_{10} \frac{I_1}{I_2} \\ &= 20 \log 1.414 \\ &= 20 \times 0.151 \\ &= 3.02 \end{aligned}$$

(See also 4.69 and 4.71.)

**6.855** If the antenna current at a 500-kc transmitter is reduced 50 per cent, what would be the percentage change in the field intensity at the receiving point?

*Answer.* The field intensity will be decreased 50 per cent. (See 4.69 and 4.71.)

6.856 If a 500-kc transmitter of constant power produces a field strength of 100 microvolts per meter at a distance of 100 miles from the transmitter, what would be the theoretical field strength at a distance of 200 miles from the transmitter?

*Answer.* 50 microvolts per meter. Assuming zero attenuation the theoretical field strength of a radiated wave is inversely proportional to the distance from the transmitting antenna. (See 4.205.)

6.857 What care should be taken in hoisting the antenna of a shipboard radiotelegraph station to avoid damage to the antenna wire and insulators?

*Answer.* Guide rope(s) should be employed during the hoisting process to prevent possible damage to the antenna wire and insulators. Avoid breaking or cracking insulators. Avoid kinking and weakening antenna wire.

6.858 Draw a sketch of a typical shipboard antenna for transmitting on 500 kc showing the supporting insulators, the safety link, and the lead-in wire. How does voltage vary along the length of the lead-in and along the antenna?

*Answer.* Figure 6-16 illustrates a typical shipboard-antenna installation.

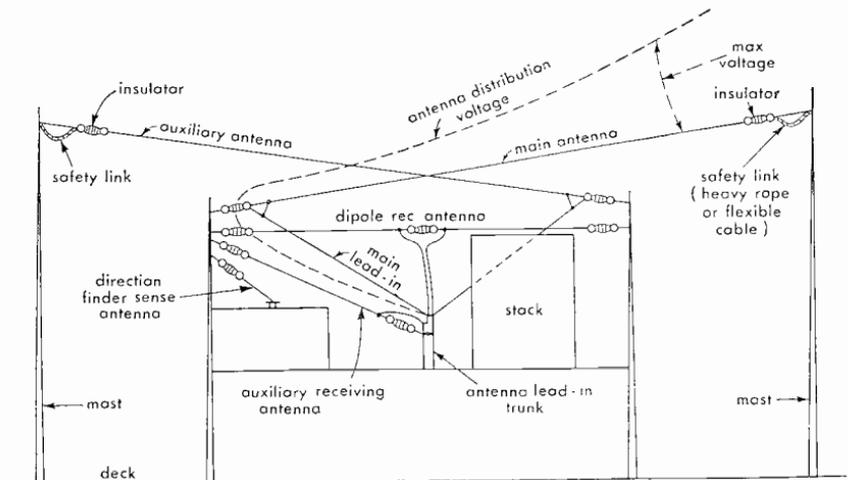


FIG. 6-16. Shipboard antenna installation showing lead-in and safety link.

A shipboard antenna designed for 500-kc operation is generally of the single-wire Marconi grounded or quarter-wave type. The leadin may be connected as a T or inverted L to the flat-top portion, depending upon physical limitations and frequency requirements.

The voltage distribution is illustrated in the diagram and is a maximum value at the free end of the flat-top portion of the antenna. The voltage at the base or transmitter terminal is a minimum, while the current distribution is in reverse relationship throughout the antenna system.

**6.859 How do multivibrator oscillators differ from Hartley oscillators? In what circuits do multivibrator oscillators find application?**

*Answer.* Hartley oscillators are essentially single-tube devices in which energy is coupled electromagnetically from the plate circuit back into the grid circuit, thus maintaining oscillations. A multivibrator oscillator is essentially a two-tube device (although the two tubes may exist within the same envelope) in which the plate output pulse from one tube turns on the second tube, by raising its grid potential. The second tube plate pulse then turns on the first tube again, the action continuing indefinitely. Whereas the Hartley oscillator is tuned by the inductance and capacitance of the tank circuit, the frequency of the multivibrator depends upon the time constants of the capacitors that couple the plate of one tube to the grid of another and the resistors from each grid to ground.

The Hartley oscillator is fundamentally a sine-wave device with relatively good frequency stability, determined by the high-Q tank circuit. The multivibrator is a square-wave device of poor frequency stability, but can be easily locked in to a stable frequency source. It is therefore frequently used as a frequency divider in frequency and timing standards of high precision. (See also 3.72, 3.436, 4.104, and 4.109.)

**6.860 Draw a simple circuit diagram of a multivibrator oscillator.**

*Answer.* See Fig. 4-11.

**6.861 List at least two essentials for making a good soldered connection.**

*Answer.* Most important of the many precautions necessary for a good soldered connection are: cleaning the conductors of all oxides and dirt, and heating the conductors to the melting temperature of the

solder. A dirty connection will show high resistance, will be mechanically weak, and may eventually corrode. If the joint is insufficiently heated, the solder may flow around it but cool so fast that it does not "wet" the conductors. Such a poor job is often referred to as a "cast" or "rosin" joint. It will eventually loosen and cause circuit noise or actual breakage of the contact.

Ordinary soldered connections in electronic and radio gear are made by scraping or otherwise completely cleaning both sides of the joint—two wires, or a lug and a wire. The joint is made mechanically secure so that it can not easily be pulled apart. Then a hot (never red-hot) soldering copper, well tinned and clean is held against the joint. A good grade of rosin-core solder is touched to the joint and allowed to flow around the conductors. Sometimes, it is convenient to touch the solder to the soldering copper and allow the molten solder to conduct heat into an irregular joint. Solder should be applied sparingly and the joint should be well heated, keeping in mind the possibility of damaging surrounding materials by heat. (See also 3.236.)

**6.862** Draw a circuit diagram showing how a microphone can be connected to an audio amplifier.

*Answer.* See Figs. 3-27 and 3-39.

**6.863** An absorption wavemeter indicates that the approximate frequency of a ship transmitter is 500 kc and at the same time the transmitter signal produces a zero beat on an accurately calibrated heterodyne frequency meter at a dial reading of 374.1. The frequency-meter calibration book indicates dial readings of 367.0, 371.5 and 376.0 for frequencies of 499.4/998.8, 499.6/999.2, and 499.8/999.6 kc, respectively. What is the frequency of the ship transmitter?

*Answer.* 499.71 kc.

*Solution:*

$$\begin{array}{r} \text{Dial div. } 376.0 = 499.8 \text{ kc} \quad 376.0 \\ \text{Dial div. } 371.5 = 499.6 \text{ kc} \quad 374.1 \\ \hline 4.5 = 0.2 \text{ kc} \quad 1.9 \text{ div} \end{array}$$

$$\frac{1.9}{4.5} \times 0.2 = 0.8444 \text{ kc (difference)}$$

$$\begin{array}{r} 499.8000 \text{ kc} \\ -0.0844 \text{ kc} \\ \hline 499.7156 \text{ kc} \\ 374.1 \text{ div.} = 499.7156 \text{ kc} \end{array}$$

**6.864** A certain frequency meter contains a crystal oscillator, a variable oscillator, and a detector. What is the purpose of each of these stages in the frequency meter?

*Answer.* The crystal oscillator serves as a substandard calibrator for adjusting the variable calibrated oscillator to zero beat with the harmonics of the crystal. The variable oscillator generates the various frequency bands of the instrument. The detector rectifies and makes audible the beats between the variable oscillator and the incoming radio-frequency signal that is being measured.

**6.865** What should be the approximate surge impedance of a quarter-wavelength matching line used to match a 600-ohm feeder to a 70-ohm antenna?

*Answer.* Approximately 205 ohms.

$$Z_0 = \sqrt{600 \times 70} = \sqrt{42,000} = 204.95 \text{ ohms}$$

(See also 4.204.)

**6.866** What determines the surge impedance of a two-wire non-resonant radio-frequency transmission line?

*Answer.* See 4.200.

**6.867** How should a radar set be adjusted by the operator to reduce "sea return"?

*Answer.* The receiver gain or sensitivity control must be adjusted to the point in which the amplitude of the sea return is reduced below that of the target echo. Some radars have an automatic-volume-control circuit which reduces the gain for the first few microseconds (sea returns at close proximity to the ship) and then restores the gain to normal for signal or target returns at greater distances. This is referred to as sensitivity time constant control, or STC.

**6.868** Approximately at what speed does the antenna of a navigational radar rotate?

*Answer.* Approximately 12 revolutions per minute. Commercial navigational types rotate between 6 and 15 rpm.

**6.869** What is the average plate-power input to a radar transmitter if the peak pulse power is 15 kilowatts, the pulse length is 2 microseconds, and the pulse repetition frequency is 900 cycles?

*Answer.* The average power is 27 watts.

$$T = \frac{1}{F} = \frac{1}{900} = 1,100$$

$$P_{\text{avg}} = P_{\text{peak}} \times \frac{\text{pulse width}}{T} = 15,000 \times \frac{2}{1,100}$$

$$= 15,000 \times 0.00181 = 27 \text{ watts}$$

Alternative method:

$$P_{\text{avg}} = P_w \times \text{PRR} \times P_p = 0.000002 \times 900 \times 15,000 = 27 \text{ watts}$$

**6.870 In what part of the radio-frequency spectrum do marine radar systems operate?**

*Answer.* Marine radar systems operate in the superhigh-frequency or microwave spectrum (3,000 to 30,000 mc or between 0.1 to 0.01 meters). The actual marine radar assignments are as follows:

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

Equipments in use utilize approximately 3,070 and 9,375 mc.

**6.871 If the velocity of a radio wave is 186,000 statute miles per second, how many nautical miles does a radar pulse travel in 1 microsecond?**

*Answer.* 0.186 statute miles, approximately 0.162 nautical miles. 186,000 statute miles is equivalent to approximately 161,599 nautical miles.

1,760 yards = 1 statute mile  
2,026.8 yards = 1 nautical mile

Since radio waves travel approximately 186,000 statute miles in a second, they travel one-millionth of this distance, or 0.186 statute miles, in a microsecond. This corresponds to a time of 5.37 microseconds required for a wave or pulse to travel 1 statute mile. Hence, since  $1,760/2,026.8 = 0.8678$ , the pulse will travel

$$0.8678 \times 0.186 = 0.1614$$

or approximately 0.162 nautical miles.

6.872 Draw a simple block diagram showing the essential components of a radar system. Label the components such as receiver, indicator, etc.

*Answer.* See Fig. 6-17.

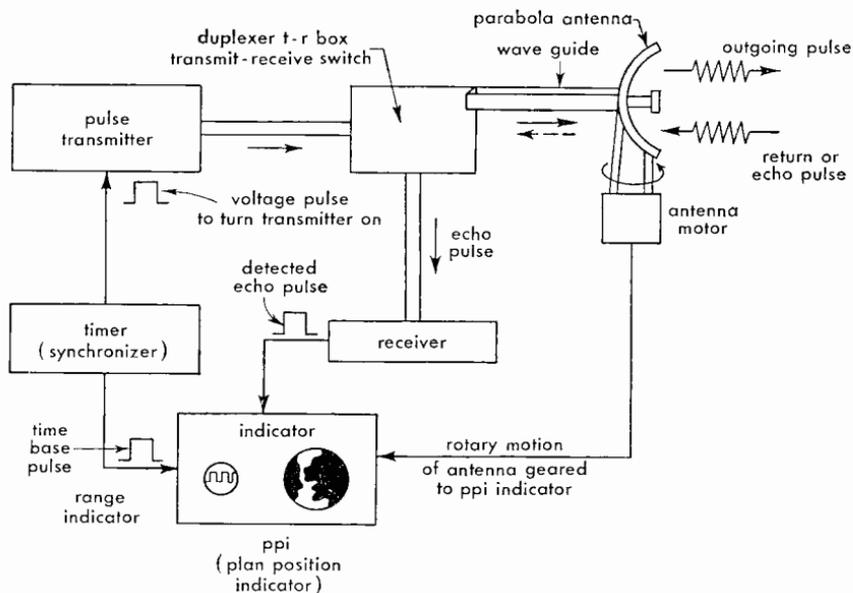


FIG. 6-17. Block diagram of radar components.

6.873 How can the operator of a loran receiver on shipboard identify the transmitting stations that are being received?

*Answer.* The receiving operator identifies a pair of stations by the radio frequency, basic pulse recurrence rate, and the specific pulse recurrence rate. When these are identical with the transmitted pair, the pulses appear to stand still on the indicator scope. In the loran system, the identification of the individual transmitting station has little significance to the navigator who is interested in the time delays resulting from the transmissions from pairs of stations. These families of delay curves are plotted on charts and are marked with simple designations that are duplicated in the loran-receiver control markings. The family of curves marked 1H3, for instance, is received when the loran receiver frequency control is set at 1 (1,950 kc), the basic pulse recurrence-rate switch is set at H (basic rate of  $33\frac{1}{3}$  pulses per second),

and the specific pulse recurrence-rate switch is set at 3 (actually  $3\frac{2}{3}$  pps). The signals that appear to stand still on the scope of a properly adjusted receiver-indicator are those from the pair 1H3. All others appear to move. It will be seen from a chart that the master station (the pip which should be placed on the top pedestal) is located at Siasconset (S) on Nantucket Island and the slave station (this signal pip will fall to the right on the lower trace) which is marked B on the chart is located at Baccaro, Nova Scotia. (See also 6.877.)

**6.874** During daytime hours approximately what is the maximum distance in nautical miles from loran transmitting stations that loran lines of position can be determined?

*Answer.* During the day, over water, loran lines of position can usually be determined up to 700 nautical miles from the pair of transmitting stations that generate these lines. Over land, during the daytime, the distance at which the signals can be used is much less. At night, a special technique using the first reflection of the signals from the nighttime *E* layer of the ionosphere extends the useful range to about 1,400 miles. More powerful transmitters will extend the ranges.

**6.875** In determining a "fix" or position by a marine loran system, what is the minimum number of land transmitters involved?

*Answer.* The minimum number of loran transmitters needed to obtain a navigational fix is three. A pair of synchronized stations generates a family of hyperbolic lines, the center line of which is straight and the others on each side curving so as to enclose the nearer station. The navigator finds that he is somewhere along one of these "lines of position." By switching to another pair of stations (usually the next pair up or down the coast), the navigator finds that he is on another line of position. Where the lines of position cross is the ship's location. In actual practice, one transmitter is usually common to two pairs of lines of position and is caused to be triggered at two rates. If this were not the customary procedure it would require a minimum of two pairs, or four transmitters for a fix.

**6.876** Explain why pulse emission rather than continuous waves are used by loran transmitters. Approximately what pulse repetition frequency, pulse duration, and operating frequency are used in loran systems?

*Answer.* The “hyperbolic” navigation systems depend upon the difference in time of arrival of signals from two different points. Since there is no simple way of “tagging” the starting cycle for identification, the simpler systems, like loran, use pulses that can be easily identified. It is necessary, of course, that the pulse duration, pulse repetition frequency, distance between synchronized stations, and the method of synchronism, be carefully chosen to aid in positive identification.

Pulse systems have the additional advantages of being much more readily distinguishable through noise and static, and they allow easy identification of signals reflected from the ionosphere. Pulse repetition frequencies based upon 25 pulses per second and 33.3 pps are generally used. The duration of the pulse from the transmitter is approximately 40 microseconds. Radio frequencies of 1,850 and 1,950 kc are used.

**6.877** When several pairs of loran transmitting stations are operating on the same frequency, how does the operator at a loran receiver select the desired pair of transmitting stations?

*Answer.* In the loran system, provision has been made to accommodate 16 pairs of stations on the same radio frequency. Eight pairs operate on a 25-pulse per second base rate and the other eight pairs use the 33.3-pps base rate. The navigator at the receiver selects the pairs of stations he wants by setting the specific rate switch for the pair desired. With the basic rate of 25 pps (L) and the specific rate 0, two stations with a pulse repetition rate of 25 pps will appear to stand still on the indicator scope. If the specific rate switch is changed to 1, the “rate 0” signals will appear to move and the “rate 1” pair will now appear to stop. The desired pairs of stations are therefore not tuned in by means of radio frequencies, but by means of their separate and distinctive pulse repetition frequencies.

**6.878** What is the relationship between a master and a slave station in reference to loran navigation systems?

*Answer.* For practical reasons that also serve to remove system ambiguities, one station of a loran pair is designated the master and sends out a series of regularly timed pulses. These pulses radiate uniformly in all directions and are received at the slave station. The slave station normally waits for 1,000 microseconds after receiving the master pulse and then sends out its pulse. The system as a whole

is set up so that the slave pulse is received at the master station before the "second" or next master pulse would normally be transmitted. No matter where a ship may be located with respect to the stations, the master pulse will always arrive at the ship's receiver at least 1,000 microseconds before the slave pulse, and usually there will be a much greater time interval. Adjustments necessary to maintain the proper delay between stations are made by the slave-station operator. However, the master-station operator monitors the delay and immediately notifies the slave station and all navigators by blinking if the delay is not properly maintained.

**6.879** Draw a simple sketch showing relative positions of pairs of master and slave stations of a loran navigation system, and indicate lines of position of each pair of stations.

*Answer.* See Fig. 6-18.

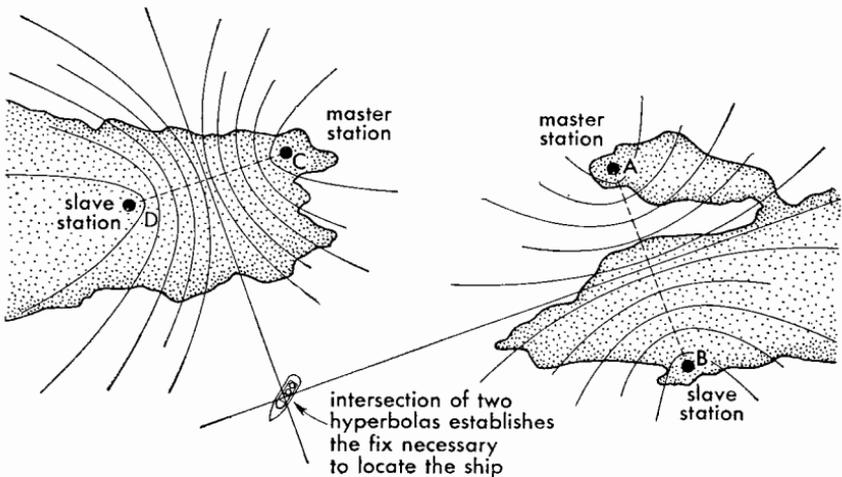


FIG. 6-18. Pairs of loran stations and lines of position.

**6.880** What is the purpose of "blinking" in a loran navigational system, and how is blinking recognized at the receiver?

*Answer.* Blinking of the loran signal or pair of signals shows that the system is temporarily out of adjustment and should on no account be used. Fixes obtained just before a blinking signal is received should not be accepted as accurate until they have been checked after blinking

stops. Blinking may appear either as an intermittent loss of signal or more usually, as a rapid, rhythmical movement of the signal from left to right (about 1,000 microseconds) on the "slow" sweep of the indicator scope. Pulses being viewed on the "fast" sweep usually disappear and reappear, because they move off the visible portion of the sweep.

**6.881 What precautions should an operator or serviceman observe when working with cathode-ray tubes and the associated circuits of radar and loran receivers?**

*Answer.* Because it is often impractical permanently to disconnect the main power while tracing trouble in radar and loran cathode-ray equipment, great care must be exercised not to forget that lethal voltages are used in these circuits. Whenever possible, an assistant should stand by ready to disconnect the main power (not the on-off switch on the set itself) in case of accident. The man making the repair should avoid touching any portion of the circuit while the power is on. If a mechanical adjustment is necessary, it should be made with an insulated screwdriver or similar nonconducting tool. If changes of parts are necessary, the repairman should develop a routine of disconnecting the main power and discharging power-supply capacitors with a grounding hook or clamp that remains in place. (And be sure that the lead to the grounding hook is grounded!) After this, the circuit change can be effected, the grounding hook or hooks removed, and the main power reconnected. A plug and receptacle connection for breaking main power to the set is preferable to a switch.

Cathode-ray tubes have been known to "implode," owing to some weakness and the tremendous force of atmospheric pressure on the outside of the glass. Occasionally when this has happened the face of the tube has blown out and bits of glass have been literally shot into surrounding walls. It is desirable, therefore, if tubes are removed from equipment, to store them in cartons; never to point them at anyone; to wear shatterproof goggles; and to use a pair of heavy gloves that still permit careful handling of the tube.

Equipment should be repaired and again secured in cabinets as quickly as possible in order to avoid accidental breakage or danger of electric shock. Remember, also, that most cathode-ray power supplies are hot both positive and negative with respect to ground. (See also 3.294.)

**6.886** Why do some ship radiotelegraph stations that are equipped with a direction finder employ an auxiliary receiving antenna for the receivers in the radio room?

*Answer.* On a vessel required by law to maintain a watch by a qualified operator or operators, an effective auxiliary antenna is often provided to avoid unauthorized interruption of the watch during use of the radio direction finder on board the same vessel. An auxiliary antenna is also required with direction-finder equipment to indicate the sense of the bearing because the loop is bidirectional in its response.

**6.887** Describe the construction and operation of a shielded loop antenna as used with a marine direction finder.

*Answer.* A representative shielded loop antenna comprises a number of turns of wire insulated from, and enclosed in, a circular metal tube. The tube is not continuous but is split at the top, the gap being filled with insulating material of adequate mechanical strength.

The two ends of the wire loop pass down a supporting tube, integral with the bottom of the loop, to a shielded direction-finding receiver, usually by way of slip rings and a shielded transmission line that allow the loop structure to be continuously rotated.

A scale is attached to the mechanism by which the loop is rotated so that direction in degrees can be read off directly.

The metal tubing acts as an electrostatic shield, but since it is not joined at the top it is not an electromagnetic shield. This shielding improves the accuracy of the loop in determining direction.

When the plane of the loop is aimed in the direction of a transmitting station and the receiver is tuned to the proper frequency, a maximum signal is received. This effect is caused by the fact that the radio wave encounters the front turns of the loop before it encounters the rear turns, resulting in a difference of potential across the terminals.

In operation, the plane of the loop is turned at right angles to the station and a null, or minimum signal, is sought. The null gives a much sharper indication of direction than the maximum signal. The signal null or minimum results from the fact that the radio wave encounters both halves of the loop at the same instant so that there is no potential difference across the ends of the loop.

In a properly operating loop, there is a 180 deg ambiguity regarding the direction of the transmitting station. In practice, therefore, an auxiliary vertical sensing antenna is momentarily switched onto the

receiver in order to determine from which direction the signal is arriving. This is necessary because a vertical antenna is nondirectional and develops a circular reception pattern. If, therefore, the energy from the antenna and the loop circuit are fed to the receiver in time phase, a cardioid or directional pattern will be produced.

A practical operating procedure follows:

1. Close direction-finder switch.
2. Disconnect the main antenna.
3. Tune for a desired radio beacon signal (rotate loop for maximum response).
4. Reorient loop for a minimum response in the telephones.
5. Adjust balance control for a sharp minimum. (The minimum should be critically adjusted by slight orientation of the loop and intensity control to obtain a zero or null point condition or no response in the telephones.)

**6.888** Draw a sketch showing how a "fix" on a ship station can be obtained by taking direction-finder bearings.

*Answer.* See Fig. 6-19.

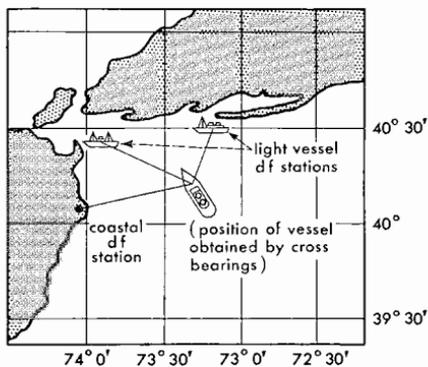


FIG. 6-19. Determining a fix with a direction finder on shipboard.



POWER SUPPLIES, BATTERIES,  
MOTORS, MOTOR-GENERATORS,  
INDICATING INSTRUMENTS

[Elements: 3, 4, 6]



## Element 3

# Basic Radiotelephone (Power)

**3.147** What is the chemical composition of the active material composing the negative plate of a lead-acid storage cell?

*Answer.* Pure sponge lead, Pb.

**3.148** What is the chemical composition of the active material composing the negative plate of an Edison storage cell?

*Answer.* Iron oxide.

**3.149** What is the chemical composition of the active material composing the positive plate of a lead-acid storage cell?

*Answer.* Lead dioxide,  $\text{PbO}_2$ .

**3.150** How does a primary cell differ from a secondary cell?

*Answer.* A secondary cell can be recharged; a primary cell cannot be recharged. As used in radio the secondary cell is either the familiar lead-type or the Edison storage battery; the primary cell is a dry cell.

**3.151** What is the chemical composition of the active material composing the positive plate of an Edison storage cell?

*Answer.* Nickel hydroxide and exceedingly thin flakes of pure nickel.

**3.152** What is the chemical composition of the electrolyte used in an Edison storage cell?

*Answer.* A 21 per cent solution of potassium hydroxide mixed with distilled water to which is added a small amount of lithium hydrate.

**3.153** What is the chemical composition of the electrolyte of a lead-acid storage cell?

*Answer.* A dilute solution of sulphuric acid mixed with distilled water. Specific gravity at full charge, usually 1.280.

**3.154** What is "polarization" as applied to a primary cell, and how may its effect be counteracted?

*Answer.* "Polarization" is the formation on the surface of the positive electrode of a cell of a film of hydrogen bubbles. This film sets up a counter emf which results in a so-called "polarization current." Polarization also increases the resistance between the electrolyte and the positive plate, resulting in a further decrease in the capacity of the cell. The effects of polarization can be minimized by the use of a depolarizing agent. The depolarizer, when the electrolyte is sulphuric acid, may be cupric sulphate or, if the electrolyte is sal ammoniac, manganese dioxide.

**3.155** Describe three causes of a decrease in capacity of an Edison storage cell.

*Answer.*

1. Allowing the temperature to go above 115 deg Fahrenheit.
2. The aging of the electrolyte.
3. The adding of impure water to replace that lost by evaporation.

**3.156** What is the cause of the heat developed within a storage cell under charge or discharge condition?

*Answer.* Charging or discharging the cell at too high a rate, raising the  $I^2R$  drop.

**3.157** How may a dry cell be tested to determine its condition?

*Answer.* By a voltage test under normal full-load conditions.

**3.158** What will be the result of discharging a lead-acid storage cell at an excessively high current rate?

*Answer.* Discharging a storage battery at an excessively high rate greatly increases the internal resistance of the cells and reduces the efficiency of the battery. The heavy rate of sulphation and internal heat generated may cause the plates to buckle and seriously reduce the life of the battery. The heat developed in the connecting leads may also provide a possible fire hazard.

**3.159** What is the approximate fully charged voltage of an Edison storage cell?

*Answer.* 1.37 volts.

**3.160** A 6-volt storage battery has an internal resistance of 0.01 ohm. What current will flow when a 3-watt, 6-volt lamp is connected?

*Answer.* For practical purposes the internal resistance is neglected. It may be assumed that the question reads, what current flows through a 3-watt 6-volt lamp.

*Solution:*

$$I = \frac{W}{E} = \frac{3}{6} = 0.5 \text{ ampere}$$

**3.161** What is the approximate fully charged voltage of a lead-acid cell?

*Answer.* 2.10 volts.

**3.162** Why is low internal resistance desirable in a storage cell?

*Answer.* The capacity of the cell is determined, in part, by its internal resistance. Therefore, the lower the internal resistance the greater will be the output capacity of the cell.

**3.163** How may the condition of charge of an Edison cell best be determined?

*Answer.* Inasmuch as the specific gravity of the electrolyte of the Edison cell does not vary during charge and discharge, the only practical method of ascertaining the condition of charge in the Edison cell is to take a voltage reading under normal load conditions. An ampere-hour meter, if available on the charging panel, will show directly the amount of charge in a battery.

**3.164** If the charging current through a storage battery is maintained at the normal rate, but its polarity is reversed, what will result?

*Answer.* It is obvious that the battery would then be in series with the charging generator instead of being parallel to it. Hence, the battery would be discharged instead of charged. In time, severe sulfation would result and the battery might be ruined.

**3.165 What are the effects of sulfation?**

*Answer.* When a cell discharges, sulfate of lead is being formed on the plates. When the cell is charged, this sulfate of lead is forced back into the electrolyte. If the charging process is discontinued before all the sulfate of lead is reconverted, a residue will remain. When the next discharge cycle occurs, this residue will be present in addition to the newly formed sulfate of lead. If, then, again the recharging process is not sufficient to reconvert all of the lead sulfate, a condition will be reached where an excessive amount of sulfate of lead is on the surface of the plate. The cell is then said to be "sulfated." The effects of sulfation are lowered cell capacity and output voltage.

**3.166 How may the state of charge of a lead-acid storage cell be determined?**

*Answer.* There are three methods of testing a lead cell for state of charge, as follows:

1. Observe the reading of the ampere-hour meter.
2. Take a specific-gravity reading of the electrolyte with a hydrometer.
3. Measure the voltage of the battery under both no-load and normal load conditions with a high resistance voltmeter.

**3.167 Why is laminated iron or steel generally used in the construction of the field and armature cores of motors and generators instead of solid metal?**

*Answer.* To reduce eddy currents. If a solid core were used, excessive heating would result from the unhindered formation of eddy currents throughout the entire core material. By using laminated iron or steel, the formation of eddy currents is retarded to a negligible value.

**3.168 What is the purpose of commutating poles or interpoles in a d-c motor?**

*Answer.* Commutating poles are provided to counteract the self-induction in the armature coil, which is in contact with the brush. This reduces sparking at the brushes to a minimum because the reversal of current in the armature comes while the armature coils are still short-circuited by the brush, and the self-induction effect present is low.

**3.169** How may the output voltage of a separately excited a-c generator, at constant output frequency, be varied?

*Answer.* This may be accomplished by varying the excitation voltage through the medium of a variable rheostat (resistance) in series with the field.

**3.170** If the field of a shunt-wound d-c motor were opened while the machine was running under no load, what would be the probable result(s)?

*Answer.* If the field of a shunt-wound machine is opened while the machine is running, the counter emf, ordinarily generated in the armature by the field, disappears with the result that the machine will race badly and possibly damage itself by its excessive speed. The armature may burn out.

**3.171** Name four causes of excessive sparking at the brushes of a d-c motor or generator.

*Answer.* There are many causes for excessive sparking at the brushes of a d-c machine as follows:

1. Overloaded.
2. Poor brush fitting or worn brush.
3. Open in armature circuit.
4. High commutator bar.
5. Dirty commutator.
6. Too rapid starting.
7. Brushes off neutral point.

**3.172** What is the purpose of a commutator on a d-c motor? On a d-c generator?

*Answer.* On a motor, the purpose of the commutator is periodically to apply the correct polarity of current flow to each armature coil. On a generator, the purpose of the commutator is periodically to reverse the polarity of the output voltage. The commutator is effectively a rectifier.

**3.173** What is meant by "counter emf" in a d-c motor?

*Answer.* The "counter emf" in a d-c motor is the emf induced in the armature winding when it rotates in the motor field. The counter

emf is of opposite polarity to the applied emf. Therefore, it acts as a limiting device on the speed of the machine.

**3.174 What determines the speed of a synchronous motor?**

*Answer.* The frequency of the alternating current ( $f$ ) supplied to the motor and the number of its pairs of poles ( $P$ ). ( $S = 120f/P$  rpm)

**3.175 Describe the action and list the main characteristics of a shunt-wound d-c motor.**

*Answer.* The principal characteristic of the shunt-wound motor is that it will maintain a fairly constant speed under varying load conditions. Action is such that when the motor has reached full speed without load, the counter emf is almost the same as the emf supplied to the motor. Hence, the motor is drawing a minimum current. As soon as a load is applied to the motor, it tends to slow down, but as it does so the counter emf becomes less, which compensates for the load drag by allowing the machine to increase its speed.

**3.176 Describe the action and list the main characteristics of a series d-c motor.**

*Answer.* See 6.826.

**3.177 Describe the action and list the main characteristics of a series d-c generator.**

*Answer.* The field of the series d-c generator is in series with its armature. Hence, it must carry the full-load current delivered by the machine. For this reason, the field consists of a few turns of heavy wire. The principal characteristic of the series d-c generator is variable output voltage under variable load conditions; that is, the output voltage depends on the amount of load the machine is carrying. Because of this characteristic the series d-c generator has practically no useful applications.

**3.178 List the main advantages of a full-wave rectifier as compared with a half-wave rectifier.**

*Answer.* The main advantages of a full-wave rectifier are low hum level, higher average output voltages, increased current-carrying capacity, and lower filter-component requirements. The increased

filtering advantages are obtained owing to the doubling of the output ripple frequency. The core of a transformer used in a half-wave circuit is magnetized by the direct current flowing in the secondary.

### 3.179 Why may a transformer not be used with direct current?

*Answer.* An excessive current flow would result, and the transformer primary may burn out. The transformer works on the principle of induction, which requires a changing magnetic field to induce an electromotive force into its secondary winding. Only a pulsating direct current such as is developed by a mechanical vibrator or an alternating current will produce this effect. Another viewpoint is the fact that only pulsating or alternating current in the primary will limit the current flow because of its reacting effect upon the source frequency. The primary offers only its low d-c resistance to the flow of direct current, while with alternating current the current flow through the winding is limited by resistance and reactance (impedance).

### 3.180 What are the primary advantages of a high-vacuum rectifier as compared with the hot-cathode mercury-vapor rectifier?

*Answer.* The principal advantages of the high-vacuum rectifier are that it may have higher maximum-peak, inverse-voltage, and power-output ratings. Although the voltage regulation of the high-vacuum rectifier is not so satisfactory as the hot-cathode mercury-vapor rectifier, the high-vacuum rectifier will stand a greater amount of abuse under high-power load conditions than will the mercury-vapor type. This is particularly true of the filaments in these tubes, the mercury-vapor tube's filament being susceptible to damage under improper operating conditions.

### 3.181 What are the primary characteristics of a gas-filled rectifier tube?

*Answer.* This type of amplifier tube operates upon the principle of "ionization due to collision." Some of its characteristics are as follows:

1. High current-carrying ability.
2. Low- and constant-voltage drop while conducting.
3. Good voltage regulation.
4. Cathode easily damaged by overload.
5. "Flashback" will result from excessive inverse peak voltages.
6. Must be used with choke-input filter to limit starting current.

7. Steep current wave fronts produce radio-frequency and audio-frequency "hash" which must be filtered to reduce interference.

**3.182 What are the primary advantages of a mercury-vapor rectifier as compared with the thermionic high-vacuum rectifier?**

*Answer.* The primary advantage of a mercury-vapor rectifier is that it has a voltage drop in the tube of only 15 volts under normal operating conditions, regardless of load. The voltage drop in the high-vacuum rectifier tube varies with the load conditions. Because of the low drop in the mercury-vapor, there is less heat dissipated in the tube, and the tube, therefore, is usually self-cooling. On the other hand, owing to the high-voltage drop under heavy load conditions in the high-vacuum rectifier, the tube must dissipate a considerable amount of heat. This makes it necessary to use a water jacket on the high-power tube. Also, because of the low internal voltage drop in the mercury-vapor rectifier tube, the voltage regulation is better with this tube than it is with the high-vacuum type. High-vacuum rectifier tubes are used in both receivers and transmitters. Water-cooling is necessary, of course, only in the high-power transmitter types.

**3.183 Why is it desirable to have low-resistance filter chokes?**

*Answer.* The lower the resistance of the filter chokes the less the voltage drop across these chokes and the greater the value of voltage available at the output terminals.

**3.184 When filter capacitors are connected in series, resistors of high value are often connected across the terminals of the individual capacitors. What is the purpose of this arrangement?**

*Answer.* To distribute the voltage strain evenly between the capacitors and to discharge the capacitors after shutdown.

**3.185 What is the primary purpose of a bleeder as used in a filter system?**

*Answer.* The purpose of a bleeder as used in a filter system is to improve the regulation of the system. The bleeder also serves to discharge the filter capacitors after shutdown, thus providing protection to the personnel against shock.

**3.186 Describe the construction and characteristics of a thermocouple meter, of a wattmeter.**

Answer. Figures 3-58 and 3-59 illustrate the component parts of a thermocouple and a wattmeter, respectively.

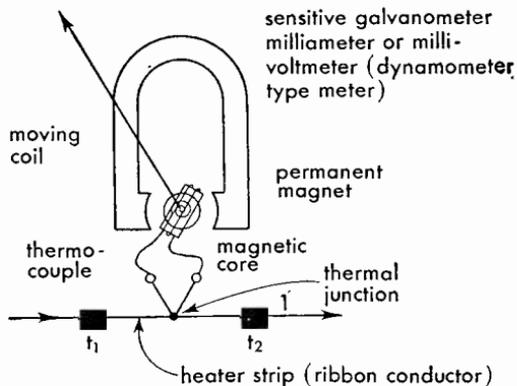


FIG. 3-58. Thermocouple-type meter.

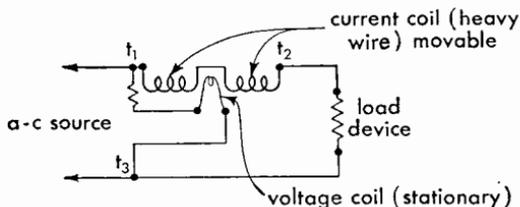


FIG. 3-59. Dynamometer-type wattmeter.

The thermocouple ammeter consists of a sensitive millivoltmeter or a D'Arsonval moving-coil (galvanometer) meter. The thermocouple is connected to the leads of the moving coil through the spiral torque springs. The thermojunction of dissimilar metals is joined to a current-conducting strip. When an alternating high-frequency or low-frequency current flows along the strip, heat generated at the thermojunction develops a d-c emf at the free ends of the thermocouple. The heating effect therefore is proportional to the square of the current. Both direct and alternating currents can be measured with this meter.

The wattmeter illustrated in Fig. 3-59 consists of a voltage coil and current coil connected as shown. This instrument reads the true power  $EI$  power factor ( $\cos \theta$ ) directly in watts or kilowatts depending upon the calibration. True power is indicated because the torque of the movement is proportional to the product of  $EI \cos \theta$ .

**3.187 Describe the construction and characteristics of a D'Arsonval meter.**

*Answer.* The D'Arsonval galvanometer or moving-coil meter illustrated in Fig. 3-58 operates upon the fundamental principles of a d-c motor. A moving coil frame supported on pivots (armature) is positioned in the magnetic field of a permanent magnet. A current flowing through the coil creates a magnetic field which causes the lines of force produced by the coil and the permanent field to distort, resulting in a torque or twist of the moving-coil element. This instrument measures extremely small direct currents and is very sensitive. Only very small voltages must be applied to avoid damage. The instrument can be used as a voltmeter or ammeter by providing series resistance or shunts, respectively. The deflection, when used on pure direct current alone, is proportional to the current and to the square root of the resistance.

In the measurement of alternating currents, the galvanometer, in conjunction with a copper oxide rectifier, is generally calibrated from a pure sine wave to give a scale indication which is the *effective* value of the wave. This effective value is evaluated from the average amplitude of the a-c wave.

If a rectifier and galvanometer are used for measuring d-c values, the instrument measures the average value of the ripple or rectified frequency.

**3.188 Describe the construction and characteristics of a repulsion ammeter.**

*Answer.* Figure 3-60 illustrates the construction of a repulsion or iron-vane meter.

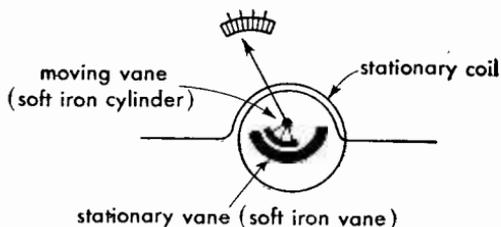


FIG. 3-60. Repulsion-type meter.

When a current flows through the stationary coil, a magnetic field is developed around it which, in turn, magnetizes the movable and

stationary iron-vane cylinders. The magnetization of the two vanes causes the two cylinders to repel each other, resulting in the displacement of the movable cylinder and corresponding movement of the pointer across the scale. It is important here to note that the induced magnetic polarity at each end of the cylinders is always the same, NN or SS, regardless of the direction of current flow. Hence the moving coil and pointer will always move in one direction thus enabling the instrument to read both d-c and a-c flow. This movement can be used to indicate effective values of volts and amperes.

### 3.189 Describe the construction and characteristics of a dynamometer indicating instrument.

*Answer.* The dynamometer or electro-dynamometer meter is illustrated in Fig. 3-61. Its operation is the same as the galvanometer with

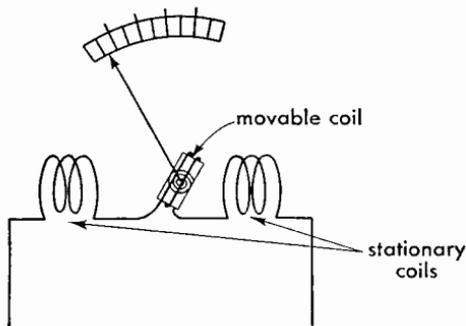


FIG. 3-61. Electro-dynamometer-type meter.

the exception that no permanent magnet is employed. The three coils are connected in series in such a manner that a current flowing through the coils in series results in a distortion of the magnetic field and causes the moving coil and pointer to move clockwise. The deflection is proportional to the square of the current. This meter can be used in both a-c and d-c circuits and reads the *effective* value of the voltage wave.

### 3.190 If two voltmeters are connected in series, how would you be able to determine the total drop across both instruments?

*Answer.* The total voltage drop across both instruments would be the sum of the individual meter readings.

**3.191** What types of meters may be used to measure radio-frequency currents?

*Answer.* The thermocouple ammeter and the hot-wire ammeter.

**3.192** If two voltmeters are connected in parallel, how may the total voltage drop across both instruments be determined?

*Answer.* The total voltage drop across both instruments would be the reading of either one of the meters.

**3.193** Why are copper oxide rectifiers, associated with d-c voltmeters for the purpose of measuring alternating current, not suitable for the measurement of voltages at radio frequencies?

*Answer.* Copper oxide rectifiers are not suitable for the measurement of voltages at radio frequencies because at these frequencies the capacitance of the rectifier unit would pass the radio-frequency current without rectification, thus making the reading inaccurate.

**3.194** If two ammeters are connected in parallel, how may the total current through the two meters be determined?

*Answer.* The total current through two ammeters connected in parallel is the sum of the individual meter readings.

**3.195** Is the angular scale deflection of a repulsion iron-vane ammeter proportional to the square or square root of the current or merely directly proportional to the current?

*Answer.* The scale deflection of a repulsion iron-vane ammeter is proportional to the square of the current.

**3.196** Does an a-c ammeter indicate peak, average, or effective values of current?

*Answer.* An a-c ammeter, exclusive of copper oxide types, indicates the effective value of current.

**3.197** If two ammeters are connected in series, how may the total current through the two meters be determined?

*Answer.* The total current through two ammeters connected in series is the average of the individual meter readings.

**3.198** How may a d-c milliammeter, in an emergency, be used to indicate voltage?

*Answer.* By using it in series with a resistor of known value. This resistor must be of a value sufficiently great so that an excessive current will not flow through the meter and burn it out. The formula for figuring the value of the multiplier resistor  $R$  is as follows:

$$R = \frac{E_1 - E_2}{I} \text{ ohms}$$

where  $E_1$  = the full-scale deflection desired.

$E_2$  = the voltage drop in the meter for full-scale deflection.

$I$  = the current flow in the meter for full-scale deflection.

**3.199 What is the purpose of a multiplier resistance used with a voltmeter?**

*Answer.* The purpose of the multiplier resistance, as used with a voltmeter, is to increase the range of the meter.

**3.200 What type of indicating instrument is best suited for use in measuring radio-frequency currents?**

*Answer.* The thermocouple radio-frequency ammeter.

**3.201 What is the purpose of a shunt as used with an ammeter?**

*Answer.* The purpose of a shunt  $R_s$  as used with an ammeter is to extend the current reading range of the instrument.

$$R_s = \frac{R_{\text{meter}}}{(N - 1)}$$

where  $N$  is the multiplication factor.

**3.205 What is the effect of local action in a lead-acid storage cell, and how may it be compensated?**

*Answer.* Local action tends to discharge the cell very slowly. Therefore, over a period of time, the capacity of a cell would be decreased. Local action is prevented as much as possible (a) by the manufacturer in making the active materials as pure as possible and (b) by keeping the cells on trickle charge.

**3.206 Why should adequate ventilation be provided in the room housing a large group of storage cells?**

*Answer.* The room housing a large group of storage cells should be well ventilated in order to allow the escape of gas fumes generated during the charging process. Smoking must not be permitted, especially when the batteries are on charge. If covers are provided on the battery boxes, they should be removed during the charging period.

**3.207 When should distilled water be added to a lead-acid storage cell, and for what purpose?**

*Answer.* Distilled water should be added when the level of the electrolyte has been reduced below normal by evaporation. Distilled water is added because the batteries operate best when the plates are entirely covered by electrolyte.

**3.208 How may the polarity of the charging source to be used with a storage battery be determined?**

*Answer.* If a suitable instrument is not at hand, the positive and negative sides of the line may be determined on circuits of 110 volts or less by dipping the ends of the two wires in a glass of water in which a very small amount of common table salt, potash, or acid electrolyte has been dissolved. Keep the wires about 1 in. apart. When there is current flowing, gas bubbles will form on both wires, but the wire where the greater amount of gas bubbles is being formed will be the negative side of the circuit.

Another method to determine the polarity of the line is to place the two wires about  $\frac{1}{4}$  in. apart on a wet piece of blue litmus paper. Where the positive wire touches the wet paper, a red mark will appear if current is flowing.

When employing these tests, the operator must use extreme care not to short-circuit the line or to get himself in contact with both sides of the line at once.

**3.209 Describe the care which should be given a group of storage cells to maintain them in good operating condition.**

*Answer.* A battery equipment, regardless of type, should have careful attention. The electrolyte should be kept about  $\frac{1}{2}$  in. above the top of the plates by replacing loss due to evaporation with distilled water. The electrolyte level should never be maintained by replacing acid unless the electrolyte is in some way spilled out. The acid does not

evaporate, it being the water in the electrolyte that is so reduced. It is important that the battery be kept fully charged, not only so that it may be ready for immediate use but also because it is best for the internal condition of the individual cells. The condition of charge of a lead-cell battery may be checked up by taking combined hydrometer and voltmeter readings of the individual cells. If the cells as a whole show comparatively low hydrometer readings, they should be charged. A low-voltage reading indicates the same condition. Storage batteries should be given a checkup about once a month. If a cell shows an unnatural condition such as low specific-gravity reading and low-voltage reading, it may indicate sulfation or plate buckling, and it should be cut out of the circuit by disconnecting the lead-strap connectors and jumping the bad cell. As soon as possible the bad cell should be taken out and repaired. The battery should be promptly recharged when the voltage of the individual cell reaches 1.7 volts; therefore the voltage of the entire bank would read  $1.7 \times$  number of cells. A battery should not be charged more frequently than once a week unless the service requires it. The few simple rules listed below apply to all cells.

1. Keep open flames away from the battery at all times.
2. Replace spilled electrolyte before charging.
3. When water in cell evaporates, add distilled or pure water.
4. Never allow cells to remain in discharged condition.
5. Mix electrolyte in clean earthen or glass jars.
6. Allow solution to cool before putting into cell.
7. Never pour water into sulfuric acid.
8. Never allow salt to get into cell.
9. Use only absolutely pure chemicals and water.
10. Always provide plenty of ventilation.
11. If burned by sulfuric acid apply ammonium hydroxide or baking soda.
12. Don't charge at a too high rate.
13. Don't discharge at a too high rate.
14. When not in use, keep on trickle charge.
15. Take frequent voltage readings.
16. Take occasional hydrometer readings.
17. Keep the level of the electrolyte about  $\frac{1}{2}$  in. above the plates by adding chemically pure water.
18. Give an overcharge about once a month.

