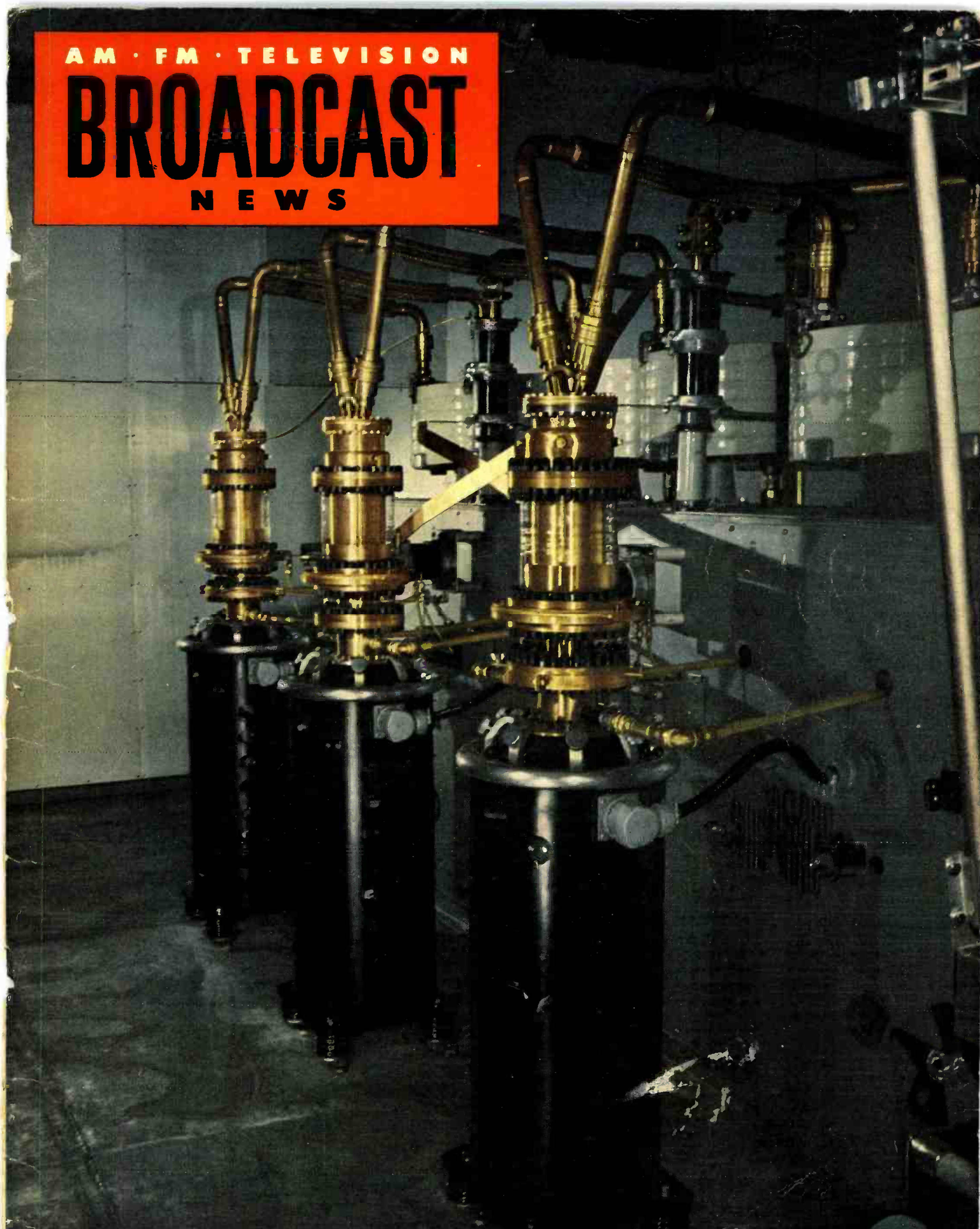
AM · FM · TELEVISION

BROADCAST NEWS



ONE MILLION WATTS . . . . . See Pg. 8

Broadcast News

AM • FM • TELEVISION

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Contents

COVER for this issue shows the power amplifier tube compartment of a one-million watt transmitter, now undergoing test. Three of the new RCA-5831 super-power beam triodes (see Pg. 8) are shown mounted in the operating position. Any two of the three may be used to obtain an output of one million watts—the third tube being maintained at low filament temperature so that it may be quickly substituted in case of failure of either of the others. In an emergency, operation may be continued with a single tube—the output with just one tube is over 500,000 watts.

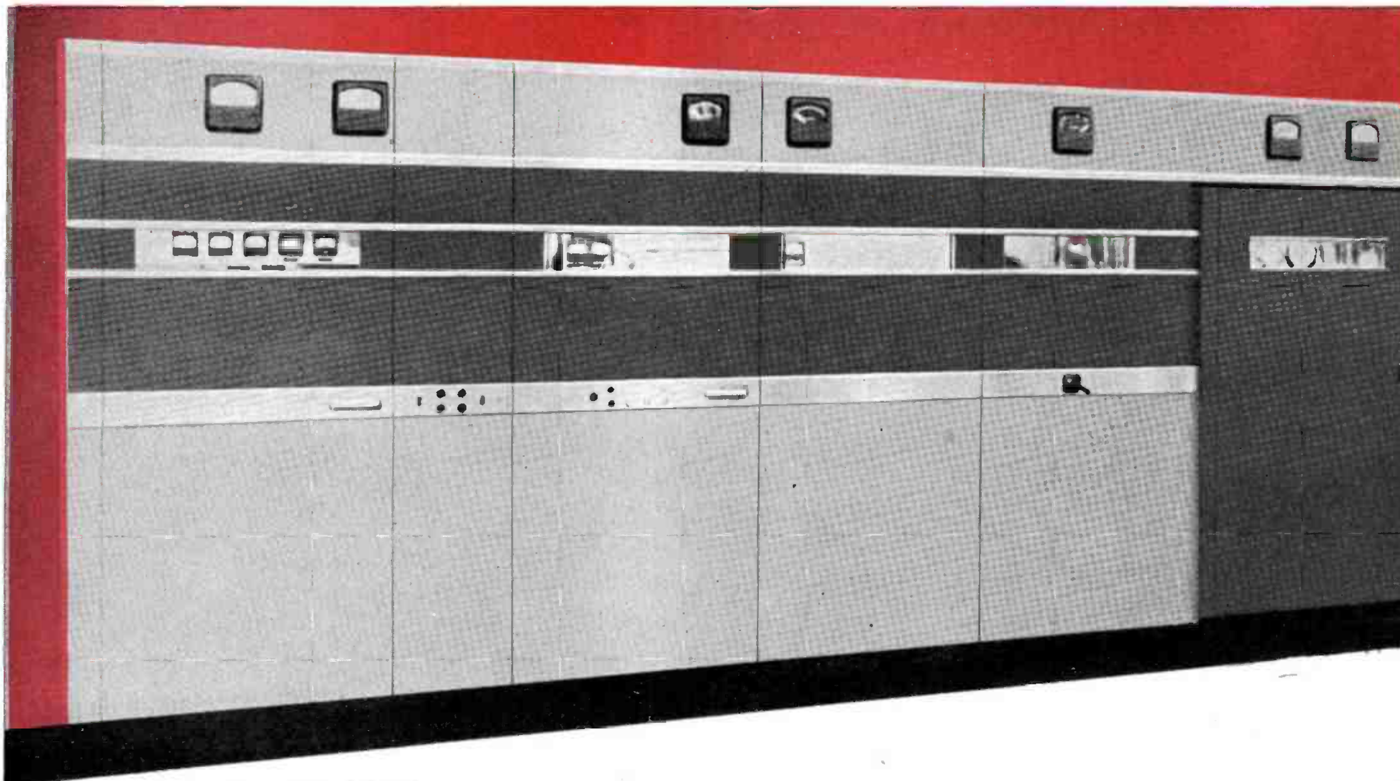
SUPERPOWER, of course, is not new to RCA engineers. In 1933 RCA supplied a 500,000 watt broadcast transmitter for WLW, which was successfully used over a period of years. Just before the war RCA built another 500,000 watt broadcast transmitter, of more advanced design, which was eventually installed in England and played an important part in pre-D-day broadcasts to Africa and Europe. Both of these transmitters used a multiplicity of tubes—of the standard 50 KW size—to obtain the desired output. With the advent of the RCA-5831 the design of super-power transmitters becomes much simpler.

YOUR BEST FRIEND, insofar as equipment problems and needs go, is your RCA Field Representative. Someone once defined a field salesman as a man who spent sixty percent of his time working for the customer (that's you) and forty percent of his time working for the company. We feel that's not fair to our field representatives—for they probably spend more like eighty percent of their time working for the customer (you). They hope, of course, to get your equipment orders—but in the meantime you've had the benefit of their advice in station planning, their experience in specification of proper equipment, and their help in necessary factory contacts. In a sense, it's like adding a planning engineer to your staff—at no extra cost. If you are not already taking advantage of this service, why not start now. On Pages 36-41 you will meet the RCA representative who covers your territory. See him at NAB—or give him a buzz when you get back home. He'll like it, you'll benefit—and there's not the slightest obligation. It's his job to serve you.

YOUR SECOND BEST friend (equipment-wise), we hope, is this very magazine you're reading now. BROADCAST NEWS, now in its nineteenth year, is published as a service to our customers and fair prospects. In it we try to provide you with information on the latest developments in equipment and descriptions of the newest and most interesting station installations (RCA, of course). We hope by this means to help you in making plans to improve your own station. Generally speaking we know the kind of information you want—but now and then we're bound to go astray. When we do we wish you'd tell us. It's your magazine. What do you want in it? More technical stories? More station stories? Less this, less that? Whatever it is, let us know, p-l-e-a-s-e!

AN INDEX to back issues of BROADCAST NEWS is something we've often considered printing. We have here in the office a card index which could be put in printed form—if there is a sufficient demand for it. We know there are many readers who keep a file of BN—but we don't know just how many there are—nor how much they would use an index. How many of you would find an index useful? Let's have a show of hands (a penny card will do).

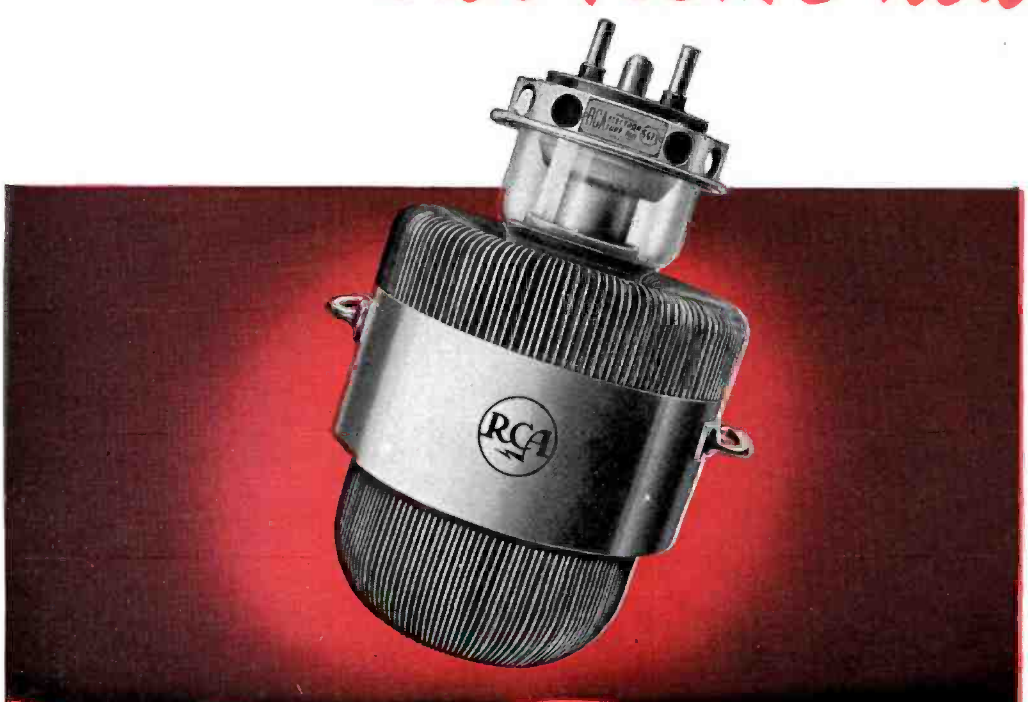
BACK ISSUES of BROADCAST are available from No. 43 (January, 1946) to No. 54 (April, 1949) inclusive, except for No. 46, of which the supply is entirely exhausted. If you're interested in completing your file we can supply any of these issues (as long as the supply lasts—there are only a few of some) at a cost of 20 cents each (covers handling and postage). Send orders to BROADCAST NEWS, RCA, Camden, New Jersey.



(Courtesy of WGAR, Cleveland, Ohio)

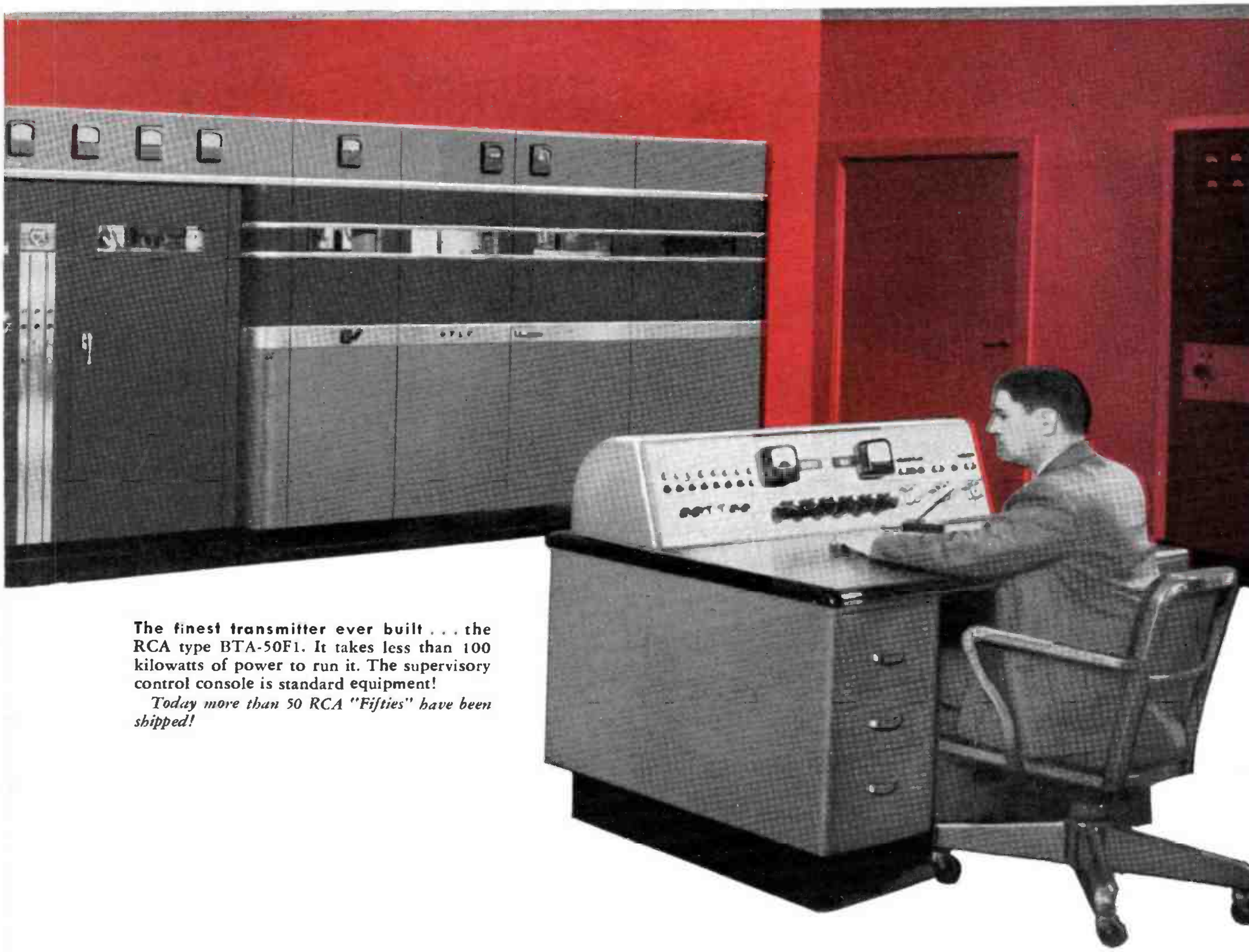
Replace your old AM transmitter

with RCA's new 50 kw...



The revolutionary, new power triode RCA-5671. This tube takes about one-third the filament power of conventional triodes used in the older transmitters. It reduces hum modulation below FCC requirements—*even without r-f feedback.*

The two 5671's in the r-f power amplifier and the two in the class B modulator of this 50-kw transmitter save up to *$1200 yearly in filament power alone.*



The finest transmitter ever built . . . the RCA type BTA-50F1. It takes less than 100 kilowatts of power to run it. The supervisory control console is standard equipment!

Today more than 50 RCA "Fifties" have been shipped!

and write off its cost in power savings alone!

It's a fact — as one high-power broadcaster recently discovered to his complete satisfaction. Now, he has replaced his old transmitter with an RCA "fifty"—*and it's paying its way.*

HERE'S WHY.

Using revolutionary new RCA-5671 power triodes that take about one-third the filament power of conventional types, this RCA "fifty" saves up to $1.75 an hour in power savings over former transmitters—*$12,000 a year, based on daily operation at 19 hours a day!*

Many other new design features, too, that add to this $12,000 savings.

For example, only 29 tubes and 11 different tube types—less than half the number used in many present 50 kw's. True walk-in accessibility that assures faster maintenance — and lowers maintenance costs. Ultra-conservative operation of tubes and components—with less chance for outages.

Here is a 50-kw AM transmitter that does away entirely with oil circuit breakers—assures faster circuit protection. Because the BTA-50F1 operates from a 460-volt supply. Control and protection circuits are the most complete of any transmitter designed to date. And its true unified front (an integral part separate from compartment enclosures) facilitates flush-mounting — gives your transmitter room a new, handsome appearance.

Write for the new 28-page brochure about the BTA-50F1. It gives you complete details — including circuits, specifications, floor plans, and full-page pictures showing the remarkable accessibility of this great transmitter.

Dept. 19HC, RCA Engineering Products, Camden, New Jersey.

RCA

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RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

HOW TO USE STANDARD FILTERS WITH NEW FLAT MAGNETIC PICKUP

FIG. 1. Closeup of RCA 70-D Turntable with Universal Pickup (at right) and Flat Magnetic Pickup, MI-11874 (at rear) installed.

By
H. E. ROYS
Audio Engineering Section

Introduction

It appears that the first application of the Flat Magnetic Pickup, MI-11874, will be in combination with the universal pickup and that it will be used solely for the reproduction of 45 and 33 1/3 RPM fine groove records.

The new pickup and tone arm will, in practically all cases, be added (see Fig. 1) to one of the existing 70 types of turntables that use the universal pickup. It is therefore desirable to use the filter that is in the turntable, making a minimum of modifications so that the new pickup can be readily added and give satisfactory reproduction.

Modifications have previously been tried for the MI-4975 filter that would make it suitable for the new flat magnetic pickup but not in combination with the universal pickup. It was reasoned then that flat magnetic pickups of different tip sizes would be used, and that the new pickups would replace the universal pickup.

It is the purpose of this article to describe changes that can be made in order to use the pickup filter for both the universal and the flat magnetic pickups. Two filters, MI-4875 and MI-4975, are considered.

Filter Modifications for MI-4975

New Switch Position, L-0.

In order to use the flat magnetic pickup in addition to the universal pickup, it is necessary to create a new switch position which I have designated as L-0 since it is one step ahead of the L-1 position. The contacts are available in the switch, it only being necessary to move the stop over another notch.

Switch Changes.

Decks A and B of the switch, which are the top decks, are used for switching the transformer of the universal pickup for vertical or lateral operation and these need not be touched.

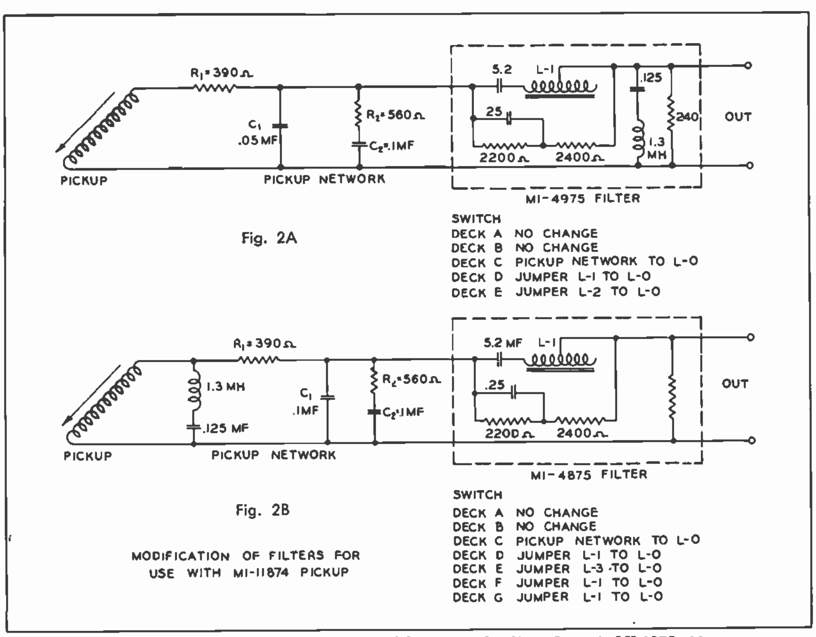


FIG. 2. Circuit diagram showing modification of MI-4975 and MI-4875 filters for use with MI-11874 Pickup.

At Deck C, an L-0 position is needed for connecting the flat magnetic pickup to the filter. Either an external lead can be used for this purpose or in the MI-4975 filter a brown lead that is in the cable can be used and the pickup can then be connected at the filter. This latter connection is more desirable since contact must also be made to the low side of the filter and there are no low side leads available at the switch.

At Deck D, a jumper should be connected between the L-1 and the new L-0 position contact.

At Deck E, a jumper should be connected between the L-2 position and the L-0 contact.

Measurement

The impedance of the flat magnetic pickup is much lower than the universal pickup with its transformer, and this impedance difference makes it impossible to connect the new pickup directly to the filter and obtain satisfactory reproduction.

To obtain the desired response, a resistance capacitance network that utilizes two resistors and two capacitors is used and the arrangement is shown in Fig. 2. These are connected directly to the pickup and give a roll-off at the high frequencies that is a compromise for both Columbia and Victor records.

A compromise must be made since the recording characteristics of the two concerns are different. Columbia uses more high frequency tip-up in recording and hence requires more roll-off than the RCA fine groove records. Columbia also boosts the low frequency end but it is difficult to effect a compromise in this region without changing the resistance capacitance network that shunts the bass boost reactor and capacitor in the filter. The response characteristic that we have been using for transcriptions that are cut according to NAB standards was therefore followed at the low frequency end.

Response measurements using an oscillator with a pickup and the network of Fig 2 (a) connected to the filter in the L-0 position are shown in Fig. 3. The tuned circut that counteracts the effect of the pickup peak which ranges between 11,000 and 13,000 cycles for the flat magnetic pickup resonants between 12,000 and 13,000 cycles.

Three curves are shown in Fig 3 showing modifications that can be made to obtain more or less high frequency response and thus more nearly meet the playback requirements of the RCA 45 and 33 1/3 fine groove records and the Columbia 33 1/3 fine groove record; the latter records requiring less high frequency response as given by curve C of Fig. 3 whereas the RCA records having less tip-up can be used with a characteristic such as Fig 3 (a).

Additional Components

Playback with the 1.0 mil pickup of the RCA test record 12-5-25 (460625-6) 33 1/3 rpm gave

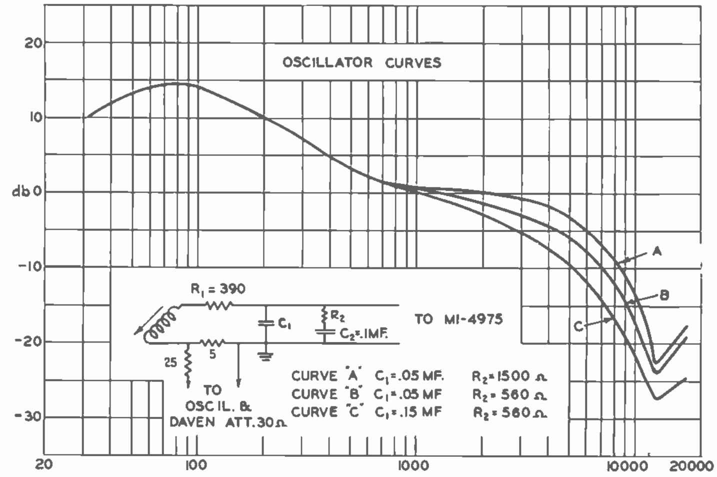


FIG. 3. Response curves (MI-4975) using different values of "C," and "R_2" with network connected as shown in 2 (a).

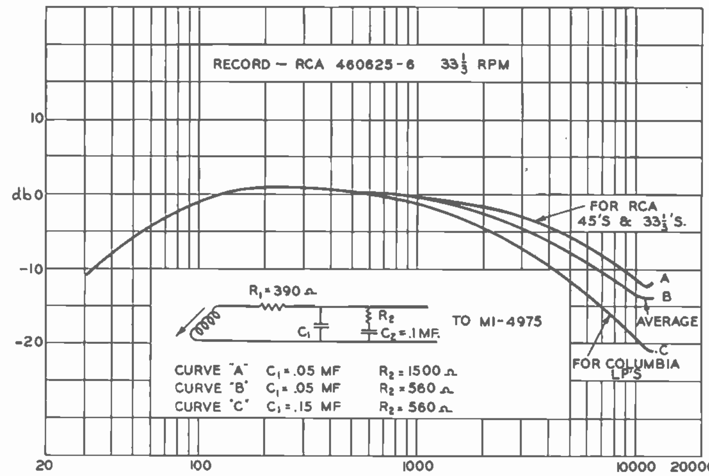


FIG. 4. Playback curves (MI-4975) of RCA, 33⅓ rpm test record for different modifications of the pickup network.

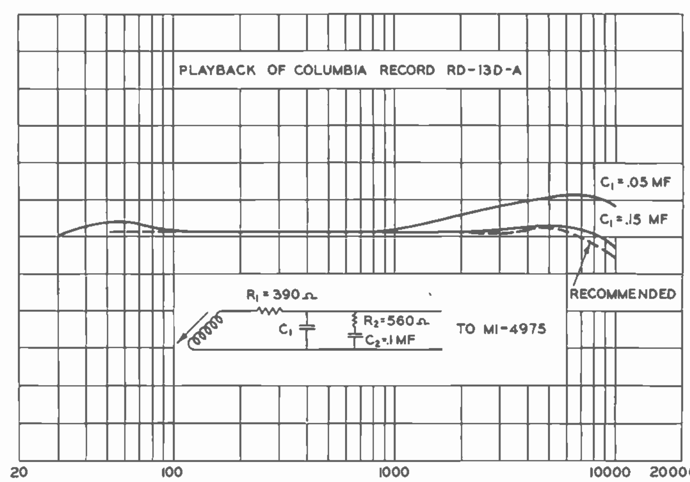


FIG. 5. Playback curve (MI-4975) of Columbia Test Record with high-frequency response, higher than recommended.

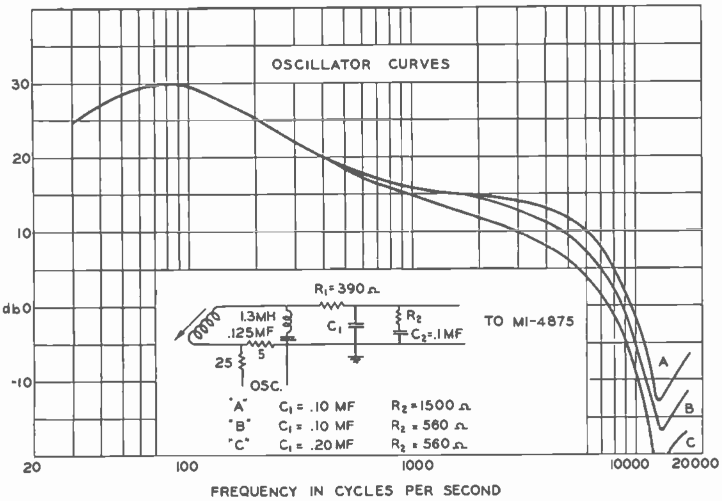


FIG. 6. Response curves (MI-4875) with component changes to permit best results from both RCA and Columbia Records.

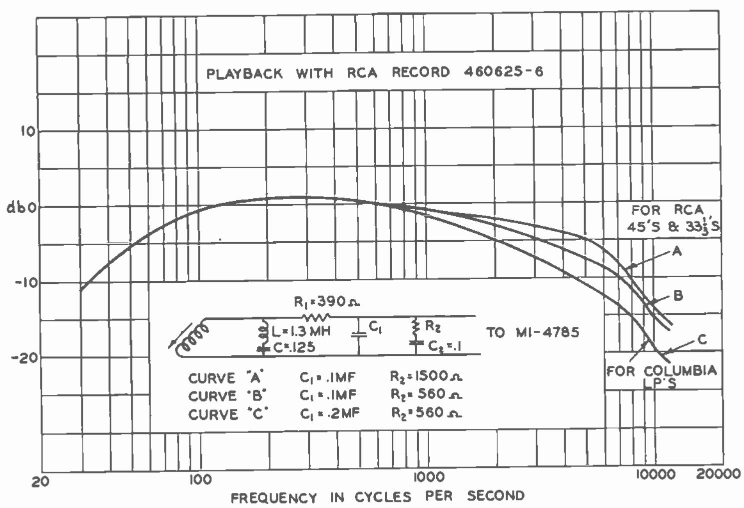


FIG. 7. Playback curve (MI-4875) of RCA. 33⅓ rpm test record for varying values of pickup network.

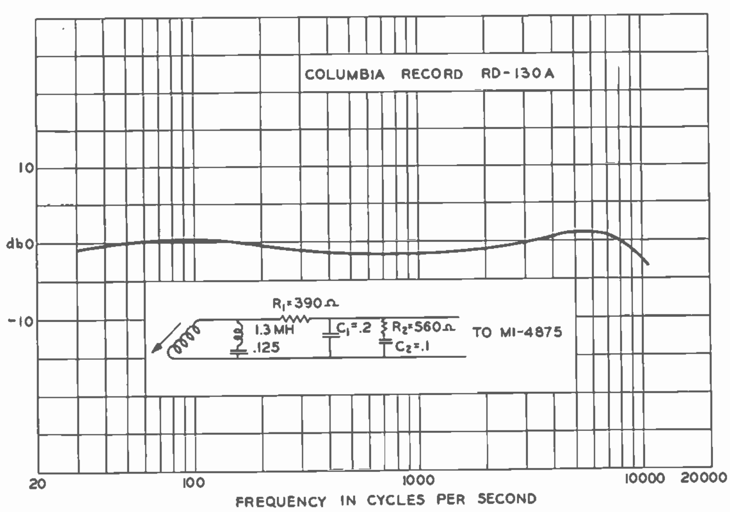


FIG. 8. Playback curve (MI-4875) of Columbia test record, RD-130A.

the results shown in Fig. 4 for the different modifications of the pickup network shown in Fig. 3. For best results with RCA 45's and 33 1/3 fine groove records, curve "A" is recommended.

A Columbia test record RD-130A and a recommended response characteristic using this record was obtained from Wm. S. Bachman of Columbia Records, and the overall response characteristic obtained with this record is shown in Fig. 5.

For the average compensation values where $C_1 = 0.05$ MF, and $R_2 = 560$ ohms, the high frequency response is higher than recommended. This can be reduced by adding a 0.1 MF capacitor in parallel with C_1 making a total capacitance of 0.15 MF. The overall response is then very close to what Columbia recommends. It will be noted in Fig. 4 that their recommended characteristic is down about 20 db at 10,000 cycles instead of 16 db used for NAB standards. The original modification work was started based upon the high frequency response of the NAB characteristic since Columbia at one time stated that such a characteristic would be suitable and thus the average, Fig. 4 (b), is somewhat higher for the Columbia RD-130A record than expected. Listening tests have shown that characteristic 4 (b) sounds good with either Columbia or RCA records.

Filter Modifications for MI-4875

A new switch position is needed and this, as stated before, is designated as L-0. Since the MI-4875 filter does not contain a trap circuit it is necessary to provide one and this can be added directly across the pickup as illustrated in Fig. 2 (b). The coil, 1.3 MH inductance, is the same one used in the MI-4975 filter. The resistance capacitance network following the pickup and trap circuit is the same as used with the MI-4975 filter with the exception of C-1 which is now increased from 0.05 MF to 0.1 MF.

Oscillator curves obtained with this network are shown in Fig. 6 with the same component changes as discussed before to permit optimum results for either Columbia or RCA records. Record curves using the RCA test record 460625-6 are shown in Fig. 7, and the results obtained with Columbia record RD-130A are given in Fig. 8.

Switch Modifications

Deck A—No change.
Deck B—No change.
Deck C—Lead from high side of pickup network to contact L-0.
Deck D—Jumper between L-1 and L-0.
Deck E—Jumper between L-3 and L-0.
Deck F—Jumper between L-1 and L-0.
Deck G—Jumper between L-1 and L-0.