19. Keep the tops of each battery dry to prevent current leakage.
20. Keep all electrical connections free from corrosion by applying a very thin layer of petroleum jelly after the connection has been made.
21. Do not add acid unless some has been lost due to spilling or flooding, and not even then unless the specific-gravity reading does not come up to normal after charging.
- Oversulfation may be caused by
1. Wrong specific gravity of electrolyte.
  2. Overdischarge.
  3. Allowing cell to remain too long in a discharged condition.

**3.210 What may cause the plates of a lead-acid storage cell to buckle?**

*Answer.* Overdischarge.

**3.211 What may cause sulfation of a lead-acid storage cell?**

*Answer.* Sulfation is caused by improper charging over a long period of time. Overdischarge will also cause sulfation.

**3.212 What chemical may be used to neutralize a storage-cell acid electrolyte?**

*Answer.* Ammonia or sodium bicarbonate, commonly known as baking soda.

**3.213 What steps may be taken to prevent corrosion of lead-acid storage-cell terminals?**

*Answer.* The terminals should be kept clean and coated with a light coating of petroleum jelly.

**3.214 Why are bypass capacitors often connected across the brushes of a high-voltage d-c generator?**

*Answer.* Bypass capacitors are often connected across the brushes of a high-voltage d-c generator to act as a protective device to prevent the generator windings from being punctured should a high-voltage kickback occur from the high-frequency circuits. These capacitors are usually made up into a unit consisting of two capacitors in series, the outer terminals being connected across the generator and the center terminal to ground.

**3.215** What may cause a motor-generator bearing to overheat?

*Answer.* The bearing of a motor generator may be caused to overheat by the lack of sufficient lubrication. This, in turn, may be caused by a defective oil ring or, in the larger machines, by a defect in the lubricating-oil line.

**3.216** How may the radio-frequency interference, often caused by sparking at the brushes of a high-voltage generator, be minimized?

*Answer.* Usually with bypass capacitors to ground and by use of a ripple filter, consisting of two 1- $\mu$ f capacitors and a 10-henry heavy-current capacity choke. In addition a radio-frequency filter consisting of radio-frequency chokes and radio-frequency bypass capacitors is sometimes used.

**3.264** Show by a diagram how to connect battery cells in series.

*Answer.* See Fig. 3-62.

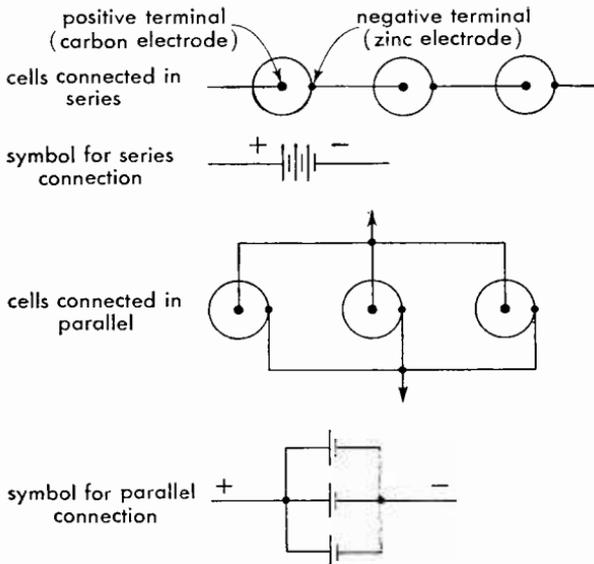


FIG. 3-62. Series and parallel cell connections.

**3.265** Show by a diagram how to connect battery cells in parallel.

*Answer.* See Fig. 3-62.

**3.266** What material is used in the electrodes of a common dry cell?

*Answer.* The electrodes in a common dry cell are composed of a rod or plate of carbon material (positive plate) and a zinc container (nega-

tive plate). The electrolyte is an absorbent material saturated with a solution of sal ammoniac and manganese dioxide or zinc chloride.

**3.297 What form of energy is stored in lead storage batteries?**

*Answer.* Chemical energy. A storage cell converts chemical energy into electrical energy.

**3.393 What factors permit high conduction currents in a hot-cathode mercury-vapor rectifier tube?**

*Answer.* High conduction currents in a hot-cathode mercury-vapor rectifier tube are permissible because the current is carried chiefly by ions in the tube rather than by electrons emitted from the cathode. The low (15-volt) voltage drop across the tube while conducting makes the plate power dissipation ( $EI$ ) low even for large values of plate current.

**3.394 List the principal advantages of a mercury-vapor rectifier over a high-vacuum-tube rectifier.**

*Answer.* The principal advantages of the mercury-vapor rectifier over a high-vacuum-tube rectifier are its better voltage regulation and higher operating efficiency. In comparing the efficiency of the high-vacuum-tube type with that of the mercury-vapor type, it has been found that the latter may be approximately 99 per cent efficient as compared with approximately 87 per cent efficiency of the former.

**3.395 What effect does the resistance of filter chokes have on the regulation of a power supply?**

*Answer.* The less resistance in the filter chokes the better will be the regulation.

**3.396 Describe the theory of current conduction and rectification by means of cold-cathode, gassy-diode vacuum tubes.**

*Answer.* When an alternating difference of potential is applied across the electrodes, one of which is a cold cathode and the other a rod-shaped anode, the strain exerted upon the gaseous atmosphere will result in the breakdown of the gas atoms (ionization due to collision). If the electrodes are identical in construction, an electron current will flow in both directions under conditions of ionization. However, in order that unilateral flow only shall take place under application of an alternating voltage, the plates are of different design with regard to each

other. This special design permits electrons to flow from one element to the other when the gas ionizes but not in the reverse direction. This action permits the use of this type of tube for rectification purposes.

**3.397 Describe the principle of operation of a synchronous type of mechanical rectifier.**

*Answer.* There are two general types of mechanical rectifiers, namely, the vibrating-reed and the synchronous-commutator types. The vibrating-reed rectifier consists of a metal strip or reed in which the reed forms the armature of an electromagnet excited from the a-c supply. The reed is arranged with contacts which are opened and closed periodically with the change of the a-c cycle. If one pair of contacts is used, the circuit will close during one-half of the cycle; if two contacts are used the circuit will close on both halves of the cycle. Thus the contacts may be closed at half-wave pulses or full-wave pulses, as desired.

The commutator type of synchronous rectifier employs a rotating arm with segmented pillars which is driven by a synchronous motor. Separate rectifying contacts are fixed in a stationary position near the movable arm. These make contact with the commutator. The stationary and rotary segments are so arranged that the connections are reversed at the instant that the current reverses and in this manner rectify the alternating current to d-c pulses.

**3.398 What might be the result of starting a motor too slowly, using a hand starter?**

*Answer.* Starting a motor too slowly, using a hand starter, may burn out the resistance units in the starting box, as they are made for temporary duty only and cannot stand a heavy current flow for more than a very short period.

**3.399 State the principal advantage of a third-brush generator for radio power supply in automobiles.**

*Answer.* The principal advantage of the third brush in a generator is to improve the voltage regulation under generator speed changes.

**3.400 What materials should be used to clean the commutator of a motor or generator?**

*Answer.* The commutator of the d-c motor or generator is kept clean by polishing it with a piece of fine sandpaper, usually No. 0000. Emery

cloth should never be used because it contains metallic dust which would short-circuit the commutator segments. A piece of coarse canvas is also useful in giving the commutator a final polish. A special commutator paste is also available. This paste should be applied sparingly with a clean cloth and the commutator then polished while the machine is running.

**3.401 List three causes of sparking at the commutator of a d-c motor.**

*Answer.* There are many causes for excessive sparking at the brushes of a d-c machine as follows:

1. Overloaded.
2. Poor brush fitting or worn brush.
3. Open in armature circuit.
4. High commutator bar.
5. Dirty commutator.
6. Too rapid starting.
7. Brushes off neutral point.

**3.402 Why is it necessary to use a starting resistance when starting a d-c motor?**

*Answer.* A starting resistance is necessary to prevent an excessive current flow in the armature of the motor before it gets up to speed. When the motor is up to running speed, the armature generates enough self-induced counter emf to keep the current in itself down to safe limits.

**3.403 List the comparative advantages and disadvantages of motor-generator and transformer-rectifier power supplies.**

*Answer.* The answer may be tabulated as follows:

MOTOR-GENERATOR

*Advantages*

1. Easy voltage control.
2. Good regulation at full voltage.
3. Exceptionally rugged.
4. May be located at remote point.
5. May be operated from a-c or d-c lines.
6. Very low maintenance costs.
7. Can stand considerable abuse.

*Disadvantages*

1. Poor regulation at low voltages.
2. High first cost.
3. Difficult to repair.
4. May be noisy.
5. May cause vibration.
6. Requires constant attention to lubrication, commutator, and brushes.
7. May require long and dangerous high-voltage leads.
8. On d-c generators output limited to about 12,000 volts.

## VACUUM-TUBE RECTIFIER

*Advantages*

1. Lower first cost than motor generator.
2. No moving parts, hence no lubrication or other care aside from cleaning.
3. Exceptionally high voltages available without danger of breakdown.
4. Mercury-vapor type has good regulation.
5. Quiet in operation; no vibration.
6. Easier repair than motor generator.
7. Can be enclosed in transmitter unit, thus no exposed high-voltage leads.

*Disadvantages*

1. Necessity to replace tubes.
2. High maintenance costs.
3. Requires careful operation, cannot stand much abuse.
4. High-vacuum type has poor regulation.
5. Must be operated from a-c line.

**3.404** If the reluctance of an iron-cored choke is increased by increasing the air gap of the magnetic path, in what other way does this affect the properties of the choke?

*Answer.* The inductance will be decreased, owing to increase in reluctance, and the filtering action is likely to be impaired. However, core saturation will not occur and so, under certain conditions, as when the choke is carrying direct current, filtering action may actually be improved. This condition results because the air gap may decrease the effects of d-c magnetization (which decreases inductance) more than the gap itself decreases inductance. (See 3.412 and 6.417.)

**3.405** What is the effect upon a filter choke of a large value of d-c flow?

*Answer.* The effect of a large value of d-c flow upon a filter choke would be to cause it to heat up excessively. If the current flow is large enough, the filter choke may burn out. Under any conditions an excessive d-c flow will cause the choke to be saturated and have less inductance.

**3.406** What are the characteristics of a capacitor-input filter system as compared to a choke-input system?

*Answer.* The capacitor-input filter will give a higher voltage output than the choke-input system, but the regulation of the capacitor-input system will not be so good. Instantaneous peak rectifier current is much higher with capacitance-input filters. This is particularly true if a mercury-vapor rectifier is used.

**3.407 What is the principal function of the filter in a power supply?**

*Answer.* The principal function of the filter in a power-supply system is to iron out the peaks of the ripple frequency and to provide an output voltage which has a minimum fluctuation characteristic and is essentially pure direct current.

**3.408 What are the characteristics of a choke-input filter system as compared with a capacitor-input system?**

*Answer.* Other things being equal, the choke-input filter system will give better regulation than the capacitor-input system, but the output voltage will be lower with the choke-input system.

**3.409 What is the percentage regulation of a power supply with a no-load voltage output of 126.5 volts and a full-load voltage output of 115 volts?**

*Answer.* The percentage of regulation would be 10 per cent, computed by the formula

$$\text{Regulation per cent} = \frac{E_{max} - E_{min}}{E_{min}} \times 100$$

**3.410 What is the definition of "voltage regulation" as applied to power supplies?**

*Answer.* "Regulation," as applied to power supplies, is the difference between no-load and full-load voltage, expressed as a percentage of the full-load voltage.

$$\text{Regulation in per cent} = \frac{E_{nl} - E_{fl}}{E_{fl}} \times 100$$

where  $E_{nl}$  is the no-load voltage, and  $E_{fl}$  is the full-load voltage.

**3.411 May two capacitors of 500 volts operating voltage, one an electrolytic and the other a paper capacitor, be used successfully in series across a potential of 1,000 volts? Explain your answer.**

*Answer.* If the voltage is of an alternating character, this cannot be done, since the electrolytic capacitor operates upon the principle of unilateral conductivity. That is, it is a conductor during one portion of the a-c cycle. Obviously at this instant the paper capacitor will be subjected to abnormal strain and will puncture. In d-c circuits the arrangement may be used provided equalizing resistors are used, the

electrolytic capacitor possesses a very low power factor, and proper polarity is observed.

**3.412 What is the principal function of a swinging choke in a filter system?**

*Answer.* The swinging choke provides an inductance value which varies inversely with the current flow, thereby improving the regulation of the power supply. This is achieved by designing the choke coil with a relatively small iron core so that it will readily saturate with heavy current flow, with a consequent decrease in its inductance. Inductance rises with a decrease in the load, improving regulation without the expense of large choke with high inductance at full load.

**3.413 What is the purpose of a bleeder resistor as used in connection with power supplies?**

*Answer.* The purpose of a bleeder as used in a filter system is to improve the regulation of the system. The bleeder also serves to discharge the filter capacitors after shutdown, thus providing protection to the personnel against shock.

**3.414 What does a blue haze in the space between the filament and plate of a high-vacuum rectifier tube indicate?**

*Answer.* A blue haze indicates the presence of gas in the tube and may mean that the tube is approaching the end of its useful life.

A blue haze on the wall of the tube or inside the surface of the glass envelope is a form of X-ray effect. This has no injurious effect upon the operation of the tube.

**3.415 When capacitors are connected in series in order that the total operating voltage of the series connection is adequate for the output voltage of a filter system, what is the purpose of placing resistors of high value in shunt with each individual capacitor?**

*Answer.* To distribute the voltage strain equally between the capacitors and to discharge the capacitors after shutdown thus protecting the personnel against shock.

**3.416 If a high-vacuum high-voltage rectifier tube should suddenly show heavy internal sparking and then fail to operate, what ele-**

ments of the rectifier-filter system should be checked for possible failure before installing a new rectifier tube?

*Answer.* The filter capacitors.

**3.417** If the plate of a rectifier tube suddenly became red hot, what might be the cause and how could remedies be effected?

*Answer.* Short-circuited filter capacitors, or excessive external load, which might be caused by improper adjustment of the radio-frequency circuit to which the rectifier tube supplies power.

## Element 4

# Advanced Radiotelephone (Power)

4.89 What is the value of voltage drop across the elements of a mercury-vapor rectifier tube under normal conducting conditions?

*Answer.* The normal voltage drop across a mercury vapor rectifier tube is 15 volts.

4.90 Draw a diagram of a bridge rectifier giving full-wave rectification without a center-tapped transformer. Indicate polarity of output terminals.

*Answer.* Figure 4-20 illustrates a full-wave bridge-rectifier arrangement.

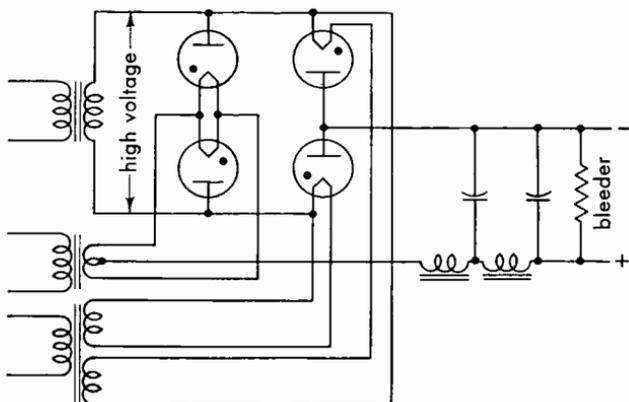


FIG. 4-20. Bridge rectifier, single-phase.

4.91 Draw a diagram of a rectifier system supplying two plate voltages, one approximately twice the other and using one high-

voltage transformer with a single center-tapped secondary, and such filament supplies as may be necessary.

*Answer.* Figure 4-21 illustrates a full-wave bridge rectifier for double-voltage supply.

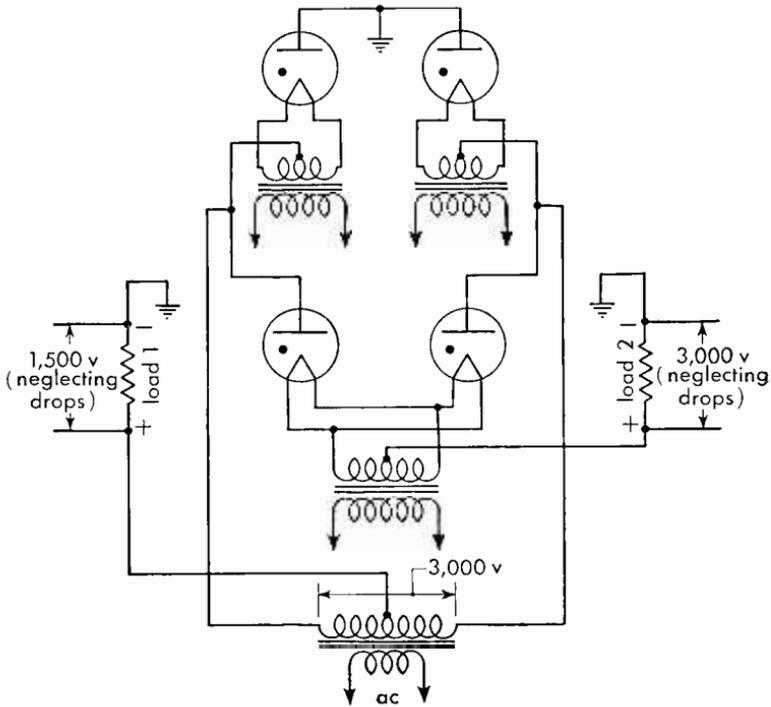


FIG. 4-21. Balanced single-phase full-wave rectifier.

**4.92** What is meant by "arcback" or "flashback" in a rectifier tube?

*Answer.* "Flashback" or "arcback" is a condition in mercury-vapor rectifier circuits in which the rectifier tube is ionized to the point of conduction in the reverse direction. For mercury-vapor tubes there is a critical voltage above which this will occur. Under normal conditions arcback may suddenly occur, caused by the input capacitor discharging back through the tube or by radio-frequency reactions from the operating circuit. Under such conditions the tube filament will be subjected to abnormal ion bombardment, and the tube may be ruined.

**4.93** What is meant by the "inverse peak voltage" rating of a rectifier tube?

*Answer.* "Inverse peak voltage" is the maximum potential difference which exists between the plate and cathode of a tube during that period of the cycle when the tube is not conducting.

**4.94** How may a capacitor be added to a choke-input filter system to increase the full-load voltage?

*Answer.* Voltage may be raised by adding an input-filter capacitor before the choke coil, but the system is then changed to the capacitor-input type.

**4.101** Why is a time-delay relay arranged to apply the high voltage to the anodes of mercury-vapor rectifier tubes some time after the application of filament voltage?

*Answer.* The time-delay relay prevents the application of high plate voltages to the rectifier until the filament has been sufficiently heated. The preheating period in mercury-vapor tubes prevents the heavy overloading condition which would exist if the plate voltage were to be applied before the filament is up to proper temperature. Another reason for preheating before applying the plate voltage on mercury-vapor tubes is to vaporize the mercury deposits upon the filament caused by the condensation which takes place when the tubes are not in use.

**4.102** Why is it important to maintain the operating temperature of mercury-vapor tubes within specified limits?

*Answer.* If the temperature of the tube itself is excessive, the inverse-peak-voltage breakdown rating will be considerably lowered and flash-back will result. Too low a temperature will damage the filament by positive-ion bombardment.

**4.176** When mercury-vapor tubes are connected in parallel in a rectifier system, why are small resistors sometimes placed in series with the plate leads of the tubes?

*Answer.* To prevent parasitic oscillations and balance ionization when tubes are connected in parallel. Small resistors are sometimes connected in series with plate leads to limit the instantaneous heavy surge currents that take place when the circuit is first closed. Without resistors, one tube may ionize first, thus lowering the voltage across

the tubes in parallel to a point where it will be impossible to obtain ionization in the other tube. Resistors keep the total voltage drop high enough so that the slower tube will ionize.

**4.177** A rectifier-filter power supply is designed to furnish 500 volts at 60 milliamperes to one circuit and 400 volts at 40 milliamperes to another circuit. The bleeder current in the voltage divider is to be 15 milliamperes. What value of resistance should be placed between the 500- and 400-volt taps of the voltage divider?

*Answer.* 1,819 ohms. A voltage drop of 100 volts at 55 milliamperes is required between the 500- and 400-volt taps. Thus,

$$R = \frac{E}{I} = \frac{100}{0.055} = 1,819 \text{ ohms}$$

**4.178** What is the approximate speed of a 220-volt 60-cycle four-pole three-phase induction motor?

*Answer.* Approximately 1,800 rpm. The running speed of an induction motor is always slightly less than the synchronous speed due to the ratio of the difference between the synchronous and the rotor speeds to the synchronous speed. This ratio is called the "slip" and is generally expressed in per cent. In commercial practice the slip usually ranges between 2 and 3 per cent.

Assuming a slip of 0.025 or 2.5 per cent, the actual speed of the induction motor may be found as follows:

$$\text{Synchronous speed} = \frac{120 \times f}{N} = \frac{120 \times 60}{4} = 1,800 \text{ rpm}$$

where  $f$  is the frequency in cycles per second, and  $N$  is the number of field poles.

$$\begin{aligned} \text{Actual speed} &= \text{synchronous speed} \times (1 - S) \\ &= \frac{120 \times f}{N} (1 - S) = \frac{120 \times 60}{4} (1 - 0.025) \\ &= \frac{120 \times 60}{4} \times 0.975 = 1,755 \text{ rpm} \end{aligned}$$

where  $S$  is slip.

**4.179** Draw a diagram of a shunt-wound d-c motor.

*Answer.* See Fig. 4-22.

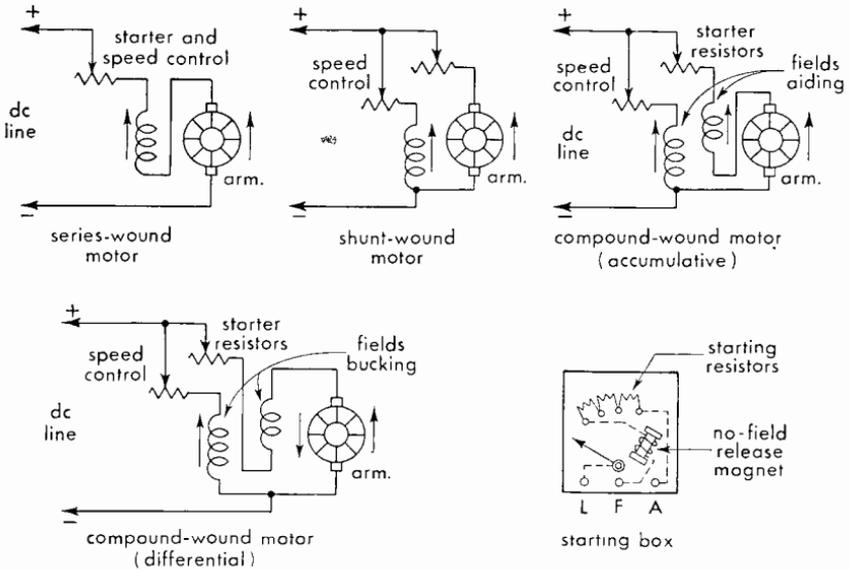


FIG. 4-22. Series, shunt, and compound d-c motors.

4.180 Draw a diagram of a voltage-doubling power supply using two half-wave rectifiers.

Answer. Figure 4-23 illustrates a voltage-doubling power-supply system employing two half-wave rectifiers.

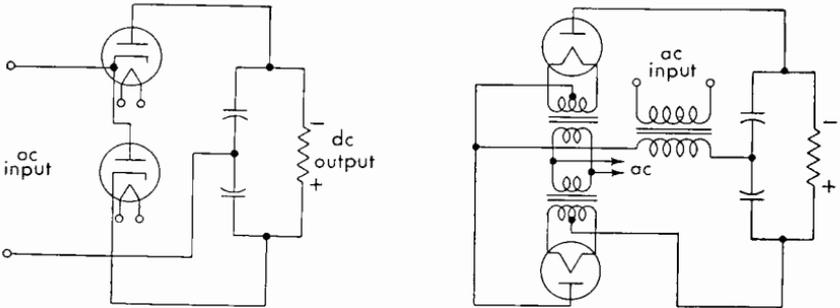


FIG. 4-23. Voltage-doubler rectifier systems.

4.192 A current-squared meter has a scale divided into 50 equal divisions. When 45 milliamperes flow through the meter, the deflection is 45 divisions. What is the current flowing through the meter when the scale deflection is 25 divisions?

*Answer.* 33.5 milliamperes. Since deflection is proportional to the square of the current flowing through the meter with an equally divided scale, the ratio of two deflections is equal to the ratio of the square of the currents producing these deflections, thus,

$$\frac{D_1}{D_2} = \frac{I_1^2}{I_2^2} \quad \frac{25}{45} = \frac{I_1^2}{45^2} \quad I_1^2 = \frac{25 \times 45^2}{45}$$

$$I_1 = \sqrt{25 \times 45} = \sqrt{1,125} = 33.5 \text{ milliamperes}$$

**4.193** What is the ohms per volt of a voltmeter constructed of a 0-1 d-c milliammeter and a suitable resistor that makes the full-scale reading of the meter 500 volts?

*Answer.* 1,000 ohms per volt. A total resistance of 500,000 ohms in series with the source potential and including the milliammeter resistance will pass 1 milliampere at 500 volts. Thus,  $500,000/500 = 1,000$  ohms per volt.

## Element 6

# Advanced Radiotelegraph (Power)

**6.415** What emergency repairs may be made to an inductance coil having burned or charred insulation?

*Answer.* The charred or burned portions may be painted with an insulating varnish or liquid colloid, provided both types of materials have low dielectric losses. If possible, the defective insulation should first be removed before applying the new insulation. Reduce operating voltage if possible.

**6.417** What is the purpose of an air gap in the core of a filter choke coil?

*Answer.* An air gap increases the reluctance of the core, thereby reducing the flux density so that it will not be saturated by the rated flow of direct current. The gap in a swinging choke, however, may be only a few thousandths of an inch wide.

**6.418** What are some uses of a low-pass filter network?

*Answer.* A low-pass filter network passes freely all frequencies below a certain point and attenuates all those above this value. This type of network is used in power-supply filter systems for transmitters and receivers. This type of filter is also used in special types of amplifying circuits where it is desired to amplify only a small band of low frequencies. Line noises and highly damped power-line surges may be attenuated by a low-pass filter.

**6.419** What is a "swinging choke"?

*Answer.* A choke coil designed to operate with varying loads is commonly referred to as a "swinging choke." The swinging action is

obtained by providing an extremely small air gap which allows saturation with a heavy current flow. (See 3.412.)

**6.420** Indicate the approximate values of power-supply filter inductances encountered in practice.

*Answer.* The maximum value of choke coils generally found in power filters is in the vicinity of 30 henrys. The limiting factor is generally the d-c resistance and its consequent voltage drop. The average current requirement might vary from 0.15 to 1 ampere. Average d-c resistance range is 200 to 600 ohms.

**6.421** Why is the core of a transformer made of sheets of iron rather than a solid piece of iron?

*Answer.* To reduce eddy-current losses.

**6.422** What factors determine the eddy-current loss in a transformer?

*Answer.* The character of the core material, the thickness of core laminations, and flux density.

**6.423** Name the losses which are present in transformers.

*Answer.* Eddy-current losses, hysteresis losses, air-gap losses, and copper losses.

**6.424** What factors determine the hysteresis losses in a transformer?

*Answer.* These losses are determined by flux density, the character of the magnetic material, and the operating frequency.

**6.425** What is the secondary voltage of a transformer which has a primary voltage of 100, primary turns 200, and secondary turns, 40?

*Answer.* The secondary voltage is 20 volts.

$$E_s = \frac{N_s}{N_p} \times E_p = \frac{40}{200} \times 100 = 20 \text{ volts}$$

**6.426** Why should emery cloth never be used to clean the commutator of a motor or generator?

*Answer.* Emery cloth contains a metallic abrasive. The particles remaining might cause short circuits between commutator bars.

**6.427** When increased output voltage is desired from a motor-generator set what is the usual procedure?

*Answer.* The output voltage is increased by strengthening the current through the generator field. This is done by decreasing the resistance in the generator-field rheostat.

**6.428** What will be the effect(s) of a short circuit in an armature coil of a d-c motor?

*Answer.* Sparking will develop around the commutator and the speed under load will be reduced.

**6.429** When starting a d-c motor-generator set, what adjustment should be made to the motor field rheostat?

*Answer.* The motor-field rheostat should be decreased to minimum resistance.

**6.430** What may be the trouble if a motor generator fails to start when the start button is depressed?

*Answer.* Blown fuse, open armature, defective starter, open field.

**6.431** What load conditions must be satisfied in order to obtain the maximum possible output from any power source?

*Answer.* Maximum power is obtained when the load resistance matches the internal resistance of the source.

**6.433** Why are bleeder resistors used in power supplies?

*Answer.* Bleeder resistors are used in filter circuits across capacitors to equalize the charge and remove the strain upon the capacitors. They are also used to stabilize the output voltage from power-supply circuits to the load circuits. The bleeder resistance in voltage-divider systems also permits reservoir action to accommodate increases in plate-current swings to the vacuum-tube plate circuits, improving regulation. Bleeder resistors also function to discharge the capacitors after shut-down, thus preventing possible shock to the operator.

**6.434** Why is a capacitor sometimes placed in series with the primary of a power transformer?

*Answer.* A capacitor is very seldom, if ever, placed in series with the primary winding of a power transformer. If a capacitor should be

used in this manner it would be done for the purpose of resonating the secondary circuit with the primary or, possibly, for controlling the primary reactance to control the current flow. This arrangement might also be used for boosting the primary voltage.

**6.436** What is the effect of low temperatures upon the operation of a lead-acid storage cell?

*Answer.* Low temperatures temporarily decrease both the discharge voltage and the ampere-hour capacity which can be taken out of the cell.

**6.437** Why should the tops of lead-acid storage batteries be kept free from moisture?

*Answer.* To prevent leakage losses and terminal corrosion.

**6.438** How may the condition of charge of an Edison cell be determined?

*Answer.* By the use of a high-resistance voltmeter test under load.

**6.439** What special precautions should be taken when lead-acid storage cells are subject to low temperatures?

*Answer.* They should be given frequent charging in order to keep the discharge voltage and ampere-hour capacity as high as possible. The cells should be kept on continuous trickle charge.

**6.440** What should be done if the electrolyte in a lead-acid storage cell becomes low due to evaporation?

*Answer.* Refill with chemically pure water.

**6.542** Describe the construction and the operation of rectifier tubes that are used for charging batteries. Draw a diagram of a battery-charging circuit employing such a tube.

*Answer.* The most commonly used battery-charging rectifier tube is the Tungar type. It is a two-element (diode) argon-gas-filled glass bulb. The tungsten filament is the cathode and a graphite button forms the anode, or plate. The argon gas is ionized and allows passage of electron current in only one direction, from cathode to anode, and through transformer and battery as shown in Fig. 6-20.

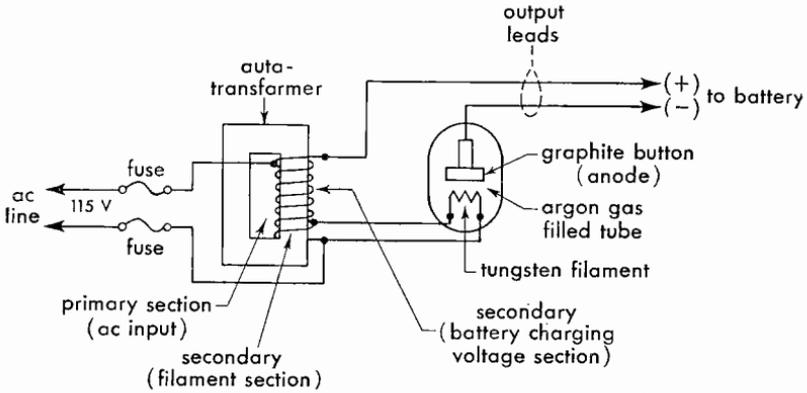


FIG. 6-20. Tungar-Rectigon type rectifier battery charger.

6.543 Draw a simple schematic diagram of a rectifier and filter for supplying plate voltage to a radio receiver.

Answer. See Fig. 6-21.

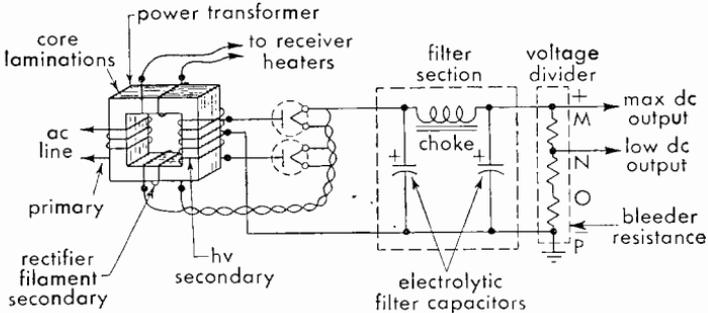


FIG. 6-21. Rectifier and filter plate supply system.

6.544 In a rectifier and filter power supply what is the relationship between the ripple frequency in the output of the filter and the input frequency to the rectifier?

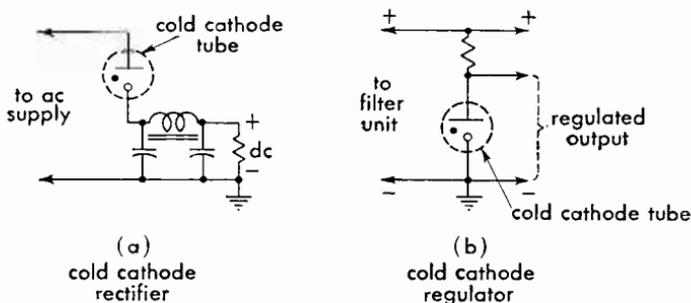
Answer. See 4.175, 6.404.

6.545 Compare the advantages and disadvantages of high-vacuum and hot-cathode mercury-vapor rectifier tubes.

Answer. See 3.181, 3.182, 3.394, 4.176, 6.706, 6.707.

6.546 Draw a simple schematic diagram of a cold-cathode electron tube connected as a voltage regulator. As a rectifier.

*Answer.* See Fig. 6-22.



*note:* use of ground depends on circuit requirements

FIG. 6-22. Cold-cathode or glow-discharge tube rectifier and regulator.

6.547 What is meant by "regulation" of a power supply? What causes poor regulation?

*Answer.* The "regulation" of a power supply is its ability to sustain a constant output voltage under normal varying load conditions.

Poor regulation may be due to excessive power-supply drain (overloading), insufficient or open bleeder resistance, open filter capacitor, defective rectifier tube, defective voltage regulator tube (if used), insufficient filter capacitance, defective input choke, or high resistance in the filter chokes.

6.548 Why are small resistors sometimes placed in series with each plate lead of mercury-vapor rectifier tubes connected in parallel?

*Answer.* See 4.176.

6.549 Why should the temperature of the filament or heater in a mercury-vapor rectifier tube reach normal operating temperature before the plate voltage is applied?

*Answer.* The filament should be heated for approximately one-half minute before applying the anode potential to ensure vaporization of the mercury and to protect the filament from excessive strain. If the plate voltage is applied before the filament temperature is raised to normal, the heavy positive-ion bombardment on the filament may

break off the active material and decrease its effective emission. A new mercury-vapor tube should be heated for at least 20 min without plate potential to ensure proper distribution of the mercury.

**6.550** A storage battery with a terminal voltage of 12.5 is to be trickle-charged at a 0.5-ampere rate. What value of resistance should be connected in series with the battery if the trickle charge is to be made from a 110-volt d-c line?

*Answer.* 195 ohms.

*Solution:*

$$R = \frac{E - e}{I} = \frac{110 - 12.5}{0.5} = 195 \text{ ohms}$$

**6.551** If the power input to a radio receiver is 75 watts, how many kilowatthours does the receiver consume in 24 hr of continuous operation?

*Answer.* 1.8 kilowatthours.

*Solution:*

$$\begin{aligned} 75 \text{ watts} &= 0.075 \text{ kilowatts} \\ 0.075 \times 24 &= 1.8 \text{ kilowatthours (1,800 watthours)} \end{aligned}$$

**6.552** What is the purpose of a center-tap connection in a filament supply transformer?

*Answer.* See 3.479.

**6.553** Name two devices that are sometimes designed for use on a three-phase power supply. Does a radio receiver ordinarily use single-phase or three-phase power?

*Answer.* Transformers (delta, V, or Y), polyphase motors, gyroscopes, mercury-arc and mercury-vapor rectifiers. Certain types of high-power transmitters, motor generators, and remote-control devices are sometimes designed for three-phase power supply. Radio receivers ordinarily use single-phase power supplies.

**6.554** What is a thermocouple?

*Answer.* A thermocouple or thermojunction is composed of two dissimilar metals or wires welded together at one point to form a contact of the two metals. When the junction is heated by the flow of alternating or direct currents, it will develop an emf at the free ends

of the couple which may be used for deflecting a sensitive galvanometer to read the flow of radio-frequency currents. See Fig. 3-58. Some types of thermocouples are composed of copper-constantan, nickel-zinc, cadmium-selenium, constantan-steel, or iron-tellurium.

**6.555 What are some uses of copper oxide rectifiers?**

*Answer.* Copper oxide rectifiers are commonly used in conjunction with electric meters, battery chargers, plate power supplies, relays, and vacuum tubes for the conversion of a-c to d-c requirements.

**6.556 Explain methods whereby radio interference from motors and generators can be eliminated.**

*Answer.* See 3.506 and 3.516.

**6.557 Describe the construction of a dynamotor. What are its operational characteristics?**

*Answer.* See 3.515.

**6.615 What is the principal disadvantage of using a dynamotor rather than a motor generator to furnish plate power to a small mobile transmitter?**

*Answer.* The voltage output of a dynamotor is dependent upon the stability of the source voltage. Since the source voltage is generally of the battery variety the stability of the plate voltage may be affected with the change from full-load to light-load conditions. The variation in fully charged as compared with low-charged battery conditions will affect the generator output. The dynamotor, furthermore, does not possess the high degree of voltage output stability which the motor-generator possesses.

**6.616 How may the voltage output of a dynamotor be regulated?**

*Answer.* This may be accomplished by increasing or decreasing the source voltage.

**6.617 What is the line current of a single phase 7-hp a-c motor when operating from a 120-volt line at full-rated load and at a power factor of 0.8 and 95-per cent efficiency?**

*Answer.* The line current under the above stated conditions will be 57.5 amperes. 1 hp = 746 electrical watts. 7 hp = 5,222 watts.

$$I = \frac{P}{E \times pf \times eff}$$

$$= \frac{5,222}{120 \times 0.80 \times 0.95} = 57.2 \text{ amperes}$$

**6.618** What is the effect of an inductive load on the output voltage of an alternator?

*Answer.* An inductive load placed on the output terminals of an alternator will decrease its voltage and cause a lagging power factor.

**6.619** What is the principal advantage in the use of a dynamotor, rather than a motor generator, to furnish plate power to a small mobile transmitter?

*Answer.* The principal advantage of the dynamotor over the motor generator is its compactness. In the dynamotor two separate armatures have their respective windings placed over a common iron core. The motor field and generator field are one unit which receives its excitation from the same source as the motor armature. It is a very compact and convenient unit for operation from a 6-volt storage battery to deliver plate supply voltages of 400 or more volts.

**6.620** Define "voltage regulation."

*Answer.* "Voltage regulation" is the change in voltage between full load and no load referred to the full-load value and expressed in per cent.

Voltage regulation in per cent may be determined by the following formula:

$$\text{Voltage regulation} = \frac{(\text{no-load voltage} - \text{full-load voltage})100}{\text{full-load voltage}}$$

**6.621** What means may be used to measure radio-frequency current?

*Answer.* Thermocouple ammeter, hot-wire ammeter.

**6.622** How may the range of a thermocouple ammeter be increased?

*Answer.* The range of a thermocouple ammeter may be increased by the insertion of a higher range thermocouple properly calibrated

to fit the galvanometer for the higher range or by a low resistance (low-temperature-coefficient shunt) connected across the thermocouple current-carrying strip. The latter method is recommended only in cases of emergency. If the thermocouple is a separate unit, a multiplier resistor may be used in series with the meter.

**6.623 Does the scale of an a-c ammeter indicate peak, effective, or average current values? Explain your answer.**

*Answer.* An a-c ammeter indicates neither peak nor average current values. The conventional a-c ammeter indicates effective current values. The average or peak values of a sinusoidal wave taken over a complete cycle is zero, and consequently no deflection of these values can be obtained with ordinary a-c meters.

The theoretical reason for this condition may be more clearly understood by analyzing the action of the electro-dynamometer. This is an alternating-current or -voltage-indicating device which operates upon the principle illustrated in Fig. 3-61.

Two stationary coils are connected in series with a movable coil and a pointer. The electrical connection to the moving coil is made through two springs which also serve to resist the turning force of the coil produced by the current. The force which tends to move the coil is proportional to the product of the field strength of the stationary and movable coils. Now since the field strength of each is proportional to the current which is flowing through them, the force tending to turn the coil at any instant is proportional to the square of the current flowing at that instant. Therefore, as this current varies from zero to the peak value for every half cycle, the force will also vary from zero to peak value each half of the cycle. The inertia of the coil, however, does not permit it to move rapidly enough to follow these fluctuations and, therefore, the pointer attached to the moving coil moves to a point corresponding to the average value of the deflecting force. Now since this is a measure of the current squared it will, therefore, be proportional to the effective value of the current.

**6.624 How may the power in an a-c circuit be determined?**

*Answer.* The true power expended in an a-c circuit may be determined by a direct-reading wattmeter or by the readings of an a-c voltmeter and an a-c ammeter multiplied by the power factor of the

circuit. The power factor of a circuit is determined by the ratio of the resistance to the impedance of the circuit,

$$\begin{aligned}\text{Power factor} &= R/Z \text{ or } W/EI \\ \text{Power} &= E \times I \times pf \text{ watts}\end{aligned}$$

**6.687** What is meant by the expression "motor generator is hunting"?

*Answer.* "Hunting" is the term applied to motors and generators which swing or oscillate in their armatures when they are accelerated above and below their normal average speed. This swinging action is set up primarily by variations in the rotative speed resulting from irregularity in the turning force.

**6.688** If the automatic starter for the transmitter motor-generator failed to operate when the switch was closed, what might be the trouble?

*Answer.* The starter or plunger solenoid may be open, the starting switch itself may be defective, the line-fuse blown, or the armature circuit may be open.

**6.689** Why is a series motor not used in radio power-supply motor generators?

*Answer.* The series motor does not maintain constant speed under a varying external load. If it were used to drive a generator, the output voltage and frequency would be unstable.

**6.690** If a 3-hp, 110-volt d-c motor is 85-per cent efficient when developing its rated output, what will be the line current?

*Answer.* Three horsepower is equal to  $3 \times 746$  watts, or 2,238 watts. The current flow at 100 per cent efficiency will be,  $I = P/E = 20.34$  amperes. At 85 per cent efficiency, therefore, the line current will be 23.9 amperes.

**6.691** If an auxiliary storage battery has a voltage of 12.4 volts on open circuit, and 12.2 volts when the charging switch is closed, what is the difficulty?

*Answer.* This condition indicates that the charging voltage is too low.

**6.692** Why should an Edison storage battery not be charged at less than the normal rate specified by the manufacturer? Explain.

*Answer.* Because the chemical reaction or oxidation process which takes place during the charge cannot be sufficiently accomplished at low charging rates. The internal resistance of the Edison cell is relatively higher than that of the lead-plate cell. Low capacity results from charging at less than the normal rate.

**6.693** Lacking an hydrometer, how may the state of charge of a storage battery be determined?

*Answer.* By the use of a high-resistance voltmeter under load conditions. It may also be determined by the gassing period while undergoing a charge, or by an ampere-hour meter.

**6.694** Your emergency storage battery has a specific gravity reading of 1.120. What should be done?

*Answer.* The battery should be filled with chemically pure water and immediately placed on full charge.

**6.695** Why should care be taken in the selection of water to be added to a storage cell to replace that lost by evaporation?

*Answer.* Chemically pure or distilled water should be used to deter chemical or metallic impurities from entering the solution. Impure water would generate local action and may ruin the cell.

**6.696** A discharged storage battery of three cells has an open-circuit voltage of 1.8 volts per cell and an internal resistance of 0.1 ohm per cell. What potential is necessary to produce an initial charging rate of 10 amperes?

*Answer.* The charging potential must be 8.4 volts.

*Solution:*

$$3 \times 1.8 \text{ volts} = 5.4 \text{ volts}$$

$$3 \times 0.1 \text{ ohm} = 0.3 \text{ ohm (internal resistance)}$$

The voltage drop across the internal resistance when a current of 10 amperes will flow is,  $E = IR = 10 \times 0.3 = 3$  volts. Thus the charging voltage must be sufficient to overcome the  $IR$  drops, or  $5.4 + 3 = 8.4$  volts.

**6.697** What capacity storage battery is required to operate a 50-watt emergency transmitter for 6 hr, assuming a continuous transmitter load of 70 per cent of the key-locked demand of 40 amperes? The emergency light load is 1.5 amperes.

*Answer.* A storage battery having a rated capacity of 200 ampere-hours would satisfy this condition. The actual capacity rating of the battery in accordance with the values given in this example, however, need be only 177 ampere-hours.

**6.698** Why does the charging rate to a storage cell, being charged from a fixed-voltage source, decrease as charging progresses?

*Answer.* As the charging progresses the gravity of the electrolyte increases, the cell voltage increases and produces greater opposition to the charging-current flow. Also, gas bubbles forming on the plates greatly increase the internal resistance, thereby reducing current flow.

**6.699** If you placed the emergency batteries on charge and the overload circuit breakers refused to stay closed, what is the trouble?

*Answer.* The charging voltage is reversed, no charging voltage is present, the charging voltage may be too low, or the charging circuit may be grounded.

**6.700** If part of the secondary winding of the power-supply transformer of a transmitter were accidentally short-circuited, what would be the immediate effect?

*Answer.* The momentary rise in secondary current due to the short circuit would react upon the primary winding to decrease its self-inductance, thereby raising the primary current. A fuse would probably blow.

**6.701** What are the relative advantages of the capacitor-input and choke-input filter circuits?

*Answer.* The capacitor-input arrangement permits the use of lower rated high-voltage secondaries since the capacitor serves to increase the voltage. The choke-input system introduces an additional voltage drop, but improves regulation. It also prevents flashback in systems where mercury-vapor rectifier tubes are used.

**6.702 What is the principal function of the filter in a power supply?**

*Answer.* To smooth out the rectified ripples in order to provide a steady direct current to the vacuum-tube plates.

**6.703 How may a filter capacitor be checked for leakage?**

*Answer.* By the use of a voltmeter in series with a source of d-c potential, or by an ohmmeter.

**6.704 What is the maximum allowable total secondary voltage of a transformer to be used as a center-tapped fullwave rectifier in connection with rectifier tubes having a peak inverse voltage rating of 10,000 volts?**

*Answer.*  $E_{\text{eff}} = E_{\text{max}} \times 0.707 = 7,070$  volts

**6.705 Discuss the uses of copper oxide rectifiers.**

*Answer.* Copper oxide rectifiers are used most commonly in conjunction with d-c voltmeters to read alternating-voltages. Any d-c galvanometer may serve a universal function for direct- and low-frequency a-c measurements by using it in conjunction with a copper oxide rectifier. They are used commercially as power rectifiers and peak limiters.

**6.706 Explain the principle of operation of the cold-cathode gaseous rectifying diodes.**

*Answer.* These tubes operate solely upon the principle of the ionization of gases between two oppositely charged electrodes. For example, if a potential difference is applied between two electrodes enclosed in a glass bulb including an inert gas, such as neon or argon, the potential difference will cause the gas molecules to be broken up into positive ions and negative ions. The positive charges or ions move to the plate charged with the negative potential while the negative charges, or electrons, move toward the plate charged with the positive source potential.

**6.707 What are the advantages of the high-vacuum rectifier tube as compared with the hot-cathode gas-filled tube?**

*Answer.* The advantages of the high-vacuum rectifier tube as compared with the hot-cathode gas-filled tube are the ability of the high-vacuum tube to withstand high inverse peak voltages and to operate

immediately without preheating. Comparing the efficiency of the high-vacuum-tube type with that of the mercury-vapor type, it has been found that the latter may be approximately 99 per cent efficient as compared with approximately 87 per cent efficiency for the former.

6.708 What action permits the high-conduction currents of a hot-cathode gas-filled rectifier tube?

*Answer.* Ionization due to collision.

6.826 Explain the principle of operation and list the main characteristics of a shunt d-c motor, a series d-c motor, and a compound d-c motor. Explain how the speed of each can be regulated. Draw a simple schematic diagram of each of the types of motors including a starting device.

*Answer.* Figure 4-22 illustrates the circuit arrangement of a shunt, series, and compound motor with speed control and starting devices.

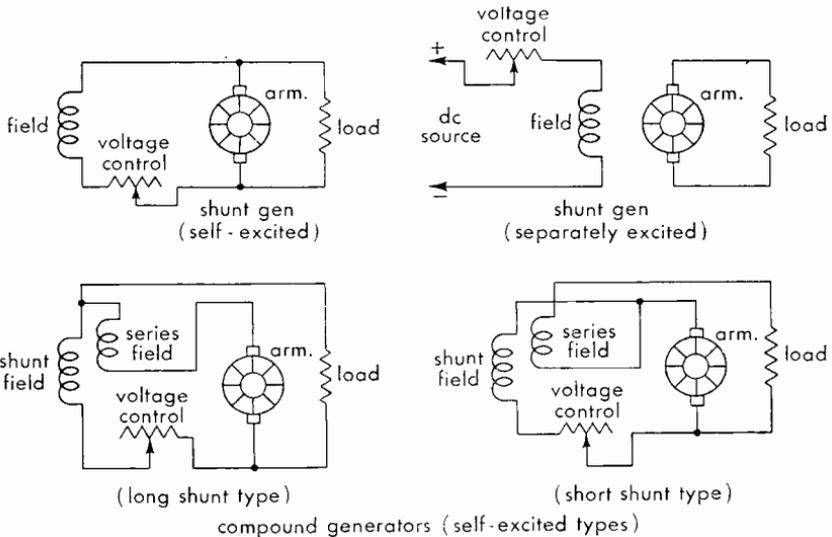


FIG. 6-23. Self- and separately excited shunt-compound d-c generators.

The shunt motor possesses a fairly constant speed characteristic under no-load versus full-load conditions. The series motor on the other hand shows a relatively greater drop in speed when the load is applied. The compound-wound motor because of its series and shunt field connec-

tions provides the advantages of both the speed and torque characteristics of the series and shunt types. It provides a more effective starting torque and, on the whole, gives better speed regulation under changes in full-load to no-load operating conditions than either the shunt or series types. (See also 3.170 and 3.304.)

**6.827 What is the danger of operating a d-c series motor without a load?**

*Answer.* The removal of the load in a d-c series motor will cause the motor to run at an abnormally high speed. When a series motor is operated without a load or if the load is suddenly removed, the instantaneous rise to a very high speed may cause the motor to be mechanically disrupted or torn apart. A series motor under these conditions develops an increased counter emf owing to the increased rate in which the magnetic field is cut. The line current therefore is relatively less than under full-load operating conditions.

**6.828 Explain the principle of operation and list the main operating characteristics of a d-c shunt generator and a d-c compound generator. Explain how the voltage of a d-c generator can be controlled. Draw a simple schematic diagram of each of these types of generators.**

*Answer.* The shunt-wound and compound-wound d-c generators are illustrated in Fig. 6-23. The shunt generator has a tendency to lose excitation under an overload condition. This serves as a protective medium when the generator is subjected to overload. The output terminal voltage will be decreased in approximate proportion to the  $IR$  drop in the armature and the armature reaction.

The most important characteristic of the compound-wound d-c generator is its more constant output voltage under load conditions. The additional series field winding compensates for the  $IR$  drop and field demagnetization and tends to regulate the output voltage to a steady level. It is also possible to increase the strength of the series winding so that the output voltage may rise slightly under loading conditions. The former is referred to as a "flat-compounded" generator, and the latter as an "overcompounded" generator.

**6.829 Explain the principle of operation of an induction motor and how such motors are started.**

*Answer.* The induction motor operates upon a principle similar to that of a transformer with a rotatable secondary winding.

Starting of induction motors is accomplished by the insertion of a series resistance in the rotor circuit with a short-circuiting switch across the resistor for operation at normal load speeds. Other starting methods are the autotransformer and double-winding types. In the former method, a tapped autotransformer is connected across the line with the necessary taps to limit the current flow during the start period. In the latter method, two rotor windings are provided, one of high resistance for starting and the other of low resistance for normal running speeds. Induction motors below 3-hp rating generally do not require starting devices. Some types of single-phase induction motors employ capacitor starters which include a capacitor and a separate winding in series to effect the proper phase shift when starting. This circuit is automatically disconnected when the rotor comes up to normal running speed.

**6.830** What conditions must be met before two a-c generators can be operated in parallel?

*Answer.* The essentials for operating a-c generators in parallel are as follows: the terminal polarities of both generators must be the same, the voltage must be balanced between the generators both under no-load and full-load conditions, and both generators must be running at the same frequency and in phase.

**6.831** If a 220-volt, 60-cycle, single-phase line delivers 100 watts at 80 per cent power factor to a load, what is the phase angle between the line current and the line voltage? How much current flows in the line?

*Answer.* Phase angle =  $\theta = 37$  degrees. 0.568 ampere.

Since

$$\text{Power factor} = \cos \theta = \frac{P}{EI} = \frac{\text{real watts}}{\text{apparent watts}}$$

then

$$0.8 \text{ (80 per cent)} = \frac{100}{\text{apparent watts}}$$

$$\therefore \text{Apparent watts} = IE = \frac{100}{0.8} = 125$$

but

$$E = 220 \text{ volts} \quad \therefore I = \frac{W}{E} = \frac{125}{220} = 0.568 \text{ ampere}$$

From the table of cosines,  $\cos \theta = 0.800$ , and  $\theta = 36^\circ 50'$ , or approximately 37 deg.

6.832 Draw diagrams showing various ways by which three power transformers can be connected for operation on a three-phase circuit. Show how only two transformers can be connected for full operation on a three-phase circuit.

*Answer.* See Fig. 6-24.

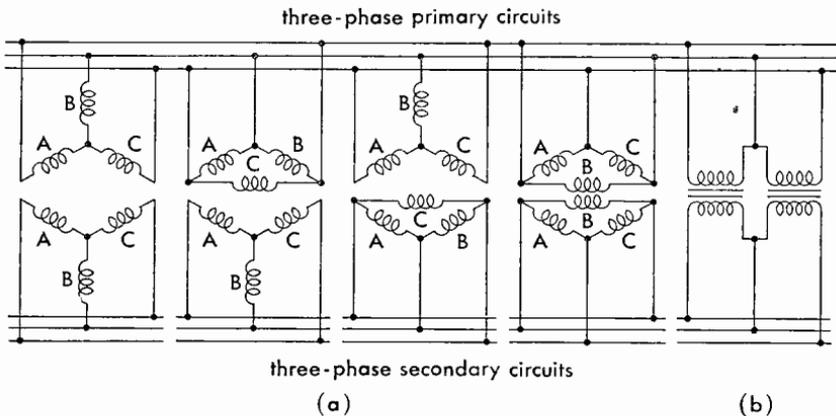


FIG. 6-24. Method of connecting three single-phase transformers for 3-phase operation (a) and connecting two single-phase transformers for 3-phase (b).

6.833 How can low power factor in an electrical power circuit be corrected?

*Answer.* Power factor in an inductive circuit containing a transformer or motor can be corrected by inserting a capacitance (condenser) across the device.

6.834 Draw a simple circuit diagram of a voltage-doubling power supply using two one-half wave rectifiers.

*Answer.* See Fig. 4-23.

6.835 How can the condition of charge of dry B batteries be determined?

*Answer.* By the use of a high-resistance voltmeter under normal circuit-load conditions.

**6.836** What precaution should be observed in storing spare B batteries?

*Answer.* Dry batteries should be stored in a dark, dry compartment or container, preferably in a reasonably cool temperature. Excessive heat and moisture will increase deterioration.

**6.837** What are the main differences between Edison and lead-acid storage batteries?

*Answer.* See 3.147, 3.151–153, 3.166, 6.438.

**6.838** Draw a sketch showing the construction of a storage cell.

*Answer.* See Fig. 6-25.

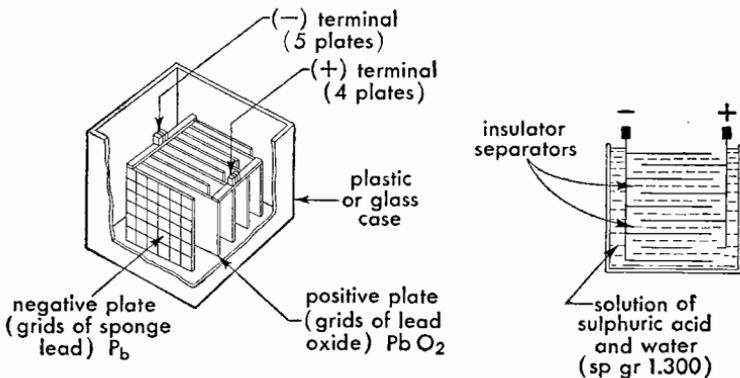


FIG. 6-25. Construction of a lead-acid storage cell.

**6.839** Define "specific gravity" as used in reference to storage batteries.

*Answer.* "Specific gravity" refers to the density of the electrolyte used in storage cells. It is the ratio of the mass of a body to the mass of an equal volume of water at 4 deg centigrade.

**6.840** Draw a diagram of the charging circuits of two batteries using a four-pole double-throw switch such that, while one battery

is on charge, the other is on discharge. Indicate the d-c power source, voltage-dropping resistors, and connections to the battery load.

*Answer.* See Fig. 6-26.

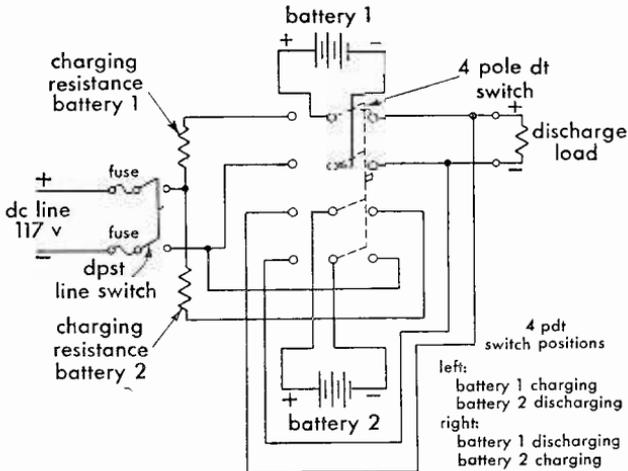


FIG. 6-26. Simultaneous charge and discharge battery connections.

**6.841** What is indicated if, in testing a storage battery, the voltage polarity of some of the cells in the battery is found reversed?

*Answer.* Such a condition might arise in two different ways. If, during a routine maintenance program, one or more cells were replaced in reversed polarity, the rest of the battery would tend to keep the reversed cells charged up. A more likely explanation would be that the cells had become discharged more than most of the others and that their resistance was high. If then, the resistance of the battery load were low compared to the resistance of the discharged cells, the rest of the battery would then charge the low cells via the external circuit, and they would then be found with reversed polarity, despite any contrary markings appearing on their terminals.

It is sometimes the practice, notably in telephone offices, to provide "counter emf" cells that can be switched into series connection with the storage battery bank in order to reduce the voltage, particularly just after the battery has been charged. In certain applications, the counter emf cell is preferable to a series resistance for reducing voltage.

**6.842** If a hydrometer is not available, how can the condition of charge of a storage battery be determined?

*Answer.* See 6.693 and 6.438.

**6.843** What is indicated if a voltmeter connected between the negative side of a ship's d-c line and ground reads the full line voltage?

*Answer.* If the negative side of the ship's generator is normally grounded, a voltage reading between the negative side of the ship's d-c line to ground will indicate an open fuse or contact in that side of the line. The voltmeter will read because of its connection to the positive side of the line through the circuit load connections such as lamps and motors. This condition could also prevail in the case where the positive side of the ship's generator is grounded and the negative side ungrounded.



## SPECIAL ENDORSEMENTS

[Elements: 7, 8]



## Element 7

# Aircraft Radiotelegraph

### REGULATION AND TREATY

**7.01 Under what conditions is a flight radio operator required aboard scheduled aircraft engaged in flights outside the continental United States?**

*Answer.* A licensed radio operator shall be required for flight over any area, route, or route segment over which the administrator has determined that radio telegraphy is necessary for communication with ground stations during flight.

**7.02 Under what conditions are flight radio operators required in U.S. irregular air-carrier operation?**

*Answer.* An airman holding a flight radio operator's certificate shall be required for flight over any area which the Administrator has determined that radio telegraphy is necessary for communication with ground stations during flight.

**7.03 Is it mandatory that one crew member other than the flight radio operator be capable of operating the radio equipment in an emergency?**

*Answer.* Yes. If a flight requires only one radio operator, another crew member must be capable of operating the emergency equipment.

**7.04 What are the FCC license requirements for an air radiotelegraph operator?**

*Answer.* On an aircraft employing radiotelegraphy the holder of a first- or second-class radiotelegraph operator license may not operate the radiotelegraph station during the course of normal rendition of

service unless he is at least 18 years of age and has satisfactorily completed a supplementary examination qualifying him for that duty or unless he has served satisfactorily as chief or sole radio operator on an aircraft employing radiotelegraphy prior to February 15, 1950. The supplementary examination consists of written examination Element 7, and for a second-class operator, a transmitting and receiving code test at 25 words per minute plain language and 20 code groups per minute. See also additional information for study material listed at the end of this element.

**7.05 What is meant by "long-distance" operation in scheduled air-carrier flights outside the continental United States?**

*Answer.* A long-distance operation is one in which the time interval between stops is of sufficient duration to require that the dispatch be based entirely on forecasts of weather expected at the intended destination and alternates.

**7.06 An aircraft is engaged in "long-distance" operation. What radio equipment is required aboard for this operation?**

*Answer.*

*a.* One of two independent means must be provided whereby communications and meteorological information can be transmitted to at least one ground station from any point on the route from a distance of not less than 25 miles to airport traffic-control towers located at airports approved for the route.

*b.* Communications must at all times be receivable at any point on the route.

*c.* In addition to (a) the equipment must provide for the reception of meteorological information on the route and receive instructions from ATC (Airport Traffic Control) towers located at airports approved for this route.

*d.* Also by one of two independent means the equipment must facilitate the reception of radio navigational signals from any radio aid to navigation in accordance with the rules regarding the distance of operation, airport lighting facilities and so on. For long-distance operation, the equipment must be capable of obtaining reliable radio bearings for a radius of within 200 miles of any regular or approved alternate airport.

**7.07** For "long-distance" operation outside the continental United States, what ground radio navigational aids are required at scheduled stops and alternate airports?

*Answer.* In addition to (d) of the previous question, facilities must be provided too for making accurate instrument approach: provided, that the administrator at a particular airport or airports, may approve facilities which provide less coverage than that required herein if he finds that adequate safety is provided.

**7.08** What are the requirements for a two-way air-to-ground communications system in scheduled air-carrier operations outside the continental United States?

*Answer.* A two-way ground-to-aircraft radio communications system shall be available at such points as are necessary to ensure adequate communication between plane and ground over the entire route.

**7.09** For "long-distance" scheduled air carrier operations outside the continental United States, what is the required communication range from aircraft to ATC towers at airports approved for the route?

*Answer.* See 7.06a-d.

**7.10** For "long-distance" scheduled aircraft operations outside the continental United States, what are the aircraft receiver requirements for receiving communications, meteorological, and navigational information?

*Answer.* See 7.06d.

**7.11** For "long-distance" scheduled air-carrier operations outside the continental United States, what aircraft transmitting equipment is required and over what distances should this equipment operate?

*Answer.* See 7.06a.

**7.12** What radio equipment is required aboard foreign-flag aircraft operating into the United States and outlying possessions?

*Answer.* Each aircraft shall be provided with such radio equipment as is necessary to make use of the air navigation facilities along or adjacent to the route to be flown within the United States and to

maintain communication with ground stations along and adjacent to such routes.

**7.13 Discuss the requirements for electrical power and radio equipment required for continuance of flight.**

*Answer.* The power equipment requirements are as follows: One or more storage batteries or other source of electrical supply sufficient to operate all radio and electrical equipment necessary for the flight. In addition, two of the following three units of radio equipment:

1. One transmitter for two-way communication.
2. One receiver for two-way communication.
3. One receiver capable of receiving navigational signals.

In addition, one of the radio navigational systems required in 7.06d. Also three spare fuses of each capacity are required.

**7.14 An aircraft is at midocean and experiences a communication failure. What procedure would the pilot follow after being advised by the flight radio operator that the aircraft is out of communication?**

*Answer.* The following procedure shall be followed: proceed according to the current flight plan, maintaining the minimum instrument altitude of the last acknowledged assigned altitude, whichever is higher, to the airport of intended landing and commence descent at approach time last authorized or, if not received and acknowledged, at the estimated time of arrival in the flight plan; or, if weather conditions permit, proceed in accordance with contact flight rules; or, land as soon as practicable.

**7.15 Define the point-of-no-return as used in air carrier operations.**

*Answer.* This term refers to the condition in which an aircraft has insufficient fuel to return to the point of departure or any alternate for that point.

**7.16 If a flight operator noted an irregularity or hazard which, in his opinion, made for unsafe operation, to whom should he report such hazard or irregularity?**

*Answer.* A report should be made immediately to the operations manager. If said report is found justified by the operations manager, notice of the irregularity or hazard must be made to the administrator at once.

**7.17** With regard to air-to-ground communication, what is the order of priority for communications on a channel that is used for point-to-point as well as air-to-ground contacts?

*Answer.* Priority shall be given to plane-to-ground and ground-to-plane communications.

**7.18** What is meant by "type certification" of radio equipment on United States scheduled air-carrier aircraft?

*Answer.* A type certification refers to the CAA regulations which requires that all aircraft radio equipment must conform with certain requirements to satisfy airworthiness. To be eligible for a type certificate, an applicant must submit the following technical data:

Drawings, drawing list, and parts list; in addition, complete technical data relative to design and tests together with inspections, identifications, and changes to prove airworthiness must be included.

**7.19** What is an air-carrier operating certificate and by whom is it issued?

*Answer.* A certificate prescribing the type of operation, the routes over which such operation may be conducted, the airports that may be used, and other specifications and restrictions as may reasonably be required in the interest of safety. An air-carrier operating certificate is issued by the administrator.

**7.20** What are the requirements regarding marker-beacon receivers on United States irregular air-carrier aircraft operating outside the continental United States?

*Answer.* At least one marker-beacon receiver and such radio equipment as is necessary to receive satisfactorily, by either of two independent means, radio navigational signals from any other radio aid to navigation intended to be used. (See also 7.06.)

**7.21** Is it mandatory that United States irregular carriers operating outside the continental United States maintain a ground communication system to provide radio contact at all times with their aircraft?

*Answer.* Yes. See 7.06(b).

**7.22** When a United States irregular air-carrier aircraft is operating outside the continental United States on long distance flights

over water or uninhabited terrain, what transmitting means are required?

*Answer.* See 7.20.

**7.23 Define a "route segment" as used in scheduled air-carrier operations.**

*Answer.* A route segment is a portion of a route in which the boundaries are identified by a continental or insular geographic location, a point at which some specialized aid to air navigation is located, or a point at which a definite radio fix is located.

**7.24 When an aircraft is in distress, upon what frequency or frequencies should the first radio transmission of distress call and message be made?**

*Answer.* Any aircraft in distress must transmit the distress call on the frequency on which the land or mobile stations capable of helping it keep watch. When the call is addressed to stations of the maritime mobile service, frequencies shall be 500 or 8,280 kc (or 8,364, see latest Rules). The distress call should be preceded by the autoalarm signal of twelve four-second dashes, with intervals of one second between each dash. The frequency of 121.5 mc is the universal simplex channel for emergency and distress communications. A frequency of 2,182 kc has been specified as a world-wide distress channel for radiotelephone-equipped stations. However, at the present time, adequate monitoring facilities do not guard this frequency at all locations.

**7.25 In event of an aircraft in distress, how often should the distress message be repeated?**

*Answer.* The distress message should be transmitted at intervals until acknowledged.

**7.26 Under what conditions should an aircraft, becoming aware that another aircraft is in distress, transmit the distress call and message?**

*Answer.* Provided that the aircraft in distress is not itself in a position to transmit or if the intervening command believes that further help is necessary.

**7.27 What is the distress signal used on VHF A3 emission?**

*Answer.* For VHF radiotelephony the signal MAYDAY is used.

**7.28 List the order of priority in the establishment of communications in aeronautical mobile radio service.**

*Answer.* The order of priority in the establishment of communications in the aeronautical services is as follows:

Distress calls, distress messages and distress traffic; urgency messages, safety messages; communications relating to direction finding; flight safety messages; meteorological messages; flight regularity messages.

**7.29 A control station receiving a distress message from an aircraft shall forward the information immediately to what offices?**

*Answer.* The information shall be forwarded immediately to the area TFC center or flight information center.

**7.30 In aircraft distress communications, what is the normal speed of radiotelegraphic transmission?**

*Answer.* The speed should not normally exceed 16 words per min.

**7.31 List the information that should be transmitted, if time permits, from an aircraft in distress.**

*Answer.* The estimated position and time, true heading and indicated air speed, altitude, type of aircraft, nature of distress, and the intention of the person in command of the distressed aircraft as to the type of forced landing required.

**7.32 What action should be taken by the flight radio operator immediately prior to ditching or crash landing?**

*Answer.* The telegraph keying or radiophone circuits should be closed to ensure continuous transmissions.

**7.33 List the emergency and distress frequencies for aircraft in the MF band.**

*Answer.* The distress frequencies are 500 kc (MF); 2,182 kc (radio-telephone) (MF); 8,364 kc (HF); and 121.5 mc (VHF).

**7.34 What is the international frequency in the high-frequency band for use by life rafts for search and rescue communication with stations of the maritime mobile service?**

*Answer.* The lifeboat frequency is 8,364 kc. A frequency of 121.5 mc is also provided for emergency and distress communications.

**7.35 What is the common VHF aircraft emergency frequency?**

*Answer.* 121.5 mc.

**7.36 How would a flight radio operator alert the search and rescue facilities in his particular area?**

*Answer.* The radio operator would notify the appropriate controlling authority, rescue unit, or other assisting organization to guard some radio frequency or stand by to proceed on a mission.

**7.37 What procedure is used by an aircraft to cancel a distress message?**

*Answer.* The aircraft must transmit a message, on the distress frequency, canceling the state of distress.

**7.38 What is the meaning of: (a) air-carrier aircraft station, (b) airdrome-control radio station, (c) aeronautical land station, (d) aeronautical fixed station, (e) radio beacon station, (f) radio range station, (g) localizer station, (h) glide-path station, (i) aeronautical marker beacon station, (j) surveillance radar station, and (k) aeronautical public-service station?**

*Answer.*

*a.* A radio station aboard an aircraft engaged in, or essential to, transportation of passengers or cargo for hire.

*b.* A radio station providing communication between an airdrome control tower and aircraft or aeronautical mobile utility stations.

*c.* A land station in the aeronautical mobile service carrying on a service with aircraft stations, but which may also carry on a limited communication service with other aeronautical land stations.

*d.* A radio station used in the fixed service for the handling of communications between fixed points relating *solely* to actual aviation needs.

*e.* A special radio station, the emissions of which are intended to enable an aircraft to determine (1) its radio bearing or direction with reference to the radio beacon station, or (2) the distance which separates it from the latter, or (3) both of these.

f. A form of radio beacon, the emissions of which provide definite track guidance.

g. A directional radio beacon normally associated with an instrument landing system which provides guidance in the horizontal plane to an aircraft for purposes of approach landing.

h. A directional radio beacon associated with an instrument landing system which provides guidance in the vertical plane to an aircraft for purposes of approach in landing.

i. A radio station marking a definite small area above the ground as an aid to navigation.

j. A land station using radar to display presence of aircraft within its range.

k. A radio station, ground or aircraft, operated in the aeronautical public-communication service.

**7.39 In general, what language shall be used in radiotelephone communications between aircraft and aeronautical stations in the international service?**

*Answer.* Communications shall, in general, be conducted in the language of the ground station. In English-speaking countries, first choice alternate will be French and Spanish, the selection being made regionally.

**7.40 In event of noncommunication with an aircraft what offices should be advised immediately by the control station operator?**

*Answer.* The ATC Office and the airline operating agency should be notified immediately.

**7.41 In communications between aircraft radio stations, what station controls the duration of continuous work?**

*Answer.* The control is governed by the receiving station or intervening relay station.

**7.42 How should an aircraft flying over the sea signal its position?**

*Answer.* The aircraft shall signal the time of its position in latitude and longitude, using GMT, but may give the true bearing and distance in nautical miles from some known geographical point.

**7.43 How should an aircraft flying over land signal its position?**

*Answer.* The aircraft shall signal its position by the name of, and approximate distance and direction of, the nearest reference point.

**7.44 What procedure should an over-ocean aircraft follow if it is unable to establish communications for any reason other than transmitter failure?**

*Answer.* The aircraft shall transmit periodic reports at scheduled times, or positions, on the assigned frequency.

**7.45 In air-to-ground radiotelephone communications, how is the "invitation to reply" spoken in standard voice procedures?**

*Answer.* The word OVER is given to invite a reply.

**7.46 What is meant by the priority prefix SVH?**

*Answer.* SVH is the prefix embodying all messages in the aeronautical service pertaining to the safety of human life.

**7.47 After communication has been established between an aircraft and its control station, is it permissible to dispense with the radio call letters in subsequent communication?**

*Answer.* After communication has been established the call letters may be abbreviated by using the first and last two characters of the call letters.

**7.48 Is it mandatory that an aircraft maintain continuous watch in flight on the air-to-ground route frequency?**

*Answer.* Yes.

**7.49 In radiotelephone communications what word is spoken to denote that an error has been made in transmission?**

*Answer.* The word CORRECTION is used.

**7.50 In radiotelephone communication, how is termination of communication indicated by the receiving station?**

*Answer.* The word OUT.

**7.51 With which station should an aircraft normally communicate when flying over a particular route?**

*Answer.* Communication should be maintained with the control station of the area in which the plane is flying unless receiving conditions demand otherwise.

**7.52 What is the radiotelephone spoken equivalent of radiotelegraph signal  $\overline{\text{IMI}}$ ?**

*Answer.* The word, REPEAT.

**7.53 What is the radiotelephone equivalent of the radiotelegraph signal C?**

*Answer.* The phrase, THAT IS CORRECT.

**7.54 What is meant by break-in procedures in aircraft radiotelegraph communications?**

*Answer.* This term refers to the process of interrupting the transmission of another station for repeat or emergency purposes. Break-in is accomplished by transmitting the letters BK followed by a brief pause for acknowledgment from the transmitting station.

**7.55 What type of information is generally included in a broadcast service known as NOTAMS?**

*Answer.* Information contained in scheduled broadcasts of notices to airmen, including general and urgent information affecting the safety of air navigation. These reports *do not* include meteorological information.

**7.56 Describe the structure of the NOTAM code as used in international flight operations?**

*Answer.* The code is composed of five letters, each of which has a specific meaning.

The first letter of the code group is always the letter Q to indicate that it is code abbreviation for use in the composition of NOTAMS. The second and fourth letters shall in all cases be a vowel. The third and fifth letters may be any letter of the alphabet. See the Appendix for complete list.

**7.57 What is meant by the ICAO (International Civil Aviation Organization) abbreviations such as: CNL, ARR, DEP, PLN?**

*Answer.* CNL . . . Cancellation message.  
ARR . . . Arrival message.  
DEP . . . Departure message  
PLN . . . Flight plan message.

**7.58 How are the ICAO complementary code groups used in air-to-ground communications?**

*Answer.* The complementary code groups are abbreviations to be used in conjunction with Q signals to reduce the length of transmissions. Some typical examples are as follows:

AD . . . . . Airdrome  
ADZ . . . . . Advise  
GND . . . . . Relative to ground  
RNG . . . . . Radio range

**7.59 What radio information is contained in the IFR flight plan of scheduled air-carrier operation outside the continental limits of the United States?**

*Answer.* The information contained in an IFR flight plan is of considerable detail and includes such items as, type of aircraft, name of pilot in command, point of departure, cruising altitude, estimated time of arrival, and so on. The information relating specifically to radio includes aircraft identification (radio call letters) and the transmitting and receiving frequencies to be used.

**7.60 What is the working frequency in the medium-frequency band reserved for aircraft flying over the seas?**

*Answer.* 457 kc.

**7.61 Is it mandatory that United States air-carrier aircraft operating within the United States and overseas be equipped with a radio altimeter?**

*Answer.* The regulations do not indicate that a radio altimeter is mandatory.

**7.62 What are the requirements regarding a master switch in an aircraft electrical installation?**

*Answer.* If electrical equipment is installed, a master-switch arrangement shall be provided which will disconnect all sources of electrical power from the main distribution system at a point adjacent to the power sources.

The master switch or its controls shall be installed so that it is easily discernible and accessible to a member of the crew in flight.

**7.63 Air-carrier aircraft electrical installations incorporate storage batteries in the primary systems. Discuss the requirements for battery vents, cooling, containers, and protection against acids.**

*Answer.* The battery compartment must have provisions for releasing gases through suitable means outside the airplane. A completely enclosed compartment shall be provided to prevent acid and corrosive substances from coming in contact with other parts of the plane which are essential to safe operation. The aluminum container should be frequently examined for evidence of leakage. The battery compartment is cooled by adequate ventilation, but care must be exercised by frequent inspection to make certain that the batteries are not overheating due to excessive charging rates.

**7.64 With reference to aircraft generators, what are the requirements concerning generator capacity, generator switch, generator rating, generator controls, and a reverse current cutout?**

*Answer.* The requirements are as follows: The generator must be designed to be capable of delivering its continuous rated power with a minimum of overheating. The generator switch must be capable of carrying the rated current and shall be of such construction that there is sufficient distance or insulating material between current-carrying parts and the housing so that vibration in flight will not cause short circuiting. The generator rating must conform with the total load requirements of the installation. Its output capacity must be sufficient to supply the complete load demands on the basis of continuous operating conditions. The generator must be equipped with a suitable control device (carbon pile regulator) which is capable of dependably regulating the generator output within rated limits. A reverse current cutout must be provided for the purpose of disconnecting the generator from the batteries and other generators under conditions when the generator is developing a voltage below that of its normal value. It is in reality an underload relay which prevents the batteries or other generators

from discharging back through the main generator when its voltage falls lower than that of the other parallel units.

## RADIO THEORY

**7.65** What type of radio wave is the most suitable for aircraft radio direction finding, vertically or horizontally polarized waves?

*Answer.* Vertically polarized waves are used because they are less easily reflected from the ionosphere or from obstructions (such as mountain ranges) than are horizontally polarized waves. Such reflections, usually resulting in waves with strong horizontal components, give rise to spurious signals that cause multiple course indications.

**7.66** Explain the term "quadrantal or aircraft error" and what is done to counteract this error in modern aircraft radio installations? How does quadrantal error vary with frequency?

*Answer.* Quadrantal or aircraft error, sometimes known as "loop deviation," is the error caused by the bending or reradiation of the incoming signal by the metal of the plane. These additional signals are often strong enough to cause the loop to give false indications. Loops are mounted well forward on the underside of the plane to minimize reflections. In addition, a correction chart, special azimuth scale, or built-in error-correcting cam is furnished to provide the pilot with an accurate indication.

The amount of error increases with frequency because shorter lengths of wire and metal become more effective reflectors at higher frequencies.

**7.67** Normally, what are the maximum and minimum frequencies upon which a standard transport aircraft DF loop will give satisfactory operation?

*Answer.* Between about 200 and 1,750 kc.

**7.68** An aircraft loop antenna is influenced by the field of a vertically polarized wave front. Will the magnetic lines of force cut the loop from top to bottom or from side to side?

*Answer.* The vertical lines of force will cut only the vertical sides of a loop. If the loop is oriented so that its plane is at right angles to the wave front, the current induced front and back will add. In a

circular loop, any curved sector can be thought of as having both a vertical and a horizontal component, and therefore the loop as a whole will have electrical top, bottom, and sides.

**7.69** It is common practice to employ plastic housings to streamline electrostatically shielded loop antennas on air-carrier aircraft. Do these housings have a conductive or nonconductive surface?

*Answer.* Such housings have a conductive coating. They are often impregnated with graphite. The conductivity of the surface should be such that the resistance from any square-inch area to the supporting metallic structure does not exceed 10 megohms.

**7.70** Explain how aircraft DF loops are constructed so that they intercept electromagnetic waves and reject electrostatic charges.

*Answer.* A simple shielded DF loop comprises a number of turns of wire insulated from and enclosed in a circular metal tube. The tube is not continuous but is split at the bottom, the gap being filled with insulating material. The loop is thus affected by electromagnetic waves but is shielded from electrostatic charges. (See also 6.887.) Newer types have powdered-iron cores and are physically smaller.

**7.71** When using a manual direction finder on a homing station how should the DF loop and the associated receiver be adjusted?

*Answer.* The loop is oriented until the azimuth reads zero and a course is flown such that a null signal is always received. The receiver gain should be high but should be reduced as the station is approached, otherwise the receiver will block. There is normally no cone of silence above such a station.

**7.72** In an aircraft DF installation, is the loop calibration curve considered accurate for any frequency between 200 and 1,800 kc?

*Answer.* Yes, but too much reliance must never be placed in an over-all calibration curve. It is desirable to make spot checks at frequencies frequently used.

**7.73** What effect does a coast line have upon radio bearings taken aboard an aircraft flying offshore?

*Answer.* If the radio beacon is located upon the shore and the path between it and the aircraft is entirely over water, the coast line has

no effect. Similarly, if bearings are taken on an inland station on a line at right angles to the shore line, there is no effect. However, bearings taken at an acute angle across the coast line are subject to an error that increases as the angle with the shore decreases. This effect, known as "coastal refraction" or "land effect," is caused by the refraction of a radio wave in crossing the boundary of land and water. A ray from a shore station to a plane over water would always be bent in towards the coast line. Systems such as loran are essentially unaffected.

**7.74 In aircraft DF work, is the minimum or maximum signal used to observe bearings? Explain.**

*Answer.* The minimum signal is used to observe bearings. When a loop is pointed directly at the transmitting station, a maximum signal is received. However, a maximum is an indefinite quantity that may depend not only upon orientation of the loop but also upon other factors, such as propagation and receiver gain setting. The minimum or null position of the loop is a definite and also a much sharper indication. It is accordingly used as soon as the transmitter has been identified and the bearing is to be taken.

**7.75 In aircraft radio navigation, what is meant by a "reciprocal"?**

*Answer.* A reciprocal is the direction of bearing  $\pm 180$  deg.

**7.76 Is quadrantal error in a loop installation aboard an aircraft maximum or minimum at the cardinal points of the azimuth?**

*Answer.* It is minimum at the cardinal points and maximum at points midway between the cardinal points.

**7.77 Describe the function of the sense antenna used in conjunction with an aircraft ADF installation.**

*Answer.* With a simple loop antenna, there is always a 180-deg ambiguity in the direction because there are always two positions that give a maximum (or null) signal. If, however, a separate sense antenna is connected to the receiver in such a way that the resultant pattern of the two antennas is a cardioid, the loop azimuth can be read directly as the direction of the transmitting station. The automatic direction finder (ADF) requires such a sense antenna in order to function automatically.

**7.78 What is the purpose of the threshold sensitivity control on an aircraft ADF unit?**

*Answer.* The sensitivity control (usually a screwdriver adjustment) is a bias control on the thyratrons that control the loop motor. The loop seeks always to remain at null signal. If the aircraft changes position relative to the homing transmitter, one of the thyratrons will fire and cause the motor to turn the loop to null again. When the thyratrons are biased down, they do not fire so quickly and the system is not subject to "hunting" or continuous movement back and forth through the null.

**7.79 What circuits of an aircraft ADF use thyatron tubes?**

*Answer.* The control circuits that drive the loop motor to seek a null position.

**7.80 What is the purpose of the silica gel crystals in an aircraft ADF installation?**

*Answer.* The plastic housing of the loop, mounted externally to the aircraft, is kept airtight but is subject to temperature extremes because of its exposed location. The changes of temperature allow breathing of warm moist air from the plane, and moisture condenses on the interior of the housing. The air opening (inside the plane) is connected via a rubber tube to a glass cylinder containing silica gel, a desiccant. Moisture is taken out of the air before it can leak into the housing, which is thus assured of dry air from which there is no moisture to condense.

**7.81 With reference to ground DF stations, what is the principal advantage of the Adcock station over the early loop DF stations?**

*Answer.* Ground direction-finding stations using Adcock antennas pick up essentially only vertically polarized waves and can therefore give more exact determinations of direction than earlier loop stations that often picked up other components. The Adcock receiving antenna shares the same advantages for reception as for transmitting at a radio beacon.

**7.82 What is meant by the term "hunting" in an ADF system?**

*Answer.* When the motor-control thyratrons in an ADF system are not sufficiently biased, the system responds to many small irregular impulses and the loop is shifted quickly back and forth over the null region. This phenomenon is called hunting.

**7.83 Will static crashes affect the operation of an aircraft ADF?**

*Answer.* Yes. During a heavy thunderstorm off to one side of the course the ADF may spend a great part of its operating time taking a null on the storm, shifting back and forth between it and the desired beacon signal.

**7.84 What is the purpose of a compensator cam in an aircraft ADF installation?**

*Answer.* Planes of a type and even those of different types have nearly the same quadrantal error characteristic. If the ADF loop is provided with a correction cam that removes the quadrantal error, the direction indicator can be made direct reading.

**7.85 What is an Autosyn as used with ADF systems and what device furnishes power to the Autosyn?**

*Answer.* The Autosyn is essentially a three-phase motor which, when properly connected to a similar motor, assumes the successive positions of the second motor as the latter is turned. It is powered by alternating current which is either furnished by a separate inverter run from the aircraft battery, or from the 400-cycle a-c system with which many large planes are equipped.

**7.86 What type of radio range gives satisfactory ADF operation? What type gives unsatisfactory operation?**

*Answer.* The SBRA type. The older loop radio range often gives false readings. The newer Adcock radio range produces essentially pure vertical polarization and is entirely satisfactory for automatic direction finding.

**7.87 Why is it inadvisable to take ADF bearings on synchronized broadcast stations?**

*Answer.* Synchronized broadcast stations operate on the same frequencies and broadcast the same programs. It is therefore practically impossible to distinguish which transmitter is being received, unless the aircraft is near one and the terrain can be distinguished. The automatic direction finder would tend to follow the nearer and stronger station. It would give wholly confusing indications when flying between the two stations.

**7.88** In reference to an ADF system, explain why the position of the loop determines when power will be delivered to the loop motor-control circuit.

*Answer.* If the loop is oriented towards a null, a minimum signal will be received and the thyatron motor-control tubes will not fire. However, if the aircraft swings so that the loop shifts out of the null and a signal is received, a thyatron will be fired by this signal and power will be supplied to the loop motor in such a way as to move the loop back in the direction away from the signal. When the null is once again received, the thyatrons are extinguished and the motor turns off.

**7.89** Why is a low-inertia motor used as the loop control motor in an ADF system?

*Answer.* A high-inertia motor that took some time to go into operation and to stop would increase the hunting in the system and result in a continual movement of the indicator needle as the system tried unsuccessfully to find and maintain the orientation of the loop on the null during normal flying.

**7.90** When using the aircraft ADF receiver for aural flying of a low-frequency radio range, the function switch should be in the "antenna" position instead of the "compass" position. Explain.

*Answer.* When the switch is in the antenna position, the sense antenna, which has better pickup than the loop, is connected to the receiver and is used for maximum signal (rather than null) reception of the radio range. When the selector is in the "compass" position, the AVC is operating and this is not desirable since accurate close-in flying of an I-f range depends upon the pilot's ability to recognize signal changes. Since the AVC tends to make the signal level steady, it should not be used. The pilot carefully backs off manual volume control, or leaves it alone for "fade" orientation.

**7.91** What is the purpose of the rotatable scale on the aircraft ADF azimuth indicator?

*Answer.* The rotatable scale is connected with the gyrocompass so that the magnetic direction of the radio beacon is immediately apparent to the pilot. All rotatable scales on ADF azimuths are not

connected to the gyrocompass. There is a manual knob for setting up heading and reading the bearing directly off the scale.

**7.92 Why is it important that an aircraft employ bonding and shielding of various radio and electrical units?**

*Answer.* Different masses of metal acquire unequal charges or may rest at different potentials because of connection to sources of power. If sparking occurs as a result of voltage breakdown, or if vibration causes contact between circuits or equipment at slightly differing potential, the resulting sparking sets up an electrical disturbance that is readily picked up in sensitive receiving equipment. It is therefore necessary that all radio and electric equipment be grounded to a common lead or metal frame in order to avoid potential differences. Wires carrying high-voltage alternating currents must be shielded to avoid pickup of these currents; wires to high-gain electronic equipment must be shielded from all extraneous disturbances.

**7.93 In bonding aircraft radio and electrical units on an aircraft, should the resistance of the bond be of a high or low value?**

*Answer.* The resistance of bonds should be held to as low a value as possible.

**7.94 In a carbon-pile voltage regulator, is the carbon pile connected in series or in parallel with the shunt field of the generator?**

*Answer.* It is connected in series with the shunt field.

**7.95 In the resistance element of a carbon-pile voltage regulator does the resistance vary inversely or directly with the amount of pressure on the carbon?**

*Answer.* Resistance varies inversely with pressure.

**7.96 What operating characteristics of the carbon-pile voltage regulator makes it well suited for aircraft use?**

*Answer.* Regulation of the generator output voltage is good because of the continuous resistance change. The resistance changes instantaneously to compensate for changes in the output voltage of the generator. Radio interference is reduced by avoiding the opening and closing of contacts. Its construction allows it to carry heavy currents without damage, and its resistance variation makes it effective over a

wide range of field current. It is relatively unaffected by vibration or shock experienced in aircraft.

**7.97 What is the purpose of the equalizer circuit in a parallel generator system using a carbon-pile voltage regulator?**

*Answer.* The equalizer circuit permits the use of two generators for battery charging and effectively prevents voltage differences between the generators. The reverse-current relays and carbon-pile regulators are often assembled in a single cabinet sometimes called the load center.

**7.98 At what speed of the aircraft engine should the generator develop its normal voltage?**

*Answer.* At the normal cruising speed of the engine. The generator should develop normal voltage at about 1,500 rpm engine speed. Owing to usual gearing, the generator will be turning at about 2,250 rpm.

**7.99 How is the rating on an aircraft generator usually stated?**

*Answer.* An aircraft generator is usually rated by its current-carrying ability in amperes.

**7.100 List at least two sets of figures for generator ratings on present-day transport aircraft.**

*Answer.*

Direct voltage.....	30 volts	28.5 volts
Direct current.....	50 amperes	200 amperes
Power output.....	1,500 watts	5.7 kilowatts
Speed.....	2,400/3,600 rpm	2,500/4,500 rpm
Cooling.....	Fan	Air blast

**7.101 What is the purpose of employing differential-voltage reverse-current relays in aircraft generator systems?**

*Answer.* Protective relays are employed in aircraft generator systems to disconnect the generator when the engine is idling because the generator voltage is low, and the battery would otherwise tend to discharge into it. Reverse-current relays also protect the whole system in case the generator polarity should become reversed. If no protective device were employed, the generator and the battery would, in effect, short-circuit into each other. A reverse current cutout is also necessary when more than one generator is used.

**7.102 Discuss air-carrier aircraft electrical systems with regard to general wiring (single wire, two wire).**

*Answer.* Single-wire systems use a bus bar attached to the aircraft structure as ground return. This type of wiring is least expensive, considering both materials and labor costs, and is generally employed in transport airplanes. If appreciable current is carried, magnetic fields are set up that disturb instruments like the magnetic compass. The more expensive two-wire system uses a pair of wires that are twisted together, thus canceling out the magnetic field and cutting down disturbances. It is customary to provide cables made up to serve given areas of a plane, rather than to run single cables for each use. These completely shielded cable sections are joined in junction boxes. This system allows maintenance or replacement of faulty sections. The ignition system, in particular, uses a harness and shielded cable made up as a unit. Voltage breakdown in this part of the electrical system is not only disastrous to the operation of the aircraft, but can also be a source of strong interference to the radio communication and navigation equipment.

**7.103 Describe the operational characteristics of "trip-free" and "nontrip-free" circuit breakers as used in aircraft radio and electrical installations.**

*Answer.* A trip-free circuit breaker is one that cannot be overridden. Once it has blown, it is not possible to close the circuit against the heavy-current condition that caused the breaker to operate. If the heavy-current condition has cleared by itself, then the breaker can be reclosed normally. A nontrip-free circuit breaker is one that can be restored to its operating position even though the heavy current that caused it to blow is still flowing. Trip-free circuit breakers are used in all nonemergency circuits in aircraft. Emergency circuits, that is, those the failure of which may result in the inability of the airplane to maintain controlled flight, use the nontrip-free type. Such circuits must also employ flame-resistant cable.

**7.104 Name one important reason why alternating current is not ordinarily used for the primary power source on transport aircraft.**

*Answer.* An aircraft is dependent upon its storage battery for such initial functions as starting (although large aircraft require special ground starting-generator sets). Since this battery must be kept

charged, a generator for the purpose can be designed not only for charging but also to furnish additional current to other devices. Alternators for the production of alternating current must be brought up to speed before their voltage and frequency are generally useful. Devices operating from a battery and a generator in parallel are immediately useful and independent of the speed of the engines.

**7.105 Explain how transport-aircraft generators are driven.**

*Answer.* Aircraft generators are gear-driven from the aircraft engine. The splined end of the generator rotor fits a geared coupling on the engine and has a step-up ratio of about 1.5:1 so that the generator revolves faster than the engine.

**7.106 What particular electrical system on an aircraft is difficult to shield by the use of filters?**

*Answer.* The ignition system cannot be filtered to prevent interference to radio equipment, but it is shielded as completely as possible, with the shielding bonded to the engine or metal framework of the aircraft at least every 18 in.

**7.107 Polyethylene-covered antenna wire is being used on many transport-aircraft radio installations. What is the advantage of this type of antenna wire over the small diameter braided copper wire? Over solid copper wire?**

*Answer.* Corona discharge from radio antennas is not the sole source of interference from precipitation static but it is one of the worst. Insulated antennas provided with special supporting fittings are vastly superior to small braided wire in reducing corona effects because the latter develops small sharp points from which corona takes place at relatively low voltage. The insulated antennas prevent corona discharge under all normal conditions. If the insulation is punctured, however, the polyethylene-covered antenna loses its effectiveness. It must be inspected periodically for punctures. Solid copper wire is superior to braid because it does not develop the sharp projections. If it has a sufficiently large diameter, its corona onset potential is high, and it may be as useful as the insulated type from this point of view. It has no insulation to puncture, and when used for transmitting, it has lower  $I^2R$  loss. Installation and maintenance costs are low. How-

ever, the appreciable mass of large-diameter copper wire may often make it mechanically unsuitable. (See 7.114.)