As before the pickup and network must be connected between the L-0 contact of Deck C of the switch and the low side of the filter.

THE BN-2A PROVIDES *Flexibility*

The BN-2A Portable Amplifier provides the basic unit for a flexible set of remote equipment. In the single instrument you have a portable amplifier that handles simple setups and at the same time provides the central unit for complex arrangements.

The amplifier is a three-channel unit and has capacity for four microphone connections. (The rear plate has room for any receptacle in common use today.) Three of the microphones can be cut in simultaneously, with the third and fourth interchangeable on a front panel switch. High level mixing is employed to give the same signal-to-noise performance as a studio system. The master gain is placed between the first and second stages of the main amplifier for the same reason. The main amplifier has two feed back loops to reduce distortion and stabilize the gain.

A standard sized VU meter is provided with an illuminated scale. A switch provides two levels of brightness and the lamp also serves as a pilot light for the power.

The output of the amplifier can be fed to the line and to a PA system simultaneously. The operator then can separately control the level of the PA Feed and avoid the annoying feedback problems that occur on broadcasts when the PA system is not under his control. The cue line can also be switched into the PA feed so the audience and cast can receive their cue direct from the station. All line and cue terminals are simple binding posts on the front panel. No special tools or connectors are required for line connections, and the wires are under observation all the time. These are important details to an operator going to an unknown setup with limited facilities, and where the wires may be jerked by tripping feet, etc.

The new battery kit cover (MI-11279) now supplies an extra safety feature. Where the a-c power is uncertain or non-existant this kit can provide power for two hours or more. A switch provides changeover when the a-c fails and returns.

Where more elaborate setups are desired, the BN-2A also comes in handy. The portable mixer, OP-7, can be used with the BN-2A to give six channel mixing (7 microphones connected) by simply connecting the output of the OP-7 to the BN-2A through a microphone channel in the latter. Fig. 2 shows such a setup.

Another combination can now be made also. A simple modification of the BN-2A makes it possible to connect two of the amplifiers together at the mixer bus. The two equipments side by side then give you six channel mixing (8 microphones connected). Moreover, the two main amplifiers are in parallel and one can become an emergency channel for the other. Failure of power or components in one unit will not affect the other unless the mixer bus is shorted, and it can be quickly disconnected. Additional information for the modification can be obtained by writing the RCA Broadcast Sales Office in Camden, N. J. Fig. 3 shows a pair of BN-2A amplifiers with the mixer bus tied together.

All of these combinations use high level mixing and feature studio performance so far as noise level, frequency response, and distortion are concerned. The spacing of the knobs, the gain available, the size of the meter, etc., are comparable to the studio operation. Such features make it possible for the operator to turn out a studio quality performance.

FIG. 1 (at right). The BN-2A provides both A-C or battery operation by use of the new Battery Cover Kit (MI-11279).

FIG. 2 (center below). The BN-2A may be used with the OP-7 to provide six-channel mixing facilities.

FIG. 3 (bottom). Two BN-2A's in tandem also might be utilized to provide six-channel mixing.

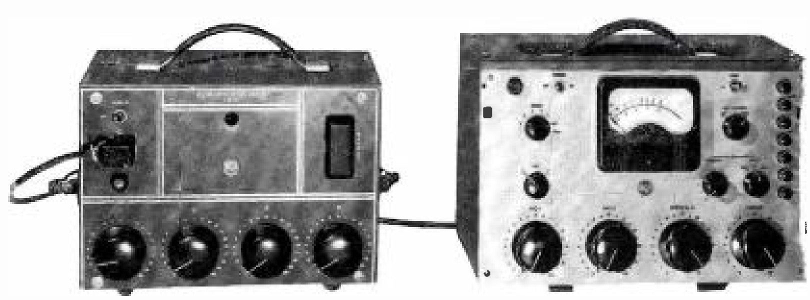


FIG. 1. RCA's new "Super-Power Beam Triode," which is capable of 500 kilowatts output and which has been tested at 1,000,000 watts input, is shown above with Dr. L. P. Garner, head of the Advance Development Lab of the RCA Lancaster, Pa. tube plant, in which the tube was developed. Despite its enormous power output, the new tube is of relatively compact design, weighing only 135 pounds and measuring only 38¾ inches in length. Present applications of the new tube are in high power CW applications and International Broadcast Service.

NEW SUPER-POWER BEAM TRIODE PROVIDES OUTPUT of 500,000 WATTS

What is believed to be the world's most powerful electron tube, a high-vacuum beam triode capable of 500 kilowatts of continuous output, has been announced by the RCA Tube Department.

The new tube, RCA Type 5831, represents the first commercial attempt to build power output of this magnitude into a single tube. In unmodulated class C service, the 5831 has a maximum plate-voltage rating of 16,000 volts, a maximum plate input of 650 kilowatts, and a maximum plate dissipation of 150 kilowatts.

The new tube generates its tremendous power at high efficiency and with exceptionally low driving power. To provide 500 kilowatt output in unmodulated class C service, under typical operating conditions, the 5831 requires only about 900 watts grid drive. It can be operated with maximum rated plate voltage and plate input at frequencies throughout the "Standard Broadcast Band" and much higher.

The cover for this issue of BROADCAST NEWS shows the power amplifier tube compartment of a one-million watt transmitter, now undergoing test. Three of the new RCA 5831 super-power beam triodes are shown mounted in the operating position. Any two of the three may be used to obtain an output of one million watts—the third tube being maintained at low filament temperatures so that it may be quickly substituted in case of failure of either of the others. In an emergency, operation may be continued with a single tube—the output with just one tube is over 500,000 watts.

The great power capabilities of the new tube are due largely to the use of an array of 48 independent unit electron-optical systems arranged cylindrically in the tube, thus in effect, concentrating 48 triodes in relatively small space. Each of the independent electron-optical systems consists of a filament (in a slot in the beam-forming cylinder) grid rods, and the copper anode. Electrons leaving the emitting surface of the filament are beamed between a pair of grid rods, to the anode by the focusing action of the beam-forming cylinder. Even though the grid may be positive, relatively few stray electrons strike it.

The symmetrical electrode arrangement, compactness, and the short low-inductance rf paths from the filament, grid, and anode to their respective flange terminals, contributes to the usefulness of the 5831 for high-power, high-efficiency applications. Internal elements of the tube, including the cylindrical beam-forming structure, anode, and filament, are concentrically arranged, permitting the use of a simplified internal water-cooling system for the beam-forming cylinder and anode, with simple external hose connections.

FIG. 2. The unique internal structure of RCA's new "Super-Power Beam Triode" 5831 is shown below, as Dr. L. P. Garner, head of the RCA Lancaster tube plant's Advance Development section, directs the lowering of the anode-envelope assembly into position. The high power capability of the new tube is due largely to the arrangement of 48 separate triodes in relatively small space.

FIG. 3. The individual filament and grid elements of the unit triodes in the array are tungsten rods 8 inches long, supported at both ends by means of knife-edge V-notch arrangements. A pantagraphic device makes each filament strand and grid rod mechanically independent, and allows vertical movement without disturbing the precise alignments and spacings.

THE GENLOCK FOR IMPROVED TV PROGRAMMING

By JOHN H. ROE
Television Terminal Engineering

Introduction

Recently, the need for more and better techniques in video programming has become more and more apparent, particularly as picture quality has improved, thus focusing attention on ideas for adding some of the finer touches. Special effects, used for a long time in the motion picture industry, are rapidly approaching the category of "musts" for television programs.

One of the gaps in the present programming structures arises from the lack of synchronization between two distinct program sources which may supply successive parts of a program. Separate sync generators are used at the two sources and even though they are locked to the same power supply as a frequency reference, there is not a fixed relation in phase between the field and line scanning frequencies produced in the two generators. The field frequency pulses may be phased together by manual adjustment and they will stay so as long as the same power source is the reference for both generators, but there is no such simple solution to the problem of phasing the line frequency pulses. Usually there is a continuously changing random variation in the phase of one with respect to the other, though the average frequency is constant and the same in both generators. Of course, in cases where the two generators cannot be tied to the same power source, there is no direct way of securing any lock-in of either field or line frequency signals.

Lack of tight lock-in between two such systems results in several programming limitations. For example, when the program line is switched from one system to the other, the receivers have to adjust themselves to the new sync signal. The horizontal (line frequency) scanning changes very quickly in most cases, but the vertical (field frequency) scanning circuits have much more inertia and do not respond quickly. If the vertical pulses in the two systems happen to be in phase at the moment of switching, there will be almost no disturbance in receivers. However, such a condition is a rare occurrence, and in most cases the pulses will be out of phase. The usual result is therefore that the picture on a receiver will "roll over," much to the annoyance of the viewer.

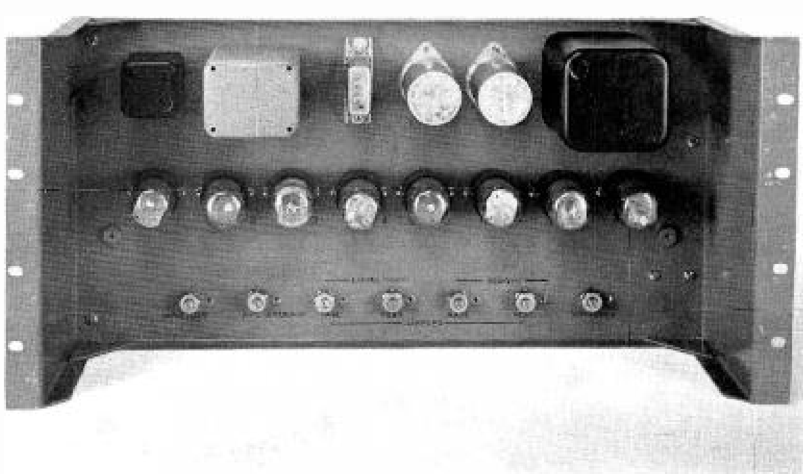
Another limitation is the impossibility of using lap-dissolves and superpositions involving pictures from two unrelated television pickup systems. The increasing use of lap-dissolves and superpositions in studio programs makes it seem more and more desirable to provide means to produce the same effects at all times regardless of the sources of the signals to be treated. To make them possible, the sync generators must be locked together tightly, field for field and line for line, just as though the whole system were operating on one generator instead of two.

The most direct solution to this problem is to provide means for locking the local sync generator, as a slave, to the remote generator, as a master. This is the direct solution because it requires no additional transmission facilities, between the two pickup points, beyond those already necessary for program connection. The remote signal, received at the main studio for connection to the transmitter, may be used for comparison with the local sync generator signal, thus providing an error signal which can be used to control the operation of the local generator. The equipment for making the comparison and for producing the error signal is located at the main studio. No special equipment is needed at the remote pickup point. Once the equipment for this control of the local generator is functioning, the remote signals may be treated as local signals in any of the common types of switching transitions and superpositions, thus making it possible to go back and forth from one source to the other without concern as to the point of origination.

A few telecasters have developed equipment for their own use* to make possible smooth integration of remote and local programs. These have served quite successfully, but so far as is known, they require very precise initial manual adjustments in order to establish the proper phase relationships.

Foreseeing the need and the demand for simple, automatic, and fool-proof means for tying two television pickup systems together, RCA engineers have developed a device called the Genlock, which accomplishes the desired lock-in automatically without any manual phasing adjustment whatever.

FIG. 1 (below). Front panel view of the Genlock which is designed for standard rack mounting.



* "Mixing Local and Remote Television Signals," W. E. Wells and J. M. Weaver, TELE-TECH, January 1950.

How It Works

The Genlock is a unit which combines two separate circuits which serve to provide control signals to the line frequency and field frequency sections, respectively, of the local sync generator.

The first consists of an afc discriminator which derives a varying d-c error signal from the comparison of the horizontal driving signal (from the local sync generator) with the separated sync signal derived from the remote picture signal. This latter sync signal must be separated from the composite picture signal in some other equipment such as the RCA TA-5C stabilizing amplifier. No separator circuit is provided in the Genlock. The error signal is applied to the reactance tube in the local sync generator, thus directly controlling the frequency and phase of the master oscillator. The control is rigid, allowing no perceptible horizontal drift or instability between the two pictures.

The second circuit compares the sync signals, one from the local sync generator and the other from the sync separator operating on the remote picture signal, and from this comparison derives an error signal in the form of a positive pulse recurring at field frequency. As long as the two field frequency signals are out of phase, the pulse exists, but as soon as they become coincident, the error pulse ceases to exist. The error signal is applied to the 7:1 counter circuit in the local sync generator (RCA TG-1A or TG-10A) in such a way as to cause it to miscount. As long as the error signal continues to recur, the local field frequency drifts at an accelerated pace causing the two signals to approach in phase. At the instant of coincidence the error signal disappears and the counter circuit begins to operate normally. Thereafter the two signals remain in phase as long as the Genlock continues to function.

The operation of the line frequency control circuit is quite rapid so that lock-in of the horizontal scanning circuits appears to be almost instantaneous. The field frequency control circuit, however, requires a variable amount of time to assume full control depending on the initial phase difference between the two signals. Phase shift brought about by the control occurs at a definite rate of 3 scanning lines per field. The maximum amount of shift ever required is one full field, or 262.5 lines. Thus the maximum time required to achieve control is about 1.46 seconds.

The accompanying block diagram illustrates the functioning of the two control circuits in the Genlock. From the local horizontal drive signal, a sawtooth wave is generated at line frequency, while the remote sync signal serves to produce a pulse signal at line frequency by means of a blocking oscillator. The sawtooth and pulse signals are then applied to an afc bridge in the usual manner, thus producing the variable d-c error signal. Coincidence of the steeper slope of the sawtooth with the blocking oscillator pulse produces an error voltage of the proper polarity to maintain lock-in.

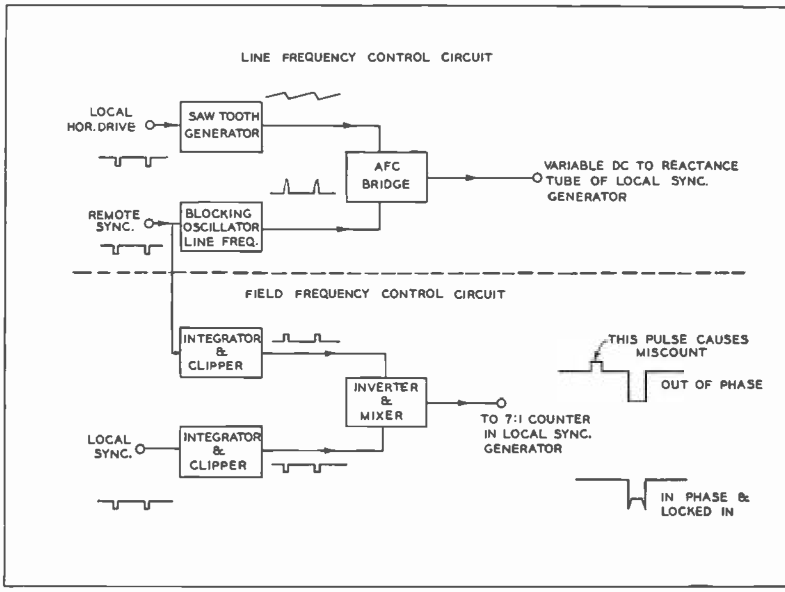


FIG. 2 (above). Simplified block diagram illustrating operation of the Genlock.

In the case of the field frequency control circuit, the two sync signals are passed through identical integrators to remove the line frequency components, and the remaining field frequency pulses are then clipped twice in similar clippers to produce well-shaped pulses of equal amplitude but slightly different width. These two pulse signals are then mixed in such a way that the wider pulse produces a negative pulse signal of large amplitude, while the narrow pulse produces a positive pulse signal of relatively small amplitude. When the two pulses are not coincident, the mixed signal appears as a combination of positive and negative pulses separated in time as illustrated in the block diagram. However, when the pulses coincide in time, the positive pulse is completely swallowed by the larger and wider negative pulse about as indicated. Since the 7:1 counter is not responsive to negative pulses, the miscounting ceases as soon as the coincidence occurs.

The Genlock never requires more than one field to bring the field frequency pulses into phase. The reason is that when it causes the counter in the sync generator to miscount, it is possible, under the proper conditions, to bring about a conversion of an "even" to an "odd" field, or vice versa. This may be understood as follows. As stated before, the rate at which the field frequency phase shift occurs is three lines per field because the pulse which causes the miscount is three lines wide. Just preceding the final cycle of miscounting, however, the positive and negative pulses may be in partial coincidence with respect to time. This partial coincidence will result in a positive pulse less than three lines wide. In fact, the pulse will have a width which is some integral number of half lines in magnitude, say, 1, 2, 3, 4, or 5 half lines. If the number is odd (1, 3, or 5), the miscount will be ½, 1½, or 2½ lines respectively, and the field sequence will be shifted automatically from "even" to "odd," or vice versa. If the number is even (2 or 4), the miscount will be 1 or 2 lines respectively, and there will be no shift in field sequence.

Thus it may be seen that the Genlock is entirely automatic in operation, and requires only the proper information in the form of suitable signals to bring about a solid "marriage" of the two sync systems. The only control necessary is a switch for disconnecting the normal frequency reference standard and at the same time connecting the output of the Genlock to the proper circuits in the local sync generator.

Acknowledgment

Credit is due to F. W. Millspaugh and A. H. Turner, who contributed much to the development of this device, and to Dr. H. N. Kozanowski, under whose direction the work was done.

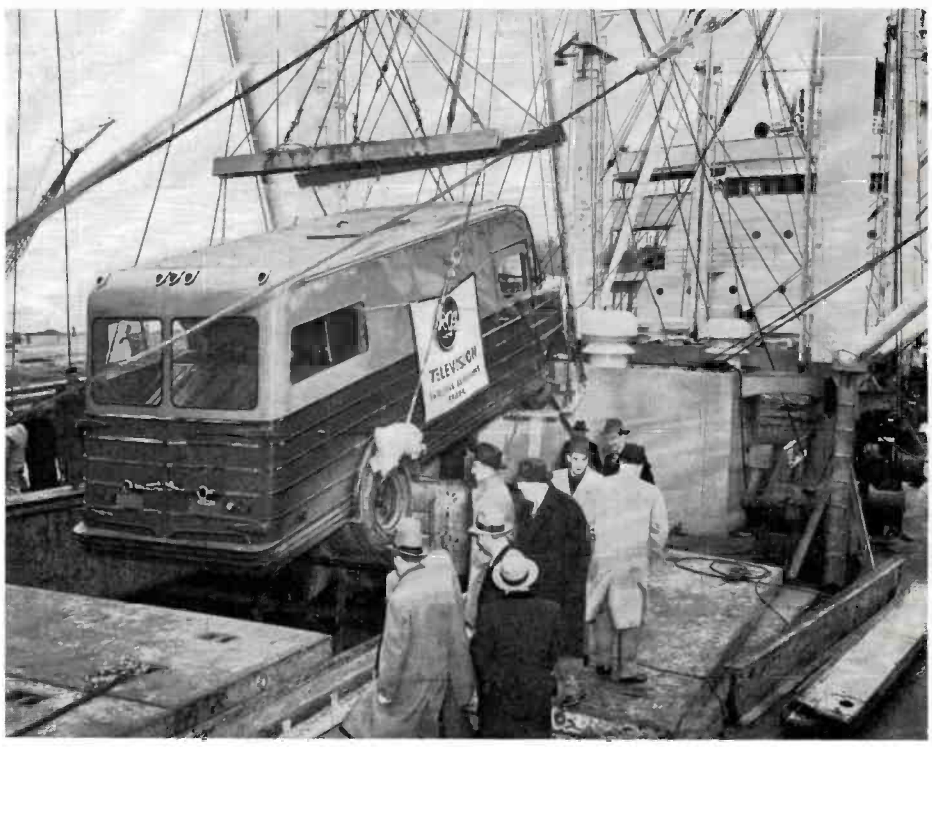
BRAZIL'S LARGEST RADIO NETWORK

Brazil's largest radio network—Emissoras Associadas—will soon introduce television to the fast-growing business center of Sao Paulo. All equipment will be supplied by the Radio Corporation of America, according to an announcement by Meade Brunet, Vice President and Managing Director of the RCA International Division.

Arrangements for the installation of the television transmitter as well as associated studio and mobile pickup equipment, were begun in 1948 and concluded during the recent visit to the United States by Dr. Assis Chateaubriand, Director General of the Brazilian network. The station is expected to be on the air in the summer of 1950.

The transmitter and antenna of the new station will be located atop Sao Paulo's highest edifice, the State Bank Building. The installation will include a three-bay super-turnstile antenna, which is to be 520 feet above street level and which is capable of radiating 20 kilowatts of power. New

(ABOVE) Complete equipment for Emissoras Associadas' TV station in Sao Paulo is being furnished by RCA. Installation will include a standard Type TT-5A (5 KW) Transmitter, a three-bay turnstile antenna, studio equipment, remote pickup equipment and a Type TJ-50A Mobile Unit (shown above being hoisted aboard ship).

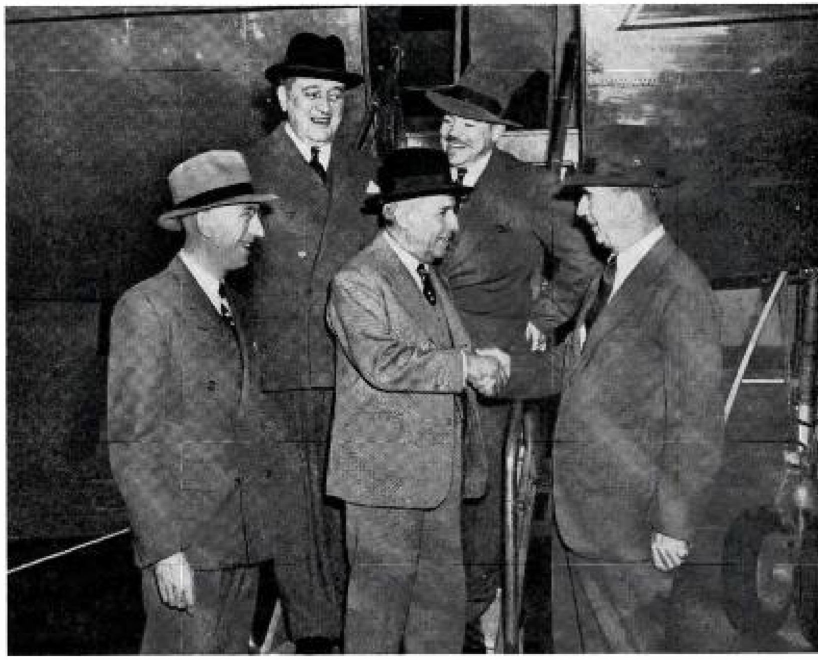


(RIGHT) Lowering the mobile unit into the hold of MORMACYORK at Philadelphia Port. Equipment, which was shipped several months ago, is now being installed and is expected to be in operation by mid-summer. Station will operate on U. S. Channel 3 (60-66 mc) and use U. S. standards of 525 lines and 60 fields.

INSTALLING RCA TV TRANSMITTER

studios now are under construction in a Sao Paulo suburb called Sumare. Provisions are being made for the use of RCA microwave transmitting equipment between the studio, outdoor mobile pickup units and the main transmitter. Since the city's power supply is of 60 cycles, it will be possible to use United States television standards of 525 lines and 60 fields. The station will operate on Channel No. 3.

In his announcement Mr. Brunet revealed that since 1946 the Brazilian network has purchased from RCA eleven broadcasting transmitters, which have been erected in that country's principal cities. He said the network had recently purchased two 50-kw transmitters for installation at the strategic ports of Bahia and Porto Alegre. At the same time a 10-kw transmitter was purchased for installation at Recife. Other RCA transmitters in Brazil are in operation in Rio de Janeiro, Sao Paulo, Belo Horizonte and Fortaleza. They include two 50-kw, two 10-kw, one 7½-kw, two 5-kw and one 1-kw stations.



WELCOME TO BRAZILIAN NETWORK HEAD. Dr. Assis Chateaubriand, front row center, President of Emissoras Associadas, Brazil's leading netwo.k, and Brazilian diplomatic representatives, are welcomed by RCA officials as they arrive in Washington to witness RCA color television demonstration. Emissoras Associadas is installing Sao Paulo's first TV station, RCA equipped. Right front: Meade Brunet, Vice President of RCA and Managing Director of RCA International Division. Left front: Perry Hadlock, President of RCA Victor Radio, S. A., RCA company in Rio de Janeiro. Second row, Left: Cyro Freitas-Valle, Brazilian ambassador to the United Nations and Theophilo de Andrade, Minister plenipotentiary of Brazil.

RCA DEVELOPS NON-SYNCHRONOUS TELEVISION RECEIVER AS STEP TOWARD SOLVING PROBLEMS OF INTERNATIONAL TELEVISION STANDARDS

A major step toward solving problems of international television standards has been achieved through development of a new RCA television receiver built to operate on the varying power line voltages and frequencies prevalent in many foreign countries. In announcing the new development. Meade Brunet, Vice President of RCA and Managing Director of the RCA International Division, said that the set, which has been especially designed for synchronous operation, was demonstrated with success recently at Milan, Italy, where competitive tests with other makes showed it to be the only receiver capable of providing satisfactory performance under varying power frequencies.

"All countries abroad are familiar with the problem of variation in voltages and frequencies," stated Mr. Brnnet. "It has been one of the main obstacles in the adoption of universal television standards."

The new RCA non-synchronous television receiver was designed for world markets by engineers of the RCA International Division in conjunction with the RCA Victor Division. It operates from any voltage between 110 and 240 and on any power frequency between 40 and 60 cycles. This power supply need not be the same as the power furnished the transmitting station. The set operates on either the American system of 60 fields (30 frames), 525 lines, or on the proposed European system of 50 fields (25 frames). 625 lines. Another feature is that the set will receive any of the 12 very high frequency channels, in contrast with most foreign-made receivers that pick up only one channel.

"The new receiver is a major step toward the establishment of international television standards," Mr. Brunet continued. "It facilitates the interchange of programs between nations, as well as between different cities of the same country with different power frequencies.

"It is a versatile receiver. For example, should the receiver be operated in a location with a power line of 220 volts, 50 cycles, it can pick up telecasts from a station operating on 60 fields and 525 lines. In another location, the same receiver may operate on 150 volts, 42 cycles, and receive from a station using 50 fields and 625 lines."

Mr. Brunet said that television engineers of the RCA International Division are continuing their efforts to achieve still more flexibility in television receivers, while maintaining a close watch on the cost to the ultimate consumer.

"It is the express policy of this Division to aid in finding a solution to the question of International Television Standards," he concluded.

THE "BANTAM" MIKE - - KB-2C

L. J. ANDERSON and **L. M. WIGINGTON**
Supervising Engineer — Design Engineer

The introduction of the Type KB-2C Velocity Microphone has provided the Broadcast Industry with a valuable tool. This new microphone, about the size of a package of cigarettes, in many respects approximates the performance of the popular Type 44-BX Velocity Microphone, and offers some further operational advantages. It is so small that the artist's or speaker's face is not hidden (see Figure 1), a feature which is valuable on remote programs and on television pickups where the microphone must be in the picture. It is also very light and requires no special amplifiers or cables, thereby simplifying transport in addition to making possible the use of light supporting means.

Small size (see Figure 2) and weight have been obtained without sacrifice in output level. Compactness has actually resulted in directional characteristics which more nearly approach the ideal for a velocity microphone over the entire frequency range (see Figures 3 and 4). The frequency range is fully adequate for all operations. The microphone contains many interesting mechanical features aside from its small size. It is rugged for its particular type and incorporates a sponge rubber cushion mounting between the head and shank assembly. Additional cushioning should be necessary only when the microphone is used on a boom where it is necessary to change the location of the microphone frequently and rapidly. The usual unsightly cable and plug connection is "built-in" the shank portion of the microphone which in addition to serving as a mounting means may be used as a handle in applications where one is required. Access to the connecting plug is obtained by means of a hinged cover forming the rear portion of the shank. The Cannon Type XL Connector was chosen for the application because its small size and quality are in keeping with the purpose of the design.

The microphone also contains electrical features which are equally as useful as the mechanical features previously described. The low frequency response is readily adjustable for either voice or music operation by means of a switch that may be operated from the outside of the microphone by use of a small screw driver. The characteristic for the voice position has been selected so that response is approximately flat when the sound source is located about 9 inches from the microphone (see Figure 5). The design of the coupling transformer has resulted in a sensitivity (to stray 60 cycle magnetic fields) low enough for any normal application. Since the sensitivity of the microphone to stray fields is a function of the direction of the field, it is possible in many applications where high intensity fields are encountered, to minimize the pickup by rotating the microphone. Sensitivity to high frequency fields is kept low by proper grounding and complete enclosure of the microphone parts in the external metal screen and case.

The question naturally arises as to how all of these things can be accomplished in a microphone of the KB-2C size without any apparent sacrifice. The answer lies in painstaking design—the careful selection and use of materials in the most advantageous places. Involved in the design, and all inter-related, are acoustical, electrical, magnetic and mechanical problems.

In a velocity microphone, the response-frequency characteristic will be flat over the frequency range in which the moving system is mass controlled and the pressure gradient applied is directly proportional to frequency.[1] In the case of a plane-wave sound-field this means that the response will be constant for any frequency well above the resonance of the ribbon and below the frequency at which the gradient is no longer proportional to frequency due to the physical dimensions of the parts surrounding the ribbon.

FIG. 1. The artist's (Jinx Falkenberg, in this photo) or speaker's face is not hidden by the Bantam KB-2C Microphone.

Because of its relationship to the low frequency response, the resonant frequency of the ribbon was the first characteristic considered in the design of the microphone. The ribbon is clamped at the ends and the system is a combination of a stretched string and a bar clamped at the two ends.[2] The lowest resonance frequency will be obtained when the tension is zero and this resonance will largely determine the absolute limit of the low frequency response. The resonant frequency for the condition of zero tension is

$$f = \frac{3.56}{l^2} \sqrt{\frac{QK^2}{P}} \text{ cycles per second.}$$

For an aluminum ribbon 0.0001 inch thick

$K = 7.3 \times 10^{-3}$ (Radius of Gyration)

$Q = 5 \times 10^{11}$ (Modulus of Elasticity, dynes per square centimeter)

$P = 2.7$ (Density, grams per cubic centimeter)

$l =$ (length of ribbon, centimeters)

In most of the microphone structures the air load will approximately equal the ribbon density for a ribbon 0.0001 inch thick. The effective value of P will therefore be about 4. Substituting in the above

$$f = \frac{93}{l^2} \text{ cycles per second.}$$

Since it is impracticable to install the ribbons without tension and because of the stiffness coupled into the mechanical system from the electrical load, the following expression is more realistic

$$fe = \frac{4.5 \times 93}{l^2} \text{ cycles per second.}$$

The low frequency limit (fe) was set at 60 cycles on the basis of satisfying most requirements. Substituting this value into the formula, the minimum ribbon length is found to be approximately 1 inch. Thus it was possible to use a ribbon only one-half the length of that in the Type 44-BX Velocity Microphone, providing the same sensitivity could be obtained.

The generated voltage in the ribbon is $e = B\, l\, \dot{v} \times 10^{-8}$ (volts)

where $B =$ Flux density in gap (gausses)

$\dot{v} =$ Velocity amplitude of the ribbon (centimeters per second)

$l =$ Length of ribbon (centimeters)

[1] "Elements of Acoustical Engineering." Dr. H. F. Olson. 2nd Edition. Chapter VIII, Pages 237-252.

[2] Unpublished Technical Report. By Dr. H. F. Olson.

FIG. 2. The KB-2C Bantam Microphone (as shown in this production line photo) is much smaller than the popular Type 44-BX Velocity Microphone.

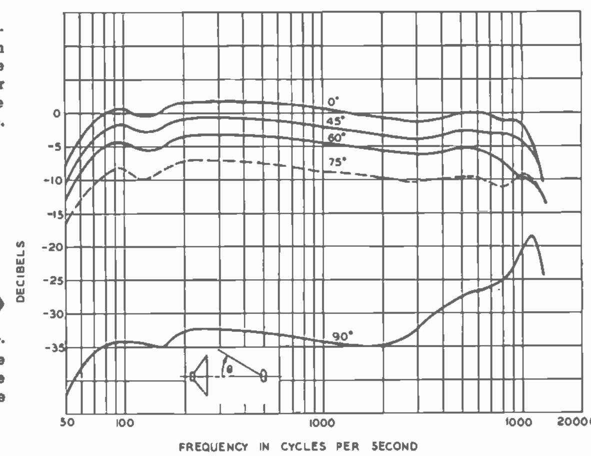


FIG. 3. Directional characteristic of the Type KB-2C Velocity Microphone when rotated about the vertical axis.

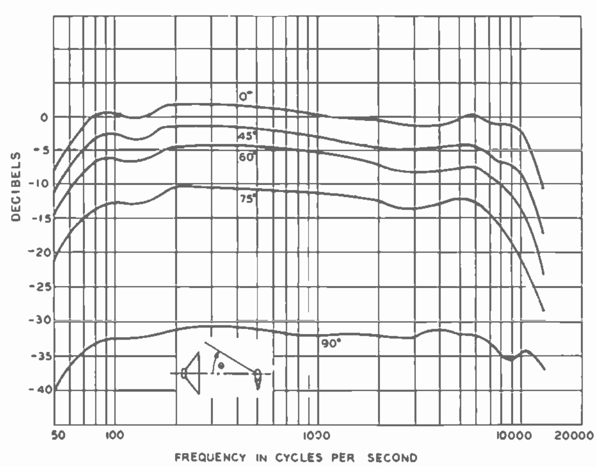


FIG. 4. Directional characteristic of the Type KB-2C Velocity Microphone when rotated about the horizontal axis.