**7.108 Name one advantage of using large-diameter bare aluminum wire for antennas on transport aircraft.**

*Answer.* Besides advantages of large-diameter conductors as aircraft antennas listed in 7.107, large-diameter bare aluminum wire has the additional advantage of being light in weight.

**7.109 What is the purpose of using trailing wicks on the wing tips and tail surfaces of transport aircraft?**

*Answer.* After the corona from antennas has been eliminated, the corona discharge from other surfaces becomes important as a source of interference. Static-discharge wicks are placed as close as mechanically possible to the wing tips and trailing surfaces of wings, elevators, and rudder. These wicks provide a sort of coupling or connection between the aircraft and the atmosphere and tend to equalize the charges between them gradually, thus avoiding or minimizing corona discharge.

**7.110 With reference to electrostatic build-ups on transport aircraft, which will produce the higher charging rate, dry snow and ice crystals, or wet snow and rain?**

*Answer.* Dry snow and ice crystals produce higher charging rates than wet snow and rain, generally causing severe precipitation-static interference for long periods of time.

**7.111 Which one of the two, air speed or ground speed, is a contributing factor in the build-up of high electrostatic potential on an aircraft flying through sleet, snow, or dust?**

*Answer.* Since the build-up of potential is a function of the speed of the moving particles against the aircraft, it is the air speed, or the actual speed of the particles relative to the plane, that is important rather than the speed of the plane in relation to the ground.

**7.112 Discuss the progress that has been made in recent years toward the elimination of precipitation static on aircraft.**

*Answer.* One of the most important discoveries has been that the worst source of interference to radio reception is corona discharge

from the receiving antenna itself. Development of polyethylene-covered antennas with suitable fittings to avoid corona has virtually eliminated disturbances from this source. Large-diameter, lightweight (aluminum) wires are also being used successfully. Although a charged metallic body suspended in the air will lose its charge in about 7 min, the continual charging of aircraft in motion does not allow it to lose its charge, and corona areas build up. Even the exhaust gases do not provide sufficient "connection" to the atmosphere to discharge the plane. Among many devices and methods tried, it was found that a soft cotton wick treated with colloidal metal is the most generally acceptable means of discharging the corona current without setting up appreciable disturbance. All the methods described have considerably reduced static discharge disturbances but have not completely eliminated them.

**7.113 Under conditions of severe precipitation static, why is a loop antenna superior to a fixed antenna in receiving radio signals?**

*Answer.* A loop antenna in itself is usually inferior to other types in its amount of signal pickup. However, since it is electrostatically shielded, it can often be used for reception when other antennas are useless because of the high noise level from static.

**7.114 What is meant by corona, or St. Elmo's fire? What design in aircraft antennas aids in preventing corona?**

*Answer.* Corona, or St. Elmo's fire, is a visible electrical discharge from a highly charged body to another of different charge or into the atmosphere. The resulting oscillation is of sufficient strength to obscure radio signals. Corona occurs first from sharp points. If these can be avoided in the construction of a radio antenna, corona can be eliminated. Large-diameter wires and particularly wires of small diameter covered with polyethylene insulation are now used to minimize corona discharge from the antenna.

**7.115 What is the advantage of the SBRA range station over the MRL range station when using the aircraft DF for bearings?**

*Answer.* The SBRA range is a scheduled broadcast station (B) with simultaneous transmission of range signals and voice (S). The range (RA) employs an Adcock antenna with vertical radiators. Its power is greater than 150 watts. The MRL range is simply a range with no

provision for voice broadcasts and employing loop radiators. Its power is between 50 and 150 watts. If the aircraft direction-finder loop is being used to pick up the transmitter, the stronger signal from the SBRA will be easier to use. Because it employs an Adcock antenna, there will also be much less night effect owing to reflections from the ionosphere. The SBRA has a cone of silence over it. With the MRL loop transmitting antenna, its horizontal component is often reflected from the ionosphere as a vertical component causing confusing readings.

**7.116 What are the principal advantages of the Adcock radio range over the loop radio range?**

*Answer.* The Adcock radio range employs vertical antennas and transmits no appreciable signal with horizontal polarization. There is a definite cone of silence over the Adcock range. Horizontal signals from a loop range are often reflected from the ionosphere as vertical polarization, causing a swinging beam or confusing signals on which no null can be found. There is actually no null over a loop range although the receiving-antenna characteristics may show one.

**7.117 Explain the principle of operation and the type of emission obtained from an aerophare.**

*Answer.* Aerophare is the international designation for aeronautical radio-beacon station. As a generic term it may refer to any one of several types, such as Consol (Sonne), low-frequency range, MOR, VOR, and RACON. However, in current usage, the term commonly refers to a station that comprises a transmitter and antenna system that sends out continuous waves of approximately uniform strength in all directions so that aircraft equipped with a direction finder can determine azimuth with relation to the aerophare. The transmitting station operates somewhere in the region between 200 and 400 kc. It is identified by dots and/or dashes and a silent period. The characteristic keying is at a modulation frequency of 1,020 cycles.

**7.118 What is the general shape of the radiation pattern of an aerophare?**

*Answer.* The continuous-wave aerophare used for homing has a generally circular pattern.

**7.119** What aircraft equipment is necessary to make use of the service of an aerophare?

*Answer.* Direction-finder receiver and loop.

**7.120** Explain the principle of operation of the omnidirectional range.

*Answer.* The omnirange illustrated in Fig. 7-1 uses a transmitter and complex antenna system of five antennas to transmit both a nondirectional signal and one that rotates at 1,800 ipm or 30 cycles per second. Both radiated signals are in phase at one instant and out of phase by varying and measurable amounts for the rest of the rotation period. The nondirectional reference signal is transmitted on a 10-ke

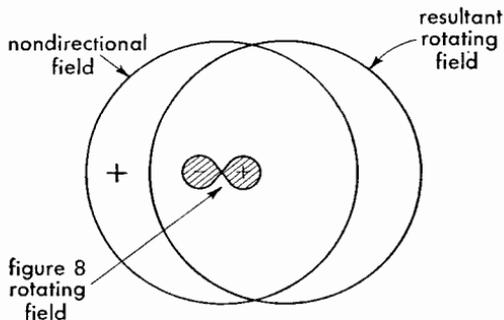


FIG. 7-1. Principle of the omnidirectional range.

FM subcarrier so that the receiver in the aircraft can separate it and compare it with that from the rotating system. Because the in-phase relationship is established when the rotating signal is directed towards magnetic north, the amount of phase deviation can be made to represent azimuth from the transmitter. For example, when the receiving system senses a 96-deg phase difference, the indicator will show that the aircraft is magnetic north plus 96 deg, or a little south of east. The low-frequency omnirange is known as the MOR facility and the more common VOR facility stands for VHF Omnidirectional Range.

**7.121** How is the rotating signal in an omnirange initially set with respect to true north, or magnetic north?

*Answer.* The rotating and reference signals are initially set in phase when the range is transmitting towards magnetic north.

**7.122 Upon what frequency do marker-beacon receivers operate?**

*Answer.* At 75 mc.

**7.123 What is the purpose of the HIGH-LOW switch used in conjunction with the aircraft marker-beacon receiver?**

*Answer.* Two different values of receiver sensitivity can be selected. At high altitudes, with the switch in the HIGH position, the receiver is more sensitive to the weaker signal. At low altitudes, the switch can be set in the LOW position to make the receiver less sensitive and therefore capable of giving a sharper indication of the marker.

**7.124 Explain how overloading in a radio-range receiver may cause apparent reversal of quadrant signals of a low-frequency range.**

*Answer.* Owing to the fact that range signals may often be used at great distances from the station, the receiver is provided with appreciable audio power output. If, as a pilot approaches the range transmitter, he does not decrease the gain-control setting there will often be sufficient signal to overload the audio amplifier. When flying in the twilight zone, either the *A* or the *N* signal is much weaker than the other. With the amplifier overloaded, the louder signal driving the amplifier grid further positive will tend to cut off the amplifier output to the phones, while the weaker signal will allow the 1,020 beat signal to come through. As a result, the pilot will hear an *N* instead of *A*, or vice versa. This situation should, however, be quickly noted by the garbling of the station identification caused by the inversion of the dots and dashes. A receiver with AVC may also give a similar effect.

**7.125 Explain the principle of operation of the radio-range filter as used on United States aircraft radio installations.**

*Answer.* The radio-range signal consists of a steady carrier at a fixed frequency and two coded carriers exactly 1,020 cycles higher in frequency. In the aircraft, the output of the receiver is provided with a bandpass filter that has minimum attenuation at 1,020 cycles. Another portion of the range filter contains a circuit with a maximum attenuation at 1,020 cycles. A switch allows the pilot to connect either the bandpass filter for range work, or the band-elimination filter so that he can receive the voice broadcasts with which the steady carrier is

occasionally modulated. A third switch position allows him to hear both the range and the broadcast together.

**7.126 What types of aircraft antennas are used for radio-range flying?**

*Answer.* An inverted-L or a fin antenna above the plane, or a vertical whip extending below the plane are often used. Inverted balanced-T, trailing wire, and other types are also in current use.

**7.127 What are the compass locator stations and on what frequencies do they operate?**

*Answer.* Compass locator stations are low-power, nondirectional radio beacons transmitting a circular pattern. They operate in the frequency band 200 to 400 kc and transmit a continuous carrier modulated with the identifying code letter or letters, at 1,020 cycles. These facilities are installed at some outer or middle marker sites as interim ILS (Instrument Landing System) aids.

**7.128 List three disadvantages of the conventional low-frequency radio range.**

*Answer.* Despite its widespread use and great utility, the low-frequency radio range has a number of disadvantages. Only four definite courses are provided and if a pilot is lost he does not know in which quadrant he is located until he completes a lengthy flying procedure. Static is prevalent in the frequency band (200 to 400 kc) used for this facility. At the frequency used, the terrain or ionospheric effects often cause bending of the beam, multiple courses, and night effect.

**7.129 In actual flying practice, how many visual courses does VOR offer simultaneously at any given altitude level—(a) 4, (b) 16, (c) 90, and (d) 360?**

*Answer.* (c) 90. Although there are, theoretically, an infinite number of courses, the width of the VOR beam is not infinitely small, but about 4 deg wide. There are, therefore, 90 definable courses in a complete 360-deg circle.

**7.130 What is the frequency of the keyed tone producing the VOR station identification signal—(a) 500 cps, (b) 1,020 cps, (c) 3,010 cps, (d) 3,000 cps, (e) 6,210 cps?**

*Answer.* The frequency of identification is (b) 1,020 cycles per second.

**7.131 What is meant by the term MOR with respect to radio aids to air navigation?**

*Answer.* The MOR facility is a low-frequency omnidirectional range, similar to VOR but operating in the frequency region between 365 and 415 kc. The system is in development at this writing. Although it should more properly be designated LOR (and was, originally) the letters MOR have been chosen so as to avoid confusion with LORAN.

**7.132 How does the Z marker provide a definite means for the aircraft determining its position over the cone of silence?**

*Answer.* The Z-marker transmitter provides a conical signal pattern within the cone of silence of a low-frequency radio range that positively identifies the region. This marker operates at 75 mc and is continuously modulated at 3,000 cycles. Its signal is received in the plane and normally actuates a white light on the instrument panel.

**7.133 What audio frequencies are associated with Z markers, fan markers, and inner and outer markers?**

*Answer.* Modulation for Z markers is 3,000 cycles continuously. Fan-marker modulation at 3,000 cycles is keyed to indicate the course, starting with one dash on the course clockwise from true north. If there is a second fan marker, the outer one is coded with the same number of dashes as the inner one but with two dots preceding the dashes. The outer marker for ILS is keyed to emit two dashes per second at 400 cycles. The middle marker for ILS is keyed to emit alternate dots and dashes at a frequency of 1,300 cycles. The boundary marker used at some special ILS installations is modulated at 3,000 cycles and keyed so as to emit six dots per second.

**7.134 What advantage, with respect to approach control, does the new bone-shaped marker offer over the standard fan-shaped marker?**

*Answer.* The latest fan marker has a bone shape and is only 1.5 miles thick at the narrowest point at the 3,000-ft level. The pilot is therefore able to determine much more precisely the exact time he is over the marker site. The standard fan marker is 4 miles thick at the same altitude. The pilot can thereby vary his holding pattern to be inbound to the range station at the exact time specified by approach control.

**7.135** If the marker-light indicator in the cockpit failed, would the flight personnel have available any other indication that signals from a marker were being received?

*Answer.* Yes, the markers are identified by continuous or keyed audio tones, depending upon the type of facility, and these tones can be received in headphones connected to the marker receiver.

**7.136** What is the signal called that is radiated from the center loop of a VOR radio facility?

*Answer.* The center loop radiates the reference phase. (See 7.120.)

**7.137** What may be considered as the normal reliable service radiation of the VOR radio facility—(a) 50 miles, (b) 2.5 miles, (c) 3 miles, (d) 3.5 miles, and (e) 100 miles?

*Answer.* (a) 50 miles. Although the signals may normally be received at 150 miles, facilities are installed approximately 100 miles apart.

**7.138** What are the three main advantages of the VAR radio facility?

*Answer.* The VAR (Visual Aural Range) facility has the following advantages:

1. Gives instantaneous, unmistakable indication as to the quadrant in which the aircraft is located.
2. Operating at VHF, it is not subject to the multiple courses and night effects of the older low-frequency ranges.
3. It serves admirably as an interim facility, particularly in using the ILS localizer pointer (of the crosspointer indicator) for the visual courses.

**7.139** What is the average usable range of the VAR facility?

*Answer.* Although VAR signals in the 108- to 112-mc band can often be heard by planes at high altitude 200 miles away, dependable operation under normal conditions is considered to be 50 miles.

**7.140** Why are the blue and yellow visual and the A and N aural areas of a VAR referred to as sectors rather than quadrants?

*Answer.* The visual and the aural ranges of interest to the pilot are extremely narrow beams referred to as sectors. These sectors, subtend-

ing much less than 90 deg, form the boundaries that divide the air space into four quadrants identified by both a color and a Morse code letter; for example, the visual-blue aural-*N*, or the visual-yellow aural-*A* quadrants.

**7.141 Describe the method of orientation used in the VAR.**

*Answer.* The standard sector orientation for Green and Red airways (east—west) is blue visual to the north, yellow visual to the south; while the *A* aural is to the west, and *N* aural to the east. On Amber and Blue airways (north—south) the VAR facility is oriented with blue visual to the west and yellow visual to the east; *N* aural is to the north and *A* aural to the south.

**7.142 How is the "on-course" signal produced in a low-frequency radio range station?**

*Answer.* A low-frequency radio range employs two pairs of antennas that radiate energy in a double figure-of-eight pattern, in the horizontal plane. The transmitter is alternately connected first to one and then

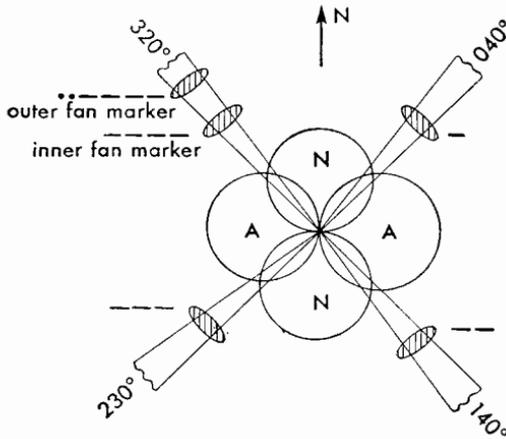


FIG. 7-2. Principle of the low-frequency range facility, showing markers.

to the other antenna system, being keyed with the Morse code *A* (· —) for one antenna and with *N* (— ·) for the other. The dots and dashes of these code signals are interlocked so that if a pilot is flying a course midway between the two maximum *A* and *N* signals, he receives a steady equisignal. If he leaves the beam he then begins to distinguish

the *A* or the *N*, depending upon which side of the course he is now flying. In addition to the double pair, a center antenna transmits an omnidirectional signal at a frequency 1,020 cycles removed from that of the *A* and *N* beams. Accordingly, the *A* and *N* indications are heard as a 1,020-cycle tone at the plane. (See Fig. 7-2.)

**7.143 What is meant by the "twilight" zone in radio-range flying?**

*Answer.* On one side of the equisignal or steady-tone region of a low-frequency range beam, the Morse code *A* can be distinguished, while on the other side of the equisignal the *N* can just be heard. These regions are often called the twilight zones. Planes keep to the right of the equisignal region traveling in either direction in order to avoid collision.

**7.144 How is the cone of silence produced over a low-frequency radio-range station?**

*Answer.* The signals from a low-frequency radio range are vertically polarized and are normally received at the aircraft on an antenna that responds best to vertical polarization. Reception of the range in a small region above the transmitting-antenna system is poor, resulting in the phenomenon known as the cone of silence, in which the signal is either extremely weak or altogether absent, depending upon the transmitting antenna system and upon the gain control setting.

**7.145 In radio-range flying what is meant by "multiple courses"?**

*Answer.* Particularly in mountainous country, the equisignal of a radio range may be broken up into several segments over a space of 10, 15, or more degrees. Between the separate beams the *A* and *N* quadrant signals may be heard, sometimes in their proper relation to the on-course signal and sometimes reversed.

**7.146 If an aircraft is flying at right angles to a range leg affected by multiple courses, what signals would be heard in the radio-range receiver?**

*Answer.* A series of *A*, on-course, and *N* signals would be heard over a spread of 15 deg more or less. The signals might occur in the order listed; in reverse order if the plane were flying in the opposite direction, or an *A* signal might both precede and follow the on-course equisignal. The same might be true of *N* signals.

### 7.147 Explain the operation of the ground portion of an ILS.

*Answer.* The ground portion of the ILS system is shown in Fig. 7-3. It comprises a localizer transmitter operating on a frequency in the region between 108 and 112 mc. Sufficient power is transmitted so that an on-course signal can be received at least 25 miles from the runway. The course signal is produced by a field pattern modulated at two different frequencies. The approach sector to the right, looking

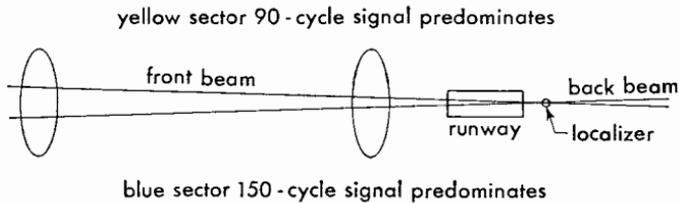
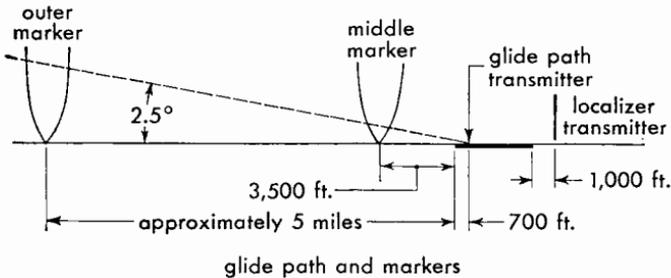


FIG. 7-3. Ground portion of the ILS system.

towards the transmitter, is identified by a 150-cycle signal and is designated on charts and instruments as the blue sector. The left side of the on-course signal is identified by a 90-cycle modulation and is designated as the yellow sector. The equisignal region is very sharp but the beam is about 70 ft wide at the touchdown point and more than a mile wide at a distance of 10 miles from the transmitter. Each localizer transmitter is identified by a three-letter code and voice modulation is generally used for approach control.

The glide-path transmitter is located 1,000 ft from the approach end of the runway and about 400 ft from the center line of the runway. It operates upon a frequency paired with that of the localizer and is somewhere in the region between 328 and 336 mc. Its course is formed in the same way as that of the localizer, except that it is at right angles

so that the cross section in space is approximately a plus sign. The upper side of the beam is modulated at 90 cycles and the lower side at 150 cycles. There is no color identification used with the glide path that rises from the ground at an angle of 2.5 deg. It is 1 deg wide at the ground and spreads to a vertical thickness of nearly 1,400 ft 10 miles away.

About 4.5 miles from the runway is located the outer fan marker, operating at 75 mc and modulated at 400 cycles with two dashes a second. A middle marker about 3,500 ft from the approach end of the runway operates at a carrier frequency of 75 mc and emits alternate dots and dashes of 1,300-cycle tone.

When used, a boundary marker is located 300 ft from the approach end of the runway, its housing 200 ft off the runway. This transmitter likewise operates on a carrier of 75 mc. It is modulated by a series of dots (six per second) transmitting 3,000-cycle tone.

Compass locators operating in the 200- to 400-kc band transmit a single code letter (now being modified to two) with 1,020-cycle tone. They are often used as an interim facility to get aircraft into the ILS system, or for flying a holding pattern.

**7.148 In the ILS, which is the sharpest course—the localizer or the glide path?**

*Answer.* The glide path is the sharper course of the two.

**7.149 On what frequency do marker beacons used in conjunction with ILS operate?**

*Answer.* On 75-mc carrier frequency but with different audio modulation depending upon the location of the beacon.

**7.150 What aircraft radio equipment is necessary to make use of all units of ILS?**

*Answer.* Required are ILS receiver for localizer and glide path, localizer and glide-path antennas, cross-pointer indicator, marker receiver (with antenna) with frequency-discriminating circuits and signal lights.

**7.151 What instrument is used for the cross-pointer indication on the instrument panel of an aircraft when using ILS?**

*Answer.* A special dual microammeter.

**7.152** What is the purpose of the aircraft flag warning used with the ILS indicator?

*Answer.* The flag warning is actually a miniature voltmeter that is actuated when there is insufficient or no signal from either the localizer or the glide-path transmitter, or both. If any part of the flag is showing, the pilot does not use the ILS system.

**7.153** Is the following statement TRUE or FALSE? "In the ILS, regardless of the position or heading of an aircraft, the localizer needle will always be deflected in that color area in which the aircraft is flying."

*Answer.* True, but when approaching the airport on the back beam, the blue sector will be at the left and the yellow at the right of the craft, rather than as marked on the ILS cross-pointer instrument. It is not safe to use the back beam without first determining its characteristics.

**7.154** In flying the ILS, when the aircraft is above the glide path, will the horizontal needle be deflected UP or DOWN?

*Answer.* The needle will be deflected down. The pilot identifies the center of the meter with his craft and the meter needle with the path. He corrects so as to bring his plane onto the path.

**7.155** If noise breaks through in the headset on a VHF communications unit, what adjustment can be made?

*Answer.* The threshold of the carrier-operated squelch circuit can be adjusted so that noise does not operate the receiver.

**7.156** Certain aircraft communications receivers have an antenna-aligning control on the panel. Electrically, what is accomplished when this control is adjusted?

*Answer.* The alignment control tunes the input circuit to match the antenna characteristic to that of the receiver and effects an optimum transfer of energy to it.

**7.157** What are the approximate CW, MCW, and voice power ratings of transmitters used in U.S. air-carrier aircraft operating overseas?

*Answer.* Power ratings for a given equipment vary with type of modulation or absence of modulation. Power output from various types of equipment in current use ranges from 50 to 125 watts.

**7.158 What is the purpose of an isolation amplifier in an aircraft radio installation?**

*Answer.* Various crew members may wish to listen to different combinations of signals from radio facilities or interphones. If phones are simply bridged across the several outputs, the facilities will then be paralleled for all listeners and the level will decrease. Isolation amplifiers are so arranged that the crew member can listen to the output of the appropriate amplifier to which various input signals can be connected through very high resistances. There will then be no noticeable crosstalk for those not desiring the particular combination of signals.

**7.159 What is the purpose of the side-tone feature in an aircraft radio installation? How is side tone obtained?**

*Answer.* Side tone is a monitor signal derived from the transmitter so that the pilot can hear his own transmission. By this means, he is able to adjust the level of his voice to modulate the transmitter properly. Side tone can be obtained from the output of the microphone circuit, from the last audio stage of the receiver, or more usually, from a special side-tone amplifier that is a part of the interphone system. One system using a dry-disk rectifier produces no signal unless the transmitter is sending out a modulated signal.

**7.160 What may cause severe arcing in aircraft transmitters at high altitudes?**

*Answer.* Air at low pressures is a poor insulator. When high voltages are involved, corona takes place. High-voltage plate conductors and radio-frequency leads, unless properly insulated or adequately spaced away from ground, will arc over at high altitudes.

**7.161 In tuning an aircraft radio transmitter can it always be expected that the same antenna current will be secured on all frequencies?**

*Answer.* No. Maximum antenna current is usually an indication of optimum tuning, but the same maximums should not be expected for all frequencies using the same antenna. As the frequency is changed

the current distribution along the antenna changes. The meter is fixed at one point in the antenna and reads the current at a given physical point.

**7.162** In aircraft communications, how does the line-of-sight communication range vary with the altitude of the aircraft? At an altitude of 5,000 ft over level terrain, what maximum line-of-sight VHF communication range may be expected from the aircraft to a ground station?

*Answer.* At VHF, the line-of-sight communication range increases as a function of altitude of the aircraft. At 5,000 ft, the line-of-sight range is approximately 87 miles. In many cases, however, communication might be carried on over a considerably greater distance than this.

**7.163** When using automatic keying on the AN/CRT-3 (modified Gibson Girl life-raft transmitter), what signals are transmitted and upon what frequencies?

*Answer.* A 500-kc signal modulated with 1,000-cycle tone sends out six groups of SOS followed by a dash not exceeding 20 seconds in length. A switching mechanism then shifts frequency to 8,280 kc and six groups of SOS are sent by continuous wave (no modulation) followed by a dash (for direction-finding purposes) not exceeding 20 seconds in length.

**7.164** Discuss the advantages and disadvantages of the following aircraft antennas: fixed, trail, whip, stub mast, and loop.

*Answer.* The fixed antenna is desirable for reception and transmission of low and medium frequencies, but because of its length is subject to a considerable icing load. A trailing wire is even better for low-frequency work, but constitutes a hazard and is likely to be lost if not reeled in before landing. The whip suffers from its short length but is useful and less likely to be damaged than some other types. Because it is usually mounted below the body of the aircraft it tends to remain in a vertical position even when the craft is turning. A stub mast is somewhat hazardous to flight and its large area ices heavily. Although it does not vibrate appreciably, it may cause loss of signal when the plane turns since it is then going into a horizontal position. It can be mounted either above or below the body of the craft. The loop is

mandatory for ordinary direction finding and is shielded against the worst effects of precipitation static, but it has poor signal pickup.

**7.165** What type of aircraft antennas will permit maximum radiation on such medium frequencies as 333 and 500 kc?

*Answer.* The trailing wire or long wire from front to fin is best for these frequencies, with the fixed type a poor second.

**7.166** Explain the principle of operation of the antenna change-over relay in an aircraft radio installation. What is a vacuum antenna relay?

*Answer.* When an antenna is to be used for both transmitting and receiving, it is necessary that a quick means be provided to switch the antenna from one position to the other. The antenna is normally connected to the receiver and the antenna relay actuated only when the transmitter is turned on. For voice transmission, the antenna is switched to the transmitter for an appreciable length of time. For CW transmissions, the antenna relay follows the keying. A vacuum antenna relay is one with contacts enclosed in an evacuated glass bulb. The contacts are protected thereby from dust, dirt, moisture, fumes, the oxidizing effects of air, and arc-over at high altitudes.

**7.167** How may an aircraft DF loop be utilized for antistatic reception of radio range signals?

*Answer.* If the loop is directed towards the range, signal strength will be maximum and static will be at a minimum.

**7.168** Describe the physical construction of antennas used with the aircraft radio altimeter.

*Answer.* Antennas commonly used for the aircraft radio altimeter operating at 440 mc are two half-wave dipoles, usually mounted below the belly of the craft and some distance apart. Each antenna is a dipole about  $11\frac{1}{4}$  in. in over-all length with ceramic insulating material between the two halves at the center. The dipole is supported by  $5\frac{1}{2}$ -in. long quarter-wave tubes that are integral with the inner ends of the two halves. A metal base plate for the quarter-wave standoff tubes completes the rugged construction. A coaxial fitting makes connection to this plate, and the center lead runs down inside one

tube and through the inside of the insulator to connect to the half of the dipole supported by the other tube.

**7.169 Explain the principle of operation of the Flux Gate compass system.**

*Answer.* The Flux Gate (a trade mark of Bendix Aviation Corp.) compass system comprises a Gyro Flux Gate transmitter, mounted in the wing or tail of the plane, a master direction indicator at the instrument panel, an amplifier, and a caging switch box convenient to the pilot. Other equipment, such as a repeater indicator, is either necessary or customarily used. The essentials of the system are shown in the block diagram Fig. 7-4.

The Flux Gate primary is alternately saturated and demagnetized by current from the 487.5-cycle oscillator at a rate of 975 times a second. No inductive effects are produced in the secondary by this saturation of the core. However, the d-c magnetic flux of the earth's field cuts the secondary winding 975 times a second (by virtue of the alternate saturation and demagnetization action of the primary). The voltage induced in each secondary depends upon its position in the earth's magnetic field. Because it is desired to determine a plane's heading by the various unique induced-voltage combinations, it is necessary to hold the Flux Gate horizontal at all times. A vertical gyroscope is used for this purpose.

Signals from the Flux Gate secondary are fed into a special self-synchronous motor, known under the trade names of Autosyn and Selsyn, and identified as a synchro by joint Army-Navy designation. The stator uses a wye connection. The two-pole rotor (with slip rings) picks up any change in the signal and feeds it to the signal amplifier. The signal is still further stepped up in the power amplifier and sent out to the variable-phase winding of the low-inertia induction motor. This motor is also supplied with fixed-phase voltage from the 975-cycle oscillator. The motor turns the gear train (in the proper direction, depending upon the phase of the signal) until signal voltage from the Autosyn rotor falls to a null. At the same time, the indicator dial and the repeaters have been turned to the new heading. As long as the aircraft flies this course, the Flux Gate secondary will detect no changes in the effect of the earth's field. If the aircraft turns, a new pattern of voltages will be induced in the Flux Gate secondary, a new field pattern will be set up in the stator of the Autosyn, the rotor will send a signal

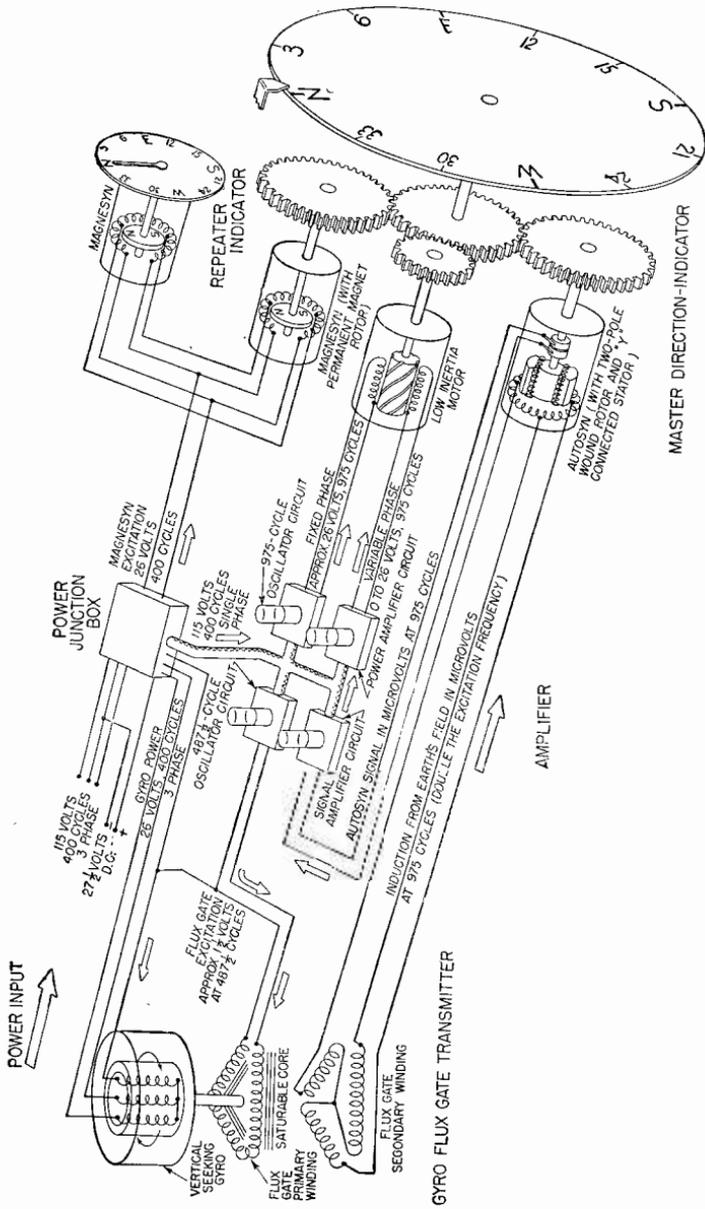


Fig. 7-4. Block diagram of a Flux Gate compass system. (Courtesy Bendix.)

to the amplifiers, and the low-inertia motor will turn the Autosyn rotor to a new null. The indicators will show the new heading.

Although not specifically asked for, the student would be well advised to compare the Sperry Gyrosyn compass with the Bendix Flux Gate compass. The two systems have similarities, but the Sperry device employs a pendulously mounted Flux Valve and a horizontal gyroscope in the indicator. Similarly named parts, such as indicators and amplifiers, are not interchangeable between the two systems.

**7.170 What type of power supply is used in the Flux Gate compass system?**

*Answer.* The Flux Gate compass system requires a source of 115-volt 400-cycle three-phase power and 27.5 volts d-c.

**7.171 Explain the purpose of the gain control on the amplifier unit of the Flux Gate compass system.**

*Answer.* The gain control on the amplifier allows an adjustment of the sensitivity of the equipment under different operating conditions and over terrain with varying magnetic fields. The gain is set as high as possible without oscillation of the master indicator dial. If the gain is set too high, the system becomes too sensitive and tends to "hunt" about the null point.

**7.172 What functions are performed by the amplifier unit of the Flux Gate compass?**

*Answer.* The amplifier is the power distributing center for the system as well as the source of voltage and power amplification for the signals. The 487.5- and 975-cycle oscillators are located here. The unit also serves as a junction point for conductors that have no connection to the amplifier circuits.

**7.173 Why is the sensitive compass element in the Flux Gate system usually located in a remote spot such as the aircraft wing tip?**

*Answer.* The Flux Gate compass unit must be as far as possible from other wiring, ferrous metal, or anything capable of causing a magnetic disturbance, in order to avoid false direction indications.

**7.174 In what portion of the Flux Gate compass system is a low-inertia motor used?**

*Answer.* A low-inertia induction motor is used to translate the signal (resulting from a change in heading) into a mechanical rotation that moves the indicator dial to show the new heading. At the same time, it resets the rotor of the Autosyn that has detected the signal resulting from the change in orientation of the Flux Gate element.

**7.175** In the Flux Gate compass system, the gyroscope is a self-erecting vertical gyroscope. Explain the function of the gyroscope.

*Answer.* The gyroscope supports the coils of the Flux Gate element so that they remain essentially horizontal at all times that the compass system is in use. Since the orientation of the element determines the indicated position of the plane with respect to the earth's lines of magnetic force, its indications would be wholly meaningless if it were not held horizontal at all times, despite the altitude of the aircraft.

**7.176** What is meant by "caged" and "uncaged" in a Flux Gate compass?

*Answer.* The vertical gyroscope in the Flux Gate unit is said to be caged when two pairs of roller arms are in such position that the gyroscope cannot be tilted in any direction. It is uncaged when these arms are withdrawn and the gyroscope is free to tilt. There is a visual signal to show the pilot that the gyroscope is either caged or uncaged.

**7.177** In loran terminology, what would be indicated by the legend 1L3-2120?

*Answer.* In the legend, the figure 1 indicates that the radio frequency of the transmitter is 1,950 kc; *L* shows that the basic pulse recurrence rate is 25 pps; the figure 3 denotes a station recurrence rate of 3 (for which the pulse-recurrence rate is actually about  $25\frac{3}{17}$  pps). The remaining figures 2,120 are the *T* or reading for a particular line and denotes the time delay in microseconds between the arrival of the pulses from the master and the slave stations. (See also 6.873 and 6.877.)

**7.178** How is a loran fix indicated on a loran navigation chart?

*Answer.* A fix is indicated by the intersection of two or more loran lines of position plotted on a loran chart. Care should be taken to use loran stations generating lines of position that cross as nearly at right angles as possible. When crossing angles are small and no third line of

position is available, several readings and times should be averaged for better accuracy.

**7.179 Does precipitation static affect operation of the loran receiver-indicator?**

*Answer.* Loran reception, like that of all airborne radio systems, is seriously affected by precipitation static. However, because it presents information on a cathode-ray oscilloscope, pulses can be matched with great precision under conditions of heavy noise and interference. The eye is able to distinguish signal from noise because the signal is recurrent. In the ear, noise masks the signal more effectively.

**7.180 What is the approximate usable over-water range in nautical miles of the loran system in both day and night operation?**

*Answer.* During the day, loran signals are generally usable over water up to 700 nautical miles via ground wave but utility is reduced to about 500 miles at night. However, first-hop *E*-layer reflections from the ionosphere can be used at night for distances up to about 1,400 nautical miles. (See also 6.874.)

**7.181 To what reading, or indication, is sky-wave correction applied in loran navigation?**

*Answer.* At great distances from loran transmitters, particularly at night, and occasionally during the day, the first-hop *E*-layer reflections are used, rather than the ground wave. The  $T_s$  (sky-wave reading in microseconds) must be corrected to remove the error caused by the longer travel to and from the ionosphere. The appropriate sky-wave correction and its algebraic sign are indicated on loran charts and in tables.

**7.182 What frequency channels are used in the present loran system?**

*Answer.* Channel frequencies of 1,850 and 1,950 kc are used.

**7.183 What type of power supply is used with the loran receiver aboard aircraft?**

*Answer.* Airborne loran receiver-indicators are designed for operation at 117 volts, 400 to 2,400 cycles. Primary power from storage batteries is used to operate inverters that change 28-volt d-c to 117-volt 400 to 2,400 cycle power.

**7.184** Consol is a long-range radio aid to navigation undergoing considerable practical use in certain sections of the world. Explain briefly the principle of operation of the Consol system.

*Answer.* The Consol station comprises a directional antenna system and a transmitter operating in the region between 263 and 319 kc. Three antennas in line are spaced at about three wavelengths at the operating frequency (see Fig. 7-5).

There are two coverage areas of useful signals, one on each side of the antenna array. The radiation pattern consists of sectors 15 deg wide. Sectors in which dots are heard alternate with those in which the signal is broken into dashes. An equisignal region exists between these sectors. The pattern is caused to rotate through one sector during a 60-sec period

(tests are being made using a 40-sec period). The observer listening on a communications receiver will hear a series of dots (or dashes) followed by an equisignal and then a series of dashes (or dots). The equisignal indicates the observer's bearing from the station, which he can interpret by means of his stop watch, and the number of dots and/or dashes he has counted, using a Consol table or map. After the above sequence, a steady note and the station call letters are transmitted for regular direction-finding procedures. These are necessary in order to establish which one of the equisignals has been observed, in the event that the navigator has no idea of his position.

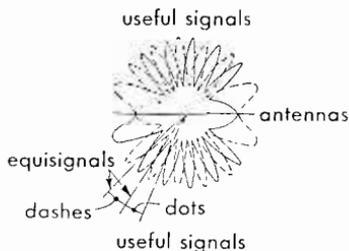


FIG. 7-5. Principle of Consol facility.

**7.185** What aircraft radio equipment is necessary to make use of RACON beacons?

*Answer.* Radar beacons (RACONS) are electronic beacons that give indications of both range and azimuth, as well as a coded identification signal. They must be triggered by radar signals on the proper frequency from the aircraft.

## OPERATING PROCEDURES

**7.186** In air traffic control procedures, what is meant by a service known as "approach control"? How are communications handled between aircraft and approach control?

*Answer.* Approach control is a service whereby the CAA airport traffic control towers issue control directions in instrument weather conditions, by communicating *directly* with pilots over the voice feature of a radio range, or over a very-high-frequency channel of the control tower.

Communications between aircraft and approach control is made by the pilot to Approach Control giving all particulars as to time and altitude, change of flight level, and so on.

**7.187** A Constellation aircraft of Midway Airways, Trip 14, with radio call KHCBX, licensed as NC 18947, is entering the traffic pattern at a particular airport. What is the correct procedure to be followed by the air traffic control tower in establishing radiotelephone communication with this aircraft?

*Answer.* When an aircraft enters a traffic pattern at a particular airport the pilot transmits a message to the control tower including the following information: (a) geographical position; (b) time (optional), (c) flight altitude of the aircraft, (d) request for information or clearance—if pertinent.

The air traffic control (ATC) tower will acknowledge as follows:

Tower: "Constellation 18947 Time Height Location.

Cleared to enter Traffic Pattern

Runway number. Wind. OVER."

Aircraft: "Constellation 18947. ROGER."

**7.188** Certain U.S. Coast Guard radio beacons have undergone modifications to permit satisfactory use with aircraft ADF (aircraft direction finders). Describe.

*Answer.* The U.S. Coast Guard Beacon station at Montauk Point, N.Y., for example, has been modified to continuous carrier transmission of the radio-beacon system throughout 24 hr of the day.

The beacon transmits a continuous code signal (— · — —) with operating intervals of 60 sec "on" and 120 sec "silent" during 24 hr of the day. Three beacons are utilized in this modification, each operating in proper sequence to provide continuous transmission of the signals.

**7.189** What aircraft radio equipment is needed to carry out a GCA (Ground Controlled Approach) problem?

*Answer.* Ground Controlled Approach is a system using radar techniques at a specially designed ground station for providing information by which aircraft approaches may be directed via radio communications.

The standard aircraft receiver and headphones are the only requirements on board an aircraft for obtaining a GCA approach. The observers on the ground give the pilot his exact location by radiotelephone. At regular intervals, the observers tell the pilot what corrections must be made in the flight progress to stay on the proper glide path or course. In effect, the pilot is "talked-down" by radiotelephone.

**7.190 Define the following terms as used in air traffic control procedures: approach clearance, approach sequence, approach time, control area, control zone, control altitude, essential traffic, local traffic, traffic pattern, IFR, VFR, downwind leg, base leg, and final approach.**

*Answer.* Approach clearance: The clearance, issued to the pilot of an aircraft making a flight subject to instrument flight rules (IFR), authorizing an approach for landing by such aircraft.

Approach sequence: Two or more aircraft, vertically separated at the same holding point, awaiting an approach clearance.

Approach time: The time at which an aircraft is expected to commence its approach procedure preparatory to landing.

Control area: An air space of defined dimensions, designated by the administrator, extending upwards from an altitude of 700 ft above the surface, within which air traffic control is exercised.

Control zone: An air space of defined dimensions, designated by the Administrator, extending upwards from the surface, to include one or more airports, and within which rules additional to those governing flights in control areas apply for the protection of air traffic.

Cruising altitude: A constant altimeter indication, in relation to sea level, maintained during a flight or portion thereof.

Essential traffic: Information on aircraft which are expected to be overtaken, passed, or approached within a distance of less than 10 min when such aircraft are within a level of 1,000 ft, or less vertically, above or below the aircraft being cleared.

Local traffic: Aircraft operating in the traffic pattern of a specific landing area concerned.

Traffic pattern: The flow of aircraft operating in the vicinity of an

airport during specified wind conditions as established by the appropriate authority.

**IFR:** This symbol is used to designate Instrument Flight Rules.

**VFR:** This symbol is used to designate Visual Flight Rules.

**Downwind leg:** This term refers to that portion of the approach parallel to, but in the opposite direction to, the landing.

**Base leg:** Refers to that portion of the approach at a right angle to the landing direction on the downwind side of the airport.

**Final approach:** Refers to that portion of the approach from the last turn into the landing direction until contact is made with the airport.

**7.191 Is it possible for an aircraft to contact U.S. radio-range stations by using A2 emission?**

*Answer.* Contact with a radio-range station is made only by type A3 amplitude-modulated telephone (voice) transmissions. If a plane were to transmit telegraphic signals of inquiry to the radio-range station, and the receiver of the latter is adjusted for continuous wave reception at the proper listening frequency, communications could be established in an emergency. Although the CAA operators are qualified to handle the Morse code, they would acknowledge by radiotelephone on the listening frequency.

**7.192 What is the "attention" signal used on United States radio-range station transmissions?**

*Answer.* The attention signal comprises a series of dots used in place of the A and N signals immediately preceding a notice to airmen.

**7.193 Explain how marker beacons identify the legs of a four-course radio-range station. If the legs of a radio range station are spaced at 040, 140, 230, and 320 deg, respectively, what range leg would an approaching aircraft be on if a marker-beacon identification of two dashes (— —) were intercepted?**

*Answer.* Fan markers are located at strategic points along the legs of the range beam to indicate the position of the aircraft. Their radiation is either a conical signal similar to that of the Z marker or a newer type of pattern that is bone-shaped in cross section. The 3,000-cycles-per-second modulation of the 75-mc fan marker is keyed in dashes to indicate the range course as shown in Fig. 7-2. The courses are numbered clockwise beginning with true north. When more than one marker

is provided on a given leg, the outer employs the same dash signal as the inner marker but the dash signal is preceded by two dots (as indicated for the 320-deg course leg). For the example given the aircraft would be on the 140-deg leg.

**7.194 Explain the method of determining "overhead" on a radio beacon using the aircraft manual DF loop.**

*Answer.* "Overhead" or "cone of silence" is that area directly above the beacon pattern where no signal will be heard. For example, when a pilot is entering a given beacon pattern his signals will continue to increase until he passes directly over the transmitter. At this point the signal will fall off rapidly to a minimum or zero response. However, as the plane passes out of the cone of silence the signals will again reappear very strongly and then gradually diminish as the plane moves out of the beacon range.

The manual adjustment of the direction-finder loop is rotated for a maximum signal as the plane approaches the pattern.

**7.195 What U.S. Government document gives the location, frequency, identifier, and hours of operation of all marine radio beacon stations?**

*Answer.* This information is contained in the U.S. Government publication, "Radio Navigational Aids," HO (Hydrographic Office) No. 205, U.S. Navy Department.

**7.196 What agency of the U.S. Government may be called upon to render emergency direction-finding aid to aircraft? How is this agency contacted?**

*Answer.* The FCC maintains an emergency DF network to aid aircraft in distress. FCC is contacted through the regular air/ground station or control tower. At least 15 to 20 min advance notice is required. CAA communications stations render similar service.

**7.197 A control station operator desires to determine whether or not an aircraft is flying in accordance with visual flight rules (VFR). What is the appropriate signal to use?**

*Answer.* The signal QDT is used. This signal carries the following meaning:

"Are you flying in VFR weather conditions?"

**7.198** An aircraft is approaching its point-of-no-return and desires amendments to the flight forecast. What is the correct signal?

*Answer.* The signal QMZ is transmitted. (See 7.206.)

**7.199** An aircraft is preparing to make a QDM approach at a foreign terminal. What signals are used to request a series of QDM's from a ground direction finding station? [QDL is currently used, which means: "I intend to ask you for a series of bearings." when transmitted in the affirmative form.]

*Answer.* Signals QUV or QUX are used in addition. (See 7.206.)

**7.200** An over-ocean aircraft desires to check its distances out from an ocean station vessel (OSV) by using the vessel's radar equipment. What signals are used to obtain this information?

*Answer.* QGE NLM QTE IMI. "What is my distance to your station in nautical miles?" "What is my true bearing from you?" (QGE must be used in connection with QTE or some similar bearing-indication "Q" signal.) It means: "What is my distance to your station?"

**7.201** A flight radio operator copies the following signals from the control station: QAK QAH 8500 ft IMT. The pilot should be advised immediately. Why?

*Answer.* The signal QAK indicates there is a risk of collision. QAH means, "Arrange your flight so as to reach 8,500 ft immediately." QAH also is used to report altitude.

**7.202** What signal would the flight radio operator transmit to request the surface wind at a particular airport?

*Answer.* The signal QAN ("What is the surface wind direction and speed at \_\_\_\_\_?") would be transmitted.

**7.203** An aircraft is estimated to be within DF range of a certain radio beacon, but the signals cannot be heard on the aircraft. To request information as to whether or not the radio beacon is in operation, the "Q" signal \_\_\_\_\_ should be transmitted.

*Answer.* The signal QFS should be transmitted. This signal queries, "Is the beacon radio facility at \_\_\_\_\_ (place) in operation?"

**7.204** An aircraft cleared to cruise at 12,000 ft is climbing on course under IFR conditions. OATC, through the control station, requests the aircraft to report immediately upon reaching cruising altitude. What are the correct "Q" signals?

*Answer.* The correct signal to use is QBV ["Have you reached the altitude of \_\_\_\_\_ (height)?"]. The operator on the aircraft acknowledges by transmitting the signal QBV ["I have reached the altitude of \_\_\_\_\_ (height)."]

**7.205** What is meant by the terms POMAR, METAR, NAREPS, RAWIN, PIBALS, PIREPS?

*Answer.* POMAR refers to observations of position and weather on reports from international overseas flights; METAR is the hourly weather broadcast made on CW; NAREPS are Navy aerological reports. A RAWIN report concerns winds aloft data obtained from radar-tracked balloons carrying reflectors; PIBALS are pilot balloon observations of winds aloft obtained from theodolite observations. PIREPS are weather reports from private pilots.

**7.206** What is the meaning of the following signals?

QAA through QAZ

QBC (used with QMI, QFT, QBJ, QMZ and QTH)

QBF, QBG, QBH, QBI, QBS, QBX, QCB, QCE, QDR,

QDX, QFE, QFG, QFH, QFM, QGJ, QGZ, QHH, QJD,

QLH, QMH, QNI, QNT, QUG, QUO, QUR, QUS, QUU,

QUV, QUX, QRF.

*Answer.* A complete list of these signals is shown in the Appendix.

**7.207** What is an ocean station vessel (OSV)?

*Answer.* An ocean station vessel in the maritime service is a vessel located in strategic geographical areas to provide weather and radio-beacon information. These vessels are normally under way in a given location and are not drifting. The area of coverage is approximately 10 miles square.

**7.208** How are radio-beacon transmissions from ocean station vessels identified?

*Answer.* Radio-beacon transmissions from ocean station vessels are continuous carrier waves with the identifying letters superimposed upon them. The signal consists of four letters. The first two letters comprise the characteristic signal of the station listed; the last two indicate its position within the ten-mile square and are obtained from a chart arranged in the form of a grid graph with lateral and vertical markings to determine a given position.

**7.209** What radio-beacon service is maintained by an ocean station vessel when it is driven off station with position unknown?

*Answer.* No beacon service will be given under these conditions unless requested for homing purposes. In this case, the station's international call letters will be used as the identifying signal.

**7.210** What radio-beacon service is maintained by an ocean station vessel when it is off station proceeding on a distress mission?

*Answer.* The same procedure is followed as in the previous explanation.

**7.211** How does an ocean station vessel indicate "on station," "off station"?

*Answer.* For "on station" (within the 10-mile square at the center) the last two letters transmitted will be OS, the latitude and longitude designators, respectively. If, on the other hand, the ship is "off station," but on the grid, the latitude and longitude designators of whatever square the ship is in are transmitted as the last two letters of the signal. *The latitude designation is always given first.*

**7.212** With reference to ocean station vessels, what is meant by the grid system? Explain its operation.

*Answer.* The grid system is a position-indicating system which enables a ship or plane to determine its position with reference to an ocean station vessel on a specially designed chart. The chart is arranged in squares or grid network in which the outside borders are arranged in alphabetical sequence. The center of the grid is indicated by a plus or zero with extensions vertically and horizontally marked from 10, 20, 30 . . . 100. In addition, a 360-deg circle to indicate degrees is located in the exact center of the chart. The center of the grid is the established location of the station. The grid lines are 10 nautical miles apart. The

latitude designator on the chart is represented by the letter *O* and is located at the left and right center ends of the chart. The letter *S*, representing longitude, is located at the top and bottom center of the chart.

The position of the ship may be determined by the grid system as follows: Assume that an ocean station vessel transmits the characteristic signal, QJ (— — · — · — — —), followed by the letters LM. (L represents the latitude locator, and M the longitude locator.) Hence, by reference to the chart, it would be seen that the station vessel bears 125 deg true and 35 miles from its assigned position. In other words, the designators reveal the grid square in which the ship is located, bearing in mind that the latitude designator is always given first. (See also 7.195 for reference data.)

### 7.213 Name the frequencies used by stations WWV, NSS, and NPG for transmitting time signals.

*Answer.*

Station	Time Signals	Operating Frequencies
WWV	Continuously (24 hr per day)	2.5, 5, 10, 15, 20, 25 mc
NSS	For 5 min immediately preceding each even hour (GMT)	122, 4,390, 9,425, 12,630, 17,000 kc
NPG	0255-0300	115, 9,255, 12,540 kc
	0755-0800	115, 9,255, 12,540 kc
	1455-1500	115, 9,255, 12,540 kc
	1655-1700	115, 9,255, 12,540 kc
	1955-2000	115, 9,255, 12,540 kc
	2355-2400	115, 9,255, 12,540 kc

### 7.214 List one typical DAY CW frequency and one NIGHT CW frequency used in a CAA Overseas Foreign Aeronautical Communications Station.

*Answer.* NIGHT operating frequencies are generally in the range between approximately 3,000 and 5,500 kc. The DAY operating frequencies range approximately from 5,500 to 13,400 kc. A typical NIGHT operating frequency is 2,931 kc. A typical DAY operating frequency is 8,947.5 kc.

Note: The International distress frequencies for the aeronautical services are 500 and 8,280 kc. The Atlantic City Radio Conference has recommended the frequency of 8,364 kc to replace the present fre-

quency. When these regulations become effective, 8,364 kc will replace 8,280 kc.

**7.215** Which one of the following frequencies would work satisfactorily for CW air-to-ground communication and homing with the aircraft ADF: (a) 1,638 kc, (b) 2,970 kc, (c) 8,465 kc, or (d) 11,319 kc?

*Answer.* The frequency of 1,638 kc since this particular frequency is also well suited for homing purposes.

**7.216** Under normal conditions in a daylight flight between two points of approximately 1,100 nautical miles apart, what would be a good pair of CW air-to-ground frequencies to select?

*Answer.* A frequency of either 5,611.5 or 8,947.5 kc depending upon the time of the day. See 7.214 for the approximate range of day operating frequencies in the OFAC service.

**7.217** Why do scheduled aircraft change from DAY to NIGHT frequencies in radio communications? Which frequency, 5,692 kc or 3,162 kc, is better suited for day operation?

*Answer.* The use of higher radio frequencies in the daytime is seasonally more effective than the lower frequencies because of their better reflecting effect from the surface ionization around the earth caused by the sun's radiations. The higher frequencies at night however are not as effective as the lower since they penetrate the ionosphere and as a result do not reflect back to earth thereby making long distance radio transmission practically impossible. In effect, as ionization varies with the activity of the sun's radiation, the *reflection* of sky waves varies, causing variations in the range of radio transmission. In this case, the frequency of 5,692 kc would be better suited for day operation.

**7.218** An over-ocean aircraft is circling at the scene of distress where another aircraft has ditched. What would be an appropriate frequency for the circling aircraft to transmit homing signals on to permit surface vessels and other aircraft to effect a rendezvous at the scene?

*Answer.* An ideal scene of action frequency for this purpose would be 333, 535, 757 kc, a common VHF frequency, or the telephone distress frequency of 2,182 kc.

**7.219 What is meant by simplex operation in air-to-ground communication?**

*Answer.* Simplex operation is the term applied to the operation of a radiotelegraph system in only one direction at a time. In aeronautics, a frequency of 121.5 mc has been assigned as a universal simplex channel for emergency and distress communications.

**7.220 What is meant by "night effect" in reference to aircraft direction finding? What can be done to counteract night effect when taking aircraft radio bearings?**

*Answer.* Night effect, or night error, is the phenomenon of reflection of radio waves during sunset and night periods caused by the ionosphere, or Heaviside layer. Night effect causes erratic behavior of radio direction finders and impairs the general null or sharp minimum tuning conditions required in the effective use of radio direction finders. It is in reality a change in reflection due to the shifting of the ionosphere and a phase shift between the reflected sky waves and ground waves.

The adverse effects caused by night error may be overcome by using low-frequency bearing signals. The low-frequency signals are primarily ground waves and consequently do not penetrate into the ionosphere layers to produce sky-wave reflections.

Another means of correcting night error is obtained by the use of an Adcock loop-antenna system. With this antenna, the vertical or sky-reflected wave is canceled out and only the horizontal ground wave will be received.

**7.221 How is wind drift compensated for when using a radio compass for homing?**

*Answer.* Accurate compensation for wind drift can be accomplished only by making a precise comparison of the radio compass indications with the ship's stable magnetic compass, or with a directional gyrocompass.

For example, a plane leaving an airport observes that the visual indicator shows a deviation from the direct route. The drift angle may be quickly determined by heading the airplane so as to center the indicator, and noting the difference in degrees from the original heading.

**7.222 Is it possible for one aircraft to use a second aircraft as a homing facility with the presently installed ADF equipment? Explain.**

*Answer.* Yes, provided the aircraft is equipped with a transmitter capable of transmitting signals on the homing aircraft's ADF frequency.

**7.223 How is aircraft ADF equipment used to make an instrument approach?**

*Answer.* In the modern automatic direction finders aboard aircraft, bearings are indicated by a pointer moving through a 360-deg azimuth scale. The only requirements necessary for the pilot to make an instrument approach with this equipment is to adjust the ADF receiver to the frequency of the station on which the approach is to be made. The automatic control unit provides the pilot with continuous visual bearing readings on the azimuth scale.

**7.224 What is the minimum number of ground stations required to provide an instantaneous radio fix with the aircraft DF?**

*Answer.* Two ground stations are required to obtain an instantaneous radio position fix.

**7.225 In aircraft radio direction finding, what is an instantaneous fix? A running fix?**

*Answer.* An instantaneous fix is represented by the intersection of two lines of geographical bearing from two separate radio stations.

A running fix is a bearing obtained from two stations at two different time intervals in flight, or two bearings taken on two stations at short time intervals during the flight.

**7.226 Discuss briefly the DF procedure known as "boxing."**

*Answer.* The practice of rapid familiarization of the 360-deg system so that a pilot may visualize instantly the direction corresponding to any given number of degrees.

**7.227 Radio bearing errors due to terrain effect decrease as the altitude of the aircraft decreases. TRUE or FALSE?**

*Answer.* The statement is false. Bearings taken over terrain at low altitude are erratic due to the bending or refraction of the radio waves.

**7.228 Will flying in or near the vicinity of a severe electrical storm cause erratic functioning of an aircraft ADF unit?**

*Answer.* Yes. Electrical or magnetic storms may cause erratic functioning due to the fact that the ADF will be influenced by the storm's magnetic field and will tend to point or follow the direction of the storm area.

**7.229** Does the aircraft's heading affect the error in radio bearings caused by coast-line refraction?

*Answer.* No. The heading of the airplane does not influence the error in radio bearings caused by coast-line refraction.

**7.230** An aircraft is flying parallel to a coast line and observes a relative bearing of 10 deg on a radio beacon located ahead of the aircraft's position. Will the correct relative bearing be greater or less than the observed 10 deg relative? Explain.

*Answer.* The correct relative bearing will be greater. Due to coastal effects, the errors are greater when the bearings are taken within approximately 30 deg of a line parallel to the coast. (See 7.73.)

**7.231** Explain fully the procedure in obtaining a radio fix on two stations using the aircraft DF loop.

*Answer.* A fix from two transmitting stations may be obtained only on the basis that the airplane direction of movement, or "heading," is known. Otherwise, a fix can be obtained only by procuring three relative bearings from three different radio stations.

On the assumption that the airplane's magnetic compass is in operation, a fix may be established by adhering to the following procedure:

Adjust the DF loop for a maximum response from station *A* and then rotate for minimum response and sharp null point. This establishes one line of direction in relation to the magnetic heading. Proceed immediately to obtain a line of direction from station *B*. We have now completed two relative bearings. Combining these with the airplane's heading, we obtain two geographical bearings. The geographical positions are then located on a chart in proper position. The two lines intersecting as a result of this plotting will establish the fix. For accurate results, the relative bearings indicated on the azimuth scale in comparison with the magnetic compass facilitate rapid conversion into geographical bearings. The time elapsed between the reading of the two directional bearings must also be included in the calculations.

**7.232** What angular separation of transmitting stations will give best results when taking radio bearings to get a three-station fix?

*Answer.* The angular separation should be 120 deg in order to obtain best accuracy with a minimum separation of 10 deg.

**7.233** Explain the "45-90"-deg distance-off procedure of determining distance from an aircraft to a radio beacon station.

*Answer.* The 45- or 90-deg problem is a simplified means of determining a fix of an airplane in flight relative to a given beacon station. It is an effective method for obtaining a running fix from *one* station.

The procedure followed with this method is simply one in which the radio compass loop is adjusted to a null response position at a relative bearing that provides a 45-deg angle to the airplane's course. The exact time is then noted and another adjustment is made when the plane reaches a 90-deg angle to the airplane's course. The time differential between the 45- and 90-deg null settings, together with the speed of travel, will determine the exact distance and time at the instant the plane passes the station. For example, if the plane is traveling at 360 miles per hr, and the time difference is assumed to be 5 minutes between the two bearings, the airplane is 30 miles from the beacon station.

The 90-deg method is similar to the previous problem but has an advantage in that it enables the pilot to calculate the distance from the beacon station *before* he passes it.

**7.234** On which side of an aircraft is a radio beacon located if the relative bearings taken aboard the aircraft are progressively increasing?

*Answer.* An increase of the relative bearing readings during flight indicates that the beacon station is located on the right side of the plane.

**7.235** Describe the procedure for determining sense (orientation) using an aircraft manual DF loop and an aerophare.

*Answer.* The characteristics of a loop antenna provide a definite line of direction—north or south, east or west—but it does not indicate a *definite* direction.

Orientation with a manual DF is a simple process whereby the aircraft is turned right or left to bring the station abeam —90 deg or 270

deg, preferably 90 deg for reasons of simple mathematical calculations, then maintaining a steady heading until the relative bearing has changed appreciably (at least 15 deg if flying in rough air).

If the bearing increases, the station is on the right and the aircraft need be turned that number of degrees to the right to home in. If the bearing decreases, the manual loop should be reversed quickly to the null on the 180–360 deg semicircle and the aircraft turned left the number of degrees difference between the relative bearing and 360 deg. For example: 260 deg relative, turn left 100 deg to home in.

It should be noted that aircraft DF manual loops do not incorporate a sense antenna for orientation although the ADF does work in conjunction with a sense antenna.

**7.236 Upon what factors does the usable range of an aircraft DF loop depend?**

*Answer.* The usable range of an aircraft direction-finder loop is dependent upon such factors as height of plane above terrain, distance from the transmitter, sensitivity of the receiver, loop dimensions, frequency, and the time of the day or night the equipment is used.

**7.237 With reference to loop orientation, what is meant by the "pointer-progression" method?**

*Answer.* The pointer-progression system requires that the loop be set in a range position 90 deg to null-point position.

The pilot observes the direction of the pointer during flight for each adjustment to the null-point signal. The direction of the loop rotation is carefully noted to determine the direction of the homing station. For example, if the rotation of the loop is counterclockwise, the homing station is located off the left wing of the airplane.

**7.238 An aircraft is establishing a fix with radio bearings on two stations. One station is dead ahead, the second station approximately abeam to the right. Which bearing is it advisable to secure first, the speed line or the course line?**

*Answer.* It is advisable to secure the course line first since the distance a line (plotting) is moved during flight is always measured along the course.

**7.239 Explain the method of determining the aircraft's position by "doubling the angle."**

*Answer.* This method is similar to the 45-deg problem discussed in 7.233 with the exception that the bearing is taken when the plane is ahead of the station from which the bearing is to be taken.

For example, an initial bearing is taken and the time noted. A second bearing is then taken with the loop adjusted to null position at a relative bearing on the azimuth scale which will be precisely double the first angle off the course. The time differentials between the two null points are then noted and the distance covered is calculated. Hence, with a given speed and time, the distance is readily calculated by trigonometric functions employing an isosceles triangle.

**7.240 Why is it necessary to maintain constant heading and level flight when taking radio bearings with the aircraft DF?**

*Answer.* A constant heading must be maintained to ensure an accurate relationship between the magnetic compass, or gyrocompass, and the relative bearing.

Level flight is necessary since errors in observed bearings result if the aircraft is in steep turns.

**7.241 To increase the relative bearing on an aircraft DF loop, should the aircraft be turned RIGHT or LEFT?**

*Answer.* The aircraft should be turned towards the left to increase the relative bearing. For example, assume an airplane heading and bearing line to give a 30-deg relative bearing indication. Thus, if the plane is turned to the left, the angle between the bearing line and the airplane heading will be increased.

**7.242 Describe briefly the operational procedure for calibrating an ADF installation in flight.**

*Answer.* The calibration of an automatic direction finder is generally made by the adjustment of a corrector cam during initial installation to compensate for deviations due to physical location and mounting. During flight, the calibration of the direction finder is primarily a matter of adjusting the radio loop to a given "On Station" signal so that the pointer indicator remains centered. On the automatic direction finder, adjustments must be made to permit true bearing readings on the instrument. A deviation correction adjustment is provided in all modern ADF's so that bearings may be used directly as read. This adjustment may be varied during flight to permit accurate calibration of the unit.

**7.243 Define the following: relative bearing, magnetic bearing, true bearing, Mercator bearing, true course, track, magnetic heading, compass heading, true heading, compass error, advanced bearing, retarded bearing, and radio line of position.**

*Answer.* Relative bearing: The number of degrees between the bearing line (transmitting station and plane) and the airplane heading line (direction in which the plane is flying or heading).

Magnetic bearing: The number of degrees between the magnetic north line and the heading line, plus the relative bearing angle. For example, if the magnetic north is a variation of 15 deg west of true north and the plane heading is 55 deg with respect to true north, and the relative bearing is 35 deg, the magnetic bearing is 70 deg plus 35 deg, or 105 deg.

True bearing: The number of degrees between the true heading and the relative bearing, or as in the preceding example,  $55 + 35$  deg, or 90 deg.

Mercator bearing: A method of obtaining a bearing for long-distance air navigation by the use of a Mercator projection chart. This method employs a straight line between two points (rhumb line) for determining a given bearing. (See 7.244 for details.)

True course: The indication of the directional gyroscope or compass, as to the magnetic course to a station at any particular instant during flight. It does not refer to the heading direction of the plane.

Track: This term refers to the straight line between two points as employed in the plotting of all aeronautical charts. The two common terms used in connection with these charts is the *rhumb-line track* and the *great-circle track*.

Magnetic heading: This term applies to the direction toward which the airplane is heading as compared with the compass indication. It is the number of degrees between the airplane heading and the magnetic north.

Compass heading: The number of degrees between the airplane heading and the compass north. For example, if the airplane heading and true north represent 55 deg, and 15-deg variation exists between true north and magnetic north, and 5-deg deviation exists between magnetic north and compass north, then the total, or 75 deg, is the compass heading.

True heading: The number of degrees between the airplane heading and true north.

Compass error: The degree of fixed error, or deviation, introduced

into a magnetic compass by the local magnetic fields set up on the airplane.

**Advanced bearing:** This refers to the situation in which a pilot desires to plot a running fix on two or more stations. This practice is preferred over an instantaneous fix whenever the running time of the airplane is considerably longer than two minutes, or the ground distance covered is in excess of five miles. Two bearings are plotted at approximate intervals of ten minutes, one bearing from station *A*, at say 0800 GMT, and another bearing at 0810 GMT from station *B*. The resultant plotting computations of these two running fixes will then reveal the airplane's movement between the two time periods or, in this case, an advanced fix is obtained at time 0810 GMT.

The fix can be established by either advancing or retarding the bearing to the upper or lower time period, as desired.

**Retarded bearing:** This term refers to the condition in which a pilot plots a running fix between two stations as in the previous explanation with the exception that the second bearing taken is moved back along the course instead of in advance of the first bearing.

Both advanced and retarded bearing indications obtained by a running fix serve as a means for determining an airplane's geographic position at a certain time by two or more bearings taken at different time intervals.

A radio line of position is that curve on the earth for all points of which the sending station lies at a constant great-circle bearing.

## RADIO NAVIGATION OF AIRCRAFT

**7.244** Explain why Mercator charts are used in long-range air navigation? What is a rhumb line? What is a great circle?

*Answer.* Mercator charts are used in long range air navigation because they utilize the projection method of charting large oceanic areas. The projection method makes use of a straight line between two points rather than the arc of a great circle. This straight line is referred to in air navigation as a "rhumb line" and is one that crosses all meridians throughout its length at the same angle. A "great circle" is defined as the line of intersection obtained on the surface of the earth by *any* plane through the center of the earth.

**7.245** Give the rules for applying Mercator correction to a radio bearing taken by the aircraft; by the ground direction-finder station.

*Answer.* If the bearings are taken by an aircraft, the sign of correction on the Mercator chart to convert a radio bearing to Mercator bearing is accomplished as follows:

The correction is  $\frac{\text{additive}}{\text{subtractive}}$  if the airplane is in *south* latitude and is flying  $\frac{\text{eastward}}{\text{westward}}$  of the ground direction finder station. If, on the other hand, the airplane is in a north latitude area but of the same  $\frac{\text{eastward}}{\text{westward}}$  relationship to the ground station, the correction will be  $\frac{\text{subtractive}}{\text{additive}}$ .

The same procedure is followed for ground stations with the exception that the sign of correction is reversed.

### 7.246 On a Mercator chart, are the rhumb line and great-circle tracks always represented by a straight line?

*Answer.* No. Any arc on the great circle is indicated on the Mercator chart as a curved line connecting the two points of the rhumb line. However, when the chart is used to determine a bearing, the curved line is not used and the bearing is plotted as a straight line by calculating the difference between the rhumb line and great-circle tracks. This correction is then applied to the bearing and drawn on the chart as a rhumb line.

### 7.247 Explain why it is necessary to apply Mercator correction to radio bearings?

*Answer.* Radio waves in the frequency spectrum of aircraft direction finders follow the great-circle track and therefore do not represent the true line between two points on the Mercator chart. Hence, the angular direction of the radio wave and its relation to the rhumb line must be considered to obtain the proper correction factor.

### 7.248 Under what conditions is it unnecessary to apply Mercator correction to an observed true bearing?

*Answer.* Mercator corrections are not required if true bearings are taken over distances of less than 100 miles.

### 7.249 What is meant by compass deviation? Magnetic variation?

*Answer.* The term "compass deviation" refers to the difference in degrees between the magnetic north and the compass north. "Magnetic variation" refers to the number of degrees variation between magnetic north and true north.

7.250 What is the relative bearing of a radio station as observed on an aircraft if the true bearing from a radio station to the aircraft is 060 deg and the aircraft has a compass heading of 020 deg with a compass error of 2 deg west and a variation of 10 deg west?

*Answer.* 232 deg. Figure 7-6 illustrates the vector solution of the problem.

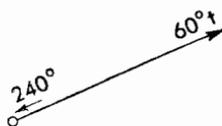


FIG. 7-6. Vector solution of a relative bearing problem.

*Solution:*

True heading (TH) = compass heading (CH) -  
compass error (west) - variation (west)  
True heading = 20 - 2 - 10 = 8°

$$\begin{aligned} 60^\circ + 180^\circ &= 240^\circ \\ 240^\circ &T \text{ to the station from the aircraft.} \\ 60^\circ &= \text{true bearing of aircraft from station} \\ 240^\circ &= TB \\ \underline{-8^\circ} &= TH \\ 232^\circ &= \text{relative bearing} \end{aligned}$$

7.251 An aircraft is flying from station A to station B using the dual ADF with the RED pointer on station A and the GREEN pointer on station B. What ADF readings would indicate that the aircraft is on course with a 15-deg drift angle?

*Answer.*

Right semicircle of dial = GREEN = 15 and 195 deg, or  
Left semicircle of dial = RED = 340 and 165 deg

7.252 An aircraft is on a true heading of 225 deg. Variation is 2 deg west and deviation is 3 deg east. What relative bearings would be necessary to obtain true bearings of 275 and 45 deg?

*Answer.* 51 and 181 deg.

*Solution:*

$$\begin{aligned} CH &= TH + V - D = 225 + 2 - 3 = 224^\circ \\ RB &= TB - CH \pm 360^\circ \\ (1) RB &= 275 - 224 = 51^\circ \\ (2) RB &= 45 - 224 + 360 = 181^\circ \end{aligned}$$

7.253 An aircraft is on a magnetic heading of 50 deg and relative bearings are being taken on a station off to the RIGHT. If it is desired to turn directly toward the station when a QDM of 90 deg is reached, what relative bearing will give the desired QDM?

*Answer.* 40 deg (when QDM of 90 deg).

*Solution:*

$$\begin{aligned} CH + RB &= QDM \\ RB &= QDM - CH = 90 - 50 \\ &= 40^\circ \end{aligned}$$

7.254 An aircraft is on a true bearing of 100 deg from a radio beacon. What is the relative bearing if the magnetic heading is 015 deg and the variation is 10 deg west?

*Answer.* 95 deg. (Reciprocal = 275 deg.)

*Solution:*

$$\begin{aligned} TH &= CH - V \text{ (west)} = 15 - 10 = 005^\circ \\ TH + RB &= TB \\ RB &= TB - TH = 100 - 5 = 95^\circ \end{aligned}$$

7.255 An aircraft observes a relative bearing of 254 deg on an aerophare. If the compass heading is 41 deg, deviation 2 deg east, variation 8 deg west, what is the true bearing of the aerophare?

*Answer.* 289 deg.

*Solution:*

$$\begin{aligned} TH &= CH + D - V = 41 + 2 - 8 = 35^\circ \\ TB &= TH + RB = 35 + 254 = 289^\circ \end{aligned}$$

7.256 What is the true bearing of an aerophare with respect to an aircraft flying a magnetic heading of 127 deg if the loop reading is 10 deg left, deviation 3 deg west, variation 4 deg east, and the quadrantal error is +2 deg?

*Answer.* 116 deg (calculated). Actual TB of aerophare = 123 deg.

*Solution:*

$$\begin{aligned} TH &= CH \pm D + V = 127 \pm 3 + 4 = 128^\circ \\ RB &= -(\text{loop reading} + \text{error}) = -(10 + 2) = -12^\circ \\ TB &= TH + RB = 128 - 12 = 116^\circ \end{aligned}$$

7.257 An aircraft is flying on a CH of 058 deg, in position 45 deg 30 min north and 14 deg 10 min west. A relative bearing of 250 deg is taken on a radio station located at 47 deg 35 min north and 16 deg 00 min west. Compass deviation is 3 deg east and magnetic variation is 10 deg west. What bearing should be plotted on a Mercator chart?

*Answer.* 300 deg 30 min. (See Fig. 7-7.)

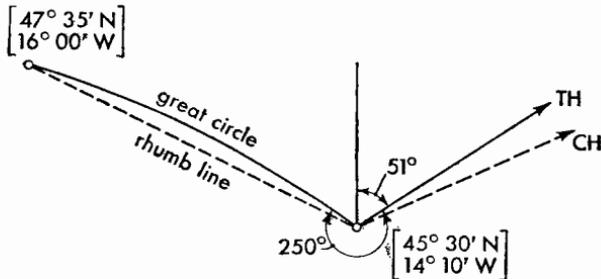


FIG. 7-7. Vector bearing solution.

*Solution:*

$$TH = CH + D - V = 58 + 3 - 10 = 51^\circ$$

$$TB = TH + RB = 51 + 250 = 301^\circ$$

$$\text{Correction on Mercator (table)} = -0.5^\circ$$

$$\text{Plotted bearing} = 301 - 0.5 = 300^\circ 30''$$

*Note:* This question does not state specifically which bearing should be plotted.

7.258 An aircraft is tracking 315 deg at a ground speed of 240 miles per hr. At 1800 GMT a radio station bears 315 deg relative, and at 1805 GMT the same station bears 270 deg relative. What is the distance from the aircraft to the ground station at 1805 GMT?

*Answer.* 20 miles.

*Solution:*

$$\text{Speed} = 240 \text{ miles per hr} = 4 \text{ miles per min}$$

$$\text{Distance from 1800 GMT to 1805 GMT} = 20 \text{ miles}$$

$$\text{Bearings covered are } -45^\circ \text{ and } -90^\circ$$

Solving by an isosceles triangle:

$$\text{Distance traveled} = \text{distance to ground station} = 20 \text{ miles}$$

**7.259** An observed relative bearing is 75 deg. Which direction and how many degrees must the aircraft be turned to move the relative bearing to 125 deg?

*Answer.* By simple vector representation, it will be evident that the plane must turn 50 deg to the left.

**7.260** An aircraft is flying in extreme turbulence. The first relative bearing is 90 deg and the second relative bearing is 95 deg. Is it safe to assume that the station is on the RIGHT?

*Answer.* No. It is not safe to assume the station is on the right because in rough air, a 5-deg change in relative bearing is not sufficiently wide definitely to indicate that the station is on the right.

**7.261** An aircraft is homing on a radio station. The correct relative bearing is zero. If the null moves slowly from 0 to 355, 350, 345, and the compass heading remains constant, is the drift RIGHT or LEFT?

*Answer.* The drift is towards the right.

*Solution:*

$$\text{Drift} = TH - \text{Track} = 360^\circ - 355 = +5^\circ, \text{ etc.}$$

**7.262** The compass heading is 125 deg. The aircraft is south of the radio beacon and both deviation and variation are 0 deg. What relative bearing will be indicated when the aircraft intercepts the 175-deg azimuth from the station?

*Answer.* 230 deg.

*Solution:*

$$TB = 180 + 175 = 355^\circ$$

$$TH = 125^\circ$$

$$RB = 355 - 125 = 230^\circ \text{ (relative bearing when on } 175^\circ \text{ azimuth).}$$

**7.263** Given: Compass heading: 195 deg

Deviation: 9 deg west

Variation: 6 deg east

Find: True heading

*Answer.* 192 deg.

*Solution:*

$$TH = CH - D + V = 195 - 9 + 6 = 192^\circ$$

7.264 If the compass heading is 289 deg, deviation 5 deg west, variation 7 deg east, and the relative bearing on the station 172 deg, what is the true bearing?

*Answer.* 103 deg.

*Solution:*

$$TH = CH - D + V = 289 - 5 + 7 = 291^\circ$$

$$TB = TH + RB = 291^\circ + 172^\circ = 463^\circ$$

$$= 463 - 360 = 103^\circ$$

7.265 An aircraft is on a compass heading of 236 deg. The relative bearing on a radio station is 326 deg. Variation is 23 deg east, deviation 2 deg west, and the loop correction is  $-4$  deg. What is the true bearing?

*Answer.* 219 deg.

*Solution:*

$$TH = CH + V - D = 236 + 23 - 2 - 4 = 253^\circ$$

$$TB = TH + RB = 253 + 326 = 579 - 360 = 219^\circ$$

7.266 The true bearing from a radio station to an aircraft is 068 deg. The aircraft is flying a compass heading of 016 deg, deviation 2 deg west, variation 11 deg west. What is the relative bearing on the aircraft loop?

*Answer.* 245 deg.

*Solution:*

$$CH = 16^\circ$$

$$D = \overline{2^\circ}$$

$$H = 14^\circ$$

$$V = \overline{11^\circ}$$

$$TH = \overline{3^\circ}$$

$$\text{Reciprocal } TB = 68^\circ + 180^\circ = 248^\circ$$

$$\text{Relative bearing} = 248^\circ - 3^\circ = 245^\circ$$

It is recommended that all candidates for this license review the reference material requirements listed below: Civil Aeronautics Bulletin No. 24, "Radio Navigational Aids," Part 9; "Rules and Regulations Governing Aeronautical Services" (FCC); and the ICAO (International Civil Aviation Organization) "Standards and Recom-

mended Practices, Aeronautical Telecommunications (Annex 10)" and "Procedures for Air Navigation Services, Rules of the Air and Air Traffic Services" (effective Sept. 1952) published by the authority of the Secretary General, Montreal, Canada, are some of the most important requirements for detailed study purposes.

Much valuable information on instrument flight problems is also contained in the text "Radio Navigation for Pilots" (out of print) by Colin H. McIntosh and in "Principles of Aeronautical Radio Engineering" by R. C. Sandretto, both of which are published by the McGraw-Hill Book Company, Inc., New York.

The authors have included extracts from information contained in the FCC, CAA, ICAO, and related publications as specifically related to rules and regulations important to the field of radio operating.

## **Element 8**

# **Ship Radar Techniques**

**8.01 What are the FCC license requirements for the operator who is responsible for the installation, servicing, and maintenance of ship radar equipment?**

*Answer.* All adjustments and tests during installation and maintenance must be performed by or under the supervision of a person holding a first-class or second-class radiotelephone or radiotelegraph license with ship radar endorsement. Persons not holding such licenses may replace fuses or receiving tubes.

**8.02 Who may operate radar equipment in the Ship Service?**

*Answer.* The master, or person designated by him, may operate a ship radar station licensed for shipboard use in the Ship Service.

**8.03 Under what conditions may a person who does not hold a radio operator license operate a radar station in the Ship Service?**

*Answer.* Any person may operate such a station if the equipment is licensed, meets frequency-stability requirements, if the operation of the equipment is in accordance with radio law, if such person is subject to the authority of the master of the vessel, and if such adjustments and tests are made by a properly licensed operator.

**8.04 Who may make entries in the installation and maintenance record of a ship radar station?**

*Answer.* Such entries must be made by or under the supervision of the operator concerned in each case, but the licensee has joint responsibility for the accuracy of the record.

**8.05 What entries are required in the installation and maintenance record of a ship radar station?**

*Answer.* The following entries must be signed by the responsible operator concerned: date and place of the initial installation; any steps necessary to remedy interference; nature of any complaint of interference since arising; reason for the trouble leading to the condition complained of, including the name of the faulty component; remedial measures taken and date thereof; the name, license number, and date of the ship radar operator endorsement of the first-class or second-class operator performing the work.

**8.06 Who has the responsibility for making entries in the installation and maintenance record of a ship radar station?**

*Answer.* The licensed operator doing the work, but the licensee has an equal responsibility to see that the entries are accurately made.

**8.07 Within what bands of frequencies do ship radar transmitters operate?**

*Answer.* Within 3,000 and 3,246 mc; 5,460 and 5,650 mc; 9,320 and 9,500 mc.

**8.08 May fuses and receiving tubes be replaced in ship radar equipment by a person whose operator license does not contain a ship radar endorsement?**

*Answer.* Yes.

**8.09 Explain briefly why radar interference to a radiotelephone receiver is frequently characterized by a steady tone in the radio loudspeaker.**

*Answer.* The magnetron in a radar transmitter is pulsed by a series of square waves generated in the modulator section of the transmitter. Since this wave train must have appreciable amplitude and because a square wave is made up of a large number of frequencies, there are emissions of considerable strength on up into the radio-frequency spectrum. The pulse recurrence rate (PRR) occurs at an audio frequency in the range between 700 and 3,000 pulses per second. The radio-frequency emissions resulting from the square-wave modulation are similar to ICW transmissions and appear in bands with varying intensity for various communications receivers.

**8.10 Describe how various types of interference from a radar installation may be apparent to a person when listening to a radio communications receiver.**

*Answer.* The sources of interference from a radar installation are of two general types: (a) noise and (b) signals arising from the method of pulsing. Among the sources of noise are commutator noise, high-voltage arc over, and occasionally noise from imperfect contact between slip ring and brush. All these noises are characteristic of static and sparking. The interference arising from the pulse recurrence rate of the modulator used to key the magnetron is a tone of about 1,000 cycles appearing throughout the radio-frequency spectrum. It is sometimes concentrated in bands of greater intensity. The frequency range of these bands is different for various receivers.

**8.11 How are the various types of radar interference recognized in (a) autoalarm equipment and (b) direction-finding equipment?**

*Answer.* (a) Interference in the autoalarm is indicated by the red light being illuminated. Listening on the monitor jack of the alarm equipment will also indicate the type of interference. (b) Listening to the head telephones or loudspeaker connected to the DF equipment.

**8.12 On what frequencies should the radar serviceman look for radar interference to communication receivers on ships equipped with radar?**

*Answer.* He should particularly check to see that no interference is being caused to the frequencies: 100–200 kc; 350–515 kc; 1,850–1,950 kc; and 2–30 mc.

**8.13 In checking a direction finder for interference caused by radar equipment, would it be a good policy to check for interference while the DF loop is being rotated?**

*Answer.* Yes. If the interference were coming from radar equipment on another vessel nearby, the orientation of the loop would determine the source. If interference were equally strong in all directions, it could safely be assumed that interference was coming from equipment on the same ship.

**8.14 List at least two types of indications on a loranscope that signifies that a radar installation is causing interference to the loran.**

*Answer.* Noise from a radar installation shows up as "grass" on the slow-sweep display on a loranscope, generally obscuring all but the strongest loran signals. Spikes, usually moving to the right or to the left, indicate interference from the radar modulator. Occasionally these spikes may stand still on the slow-sweep display but usually begin moving right or left in a few moments.

**8.15 Is there any likelihood of a radar installation causing interference to radio receivers if long connecting lines are used between the radar transmitter and the radar modulator?**

*Answer.* Yes. The connection between the magnetron oscillator and the pulsed modulator sections of the radar transmitter should be connected by as short a line as possible, properly terminated to avoid standing waves on the outer sheath, solidly connected at both ends, and properly grounded at both ends. All modern commercial radar equipments follow this practice to avoid generating pulse interference.

**8.16 What steps might be taken by a radar serviceman to eliminate a steady-tone type of interference to radio communication receivers, or interference to loran receivers evidenced by "spikes"?**

*Answer.* Since this type of interference is caused by radar modulator pulses, the line between modulator and magnetron should be checked for defective grounds at each end. Power leads into the radar equipment should be adequately filtered. As a last resort, it may be necessary to relocate the communications-receiver or the loran antenna in order to reduce pickup of the interfering signals.

**8.17 What steps might be taken by a radar serviceman to reduce "grass" on a loranscope or motor-generator noise in communication receivers?**

*Answer.* If it is not possible to install filters directly on commutators or other sources of noise interference, the power line to loran and radio communications equipment should be equipped with noise filters. In addition, the frames and cabinets of all receiving equipment and the housings of motor generators should be solidly grounded.

**8.18 Name at least four pieces of radio or electronic equipment aboard ship that might suffer interference from the radar installation.**

*Answer.* Among the equipment that might suffer interference are autoalarm, loran, Decca navigator, Consol, direction finder, radio communications, and VHF ship-shore radiotelephone equipment. Under certain conditions, electronic intercommunication equipment might also be affected.

**8.19 Why is it important that all units of a radar installation be thoroughly bonded to the ship's electrical ground?**

*Answer* All radar, radio, and power equipment should be well bonded to the ship's electrical ground to avoid currents being carried by cable sheaths or other conductors between various units. Good grounding helps more than anything else in the elimination of interference. Of equal importance is the fact that if equipment is left "floating," harmful or annoying voltage gradients may exist between equipment and ground. The harmful effects of electrical shock are often secondary, like the fall from a ladder, owing to an involuntary reaction to slight shock.

**8.20 What may cause bright-flashing pie sections to appear on a radar PPI scope?**

*Answer.* Flashing pie sections on the PPI (plan position indicator) scope, sometimes called "spoking," result from failure of the automatic frequency-control circuit. While the most frequent cause of this type of failure is generally failure of the AFC crystal itself, the effects of failure of the magnetron, frequency shift of the magnetron, or failure to key the magnetron with good square-wave pulses would manifest themselves in the same manner.

**8.21 What symptoms on a radarscope would indicate that the radar-receiver mixer crystal is defective?**

*Answer.* Weak signals or lack of any signals on the PPI scope, especially when testing with the echo box, might indicate that the mixer crystal was defective.

**8.22 What tests may a radar serviceman make to determine whether or not the radar-receiver mixer crystal is defective?**

*Answer.* There is usually a switch provided so that the crystal test current can be measured. This current should generally be about 0.4 milliamperes. A standard tester for crystals, such as that ordinarily

carried by a service-company employee is safe and reasonably accurate. A 20,000-ohm-per-volt meter can also be used to check the front-to-back current ratio. With the test probes in one connection, there should be a very high resistance. Do not use an ohmmeter of lower resistance, or the crystal may be damaged by too high a measuring current. Be careful in removing and replacing crystals, to avoid static discharges that may damage them. Always touch the crystal holder with the finger before touching crystal to the holder.

**8.23 In a radar set, what are indications of a defective magnetron, a weak magnet in the magnetron, and a defective crystal in the receiver converter stage?**

*Answer.* A defective magnetron may be indicated by high magnetron current or no current, overload or underload breakers open, bright-flashing pie sections on the PPI scope. A weak magnet is indicated by high magnetron current or opening of the overload breaker. A defective crystal in the receiver converter stage is indicated by weak signals on the PPI scope, particularly when testing with the echo box.

**8.24 What precautions should a radar serviceman take when working with or handling a magnetron to prevent weakening or damage to the magnetron?**

*Answer.* The magnetron should be handled carefully and when removed from the equipment should be placed so that it can not fall and so that tools or other heavy material cannot fall upon it. In particular, avoid cracking the glass or breaking the seal between glass and metal parts. Avoid bending or hitting the metal envelope or cooling fins. Prevent damage to the wave-guide connection and exclude dirt from this section. Be careful not to bend or break leads through the glass heater and heater-cathode terminal insulator. Avoid mechanical strain on these connections.

Care must be observed in handling the magnet. Do not heat it or strike it with a screwdriver or other tool.

**8.25 What precautions should a radar serviceman observe when making repairs or adjustments to a radar set to prevent personal injury to himself or to other persons?**

*Answer.* Possible injuries are of mechanical and electrical origin. Among the first are cuts and abrasions caused by striking sharp parts.

of the equipment, cuts sustained by implosion of the cathode-ray tube owing to careless handling, including poisoning by the fluorescent-screen materials, and burning the hands and arms from contact with hot vacuum tubes, particularly the metal types.

It should be noted that T-R and anti-T-R tubes often contain radioactive material. Special care must be taken when handling broken tubes. Serious injury may result if this material is absorbed through bodily contact.

Electrical injuries include shock from high-potential wires and connections and capacitors.

Whenever possible, turn off all equipment and allow it to cool before working on it. Be sure that the main power switch is off, and discharge all capacitors with a semipermanent ground lead. Wear gloves and glasses when handling cathode-ray tubes. Use a handkerchief or other cloth to protect the hands when removing hot tubes.

If it is necessary to maintain the equipment with power on, always have a competent assistant standing by who has been instructed how to turn off the main power and administer first aid in case of accident.

**8.26 Is there any danger in testing or operating radar equipment aboard ship when explosive or inflammable cargo is being handled?**

*Answer.* Yes. The superhigh frequencies used are capable of heating many materials and can therefore cause fires or explosions. For example, there have been instances in which photoflash bulbs have been ignited within their cartons when placed near radar equipment. Blasting caps with short wire leads might similarly be exploded.

**8.27 What considerations should be taken into account when selecting the location of the radar antenna assembly aboard ship?**

*Answer.* Other things being equal, the antenna assembly should be mounted as high and as clear of obstacles as possible. Its weight must be taken into consideration and adequate support provided for it. The location must also permit proper installation and adequate support for the wave guide between the transmitter and the antenna. It must be accessible for necessary maintenance. The antenna should be placed so that obstructions are toward the stern rather than in any forward direction.

**8.28 Describe briefly the construction of a wave guide. Why should the interior of the wave guide be clean, smooth, and dry?**

*Answer.* Wave guides are commonly constructed of brass tubing having a rectangular cross section. The brass is commonly plated with silver to increase the conductivity, and the silver is in turn protected from corrosion by a flash plating of rhodium, gold, or other protective metal. The ends of the wave-guide sections are equipped with special flange joints so that they can be connected together to ensure good mechanical and electrical junctions. Because of the manner in which the microwaves travel in a wave guide, the interior surface must contain no electrical discontinuities. Dirt or corrosion resulting from excessive moisture will spoil the proper propagation of the wave through the guide.

Severe attenuation may result from large accumulations of moisture even if free from dirt and corrosion.

**8.29** When installing wave guides, why should long, perfectly level sections of wave guides be avoided? Why is a small hole about  $\frac{1}{8}$  in. in diameter sometimes drilled on the underside of an elbow in a wave guide near the point where it enters the radar transmitter?

*Answer.* It would be desirable to maintain wave guides under pressure of dry air or gas so that the guide would not breathe in moisture from the surrounding air. Since it is not always possible to maintain it under pressure, the wave guide should be installed so that it slopes gently. If moisture accumulates, it can then run off to a point at which absorbent material or a drain is provided. Because it is difficult to pressurize certain sections, such as the wave guide near a rotating joint where the guide is connected to the antenna, it is often necessary to drill a small drain hole through which condensed moisture can escape.

**8.30** Why are wave guides used in preference to coaxial lines for the transmission of microwave energy in most shipboard radar installations?

*Answer.* The losses in coaxial lines at superhigh frequencies (microwaves) are very much higher than in wave guides. Because of the very large physical size required at lower frequencies, wave guides are not generally used outside the microwave region.

**8.31** Why are rectangular cross-sectional wave guides generally used in preference to circular cross-sectional wave guides?

*Answer.* Rectangular wave guides effectively suppress all but a single mode of electric field polarization and are thus somewhat easier to use. A round wave guide is used at rotating joints.

**8.32 Describe how wave guides are terminated at the radar antenna reflectors.**

*Answer.* The wave guide in a commercial marine radar is customarily coupled to a horn or wave-guide nozzle. Radio-frequency energy from this horn falls upon a parabola-section reflector and is reflected as a narrow beam.

**8.33 What precautions should be taken when installing vertical sections of wave guides with choke coupling flanges to prevent moisture from entering the wave guide?**

*Answer.* The end of the wave guide bearing the choke section should always hang down to avoid collection of moisture in the choke joint. When provided, the gasket should be inserted between the choke and the plain flange and the bolts taken up sufficiently to make a weather-proof joint.

**8.34 Why are choke joints often used in preference to flange joints to join sections of wave guides together?**

*Answer.* Choke joints prevent loss of energy from a wave-guide junction, even when the joint is not mechanically tight. It is difficult to confine the energy within a wave-guide junction made up of a simple flange joint.

**8.35 Draw a longitudinal section of a wave-guide choke joint, and explain briefly its principle of operation.**

*Answer.* Refer to Fig. 8-1. The choke joint is used so that there will be only a small loss or reflection at the gap  $J$ . This means that the impedance of the gap  $J$  must be as close as possible to zero. It is achieved by making the distance  $\lambda_G/4$  appear like a short circuit at the inner surface of the guide, when  $\lambda_G$  is the wavelength in the guide. The impedance of the slot opening into the gap  $J$  is made infinite by proportioning its depth to be equal to  $\lambda_A/4$  when  $\lambda_A$  is the free-space wavelength of the source. The slot can conveniently be thought of as a short length of coaxial line terminated in a short circuit at the far end.