A measure of the efficiency of the microphone will then be

$$\text{Eff.} \; \alpha \; \frac{e^2}{R_R} = \frac{(B\, l\, \dot{v})^2}{R_R}$$

where R_R is the electrical resistance of the ribbon in ohms. The loss in generated voltage, because of the reduced ribbon length, must therefore be made up either by increasing the flux density in the air gap, by some change in the physical structure, or a combination which will increase B, the net increase required being 1.4.

The ribbon width was chosen so as to maintain approximately the same lateral stability as in the Type 44-BX Velocity Microphone. Since the new ribbon is one-half the length of the ribbon in the Type 44-BX Velocity Microphone, as might be expected, a ribbon of approximately half the width was found to give the same stability. The reduction in width necessitates an additional increase of 1.4 in the factor $B\,\dot{v}$.

The extent of the high frequency range was tentatively established at 10,000 cycles. The limit of the high frequency response of the microphone is determined largely by the baffle area surrounding the ribbon and good response will be obtained up to the point where

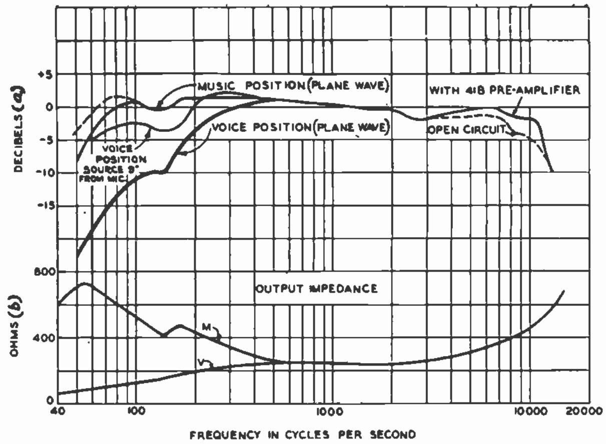
$$R = 0.5\,\lambda$$

R = the distance from the ribbon to the edge of the structure.

λ = the wavelength of the highest frequency at which good response is desired.

With 10,000 cycles established as an upper frequency limit, R will be about 0.66 inch. In the actual structure it can be somewhat larger because the path at the ends of the ribbon is less than this value, thus serving to lower the average.

FIG. 5. ("A," upper curves) Response-Frequency characteristic for plane wave and source 9 inches from microphone. ("B," lower curves) Impedance - Frequency characteristic.



The problem then remained to design a magnetic circuit which (within the established ribbon and baffle dimensions) would provide the desired output level. As mentioned, this level was tentatively set at being equal to that of the Type 44-BX Velocity Microphone. The desired result was accomplished with a magnetic circuit of novel design in which the permanent magnet material forms the pole pieces and the return path is a part of the external microphone structure. Such an arrangement is very efficient both with regard to the amount of magnet material required and the amount of iron in the return path. The amount of magnet material required is reduced by virtue of the fact that the leakage flux which must be handled is much reduced by placing the magnetic material as close to the air gap as possible; and since only a portion of the leakage flux returns through the iron path, the section of the magnetic return path is also surprisingly small. The properties of Alnico V were ideal for the permanent magnet material.

As mentioned previously the resonant frequency of the ribbon occurs at about 60 cycles, well within the audio range, and must be critically damped through the use of a suitable acoustic resistance material. This arrangement materially reduces the sensitivity of the microphone to mechanical excitation by low frequency building rumble, but does necessitate care in making ribbon replacements to assure the use of a correct value of resonance and acoustic damping. Failure to do so may result in a microphone whose low frequency response is particularly unsatisfactory because of its being excessively high.

In order to complete the small microphone it was necessary to design an extremely small impedance matching transformer, compensating reactor (see Figure 6), and switch, all of which are housed in the die casting immediately below the ribbon and magnet assembly.

The microphones have now been in service for a period of time, and an appraisal of some of the unforeseen difficulties with this radically small microphone can be made and remedies discussed.

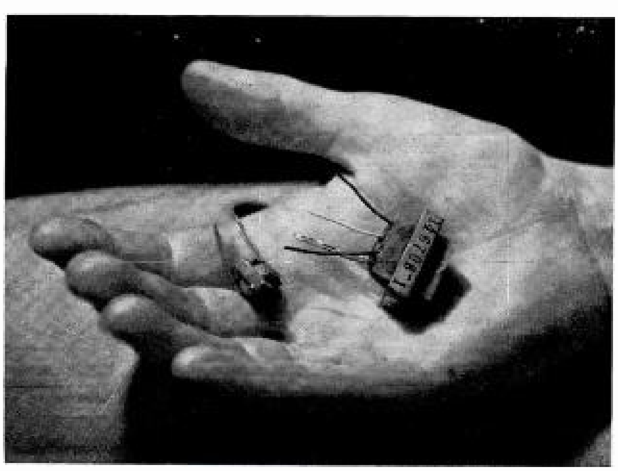


FIG. 6. Miniature size compensating reactors and impedance matching transformers are employed, as shown in this photo.

The small size of the microphone has indirectly resulted, in many cases, in an aggravated exaggeration of the low frequency response such as is always experienced when the speaker is close to a velocity microphone, and in addition the ribbon is excited by the breath puffs to a greater extent than with larger microphones such as the Type 44-BX Velocity Microphone. This condition results from a combination of two things. First, the smaller microphone apparently invites the user to get much closer because it is possible to do so without feeling restricted by the presence of the microphone. Second, the small size of the microphone screen enables the user to get much closer to the ribbon. As an example, the Type 44-BX

Velocity Microphone limits the closeness of the user to a minimum of about 1½ inches, whereas the limit on the Type KB-2C Velocity Microphone averages no more than ¾ inch. (The effect of source proximity on response is shown in Figure 7.) In addition, the excitation by breath puffs is increased beyond the normal expectancy because the effectiveness of the windscreen is reduced by its closeness to the ribbon.

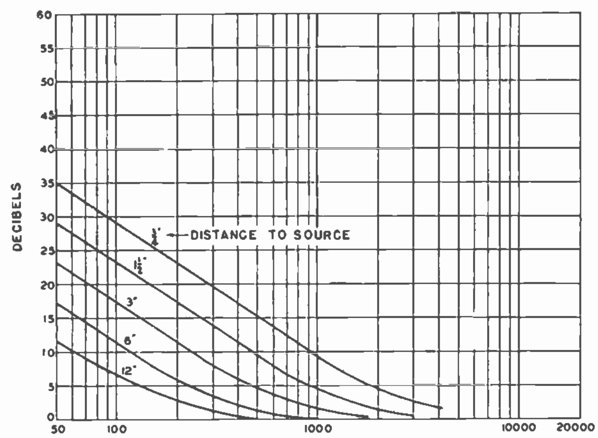


FIG. 7. (above). Curves showing increase in low-frequency response of velocity microphones due to proximity of source.

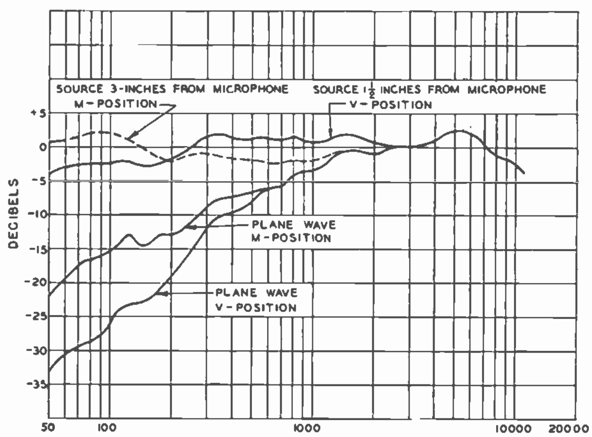


FIG. 8 (above). Response-Frequency characteristic of KB-2C for plane wave and close talking (curves show how special packing results in anti-noise characteristic).

Considerable effort has been expended in trying to improve the windscreening without seriously affecting the response-frequency characteristic or increasing the microphone size, and apparently no good solution exists.

Out of this work, however, came one interesting and useful result. Where the microphone is always used for close talking applications or where some attenuation of the low frequency response is permissible, it is possible to improve the windscreening considerably by the addition of cotton, super fine fiberglass or similar acoustic materials between the inner and outer screens. In addition other operational advantages result. Figure 8 shows the response of the modified Type KB-2C Velocity Microphone to a plane wave, and also the response when the microphone is used for close talking applications. As can be seen, the response-frequency characteristic obtained for close talking is substantially flat from 50 to 9000 cycles.

Above 1000 cycles the discrimination against random unwanted sound is about 19 db better than that obtained with a conventional pressure microphone used at a distance of 6 inches. Below 1000 cycles the discrimination increases gradually to a value of 44 db at 100 cycles. The net result is (for the first time) a high fidelity anti-noise microphone.

Numerous applications will no doubt suggest themselves, in addition to the following two. In programming, where the announcer can work close to the microphone, background noise can be eliminated. On programs where audience participation necessitates the use of a Public Address System in combination with a microphone which is circulated among the audience, feedback can be completely eliminated while maintaining a reasonably high level on the Public Address System.

The excellent frequency response, high output level, absence of excitation due to breath, and anti-feedback characteristics are truly amazing.

A temporary means of accomplishing approximately the same thing would be to enclose the screen portion of the microphone with a handkerchief which has been folded several times.

Using the standard stock microphone, satisfactory performance can be assured if the microphone is used at distances of 18 inches or more for the "M" position, and not less than 9 inches for the "V" position.

The use of high-flux densities and screens closer to the ribbon (required in a design of the KB-2C miniature size) increases the likelihood of magnetic dirt particles entering the gap between the ribbon and the pole piece. Such particles, if in contact with the ribbon, inhibit its motion thus resulting in loss of low frequency response. The collection of particles in a more remote part of the gap might cause the microphone to become noisy when it is subjected to any motion which results in relatively large, low-frequency movements of the ribbon. In this case, noise could result from intermittent contact between magnetic particles and the edge of the ribbon.

Fortunately, a simple and effective method (a magnetic screen) eliminates this possibility, and KB-2C microphones thus equipped are practically impervious to the entry of magnetic dirt particles. The magnetic screen is simply a small piece of wire mesh of magnetic material, slightly bowed, and placed over each side of the ribbon inside the outer screen. The ends are lightly plugged with cotton to prevent entry of dirt. The presence of the screen wire in the magnetic leakage field serves to concentrate the flux at the points where the wires are located. This produces magnetic poles which prevent the magnetic particles, that penetrate the outer screen, from being drawn into the air gap of the microphone. All KB-2C microphones being manufactured are equipped with magnetic screens.

The design of the Bantam KB-2C Microphone is providing broadcasters with a miniature-size unit which offers both excellent performance and reliability. Because of its lightweight and small size, the KB-2C is ideal for remote applications, as well as for banquets, night club shows, or for other occasions where it is important that the artist's face be in full view. In addition, the KB-2C is fast becoming a favorite for standard use in Television, AM and FM studios and control rooms.

FIG. 1. Housed in a modern building designed specifically for television, and situated on one of the highest hills in Baltimore, WAAM is one of the few TV stations in the country which can boast complete facilities under one roof.

WAAM
Baltimore

By
BENJAMIN WOLFE
Director of Engineering
and
GLENN LAHMAN
Chief Engineer

FIG. 2. Mr. Glenn Lahman, Chief Engineer of WAAM and co-author of this article, adjusts the on-air monitor of the TT-5A. Standing, left to right, are: Mr. Benjamin Wolfe, Director of Engineering, Mrs. Helen Powers, Administrative Director, and Len Haeseler, RCA Sales Representative.

FIG. 3. Mr. Frank Vials, transmitter engineer of WAAM, seated at the console of the RCA TT-5A Television Transmitter. WAAM operates on Channel 13 with an effective 26.1 kw visual power and 13.8 kw aural power. The antenna is a six-section Super Turnstile.

WAAM is owned and operated by a group of civic minded Washington and Baltimore businessmen under the name of Radio-Television of Baltimore, Inc. The station received its construction permit in March of 1948, and construction of the building was begun immediately. Shortages of steel and other critical materials, coupled with heavy spring rains, delayed completion of the installation, but WAAM was on the air with its television debut on November 1st, and on November 2nd covered election returns for 23 hours.

In the early planning, it was decided that the entire operation should be compact and yet retain all the requisites for possible expansion in the future. All of these things pointed to the desirability of having the entire operation under one roof. Existing buildings did not satisfy these requirements so it was decided to erect a new building at the best site obtainable.

The site chosen is practically ideal in that it is only four miles from the downtown section of Baltimore and is on the highest hill in the area. City busses run past the street leading to the station. At the top of the hill a large parking lot provides space for more than 100 automobiles.

Large picture windows in the lobby at the entrance to the building afford an excellent view of the surrounding city. A wing off the right side of the lobby contains programming, accounting, publicity, traffic and operations offices. Newsrooms, makeup rooms and rest rooms lead off this wing.

Mr. Samuel Carliner, former Judge of the Peoples Court of Baltimore, is now Vice President of Radio-Television, parent organization of WAAM. Following graduation from the University of Maryland Law School in 1926, and post-graduate work at Johns Hopkins University, Mr. Carliner entered the legal profession. He became Judge in 1935, retiring from the Judgeship in 1939.

MR. SAMUEL CARLINER

Directly in back of the lobby is a 20 by 30 foot soundproofed studio, accessible either from the lobby or from either of two corridors, one of which joins the makeup rooms and the other leading to the studio control room and the main studio. To the left of the lobby is located the art department, which in conjunction with the large main studio, forms the entire west wing of the building. Two wide corridors provide entrance to the main studio as well as an overhead sliding door opening to the outside.

The entire rear portion of the building, measuring about 50 by 75 feet, houses the engineering department and this space is sub-divided into smaller rooms housing the transmitter, master control room, projection room, film storage, announce booth and transcription storage, shop space and a garage for the mobile unit and station wagon. The master control room has large plate glass windows on three sides allowing full view of the transmitter control room, announce booth and projection rooms. A darkroom, the oil heating plant and air conditioning systems for studio and control rooms are located in the basement below the engineering department.

Installation of technical facilities was performed by Frank Viles, Roger Perbault, Maurice Johnson and Merlin Pitts under the direction of Warren L. Braun. Charles Blair and Glen Lahman joined the engineering staff before the start of air operations. In past months Charles Ports, Robert L. Hankey, Stan Anderson and Vince Yannuzzi have also joined the engineering staff.

Studios

Facilities for production of indoor live shows consist of two studios and a single studio control room. The control room being located between the studios can be used for either or both studios with ease.

Around three sides and through the center of the main studio, a steel catwalk is suspended 18 feet above the floor. Access to this is provided by three steel ladders in the corners of the studio. The catwalk allows practically any combination of lighting effects and has been used with great success in supporting cameras for overhead shots of large groups being televised.

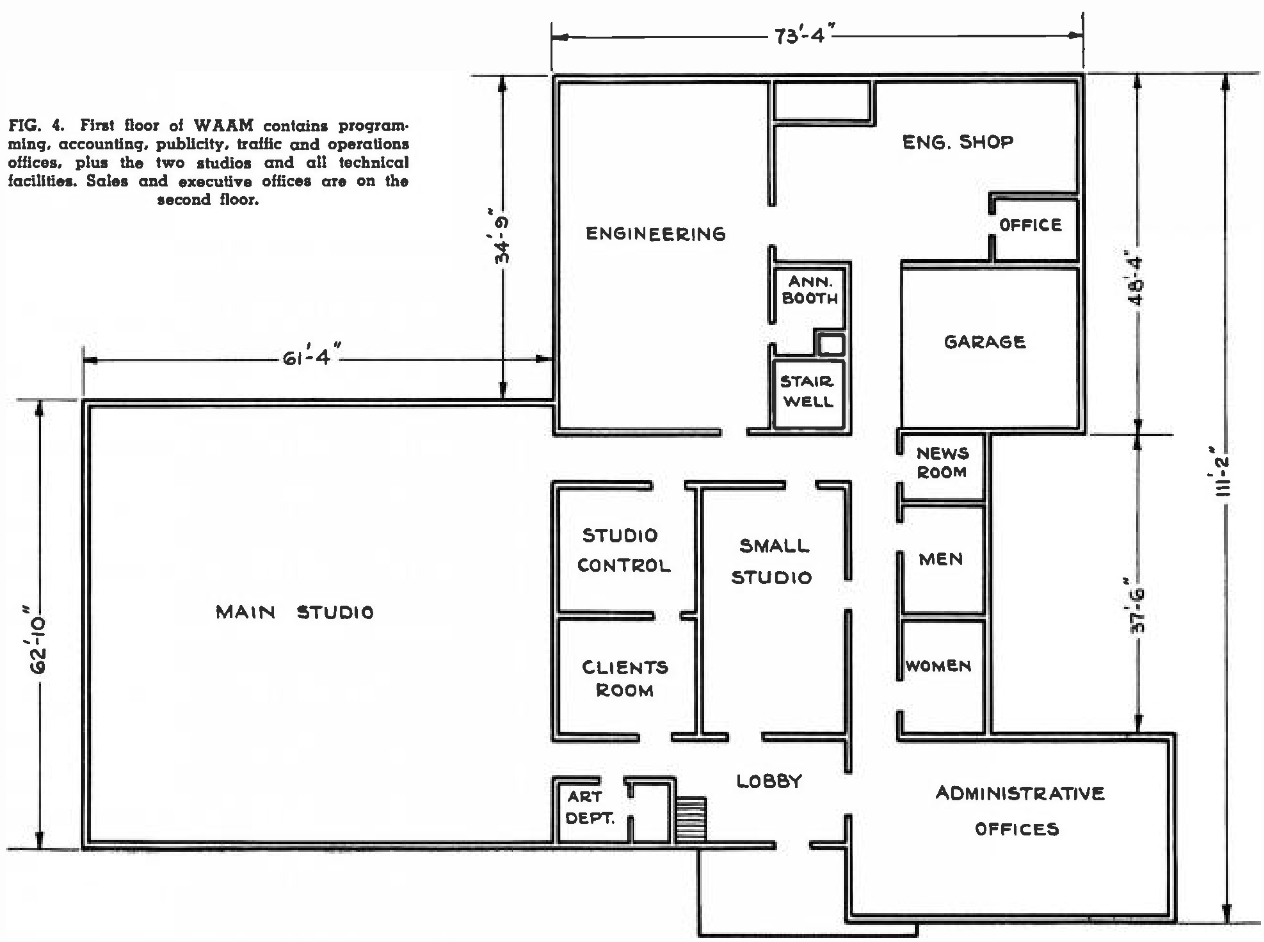
The walls and ceiling of the main studio are thoroughly sound treated with acoustical blanket 3 inches thick. The studio ceiling is suspended from the outer roof by means of a steel suspension system which provides approximately 3 feet of insulating space between the ceiling and outer roof.

The studio is air conditioned by a 25 ton unit which is located in the basement and connected to the studio through large metal sound treated ducts. The low velocity of the air and the acoustic lining of the ducts result in a noiseless system which is more than sufficient to maintain the temperature constant even though large numbers of hot lights are used.

Lighting

WAAM has experimented at great length with various types of lights. Among these have been "hot" incandescent lights, fluorescent, cold cathode and mercury vapor types. Neon tubing filled with different gasses at different pressures were also tried

FIG. 4. First floor of WAAM contains programming, accounting, publicity, traffic and operations offices, plus the two studios and all technical facilities. Sales and executive offices are on the second floor.



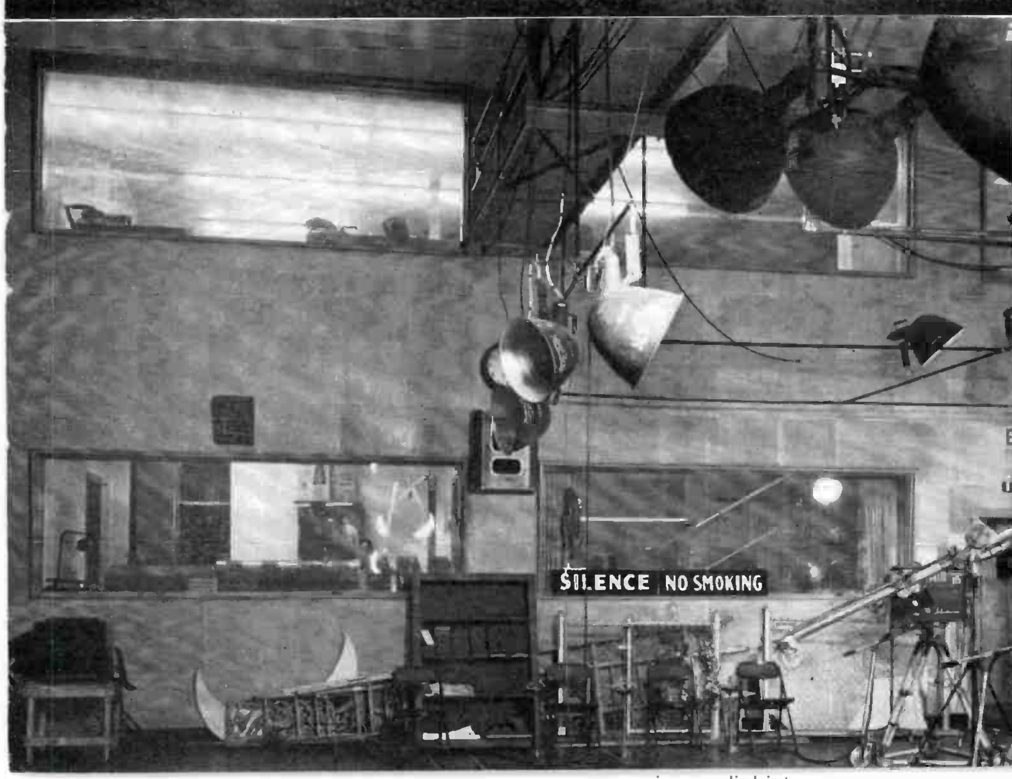


FIG. 5. The large main studio is approximately 65 x 65 x 25 feet, which allows ample room for practically any type program ever televised indoors, and a great many that are usually not. An overhead door at one end of the studio is large enough to permit the movement of large props, automobiles and trucks in and out of the studio.

FIG. 6. Studio control and client viewing rooms look out on the main studio through large windows extending the width of the studio. Both these rooms are raised about three feet above the floor level of the studio. Sales and executive offices on the second floor also overlook the main studio, providing additional space from which visitors can view productions.

FIG. 7. One side of the studio control room contains (at left) three camera controls for the three field-type cameras used in the studio. Other equipment visible, left to right, includes line monitor and TS-10A Camera Switching System, preview monitor, and two film camera controls. Audio console and equipment racks are not shown. Side window joins clients' viewing room.

with various results; no one type of neon light seemed to have been adequate for every type lighting problem. At present hot lighting is used throughout and no serious problems in the realm of color response have been encountered. The lighting system as now used is fused for a maximum of 204 KW and provisions have been made to control each lighting circuit remotely from the studio control room.

At present the lights are mounted on either swiveling arms suspended from cross-bars connected to the catwalks or from a lazy-tongs arrangement allowing adjustment in any plane. Serious consideration is being given to the prospect of mounting all lights on an electrified trolley system. With all lighting overhead the studio floor is kept clear for unlimited camera work. At times, fill-in lights mounted on floor stands are incorporated to illuminate easels, etc.

The main studio is serviced by 18 microphone jacks placed at strategic positions around the edge of the studio, several being in the floor near the middle of the studio. The remainder are located on the catwalk. Thus, a mike can be placed anywhere in the studio with a minimum cable. For outside activities 300-foot extension cables are provided on port-o-reels.

By means of a hybrid coil system in the studio control audio console, records and transcriptions may be played into the studio through bass reflex speakers without going through the regular turntable channels, through both the console and speakers or the console alone. This allows theme music, sound effects, etc., to be heard in the studio as well as on the air. The hybrid system prevents acoustic feedback which would normally result from having the microphone and turntable preamps being coupled to a common bus in the console.

Announce Console

The announce console at WAAM was especially constructed to allow the announcer to have a complete preview system, talk back facilities to either studio or master control rooms, separate monitoring speakers for program and production lines, and call systems.

The console is strongly constructed of plywood on 2 x 2 wooden framework with Masonite panels for mounting of the operating controls. The body of the console is made of plywood panels.

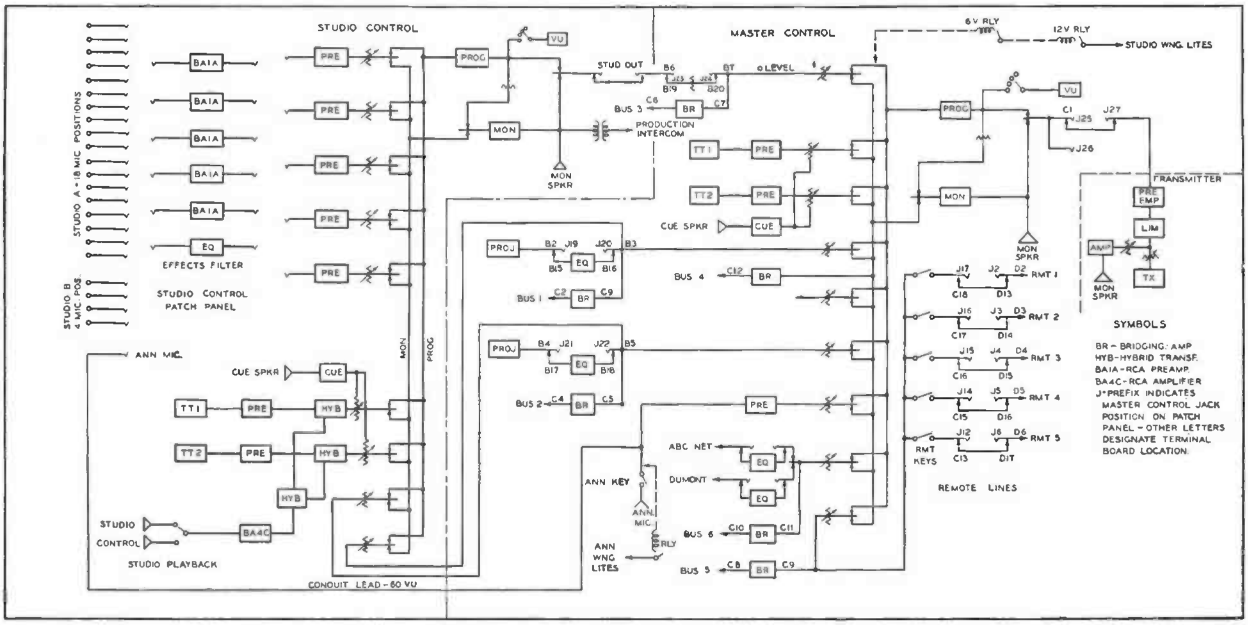
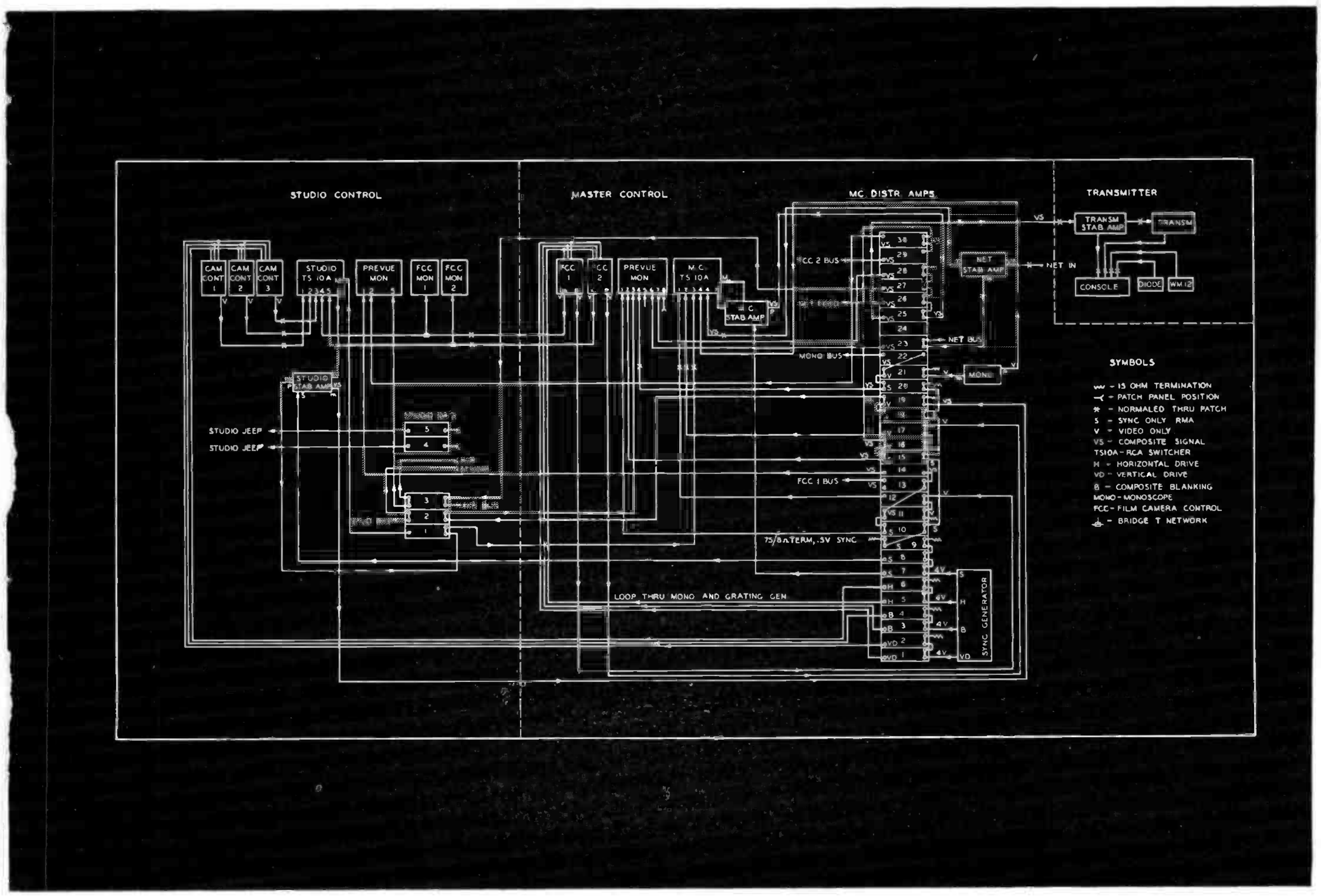


FIG. 8. Block diagrams of the audio and video system of WAAM. Diagrams show facilities for the single studio control room (which is used for two studios), master control, film, and the transmitter room.



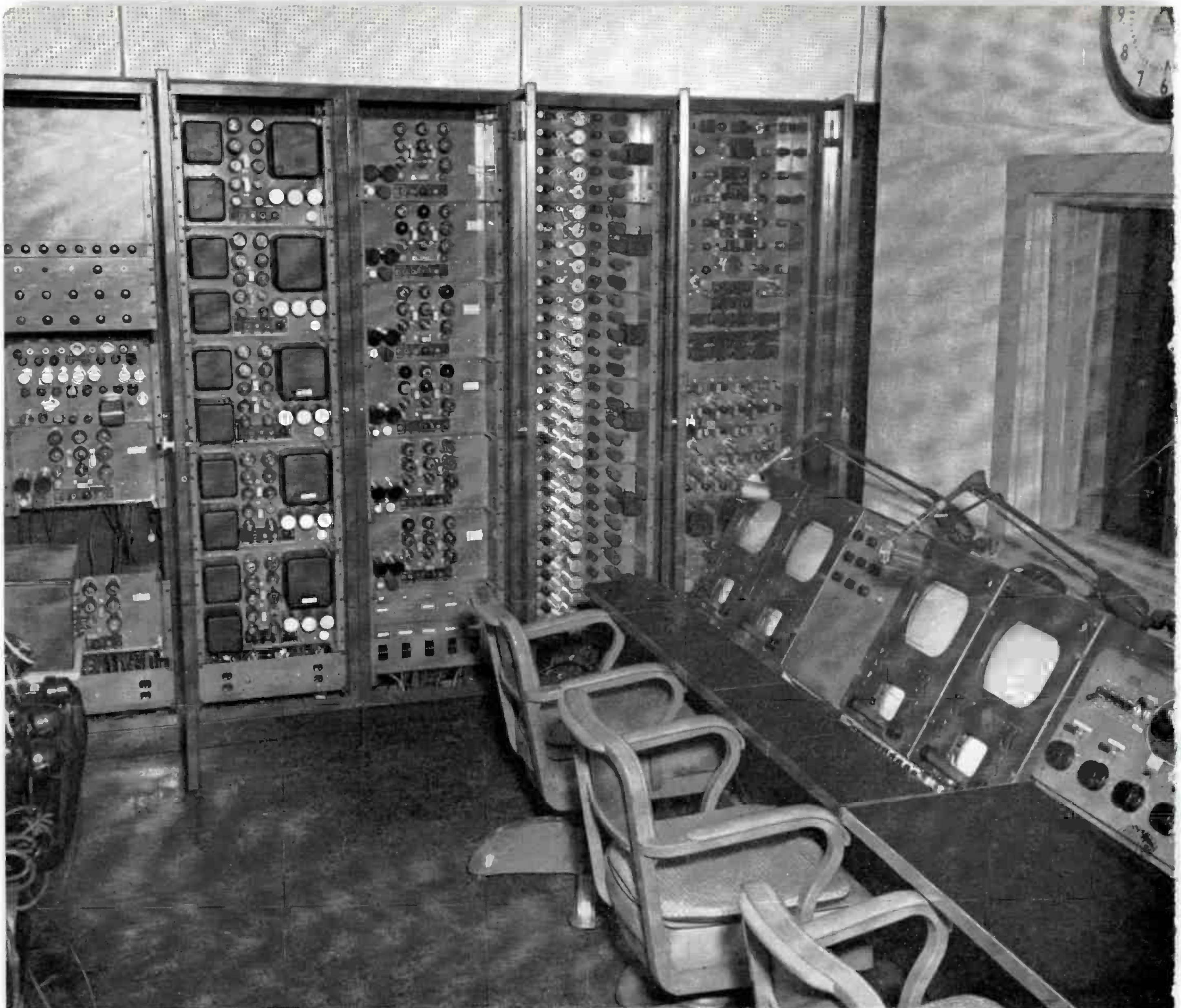


FIG. 9. Master control room above, showing equipment racks and control console. Control equipment, left to right, consists of two film camera controls, preview monitor, and, combined line monitor and TS-10A Switching System. Window looks into transmitter room.
Photo at right is a view of announce console designed and constructed by Bud Johnson, staff engineer. The announce booth is located across the corridor from master control.

An RCA 630-TS receiver chassis was chosen as the monitor unit and suitable changes were made in the audio and video circuits to adapt it to existing audio and video preview circuits in use. The video side consists of all video busses coming into the console and looping through a bridge "T" network and thence on to the next preview position. By pressing a button corresponding to the particular video bus that is desired to appear on the monitor, an associated relay opens the center leg of the "T" network and places the video input of the 630-TS across it. The input of the monitor is so compensated that no change in termination results so that any, none or all of the preview monitors can be across any given circuit with no change in circuit constants. A similar arrangement is used for the audio circuits utilizing a bridging input to the audio amplifier of the 630-TS. Separate pushbuttons for each video and its associated audio channel were used so that the announcer might monitor picture from one source and sound from another.

The three speakers on the console are: call system from master control, "on air" sound, and preview audio as selected by pushbutton assembly. The receiver chassis occupies the center portion of the console and to the right are the following controls. Microphone key and associated pilot lamp with which the announcer can put himself on the air if the master control equipment is set for this type operation. The equipment is usually used this way as the master control audio engineer is thus relieved of one operation during fast productions. When the announce mike is made "hot" all speakers are of course muted. A pair of "split" headphones are worn by the announcer and through these he may hear directions from the technical director and also program sound. Individual gain controls appearing on the console control the level in his phones or he may cut either or both out completely.

Two push buttons directly above the headset gain controls operate talk back circuits so that the announcer may call into either master control or studio control at any time that he may desire.

Drawers and compartments are provided in both sides of the console for storage of paper, pencils and numerous other necessary articles.

In the studio control room the 18 microphone positions from the main studio appear on a jack field as well as four from the small studio. In addition to these, five RCA BA-1A preamplifiers, a sound effects filter and various spares and multiples appear on patch.

Three RCA field cameras are presently used in the studios with a unique camera patching system which allows the cameras to be used in either studio without moving the camera control units. Space has been provided for mounting studio type camera controls, power supplies and current-regulators.

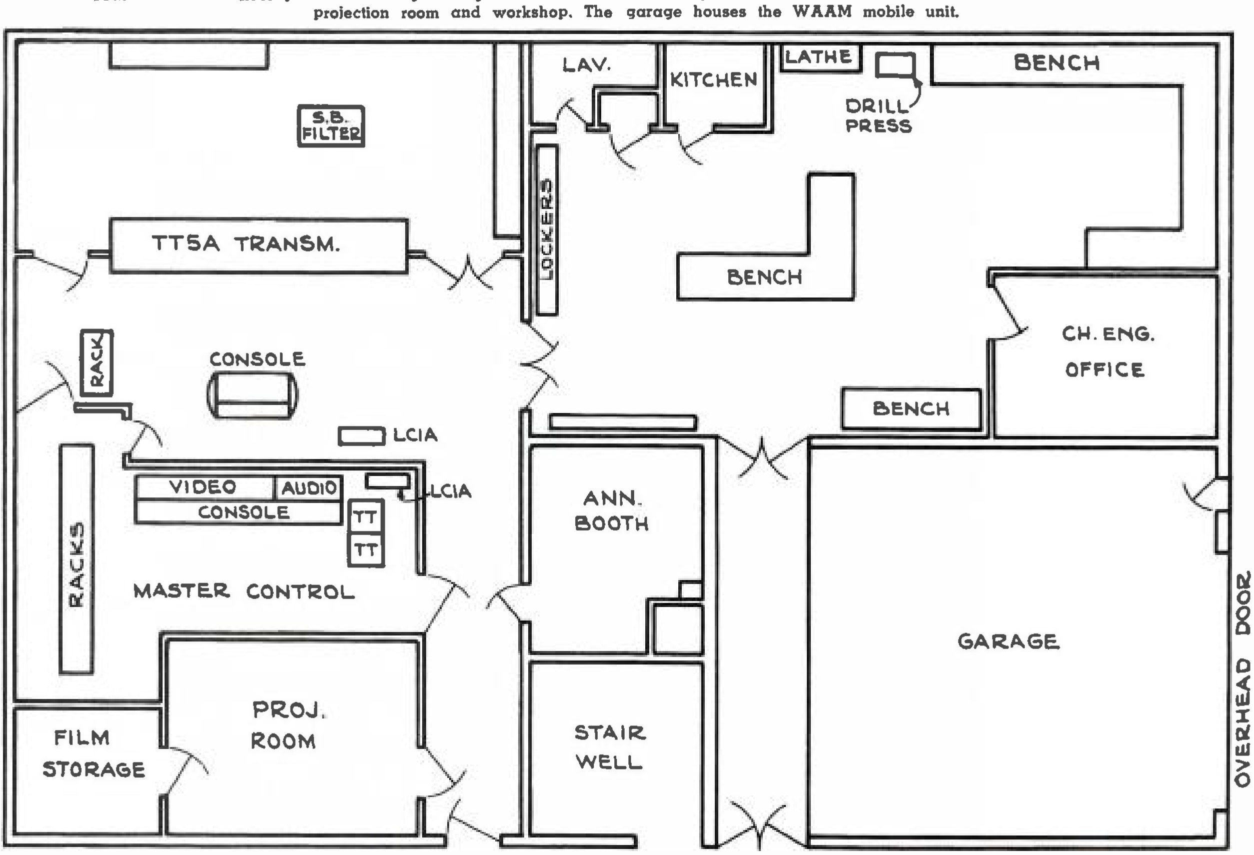
Master Control

Master control is located adjacent to both the transmitter and film projection room. Programs from ABC and Dumont networks, studio and film camera programs are routed through master control. Housed in the six racks of video equipment in master control, are the sync generator, distribution amplifiers, grating generator, network and master control stabilizing amplifiers, and all their associated power supplies. Audio terminal equipment is located in a seventh rack. Ample space has been provided in the rear of racks to assure ease of maintenance.

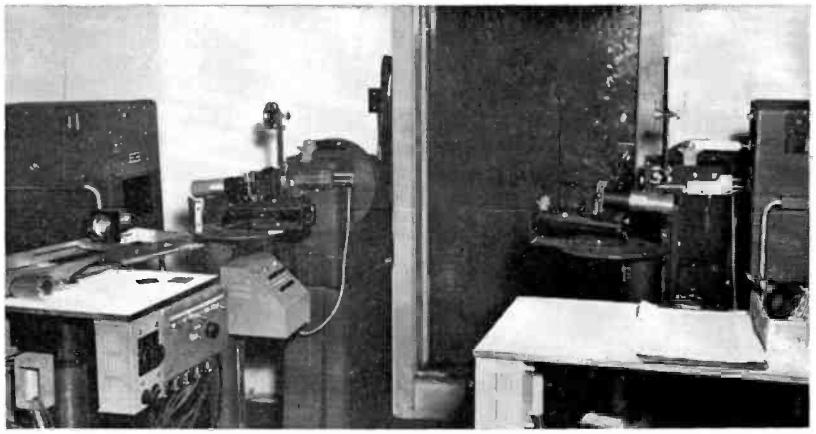
Desk mounted equipment in master control consists of two film camera controls, a TM-5A preview monitor connected to an eight position push-button system. This is part of the preview system carried throughout the station. Adjacent to this is another TM-5A monitor which is operated from the TS-10A Video Switching System. Next to the switcher is the audio console with two transcription turntables mounted at right angles to the console.

The master control room provides facilities for feeding the driving-, blanking-, and sync-pulses to the projection room, studio control and the master control equipment. In addition, closed circuit monitoring of composite signals is distributed from here through various distribution amplifiers to the entire preview system. This

FIG. 10. Partial floor plan of the engineering facilities of WAAM. Diagram shows location of TV transmitter, master control, projection room and workshop. The garage houses the WAAM mobile unit.



preview system is available to the projectionist in the projection room, to the clients' viewing room, to the studio control room, the announcer's booth and master control. Associated with each video preview system, is a similar number of push buttons which permit the selection of audio for monitoring purposes. This, too, is carried to each preview position. The video preview system is an adaptation of the "T" network circuit. Both sides of the master control room are broken by viewing windows. This enables the projectionist to observe the film camera control monitors in the master control room in addition to the monitor located in the projection room. The other viewing window gives the audio and video engineer a clear view of the transmitting room. Audio facilities are available to enable talk-back conversations between all studios, announcer's booth and both studio and master control.



Film Projection Room

The film projection room is located adjacent to the master control room at a slightly lower level. A large window gives full view between rooms. Two separate intercom systems are provided.

Film projection equipment consists of two TK-20 film cameras which are used with two RCA TP-16 film projectors and two 35mm slide projectors. In addition to this a balop is used for roll titles, time announcements, etc. One film camera is mounted on a rotating base allowing it to be turned 90 degrees, and stops are provided so that it will come into perfect alignment with a multiscope which is currently being used in conjunction with early afternoon programming. All controls for the film and slide projectors, balop, multiscope, roll titles, intercoms, etc., are duplicated at a central position between the two film cameras so that the projectionist can remain at one position and operate all equipment. This system of remote control allows him to do any and all varieties of fades, laps and dissolves completely within the confines of the projection room and greatly enhances the facilities available to the client. Film camera controls are located in the master control room and remote monitors are located in the studio control room so the producer in the studio control room can see what is on either film camera. The outputs of the film cameras are also bridged into the WAAM preview system so that they can be viewed at any monitoring position. All wiring comes into the projection room in 6 x 6 inch ducts and connections to the units are made from the ducts via conduit.

FIG. 11. RCA mobile unit of WAAM provides ample space and storage facilities for field gear used in remote pickups.

FIG. 12. Pickups in WAAM's outdoor studio constitute large percentage of WAAM's activities. Pictures at right exemplify types of programs televised. For telecasts covering larger area cameras are often placed on the flat roof of the station building.

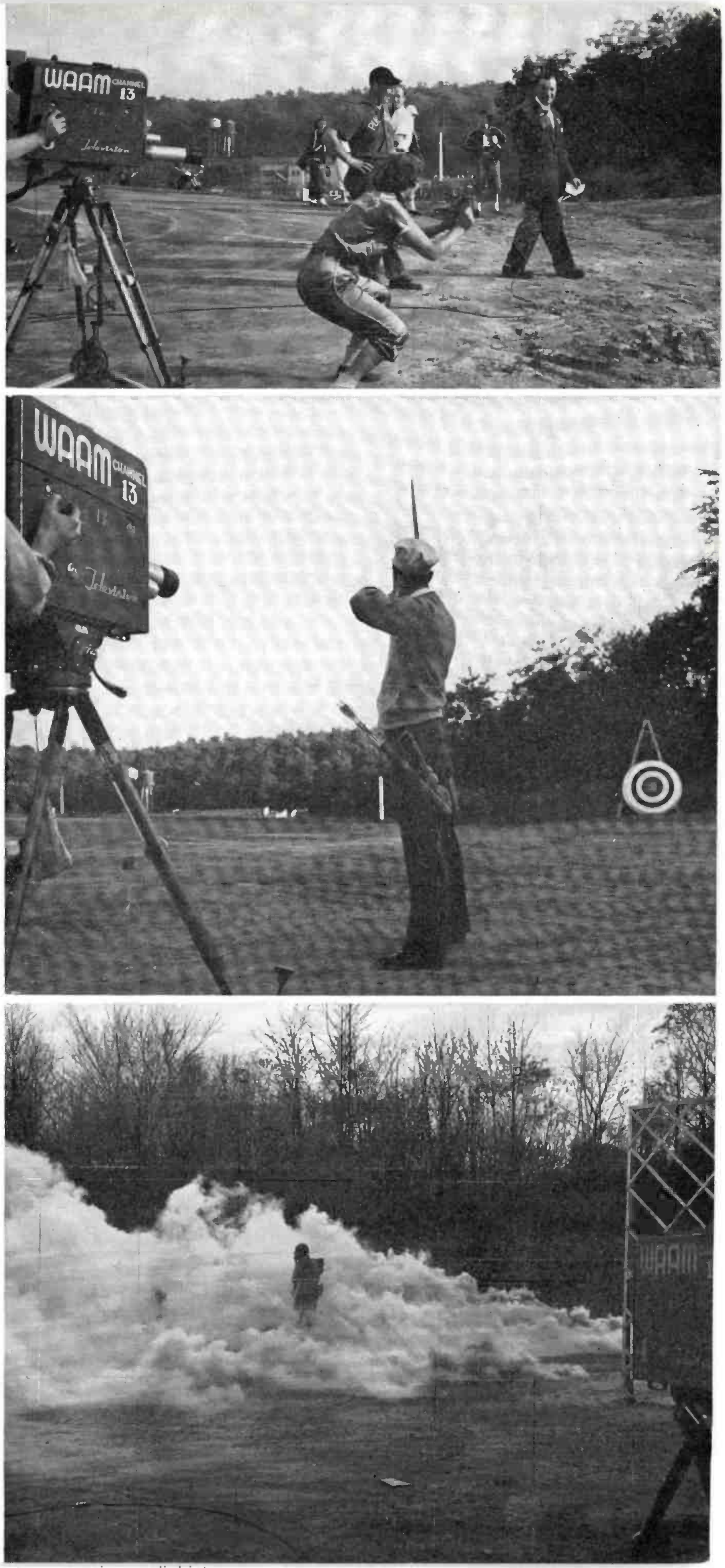


FIG. 13. View inside projection room. Film facilities consist of slide projectors and balops, plus two film cameras and two 16mm projectors.

WAAM Uses Large "Outdoor Studio" for Many Telecasts

WAAM's spacious acres allow many activities that few TV stations can enjoy. Among these are the televising of baseball and softball games. Exhibitions of racing cars, speedboats, order drills by the armed forces, and in general, anything an area the size of a football playing field can accommodate. These activities are covered by moving the cameras and any necessary props out of the studio and onto the field. With all operational facilities housed on the first floor of the plant, movement of props and equipment is greatly simplified.

The roof of the plant being flat provides an excellent site for cameras in televising activities outside the building. A large conduit joins the roof with master control so that camera cables may be fed directly from the roof. It is constructed of gypsum board, tar paper and asphalt, covered with a coating of gravel.

At the present time WAAM averages 69 hours programming a week with about 40 per cent of this time being devoted to local live studio shows. The station is served by both the ABC and Dumont Networks, thus affording the viewing public a selection of network shows in addition to the heavy schedule of local programs.

Program operations are under Mr. Herbert B. Cahan, and Mr. Anthony Farrar directs studio productions.

FIG. 1. RCA Microwave Relay Transmitter (TTR-1B) using four-foot parabolic reflector.

DIRECTIONAL ANTENNA SYSTEMS

At Microwave Frequencies

By C. A. ROSENCRANS
Terminal Equipment Section
Engineering Products Department

Before the commercial application of microwave relay equipment to television broadcasting, most radio link circuits were operated at frequencies between 170 and 350 megacycles. At these frequencies, however, such severe interference was picked up from broadcast transmitter harmonics, "ham" transmitters, ignition noise, and high frequency generators used in diathermy, that the lower frequency equipment was soon considered unsatisfactory for television broadcasting. Even though directional antennas were employed, the transmitted beam was so broad that multipath propagation effects were quite serious. For ranges greater than a few miles, the equipment was too large to be portable and required considerable power for operation.

When microwave relay equipment was generally adapted for television broadcasting, most of the previous conditions of interference were no longer experienced. Microwave equipment operating in the 6800 to 7100 megacycles today serves well over ninety percent of the stations and provides virtually noise-free transmission over line-of-sight paths greater than thirty miles. The equipment is so compact that it is portable and so efficient that with a transmitter power of only 100 milliwatts, an equivalent power of 500 watts is obtained.

At microwave frequencies, a wavelength measures less than five centimeters so that compact high-gain antennas can be used. The parabolic reflector shown in Fig 1, which measures only four feet in diameter, has a gain of 5000. In fixed installations, even larger reflectors become practical. The parabolic antenna has many advantages: it makes possible broadband transmission over long distances; equally important is its ability to concentrate the radiated power into a very narrow beam. Thus, a system using such an antenna at the receiver, as well as at the transmitter, has very effective directional characteristics which almost completely eliminate multipath effects. There are other advantages to the use of a microwave relay system such as the ease with which wide band modulation may be obtained and the fact that numerous links may be operated in the same area without interference.

The use of highly directive antenna systems does, however, present some problems to the user. For instance, a line-of-sight path between the transmitter and receiver is almost always required. It is the purpose of the following notes to describe some of the problems encountered together with their practical solutions. A full description of portable microwave equipment has already appeared in Broadcast News. Vol. No. 46, October, 1946: "Microwave Equipment for Television Relay Service."

A more common type of antenna system employed in microwave systems uses an elementary radiator and parabolic reflector to form a highly directive antenna. It is the purpose of this memorandum to present some of the characteristics of such an antenna and the problems involved in its use with the RCA Television Microwave Relay Equipment.

1. Power Gain

The power gain of any antenna system may be obtained by comparing its effective area with that of an elementary antenna. In the material to be presented the effective area of an isotropic radiator is used as the basis of comparison. Thus the power gain for a system employing a parabolic reflector may be expressed as:

$$\text{Power Gain} = \frac{4\pi a}{\lambda^2} \qquad (1)$$

where "a" equals the effective area of the parabolic system. This equation simplifies to

$$\text{Power Gain} = \frac{4\pi A}{\lambda^2} \times .65 \qquad (2)$$

where A is the projected area of the parabolic reflector.

This equation will be only slightly in error as long as λ is small compared to the diameter of the reflector. From this simple equation the effect of various changes in antenna systems may be compared. It can be seen that the gain is directly proportional to the effective area, the frequency squared, or inversely proportional to the wavelength squared. Curves showing these first two relations are shown in Fig. 4.

2. Relative Power

Often questions arise as to the relative merits of two transmission systems utilizing the same type of antennas but operating on different frequencies. The two may be compared quite simply with the aid of equation (2) or

$$\frac{\text{Power Gain} - \text{System A}}{\text{Power Gain} - \text{System B}} = \frac{\dfrac{4\pi A_A}{\lambda^2_A}}{\dfrac{4\pi A_B}{\lambda^2_B}} \qquad (3)$$

FIG. 2 Special plastic housing, known as a "Radome," protects NBC's microwave relay equipment from high velocity winds and adverse weather conditions often encountered atop the skyscraper RCA building in Radio City. Shown in the picture is O. B. Hanson, NBC Vice-President and Chief Engineer.

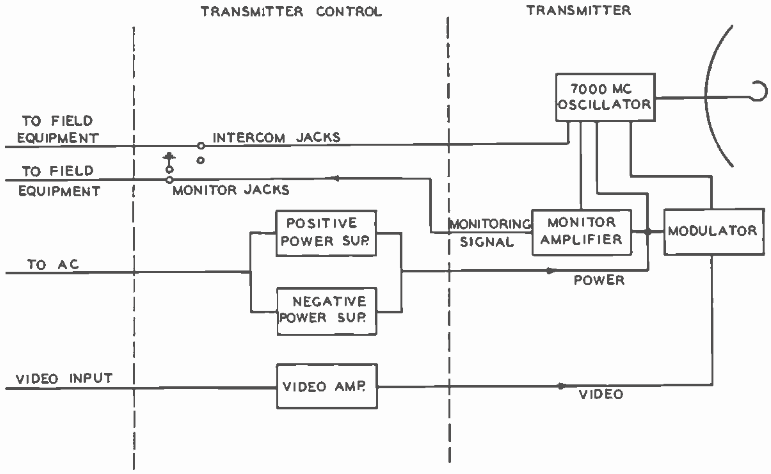


FIG. 3. Block diagram of the RCA Television Relay Transmitter shows the simplified circuit used in the microwave unit. The equipment is built into sturdy, weatherproof housing to withstand continuous outdoor use.

When both antennas have the same area this becomes

$$\frac{G_A}{G_B} = \frac{\lambda^2_B}{\lambda^2_A} \text{ or } \frac{f^2_A}{f^2_B} \qquad (4)$$

in terms of frequency. Thus a transmitter operating under these conditions at 1100 Mc. needs approximately 40 times more power than one operating at 7000 Mc. to provide the same signal at the receiving location. The curve of Fig. 5 gives the relation of equation (3) based on a frequency of 7000 Mc. The antenna systems are assumed to have the same effective area.

3. Beam Width

The beam width of a directional antenna system is usually defined in terms of the angle through which the antenna system must be rotated in order to reduce the power available at the receiver to ½ of the maximum value. Often, twice this angle is called the half-power beam width. An expression for this is as follows:*

* Reference Data for Radio Eng., 2nd Edition, page 219.

$$\theta = 70 \left(\frac{\lambda}{d}\right) \text{ degrees} \qquad (5)$$

λ = wavelength.
d = diameter of parabolic reflector.

The equation (5) is quite accurate for angles less than 20°.

Thus, a parabolic reflector 4 feet in diameter used at 7000 Mc. ($\lambda = 4.28$ cm) would be expected to have a half power beam width of 2.46°. Practically, the figure is subject to variations and our production antennas have a half-power beam width of approximately 3°. Fig. 6 presents equation (5) both in terms of wavelength (frequency) and reflector diameters.

4. Free Space Transmission

It is possible to calculate the power available at the receiver for most setups one would use in practice. All cases are based upon line of sight propagation paths as figured from the actual terrain elevations and normal curvature of the earth. The formula is given in equation (6).

$$\frac{P_R}{P_T} = \frac{A_R A_T}{d^2 \lambda^2} \qquad (6)$$

where

P_T is the power generated at the transmitter.

P_R is the power available at the receiver.

A_R is the effective area of the transmitting antenna.

A_T is the effective area of the receiving antenna.

d is the line of sight distance between transmitter and receiver.

λ is the wavelength.

Where both antennas are parabolic reflector systems equation (6) may be arranged so that actual projected areas rather than effective areas can be used. It is also desirable to replace λ with frequency. Equation (6) then becomes

$$\frac{P_R}{P_T} = \frac{A_R A_T f^2}{d^2 \times 2290 \times 10^{+15}} \qquad (7)$$

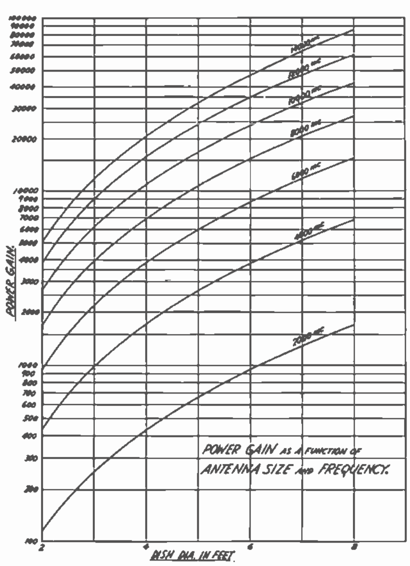


FIG. 4. Power gain characteristic of antennas using paraboloid reflectors.

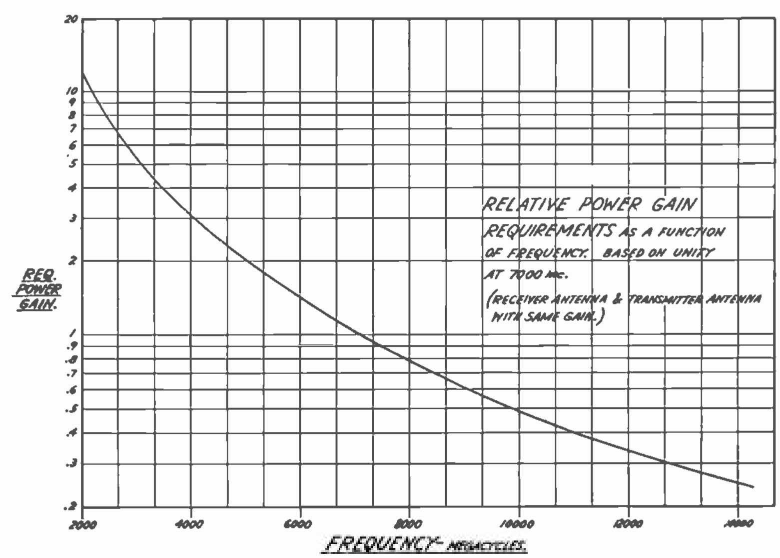


FIG. 5. Required power gain of system operating at frequencies other than 7000 mc may be calculated from this curve.

where

f is in cycles per second

A_R, A_T, and d^2 are in ft^2

The relations existing in any field setup are shown by this equation. Notice that the power available at the receiver is proportional to the frequency squared, the area of an antenna, and inversely proportional to the square of the distance between the transmitter and receiver. It is these proportional relations which are of interest to the engineer planning a field installation. The operation of a proposed installation may be readily evaluated in terms of the known performance of some other arrangement.

As a simple illustration suppose the performance of a system using 4 foot reflectors operating over a range of 10 miles is to be duplicated over a distance of 20 miles. Several choices not involving frequency are available although doubling the frequency would be one solution. First, the transmitter power could be increased by a factor $(d_1)^2/(d_2)^2$ or 4. A more practical arrangement would be to increase the area of the reflectors, each by a factor of 2. Practically, this means that 6 foot reflectors would be used in place of the 4 foot reflectors.

5. Radiation Patterns

The factors determining beam width have been discussed briefly in Section 3 but there remains the question as to the nature of the radiation pattern. This pattern is not completely specified by the beam width alone. It is a function of the electrical arrangement of the antenna reflector and feed (radiating element). For the purpose of this article the following discussion will be based upon the use of a normalized pattern shown in Fig. 8. This plot assumes the pattern to be symmetrical about the axis of the reflector, and is based upon a system having half power beam width of 1.0. Consequently, it can be used to specify the pattern of any antenna of this type by multiplying the θ scale by the beam width of the antenna.

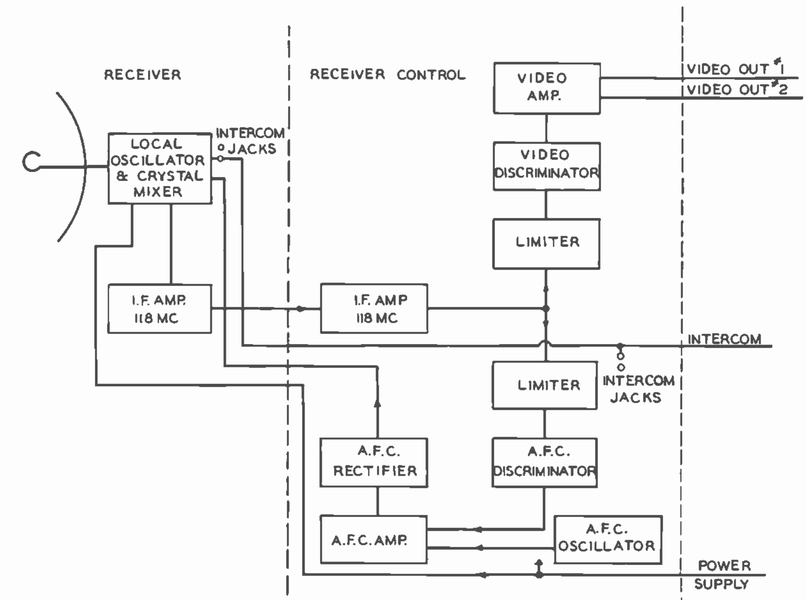


FIG. 7. Block diagram of the RCA Television Relay Receiver shows the automatic frequency control system. Intercom jacks are provided at both antenna and control positions to assist in antenna orientation.

It should be realized that this curve is not a complete pattern of the type obtained by actual measurements. A complete pattern would be something like that shown in Fig. 9 and would vary in detail from antenna to antenna. However, the normalized curve is useful in the solution of several field problems likely to be encountered in practice.

For example, consider the problem of determining the power level of the interfering signal between two systems operating on the same frequency but differing in physical location. A simple case is illustrated in Fig. 10. We will assume that both are using identical equipment; 3° reflectors, 0.1 watt power, and a frequency of 7000 Mc. In order to solve the problem it is first necessary to evaluate the angle (θ) and the distance X.

From the simple geometrical relation

$$\text{Tan}\ (\theta) = \frac{1000}{5 \times 5280} = .0379,$$

$$(\theta) = 2.1 + \text{degrees} \quad (8)$$

$$X = \frac{5}{\cos(\theta)} = \frac{5}{.9993} = 5 \text{ miles approx.}$$

Since the path length of the "B" system is almost exactly the same as the path length for the interfering signal the transmission loss over both paths may be taken to be the same. This leaves the interfering signal attenuated only by the directivity of the "B" receiving antenna and the "A" transmitting antenna. This attenuation may be obtained from Fig. 8. At 2.1 degree off the center of the beam the power is approximately 0.23 of maximum. Since this

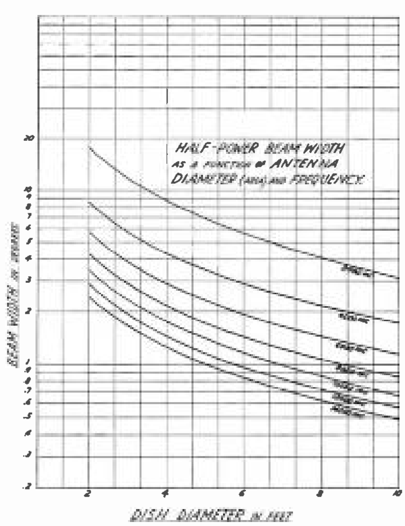


FIG. 6. Half-power beam width of antennas using parabolic antenna.

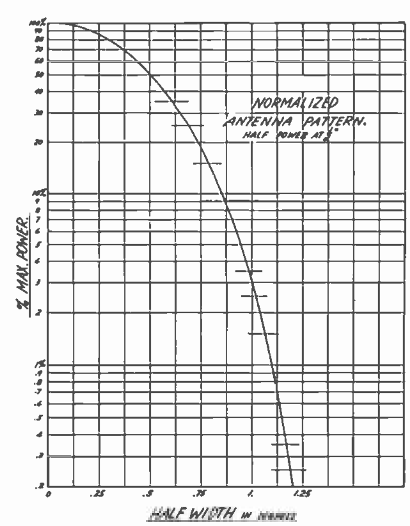


FIG. 8. Normalized antenna pattern.

reduction occurs at both antennas the total reduction is .23 × .23 or .05 or 20 times. A similar calculation for the interfering signal at Receiver A from Transmitter B gives a reduction of approximately 5 times.

6. Calculations of the Line-of-Sight Path

Before any installation is made involving situations where the transmitter is not distinctly visible from the receiver, a plot should be made in order to determine the terrain clearance existing along the path. Good maps are required; contours should show at least 10 foot elevation intervals.

The usual procedure is to lay out the path on the map and obtain elevations at frequent intervals along the whole path. These elevations must then be corrected to allow for the curvature of the earth. This correction may be calculated for each elevation from the equation

$$e = \left(\frac{D - d}{1.23}\right)^2 - \left(\frac{D}{1.23}\right)^2$$

e is in feet. Where D = ½ distance in miles between terminals d = the distance in miles from terminal to point on the path for which the elevation is being calculated. (9)

This is derived from the basic equation

$$D = 1.23 \sqrt{H} \qquad (10)$$

where D is the line of sight distance to the horizon. H is the elevation (above sea level) of the sighting point.

Fig. 11 shows a typical profile plot. The allowance for terrain clearance depends upon many things, but it is generally considered good practice to choose sites which provide a minimum clearance of at least 100 feet above the terrain. If this area is wooded or built-up, due allowance should be made for the height of the buildings or trees. Where the profile shows questionable clearance, it is best to make a test transmission over the path as a final check of the performance to be expected.

7. Special Considerations

So far multi-path transmission has not been a serious problem. There are possibilities of such effects occuring, especially over large cities. The general problem is pictured in Fig. 12. A receiving antenna at distance D subtends an angle (θ). An isolated, smooth reflecting surface is at a distance from the transmitter and subtends an angle B. The orientation of the surface is such that a wave front approaches it at an angle ϕ. Then the wave reflected from the surface will leave at an angle α and so reach the receiving antenna arriving from the same direction ϕ. Some general conclusions may be shown as to the effects to be expected without resorting to the elaborate calculations required to obtain a quantitative answer.