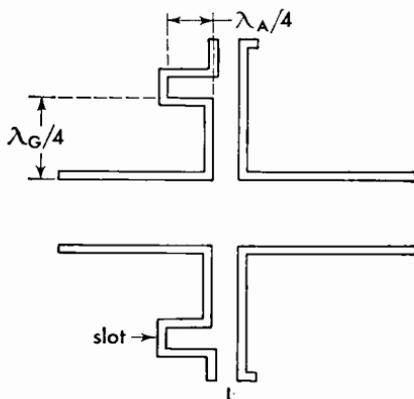


FIG. 8-1. Wave-guide choke joint.

**8.36 Describe how a radar beam is formed by a paraboloidal reflector.**

*Answer.* Refer to Fig. 8-2. The antenna or source of radiation is located at the focus  $F$  of the parabola, which has a characteristic such that the resulting beam of radiated energy appears to come from many properly phased antennas. Any line drawn from the focus to to

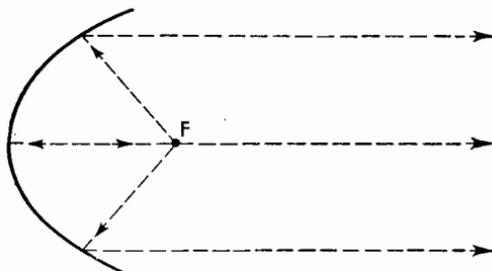


FIG. 8-2. Elementary parabolic reflector.

the surface of the reflector will be reflected along a line parallel to those already drawn in the figure. It is customary in commercial marine radar to use a section of a parabola, sometimes called a “truncated parabola,” to form the type of beam desired.

**8.37 What effect, if any, does the accumulation of soot or dirt on the antenna reflector have on the operation of ship radar?**

*Answer.* Normal accumulation of soot or dirt has little noticeable effect on the operation of the ship radar. However, dirt on the plastic

cover over the end of the wave-guide nozzle or horn will adversely affect operation. Moreover, this plastic cover should never be painted with ordinary paint.

**8.38 What is the purpose of an echo box in a radar system? Explain the principle of operation of the echo box. What indications may be expected on a radarscope when using an echo box and the radar set is operating properly? When the radar set is not operating properly?**

*Answer.* An echo box is used to test the radar system in the absence of signals or when it is desired to compare performance with a previously attained standard. The echo box is actually a high-Q resonant cavity that is caused to ring by receiving energy from the radar transmitter. Since the ringing dies out relatively slowly, a portion of the energy is picked up by the radar receiver to give a PPI display. The length of the radial spoke or spokes from the center of the cathode-ray tube is a relative measure of the effectiveness of the system, as compared to a past setting. On some commercial equipments, the echo box tests only the output of the transmitter. On others, it tests the output of the wave-guide horn. When the radar is operating properly, the radial line or lines on the PPI scope should extend out some distance from the center. If the equipment is not functioning properly, the length of these lines will be short compared to those obtained with some known previous setting of controls.

**8.39 Draw a block diagram of a radar system, labeling the antenna, duplexer, transmitter, receiver, modulator, timer, and the indicator.**

*Answer.* See Fig. 8-3.

**8.40 Explain briefly the principle of operation of a radar system.**

*Answer.* Refer to Fig. 8-3. The purpose of a radar system is to gain knowledge about the presence, general size, and distance of above-water obstacles to navigation. In order to simplify commercial equipment, one antenna is used both for transmitting and receiving. A duplexer or T-R assembly is provided so that power from the transmitter will not damage the sensitive receiver. This duplexer also prevents the loss of the received signal in the transmitting equipment. The heart of the radar system is the timer that sends out regular signals to

operate the modulator. The modulator keys the magnetron transmitter on and off so that it sends out a uniform series of short pulses. The timer also sends blanking signals to the indicator so that any local signal leaking into the receiving system will not be displayed on the plan

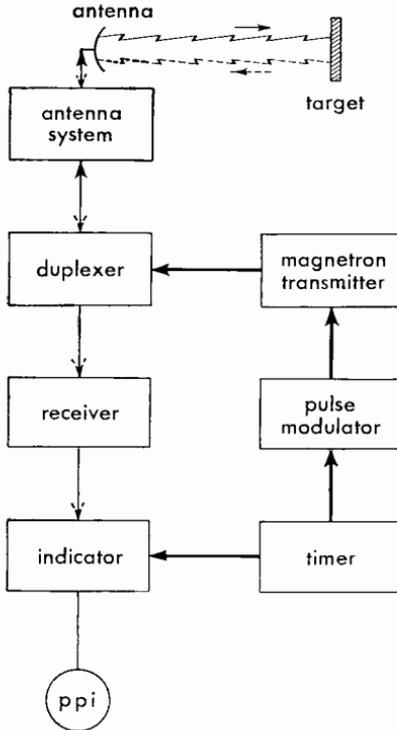


FIG. 8-3. Block diagram of a radar system.

position indicator (PPI) oscilloscope tube. The indicator also provides distance-marker circles that facilitate accurate determination of the distance from the ship to the obstruction. The receiver converts radio-frequency energy into video signals that are displayed on the PPI scope.

**8.41** Draw a simple block diagram of a radar duplexer system, labeling the wave guide, the T-R box, anti T-R box, the receiver, and the transmitter.

*Answer.* See Fig. 8-4.

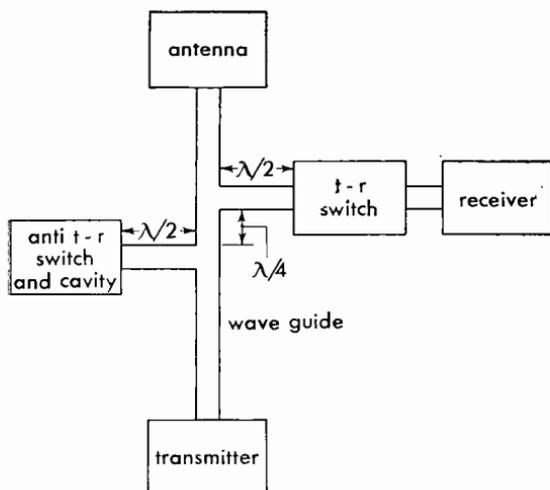


FIG. 8-4. Radar duplexer system.

8.42 Draw a simple block diagram of a radar receiver, labeling the signal crystal, the local oscillator, the AFC crystal stage, the intermediate-frequency amplifier, and the discriminator.

*Answer.* See Fig. 8-5.

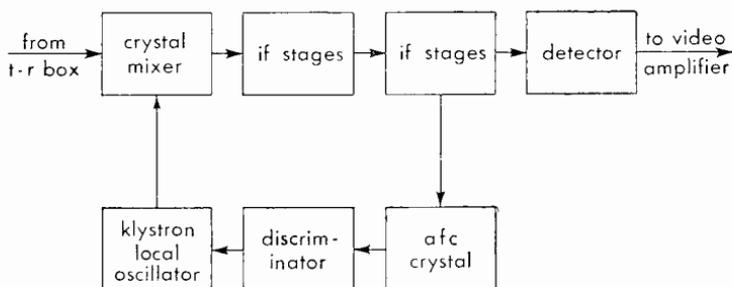


FIG. 8-5. Block diagram of a radar receiver.

8.43 Draw a simple cross-sectional diagram of a magnetron, showing the anode, cathode, and the direction of electronic movement under the influence of a strong magnetic field.

*Answer.* See Fig. 8-6.

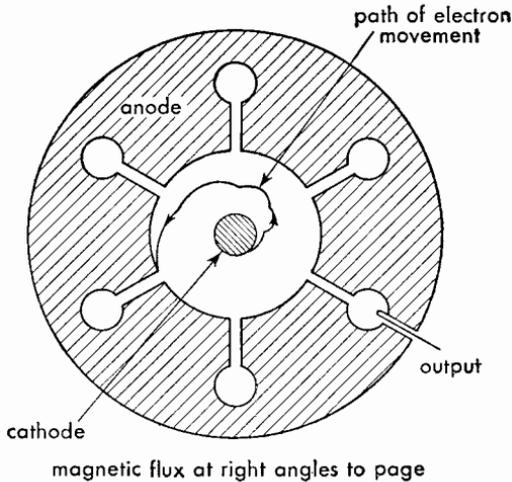


FIG. 8-6. Cross-section of a cavity magnetron.

**8.44 Explain briefly the principle of operation of the magnetron.**

*Answer.* Refer to Fig. 8-6. Electrons are emitted from the cathode when the magnetron is keyed or turned on by the modulator. Some of these return to the cathode and do no useful work. Others, like that for which the path is drawn, finally reach the anode. In their movement past the slots leading to the various cavities, they give up energy and cause the magnetron to oscillate. A strong magnetic flux is set up, usually by a permanent magnet, along the direction of the cathode. In the simple drawing, only the end of the cathode is shown. If the magnet is weakened, the electrons, instead of spiraling along the cathode, will go more directly to the anode, increasing the current to dangerously high values. Output is taken from a probe in one of the cavities.

**8.45 Why is the anode in a magnetron in a radar transmitter normally maintained at ground potential?**

*Answer.* Although the anode must be maintained at a positive voltage, it is more convenient for mechanical reasons to ground the anode. The cathode, therefore, is carefully insulated and maintained at a large negative potential.

**8.46** Draw a simple frequency-converter circuit (mixer) as frequently used in radar superheterodyne receivers, and indicate which is the crystal stage.

*Answer.* See Fig. 8-7.

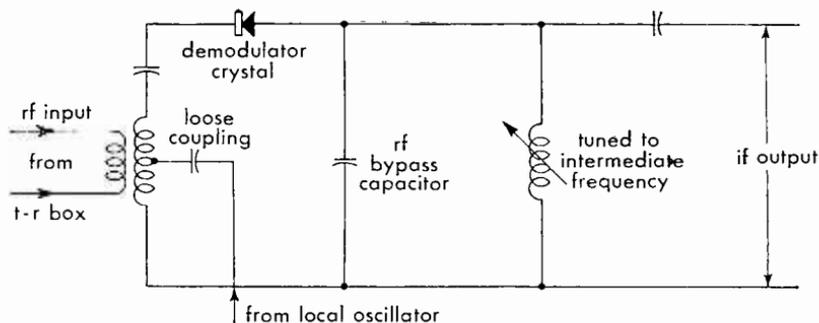


FIG. 8-7. Simplified radar frequency-converter circuit.

**8.47** What is the purpose of the klystron tube in a radar set?

*Answer.* The klystron tube in a radar set functions exclusively as local oscillator.

**8.48** Explain briefly the principle of operation of the reflex klystron.

*Answer.* In a reflex klystron tube, the electron beam is velocity modulated as it passes between the resonator grids. A retarding electric field beyond these grids causes the electron-beam velocity to decrease to zero and reflects the beam back through the grids. Bunching occurs during the transit interval between reflections. When the proper negative voltage has been impressed on the repeller plate, the bunched electrons deliver energy to the resonator grids on the return trip.

**8.49** What care should be taken when handling silicon crystal rectifier cartridges for replacement in radar superheterodyne receivers?

*Answer.* The care that should be exercised when handling silicon crystal rectifier cartridges for replacement in radar superheterodyne receivers is the avoidance of mechanical shock, the accidental discharge of static charge through the crystal during insertion in the crystal holder, and exposure to strong electric fields.

**8.50 What nominal intermediate frequencies are commonly found in radar receivers?**

*Answer.* Intermediate frequencies of from 15 to 60 mc are used in radar receivers. The intermediate and video frequencies are more readily separated when the higher frequencies are used. On the other hand, the tube capacitance will have minor effect on the alignment when the lower frequencies are used.

**8.51 Describe briefly the construction and operation of radar T-R and anti T-R boxes. What is the purpose of a "keep alive" voltage?**

*Answer.* The T-R and anti T-R boxes are cavity resonators with a spark gap located one-quarter wavelength from the end. The T-R box functions as a double-pole double-throw switch. It connects the receiver to the common antenna during the resting period of the transmitter and disconnects it during the transmission period. The anti T-R box is located an odd number of quarter wavelengths from the T-R box and is shunted across the main transmission line. It works in conjunction with the T-R box to see that all the available echo energy is absorbed by the receiver and that none of it reaches the transmitter during its resting period.

The purpose of the "keep alive" voltage is to ionize the spark gap so that it breaks down quickly under initial pulsing conditions. This increases the protection to the receiver's crystal.

**8.52 What is the purpose of the discriminator stage in a radar superheterodyne?**

*Answer.* The purpose of the discriminator stage in a radar superheterodyne receiver is to provide an automatic frequency control voltage for the repeller electrode of the radar beating oscillator.

**8.53 What type of detector is used frequently in radar receivers?**

*Answer.* One of the most frequently used types of demodulators used in radar receivers is the semiconductor diode detector.

**8.54 What is "sea return" on a radar scope?**

*Answer.* The sea return is the reflection of the radar signal from the sea. These echoes are amplified and presented on the scope in the same manner as the target return.

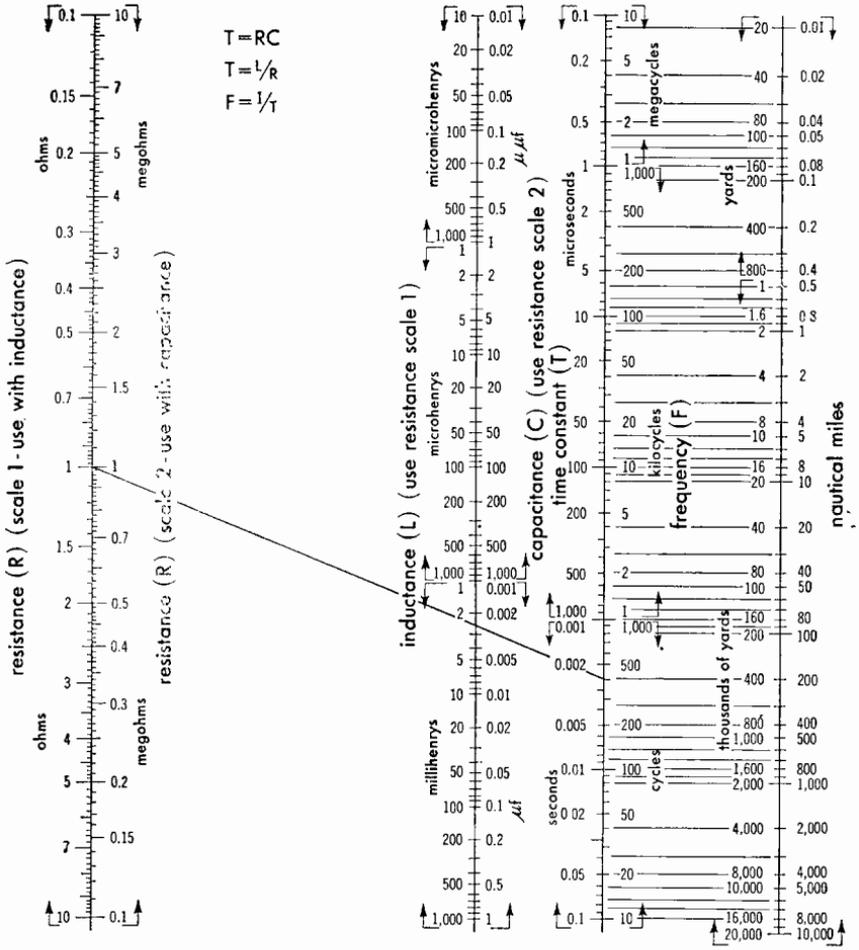


FIG. 8-8. Time constants for series circuits and radar ranges.

*Example:* Given a resistance of 1 megohm in series with a capacitance 0.0025 microfarad, find the time constant of the network. Placing a straight edge through these respective values (using resistance scale 2 and capacitance scale 2), the time constant scale is intersected at 0.0025 second, a frequency of 400 cycles and a maximum possible range of 200 miles.

**8.55** Explain briefly the purpose of the sensitivity-time-control circuit in a radar set.

*Answer.* The purpose of the sensitivity-time-control circuit in a radar set is to control the receiver gain so that the gain increases with range to offset the decrease of echo amplitudes, and so that nearby targets will not be obscured by sea return or blocking by the transmitted signal.

**8.56** What is the distance in nautical miles to a target if it takes 123 microseconds for a radar pulse to travel from the radar antenna to the target, back to the antenna, and be displayed on the PPI scope?

*Answer.* Reflection interval for 1 nautical mile = 12.361 microseconds (time for pulse journey out and back).

$$\frac{123}{12.3} = \text{approximately } 10 \text{ nautical miles}$$

(See also Fig. 8-8 for information on time constant and range.)

**8.57** What is the purpose of an artificial transmission line in a radar set?

*Answer.* Artificial transmission lines are employed for pulse formation in driver stages of modulators. The lines consist of a number of capacitors and inductors in certain combinations. The artificial line will deliver a voltage for a definite period of time to a load, in a similar way to the action of a battery rapidly switched on and off. Its advantage lies in the accuracy with which the magnitude and duration of pulses of energy can be delivered and in the extreme rapidity of the action.

**8.58** Draw a simple diagram of an artificial transmission line showing inductance and capacitance, source of power, the load, and the electronic switch.

*Answer.* See Fig. 8-9.

**8.59** What component in a radar set determines the pulse repetition rate?

*Answer.* The timer or synchronizer unit in a radar set determines the pulse repetition rate.

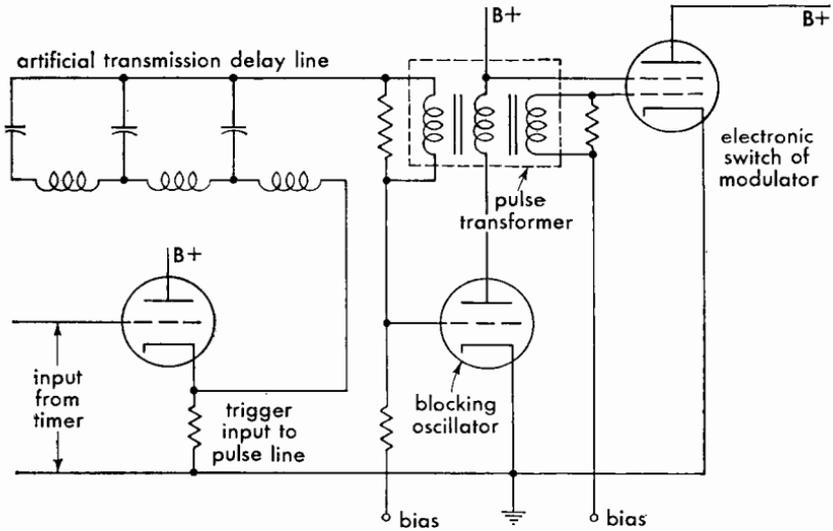


FIG. 8-9. Simplified artificial transmission-line pulser.

### 8.60 What circuit element determines the operating frequency of the self-blocking oscillator?

*Answer.* An oscillator in which the plate and grid circuits are closely coupled through an iron-core transformer is called a "blocking oscillator" or "transformer-coupled multivibrator." The operating frequency depends principally upon the RC time constant of the grid resistor and grid capacitor.

### 8.61 What is the purpose of the rotary spark gap used in some radar sets?

*Answer.* The rotary spark gap is used in some radar sets (such as some Navy types) to function as a short-circuit switch for pulse-forming networks. One side of the gap is rotated on a wheel in such a way that it passes a fixed electrode at regular intervals. When the rotating electrode is directly under the fixed one, an arc is formed that discharges the pulse-forming network through its useful load. After the rotating electrode has passed the stationary one, the arc is extinguished. This action allows the storage elements of the network to be recharged. The process is then repeated.

**8.62** What is the peak power of a radar pulse if the pulse width is 1.0 microsecond, pulse repetition rate is 900, and the average power is 18 watts? What is the duty cycle?

*Answer.* The peak power is 20 kilowatts, and the duty cycle is 0.0009.

$$\frac{\text{Average power}}{\text{Peak power}} = \frac{\text{pulse width}}{\text{pulse repetition time}} = \text{duty cycle}$$

$$\text{Peak power} = \frac{(18) \times 10^6}{900} = 20,000 \text{ watts}$$

$$\text{Duty cycle} = \frac{\text{average power}}{\text{peak power}} = \frac{18}{20,000} = 0.0009$$

**8.63** What is meant by "bearing resolution" of a radar set?

*Answer.* Bearing, or azimuth, resolution refers to the ability of a radar set to distinguish between two targets close together at the same range distance. This ability depends upon a number of factors, such as radio frequency of operation (being generally improved at higher frequencies), pulse width, antenna characteristics, and receiver adjustments.

**8.64** Explain how heading flash and range-marker circles are produced on a radar PPI scope.

*Answer.* Heading flashes can be reproduced on a radar PPI scope in the following manner: A snap-action switch is mechanically connected to the antenna so as to be closed by a cam. The switch closes on the dead-ahead position of the antenna (coinciding with the longitudinal axis of the mobile unit). When it is closed, a different bias is applied to the indicator sweep; as a result, the sweep coinciding with the mobile unit's heading is exceptionally bright.

Range markers can be produced in the following manner: A series of differentiating circuits produces a series of pips evenly spaced at intervals corresponding to the ranges desired. When these pips are injected into the video amplifier and appear on the indicator screen, the azimuth sweep forms them into circles of illumination that can be used for calculation of distance from the target.

**8.65** Draw a diagram of a cathode-ray tube as used in radar, showing the principal electrodes in the tube and the path of the electron beam.

*Answer.* See the labeled diagram in Fig. 8-10.

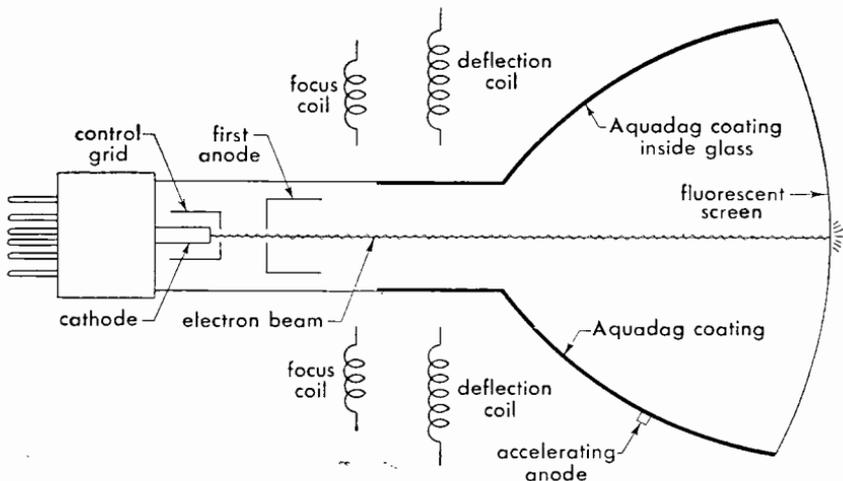


FIG. 8-10. Cross section of magnetic-deflection cathode-ray tube.

**8.66** What is the purpose of Aquadag coatings on radar cathode-ray tubes?

*Answer.* Aquadag is the trade name of a colloidal graphite conducting coating painted upon the inside of cathode-ray tubes in order to form an accelerating or second anode. This conducting coating also acts to some extent as an electrostatic shield to prevent external voltage gradients from deflecting the electron beam.

**8.67** Explain the principle of operation of the cathode-ray PPI tube, and explain the function of each electrode.

*Answer.* A simplified cross-sectional view of a typical electromagnetic-deflection cathode-ray tube is shown in Fig. 8-10. Within the electron-gun assembly at the left is a heater surrounded by a nickel cathode tube. This nickel tube is coated with oxides of various metals that give off electrons when heated. They are effectively shot out of the electron-gun assembly by the influence of the highly positive first anode through which they pass. A suitable negative voltage on the grid controls this electron flow. A still higher positive voltage on the second or accelerating anode speeds up the electron stream so that it strikes the fluorescent screen, causing light to appear wherever the screen is hit.

A movable permanent magnet or coil through which the current

can be varied is used to focus the electron beam to make it hit the fluorescent screen in a small spot. Another electromagnetic-deflection coil causes the beam to move in response to signal currents.

In a set employing PPI, the antenna is rotated uniformly about a vertical axis so that the main axis of the radiated beam sweeps all angles in the horizontal plane. This gives a map-like representation of the area scanned on the screen. The range of the objects reflected back is determined by their calibrated distance from the center of the screen. Direction is determined by the azimuth angle of the radial line from a predetermined reference point. One means of generating the sweep for the PPI is by means of a rotating yoke system, utilizing the deflection coil.

### 8.68 What precautions should the service and maintenance operator observe when replacing the cathode-ray tube in a radar set?

*Answer.*

1. Be sure the main switch is off and all high-voltage capacitors are discharged.
2. Wear safety goggles and gloves in case the tube should implode.
3. When inserting tube horizontally into a socket, grip the neck for guidance only; support most of the weight at the screen end.
4. If a tube does break and you get a small cut, wash all dirt away and remove the small particles. Fluorescent materials may prevent a wound from healing.

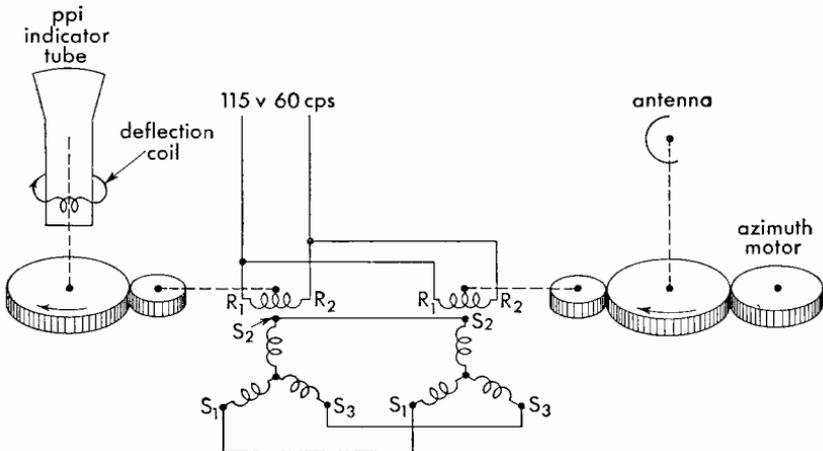


FIG. 8-11. Synchro-motor coupling between radar antenna and PPI scope.

5. Never place the tube face down unless it is protected by felt or similar soft material.

**8.69** Draw a simple diagram, showing how a synchro generator located in the radar antenna assembly is connected to a synchro motor located in the indicator to drive the deflection coils. Show proper designation of all leads, designating where alternating voltages (if needed) are applied.

*Answer.* See the drawing in Fig. 8-11.

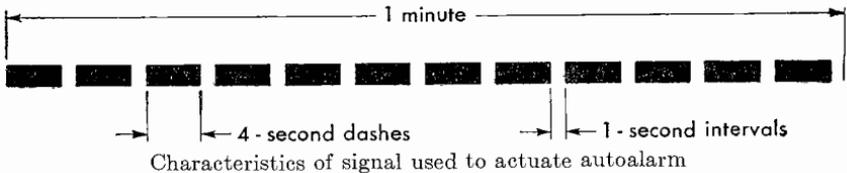
# APPENDIX

## ORDER OF PRIORITY OF COMMUNICATIONS IN THE MOBILE SERVICE

The order of priority of communications in the mobile service is as follows:

1. Distress calls, distress messages, and distress traffic.
2. Communications preceded by the urgency signal.
3. Communications preceded by the safety signal.
4. Communications relative to radio direction-finding bearings.
5. Radiotelegrams relative to the navigation and safe movements of aircraft.
6. Radiotelegrams relative to the navigation, movements, and needs of ships; weather observation messages destined for an official meteorological service.
7. Government radiotelegrams for which priority right has been claimed.
8. Service radiotelegrams relating to the working of the radiocommunication service or to radiotelegrams previously transmitted.
9. All other communications.

(From *International Telecommunication Convention, Atlantic City, 1947.*)



## INTERNATIONAL MORSE CODE

With extracts from the list of punctuations and other signs contained in the *Telegraph Regulations of the Atlantic City Convention, 1947.*

### Letters

a . —	i ..	r . — .
b — . . .	j . — — —	s . . .
c — . — .	k — . —	t —
d — . .	l . — . .	u . . —
e .	m — —	v . . . —
f . . — .	n — .	w . — —
g — — .	o — — —	x — . . —
h . . . .	p . — — .	y — . — —
	q — — . —	z — — . .

## Figures

1 . — — — —	6 — . . . .
2 .. — — — —	7 — — . . . .
3 ... — — —	8 — — — . . .
4 .... — —	9 — — — — .
5 ..... —	0 — — — — —

## Punctuation and Other Signs

Period.....	.	. — . . . . —
Comma.....	,	— — . . . . —
Colon.....	:	— — — . . . .
Question mark, or request for repetition of a transmission not understood.....	?	. . — . . . .
Apostrophe.....	'	. — — — — .
Dash or hyphen.....	—	— . . . . —
Fraction bar.....	/	— . . . . —
Parenthesis (before and after words).....	( )	— . — — — . —
Inverted commas (quotation marks) (before and after words).....	“ ”	. — . . . . —
Equal sign.....	=	— . . . . —
Understood.....		. . . . —
Error.....		. . . . .
Cross or end of telegram or end of transmission.....		. — . . . .
Invitation to transmit.....		— — — —
Wait.....		. — . . . .
End of work.....		. . . . —
Starting signal (beginning every transmission).....		— . — . —

The following optional letters and signals may be used exceptionally on connections between countries allowing them:

ä . — . . —	ñ — — . — —
á or â . — — . —	ö — — — .
ch — — — —	ü . . — —
é . . — . .	

Figures and letters are sent without intervening spaces. In transmitting numbers involving a fraction, a hyphen is transmitted before or after the fraction, as the case may be. For example,  $44\frac{1}{2}$  is sent as 44- $\frac{1}{2}$  (44 — . . . . —  $\frac{1}{2}$ ).

## Abbreviations Available for All Services—Q Code

<i>Abbreviation</i>	<i>Question</i>	<i>Answer or Advice</i>
QRA	What is the name of your station?	The name of my station is ____.
QRB	How far approximately are you from my station?	The approximate distance between our stations is ____ nautical miles (or kilometers).
QRC	By what private enterprise (or State Administration) are the accounts for charges for your station settled?	The accounts for charges of my station are settled by the private enterprise ____ (or State Administration).
QRD	Where are you bound and where are you from?	I am bound for ____ from ____.
QRE	What is your estimated time of arrival at ____ (place)?	My estimated time of arrival at ____ (place) is ____ hours.
QRF	Are you returning to ____ (place)?	I am returning to ____ (place) or Return to ____ (place).
QRG	Will you tell me my exact frequency (or that of ____)?	Your exact frequency (or that of ____) is ____ kc (or mc).
QRH	Does my frequency vary?	Your frequency varies.
QRI	How is the tone of my transmission?	The tone of your transmission is ____. 1. Good. 2. Variable. 3. Bad.
QRK	What is the readability of my signals (or those of ____)?	The readability of your signals (or those of ____) is ____. 1. Unreadable. 2. Readable now and then. 3. Readable, but with difficulty. 4. Readable. 5. Perfectly readable.
QRL	Are you busy?	I am busy (or I am busy with ____). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you troubled by static?	I am troubled by static.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster (____ words per minute).
QRR	Are you ready for automatic operation?	I am ready for automatic operation. Send at ____ words per minute.
QRS	Shall I send more slowly?	Send more slowly (____ words per minute).
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.

## Abbreviations Available for All Services—Q Code (Continued)

Abbreviation	Question	Answer or Advice
QRV	Are you ready?	I am ready.
QRW	Shall I inform ____ that you are calling him on ____ kc (or mc)?	Please inform ____ that I am calling him on ____ kc (or mc).
QRX	When will you call me again?	I will call you again at ____ hours [on ____ kc (or mc)].
QRY	What is my turn? (Relates to communication)	Your turn is Number ____ (or according to any other indication.) (Relates to communication.)
QRZ	Who is calling me?	You are being called by ____ [on ____ kc (or mc)].
QSA	What is the strength of my signals (or those of ____)?	The strength of your signals (or those of ____) is ____. 1. Scarcely perceptible. 2. Weak. 3. Fairly good. 4. Good. 5. Very good.
QSB	Are my signals fading?	Your signals are fading.
QSC	Are you a cargo vessel?	I am a cargo vessel.
QSD	Is my keying defective?	Your keying is defective.
QSG	Shall I send ____ telegrams at a time?	Send ____ telegrams at a time.
QSI		I have been unable to break in on your transmission. or Will you inform ____ (call sign) that I have been unable to break in on his transmission [on ____ kc (or mc)].
QSJ	What is the charge to be collected per word to ____ including your internal telegraph charge?	The charge to be collected per word to ____ including my internal telegraph charge is ____ francs.
QSK	Can you hear me between your signals?	I can hear you between my signals.
QSL	Can you acknowledge receipt?	I am acknowledging receipt.
QSM	Shall I repeat the last telegram which I sent you, (or some previous telegram)?	Repeat the last telegram which you sent me [or telegram(s) number(s) ____].
QSN	Did you hear me [or ____ (call sign)] on ____ kc (or mc)?	I did hear you [or ____ (call sign)] on ____ kc (or mc).
QSO	Can you communicate with ____ direct or by relay?	I can communicate with ____ direct (or by relay through ____).
QSP	Will you relay to ____ free of charge?	I will relay to ____ free of charge.
QSQ	Have you a doctor on board [or is ____ (name of person) on board]?	I have a doctor on board [or ____ (name of person) is on board].

## Abbreviations Available for All Services—Q Code (Continued)

Abbreviation	Question	Answer or Advice
QSS	What working frequency will you use? ( <i>This signal used by British coast radiotelegraph stations.</i> )	I will use working frequency _____ kc ( <i>normally only last three figures of the frequency.</i> )
QSU	Shall I send or reply on this frequency [or on _____ kc ( <i>or mc</i> )] (with emissions of class _____)?	Send or reply on this frequency [or on _____ kc ( <i>or Mc</i> )] (with emissions of class _____).
QSV	Shall I send a series of V's on this frequency [or _____ kc ( <i>or mc</i> )]?	Send a series of V's on this frequency [or _____ kc ( <i>or mc</i> )].
QSW	Will you send on this frequency [or on _____ kc ( <i>or mc</i> )] (with emissions of class _____)?	I am going to send on this frequency [or on _____ kc ( <i>or mc</i> )] (with emissions of class _____).
QSX	Will you listen to _____ [call sign(s)] on _____ kc ( <i>or mc</i> )?	I am listening to _____ [call sign(s)] on _____ kc ( <i>or mc</i> ).
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency [or on _____ kc ( <i>or mc</i> )].
QSZ	Shall I send each word or group more than once?	Send each word or group twice ( <i>or _____ times</i> ).
QTA	Shall I cancel telegram number _____ as if it had not been sent?	Cancel telegram number _____ as if it had not been sent.
QTB	Do you agree with my counting of words?	I do not agree with your counting of words; I will repeat the first letter or digit of each word or group.
QTC	How many telegrams have you to send?	I have _____ telegrams for you ( <i>or for _____</i> ).
QTE	What is my TRUE bearing from you?	Your TRUE bearing from me is _____ degrees (at _____ hours).
or	What is my TRUE bearing from _____ ( <i>call sign</i> )?	Your TRUE bearing from _____ ( <i>call sign</i> ) was _____ degrees (at _____ hours).
or	What is the TRUE bearing of _____ ( <i>call sign</i> ) from _____ ( <i>call sign</i> )?	The TRUE bearing of _____ ( <i>call sign</i> ) from _____ ( <i>call sign</i> ) was _____ degrees at _____ hours.
QTF	Will you give me the position of my station according to the bearings taken by the direction-finding stations which you control?	The position of your station according to the bearings taken by the direction-finding stations which I control was _____ latitude, _____ longitude, class _____ at _____ hours.
QTG	Will you send two dashes of ten seconds each followed by your call sign (repeated _____ times) [on _____ kc ( <i>or mc</i> )]?	I am going to send two dashes of ten seconds each followed by my call sign (repeated _____ times) [on _____ kc ( <i>or mc</i> )].
or		or

## Abbreviations Available for All Services—Q Code (Continued)

Abbreviation	Question	Answer or Advice
	Will you request ____ to send two dashes of ten seconds followed by his call sign (repeated ____ times) on ____ kc (or mc)?	I have requested ____ to send two dashes of ten seconds followed by his call sign (repeated ____ times) on ____ kc (or mc).
QTH	What is your position in latitude and longitude (or according to any other indication)?	My position is ____ latitude ____ longitude (or according to any other indication).
QTI	What is your TRUE track?	My TRUE track is ____ degrees.
QTJ	What is your speed?  (Requests the speed of a ship or aircraft through the water or air respectively.)	My speed is ____ knots (or kilometers per hour).  (Indicates the speed of a ship or aircraft through the water or air respectively.)
QTK	What is the speed of your aircraft in relation to the surface of the earth?	The speed of my aircraft in relation to the surface of the earth is ____ knots (or kilometres per hour).
QTL	What is your TRUE heading (TRUE course with no wind)?	My TRUE heading is ____ degrees.
QTN	At what time did you depart from ____ (place)?	I departed from ____ (place) at ____ hours.
QTO	Have you left dock (or port)? or Are you airborne?	I have left dock (or port). or I am airborne.
QTP	Are you going to enter dock (or port)? or Are you going to alight (or land)?	I am going to enter dock (or port). or I am going to alight (or land).
QTQ	Can you communicate with my station by means of the International code of signals?	I am going to communicate with your station by means of the International code of signals.
QTR	What is the correct time?	The correct time is ____ hours.
QTS	Will you send your call sign for ____ minute(s) now (or at ____ hours) [on ____ kc (or mc)] so that your frequency may be measured?	I will send my call sign for ____ minute(s) now (or at ____ hours) [on ____ kc (or mc)] so that my frequency may be measured.
QTU	What are the hours during which your station is open?	My station is open from ____ to ____ hours.
QTV	Shall I stand guard for you on the frequency of ____ kc (or mc) (from ____ to ____ hours)?	Stand guard for me on the frequency of ____ kc (or mc) (from ____ to ____ hours).
QTX	Will you keep your station open for further communication with me until further notice (or until ____ hours)?	I will keep my station open for further communication with you until further notice (or until ____ hours).
QTM (new)	What is your magnetic heading?	My magnetic heading is ____ degrees.

## Abbreviations Available for All Services—Q Code (Continued)

Abbreviation	Question	Answer or Advice
QUA	Have you news of ____ (call sign)?	Here is news of ____ (call sign).
QUB	Can you give me, in the following order, information concerning: visibility, height of clouds, direction and velocity of ground wind at ____ (place of observation)?	Here is the information requested.
QUC	What is the number (or other indication) of the last message you received from me [or from ____ (call sign)]?	The number (or other indication) of the last message I received from you [or from ____ (call sign)] is ____.
QUD	Have you received the urgency signal sent by ____ (call sign of mobile station)?	I have received the urgency signal sent by ____ (call sign of mobile station) at ____ hours.
QUF	Have you received the distress signal sent by ____ (call sign of mobile station)?	I have received the distress signal sent by ____ (call sign of mobile station) at ____ hours.
QUG	Will you be forced to alight (or land)?	I am forced to alight (or land) immediately.
		<i>or</i> I shall be forced to alight (or land) at ____ (position or place).
QUH	Will you give me the present barometric pressure at sea level?	The present barometric pressure at sea level is ____ (units).
QUI	Are your navigation lights working?	My navigation lights are working.
QUJ	Will you indicate the TRUE heading for me to steer toward you (or ____) with no wind?	The TRUE heading for you to steer toward me (or ____) with no wind is ____ degrees at ____ hours.
QUK	Can you tell me the condition of the sea observed at ____ (place or coordinates)?	The sea at ____ (place or coordinates) is ____.
QUL	Can you tell me the swell observed at ____ (place or coordinates)?	The swell at ____ (place or coordinates) is ____.
QUM	Is the distress traffic ended?	The distress traffic is ended.
QUN	Will vessels in my immediate vicinity [(or in the vicinity of ____ latitude ____ longitude) (or of ____)] please indicate their position, TRUE course, and speed?	My position, TRUE course, and speed are ____.
QUO	Shall I search for ____ 1. Aircraft 2. Ship 3. Survival craft in the vicinity of ____ latitude ____ longitude (or according to any other indication)?	Please search for ____ 1. Aircraft 2. Ship 3. Survival craft in the vicinity of ____ latitude ____ longitude (or according to any other indication).

## Abbreviations Available for All Services—Q Code (Concluded)

Abbreviation	Question	Answer or Advice
QUP	Will you indicate your position by _____? 1. Searchlight 2. Black smoke trail 3. Pyrotechnic lights	My position is indicated by _____. 1. Searchlight 2. Black smoke trail 3. Pyrotechnic lights
QUQ	Shall I train my searchlight nearly vertical on a cloud, occulting if possible, and if your aircraft is seen or heard, deflect the beam up wind and on the water (or land) to facilitate your landing?	Please train your searchlight on a cloud, occulting if possible, and, if my aircraft is seen or heard, deflect the beam up wind and on the water (or land) to facilitate my landing.
QUR	Have survivors _____? 1. Received survival equipment 2. Been picked up by rescue vessel 3. Been reached by ground rescue party	Survivors _____. 1. Are in possession of survival equipment dropped by ____ 2. Have been picked up by rescue vessel 3. Have been reached by ground rescue party
QUS	Have you sighted survivors or wreckage? If so, in what position?	Have sighted _____. 1. Survivors in water 2. Survivors on rafts 3. Wreckage in position _____ latitude _____ longitude (or according to any other indication).
QUT	Is position of incident marked?	Position of incident is marked (by _____).
QUU	Shall I home ship or aircraft to my position?	Home ship or aircraft 1. _____ (call sign) to your position by transmitting your call sign and long dashes on _____ kc (or mc) 2. _____ (call sign) by transmitting on _____ kc (or mc) courses to steer to reach you
QUV	What is my MAGNETIC bearing from you (or from _____)?  (This signal, in general, will not be used in the Maritime Mobile Service.)	Your MAGNETIC bearing from me (or from _____) was _____ degrees at _____ hours.  (This signal, in general, will not be used in the Maritime Mobile Service.)
QUX	Will you indicate the MAGNETIC course for me to steer toward you (or _____) with no wind?  (This signal, in general, will not be used in the Maritime Mobile Service.)	The MAGNETIC course for you to steer to reach me (or _____) with no wind was _____ degrees at _____ hours.  (This signal, in general, will not be used in the Maritime Mobile Service.)

## Miscellaneous Abbreviations and Signals

Abbreviation or Signal	Definition
AA	All after _____ (used after a question mark to request a repetition).
AB	All before _____ (used after a question mark to request a repetition).
ABV	Repeat (or I repeat) the figures in abbreviated form.
ADS	Address (used after a question mark to request a repetition).
<u>AR</u>	End of transmission (· — · — · to be sent as one signal).
<u>AS</u>	Waiting period (· — · · · to be sent as one signal).
BK	Signal used to interrupt a transmission in progress.
BN	All between _____ and _____ (used after a question mark to request a repetition).
BQ	A reply to an RQ.
C	Yes.
CFM	Confirm (or I confirm).
CL	I am closing my station.
COL	Collate (or I collate).
CP	General call to two or more specified stations.
CQ	General call to all stations.
CS	Call sign (used to request a call sign).
DB	I cannot give you a bearing; you are not in the calibrated sector of this station.
DC	The minimum of your signal is suitable for the bearing.
DE	Used to separate the call sign of the station called from the call sign of the calling station.
DF	Your bearing at _____ (time) was _____ degrees, in the doubtful sector of this station, with a possible error of _____ degrees.
DG	Please advise me if you note an error in the bearing given.
DI	Bearing doubtful in consequence of the bad quality of your signal.
DJ	Bearing doubtful because of interference.
DO	Bearing doubtful. Ask for another bearing later [or at _____ (time)].
DP	Possible error of bearing may amount to _____ degrees.
DS	Adjust your transmitter; the minimum of your signal is too broad.
DT	I cannot furnish you with a bearing; the minimum of your signal is too broad.
DY	This station is not able to determine the sense of the bearing. What is your approximate direction relative to this station?
DZ	Your bearing is reciprocal. (To be used only by the control station of a group of direction-finding stations when it is addressing stations of the same group.)
ER	Here _____.
ETA	Estimated time of arrival.
ITP	The punctuation counts.
JM	Make a series of dashes if I may transmit. Make a series of dots to stop my transmission (not to be used on 500 kc except in cases of distress).

## Miscellaneous Abbreviations and Signals (Concluded)

<i>Abbreviation or Signal</i>	<i>Definition</i>
K	Invitation to transmit.
MN	Minute ( <i>or</i> Minutes).
MSG	Prefix indicating a message to or from the master of a ship concerning its operation or navigation.
N	No.
NIL	I have nothing to send to you.
NW	Now.
OK	We agree ( <i>or</i> It is correct).
P	Prefix indicating a private radiotelegram.
PBL	Preamble ( <i>used after a question mark to request a repetition</i> ).
PTR	Used by a coast station to request the position and next port of call of a mobile station.
R	Received.
REF	Reference to ____ ( <i>or</i> Refer to ____).
RPT	Repeat ( <i>or</i> I repeat) ( <i>or</i> Repeat ____).
RQ	Indication of a request.
SIG	Signature ( <i>used after a question mark to request a repetition</i> ).
SOS	Distress Signal (· · · — — — · · · <i>to be sent as one signal</i> ).
SS	Indicator preceding the name of a ship station.
SVC	Prefix indicating a service telegram.
SYS	Refer to your service telegram.
TFC	Traffic.
TR	Used as a prefix to indicate reply to PTR.
TTT	This group when sent three times constitutes the safety signal.
TU	Thank you.
TXT	Text ( <i>used after a question mark to request a repetition</i> ).
VA	End of work (· · · — · — <i>to be sent as one signal</i> ).
W	Word(s) <i>or</i> [Group(s)].
WA	Word after ____ ( <i>used after a question mark to request a repetition</i> ).
WB	Word before ____ ( <i>used after a question mark to request a repetition</i> ).
XXX	This group when sent three times constitutes the urgency signal.

## CCIR INTERNATIONAL SIGNAL-QUALITY CODE

A signal report shall consist of the code word SINPO or SINPFEMO followed by a five- or eight-figure group, respectively, rating the five or eight characteristics of the signal code. The letter X shall be used instead of a numeral for characteristics not rated. Although the code word SINPFEMO is intended for radiotelephony, either code word may be used for radiotelegraphy or radiotelephony as may be desired. The over-all rating for radiotelegraphy shall be interpreted according to the table of Signal Quality Criteria.