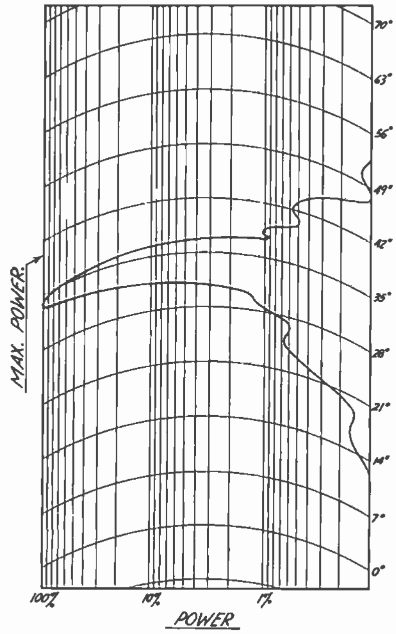


FIG. 9. Typical antenna pattern as recorded on automatic plotting equipment.

First, the energy reaching R because of the reflector will be approximately $\frac{B}{\theta}$ times that received over the direct path, when ϕ is small and B is smaller. This is further reduced by a factor (Pα) Pϕ where Pϕ is the power radiated in the direction ϕ as found from the transmitter antenna pattern and Pα the power received from a direction α degrees as found from the receiving antenna pattern.

When B becomes equal to or greater than (θ) there is no further increase in the amount of energy reflected reaching R. However, the path attenuation along the path ab increases and, at the same time, the angle ϕ increases, all of which causes a reduction in the reflected energy reaching R. Since most reflectors are not perfect, the energy reaching R will be still further reduced by a factor E depending upon the reflective efficiency of the surface.

When the area of the reflector is very large as well as a plane surface, the reflected energy reaching R will be approximately

$$P_R = \frac{D^2}{(a + b^2)} P\phi \, P\alpha \, E \, P_T \qquad (11)$$

where P_T is the power received over the direct path.

In practice, however, the situation is seldom as simple as that used in the illustration. The theory still applies but the solution is complicated by the fact that the nature and number of the possible reflectors is usually difficult to determine. Actual reflectors are seldom found to have plane surfaces so these may be effectively a large number of reflector systems operating at one time with a consequent reduction in the energy reaching the receiver. Nevertheless, the problem does illustrate the advantages of the highly directive transmitting and receiving systems in reducing the overall effects of multipath transmission.

8. Directive Systems in which One Antenna is Fixed in Elevation

In some instances, operators of television broadcast stations have relatively inaccessible locations such as the top of a high building or tower available for the installation of the RCA TRR1B relay receiver. The parabolic antenna system used with this receiver is very directive and must be aimed on the transmitter each time the transmitter is moved to a new location. Quite often the location of the receiving antenna is such that it becomes a serious problem to change the antenna from one direction to another.

Various positioning mechanisms may be designed for remote control of the antenna in both azimuth and elevation. All such mechanisms are complicated and expensive but can be simplified a great deal if

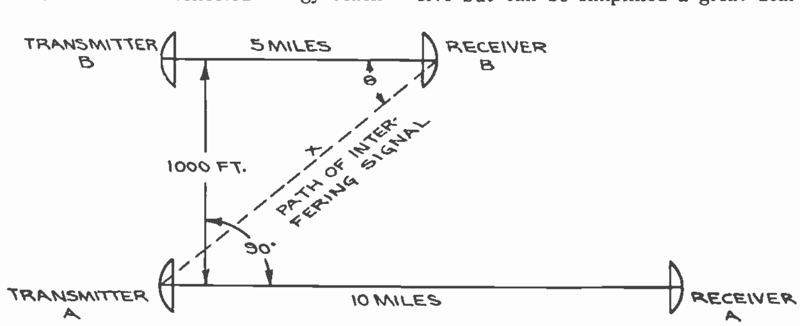


FIG. 10. Basic diagram for interference calculation.

one of the functions is omitted. We will therefore, consider the possibilities of a system in which the receiving antenna is to be controlled in azimuth but fixed in elevation.

One possibility is illustrated by the following example. The elevation of the receiving antenna is 518 feet above sea level. The calculated distance to the horizon is therefore 28 miles—just about the maximum range for consistently good equipment performance. The question arises as to how the power at the receiver will vary as the transmitter is moved toward the receiver and the receiving antenna left aligned on the horizon. The diagram of Fig. 13 illustrates the general problem.

Tower height at receiver = 518 feet (above sea level)

Distance to transmitter =

$$d = 1.23\sqrt{H} = 28 \text{ miles} \quad \text{(when transmitter is on the horizon)} \qquad (12)$$

where d is in miles
H is in feet

For any other distance d the increase in signal as the transmitter is moved toward the receiver is proportional to $\frac{28^2}{d^2}$. At the same time the receiving antenna is left aimed at the horizon. Therefore, due to the curvature of the earth, the transmitter moves below the original line of sight path by the angle θ and the distance h. Now

$$D - d = 1.23\sqrt{h} \text{ or } h = \frac{(D-d)^2}{1.23^2} \qquad (13)$$

and

$$\text{COT } \theta = \frac{d \times 5280}{h} \qquad (14)$$

or

$$\text{COT } \theta = \frac{1.23^2\, d \times 5280}{(D-d)^2} = \frac{7989\, d}{(D-d)^2} \qquad (15)$$

It is true that the actual distance between the receiving antenna and the transmitter is d' and not d. However, for the small angles involved the error is small when d is used. For instance.

Let d = 1.4 miles = 7392 ft.
then h = 470 ft.
and Cot. θ =

$$\frac{7989 \times d}{(28-1.4)^2} = \frac{7989 \times 1.4}{(26.6)^2} = 15.7$$

$$\theta \cong 3.6°$$

$$\frac{d}{d'} = \text{Cos } \theta = .9980$$

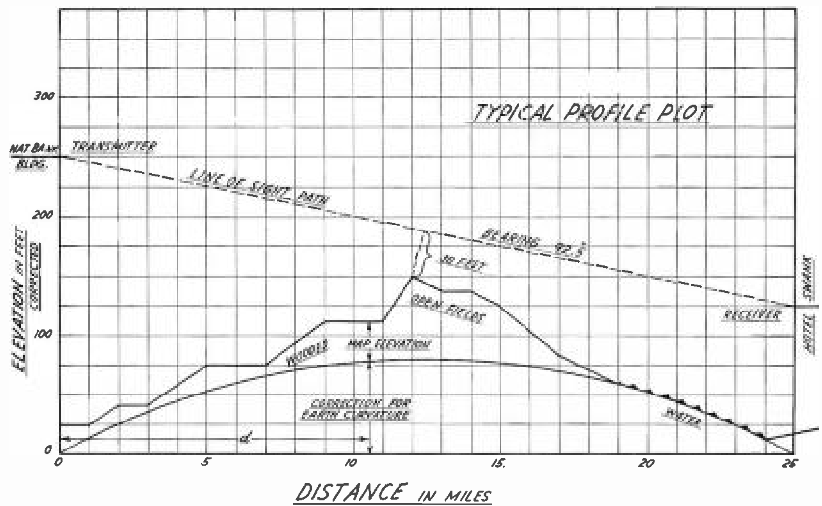


FIG. 11. Typical profile diagram. Plots such as this should be made prior to setting up a microwave relay system.

$$\frac{\text{Cos } \theta}{d} = d' \text{ or } 7407 \text{ ft.}$$

The error here is 15 feet or .24% and decreases as d becomes larger.

In order to obtain the relative signal power at the receiver for each new position of the transmitter both (θ) and d must be known. The solution is then as follows:

The increase in power due to the transmitter being moved from D = 28 miles to d is

$$\frac{P_d}{P_D} = \frac{D^2}{d^2} \qquad (17)$$

The decrease in power due to the receiving antenna no longer being aimed at the transmitter is taken from the curve of Fig. 8; a normalized antenna gain curve in terms of relative power and the angle off the main axis for an antenna having 1° beam width. If we assume that our receiving antenna has a 4° beam width, the angle coordinates on the curve must be multiplied by 4. If the power ratio obtained from this curve be $P(_\theta)$, then the net power ratio for any location d is

$$\frac{P_d}{P_D} P_\theta \qquad (18)$$

A plot of this is shown in Fig. 14. Note that as the transmitter is moved in toward the receiver, the power at the receiver first increases, but as d becomes small compared to D the power rapidly decreases.

Although the curve of Fig. 14 illustrated the solution of the general problem, it will be recalled that the solution was based on a smooth earth's surface which is very seldom found in practice.

A more typical setup is like that shown in Fig. 16 in which the more usual contour of the earth shown in Fig. 4 is used.

The new location of the transmitter at distance D = 28 miles is now above the line of sight to the horizon by some elevation E and angle ϕ. It can be seen that the general solution is much the same as before. One new problem arises, however,

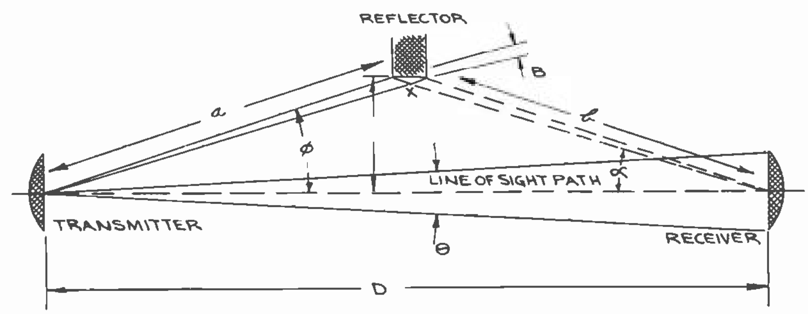


FIG. 12. Basic diagram shows the problem of multi-path transmission.

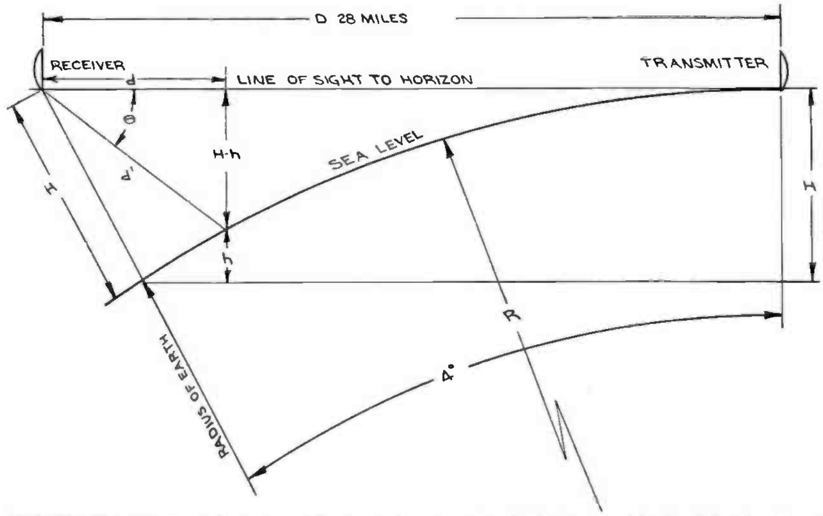


FIG. 13. This diagram shows special case where one terminal of system is fixed in elevation.

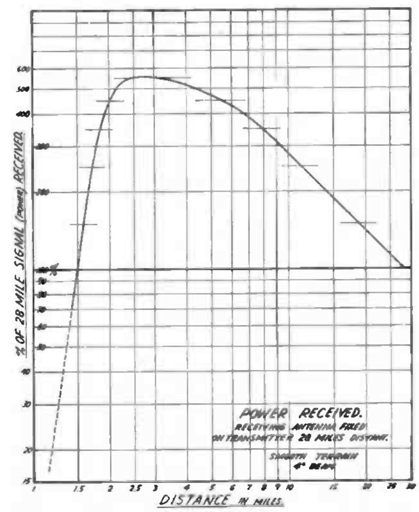


FIG. 14. Typical plot of power received for the setup shown in Fig. 13.

and that is the positioning of the receiver's antenna. If it is aligned on the new transmitter location which is now at an elevation of H + E, the angle (θ) of the first case is increased by the angle ϕ. For E = 500 feet, ϕ would be approximately 11 minutes and not affect the results obtained appreciably. The effect of E as the transmitter is moved toward the receiver is generally to improve the signal level over that calculated for the smooth earth condition.

One may conclude that it is quite feasible to locate a receiving antenna so that it need be aligned in azimuth only and still supply sufficient power to the receiver for normal operation. However, each such installation should be considered a special case and calculations should be made to find out whether or not the results will be as desired.

The methods used in the preceding example may be applied to a special case in which the azimuth angle is fixed and the elevation made the variable. This is essentially what is done in the solution of the interference problem. However, it is of interest at times to know the half-power beam width in feet as a function of distance. This function is plotted in Fig. 17 for the normalized 1° beam.

NOTE: It will be noticed that in all problems involving the antenna patterns the vertical pattern has been taken to be the same as the horizontal pattern. This is sufficiently accurate for most cases involving large parabolic reflectors although not entirely correct. Other antennas such as horn arrays, or modified parabolic systems may have entirely different horizontal and vertical patterns and this must be considered in special cases. The effect of ground reflections may also affect results in some instances where the line of sight path is near grazing. The general solution will nevertheless follow the same form.

9. Powerless Relay

It is possible that occasions may arise in practice when it is necessary to set up a system in which the transmitter and receiver are not in line of sight. The question of how to get the signal around the corner naturally arises. One method is that in which two auxiliary antennas are used.

FIG. 15. The RCA Television Relay Transmitter, Type TTR-1B is shown mounted on the new TD-11A all-metal tripod. The Relay Receiver, Type TRR-1B, looks exactly like the unit shown.

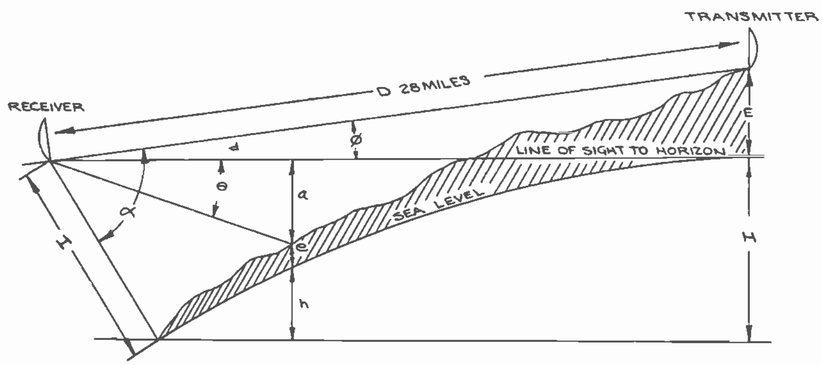


FIG. 16. Diagram above is similar to Fig. 13 with the addition of usual profile data.

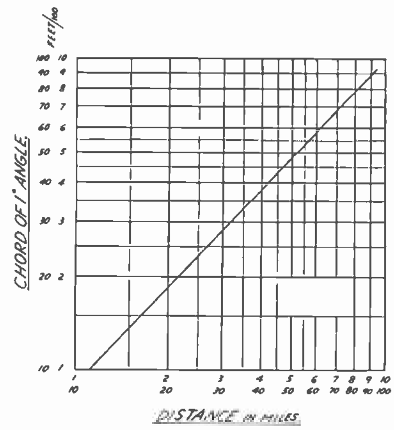


FIG. 17. Plot of half-power beam width in feet as a function of distance for normalized one degree team.

Calculations for the first method may be based on the discussion of multipath effects described in Section 7 "Special Considerations." It should be noted that the smaller the angle ϕ becomes, the larger the reflecting surface must be if the loss at the reflector is to be kept at a minimum. For very small values of ϕ the losses become excessive and the system becomes very difficult to align. Practical considerations indicate that values of ϕ less than 45° may prove to be very difficult to handle.

The second method is very inefficient since the energy propagated in the new direction is no longer a mirror reflection but instead is due to radiation from another antenna.

Suppose we consider a setup similar to that illustrated in Fig. 18. T is the transmitter having a power of W watts; R the receiver, and D the line-of-sight distance between T and R. R' and T' are the auxiliary receiving and transmitting antennas at the relay points, a distance d_1 from T and d_2 from R.

We may now calculate the ratio of the power received by the receiver R over the relay path to that over the direct path. (Under line-of-sight conditions).
Power at R_1

$$\frac{P_{R'}}{P_T} = \frac{A_{R'}\, A_T}{d_1^2}\, C \qquad (19)$$

where

P_T = transmitter power
$P_{R'}$ = receiver power (auxiliary)
$C = 1/\lambda^2 = \frac{f^2}{v^2}$ = constant
$A_{R'}$ = area of receiving antenna
A_T = area of transmitting antenna
d_1 = distance between transmitter T and receiving antenna R'

Next, assume this amount of power be transmitted by transmitter T'. In this case the power at R will be

$$\frac{P_R}{P_{T'}} = \frac{A_R\, A_T'}{d_2^2}\, C \qquad (20)$$

where

P_T' = transmitted power
A_R = area of receiving antenna
A_T' = area of transmitting antenna
d_2 = distance from T' to R
C = same constant as defined above

or

$$P_R = \frac{P_{T'}\, A_R\, A_{T'}}{d_2^2}\, C \qquad (21)$$

Since $P_{R'} = P_{T'}$ equation (19) may be written

$$P_{T'} = \frac{P_T\, A_{R'}\, A_T}{d_1^2}\, C \qquad (22)$$

Substituting (22) in (21) and introducing frequency "f"

$$P_R = \frac{\frac{(P_T\, A_{R'}\, A_T)}{d_1^2\, C_1} f^2\, (A_R\, A_{T'})\, f^2}{d_2^2\, C_1} \qquad (23)$$

Where $C_1 = v^2$

$$= \frac{P_T\, A_{R'}\, A_R\, A_{T'}\, A_T\, f^4}{d_1^2\, d_2^2\, C_1^2} \qquad (24)$$

The power which would have been received over the direct path D is

$$P_R = \frac{P_T\, A_R\, A_T\, f^2}{D^2\, C_1} \qquad (25)$$

The ratio of the two paths is therefore (24)/(25) or

$$\frac{A_{R'}\, A_{T'}\, D^2\, f^2}{d_1^2\, d_2^2\, C_1} \qquad (26)$$

Often $d_1 + d_2 \cong D$ where the paths are long so that (26) may be written,

$$\frac{P_{relay}}{P} = \frac{A_{R'}\, A_{T'}\, (d_1 + d_2)^2\, f^2}{(d_1\, d_2)^2\, C_1} \qquad (27)$$

Both equations (26) and (27) must be modified by a factor E to take into account the efficiency of the coupling between the two relay antennas.

It may be seen that the efficiency of the relay system as a whole is very poor, although it will increase when d_1 is made smaller than d_2 or vice-versa. The efficiency also increases as the antennas are made larger which is to be expected.

The chief advantage of this type of "relay" over a system utilizing a plane reflector is the relative ease with which it may be set up inasmuch as the two antennas may each be adjusted individually. However, the losses are so high as to make it impractical for any but very short distances.

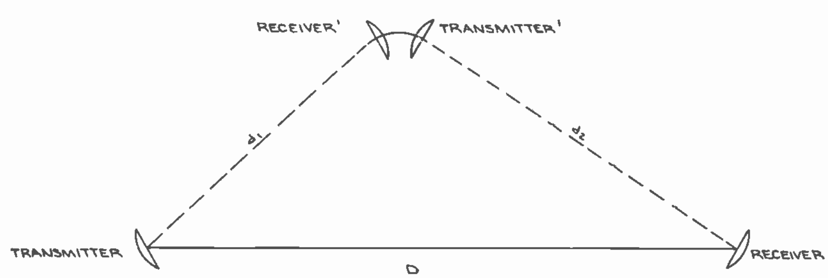


FIG. 18. Diagram of "powerless relay." Note that this method is seldom practical. A plane reflector provides a more efficient "bending" mechanism.

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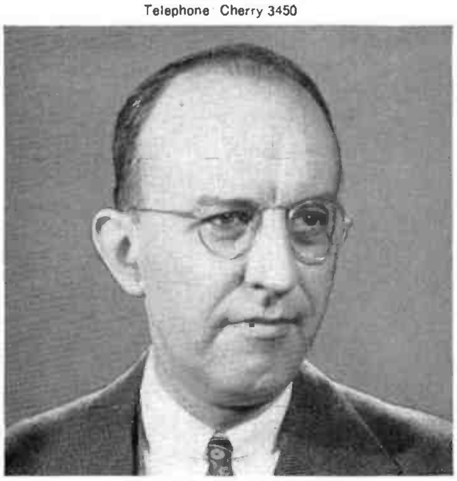

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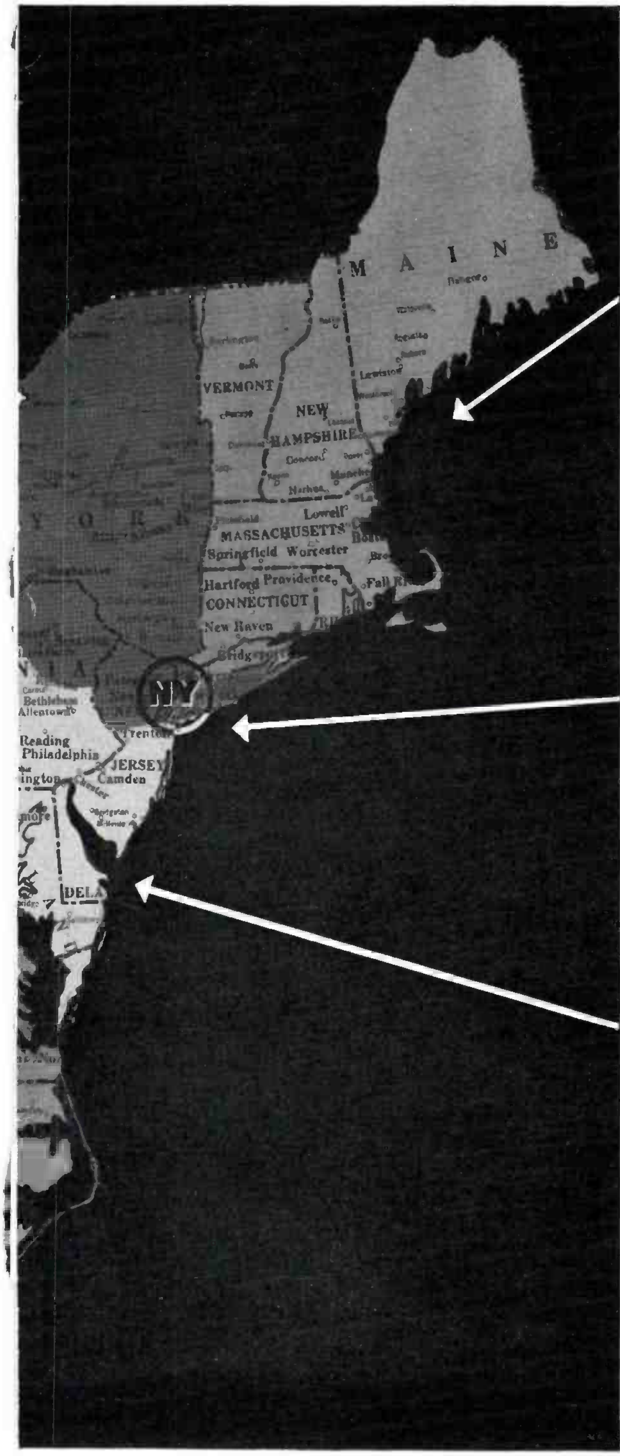

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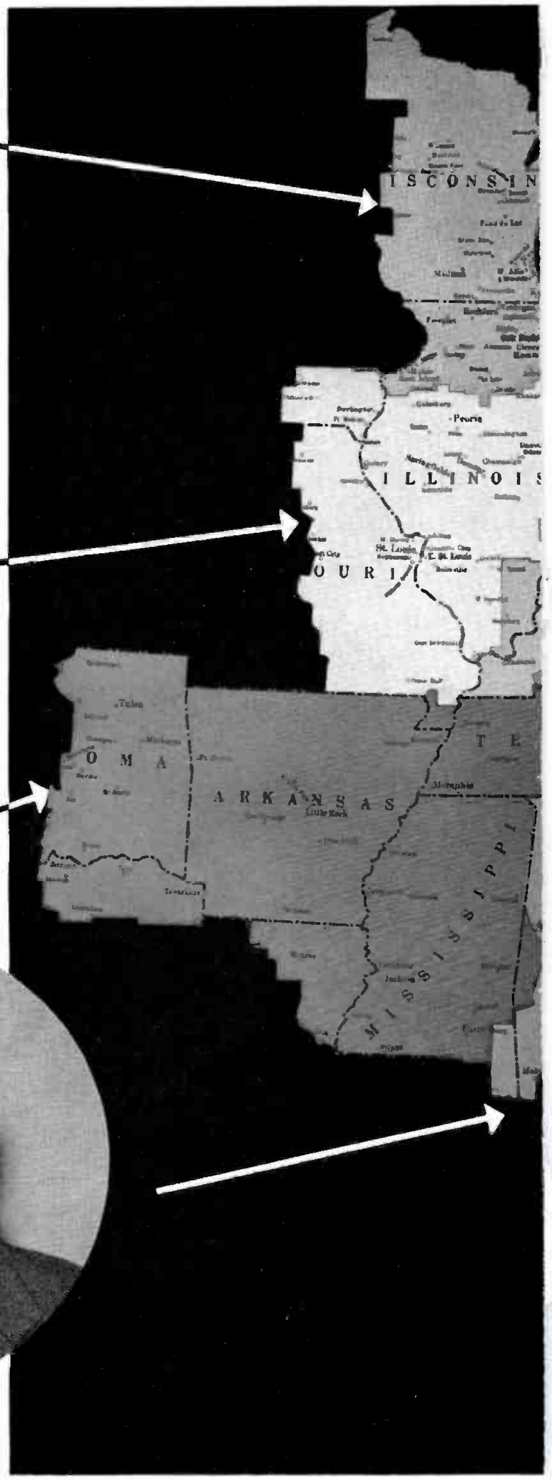

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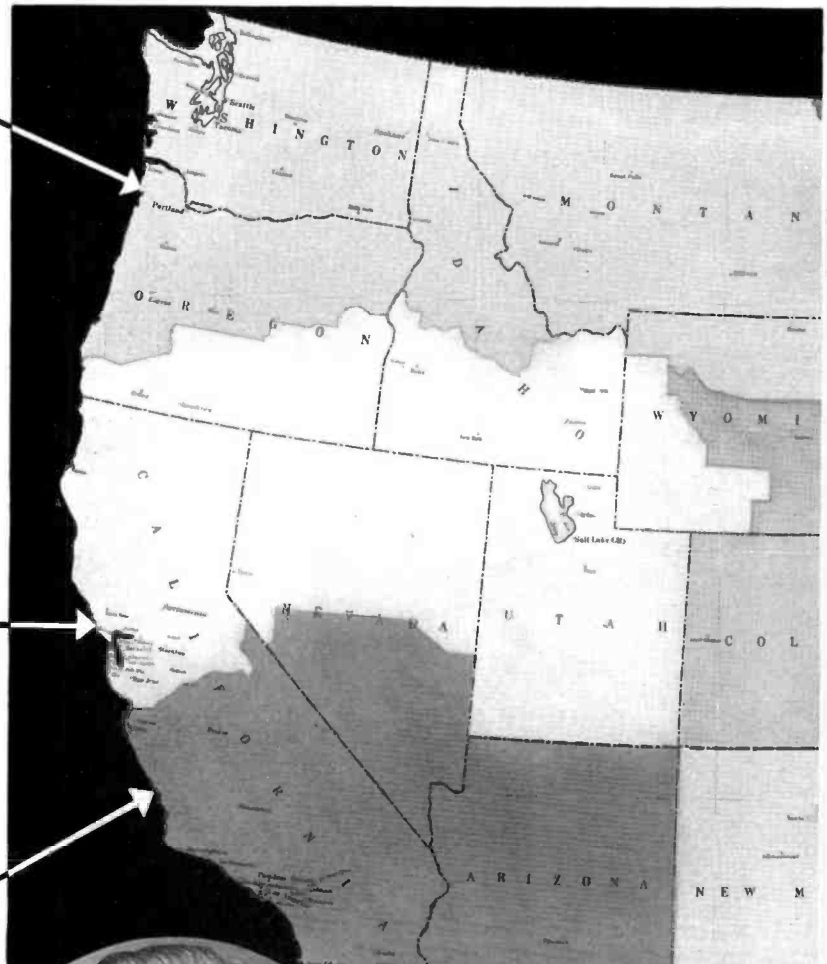

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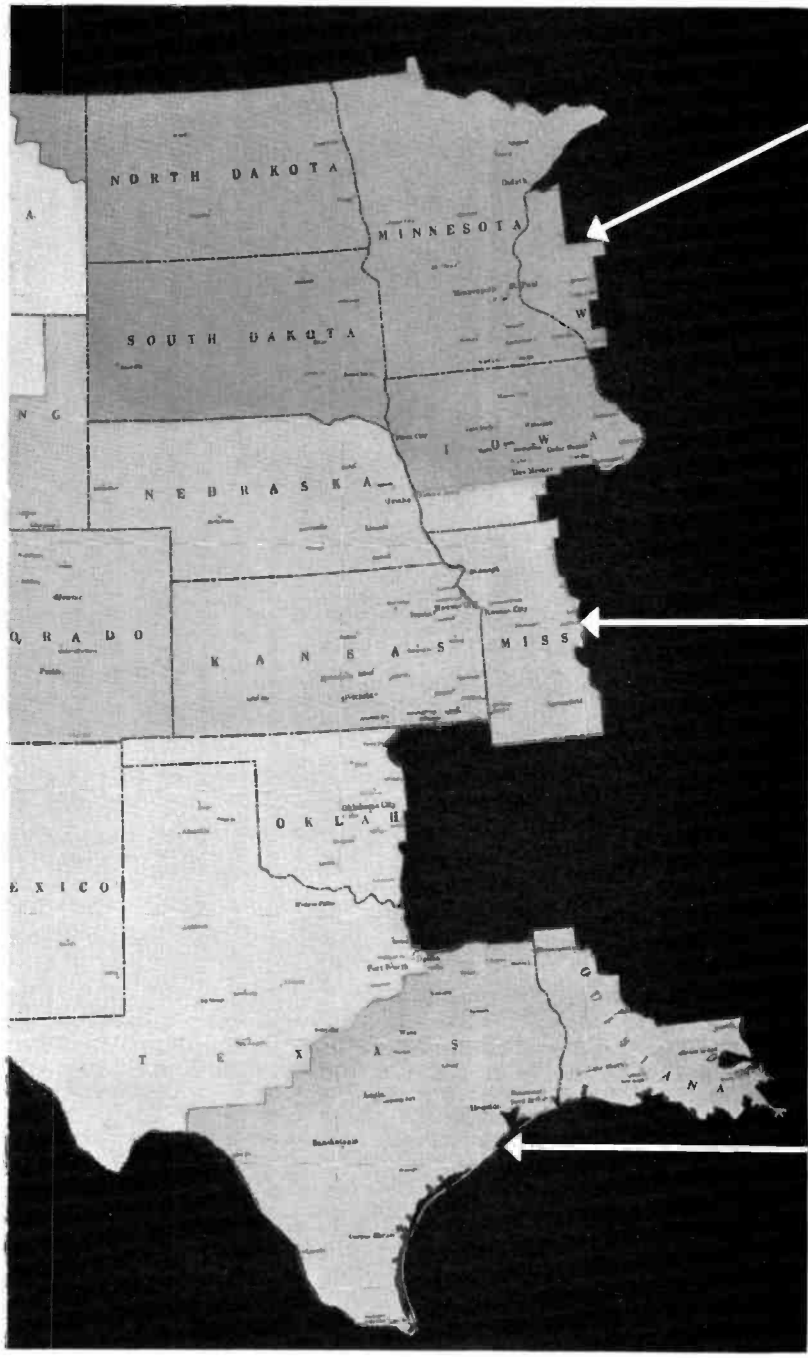

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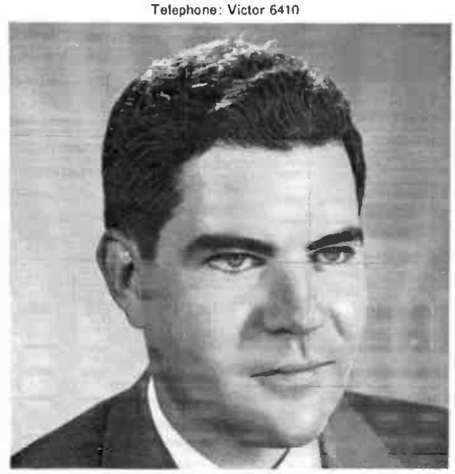

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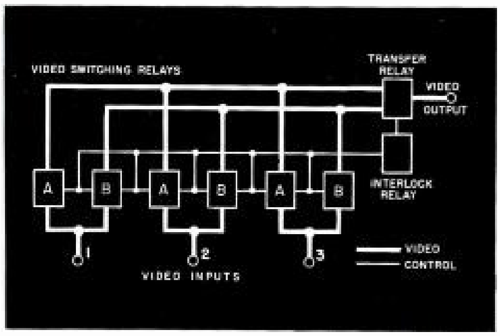


FIG. 1 (above). Block diagram showing fundamental switching scheme of RCA Remote Control Switching System. Relays A and B are electrically operated by push buttons.