## SINPO Signal Reporting Code

Rating Scale	S	I	N	P	O
	Signal Strength	Degrading Effect of			Overall Readability (QRK)
		Interference (QRM)	Noise (QRN)	Propagation Disturbance	
5	Excellent	Nil	Nil	Nil	Excellent
4	Good	Slight	Slight	Slight	Good
3	Fair	Moderate	Moderate	Moderate	Fair
2	Poor	Severe	Severe	Severe	Poor
1	Barely audible	Extreme	Extreme	Extreme	Unusable

## SINPFEMO Signal Reporting Code

Rating Scale	S	I	N	P	F	E	M	O
	Signal Strength	Degrading effect of			Frequency of Fading	Modulation		Over-all Rating
		Interference (QRM)	Noise (QRN)	Propagation Disturbance		Quality	Depth	
5	Excellent	Nil	Nil	Nil	Nil	Excellent	Maximum	Excellent
4	Good	Slight	Slight	Slight	Slow	Good	Good	Good
3	Fair	Moderate	Moderate	Moderate	Moderate	Fair	Fair	Fair
2	Poor	Severe	Severe	Severe	Fast	Poor	Poor or nil	Poor
1	Barely audible	Extreme	Extreme	Extreme	Very fast	Very poor	Continuously overmodulated	Unusable

## Signal Quality Criteria

Rating Scale	QRK	Mechanized Operation	Morse Operation
5	Excellent	Four-channel Time Division Multiplex	High-speed Morse
4	Good	Two-channel Time Division Multiplex. Single Start-Stop Printer	100 wpm Morse
3	Fair	Marginal. Single Start-Stop Printer	50 wpm Morse
2	Poor	Equivalent to 25 wpm Morse	25 wpm Morse
1	Unusable	Possible BK's. XQ's (service instructions), call letters distinguishable	Possible BK's. XQ's, call letters distinguishable

## RADIOTELEPHONE WORD LISTS

## International Word List

International procedure in the Mobile Radiotelephone Service requires that when it is necessary to spell out call signs, service abbreviations, and words, the following table is used. However, stations of the same country may use, when communicating between themselves, any other list of words recognized by their administration.

A.....	Amsterdam	N.....	New York
B.....	Baltimore	O.....	Oslo
C.....	Casablanca	P.....	Paris
D.....	Danemark	Q.....	Quebec
E.....	Edison	R.....	Roma
F.....	Florida	S.....	Santiago
G.....	Gallipoli	T.....	Tripoli
H.....	Havana	U.....	Upsala
I.....	Italia	V.....	Valencia
J.....	Jerusalem	W.....	Washington
K.....	Kilogramme	X.....	Xantippe
L.....	Liverpool	Y.....	Yokohama
M.....	Madagascar	Z.....	Zurich

Figures and punctuation to be transmitted by radiotelephone. Each transmission of figures is preceded and followed by the words "as a number" spoken twice.

1	6	Comma
2	7	Fraction bar
3	8	Break signal
4	9	Full stop (period)
5	0	

## ARRL (American Radio Relay League)

A.....	Adam	J.....	John	S.....	Susan
B.....	Baker	K.....	King	T.....	Thomas
C.....	Charlie	L.....	Lewis	U.....	Union
D.....	David	M.....	Mary	V.....	Victor
E.....	Edward	N.....	Nancy	W.....	William
F.....	Frank	O.....	Otto	X.....	X-ray
G.....	George	P.....	Peter	Y.....	Young
H.....	Henry	Q.....	Queen	Z.....	Zebra
I.....	Ida	R.....	Robert		

## APCO (Associated Police Communications Officers)

A.....	Adam	J.....	John	S.....	Sam
B.....	Boy	K.....	King	T.....	Tom
C.....	Charles	L.....	Lincoln	U.....	Union
D.....	David	M.....	Mary	V.....	Victor
E.....	Edward	N.....	Nora	W.....	William
F.....	Frank	O.....	Ocean	X.....	X-ray
G.....	George	P.....	Paul	Y.....	Young
H.....	Henry	Q.....	Queen	Z.....	Zebra
I.....	Ida	R.....	Robert		

## Navy

A.....	Able	J.....	Jig	S.....	Sugar
B.....	Baker	K.....	King	T.....	Tare
C.....	Charlie	L.....	Love	U.....	Uncle
D.....	Dog	M.....	Mike	V.....	Victor
E.....	Easy	N.....	Nan	W.....	William
F.....	Fox	O.....	Oboe	X.....	X-ray
G.....	George	P.....	Peter	Y.....	Yoke
H.....	How	Q.....	Queen	Z.....	Zebra
I.....	Item	R.....	Roger		
1.....	Wun	5.....	Fi-yiv	9.....	Niner
2.....	Too	6.....	Six	0.....	Zero
3.....	Thuh-ree	7.....	Seven		
4.....	Fower	8.....	Ate		

## Western Union

A.....	Adams	J.....	John	S.....	Sugar
B.....	Boston	K.....	King	T.....	Thomas
C.....	Chicago	L.....	Lincoln	U.....	Union
D.....	Denver	M.....	Mary	V.....	Victor
E.....	Edward	N.....	New York	W.....	William
F.....	Frank	O.....	Ocean	X.....	X-ray
G.....	George	P.....	Peter	Y.....	Young
H.....	Henry	Q.....	Queen	Z.....	Zero
I.....	Ida	R.....	Robert		

Although the regulations of the FCC allow phonetic aids for radiotelephony, they prohibit the use of names of countries, states, or cities.

## ICAO Radiotelephone Code (CAA)

A.....Alfa	J.....Juliet	S.....Sierra
B.....Bravo	K.....Kilo	T.....Tango
C.....Charlie	L.....Lima	U.....Uniform
D.....Delta	M.....Mike	V.....Victor
E.....Echo	N.....November	W.....Whiskey
F.....Foxtrot	O.....Oscar	X.....Xray
G.....Golf	P.....Papa	Y.....Yankee
H.....Hotel	Q.....Quebec	Z.....Zulu
I.....India	R.....Romeo	

Numbers shall be transmitted using the following pronunciation for the individual numerals

0.....Ze-ro	4.....Fow-er	8.....Ait
1.....Wun	5.....Fife	9.....Nin-er
2.....Too	6.....Six	1,000.....Tou-sand
3.....Tree	7.....Sev-en	⊙.....De-ci-mal

## ICAO Q CODE (AERONAUTICAL)

The Q Code comprises:

1. Groups of the Special Aeronautical Code, which have A, B, C, D, E, F, G, H, I, J, K, L, M, or N as second letter.
2. Groups of the Special Maritime Services Code which have O, P, or Q as second letter. This series is not listed.
3. Groups of the General Code whose signification and form were determined by the "International Telecommunication and Radio Conferences" (Atlantic City, 1947) and which have R, S, T or U as second letter. They are listed under "Abbreviations Available for All Services—Q Code."

The meanings assigned to Q Code abbreviations may be amplified or completed by the addition of appropriate other groups, call signs, place names, figures or numbers. It is optional to fill in the blanks shown in parentheses. Any data which is filled in where blanks appear should be sent in the same order as shown in the signification.

Detailed instructions for use of this code are contained in "Communication Codes and Abbreviations," ICAO Doc 6100-COM/504/1, effective April 1, 1952.

## ICAO Q CODE

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QAB	May I have clearance (for . . .) from . . .(place and/or control) to . . .(place and/or control) at . . .(figures and units) height above . . .(datum)?	You are cleared (or . . .is cleared) by . . .from . . .(place and/or control) to . . .(place and/or control) at . . .(figures and units) height above . . .(datum).
QAF	Will you advise me when you are (were) at (over) . . .(place)?	I am (was) at (over) . . .(place) (at . . .hours) [at . . .(figures and units) height above . . .(datum)].
QAG		Arrange your flight in order to arrive over . . .(place) at . . .hours. or I am arranging my flight in order to arrive over . . .(place) at . . .hours.
QAH	What is your height above . . .(datum)?	I am at . . .(figures and units) height above . . .(datum). (Note: An aircraft is permitted to reply to QAH IMI by using any of the answer forms of signals QBF, QBG, QBH, QBK, QBN or QBP. In such case the signal QAH is omitted from the reply.) or Arrange your flight so as to reach . . .(figures and units) height above . . .(datum) at . . .(hours or place).
QAK	Is there any risk of collision?	There is risk of collision. (Note: This signal should be followed by appropriate Q signals or ICAO approved abbreviations giving instructions for avoiding collision.)
QAL	Are you going to land at . . .(place)? or Has aircraft . . .landed at . . .(place)? [See also signal QTP.]	I am going to land at . . .(place). or (You may) land at . . .(place). or Aircraft . . .landed at . . .(place). [See also signal QTP.]
QAM	What is the latest available meteorological observation for . . .(place)?	Meteorological observation made at . . .(place) at . . .hours was as follows . . .

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QAN	What is the surface wind direction and speed at... ( <i>place</i> )?	The surface wind direction and speed at... ( <i>place</i> ) at... hours is ... ( <i>direction</i> )... ( <i>speed figures and units</i> ).
QAO	What is the wind direction in degrees TRUE and speed at... ( <i>position or zone/s</i> ) at each of the... ( <i>figures</i> )... ( <i>units</i> ) levels above... ( <i>datum</i> )?	The wind direction and speed at... ( <i>position or zone/s</i> ) at the following heights above... ( <i>datum</i> ) is:  ... ( <i>vertical distance in figures and units</i> ) ... degrees TRUE... ( <i>speed in figures and units</i> ) ... ( <i>vertical distance in figures and units</i> ) ... degrees TRUE... ( <i>speed in figures and units</i> ).
QAP	Shall I listen for you ( <i>or for...</i> ) on... kc (...mc)? [See also signal QSX.]	Listen for me ( <i>or for...</i> ) on... kc (...mc). [See also signal QSX.]
QAA	Am I near a prohibited area ( <i>or...</i> prohibited area)?	You are... 1. near 2. flying over a prohibited area ( <i>or...</i> prohibited area).
QAR	May I stop listening on the watch frequency for... minutes?	You may stop listening on the watch frequency for... minutes.
QAU		I am about to jettison fuel.
QAV	Are you able to home on your DF equipment?	I am homing on my DF equipment on... station.
QAW		I am about to carry out overshoot procedure.
QAY	Will you advise me when you pass (passed)... ( <i>place</i> ) bearing 090 (270) deg relative to your heading?	I passed... ( <i>place</i> ) bearing... degrees relative to my heading at... hours
QAZ	Are you experiencing communication difficulties through flying in a storm?	I am experiencing communication difficulties through flying in a storm.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QBA	What is the horizontal visibility at ... <i>(place)</i> ?	The horizontal visibility at... <i>(place)</i> at...hours is... <i>(distance figures and units)</i> .
QBB	What is the amount, the type and height above official airdrome elevation of the cloud base of the significant cloud [at... <i>(place)</i> ]?	The amount, the type and height above official airdrome elevation of the cloud base of the significant cloud at... <i>(place)</i> at...hours is... eighths (... <i>type</i> ) at... <i>(figures and units)</i> height above official airdrome elevation and...eighths (... <i>type</i> ) at... <i>(figures and units)</i> height above official airdrome elevation.
QBC	Report meteorological conditions as observed from your aircraft [at... <i>(position or zone)</i> ] [at...hours]	The meteorological conditions as observed from my aircraft at... ... <i>(position or zone)</i> at...hours at... ... <i>(figures and units)</i> height above... ... <i>(datum)</i> are...
QBD	How much fuel have you remaining <i>(expressed as hours and/or minutes of consumption)</i> ?	Fuel remaining is... <i>(hours and/or minutes of consumption)</i> .
QBE		I am about to wind in my aerial.
QBF	Are you flying in cloud?	I am flying in cloud at... <i>(figures and units)</i> height above... <i>(datum)</i> [and I am ascending (descending) to... <i>(figures and units)</i> height above that datum].
QBG	Are you flying above cloud?	I am flying above cloud and at... <i>(figures and units)</i> height above... <i>(datum)</i> .  <i>or</i> Maintain a vertical distance of... <i>(figures and units)</i> above cloud, smoke, haze, or fog levels.
QBH	Are you flying below cloud?	I am flying below cloud and at... <i>(figures and units)</i> height above... ... <i>(datum)</i> .  <i>or</i> Maintain a vertical distance of... <i>(figures and units)</i> below cloud.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QBI	Is flight under IFR compulsory at... <i>(place)</i> [or from...to... <i>(place)</i> ]?	Flight under IFR is compulsory at ... <i>(place)</i> [or from... to ... <i>(place)</i> ].
QBJ	What is the amount, type, and height above... <i>(datum)</i> of the top of the cloud [at... <i>(position or zone)</i> ]?	At...hours at... <i>(position or zone)</i> the top of the cloud is: amount...eighths (... <i>type</i> ) at ... <i>(figures and units)</i> height above... <i>(datum)</i> .
QBK	Are you flying with no cloud in your vicinity?	I am flying with no cloud in my vicinity and at... <i>(figures and units)</i> height above... <i>(datum)</i> .
QBM	Has ...sent any message for me?	Here is the message sent by...at...hours.
QBN	Are you flying between two layers of cloud?	I am flying between two layers of cloud and at... <i>(figures and units)</i> height above... <i>(datum)</i> .
QBO	What is the nearest airdrome at which flight under VFR is permissible and which would be suitable for my landing?	Flying under VFR is permissible at ... <i>(place)</i> which would be suitable for your landing.
QBP	Are you flying in and out of cloud?	I am flying in and out of cloud and at ... <i>(figures and units)</i> height above ... <i>(datum)</i> .
QBS		Ascend (or descend) to... <i>(figures and units)</i> height above... <i>(datum)</i> before encountering IFR weather conditions or if visibility falls below ... <i>(figures and units of distance)</i> and advise.
QBT	How far, along the runway, from the approach end, can the observer at the runway threshold see the runway lights which will be in operation for my landing [at... <i>(place)</i> ]?	At...hours, the observer at the threshold of runway number... could see the runway lights in operation for your landing [at ... <i>(place)</i> ] for a distance of... <i>(figures and units)</i> from the approach end. <i>(Note: If the station enquired of is not equipped to make the special observation requested, the reply to QBT IMI is given by the signal QNO.)</i>

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QBV	Have you reached the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )]?	I have reached the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )]. or Report reaching the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )].
QBX	Have you left the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )]?	I have left the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )]. or Report leaving the... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) [or... ( <i>area or place</i> )].
QBZ	Report your flying conditions in relation to clouds.	<i>The reply to QBZ <math>\overline{\text{IMI}}</math> is given by the appropriate answer form of signals QBF, QBG, QBH, QBK, QBN, and QBP.</i>
QCA	May I change from... ( <i>figures and units</i> ) to... ( <i>figures and units</i> ) height above... ( <i>datum</i> )?	You may change from... ( <i>figures and units</i> ) to... ( <i>figures and units</i> ) height above... ( <i>datum</i> ). or I am changing from... ( <i>figures and units</i> ) to... ( <i>figures and units</i> ) height above... ( <i>datum</i> ).
QCB		Delay is being caused by... 1. your transmitting out of turn. 2. your slowness in answering. 3. lack of your reply to my...
QCE	When may I expect approach clearance?	Expect approach clearance at... hours. or No delay expected.
QCF		Delay indefinite. Expect approach clearance not later than... hours.
QCH	May I taxi to... ( <i>place</i> )?	Cleared to taxi to... ( <i>place</i> ). [ <i>The place is given in plain language.</i> ]

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QCI		Make a 360-deg turn immediately (turning to the...).
		<i>or</i>
		I am making a 360-deg turn immediately (turning to the...).
QCS		My reception on...frequency has broken down.
QCX	What is your full call sign?	My full call sign is...
		<i>or</i>
		Use your full call sign until further notice.
QCY		I am working on trailing aerial.
		<i>or</i>
		Work on trailing aerial.
QDB	Have you sent message...to...?	I have sent message...to...
QDF	What is your D-Value at...(position)?	My D-Value at...(position) at...(figures and units) height above the 1013.2 millibars datum is...(D-Value figures and units)...(specify plus or minus).
		<i>or</i>
	What is the D-Value at...(place or position) (at...hours) for the...millibar level?	The D-Value at...(place or position) at...hours for the...millibar level is...(D-Value figures and units)...(specify plus or minus).
QDL	Do you intend to ask me for a series of bearings?	I intend to ask you for a series of bearings.
QDP	Will you accept control (or responsibility) of (for)...now (or at...hours)?	I will accept control (or responsibility) of (for)...now (or at...hours).
QDT	Are you flying in VFR weather conditions?	I am flying in VFR weather conditions.
		<i>or</i>
		Fly at all times in VFR weather conditions.
QDV	Are you flying in a horizontal visibility of less than...(figures and units)?	I am flying in a horizontal visibility of less than...(figures and units) at...(figures and units) height above...(datum).

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QEA	May I cross the runway ahead of me?	You may cross the runway ahead of you.
QEB	May I turn at the intersection?	Taxias follows at the intersection . . . straight ahead . . . DRT turn left . . . . . LEFT turn right . . . . . RITE
QEC	May I make a 180-deg turn and return down the runway?	You may make a 180-deg turn and return down the runway.
QED	Shall I follow the pilot vehicle?	Follow the pilot vehicle.
QEF	Have I reached my parking area?  <i>or</i> Have you reached your parking area?	You have reached your parking area.  <i>or</i> I have reached my parking area.
QEG	May I leave the parking area?  <i>or</i> Have you left the parking area?	You may leave the parking area.  <i>or</i> I have left the parking area.
QEH	May I move to the holding position for runway number . . . ?  <i>or</i> Have you moved to the holding position for runway number . . . ?	Cleared to the holding position for runway number . . .  <i>or</i> I have moved to the holding position for runway number . . .
QEJ	May I assume position for take-off?  <i>or</i> Have you assumed position for take-off?	Cleared to hold at take-off position for runway number . . .  <i>or</i> I am assuming take-off position for runway number . . . and am holding.
QEK	Are you ready for immediate take-off?	I am ready for immediate take-off.
QEL	May I take-off (and make a . . . hand turn after take-off)?	You are cleared to take-off (turn as follows after take-off . . .).
QEM	What is the condition of the landing surface at . . . ( <i>place</i> )?	The condition of the landing surface at . . . ( <i>place</i> ) is . . .

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QEN	Shall I hold my position?	Hold your position.
QEO	Shall I clear the runway ( <i>or</i> landing area)? <i>or</i> Have you cleared the runway ( <i>or</i> landing area)?	Clear the runway ( <i>or</i> landing area). <i>or</i> I have cleared the runway ( <i>or</i> landing area).
QES	Is a right-hand circuit in force at . . . ( <i>place</i> )?	A right-hand circuit is in force at . . . ( <i>place</i> ).
QFA	What is the meteorological forecast for . . . ( <i>flight, route, section of route, or zone</i> ) for the period . . . hours until . . . hours?	The meteorological forecast for . . . ( <i>flight, route, section of route, or zone</i> ) for the period . . . hours until . . . hours is . . .
QFB		The . . . 1. approach 2. runway 3. approach and runway lights are out of order.
QFC	What is the amount, the type and the height above . . . ( <i>datum</i> ) of the base of the cloud at . . . ( <i>place, position, or zone</i> )?	At . . . ( <i>place, position, or zone</i> ) the base of the cloud is . . . eighths . . . type at . . . ( <i>figures and units</i> ) height above . . . ( <i>datum</i> ).
QFD	1. Is the . . . visual beacon [at . . . ( <i>place</i> )] in operation? 2. Will you switch on the . . . visual beacon [at . . . ( <i>place</i> )]? 3. Will you extinguish the airdrome visual beacon [at . . . ( <i>place</i> )] until I have landed?	1. The . . . visual beacon [at . . . ( <i>place</i> )] is in operation. 2. I will extinguish the airdrome visual beacon [at . . . ( <i>place</i> )] until your landing is completed.
QFE	[At . . . ( <i>place</i> )] what is the present atmospheric pressure at official airdrome elevation?	At . . . ( <i>place</i> ) the atmospheric pressure at official airdrome elevation is ( <i>or</i> was observed at . . . hours to be) . . . tenths of millibars.
QFF	[At . . . ( <i>place</i> )] what is the present atmospheric pressure converted to mean sea level in accordance with meteorological practice?	At . . . ( <i>place</i> ) the atmospheric pressure converted to mean sea level in accordance with meteorological practice is ( <i>or</i> was determined at . . . hours to be) . . . tenths of millibars.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QFG	Am I over the airdrome?	You are over the airdrome.
QFH	May I descend below the clouds?	You may descend below the clouds.
QFI	Are the airdrome lights lit?	The airdrome lights are lit. <i>or</i> Please light the airdrome lights.
QFL	Will you send up pyrotechnical lights?	I will send up pyrotechnical lights.
QFM	What height above... ( <i>datum</i> )... 1. should I maintain?  2. are you maintaining?  3. do you intend cruising at?	1. Maintain ( <i>or fly at</i> )... ( <i>figures and units</i> ) height above... ( <i>datum</i> ). 2. I am maintaining... ( <i>figures and units</i> ) height above... ( <i>datum</i> ). 3. I intend cruising at... ( <i>figures and units</i> ) height above... ( <i>datum</i> ).
QFO	May I land immediately?	You may land immediately.
QFP	Will you give me the latest information concerning... facility [at... ( <i>place</i> )]?	The latest information concerning... facility [at... ( <i>place</i> )] is as follows...
QFQ	Are the approach and runway lights lit?	The approach and runway lights are lit. <i>or</i> Please light the approach and runway lights.
QFR	Does my landing gear appear damaged?	Your landing gear appears damaged.
QFS	Is the... radio facility at... ( <i>place</i> ) in operation?	The... radio facility at... ( <i>place</i> ) is in operation ( <i>or will be in operation in... hours</i> ). <i>or</i> Please have the... radio facility at... ( <i>place</i> ) put in operation.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QFT	Between what heights above... ( <i>datum</i> ) has ice formation been observed [at...( <i>position or zone</i> )]?	Ice formation has been observed at ...( <i>position or zone</i> ) in the type of ...and with an accretion rate of... between...( <i>figures and units</i> ) and ...( <i>figures and units</i> ) heights above...( <i>datum</i> ).
QFU	What is the magnetic direction ( <i>or</i> number) of the runway to be used?	The magnetic direction ( <i>or</i> number) of the runway to be used is...
QFV	Are the floodlights switched on?	The floodlights are switched on. <i>or</i> Please switch on the floodlights.
QFW	What is the length of the runway in use in...( <i>units</i> )?	The length of runway...now in use is...( <i>figures and units</i> ).
QFX		I am working ( <i>or</i> am going to work) on a fixed aerial. <i>or</i> Work on a fixed aerial.
QFY	Please report the present meteorological landing conditions [at... ( <i>place</i> )].	The present meteorological landing conditions at...( <i>place</i> ) are...
QFZ	What is the airdrome meteorological forecast for...( <i>place</i> ) for the period ...hours until...hours?	The airdrome meteorological forecast for...( <i>place</i> ) for the period... hours until...hours is...
QGC		There are obstructions to the...of runway...
QGD	Are there on my track any obstructions whose elevation equals or exceeds my altitude?	There are obstructions on your track ...( <i>figures and units</i> ) height above ...( <i>datum</i> ).
QGE	What is my distance to your station ( <i>or</i> to...)?	Your distance to my station ( <i>or</i> to ...) is...( <i>distance figures and</i> <i>units</i> ).
QGH	May I land using...( <i>procedure or</i> <i>facility</i> )?	You may land using...( <i>procedure or</i> <i>facility</i> ).

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
Q GK	What track should I make good? <i>or</i> What track are you making good?	Make good a track from... ( <i>place</i> ) on... degrees... ( <i>true or magnetic</i> ). <i>or</i> I am making good a track from... ( <i>place on... degrees... (true or mag-</i> <i>netic)</i> ).
Q GL	May I enter the... ( <i>control area or zone</i> ) at... ( <i>place</i> )?	You may enter the... ( <i>control area or zone</i> ) at... ( <i>place</i> ).
Q GM		Leave the... ( <i>control area or zone</i> ).
Q GN	May I be cleared to land [at... ( <i>place</i> )]?	You are cleared to land [at... ( <i>place</i> )].
Q GO		Landing is prohibited at... ( <i>place</i> ).
Q GP	What is my number for landing?	You are number... to land.
Q GQ	May I hold at... ( <i>place</i> )?	Hold at... ( <i>place</i> ) at... ( <i>figures and units</i> ) height above... ( <i>datum</i> ) and await orders.
Q GT		Fly for... minutes on a heading that will enable you to maintain a track reciprocal to your present one.
Q GU		Fly for... minutes on a magnetic heading of... degrees.
Q GV	Do you see me? <i>or</i> Can you see the airdrome?	I see you at... ( <i>cardinal or quadrantal point of direction</i> ). <i>or</i> I can see the airdrome.
Q GW	Does my landing gear appear to be down and in place?	Your landing gear appears to be down and in place.
Q GZ		Hold on... direction of... facility
Q HE	Will you inform me when you are on... leg of approach?	I am on... 1. crosswind leg 2. downwind leg 3. base leg 4. final leg } of approach.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QHG	May I enter traffic circuit at... (figures and units) height above... (datum)?	Cleared to enter traffic circuit at... (figures and units) height above... (datum).
QHH	Are you making an emergency landing?	I am making an emergency landing.  <i>or</i> Emergency landing being made at... (place). All aircraft below... (figures and units) height above... (datum) and within a distance of... (figures and units) leave... (place or headings).
QHI	Are you (or is...) 1. waterborne? 2. on land?	I am (or...is) 1. waterborne } at...hours 2. on land }
QHQ	May I make a...approach [at... (place)]?  <i>or</i> Are you making a...approach?	You may make a...approach [at... (place)]  <i>or</i> I am making a...approach
QHZ	Shall I circle the airdrome (or go around)?	Circle the airdrome (or go around)
QIC	May I establish communication with...radio station on...kc (or ...mc) now (or at...hours)?	Establish communication with... radio station on...kc (or...mc) now (or at...hours)  <i>or</i> I will establish communication with ...radio station on...kc (or... mc) now (or at...hours)
QIF	What frequency is...using?	...is using...kc (or...mc)
QJA	Is my... 1. tape 2. mark and space } reversed?	Your... 1. tape 2. mark and space } is reversed
QJB	Will you use... 1. radio? 2. cable? 3. telegraph? 4. teletypewriter? 5. telephone? 6. receiver? 7. transmitter? 8. reperforator?	I will use... 1. radio. 2. cable. 3. telegraph. 4. teletypewriter. 5. telephone. 6. receiver. 7. transmitter. 8. reperforator.

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QJC	Will you check your . . . 1. Transmitter distributor? 2. auto-head? 3. perforator? 4. reperforator? 5. printer? 6. printer motor? 7. keyboard? 8. antenna system?	I will check my . . . 1. transmitter distributor. 2. auto-head. 3. perforator. 4. reperforator. 5. printer. 6. printer motor. 7. keyboard. 8. antenna system.
QJD	Am I transmitting . . . 1. in letters? 2. in figures?	You are transmitting . . . 1. in letters. 2. in figures.
QJE	Is my frequency shift . . . 1. too wide? 2. too narrow? 3. correct?	Your frequency shift is . . . 1. too wide. 2. too narrow (by . . . cycles). 3. correct.
QJF		My signal as checked by monitor . . . is satisfactory . . . 1. locally. 2. as radiated.
QJG	Shall I revert to automatic relay?	Revert to automatic relay.
QJH	Shall I run . . . 1. my test tape? 2. a test sentence?	Run . . . 1. your test tape. 2. a test sentence.
QJI	Will you transmit a continuous . . . 1. mark? 2. space?	I am transmitting a continuous . . . 1. mark. 2. space.
QJK	Are you receiving . . . 1. a continuous mark? 2. a continuous space? 3. a mark bias? 4. a space bias?	I am receiving . . . 1. a continuous mark. 2. a continuous space. 3. a mark bias. 4. a space bias.
QKA		I have effected rescue and am proceeding to . . . base [with . . . persons injured requiring ambulance].

## ICAO Q CODE (Continued)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QKC		The sea conditions (at...position) ... 1. permit alighting but not take-off. 2. render alighting extremely hazardous.
QKN		Aircraft plotted (believed to be you) in position...on track...degrees at .hours.
QLB	Will you monitor...station and report regarding range, quality, etc.?	I have monitored...station and report ( <i>briefly</i> ) as follows...
QLH	Will you use simultaneous keying on...frequency and...frequency?	I will key simultaneously on...frequency and...frequency.
QLV	Is the...radio facility still required?	The...radio facility is still required.
QMH		Shift to transmit and receive on...kc ( <i>or</i> ...mc); if communication is not established within 5 min, revert to present frequency.
QMI	Report the vertical distribution of cloud [at...(position or zone)] as observed from your aircraft.	The vertical distribution of cloud as observed from my aircraft at...hours at...(position or zone) is: lowest layer observed*...eighths (...type) with base of...(figures and units) and tops of...(figures and units) [* and similarly in sequence for each of the layers observed.]
QMU	What is the surface temperature at...(place) and what is the dew-point temperature at that place?	The surface temperature at...(place) at...hours is...degrees and the dew-point temperature at that time and place is...degrees.
QMW	At...(position or zone) what is (are) the height(s) above...(datum) of the zero centigrade isotherm(s)?	At...(position or zone) the zero centigrade isotherm(s) is (are) at...(figures and units) height(s) above...(datum).
QMX	What is the air temperature [at...(position or zone)] (at...hours) at the...(figures and units) height above...(datum)?	At...(position or zone) at...hours the air temperature is...(degrees and units) at...(figures and units) height above...(datum).

## ICAO Q CODE (Concluded)

<i>Signal</i>	<i>Question</i>	<i>Answer, Information, or Advice</i>
QMZ	Have you any amendments to the flight forecast in respect of section of route yet to be traversed?	The following amendment(s) should be made to the flight forecast . . .  [If no amendments, signal QMZ NIL.]
QNE	What indication will my altimeter give on landing at . . . (place) at . . . hours, my subscale being set to 1013.2 millibars (29.92 in.)?	On landing at . . . (place) at . . . hours, with your subscale being set to 1013.2 millibars (29.92 in.), your altimeter will indicate . . . (figures and units).
QNH	What should I set on the subscale of my altimeter so that the instrument would indicate my elevation if I were on the ground at your station?	If you set the subscale of your altimeter to read . . . tenths of millibars (or hundredths of an inch), the instrument would indicate your elevation if you were on the ground at my station at . . . hours.
QNI	Between what heights above . . . (datum) has turbulence been observed at . . . (position or zone)?	Turbulence has been observed at . . . (position or zone) with an intensity of . . . between . . . (figures and units) and . . . (figures and units) heights above . . . (datum).
QNO		I am not equipped to give the information (or provide the facility) requested.
QNR		I am approaching my point of no return.
QNT	What is the maximum gust speed of the surface wind at . . . (place)?	The maximum gust speed of the surface wind at . . . (place) at . . . hours is . . . (speed figures and units).
QNY	What is the present weather and the intensity thereof at . . . (place, position, or zone)?	The present weather and intensity thereof at . . . (place, position, or zone) at . . . hours is . . . (duststorm, sandstorm, rain, snow, hail, thunderstorm, etc.).

## Miscellaneous Abbreviations (Aeronautical)

<i>Abbr- viation</i>	<i>Meaning</i>	<i>Abbr- viation</i>	<i>Meaning</i>
AC	Alto cumulus.	DCT	Direct ( <i>in relation to flight plan clearances and type of approach</i> ).
ACC	Area control.	DES	I am descending [to... ( <i>figures and units</i> ) height above... ( <i>datum</i> )].
AD	Airdrome.	DRT	Keep straight ahead.
ADZ	Advise.	DU	Position not guaranteed.
AERO	Aero form of the International Code.	E	East or Eastern longitude.
AGN	Again.	ERB	Landing off a runway is permitted.
AIR	Relative to air.	ETD	Estimated time of departure.
ANT	Before.	ETI	The information is estimated.
APP	Approach control.	FAH	Degrees Fahrenheit.
APR	After... ( <i>time or place</i> ).	FBL	Light ( <i>used to qualify icing, turbulence, interference, or static reports</i> ).
ARFOT	Area forecast in units of English system.	FC	Flight control.
ARMET	Area forecast in units of metric system.	FIR	Flight information region.
ARR	Arrive ( <i>or arrival</i> ).	FLT	Flight.
AS	Altostratus.	FNA	Final approach.
ASC	I am ascending [to... ( <i>figures and units</i> ) height above... ( <i>datum</i> )].	FOT	Units of English system.
ATC	Air traffic control ( <i>in general</i> ).	FRCU	Fractocumulus.
ATP	At... ( <i>time or place</i> ).	FS	Fractostratus.
AWY	Airway.	FSL	Full stop landing.
BABS	Beam approach beacon system.	FT	Feet ( <i>dimensional unit</i> ).
BCST	Broadcast.	GCA	Ground controlled approach system.
BOH	Break-off height.	GEO	Geographic or true.
BRF	Short ( <i>used to indicate the type of approach desired or required</i> ).	GMT	Greenwich mean time.
BTN	Between.	GND	Relative to ground.
CB	Cumulonimbus.	HEL	Helicopter.
CC	Cirrocumulus.	HF	High frequency [3,000-30,000 kc].
CEN	Degrees centigrade.	HR	Hours ( <i>period of time</i> ).
CI	Cirrus.	IAR	Intersection of air routes.
CLA	Clear type of ice formation.	ID	Identification.
CLR	Cleared to...	IFR	Instrument flight rules.
CS	Cirrostratus.	ILS	Instrument landing system.
CTA	Control area.		
CTR	Control zone.		
CU	Cumulus.		

## Miscellaneous Abbreviations (Aeronautical) (Continued)

<i>Abbreviation</i>	<i>Meaning</i>	<i>Abbreviation</i>	<i>Meaning</i>
IMI	Interrogation sign (question mark) [ <i>· — — ·</i> ].	ML	Statute mile(s).
IMT	Immediately.	MNTN	Maintain.
INA	Initial approach.	MOD	Moderate ( <i>used to qualify icing, turbulence, interference or static reports</i> ).
INF	Below . . .	MPH	Statute miles per hour.
INP	If not possible.	MRG	Medium range.
INS	Inches ( <i>dimensional unit</i> ).	MS	Minus.
IR	Ice on runway.	MSL	The indication of vertical distance is given as the reading, without correction for ambient temperature, of a pressure altimeter set to QNH.
IRL	Intersection of range legs.	MTU	Metric units.
IVB	If forward visibility is less than . . . ( <i>figures and units</i> ).	MX	Mixed type of ice formation ( <i>white and clear</i> ).
IVR	If forward flight visibility remains . . . ( <i>figures and units</i> ).	N	North latitude. ( <i>To be used only with figures indicating latitude, e.g. 4730N.</i> ) <i>Aeronautical note: In the maritime mobile service, the abbreviation N signifies No and is used in that service to give a negative sense to Q signals.</i>
KC	Kilocycles per second.	NDB	Nondirectional radiobeacon.
KG	Kilograms.	NE	North-East.
KM	Kilometers.	NM	Nautical mile(s).
KMH	Kilometers per hour.	NML	Normal.
KT	Knots.	NO	No.
LB	Pounds ( <i>weight</i> ).	NORTH	North ( <i>cardinal point of direction</i> ).
LEFT	Left ( <i>direction of turn</i> ).	NR	Number.
LF	Low frequency [30–300 kc].	NS	Nimbostratus.
LNG	Long ( <i>used to indicate type of approach desired or required</i> ).	NW	North-West.
LRG	Long range.	OPA	White type of ice formation.
M	Meters.	OPC	The control indicated is Operational Control.
MAG	Magnetic.	ORD	Indication of an order.
MB	Millibars.	PLA	Practice low approach.
MC	Megacycles per second.		
MER	The indication of vertical distance is given as TRUE height above mean sea level ( <i>e.g. after applying the correction for ambient temperature to the altitude reading of a pressure altimeter set to QNH</i> ).		
MET	Meteorological.		
MF	Medium frequency [300–3000 kc].		
MKR	Marker radio beacon.		

## Miscellaneous Abbreviations (Aeronautical) (Continued)

<i>Abbreviation</i>	<i>Meaning</i>	<i>Abbreviation</i>	<i>Meaning</i>
PP	Descent through cloud ( <i>procedure</i> ).	SOL	The indication of vertical distance is given as the reading, without correction for ambient temperature of a pressure altimeter set to QFE. ( <i>The abbreviation should only be used in the vicinity of the station which provided the QFE setting.</i> )
PRES	The indication of vertical distance is ( <i>or is to be</i> ) replaced by the indication of the pressure, expressed in millibars, at the level and the position of the aircraft.	SRG	Short range.
PREVU	The information refers to forecast and not to present conditions.	ST	Stratus.
PSGR	Passenger(s).	STA	Straight in approach.
PS	Plus.	STD	The indication of vertical distance is given as the reading, without correction for ambient temperature, of a pressure altimeter having the sub scale set to 1013.2 millibars (29.92 in.).
PTN	Procedure turn.		
QUAD	Quadrant.		
RAD	The control referred to is Radio Control.	SUP	Above . . .
RCA	Reach cruising altitude.	SW	South-West.
RDO	Radio.		
REP	Reporting point.	TAFOT	Airdrome forecast in units of English system.
RITE	Right ( <i>direction of turn</i> ).	TAMET	Airdrome forecast in units of metric system.
RNG	Radio range.	TER	The indication of vertical distance is given as TRUE height above official airdrome level ( <i>e.g. after applying the correction for ambient temperature to the vertical distance reading of a pressure altimeter set to QFE</i> ).
RN WY	Runway.		
ROFOT	Route forecast in units of English system.		
ROMET	Route forecast in units of metric system.		
RON	Receiving only.		
RP	Rapid.		
RTT	Radioteletypewriter.		
S	South <i>or</i> southern latitude.	TFZ	Traffic zone.
SAP	As soon as possible.	TGL	Touch and go landing.
SC	Stratocumulus.	TIL	Until.
SE	South-East.	TIP	Until past . . . ( <i>place</i> ).
SEV	Severe.	TO	To . . . ( <i>place</i> ).
SIA	Standard instrument approach.	TRB	It is not necessary to keep to the runways and taxiways after landing.
SID	Standard instrument departure.	TT	Teletypewriter.
SKED	Schedule.	TWR	Airdrome control.
SLW	Slow.		

## Miscellaneous Abbreviations (Aeronautical) (Continued)

<i>Abbreviation</i>	<i>Meaning</i>	<i>Abbreviation</i>	<i>Meaning</i>
UAB	Until advised by . . .	VOR	VHF omnidirectional radio range.
UFN	Until further notice.	VSA	By visual reference to the ground.
VAN	Runway control van.	W	West or western longitude.
VIA	By way of . . .	WX	Weather.
VIO	Heavy ( <i>used to qualify icing, turbulence, interference or static reports</i> ).	XS	Atmospherics.
VFR	Visual flight rules.	YD	Yards.
VHF	Very high frequency [30,000 kc to 300 mc].	YR	Your.
VLR	Very long range.		

Procedure and Operating Signals Employed in the Aeronautical Telecommunications Service  
(in Addition to Miscellaneous Abbreviations and Signals, page 496)

<i>Abbreviation of Signal</i>	<i>Definition</i>
AL	Repeat all that has just been sent.
<u>BT</u>	Separative sign (— . . . —).
CMN	Circuit message number.
COR	Correction.
CTF	I am referring to the originator ( <i>or . . . station</i> ) to answer your query [ <i>or the following groups have been referred back to the originator for confirmation or correction</i> ].
DTG	Date-time group.
DUPE	This is a duplicate message.
GA	Resume sending. ( <i>To be used especially in the fixed service.</i> )
LR	The last message received by me was . . .
LS	The last message sent by me was . . . ( <i>or last message was . . .</i> ).
MC . . . (number)	Multiple copy for delivery to . . . addresses.
MIS	Missing . . . ( <i>circuit message number</i> ).
MSR	The following message has been misrouted. I am forwarding it to you for delivery or relay.
POUR	Station . . . replaces station . . .
RT	Relay message to . . . addresses.
VVV	Marking or test transmission.

### NOTAM CODE

The NOTAM code is provided to enable information regarding radio aids, airdromes and lighting facilities, dangers to aircraft in flight or landing, or action regarding search and rescue, to be coded. The coding facilitates the transmission of NOTAMs over telecommunications channels. Plain language shall be used in the composition of a notice to airmen in cases where the NOTAM code cannot convey the meaning.

All NOTAM Code groups shall contain a total of five (5) letters.

*The first letter* of the code group will always be the letter Q to indicate that it is a code abbreviation for use in the composition of NOTAMs. The letter Q has been chosen to avoid conflict with any assigned radio call or other code abbreviations. Five letter groups have been chosen to avoid confusion with three and four letter Q signal abbreviations.

*Second and third letters:* The appropriate combination of two letters selected from the "Second and Third Letters" section of the Code to identify the facility, service or danger to aircraft in flight being reported upon. It should be noted that the second letter has been restricted to A, E, I, O, or U.

*Fourth and fifth letters:* The appropriate combination of two letters selected from the "Fourth and Fifth Letters" section of the Code to denote the status of operation of the facility, service or danger to aircraft in flight reported upon. It should be noted that the fourth letter has been restricted to A, E, I, O, or U.

The first five (5) letter NOTAM Code group in any NOTAM text shall in all cases be immediately preceded by the full name of the location of the particular facility, service, or danger to aircraft in flight being reported except that, in cases where an ICAO place-name abbreviation has been assigned, this shall be used to identify the geographical location.

## NOTAM CODE

## Second and Third Letters

*Radio Aids*

<i>Second and Third Letters</i>	<i>Meaning</i>	<i>Second and Third Letters</i>	<i>Meaning</i>
AA	...air traffic control receiver ...kc (or...mc) [specify TWR, APP, ATC or OAC].	AS	Radio range leg.
AB	Inner marker, Instrument Landing System.	AT	Attention signal.
AC	...air traffic control transmitter...kc (or...mc) [specify TWR, APP, ATC or OAC].	AU	Meteorological communications...kc (or...mc).
AD	Middle marker, Instrument Landing System.	AV	Voice communications...kc (or...mc).
AE	Outer marker, Instrument Landing System.	AW	
AF	Fan-type marker.	AX	Radio beacon homing and voice facility.
AG	Glide path, Instrument Landing System.	AY	200 mc Distance Measuring Equipment (DME).
AH	Radio beacon homing facility.	AZ	Station location marker VHF.
AI	Instrument Landing System (ILS).	EA	
AJ	Radio range and associated voice communications [...kc* (or...mc)].	EB	
AK	Radio receiving facilities.	EC	Consol station (...position).
AL	Localizer, Instrument Landing System.	ED	Decca.
AM	Compass locator, inner, Instrument Landing System.	EE	Ground Controlled Approach System (GCA).
AN		EF	Airdrome Control Radar System (ACR).
AO	Compass locator, outer, Instrument Landing System.	EG	Gee.
AP		EH	HF DF.
AQ		EI	Automatic radio range track monitoring device.
AR	Radio range [...kc* (or...mc)].	EJ	All air-ground facilities (except ...).
		EK	Precision Approach Radar (PAR).
		EL	Loran
		EM	MF DF.
		EN	1,000 mc. Distance Measuring Equipment (DME).
		EO	Beam Approach Beacon System (BABS).

\* For use when reporting locations at which both MF and VOR installations are located—in these instances the appropriate frequency is given to avoid confusion.

## NOTAM CODE (Continued)

## Second and Third Letters

*Radio Aids*

<i>Second and Third Letters</i>	<i>Meaning</i>	<i>Second and Third Letters</i>	<i>Meaning</i>
EP	Surveillance Approach Radar. Transmitting facility(ies) . . . ke (or . . .mc).	EU	VHF DF. SBA system. SBA system, localizer. SBA system, inner marker. SBA system, outer marker.
EQ		EV	
ER		EW	
ES	All radio-navigation facilities (except . . .).	EX	
ET	Teletypewriter transmitting facility(ies).	EY	
		EZ	

*Lighting Facilities*

<i>Second and Third Letters</i>	<i>Meaning</i>	<i>Second and Third Letters</i>	<i>Meaning</i>
IA	Boundary lights.	IN	Approach lights with descent path indication.
IB		IO	
IC	Channel lights.	IP	Obstruction lights. Approach lights (for runway number . . .). Runway lights (for runway number . . .). Strip lights.
ID		IQ	
IE		IR	
IF		IS	
IG		IT	
IH		IU	
II		IV	
IJ		IW	
IK		IX	
IL		IY	
IM	All landing area lighting facilities.	IZ	Airway course lights.

## NOTAM CODE (Continued)

## Second and Third Letters

*Airdromes: Search and Rescue: Dangers to Aircraft in Flight*

<i>Second and Third Letters</i>	<i>Meaning</i>	<i>Second and Third Letters</i>	<i>Meaning</i>
OA	Land airdrome.	OY	
OB	Beaching facilities.	OZ	Warship.
OC	Water airdrome.	UA	
OD	Meteorological forecast service.	UB	Mooring buoys.
OE	Meteorological observation service.	UC	
OF		UD	
OG		UE	Aircraft.
OH		UF	Fixed balloons.
OI		UG	Bombing.
OJ		UH	Air exercises.
OK		UI	Gun firing.
OL		UJ	Glider flying.
OM	All runways [except number(s) ...].	UK	Demolition of explosives.
ON		UL	Landing direction indicator.
OO	Taxiway(s).	UM	Mooring and docking facilities.
OP	Rescue vessel.	UN	
OQ	Ocean Station Vessel.	UO	
OR	Refueling facilities.	UP	
OS	Search and rescue aircraft [specify VLR, LRG, MRG, SRG, or HEL].	UQ	Apron.
OT		UR	Runway(s) number(s) . . .
OU		US	
OV		UT	Grass landing area.
OW		UU	
OX		UV	Fog dispersal equipment.
		UW	
		UX	
		UY	
		UZ	

## NOTAM CODE (Continued)

## Fourth and Fifth Letters

*Hazard or Status of Operation*

<i>Fourth and Fifth Letters</i>	<i>Meaning</i>	<i>Fourth and Fifth Letters</i>	<i>Meaning</i>
AA	Usable for length of...and width of...	EB	Location change to...effective... <i>(date/time)</i> .
AB		EC	Characteristics or identification or radio call sign changed to...
AC		ED	Operating frequency(ies) will be changed to...kc (or...mc) effective... <i>(date/time)</i> .
AD		EE	Not heard.
AE		EF	
AF		EG	
AG		EH	
AH		EI	
AI		EJ	
AJ		EK	
AK	EL		
AL	EM		
AM	EN	Completely withdrawn.	
AN	EO	Military operations only.	
AO	EP	Available on prior permission only.	
AP	EQ		
AQ	ER		
AR	ES		
AS	ET		
AT	EU		
AU	EV		
AV	EW		
AW	EX		
AX	EY		
AY	EZ	Report of apparent unreliability or track displacement hereby is cancelled.	
AZ	IA		
	IB		
	IC	Available on request to...	
EA	ID		
	IE		

## NOTAM CODE (Continued)

## Fourth and Fifth Letters

*Hazard or Status of Operation*

<i>Fourth and Fifth Letters</i>	<i>Meaning</i>	<i>Fourth and Fifth Letters</i>	<i>Meaning</i>
IF	Flight checked and found reliable.	OC	Resumed operation—ground checked only, awaiting flight check.
IG		OD	
IH		OE	
II		OF	
IJ		OG	
IK	Available on request immediately [or at . . . minutes notice]	OH	
IL	Hours of service are now . . .	OI	
IM	Ground checked only, awaiting flight check.	OJ	
IN	Operative or reoperative from . . .	OK	
IO	Operating normally.	OL	
IP	Track(s) reported to be displaced (. . . degrees) (. . . direction) of published bearing(s), other tracks probably have shifted.	OM	Resumed normal operation. Track(s) ground checked, approved for instrument flying. Shut down for maintenance from . . . (date/time) for an unknown duration [or until . . . (date/time)]—disregard all signals.
IQ	To be used as radio beacon only.	ON	
IR	Magnetic track(s) towards station is (are) now . . . [will be . . . at . . . (date/time)].	OO	
IS		OP	
IT	Aircraft restricted to runways and taxiways.	OQ	
IU	Unserviceable for aircraft heavier than . . . tons.	OR	
IV	Unsafe from . . . (date/time) for an unknown duration [or until . . . (date/time)].	OS	
IW		OT	
IX		OU	
IY		OV	
IZ		OW	
OA		OX	Exercising at . . . (date/time, location and height above the specified datum).
OB		OY	

## NOTAM CODE (Concluded)

## Fourth and Fifth Letters

*Hazard or Status of Operation*

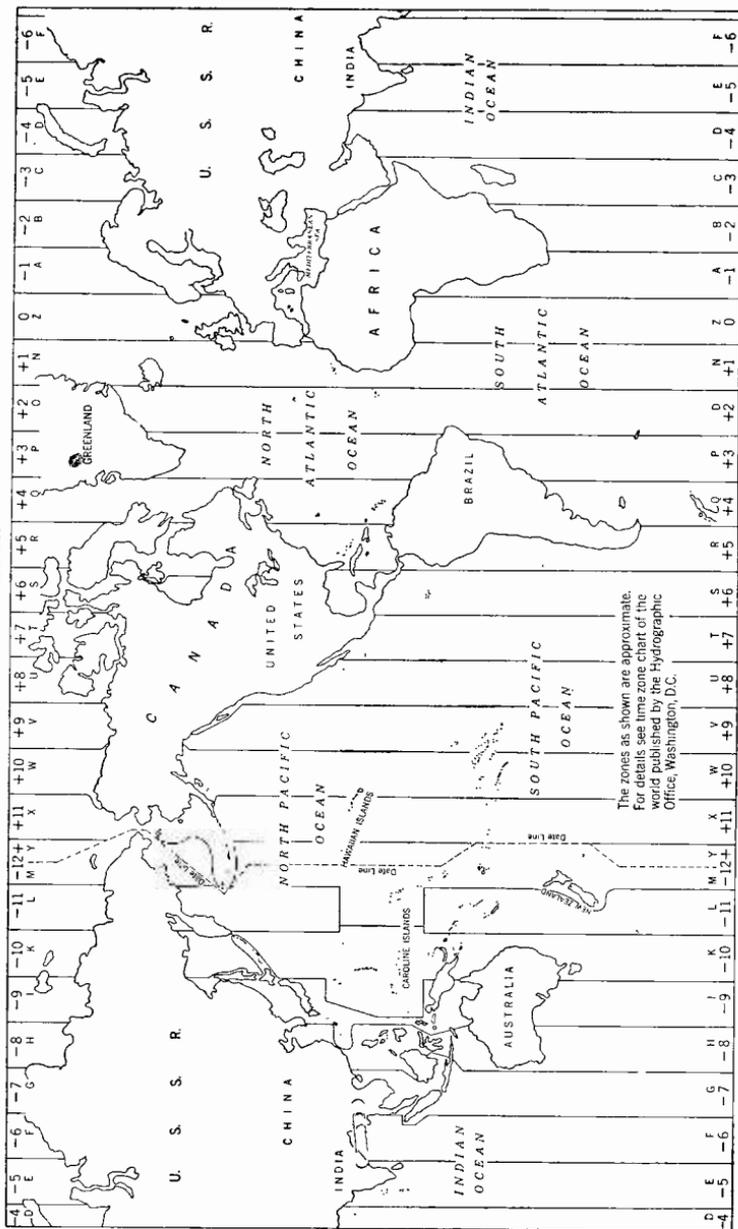
<i>Fourth and Fifth Letters</i>	<i>Meaning</i>	<i>Fourth and Fifth Letters</i>	<i>Meaning</i>
OZ		UJ	
UA	Closed to all operations from ... <i>(date/time)</i> for an unknown duration [or until ... <i>(date/time)</i> ].	UK	
UB		UL	
UC		UM	
UD	Closed to all night operations from ... <i>(date/time)</i> for an unknown duration [or until ... <i>(date/time)</i> ].	UN	Operative but caution advised due to flood.
UE		UO	Operative but caution advised due to ice or snow.
UF	Closed for an unknown duration due to flood.	UP	Operative but caution advised due to thaw.
UG	Closed for an unknown duration [or until ... <i>(date/time)</i> ] due to ice or snow.	UQ	Operative but caution advised due to repairs or construction.
UH	Closed for an unknown duration (or until ... <i>(date/time)</i> ) due to thaw.	UR	Operative but caution advised due to obstruction.
UI	Closed from ... <i>(date/time)</i> for an unknown duration [or until ... <i>(date/time)</i> ] for maintenance.	US	Operative but caution advised due to rough water.
		UT	Operative but caution advised due to special conditions.
		UU	
		UV	
		UW	
		UX	
		UY	
		UZ	

## Emission and Modulation Symbols

<i>Type of Modulation or Emission</i>	<i>Type of Transmission</i>	<i>Sym- bol</i>
Amplitude.	Absence of any modulation.	A0
	Radiotelegraphy without the use of modulating audio frequency (on-off keying).	A1
	Radiotelegraphy by the keying of a modulating audio frequency or audio frequencies or by the keying of the modulated emission. (Special case: an unkeyed modulated emission.)	A2
	Radiotelephony:	
	Double sideband, full carrier.	A3
	Single sideband, reduced carrier.	A3a
	Two independent sidebands, reduced carriers.	A3b
	Facsimile.	A4
	Television.	A5
	Composite transmissions and cases not covered by the above.	A9
	Composite transmissions, reduced carrier.	A9c
	Frequency (or phase) modulated.	Absence of any modulation.
Radiotelegraphy without the use of modulating audio frequency (frequency shift keying).		F1
Radiotelegraphy by the keying of a modulating audio frequency or audio frequencies or by the keying of the modulated emission. (Special case: an unkeyed emission modulated by audio frequency.)		F2
Radiotelephony.		F3
Facsimile.		F4
Television.		F5
Composite transmissions and cases not covered by the above.		F9
Pulsed emissions.		Absence of any modulation intended to carry information.
	Radiotelegraphy without the use of modulating audio frequency.	P1
	Radiotelegraphy by the keying of a modulating 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 their 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
	Radiotelephony:	
	Amplitude-modulated pulse.	P3d
	Width-modulated pulse.	P3e
	Phase- (or position-) modulated pulse.	P3f
	Composite transmissions and cases not covered by the above.	P9



TIME ZONE CHART



Naval Radio station NSS, Annapolis, Md., transmits time signals beginning five minutes before each even hour, universal time (same as GCT or GMT) on the following frequencies, in kilocycles: 122, 4,390, 9,425, 12,630, 17,000. Station NPG, Mare Island, Calif., transmits on 115 kc at 0, 3, 8, 15, 17 and 20 hr, universal time and in addition on 9,255 and 12,540 kc at 3, 8 and 15 hrs, universal time. Stations NPM, Pearl Harbor, T.H., and NBA, Balboa, C.Z., also transmit time signals on other frequencies. All times and frequencies listed are subject to change without notice. The time-zone chart shows how to convert to local standard time from universal time.

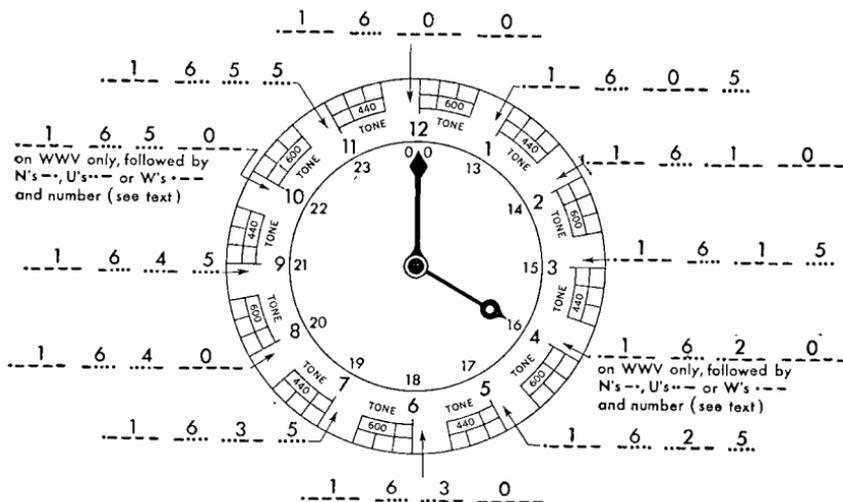
Standard radio and audio frequencies and standard time signals are continuously broadcast from the National Bureau of Standards (NBS) radio stations WWV, near Washington, D.C., and WWVH, near Puunene, T.H. Each second is indicated by a faint tick superimposed upon the other tones. Radio propagation conditions are indicated in International Morse code at 19½ min and 49½ min past each hour from WWV. The letters N, U, and W signify that radio propagation conditions are normal, unsettled, or disturbed for the North Atlantic transmission path. The letter is followed by a digit that forecasts average quality of communications conditions according to the table below. Short-term propagation forecasts for the North Pacific area are broadcast from WWVH on 5, 10, and 15 mc in Morse code at 9 and 39 min past the hour.

<i>Digit (Forecast)</i>	<i>Propagation Condition</i>	<i>Letter (Current)</i>
1	Impossible	W
2	Very poor	W
3	Poor	W
4	Fair to poor	W
5	Fair	U
6	Fair to good	N
7	Good	N
8	Very good	N
9	Excellent	N

The schedule of transmissions is given in the table below. Note that all time is universal time, which is the same as GCT or GMT. Use the time-zone chart to convert to local standard time.

These transmissions are subject to change after adequate notice.

the hour illustrated is 1600 to 1700 in 24-hour universal time (GCT, GMT)



a voice announcement of eastern standard time is given each five minutes from station WWV

no seconds pulse is transmitted at the beginning of the last second of each minute

Carrier Frequency, mc	Station WWV		Station WWVH*	
	Power, kw	Modulation, cps	Power, kw	Modulations, cps
2.5	0.7	1,440 or 600		
5	8.0	1,440 or 600	2.0	1,440 or 600
10	9.0	1,440 or 600	2.0	1,440 or 600
15	9.0	1,400 or 600	2.0	1,440 or 600
20	8.5†	1,440 or 600		
25	0.1	1,440 or 600		

\* The entire broadcast from station WWVH is interrupted for 4 min following each hour and half hour and for periods of 34 min each day beginning at 1900 UT (universal time).

† 2.0 kw for first four workdays after first Sunday of even months.

WWV is off the air for about 4 min each hour. The silent period begins at 45 min, plus or minus 15 sec, after each hour.

### Dominion Observatory Time Signals

Continuous time signals are transmitted on 3330, 7335, and 14670 kc using 1000-cycle modulated continuous wave from radio station CHU at Ottawa, Ontario, Canada. In addition, these signals are sent for the five-minute periods preceding 0300 and 1500 universal time (GCT and GMT) on 115 kc CW from radio station CFH, near Halifax, Nova Scotia, Canada. The coding of the time signals is the same as that for U.S. Naval Observatory time signals with the exception that the Canadian signals employ a long dash to identify only the beginning of the hour (the successive five-minute periods begin with a normal dash); and during the first minute of each hour the Morse code letters CHU CANADA CHU are sent twice. The Dominion Observatory signals are particularly useful for quick check of a timepiece that is known to be in error by not more than a minute or two.

Recently, Dominion Observatory time signals have been given added voice identification that makes it possible to determine within 2 min at most what hour and minute will start after the silent or blank period.

A recorded announcement states, "Dominion Observatory Canada, Eastern Standard Time," and then the appropriate hour and minute, such as "Eleven hours, twenty-seven minutes." On the hour, the announcement "Exactly" is given instead of the number of minutes.

The table below shows how to identify minutes quickly in a time-signal system of the type employed by the U.S. and Canadian Observatories. Signals start on the hour and are repeated in a five-minute sequence. The numbers in the boxes show dashes and blank spaces of seconds signals.

<i>Time of First Dash</i>	<i>(0th Second Start) Dashes</i>	<i>(29th Second) Blank</i>	<i>(30th Second Start) Dashes</i>	<i>Blank</i>	<i>Dashes</i>	<i>Blank</i>
XXX0.0	29	1	21	1	4	4
XXX1.0	29	1	22	1	3	4
XXX2.0	29	1	23	1	2	4
XXX3.0	29	1	24	1	1	4
XXX4.0	29	1	21	9		
XXX5.0	29	1	21	1	4	4

Note that the 29th second is not ever transmitted (blank) and that the upcoming first minute of a five-minute sequence is denoted by an increasing number of dashes, a blank second, and then a decreasing number of dashes. For example, near the end of the number-3 minute (XXX3.55) a single dash shows that the fourth minute is about to start after the four-second silent period. In

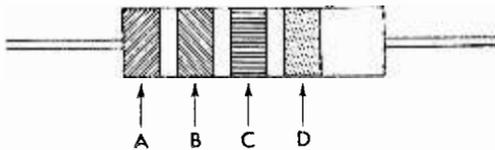
adding dashes and blanks across any horizontal line in the box above, note that the total is always 60. For determining correct time in other five-minute periods, add 5, 10, or 15 and so on to each number in the first column.

Further information on other time-signal systems in use in other parts of the world will be found in Hydrographic Office Publication No. 205, "Radio Navigational Aids," which may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

## RTMA COLOR CODE

### Resistors

It shall be standard in fixed composition resistors with axial leads to indicate the nominal resistance value of the resistors by bands of color of equal width around the body of the resistor, in accordance with the following system:



Three or more bands of color of equal width (except as noted) shall provide indications in accordance with the RTMA color code as follows:

Band A shall indicate the first significant figure of the resistance of the resistor. A band of double width signifies a wire-wound resistor.

Band B shall indicate the second significant figure.

Band C shall indicate the decimal multiplier.

Band D, if any, shall indicate the tolerance limits about the nominal resistance value.

Examples:

	A	B	C	D
10 ohms	Brown (1)	Black (0)	Black (No ciphers)	— ± 20%
220 ohms	Red (2)	Red (2)	Brown (One cipher)	Silver ± 10%
3,000 ohms	Orange (3)	Black (0)	Red (Two ciphers)	— ± 20%
43,000 ohms	Yellow (4)	Orange (3)	Orange (Three ciphers)	Silver ± 10%
43,000 ohms	Yellow (4)	Orange (3)	Orange (Three ciphers)	Gold ± 5%

### *Decimal Multipliers, Tolerances, and Color Code*

It shall be standard to indicate the significant figures of the resistance value, the decimal multiplier and the tolerance in accordance with the modifications and extensions of the standard RTMA color code as given below:

Color	Significant Figure	Decimal Multiplier		Tolerance
		Power of 10	Multiplying Value	
Black.....	0	$10^0$	1	
Brown.....	1	$10^1$	10	
Red.....	2	$10^2$	100	
Orange.....	3	$10^3$	1,000	
Yellow.....	4	$10^4$	10,000	
Green.....	5	$10^5$	100,000	
Blue.....	6	$10^6$	1,000,000	
Violet.....	7	$10^7$	10,000,000	
Gray.....	8	$10^8$	100,000,000	
White.....	9	$10^9$	1,000,000,000	
Gold.....	..	$10^{-1}$	0.1	± 5%
Silver.....	..	$10^{-2}$	0.01	± 10%
No color.....	..	....	.....	± 20%

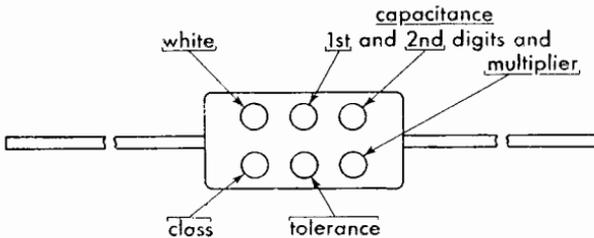
*Body Colors*

1. *Insulated Resistors.* The exterior body color of insulated resistors shall be any color other than black. (Natural tan is the preferred color.)

2. *Uninsulated Resistors.* The exterior body color of uninsulated resistors shall be black.

**Molded Mica Capacitors**

The significance of the positions of the colors and of the colors, themselves, shall be as follows:



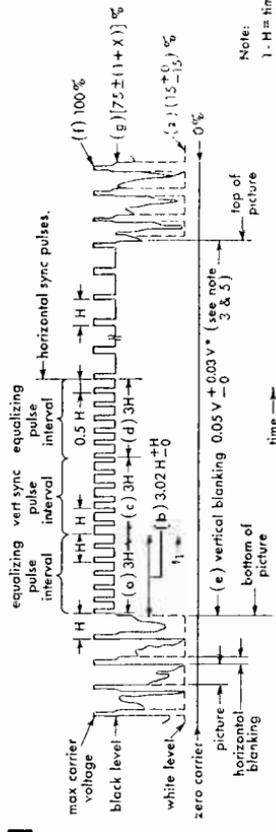
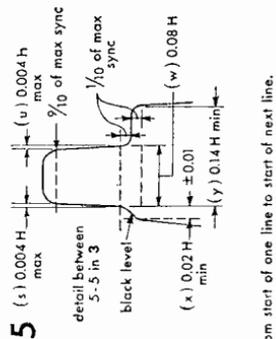
<i>Color</i>	<i>Numerical Significance</i>	<i>Decimal Multiplier</i>	<i>Capacitance Tolerance</i>	<i>Class Designation</i>
Black.....	0	1	20%	A
Brown.....	1	10	....	B
Red.....	2	100	2%	C
Orange.....	3	1000	3%	D
Yellow.....	4	10000	....	E
Green.....	5	.....	5%	
Blue.....	6			
Violet.....	7			
Gray.....	8	.....	....	I
White.....	9	.....	....	J
Gold.....	..	0.1		
Silver.....	..	0.01	10%	

## Class Designation

<i>Class Designation</i>	<i>Insulation Resistance Not less than</i>	<i>Temperature Coefficient Not more than</i>	<i>Capacitance Drift Not more than</i>
A	3,000 megohms	$\pm 1,000$ ppm	$\pm (5\% + 1 \mu\text{mf})$
B	6,000 megohms	$\pm 500$ ppm	$\pm (3\% + 1 \mu\text{mf})$
C	6,000 megohms	$\pm 200$ ppm	$\pm (0.5\% + 0.5 \mu\text{mf})$
I	6,000 megohms	+ 150 ppm - 50 ppm	$\pm (0.3\% + 0.2 \mu\text{mf})$
D	6,000 megohms	$\pm 100$ ppm	$\pm (0.3\% + 0.1 \mu\text{mf})$
J	6,000 megohms	+ 100 ppm - 50 ppm	$\pm (0.2\% + 0.2 \mu\text{mf})$
E	6,000 megohms	+ 100 ppm - 20 ppm	$\pm (0.1\% + 0.1 \mu\text{mf})$

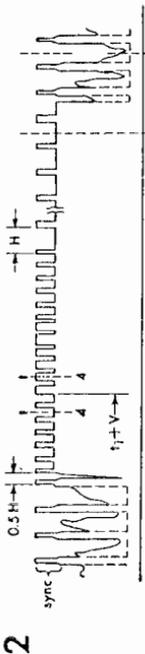
## Chassis Wiring

<i>Color</i>	<i>Circuit</i>
Black.....	Grounds, grounded elements, and returns
Brown.....	Heaters or filaments, off ground
Red.....	Power supply B plus
Orange.....	Screen grids
Yellow.....	Cathodes
Green.....	Control grids
Blue.....	Plates
Violet.....	Not used
Gray.....	A-C power lines
White.....	Above or below ground returns, AVC etc.

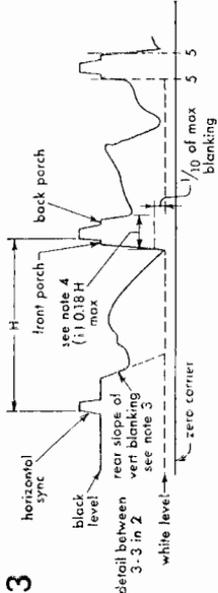


- Note:
- 1 - H = time from start of one line to start of next line.
  - 2 - V = time from start of one field to start of next field.
  - 3 - leading and trailing edges of vertical blanking should be complete in less than 0.1 H
  - 4 - leading and trailing slopes of horizontal blanking must be steep enough to preserve min and max values of (x+y) and (i) under all conditions of picture content.
  - \*5 - dimensions marked with an asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.
  - 6 - equalizing pulse area shall be between 0.45 and 0.5 of the area of a horizontal sync pulse.

(extract from RTMA standards)



horizontal dimensions not to scale in 1, 2 & 3



RTMA Standard visual transmitter output signal waveform

### Antenna and Ground Leads

When leads for antenna and ground connections are provided on the receiver, it shall be standard to color code the antenna lead blue and the ground lead black. Special antenna-connection leads shall be coded with combinations of blue and black.

### STANDARD TECHNIQUE FOR EXECUTING THE BACK PRESSURE—ARM LIFT METHOD OF ARTIFICIAL RESPIRATION

#### 1. Position of the Subject.

Place the subject in the face-down, prone position. Bend his elbows and place the hands one upon the other. Turn his face to one side, placing the cheek upon his hands.



#### 2. Position of the Operator.

Kneel on either the right or left knee at the head of the subject facing him. Place the knee at the side of the subject's head close to the forearm. Place



the opposite foot near the elbow. If it is more comfortable, kneel on both knees, one on either side of the subject's head. Place your hands upon the flat of the subject's back in such a way that the heels lie just below a line running between the armpits. With the tips of the thumbs just touching, spread the fingers downward and outward.

### 3. Compression Phase.

Rock forward until the arms are approximately vertical and allow the weight of the upper part of your body to exert slow, steady, even pressure



downward upon the hands. This forces air out of the lungs. Your elbows should be kept straight and the pressure exerted almost directly downward on the back.

### 4. Position for Expansion Phase.

Release the pressure, avoiding a final thrust, and commence to rock slowly backward. Place your hands upon the subject's arms just above his elbows.



### 5. Expansion Phase.

Draw his arms upward and toward you. Apply just enough lift to feel resistance and tension at the subject's shoulders. Do not bend your elbows, and as you rock backward the subject's arms will be drawn toward you. Then drop the arms to the ground. This completes the full cycle. The arm lift expands the chest by pulling on the chest muscles, arching the back, and relieving the weight on the chest.



The cycle should be repeated 12 times per minute at a steady, uniform rate. The compression and expansion phases should occupy about equal time; the release periods being of minimum duration.

#### Additional Related Directions.

It is all important that artificial respiration, when needed, be started quickly. There should be a slight inclination of the body in such a way that fluid drains better from the respiratory passage. The head of the subject should be extended, not flexed forward, and the chin should not sag lest obstruction of the respiratory passages occur. A check should be made to ascertain that the tongue or foreign objects are not obstructing the passages. These aspects can be cared for when placing the subject into position or shortly thereafter, between cycles. A smooth rhythm in performing artificial respiration is desirable, but split-second timing is not essential. Shock should receive adequate attention, and the subject should remain recumbent after resuscitation until seen by a physician or until recovery seems assured.



### Element 3 New Questions

**3.528** Describe the physical structure of two types of transistor and explain how they operate as an amplifier.

*Answer.* The transistor (from *transfer resistor*) is essentially a triode form of the germanium or silicon crystal diode. In its initial form, now known as a point-contact type, the transistor comprises a block of germanium soldered to a metal disk. Two very fine tungsten wires make contact with the upper face of the germanium at points 0.002 in. apart. These wires are sometimes welded to the surface.

Useful conduction in semiconductors, such as germanium and silicon, is enhanced by a small controlled amount of impurity carefully introduced on the surface. Silicon or germanium doped with phosphorus produces *n*-type material, and that to which a slight amount of boron has been added produces the *p* type. Conduction in the first case is said to be caused by an excess of electrons; for the *p* type, conduction is said to result from holes caused by lack of electrons.

A later development is the junction transistor that is made up of three alternate layers. They may occur in the order *pnp* or *npn*. An electrode is attached to each end and to the center material of the sandwich. These various types and their schematic circuit symbols are shown in Fig. 3-63.

A simple *n*-type point-contact transistor amplifier circuit is shown in Fig. 3-64, with the base (*B*) used as common return for the emitter (*E*) input circuit and collector (*C*) output circuit.

When positive potential is connected to the emitter, electrons are drawn from the crystal, leaving holes (as they are called) in the crystal structure. These holes now flow to the collector, which has a negative potential, and increase collector current. The action is analogous in this circuit to that in a grounded-grid vacuum-tube circuit.

Because they are essentially low-impedance devices, transistors effect current rather than voltage changes. The current amplification factor (called "alpha") of a transistor is the ratio of change in collector cur-

rent to change in emitter current when the collector voltage is held constant. For point-contact transistors, alpha is greater than unity.

If the transistor in Fig. 3-64 were of the *p* type, the battery voltages would be reversed and holes would be drawn from the crystal into

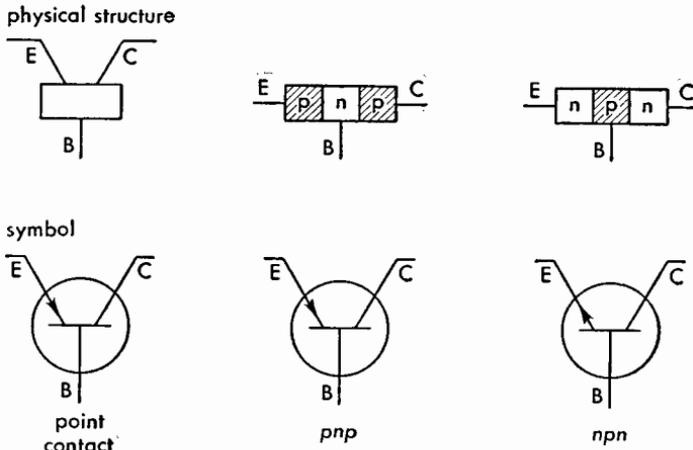


FIG. 3-63. Physical structure (above) and schematic diagram (below) of point-contact and junction transistors.

the emitter, leaving an excess of electrons to be attracted to the collector.

In a junction transistor, such as the *nnp*, electrons from the *n* layer diffuse through the *p* layer and flow toward the collector, which is positive, as shown in Fig. 3-65. Because the *p* layer is thin and has a

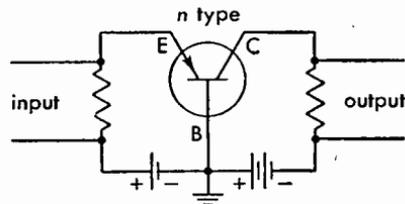


FIG. 3-64. Simple circuit of point-contact transistor amplifier.

surplus of holes, electrons from the emitter will reach the collector without neutralizing the holes. Most of the electrons that leave the emitter reach the collector. Alpha of junction transistors never attains unity but approaches it. In *pnnp* transistors, the potentials are reversed as shown and conduction is by holes instead of electrons.

Although the amplifier circuits shown in Fig. 3-65 may be used for either point-contact or junction transistors, the grounded-base circuit

is recommended for point-contact types. All can be used with junction types.

Tetrode transistors have been made but are not yet in general use.

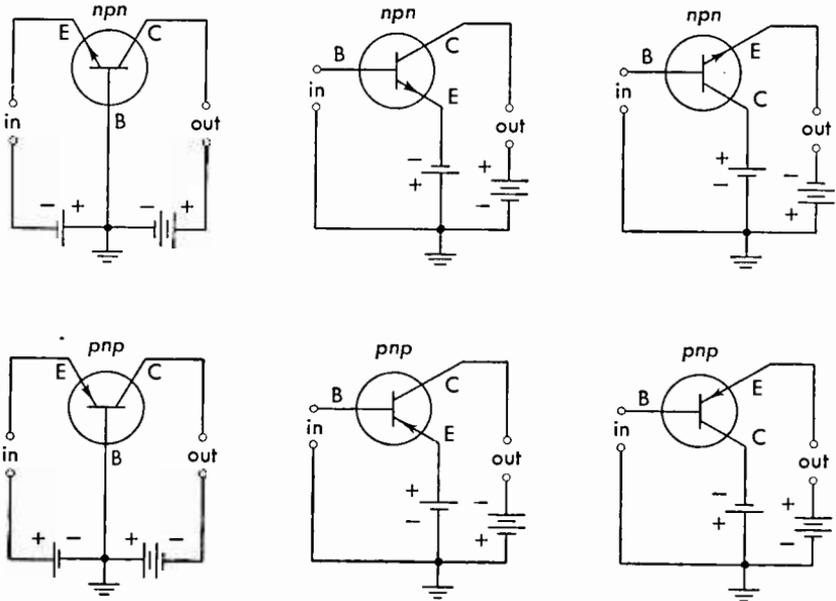


FIG. 3-65. Grounded-base, grounded-emitter, and grounded-collector connections for *npn* (upper) and *pnp* (lower) junction-transistor amplifiers.

**3.529** Draw a simple schematic circuit diagram of a two-stage audio amplifier using transistors.

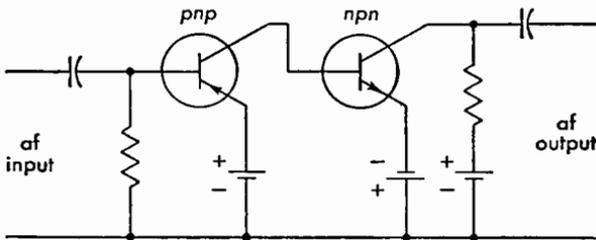


FIG. 3-66. Audio-frequency amplifier utilizing the complementary characteristics of two types of junction transistor.

*Answer.* The direct-coupled audio-frequency amplifier shown in Fig. 3-66 uses the two types of junction transistors. Increasing col-

lector current in the first transistor causes decreasing collector current in the second stage.

**3.530 Describe briefly the construction and purpose of a waveguide. What precautions should be taken in the installation and maintenance of a waveguide to ensure proper operation?**

*Answer.* A waveguide is a metallic pipe generally of rectangular, but often of circular, cross section. It is used as a transmission line to guide or transfer electromagnetic waves. Because its size would be prohibitive at lower wavelengths, it is used principally for radar and microwave applications above 3,000 mc. However, it is finding use also in the ultrahigh-frequency television band above 500 mc.

The waveguide must be carefully handled and installed to avoid denting or other mechanical damage, since this might adversely affect its transmission properties. Joints between adjacent sections must be mechanically and electrically tight to avoid leakage of radio-frequency energy and to prevent impedance mismatch.

Moisture within the waveguide must be kept low to avoid radio-frequency losses and prevent deterioration of the inner surface of the metal. In some cases drain holes are provided to allow excess condensation to run out. A preferable practice is to keep the waveguide system under a pressure slightly in excess of atmospheric pressure and to pump in only dry air or nitrogen.

**3.531 Describe the physical structure of a multinode magnetron and explain how it operates.**

*Answer.* A magnetron is a diode that has a magnetic field perpendicular to the electric field existing between cathode and anode. Its essential operating parts comprise a central cathode within a concentric anode as shown in Fig. 8-6. The anode may consist of a copper block from which have been milled a number of resonant cavities each tuned to the operating frequency. The mode of operation is described in 8.44. A photograph of one modern commercial type is shown in Fig. 3-67. Poles of a permanent magnet (not shown) bear against the steel inserts. Output is taken through a standard waveguide fitting.

**3.532 Describe the physical structure of a klystron tube and explain how it operates as an oscillator.**

*Answer.* The physical structure of a reflex klystron tube of a type used as a radar local oscillator is shown in Fig. 3-68. Oscillations are

produced in the following manner: A stream of electrons from the gun passes through grid apertures in the cavity resonator. The radio-frequency field resulting from oscillations (which may be initiated by noise) in the resonant circuit will affect the speed of electrons attracted by the d-c potential existing between cathode and cavity. Velocity

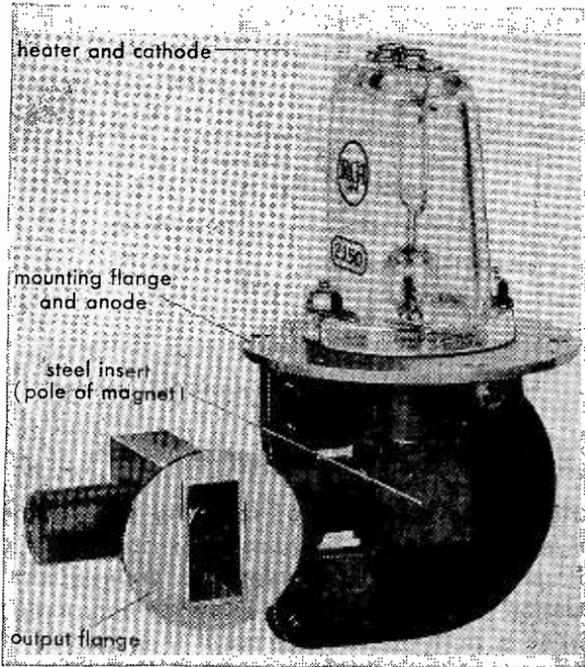


Fig. 3-67. Commercial cavity magnetron shown without magnet.

modulation will be produced because the radio-frequency field will accelerate one group of electrons while a succeeding group will be slowed down as the radio-frequency phase changes.

In this type of tube, the repeller or reflector, to which is connected a negative potential with respect to the cavity, will send the group of electrons back through the cavity apertures.

If the groups cross the gap at the instant that the radio-frequency field is retarding, kinetic energy will be changed to radio-frequency energy and oscillations strengthened.

Useful output of very low power is taken off through a coupling loop within the cavity.

For simplicity, details such as the accelerator grid (effectively connected to the cavity) and a focusing electrode are not shown in the drawing.

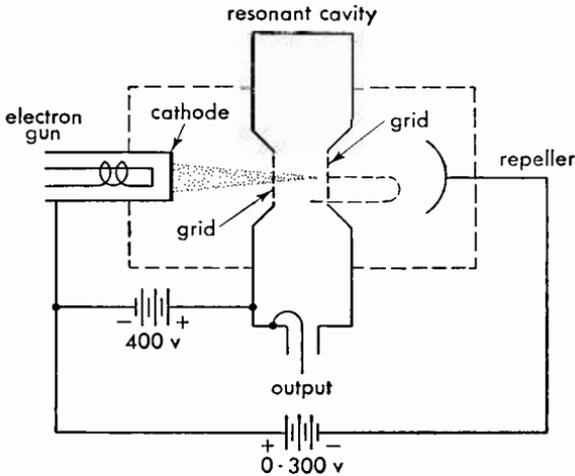


FIG. 3-68. Elements of a reflex klystron.

### 3.533 Describe three methods for reducing the radio-frequency harmonic emission of a radiotelephone transmitter.

*Answer.* Proper design of radiotelephone transmitters will keep harmonic emission to a very low level. Even harmonics are practically eliminated when a push-pull output stage is employed. A Faraday shield between output tank and antenna circuit prevents electrostatic coupling that would provide a low-impedance path for high frequencies. Since selectivity increases with  $Q$ , that of the plate-tank circuit should be as high as is consistent with tank-circuit efficiency, usually about 12.

On relatively inexpensive mobile radiotelephone transmitters in present use, other methods of reducing harmonic emission may be more practicable. If the antenna is tapped directly onto the plate coil, conditions are favorable for maximum harmonic emission. Often, by adding two capacitors, the output circuit can be modified to a pi network. A properly designed network of this type will reduce harmonic output. A second type of change utilizes a trap comprising coil and

variable capacitor tuned to the second harmonic or other offending frequency and placed in series between the output circuit and antenna.

Harmonic emission may be caused by overdriving the amplifier of an AM transmitter. This can be caused as a practical matter by shouting into the microphone. Some kind of modulation indicator or automatic peak limiter should be employed to eliminate harmonic emission arising from this source.

**3.534** A ship radiotelephone transmitter operates on 2,738 kc. At a certain point distant from the transmitter, the 2,738-kc signal has a measured field of 147 millivolts per meter. The second harmonic field at the same point is measured as 405 microvolts per meter. To the nearest whole unit in decibels, how much has the harmonic emission been attenuated below the 2,738-kc fundamental?

*Answer.* 51 db.

$$\begin{aligned}
 2,738\text{-kc signal} &= 147 \times 10^{-3} \text{ volt} \\
 5,476\text{-kc signal} &= 405 \times 10^{-6} \text{ volt} \\
 \text{Attenuation in db} &= 20 \log \frac{147 \times 10^{-3}}{405 \times 10^{-6}} \\
 &= 20 \log 363 \\
 &= 20 \times 2.55991 \\
 &= 51.1982
 \end{aligned}$$

### *Element 4 New Questions*

**4.285** Describe the composition of the chrominance subcarrier used in the authorized system of color television.

*Answer.* The chrominance subcarrier used to transmit color information in the FCC-authorized broadcast color television system has a frequency of 3,579,545 mc  $\pm$  10 cycles with a maximum rate of change not exceeding 0.1 cycle per second. This is often referred to as 3.58 or 3.6 mc for convenience.

The color information itself is transmitted as a pair of AM sidebands. The subcarriers from which the sidebands are produced are in quadrature, that is, they are 90 deg out of phase. Since the important information is in the two sets of sidebands, the subcarriers themselves are suppressed.

One subcarrier component called the I (for in-phase) component carries colors in the range from orange to cyan, while the other, called

the Q (for quadrature) component carries the blues, for which the eye has less acuity. The bandwidths available are indicated in Fig. 4-24, and it should be noted that the orange-cyan information is carried in the I component that has available a relatively broad lower sideband.

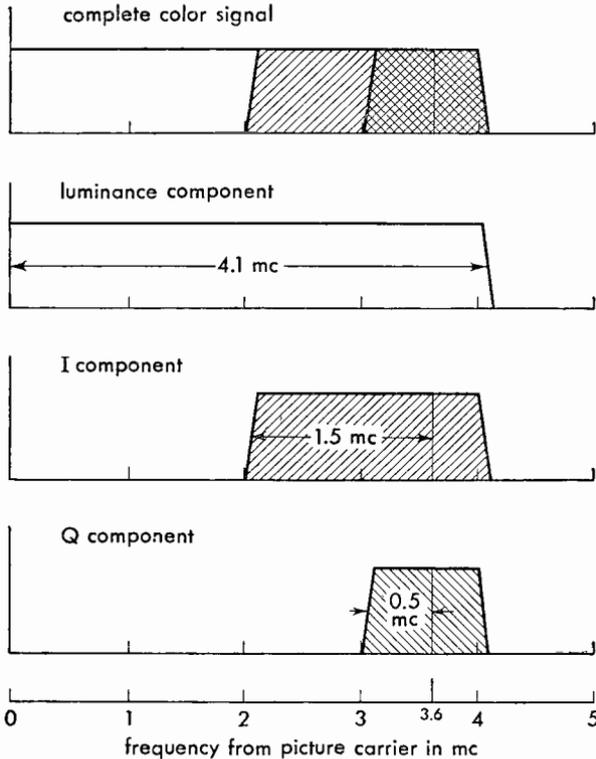


FIG. 4-24. Bandwidths of various components that make up the color television signal.

The luminance or brightness component of the color television system depends upon amplitude modulation of the picture carrier.

Since the 3.58-mc subcarrier itself is suppressed, it is necessary to synchronize color information between transmitter and receivers. This is done by transmitting a 3.85-mc color burst consisting of not less than 8 cycles on the back porch of the blanking pedestal following each horizontal pulse but not following equalizing and broad vertical pulses.

**4.286 Describe the procedure and adjustment necessary to couple properly a typical VHF visual transmitter to its load circuits.**

*Answer.* Because a television picture transmitter is required to pass signals of an extremely wide band, it is not possible to tune it up and couple it into an antenna merely on the basis of meter readings.

It can generally be assumed that output will pass through a vestigial-sideband filter or equivalent that is correctly adjusted and that the television antenna will be properly installed and tested together with its diplexer.

Uniform amplitude of output with frequency is necessary, and an indication of this condition is most easily obtained with a sideband-response analyzer. The sideband analyzer is essentially a narrow-band detector that picks up the signal from a television transmitter while it is emitting a signal resulting from a video sweep oscillator. The receiver is swept by the same frequencies. Typical single-sideband response of a well-adjusted transmitter operating into a dummy load or antenna is shown in the oscillogram in Fig. 4-25.

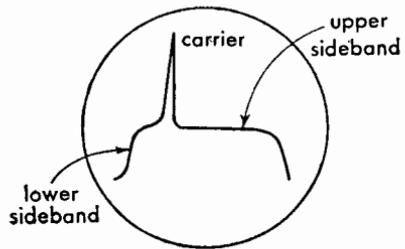


FIG. 4-25. Sideband-response-analyzer oscillogram.

Actual adjustments of the picture transmitter depend upon the type and the circuits employed. In general, it is necessary to tune the plate circuit and the output coupling circuit separately (although not to the same frequency). Then the two circuits must be coupled together. They are overcoupled to the proper degree to ensure broadband response and uniform response. The secondary or output circuit must also have the proper  $Q$  to ensure flat frequency response.

Adjustment of the radio-frequency driver likewise depends upon the types of circuits used. When tuned-driver-plate and tuned-amplifier-grid circuits are used, they must be adjusted like the overcoupled output circuit of a broadband amplifier.

**4.287 Draw a block diagram of a typical monochrome TV transmitter indicating the function of each part.**

*Answer.* The elements of a typical UHF television transmitter are shown in Fig. 4-26. An overtone crystal operating at one-sixth the

assigned frequency is followed by a doubler and two amplifiers. The output from the exciter unit is therefore at one-third the operating frequency.

Output from the tripler is at the assigned frequency. This amplifier is followed by two power amplifiers, the second of which drives the modulated power-amplifier stage. A swamping load dissipates part of the driver power output to furnish a more constant radio-frequency voltage over the modulation cycle.

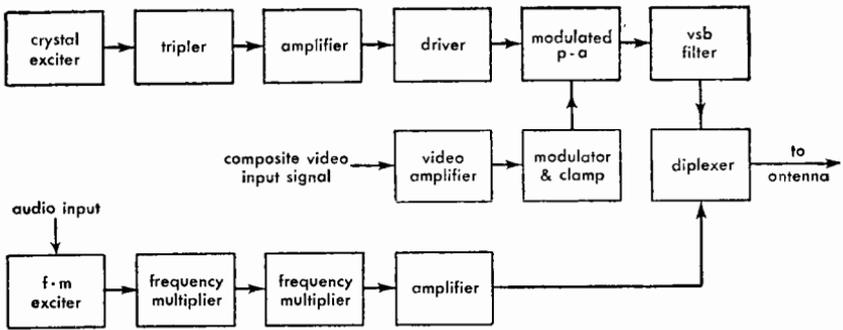


FIG. 4-26. Elements of UHF TV monochrome transmitter.

Composite video, consisting of camera signals and synchronizing signals from a sync generator, are fed into a video amplifier and then into the modulator. Associated with the modulator is a clamping circuit that holds black level constant from one picture frame to another, despite changes in the character of the scene being scanned.

Since there is insufficient space in a television channel for full double-sideband modulation, one sideband (the lower one) is attenuated before the signal goes to the antenna by being passed through a vestigial-sideband filter.

A complete television transmitter comprises both a picture transmitter and a sound transmitter. An FM exciter takes audio input, and the resultant FM signal is multiplied a sufficient number of times to bring it to the output frequency. By these multiplications the amount of frequency swing or deviation necessary for 100 per cent modulation is likewise developed.

Output from both picture and sound transmitters is combined in a kind of bridge circuit known as a "diplexer" to feed the same antenna.

**4.288 Describe the scanning process employed in connection with color television broadcast transmission.**

*Answer.* Scanning is the process of analyzing the successive light values of picture elements that constitute the total picture area. A scanning line is a single continuous narrow strip of the picture area containing highlights, shadows, and halftones. The scene is scanned from left to right horizontally and from top to bottom vertically.

The number of scanning lines per frame (a frame comprises two scanning fields) is 525, interlaced two to one in successive fields. For color television, the horizontal scanning frequency is  $15,734.264 \pm 0.044$  cycles per second and the vertical scanning frequency is 59.94 cycles per second. The aspect ratio of the picture is four units wide to three units high.

Color information comprising red, green, and blue components that are scanned simultaneously is combined with the luminance (light) information obtained from highlights, shadows, and halftones.

**4.289 Under what conditions should the indicating instrument of a television visual transmitter be read in order to determine operating power?**

*Answer.* Operating power of a picture transmitter is determined at the output terminal of the vestigial-sideband filter (if such a filter is used) or at the transmitter output terminal.

Average power must be measured while the transmitter is operating into a dummy load of zero reactance and resistance equal to that of the transmission-line surge impedance. Modulation during the measurement must comprise a standard black television picture.

Peak power is then determined by multiplying the value obtained by a factor of 1.68. At the same time, direct plate voltage and current of the last radio-frequency stage must be measured.

Operating-power readings are to be monitored with a peak-reading device that reads proportionally to voltage, current, or power in the radio-frequency transmission line. This meter is to be calibrated using the procedure described above.

Operating power monitored in this way must be held as closely as practicable to authorized operating power and must never exceed 10 per cent above or 20 per cent below authorized power except in emergencies.

As a further check, it is required that plate voltage and current of

the output stage be measured with a standard black picture with transmitter operating into the antenna. These values must be substantially the same as those described for the calibrating procedure above.

**4.290** In a transmitted monochrome television signal what is the relationship between peak carrier level and the blanking level?

*Answer.* Blanking level must be transmitted at 75 ( $\pm 2.5$ ) per cent of the peak carrier level. The maximum carrier level is determined by the peaks of the synchronization pulses, whereas blanking level represents the base of the synchronization pulses.

**4.291** Draw a simple schematic diagram of a T-type coupling network suitable for coupling a coaxial line to a standard broadcast antenna. Include means for harmonic attenuation.

*Answer.* Such a typical circuit is shown in Fig. 4-27. Capacitor  $C$  and the tapped coupling coils must be of a proper size to match the impedance of the coaxial line to that of the antenna and balance out any reactive component of the antenna impedance. The static drain resistor  $R$ , which provides a high-resistance d-c path to ground, may be replaced by a choke of suitable type.

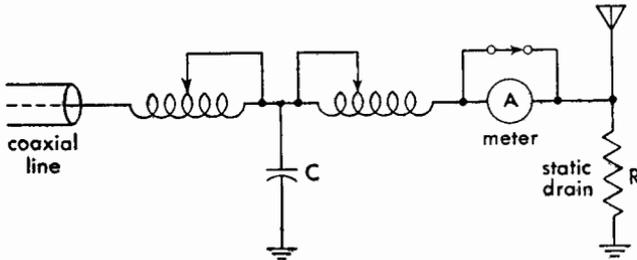


FIG. 4-27. Low-pass coupling network between coaxial line and antenna.

Because the T network is the low-pass type, this coupling circuit also attenuates harmonics.

## Element 6 New Questions

**6.896** What are waveguides and in what type of radio circuits do they find application?

*Answer.* Waveguides are described in 3.530 (Addendum). They are extensively used for radar, microwave radio, and laboratory experimental purposes.

**6.897** Describe the physical structure of two types of transistors and explain how they operate as an amplifier.

*Answer.* See 3.528 (Addendum).

**6.898** What is the crystal frequency of a transmitter having three doubler stages and an output frequency of 16,870 kc?

*Answer.* 2,108.75 kc

$$16,870 / (2 \times 2 \times 2) = 2,108.75$$

**6.899** A superheterodyne receiver is adjusted to 2,738 kc. The intermediate frequency is 475 kc; what is the frequency to which the grid circuit of the second detector must be tuned?

*Answer.* 475 kc. The grid of the second detector is always tuned to the intermediate frequency; only the radio-frequency and oscillator circuits are variable-tuned. For the example given, the radio frequency would be tuned to 2,738 kc and the oscillator to 2,263 kc (or possibly to 3,213 kc).

**6.900** In a tuned radio frequency receiver, what is the advantage of heterodyne reception as compared to autodyne reception?

*Answer.* Reception with the autodyne or regenerative detector is sometimes more difficult than with the heterodyne technique, particularly, with strong signals, since they pull the frequency of the detector and result in blocking of the receiver.

**6.901** Show by a diagram how a voltmeter and ammeter should be connected to measure power in a d-c circuit.

*Answer.* The circuit shown in Fig. 6-27 illustrates the best manner in which to connect the meters, since the current measured does not include that through the voltmeter. If the voltmeter has a very high resistance it

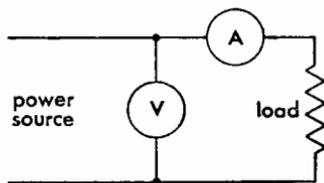


FIG. 6-27. Power measurement in d-c circuit.



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