TV REMOTE CONTROL SWITCHING

By

W. E. TUCKER & C. R. MONRO

Television Terminal Equipment Group

New Video Relay Switching Systems Handle Many and Complex Variations of TV Programs Economically

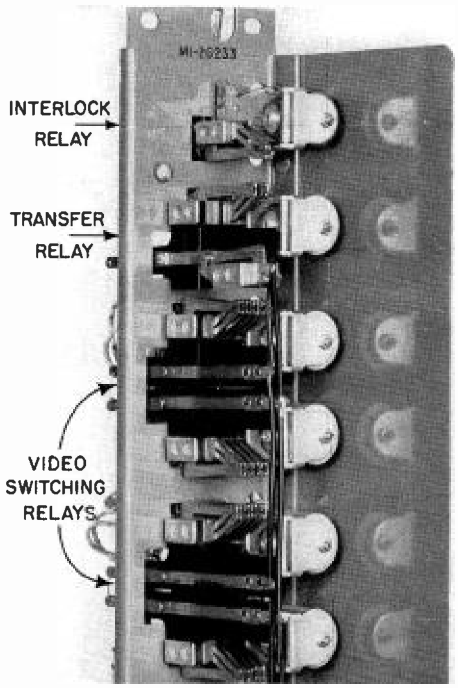


FIG. 2 (above). Sectional view of basic relay panel illustrating interlock, transfer and video switching relays employed.

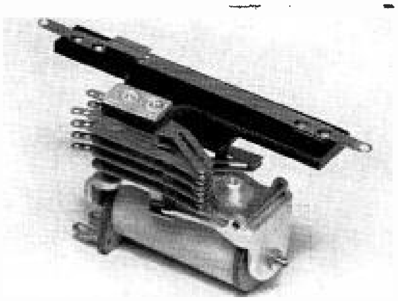


FIG. 3. Closeup view of video switching relay showing construction and design.

Whether a television installation is small or large, it will be found necessary to switch video signals in some manner. Until recently, the majority of systems have employed mechanically interlocked push switches, located directly in the video lines, which have provided for the connection of a maximum of six video signal sources to a maximum of three lines. For these maximum conditions, the control panel becomes too large to be located conveniently for the operator, mainly due to all the video coaxial cables. Smaller panels, located at the operator's position, have been made which will switch any one of six video signals to two lines.

A television station may be called upon from time to time to handle many variations of program material in its operating schedule. Maximum flexibility must therefore be had in the performance and utilization of all equipment. One means for accomplishing this is to provide video switching in one or more studios, wherein the program is assembled from all necessary sources, and then passed on to the second control point for final distribution to transmitter and network.

In a relatively small station, and especially in a large plant, where studios may be located some distance from each other, many video lines must be laid to tie studios together and provide the spare lines for possible program combinations and new facilities.

The question of future expansion is an important consideration. Being in a rapidly growing industry, even the smallest station must consider the cost of discarding present facilities at a later date or installing equipment now that may be later expanded in its usefulness at minimum additional expense.

In a television system the video signals originating in field cameras, studio cameras, or film cameras are fed through coaxial lines to associated rack-mounted equipment. If the video switches themselves can be located directly in the video lines, with the control of these switches where desired, then the video lines may be completely centralized and we have reached a practical solution of the problem. Video relays are the answer.

There are other functions which must be performed, such as providing for tally light operation, line termination, isolation of video inputs and outputs, and sync interlocking. The mechanical arrangement of the components must be such that the basic equipment will provide economical switching for the small station while, by additions, it will apply to the larger installations.

The circuits must have a minimum of capacity across the video contacts as well as the smallest possible capacity to ground in order to reduce "cross talk" and line losses. Other requirements include the use of simple non-locking push keys to operate the relay coils, relays to be operated in a lock-up type circuit—interconnected to drop out any operated relay when another is operated. The switch-over time should be as short as possible, and switch-over should be arranged so that either gap or overlap can be obtained.

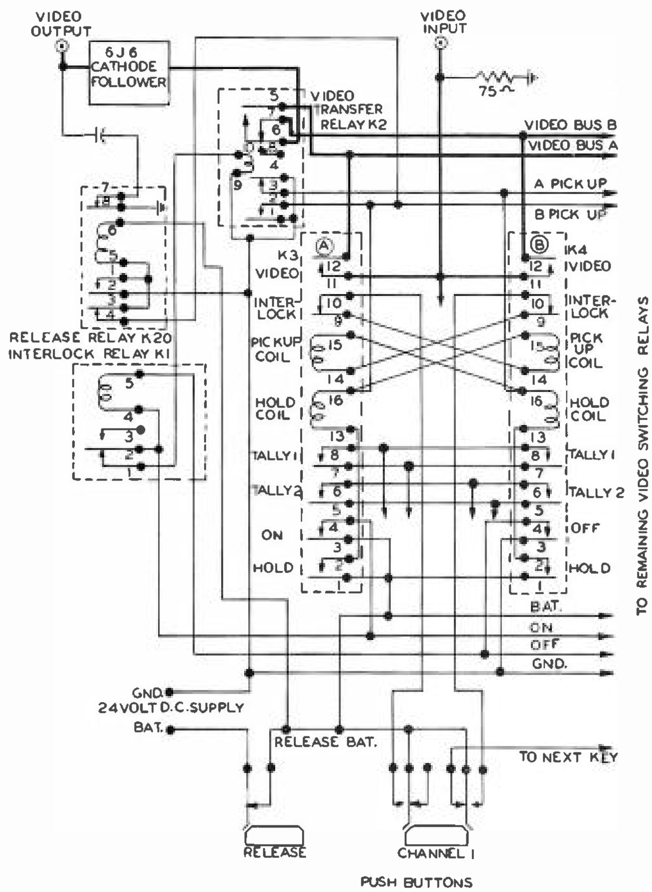
It has been found that, for minimum picture disturbance during switch-over, a slight overlap or make-before-break sequence is desirable. A zero transfer interval would be ideal, but is impractical. Overlap is chosen to avoid occurrence of black areas when switching between two similarly lighted scenes. The circuits can be arranged so that double termination is picked up during the transfer to prevent undesirable flashes. This arrangement is commonly used for camera switching. For preview monitors, however, the switching must cross over active lines without introducing any disturbances. For this application, a gap (break-before-make) sequence is desirable. The same condition exists in Master Control switching. Although, in this case, switching is most often done only between programs, the transfer interval, as in camera switching, again appears on the outgoing video signal and hence must be as short as possible.

In the course of the development of the relay switching system, several fundamental circuits were tested for conformance to the specifications set up. The simplest circuit used a mechanically interlocked push-button assembly to operate the video relays. This, however, becomes the worst case for switch-over timing, since both the push-button assembly and the relays themselves will contribute variations in the timing. The next general circuit was one in which the latching action was electrical. Briefly, on operation each relay switches itself to a "hold" bus which is in turn controlled by a separate control relay group. In this way, a gap sequence may be set up in which a push button initiates a step sequence through the control relays to release the hold on any relays already operated, restore the hold bus, and then operate the desired new video relay. Here again the switch-over time was governed by the operate and release times of the relays involved. Either timing adjustments must be provided for each relay or all of the relays must be adjusted for very critical uniformity. Also, this circuit was not easily adaptable for overlap switching, although a system using double coil relays, carefully adjusted for timing and uniformity, has been made to work quite satisfactorily. It must be remembered that we are aiming for a switch-over time of less than 10 milliseconds.

The circuit finally chosen met all of the requirements for timing and yet the switching interval was influenced only by one transfer relay instead of by all the relays involved. A short description of the circuit and physical arrangements follows: (see video diagram, Fig. 1 and relay arrangement, Fig. 2). For circuit details, refer to Fig. 4.

Each incoming video channel is connected to make contacts on a pair of switching relays. The other side of these contacts connect to two video bus wires which in turn run to a transfer relay. When a channel selecting push button is operated, one of the switching relays (let us call it "A"), will close, connecting the incoming line to one of the transfer bus wires. Next, other contacts on this switching relay operate the transfer relay to connect the outgoing line to the video bus wire and so to the incoming circuit. When some other push button is pressed, a circuit from separate contacts on the transfer relay will tell this video switching pair that the "A" bus is in use and so the "B" switching relay will operate. The video contacts on the "B" relay close to connect the new incoming video line to the "B" video transfer bus wire. Other contacts on the "B" relay close to operate an interlock relay which in turn releases the transfer relay. The outgoing line is thus transferred from the original input to the new one. As the transfer relay releases, the same "busy" circuit releases its hold on the old circuit's "A" relay. This process repeats as subsequent push buttons are operated. Actual transfer, as seen by the output circuit, is therefore accomplished

FIG. 4. Detail diagram showing how relays operate in a typical TS-20A video switching system.



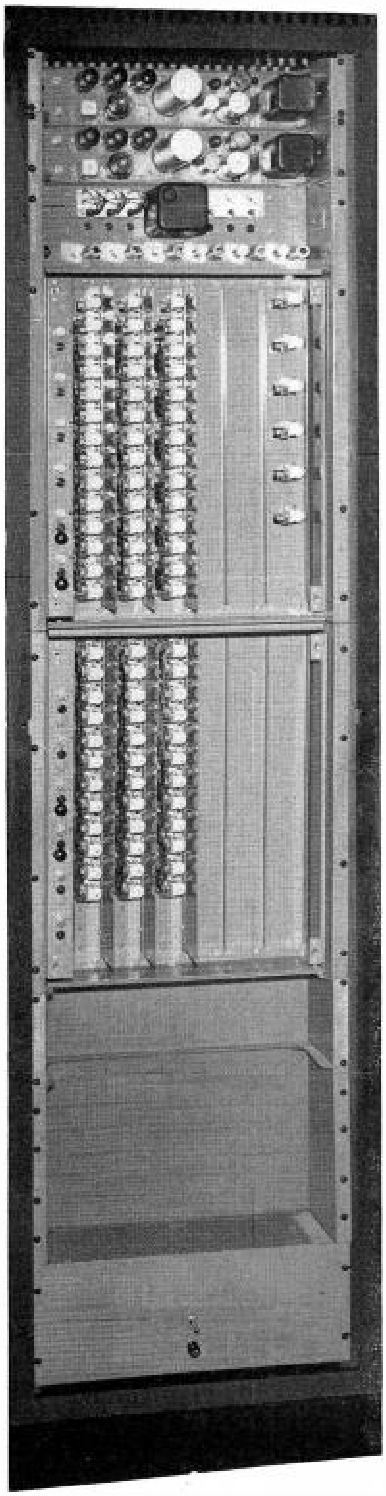


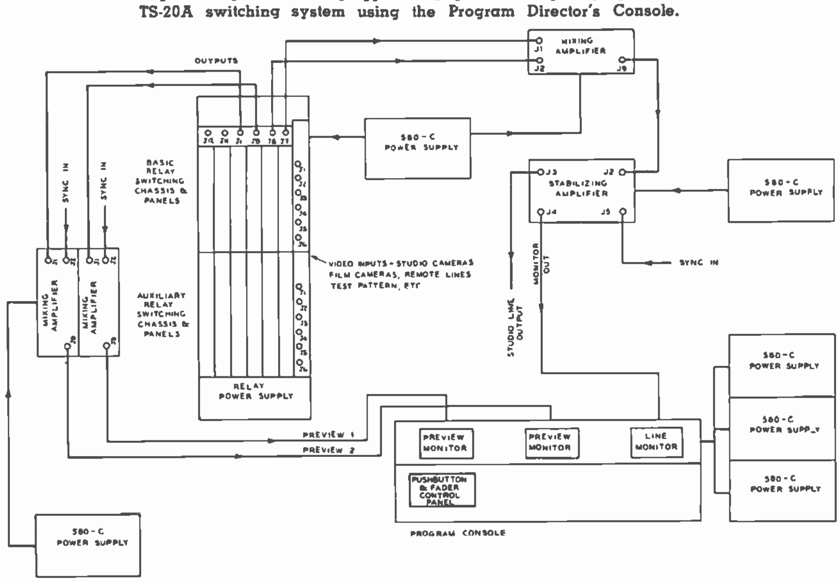
FIG. 5 (above). TS-20A remote switching equipment mounted in standard television cabinet rack (shown with dust covers removed).

in the time it takes for contact travel on the transfer relay. Also, an arrangement of contacts is provided such that either gap (break-before-make) or overlap (make-before-break) switching may be chosen by making appropriate connections to the video transfer bus wires. All of the switching relays are now freed from critical timing problems and short time—½ to 1½ milliseconds—transfer is easily and consistently accomplished. Two separate sets of contacts, parallel connected on each video switching pair, are provided for the signal or control circuits of camera tally lamps and sync interlock. Since the relay circuit is completely self latching, any type of push button or key may be used, provided only that, if mechanically interlocked, their sequence is break-before-make. Also, some other relay switching circuit may serve as the control as might be done in audio-video switching or in a preset system. For all of these variations, the transfer timing is determined entirely by the transfer relay.

Mechanically, the video switching relays (see Fig. 3) are of the small telephone type. The video contacts are arranged on a bakelite insulator, spaced well away from the relay frame. The input side of the video contacts extend down through the chassis and the output side stands above the relay frame. In this way, both stray-to-ground and lead-through capacities are very low. The relays are mounted on long narrow panels which in turn mount in a chassis for rack mounting. One type of panel termed "basic" provides for six input circuits and one output through the transfer relay. A second type of panel termed "auxiliary" provides for six additional inputs, without a transfer relay, since it is to be used only to extend the basic panel. The chassis for basic panels includes six input video line terminations and a cathode follower isolation amplifier for each of the six panels which may be mounted in it. The basic chassis is normally supplied with two panels in place, the additional panels being added at the customer's option. Another relay is provided in each output to short circuit the video when the release button is pushed to clear all of the video switching relays. Its circuit is arranged to hold it operated as long as any switching relays are operated and so its action does not appear in normal transfer switching. The chassis for the auxiliary panels includes only the input terminations, since the auxiliary relays work into the same transfer relays and output circuits appearing in the basic chassis.

In order to employ relay switching, it must form a part of a coordinated system. The RCA Type TS-20A relay switching equipment covers a group of related units which may be used in various combinations to cover widely different conditions. (See Fig. 5 for mounted equipment.)

FIG. 6 (below). Layout diagram showing typical equipment lineup employed in one version of the TS-20A switching system using the Program Director's Console.



The TS-20A equipment consists of several types of units in each of the following categories:

1. The video relay switching chassis and the panels which are used to extend the functions of the basic units.
2. The push-button panels, for operating the video relays, which are available for several switching schemes and mounting arrangements.
3. The program or master monitors, for use in conjunction with the push-button panels.
4. The various consoles for mounting the push-button panels and monitors.
5. Standard components.

The fundamental video relay switching equipment consists of the basic chassis which provides the relays and circuits for connecting six inputs to two outputs. If more outputs are required, basic relay panels can be added, one for each output. If additional inputs are required, six more can be accommodated by using the auxiliary relay chassis with the appropriate number of auxiliary relay panels. Since either gap or overlap switching is available, the switching system may be used for studio, monitor, or master control room switching.

A tally light relay panel is also available for mounting in either the basic or auxiliary chassis. It is used to extend the number of different tally and sync interlock circuits normally handled by the video switching relay units.

Panels using non-locking push buttons (see Fig. 7) are designed for mounting in a program director's console. Up to twelve inputs and four outputs are available, with provisions for manual fading between two of the outputs.

Panels using locking type push buttons are designed for mounting in a console section. Up to six inputs and two outputs are available, either with or without manual fading provisions, between the outputs.

Tally lights, for each push button, are furnished as a part of each switching panel.

Two types of monitors are available. The program monitor (see Fig. 8) is designed particularly for mounting in the program director's console. The master monitor is the familiar combination of kinescope and oscilloscope which may be mounted in a console section with video switching facilities.

To facilitate the smooth handling of studio productions, a program director's console is available (see Fig. 9). This console provides space for the video switching panel, intercom switching panels, and microphones, in a convenient desk top arrangement at which both the program director and technical director may sit. Monitors, mounted below and behind the desk top, are viewed by means of a mirror for optimum viewing distance and an unobstructed view into the studio.

A console section is available to harmonize with the standard RCA camera controls for those applications in which the switching facilities, monitors, and camera controls are to be located as a unit. The appropriate push-button panels for video switching mount in this console section.

In order to complete the system, certain standard video distribution and mixing amplifiers and power supplies are required. The number and use of these units will vary in accordance with the individual station requirements.

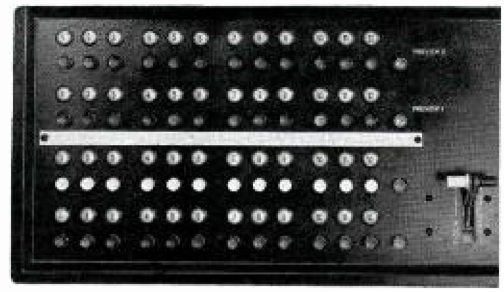


FIG. 7 (top right). Closeup of push-button switching panel (MI-26220-1) which is available for mounting in the Program Director's Console. TC-5A (shown in Fig. 9).

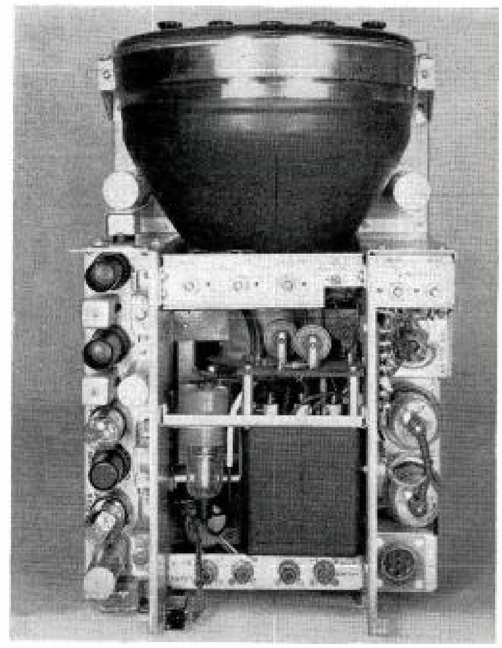


FIG. 8 (center right). Program Monitor chassis showing components and adjustment positions. (This unit is designed for mounting in TC-5A Program Console.)

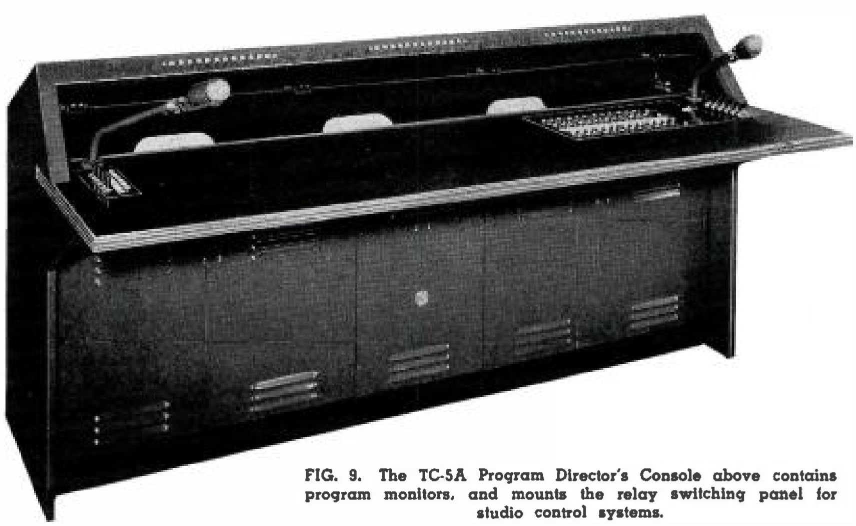


FIG. 9. The TC-5A Program Director's Console above contains program monitors, and mounts the relay switching panel for studio control systems.

HIGH GAIN AND DIRECTIONAL ANTENNAS FOR TELEVISION BROADCASTING

by LESTER J. WOLF
Engineering Products Department

Nearly all of the antennas installed up to the present time have been designed with circular patterns and have had power gains of the order of three to seven compared to a half-wave dipole. In most cases this value of gain has been satisfactory because Effective Radiated Powers approaching the 50 KW limit of the FCC regulations have been possible.

The proposal by the FCC to increase the ERP limit to values of the order of 100 KW can be met singly or in combinations of three ways:

1. Transmitter power increase.
2. Increase in antenna height.
3. Increase in antenna gain.

In those cases where no limitation exists, such as a CAA imposed height maximum or structural availability, a higher gain antenna is often the best solution. It is sometimes necessary to consider a higher gain antenna together with greater height and a higher power transmitter to achieve the desired coverage. In certain cases the need for directive patterns is obvious and a design of antenna having these characteristics is highly desired.

As an introduction to such designs, a review of the present antenna art is helpful. Most of the antennas used at the present time are of the Superturnstile or so-called bat-wing type. This type is very successful because it has a wide frequency range and can often be used simultaneously for FM as well as TV and can be built with various gains up to about 7. The Superturnstile utilizes radiators mounted on a pole and which are shaped to have a constant im-

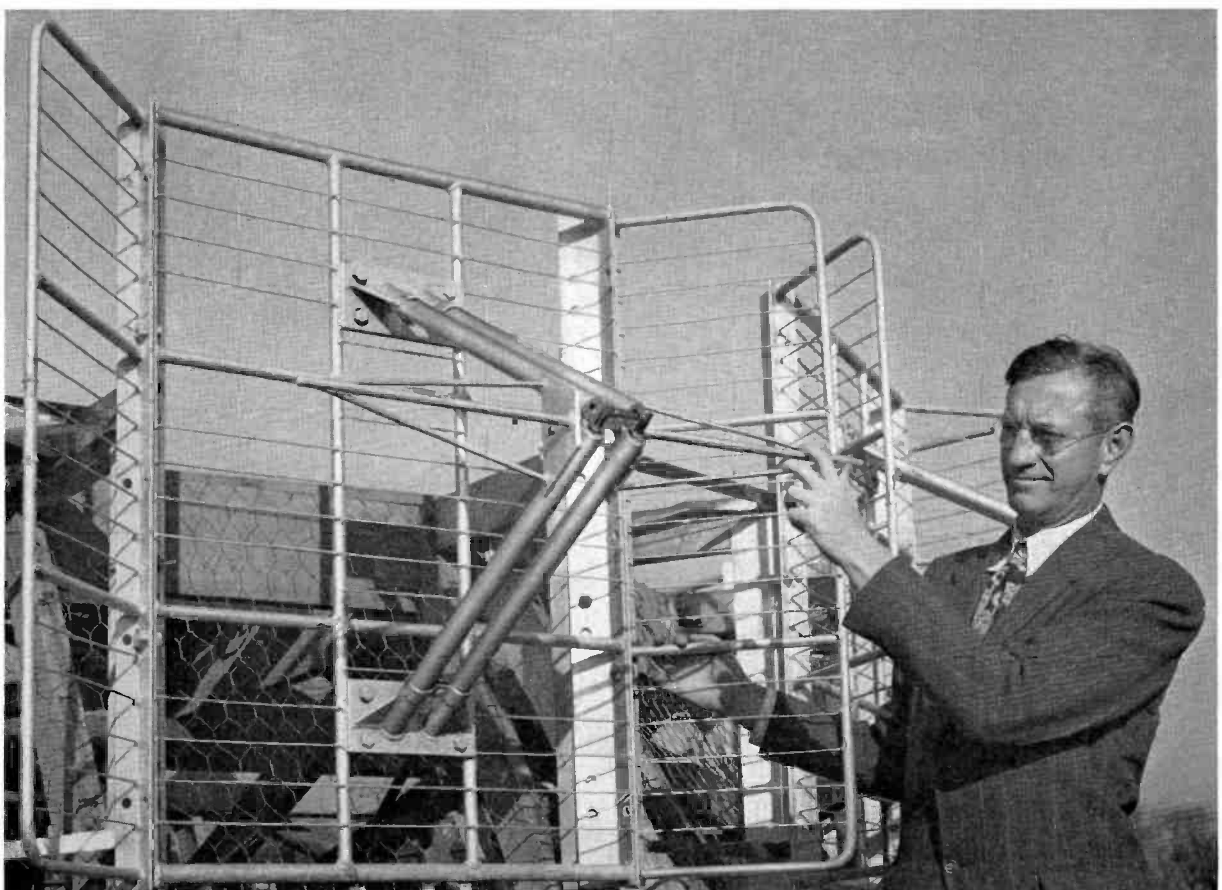


FIG. 1. L. J. Wolf examines developmental model of RCA's new Supergain Antenna. Reflecting screens on sides are used to reinforce forward radiation. Wire screen behind antenna used during tests simulates sustained tower or building.

pedance over a wide frequency band. The N-S and E-W radiators are fed with currents phased 90 degrees apart to obtain a pattern which is almost circular. This is illustrated in Fig. 3 in which the dotted lines represent the currents of each pair of radiators. The field is assumed to be unity in the north and also in the east direction since radiation is received from only one dipole in each of these cases. At an angle at which radiation is received from both dipoles, the resulting field is the vectorial sum of two fields having cosine distribution and added in quadrature. For instance, in the north-east direction (45 degrees) the radiation from each is 0.707 and the vectorial sum is unity as shown in the table.

The action of the Superturnstile radiator is best explained from slot radiation theory. In Fig. 4, (1) shows two parallel conductors a half wavelength long, short circuited at the ends and fed by a generator at the center. Under this condition a voltage wave will be set up, having a magnitude as shown by the dotted line. The spacing of the conductors is assumed small compared with a wavelength so that negligible radiation occurs.

In (2) the two conductors are assumed to be the edges of a slot in a large conducting sheet. The voltage distribution will be similar to that previously shown but currents will flow horizontally so that radiation takes place. This radiation is on both front and back sides of the sheet. It can be demonstrated that the magnitude of the currents flowing horizontally decreases with distance from the slot because of radiation resistance and that these currents decrease to a negligible amplitude at a distance of about a quarter-wavelength from the slot. It is therefore possible to eliminate sheet material that is more than a quarter-wavelength away from the slot without affecting radiation materially, as shown in (3). This configuration can be used as a radiator. It can be supported at the midpoints at either end since these are at zero potential. The vertical and horizontal patterns will closely approximate those of a half-wave dipole since most of the current flowing horizontally will be concentrated at the center. The impedance characteristic with varying frequency will also closely approximate that of a half-wave dipole.

(4) shows the method of taking advantage of the vertical dimension of the sheet radiator. This is accomplished by notching out the central part to reduce the currents flowing at the middle. As the notch depth is increased the horizontal current path at the center becomes less; this increases the impedance so less current flows. The currents at the top and bottom will then be relatively greater than that at the center and hence the vertical pattern will closely approximate that of two horizontal dipoles, spaced vertically a half-wave apart. Fortunately the impedance characteristic is broadened so that it is nearly constant over a wide frequency range. To reduce wind resistance, mesh construction is substituted for the solid sheet. This has no electrical effect since the spaces are small compared with the wavelength.

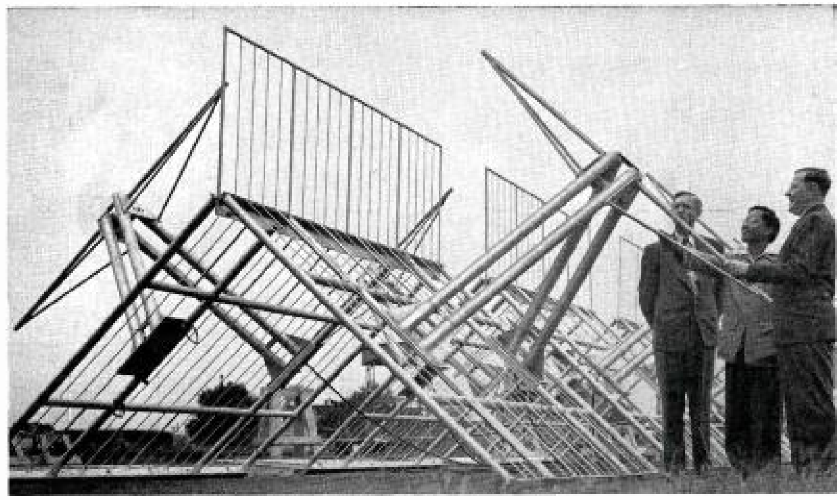


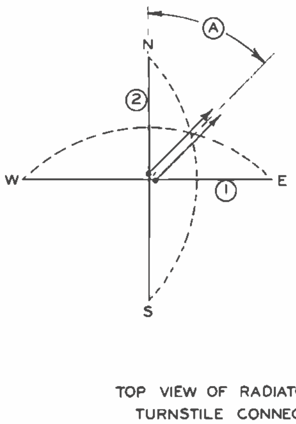
FIG. 2. The RCA Supergain Antenna designed for operation in Channel 4 being examined by L. J. Wolf (left), and Howard King (center), Engineers, and E. S. Clammer of Broadcast Equipment Sales.

The coaxial feed lines for an antenna using these radiators can be connected so that the outer conductor feeds one side and the inner conductor feeds the other side, thus the opposite sides will be fed plus and minus as indicated in the figures. The feed line can run down along the radiator and onto the pole at the upper or lower midpoint: thus no isolating device is needed. This is shown in (4). Several layers of these radiators are stacked on a pole to achieve moderate values of gain. One layer has a gain of approximately 1.2. All radiators are fed from common junction boxes with feed lines, all feed lines having the same length to maintain correct phasing.

The double transmission line feed (one for east-west and the other for north-south radiators) provides a simple method of combining the visual and aural inputs to the antenna system. Fig. 5 illustrates the connections used. In (1) is shown the schematic diagram, the lines representing the inner conductors of the coaxial lines. The two transmission lines from the antenna are connected to a wheatstone bridge type of diplexing unit so that the visual connection is push-pull and the aural connection is push-push. One transmission line is made a quarter-wavelength longer than the other, to establish the quadrature phasing of the N-S with respect to the E-W radiators.

In (2) the similarity to a wheatstone bridge is shown. The two sides of the antenna are the two upper resistance arms, and the circuits of the diplexer are the two lower reactance arms. It is thus evident that no cross talk between visual and aural can occur as long as the two resistances and the two reactances are respectively equal. This freedom from cross-coupling is independent of frequency.

The antenna is used simultaneously for both TV and FM in many cases, particularly those in which the TV frequency is near to the FM band. In this case the impedance characteristic of the antenna is such that excessive standing waves do not exist on the radiator feed lines at the FM frequency. A careful technical analysis is necessary to determine whether or not this is feasible in each case. Fig. 6 illustrates the way in which the FM transmitter is connected to the two transmission lines through frequency-selective networks. The double stub sections shown are designed to have a low impedance over a wide band of frequencies except for a narrow frequency range in which the impedance is high. At a frequency such that the lower stub of one of these circuits is a half wavelength, the impedance will be zero and over a consid-



A	1	2	RESULTANT
0	1	0	1
30	.5	.866	1
45	.707	.707	1
60	.866	.5	1
90	0	1	1

FIG. 3. The N-S and E-W radiators are fed with currents phased 90 degrees apart to obtain nearly circular pattern. Dotted lines represent the currents of each pair of radiators.

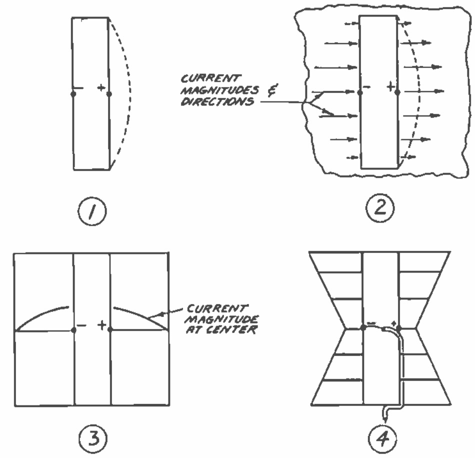


FIG. 4. Diagrams above illustrate slot-radiation theory. Number 4 shows turnstile design obtained by notching out central part to reduce currents flowing at middle.

erable range of frequency the impedance will be much lower than the characteristic impedance of the line. However, at the specific frequency where the combined length of the two stubs is a half wavelength, the impedance will be high. This circuit arrangement is therefore characterized as a "notch" circuit, because of the narrow range in which the impedance is high. The FM enters the two lines through these notch circuits which are tuned to be low impedance over the TV range, but high impedance for the narrow FM band. Two additional notch circuits are shown below the FM feed. They are placed on stubs a quarter wavelength from the transmission line and cause a short circuit at the point of connection at the FM frequency. They thus act to prevent FM feed back into the TV transmitter, but have no effect at the TV frequency band.

The phasing length, to provide quadrature feed at the FM frequency, is placed in the FM feed, and the TV quadrature loop is placed near the diplexer to correctly phase the TV transmission.

Fig. 8 illustrates methods of achieving power equalization of the N-S and E-W radiator system. Such a method is sometimes necessary, particularly if the antenna does not closely match the impedance of the transmission lines. Suppose, for example, that the impedance of an antenna input without power equalization at some frequency in the TV band is 85% of the transmission line characteristic impedance. On one side the quarter-wave phasing section will invert this impedance to 118% and hence the impedances on the two output terminals of the diplexer will be 0.85 and 1.18 respectively. Under usual considerations the voltages applied to the two sides of the antenna will be in this ratio of 0.85/1.18 and hence the power in the two sides will be in the ratio of almost 1 to 2. The antenna pattern will thus depart considerably from a circle.

Referring to the visual connection in the diplexer on the left hand side of Fig. 8,

FIG. 5. Figure below (left) shows double line quadrature feed for E-W and N-S radiators. Center diagram shows similarity of antenna and diplexer to wheatstone bridge.

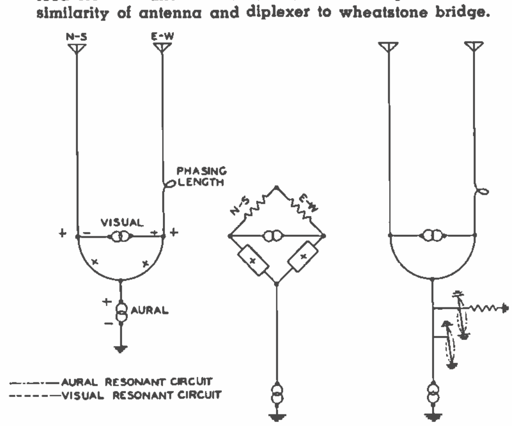
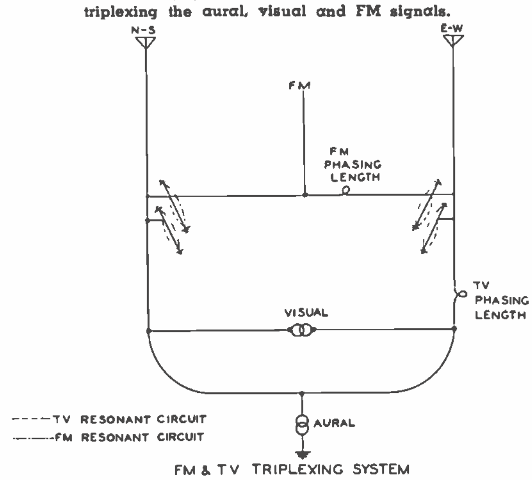


FIG. 6. Diagram illustrates method of connecting an additional FM transmitter to the transmission lines, thus triplexing the aural, visual and FM signals.



waves travelling up the two transmission lines and being reflected downward at the antenna will change in phase by 180 degrees with respect to each other because the wave on the right will have passed twice through the 90 degree phasing length. The two waves will then be in the same phase and will therefore induce no voltage in the visual transmitter. Instead they will induce voltages on the line to the aural transmitter. A suitable notch filter circuit can then separate the reflected energy from the aural input, so the reflection can be absorbed in the resistor.

Under this condition, with the power equalizer circuit operating, power dissipated in the resistor is equal to the square of the reflection coefficient. In the example above, the reflection coefficient is 0.08 and hence the power lost in the resistor is less than one percent of the input. The reflected waves do not pass back to the visual input and hence the visual transmitter delivers equal power to each side of the antenna. This equalization is achieved at the expense of less than one percent of the visual power. In addition, no echos can appear on the received picture because reflections returning down the transmission line are absorbed without returning to the antenna to be radiated.

The right-hand illustration of Fig. 8 shows another connection which utilizes only one transmission line up to the antenna. In this case the visual and aural signals are combined in a notch filter arrangement and a bridge circuit is used for the power equalizer.

This review of present antenna practices has illustrated what has been accomplished. These same techniques are available and will be useful for antennas for higher gain. For instance, the principle of quadrature feed to obtain a circular pattern, to permit an easy method of diplexing the visual and aural signals onto the same antenna and to permit power equalization, will be very useful. The notch diplexer method will also be useful since the design using only one transmission line will be important when extremely high towers are considered.

In planning for antennas of higher gain a study must first be made to determine the highest value of power gain which is practical. The only way in which higher gain values can be realized is by narrowing of the vertical pattern, so that a greater proportion of the energy is radiated in the horizontal plane where it is useful. This is done by stacking layers of radiators and feeding them with equal currents.

The antennas used at present consist of radiators mounted on a pole. For lengths up to about 50 or 100 feet the pole mounting is satisfactory, but for lengths greater than that the tower type of construction, consisting of three or four corner legs, with suitable bracing members is the most economical. In addition, the tower-type construction has the following three advantages:

FIG. 7. Photo shows units of KRON-TV Supergain Antenna before air-shipment to the San Francisco Station. These radiator elements for KRON-TV are designed for stacking on two adjacent sides of four-sided tower as shown in Fig. 15.

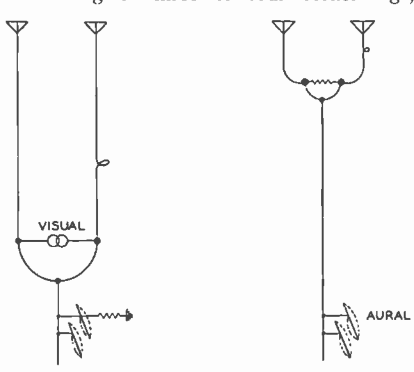


FIG. 8. Diagram above illustrates method of achieving power equalization of the N-S and E-W radiators of the Superturnstile Antenna.

1. Multiple antennas: The structure required to support an antenna having a gain of 10 or 20 can be made to support other radiating systems at only a slight additional cost. It is therefore good economics to use such a structure for as many purposes as possible. The tower type of construction lends itself to multiple use, such as an AM radiator and to support antennas for FM and other TV stations. The use of a single tower by two or more TV stations is good engineering from the standpoint that all receiving antennas will automatically be oriented in the right direction for all channels so used. The advantages of multiple usage may offset the inherent expensiveness of such structures.

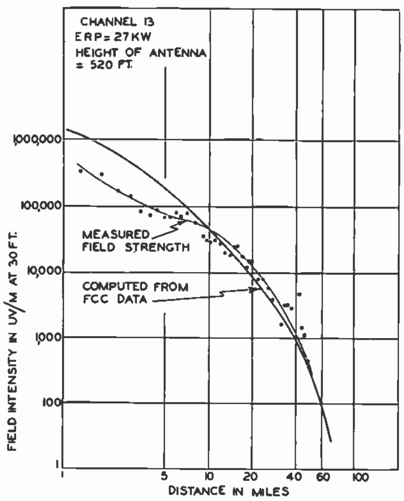


FIG. 9. Graph above shows plot of field strength vs. distance for an antenna on Channel 13 having a gain of 7.1.

2. ACCESSIBILITY: In most cases the interior of the tower is available for access to the antennas. Thus, one antenna can be serviced or repaired without inconvenience to the schedules of the other stations. If only one antenna is involved, the interior of the tower allows more room for the multiplicity of feed lines and connections which is inherent in the use of a great number of radiators.

3. CHOICE OF HORIZONTAL PATTERNS: In many cases a pattern other than circular can be used to advantage. Suitable shields can be placed on a tower to concentrate the radiation in a desired direction. The mechanical support of such screens and shields on a pole poses severe design problems.

Most antennas are mounted at rather great heights on buildings or towers. This precludes the use of a radiating system which achieves gain through large horizontal dimensions as this would require a large horizontal area on a building top or a multiplicity of towers for support. It appears best, therefore, to use an antenna design which requires only a single tower or small area on a building top. For such an antenna, having a circular pattern, the relation

$$a = \frac{61}{G}$$

gives the width of the vertical angle where "a" is the total width of the vertical angle of the main radiation lobe to the half-power points, and "G" is the power gain compared to a half wave dipole. Thus, for an antenna with a circular pattern having a gain of 20, the vertical angle is about 3 degrees, which corresponds to a half-power point of 1½ degrees negative elevation, if the beam is exactly horizontal.

At this point it is important to investigate the effect of antenna deflection under high wind conditions. A guyed tower or a building will usually have a deflection small compared to the 1½ degrees angle but a self-supporting tower may have almost any amount of deflection depending on the design. The tower manufacturers who have been contacted are confident that self-supporting towers can readily be designed to have a deflection no greater than plus/minus ½ degree under usual wind conditions. Tower deflection, therefore, places a practical limit on the maximum power gain that can be employed.

It is also important to consider the effect on the coverage in the area which is within a few miles of the antenna in order to find out how much the field strength is reduced because of the narrowness of the vertical beam. Fortunately considerable data is available because field strength surveys have been made on many stations with antennas having values of power gain up to 7. Fig. 9 shows the plot of field strength *vs.* distance for a station on Channel 13, with an antenna having a gain of 7.1. The antenna is at a height of approximately 500 fet above average terrain. It will be noted that the field strength near to the antenna location is somewhat less than the theoretical curve and that it reaches the curve at a distance of about 5 miles.

Fig. 10 shows plots of field strength *vs.* distance for several antennas having gains up to 20. The theoretical curves, plotted from FCC information, is shown for each value of gain. It will be noted in each case that the actual curve meets the theoretical curve at successively greater distances as the gain is increased, and that the actual curve is generally flat at lesser distances.

It will be seen that for a gain of 20, with an ERP of 100 KW, the calculated and

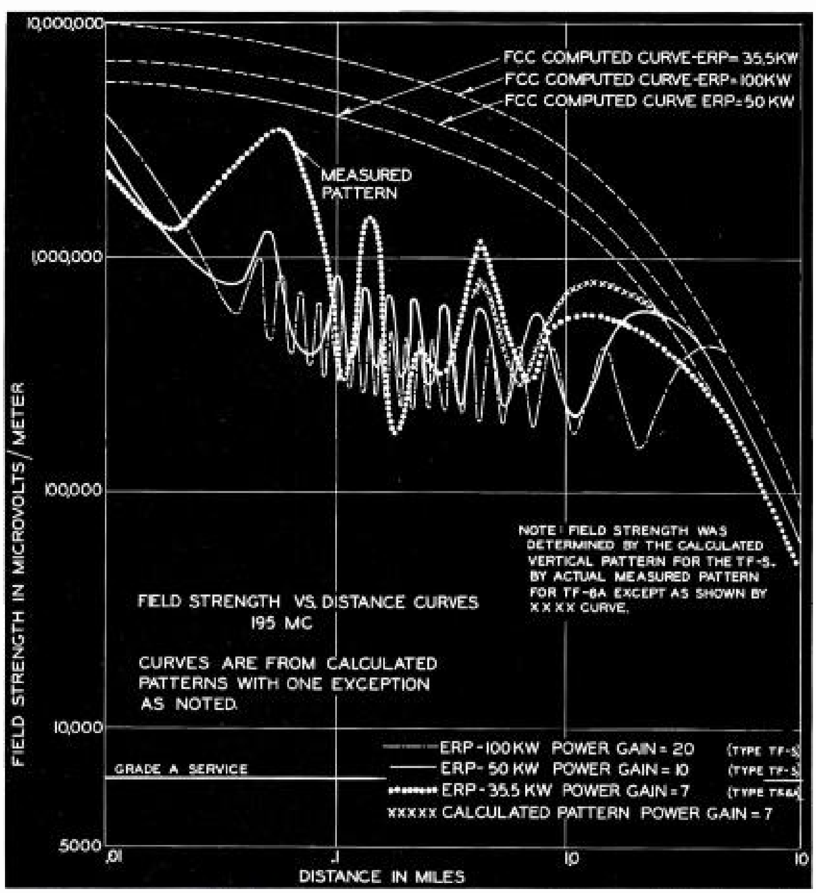


FIG. 10. Field strength vs. distance for several antennas having gains up to 20.

FCC curves meet at about five miles where the field strength is approximately 400 millivolts/meter and that there is no location from the antenna out to this distance with less than 150 millivolts/meter. This is more than enough to provide Grade A service, which requires 7.5 millivolts/meter. It appears practical, therefore, to install antennas having a power gain of the order of 20.

Another important consideration is the relation of the height, measured from highest to lowest radiator, to the height of the antenna above the terrain. If the antenna consisted of a single radiator at a great height it is obvious that adding additional radiators at the correct distance just below it would increase the gain. As radiators are added, the power must be distributed among them. When enough radiators are added so that the last one is near the ground, the effective gain is decreased because power is detracted from the highest radiators to energize the lower ones. The radiators close to the ground would not be appreciably increasing the effectiveness of the antenna. The limiting condition, beyond which no additional gain is realized, exists when the distance up to the center of radiation is about twice the distance between lowest and highest radiator as shown on Fig. 11.

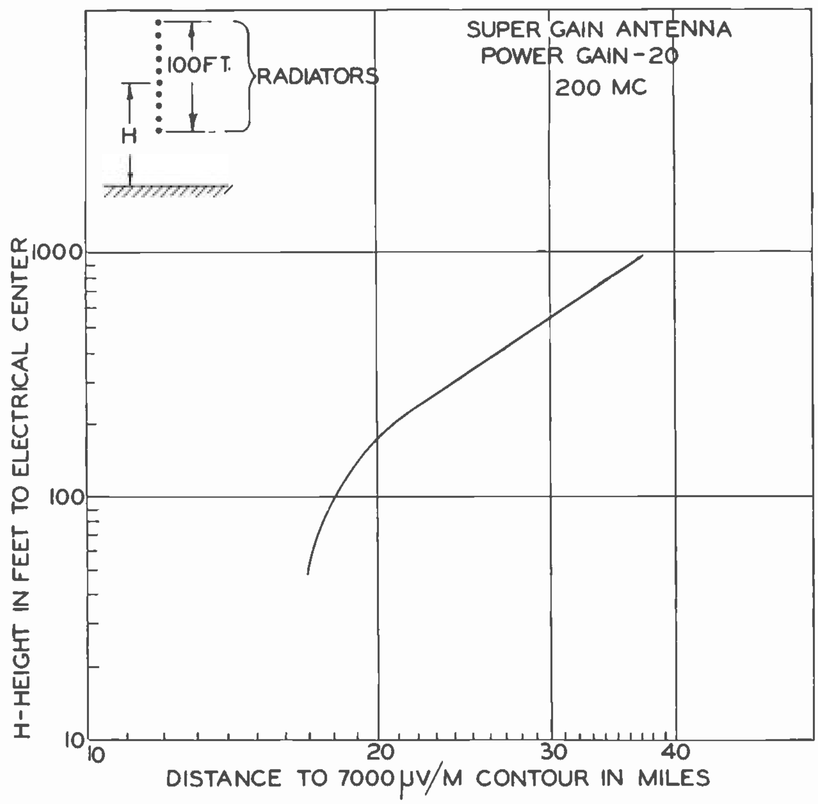


FIG. 11. As height of dipole antenna is reduced, there is a sharp drop-off in coverage. Graph shows that height of electrical center (H) must be greater than aperture height (in this instance 100 feet).

A type of radiator different from the Superturnstile bat-wing had to be chosen for the tower-mounted antenna because the bat-wings do not have a satisfactory impedance characteristic with frequency when mounted in front of a screen. This is true whether they are perpendicular or parallel to the screen. The decision was therefore made to revert to the classical dipole, consequently the radiators for the tower mounted Supergain antenna consist of dipoles mounted in front of reflecting screens. The shape of the dipoles is modified to achieve a band width somewhat greater than that of the conventional half wave dipole so as to match the feed line over the six megacycle channel. The addition of the power equalizing circuit permits full coverage of the channel without echos appearing on the received picture. However, these radiators do not have the extremely wide frequency characteristic of the bat-wing radiator, and hence the simultaneous use of the Supergain antenna for FM and TV is not recommended.

The reflecting screen is used to keep radiation out of the tower and thus prevent changes in the impedance over the channel width due to coupling with objects within the tower. In addition the screen narrows the pattern of each dipole radiator. The reflecting screens can either be furnished as separate screens to mount on the tower face, or can be fabricated into the tower itself.

In either case, the dipoles with backing screen are mounted in layers, having a vertical separation of slightly less than one wavelength as measured center to center.

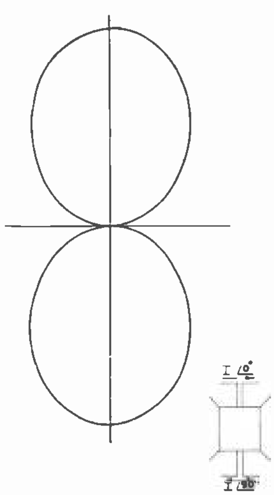


FIG. 12. Theoretical field pattern obtained by energizing the radiators on opposite side of tower. Note that nulls are quite wide.

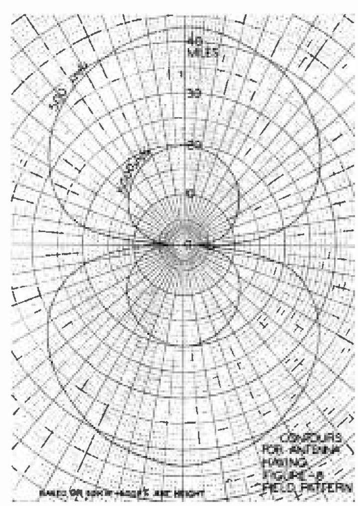


FIG. 13. This figure shows the actual coverage pattern for Fig. 12. Graph shows 5000 and 500 uv/m contours. Note that nulls are relatively narrow.

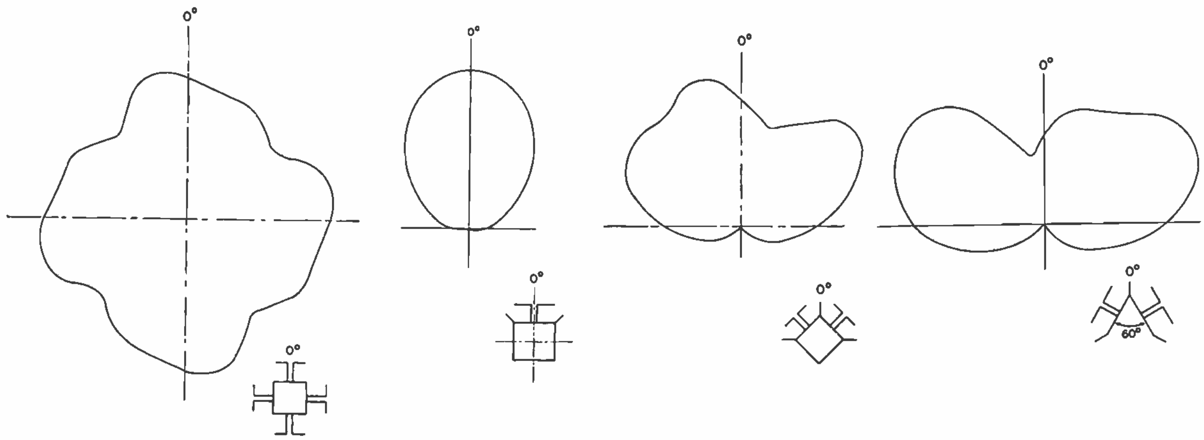
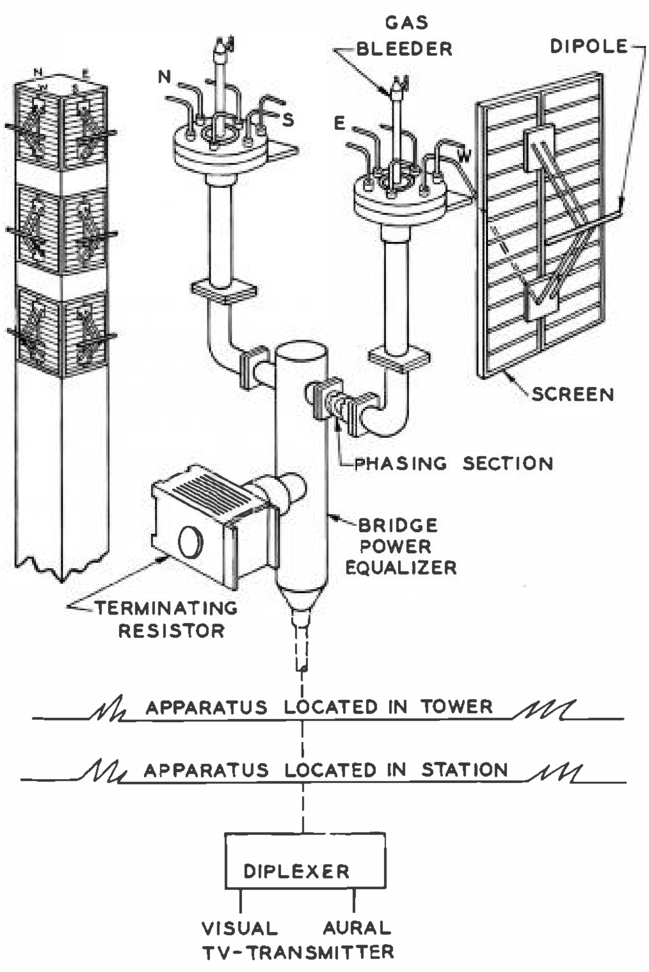


FIG. 14. Above are shown some of the special radiation patterns possible with Supergain Antennas. Small inset diagrams show current phasing of antenna sections. Circular and figure-eight patterns are also obtainable by proper installation and connection of radiators.



The electrical excitation is accomplished by feedlines, all of equal length, joining the radiators to common junction boxes. Either one or two transmission lines, depending on the system used, connect the junction boxes to the TV transmitter.

In all cases the tower has a side dimension of one-half wavelength. A smaller side dimension results in interference between dipoles on adjacent sides whereas a larger side dimension leads to pattern difficulties. Thus the width varies from 9 feet for Channel 2 to 2½ feet for Channels 10, 11, 12 and 13.

For antennas having a gain of ten or more, a means can be provided for tipping the pattern a slight amount. This is useful, for instance, in the case of an uneven terrain. The pattern can be tipped downward a degree or so to effect better coverage close in, or it can be adjusted to increase the coverage at a distant locality. To accomplish this beam tipping, the antenna is divided into upper and lower groups by the feed system. The phasing of one of these groups can be changed to provide a slight change in vertical angle without affecting the gain adversely.

As previously mentioned, this type of radiating system can be made for several types of directional pattern, as well as for a circular pattern. In general, radiators

FIG. 15. Diagram at left shows a typical arrangement for a three-layer Supergain Antenna on Channel 4. Note that N-S radiator lines are fed directly to bridge tower equalizer, while E-W line is a quarter-wavelength longer to provide quadrature feed.

may be placed on any of the faces of the tower and thus provide several combinations of directional pattern. In discussing possible directional patterns, each screen and radiator can be considered to have the same horizontal pattern as that from one side of a horizontal dipole. For instance radiators may be placed on two adjoining sides of a tower and thus cover approximately 180 degrees. Since the input power is concentrated in two instead of four sets of radiators, the power gain in the maximum direction is approximately doubled.

An important consideration on directional patterns is the difference between the coverage pattern giving field strength contours and the theoretical field pattern of the antenna itself. For instance, consider a system which gives a figure-8 pattern. This may either be a Superturnstile with only the radiators in one plane energized, or a tower with radiators on two opposite sides. Fig. 12 shows the field pattern obtained. It will be noted that the two nulls are quite wide. Fig. 13 shows the coverage pattern for both the 500 and 5,000 uv/m contours; it is evident that the nulls appearing on this figure are quite narrow.

Fig. 14 shows various combinations possible with this type of construction. The patterns obtained vary from circular with radiators on four sides energized, to the pattern which results with three sides energized.

The preferred patterns, from the engineering standpoint, are those with two sets of feed points which are fed in quadrature as this permits the use of the power equalizing circuit.

Fig. 15 shows an installation of 12 dipoles in three layers, forming a non-directional antenna with a gain of approximately three. This arrangement is used on a tower which supports another antenna and is constructed so that a future change to a directional array can be made. It is to be noted that the N-S radiator feeds are brought directly into the power equalizer while the E-W feed length is a quarter-wavelength longer, to provide the quadrature feed. One transmission line is used to connect from the antenna to the notch filter in the transmitter room.

Fig. 16 shows a typical arrangement for a 12-layer antenna on Channel 2 with a circular pattern. This antenna has a theoretical gain of 13.2 which results in an actual gain of 11.6 with feed line losses deducted. The attenuation of the transmission line further reduces the efficiency so that an effective gain of about 10 for the system is realized. It is to be noted that both the E-W and N-S feeds are split into upper and lower groups. This permits phasing sections to be used for controlling the angle of the vertical pattern.

In conclusion therefore, the art of antenna design has advanced to a position wherein antennas can be constructed with power gains of the order of 10 to 20 and can also be made to have certain directional patterns. It has been shown that higher gain antennas provide an attractive way of obtaining the higher values of ERP proposed by the FCC. These higher gain antennas are best constructed on a tower and the tower can conveniently be used for other similiar services.

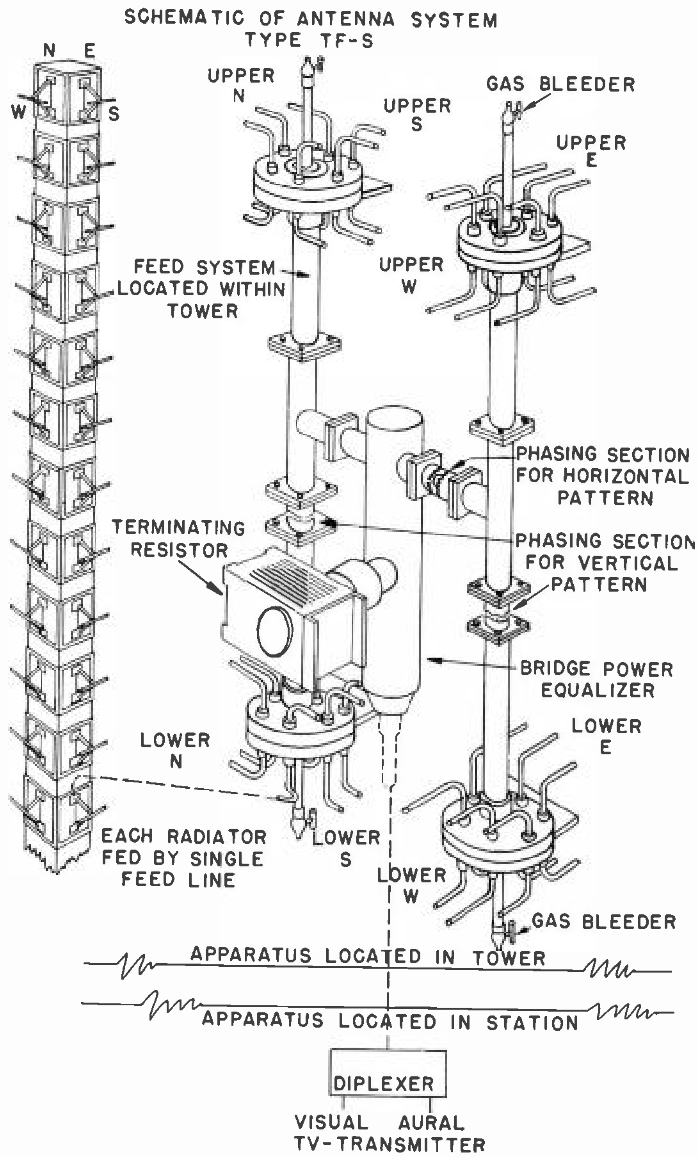


FIG. 16. Diagram above shows an installation of 12 dipoles on each side of a tower which can support another antenna. Note that both E-W and N-S feeds are split to permit phasing sections for controlling angle of vertical pattern. Only one transmission connects antenna to notch diplexer located near transmitter.

References

R. W. MASTERS, "A Power-Equalizing Network for Antennas," Proc. IRE, page 735, July 1949.

L. J. WOLF, "Triplex Antenna for Television and F-M," Electronics, vol. 20, page 88, July 1947.

O. O. FIET, "8-Section Pylon Makes 546-KW a Reality," BROADCAST NEWS, vol. 53, page 33, February 1949.

HOW TO ADJUST FREQUENCY RESPONSE IN VIDEO AMPLIFIERS FOR TV

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RCA Engineering Products Dept.

Along with all the problems connected with operating and maintaining a television station, the maintenance of video amplifiers requires certain techniques which are very likely new to the station owner and his engineers who have had past schooling and experience mainly in the handling of audio equipment. The difficulties in handling these new techniques arise mainly from the relatively high frequencies included in the upper end of the video band. If measurements and adjustments are made without adequate test equipment, or without adequate knowledge of suitable methods, the results may be erroneous and misleading. Therefore, it is the purpose of this article to outline some methods of measuring the performance of video amplifier circuits and for adjusting them, thus providing at least some of the "know-how" required for satisfactory maintenance.

The problem will be discussed almost entirely from the qualitative angle because that is the most important aspect to the maintenance man. In other words, an effort will be made to describe what happens in the circuit when changes are made in certain components, but little space will be given to theory which is thoroughly covered in existing literature. A qualitative sense, or sense of "direction", is a most valuable asset in dealing with the practical operation of circuits.

Typical Circuits

Wide-band video amplifier design is based almost exclusively on the use of resistance-capacitance coupled amplifiers, the important basic elements of which are illustrated in the simplified schematic of Figure 1. Some of the practical elements of the circuit, such as B supply, bias supply, or screen grid filter, have been omitted because it is assumed that they are designed so as to have negligible impedances for any signal frequencies involved.

The discrete components of the circuit are shown in solid lines, while another important component (stray capacitance) is shown in dotted lines. Most circuit components also include residual or stray inductance, but this is not shown because components are chosen and arranged in practical circuits so as to have negligible inductive reactance in the band of frequencies used in TV amplifiers. Stray capacitance, however, is not negligible, and care should always be exercised in working on video amplifiers not to disturb the general arrangement of wiring and components in such a way as to change the stray capacitance appreciably.

Because of the wide-band requirements, the effective load impedance is held to characteristically low values. Usually R_L (Figure 1) constitutes the principal load on the plate circuit. In other words, R_L is small compared to R_g so that R_g may be neglected in calculations involving load impedance. However, in some circumstances, the situation may be reversed so that R_g becomes the principal load and R_L becomes relatively large. This case will be discussed under output circuits.

The frequency response characteristic of an uncompensated amplifier, such as that shown in Figure 1, has the general appearance of the curve of Figure 2(a) where e_o is the alternating signal voltage appearing at the output terminals across an ideal purely resistive load when a signal at constant voltage is applied to the input terminals. Usually there is a mid-range where the output is reasonably constant (where the curve is said to be "flat") while on either side of the mid-range the response of the amplifier falls off toward zero.

It is convenient to choose some frequency, say f_1, in the mid-range which

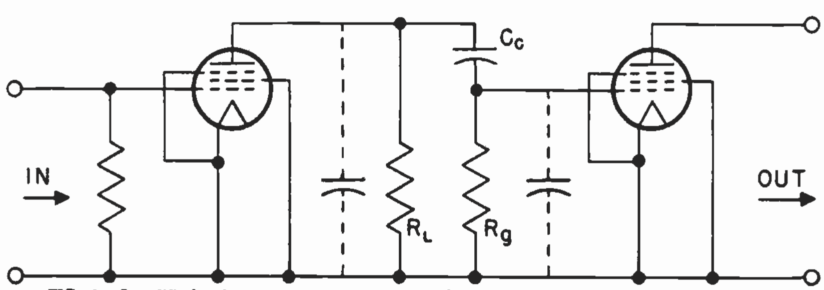


FIG. 1. Simplified schematic circuit of a typical resistance-capacitance coupled amplifier.

divides the curve into two parts. At frequencies above f_1, the curve is usually flat for an appreciable range, indicating that neither the stray shunting capacitance nor the coupling capacitance, C_c, affects the response. In other words, the reactance of C_c is negligibly small, and that of the strays is negligibly large, so that the circuit is purely resistive. However, as the frequency increases further, the shunting of the strays becomes increasingly effective, causing the output to fall off gradually. Below f_1, the shunting effect of the stray capacitance is obviously negligible, but the reactance of C_c increases as the frequency decreases, so that the voltage across R_g decreases correspondingly, and the output of the amplifier falls off to zero. Because one reactive element operates effectively on one side of f_1, and the other reactive element operates on the other side, it is easy to treat the frequency response of the amplifier in two corresponding parts which are independent of each other. These two parts are commonly called the "highs" and the "lows" respectively.

Measurement and adjustment of the highs are always made first because from this measurement the correct value for R_L is determined. The magnitude of R_L also influences low frequency compensation, but its value is fundamental to correct adjustment of the highs; therefore, once it has been determined, other elements affecting the lows must be adjusted for compensating purposes without disturbing R_L.

High Frequency Compensation

Numerous circuit arrangements have been used to improve the high frequency response of video amplifiers. Of these, two have come into common use in RCA equipment, as well as in other types. The first is illustrated in Figure 3. Here the two shunt capacitors shown in Figure 1 have been combined into one which resonates with a small inductance in series with R_L. This is commonly known as a "shunt-peaked" circuit. Because R_L is in series with L_2, the Q of the circuit is very low, and there is no prominent resonance peak in the output voltage. When the values of R_L and L_2 are correctly adjusted, the effect on the frequency response is about as illustrated by Figure 2(b). The flat part of the curve has been extended, but the cutoff is still reasonably gradual.

The circuit of Figure 3 is used occasionally where the need for increased bandwidth (or gain) is not great, and where simplicity and reasonably linear phase characteristics are important.

The more frequently used circuit, however, is shown in Figure 4, where it may be seen that a second inductive element has been added in series with the plate connection of the first amplifier. This added coil has the effect of dividing the stray capacitance into two parts and thus forming a single section of a low-pass filter in which the characteristic C is only a fraction of the total stray capactance. Therefore, the characteristic (terminating) impedance of the circuit is considerably higher than is possible in a circuit where the stray capacitance is not divided. This means simply that a higher value of R_L may be used. The figure of merit* (gain × bandwidth) of the circuit is appreciably larger than for the circuit of Figure 3. The frequency response curve is illustrated

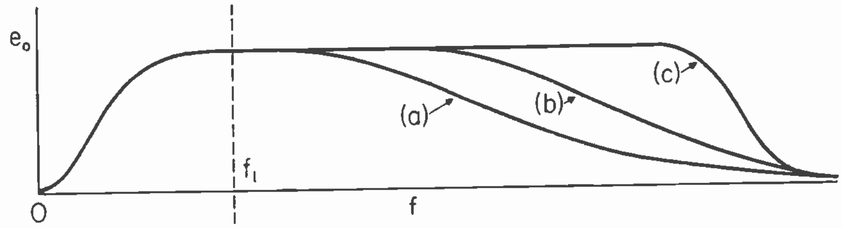


FIG. 2. Typical curves of frequency response for various kinds of compensating circuits.

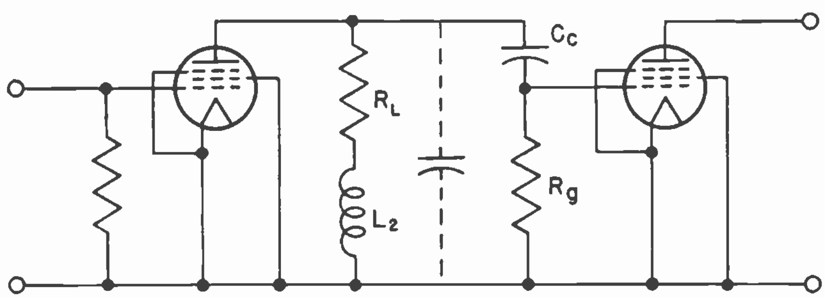


FIG. 3. "Shunt peaked" video amplifier.

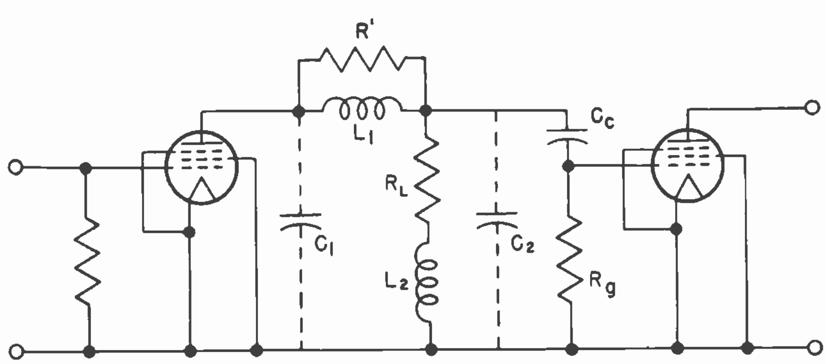


FIG. 4. Video amplifier using both shunt and series peaking.

* The performance of an amplifier is measured in terms of both gain and bandwidth. These are mutually dependent factors. As one increases, the other decreases, so that the product remains constant. It is therefore common practice to refer to the product of these two factors (gain × bandwidth) as the *figure of merit* of the amplifier. For example, if a given amplifier has a gain of 20 and a bandwidth of 4 mc., the same amplifier may be rearranged to have a bandwidth of 8 mc. and a gain of 10 by reducing R_L to one half its original value and making corresponding changes in the values of L_1 and L_2. Thus, any improvement in circuit performance obtained by improved design or execution may be used (a) to increase the bandwidth, (b) to increase the gain, or (c) to increase both by a lesser amount.

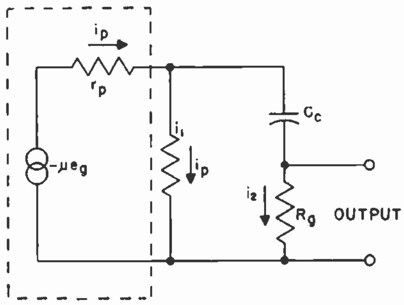


FIG. 5. Simplified circuit including only those elements which affect low frequency response.

in Figure 2(c). It should be noted that the cut-off is relatively abrupt, and that the phase response is more non-linear near cut-off than in the simpler circuits.

Low Frequency Compensation

The small coils added to the circuit for high frequency compensation have negligible reactance at frequencies below f_1. Hence, in considering the "lows", the circuit may be reduced to that shown in Figure 1, but with the shunting capacitances omitted also. It must be remembered, however, that the value of R_L has been deteremined by the needs of the "highs" and it should not be disturbed in compensating the "lows".

Because the functioning of some low frequency compensating circuits may not be understood, a little discussion of simple theory will be given here.

Figure 5 shows a simplified arrangement of the circuit of Figure 1 suited to study of the low frequency performance. The first amplifier tube is shown as a generator. with internal series resistance r_p, within the dotted enclosure. The second tube is not shown, but output terminals are shown which would be connected normally to the grid and cathode. Grid conductance is assumed to be negligible. The following relations are essentially true for screen grid tubes used in TV video amplifiers:

$$r_p \gg R_L$$
$$R_g \gg R_L$$

Therefore, it may be concluded that:

A. i_p is in phase with the generator voltage because r_p (a pure resistance) is the principal impedance in the load circuit.

B. Both Z_L and R_g may be changed considerably within their respective orders of magnitude without changing the magnitude or phase of i_p. (Z_L includes R_L and any reactive element which may be added, as in Figure 6.)

C. The current, i_1, is essentially equal to i_p in phase and magnitude.

D. The voltage drop across R_L is in phase with i_p.

E. The current, i_2, is displaced in phase by the reactance of C_c.

F. The output voltage ($i_2 R_g$) is likewise displaced in phase.

To obtain undistorted amplification, the output voltage should be kept exactly in phase with the generator voltage and i_p. There are several ways to accomplish this:

1. Make the reactance of C_c negligible at the lowest frequency in the band (make C_c larger).

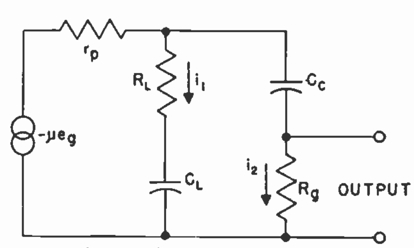


FIG. 6. Simplified circuit with addition of low frequency boost.

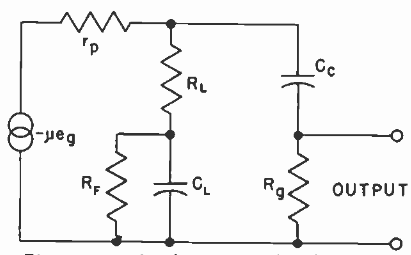


FIG. 7. Simplified circuit with addition of decoupling resistor R_F.

2. Make R_g larger so that the reactance of C_c is comparatively very small.
3. Shift the phase of the voltage across the plate load circuit so that i_2 is in phase with i_p.

The limit of the first method is reached when the coupling capacitor becomes too large to fit in available space, or when its size causes an intolerable increase in stray capacitance, thus causing deterioration of the high frequency response.

The magnitude of R_g is limited, of course, largely by the maximum resistance which can be allowed in the grid circuit of the tube to insure stable operation. This maximum is specified by the tube manufacturer to prevent gas current to the grid (positive ion current) from causing an excessive increase in average plate current.

In many cases, methods 1 and 2 are sufficient, within their limitations, to produce satisfactory results. When they are not adequate, however, method 3 is employed. The desired phase shift may be secured simply my making the two parallel branches of the load circuit *similar* in impedance characteristics, i.e. with equal phase angles, but not necessarily equal magnitudes. Addition of C_L, as shown in Figure 6, accomplishes this. The two branches now contain like impedance elements, and if C_L is chosen so that $R_L C_L = R_g C_c$, then i_1 and i_2 will have the same phase angle. This must be the same phase angle as that of i_p (under the assumptions A, B, and C) because $i_1 + i_2 = i_p$; therefore, $i_2 R_g$, the output voltage, has been corrected to be in phase with i_p and with $-\mu eg$. The relationship will continue to hold as the frequency decreases until the reactance of C_L, $\left(\frac{1}{\omega C_L}\right)$, becomes appreciable in magnitude as compared to r_p, and therefore begins to affect the magnitude and phase of i_p. This does not usually occur until the frequency becomes extremely low, well below the useful video band.

Figure 6 is not a practical circuit because it does not provide a d-c path to the anode of the first amplifier tube, but it illustrates an important principle. To make the circuit practical, another resistor, R_F, must be added as shown in Figure 7. This resistor will not affect circuit performance as long as R_F is large compared to $\frac{1}{\omega C_L}$ at the lowest frequency in the band. However, R_F is limited in size by the available B supply voltage; i.e., the d-c drop in R_F must not reduce the operating potential on the plate of the tube below a satisfactory level.

When R_F cannot be made suitably larger than $\frac{1}{\omega C_L}$, then exact compensation

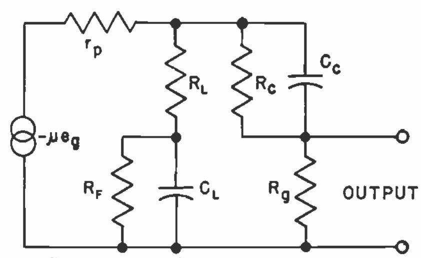


FIG. 8. Simplified circuit with addition of resistive shunt across C_L.

may be restored by adding a resistor R_e in shunt across C_c to restore the similarity of the two parallel branches of the plate load circuit. This is shown in Figure 8. The proper relations for equal phase angles in the two branches are:

$$R_L C_L = R_g C_c$$
$$\text{and } R_F C_L = R_e C_c$$

Obviously, this change provides an unwanted d-c path from the plate of one tube to the grid of the next. This necessitates a final addition in the form of a capacitor C' in series with R_e as shown in Figure 9. Of course the circuit similarity of the parallel branches is lost again by this change, but by proper choice a satisfactory compromise may be achieved which is capable of providing excellent response down to extremely low frequencies. The criterion is that $\frac{1}{\omega C'}$ must be small compared to R_e at the lowest frequency in the band.

Figure 9 not only shows this final change, but shows the complete video amplifier circuit with all the elements for both high and low frequency compensation accumulated in one diagram. Note that R_e is divided into two parts as an aid in isolating the stray capacitance of C' from the main circuit. Also note that R_g is made adjustable so that reasonably exact setting of the response is possible. By such adjustment, the one low-frequency compensating circuit may serve to correct the errors introduced by more than one coupling or de-coupling circuit, provided that no one error, nor the sum of the errors, is very large. This last point is important if several errors are to be corrected by one compensating circuit.

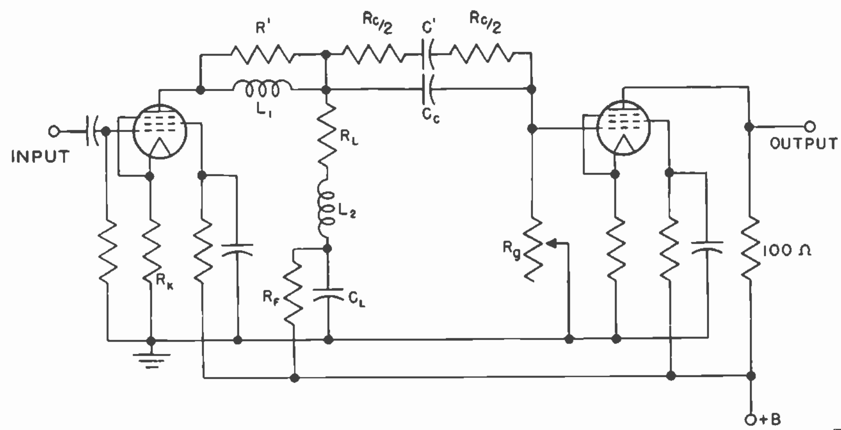


FIG. 9. Complete circuit showing all elements for both low and high frequency compensation.

Test Methods and Equipment

Both high-frequency and low-frequency response characteristics may be measured with test equipment which is readily available commercially. High-frequency response is usually determined with a frequency modulated, or sweep oscillator which sweeps over the desired band, from a point somewhat above the low end to the high end, at an approximately uniform rate, and which repeats at regular intervals. The repetition rate is usually chosen for convenience at 60 cycles. In the intervals between sweeps, the signal is cut off. Care is taken to provide reasonably uniform amplitude during each sweep. The signal produced by such a sweep generator appears about as shown in Figure 10-A. Demodulation of such a signal with a diode detector yields a 60 cycle rectangular wave as shown in Figure 10-B. Such a wave may be observed easily on a cathode ray oscilloscope which has good low-frequency response so that distortion of the 60 cycle rectangular wave is not introduced by the oscilloscope. The oscilloscope used for this purpose need not have high-frequency response beyond 50 to 100 KC.

The sweep oscillator signal is applied to the amplifier to be tested, and the output of this amplifier is coupled into the diode detector. Variations in frequency response of the amplifier then appear as distortion of the wave-shape of the rectangular wave. In other words, the oscilloscope draws the graph of output voltage vs. frequency of the amplifier being tested. Arrangement of equipment is illustrated in Figure 11.

Sweep oscillators are generally provided with tunable, calibrated absorption markers which produce a small notch in the demodulated wave to indicate points on the frequency scale. Such a marker notch is evident in several of the oscillograms shown on following pages.

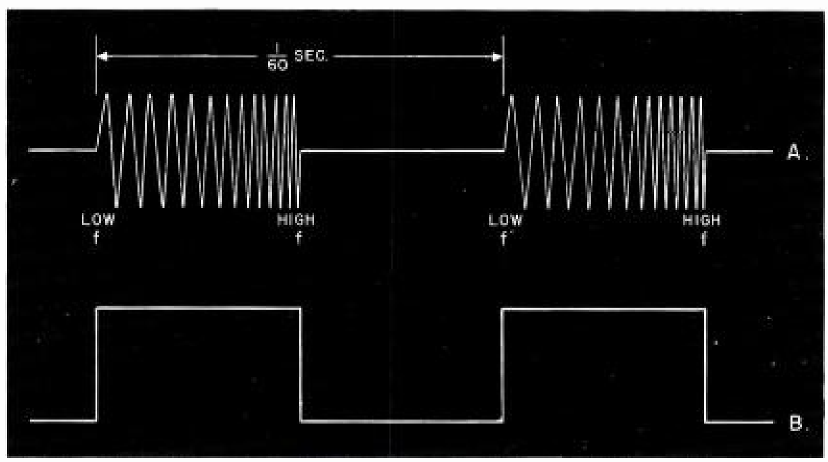


FIG. 10. Wave forms of sweep oscillator output—A. Direct; B. Demodulated.

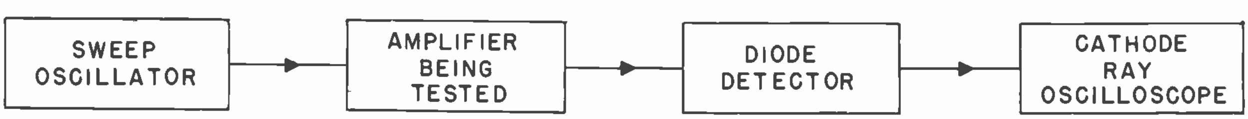


FIG. 11. Block diagram of equipment for measuring high-frequency response.

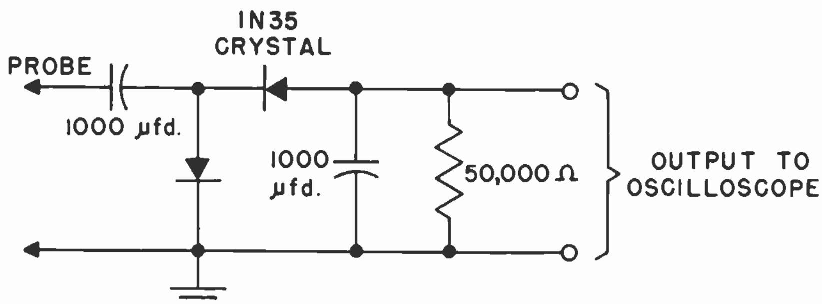


FIG. 12. Schematic circuit of peak-to-peak diode detector for use with a sweep oscillator.

The RCA WA-21A Video Sweep Generator provides a sweep range adequate for the video amplifiers in television terminal equipment, as well as a suitable frequency calibration marker, and an output attenuator. The low end of the sweep range extends to about 100 KC and the high end to about 10 mc.

A suitable diode detector with good sensitivity may be constructed quite easily by using a pair of crystals as illustrated in Figure 12. A dual diode, such as the 6AL5, may be used with equally good results in the same circuit, but it has the disadvantage of requiring a heater supply. Germanium crystals, such as the 1N35, are a simpler arrangement. The circuit of Figure 12 is a peak-to-peak rectifier which provides more output signal than a single half wave rectifier, and which also tends to average out discrepancies in wave form, from stage to stage of the amplifier being tested, if the signal generator has second harmonic distortion. In constructing such a unit, care should be used to make it compact, and to keep stray capacity of the probe and input to a minimum.

Application of this equipment to the measurement of the frequency response of amplifiers cannot be made in an indiscriminate and careless manner without obtaining spurious results. Well defined and relatively simple procedures are available and should be adhered to, to secure correct results. The reason why care must be used is that connecting test equipment to parts of an amplifier circuit which are compensated for, or are critical to, stray capacitances will cause mis-adjustment of the compensation because of the stray capacitance added by the test equipment. The following general procedure will avoid pitfalls of this kind.

The output of a television amplifier is almost invariably a low impedance circuit intended for feeding a coaxial transmission line. Its impedance is so low (75 ohms or less) that a diode detector may be coupled to it directly without serious effect. Therefore, it is desirable to connect the detector at this point, and leave it there for sweep oscillator tests on any or all stages of the amplifier. Test and adjustment of each stage in a multi-stage amplifier may be made with this arrangement by testing the stages in reverse order, beginning with the one which just precedes the output stage, and progressing toward the input. By these means the performance of each stage is measured through stages which have been adjusted previously to be satisfactorily "flat", and after adjustment of the final (input) stage, the performance of the entire amplifier is observable.

Figure 13 shows a diagram of a typical amplifier with indications of the proper points for application of the test equipment. The output terminal should be bridged with a resistor equal to the characteristic impedance of the transmission line normally connected there, but the line should *not* be connected during test of the amplifier because it is desirable to avoid discrepancies which might be introduced by line reflections. The effect of the transmission line and its termination should be treated separately. With the detector connected to the output as shown, the sweep oscillator should be connected at (a) when aligning circuit (A), at (b) when aligning circuit (B), and so on in alphabetical order until all circuits are completed.* Sometimes it is desirable to disconnect the plate circuit of the preceding tube when connecting the sweep oscillator to a grid in order to avoid the loading effect of the plate circuit on the sweep generator. For example, in Figure 13, the circuit would be opened temporarily at the point marked X when connecting the sweep generator at (a).

If some intermediate stage requires special treatment which necessitates testing without association with the rest of the amplifier, then the plate circuit of the tube following the circuit in question should be connected temporarily as a low impedance output circuit similar to the output stage shown in Figure 13. Some high-gain multistage amplifiers become unstable when an effort is made to test all the stages at once because the connections to the test equipment provide unavoidable paths for feedback. In such cases the amplifier may be tested in two parts by using the technique just described of converting one of the in-

*A note of caution should be added about the use of the sweep generator. The attenuator and output circuit of the sweep provide very low resistance across the output terminals. The circuit does not include a blocking condenser; therefore, it should *never* be connected to any part of an amplifier where there is a d-c voltage, as, for example, directly to the plate circuit of an amplifier. If this should be done, the sweep generator would be seriously damaged.

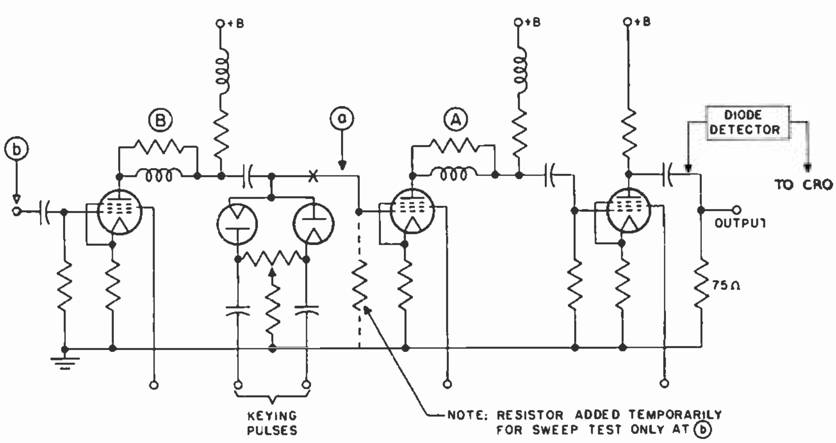


FIG. 13. Typical schematic of multi-stage amplifier showing points where test equipment should be connected.

termediate stages temporarily to a low impedance output arrangement for use in testing the low level or head-end section.

Another special case exists where a clamp circuit is used as shown between the first two stages in Figure 13. The clamp, if left in operation, would cause spurious results because the sweep generator does not provide television blanking pulses on which the clamp normally operates. Therefore, it becomes necessary to immobilize the clamp. This may be done by adding a grid leak (of about 0.1 megohm) as noted in Figure 13, and by substituting a "dummy" diode (one in which the heater circuit has been opened by cutting off a base pin) for the normal clamp diode. This latter is necessary in order to maintain the stray capacitances in the amplifier circuit at their normal values without any diode action.

Another method is possible which makes it unnecessary to immobilize the clamp circuit. This method involves the introduction of blanking pulses into the sweep signal so that the clamp operates in its usual fashion. Such mixing should not be attempted on a simple basis in temporary equipment. However, it may be done satisfactorily by using the RCA TK-30A Monoscope Camera which has an auxiliary input terminal provided for such a purpose. If such a setup should be used, it would be necessary to regard the Monoscope Camera as part of the sweep generator, and to be sure that the performance of the complete equipment is satisfactory for use as a signal generator.

Still another special case is encountered when it is desired to determine the overall frequency characteristic of a camera preamplifier. This amplifier usually contains two circuits which do not have flat frequency response individually, but rather they are complementary so that the overall response is flat. The two circuits in question are the input circuit where the pickup tube is coupled to the amplifier, and the so-called "high peaker" circuit.

The input circuit comprises not only the load resistor normally connected to the pickup tube, but also the stray capacity of the circuit including the signal plate of the pickup tube and the grid of the first amplifier with necessary wiring and coupling capacitor. It is not satisfactory to couple the sweep oscillator directly to the input of such an amplifier because it changes the impedance from a relatively high value to a very low value, and, therefore, it upsets the normal configuration of the circuit which is to be checked.

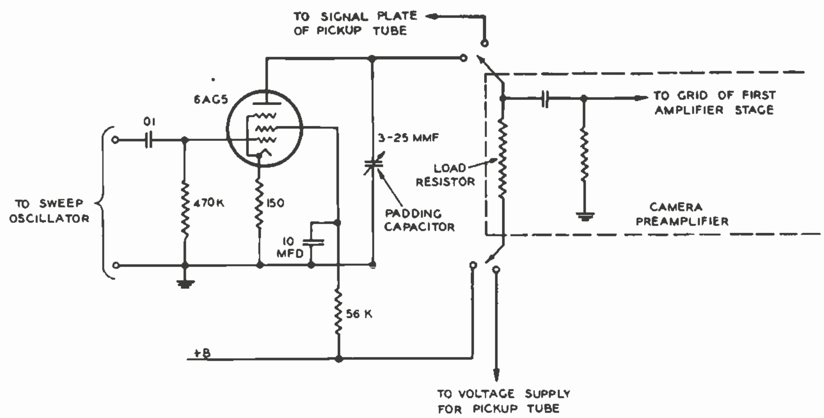


FIG. 14. Buffer amplifier for coupling sweep oscillator to preamplifier.

A satisfactory method of coupling to an input circuit of this kind is to use a low-gain pentode tube as a buffer between the sweep oscillator and the input terminal of the amplifier. The plate load for the buffer should be the same load that is normally used for the pickup tube, with such changes in supply voltages as may be necessary for suitable operation of the buffer. Signal input and gain of the buffer should be adjusted so as to provide no more than normal signal level at the amplifier input. Careful measurement of the stray capacity normally present in the input circuit, with the pickup tube connected to it, should be made. Then when the pickup tube is disconnected, and the buffer is connected, the circuit should be padded with additional capacity until the total is the same as that which was measured in the normal circuit.

A typical circuit arrangement for such a buffer stage is shown in Figure 14.

Low-frequency response may be measured most quickly and satisfactorily by the square wave method. Square waves with a fundamental frequency equal to the field frequency of the television system (60 cycles for the American system) are adequate. Several commercial generators are available to provide such a signal. For observation of the results, a cathode ray oscilloscope similiar to that required for the sweep signal tests may be used, good low frequency response being the principal requirement. The technique for applying the test equipment to the amplifier under test is similar also. The oscilloscope should be connected to the output circuit which does not contain elements critical to frequency response. The signal is applied to each stage in succession and progressively toward the input until the entire unit is tested.

Square wave response tests (at low frequencies) need to be applied only to those parts of an amplifier which *follow* a clamp circuit. Other parts which precede the clamp are usually *intended* to have poor low frequency response in order to minimize microphonics or other disturbances, and therefore testing them is pointless. The clamp restores the low frequency components in the video signal which are lost in such circuits.

It is generally considered sufficient to make the two tests described in the foregoing paragraphs even though they leave the intermediate region from 60 cycles to 100 KC unchecked. If both such tests indicate proper adjustment, there is little likelihood that there is serious trouble in the intermediate region. However, if it is desired to make a check covering this range, it may be done simply by changing the frequency of the square wave generator to about 15 KC, and observing the accuracy with which the wave shape is reproduced. Faulty response is indicated by tilted peaks on the waves, or by transient overshoots on wave fronts, or by badly rounded corners on the peaks of the waves. The last two faults are indications of poor high-frequency response which would show very prominently in the sweep test. For such an intermediate frequency test, a wide-band oscilloscope, such as the RCA types 715 or WO-79, is required.

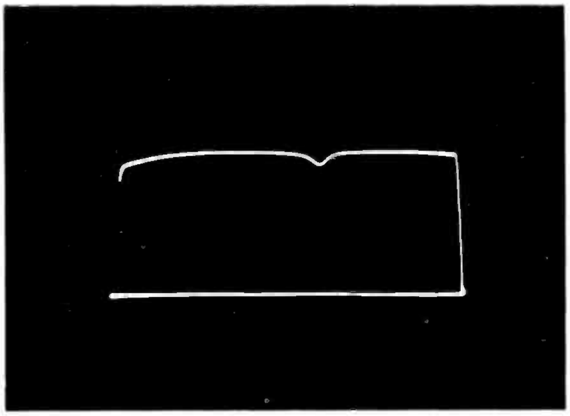


FIG. 15. Demodulated output of the video sweep oscillator. Minimum frequency less than 1 mc, maximum 12 mc, marker notch at 7 mc.

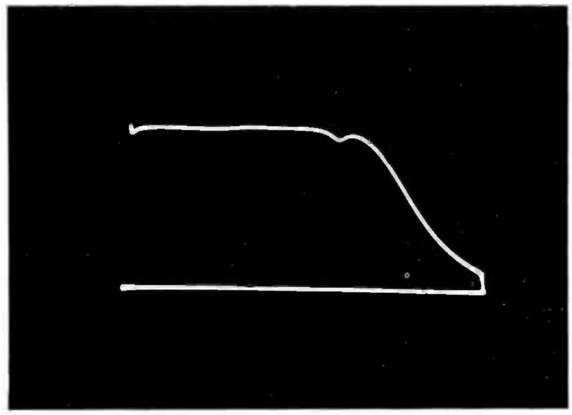


FIG. 16. Output of single compensated amplifier stage as in Fig. 9, with circuit adjusted normally. Marker notch at 7 mc.

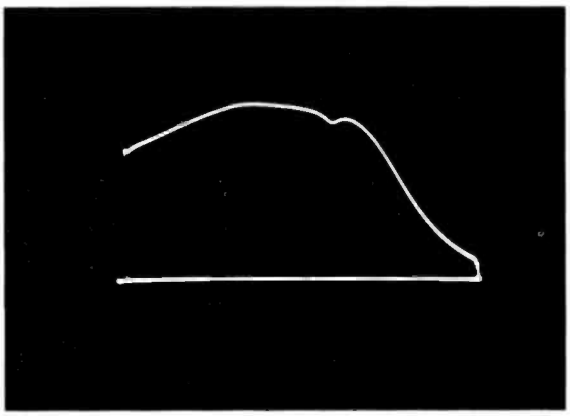


FIG. 17. R_L too small. Note reduced output at low frequencies and upward slope of curve toward middle range. High frequency end of curve unchanged.

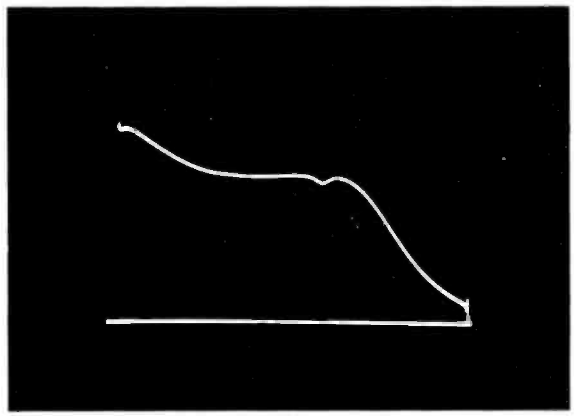


FIG. 18. R_L too large. Note excess output at low frequencies, and particularly the downward slope toward the middle range.

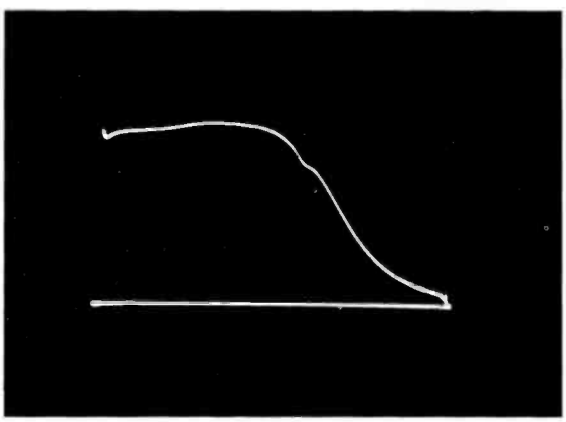


FIG. 19. L_1 too large. Principal effects are reduced cutoff frequency and slight upward slope from low end toward mid-range. Conversely, with L_1 too small, the cutoff frequency will be larger and low-frequency output too large.

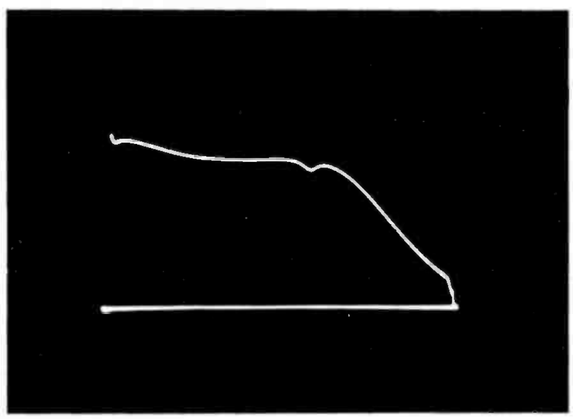


FIG. 20. L_2 too small. Note reduced gain in upper frequency range.

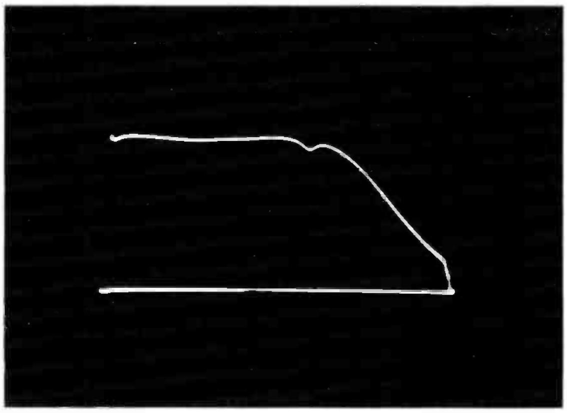


FIG. 21. L_2 same as in Fig. 20, but with R_L also reduced to level off the low-frequency response. Results are reduced output and slight sag in mid-range as compared to Fig. 16.

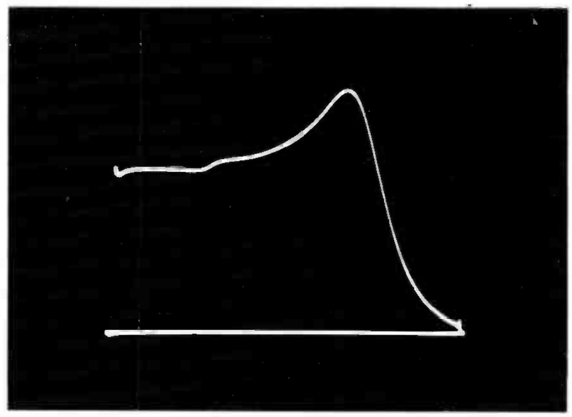


FIG. 23. R[1] too large. Note reduction of both the fundamental and second harmonic resonances compared to Fig. 22. Marker notch not used.

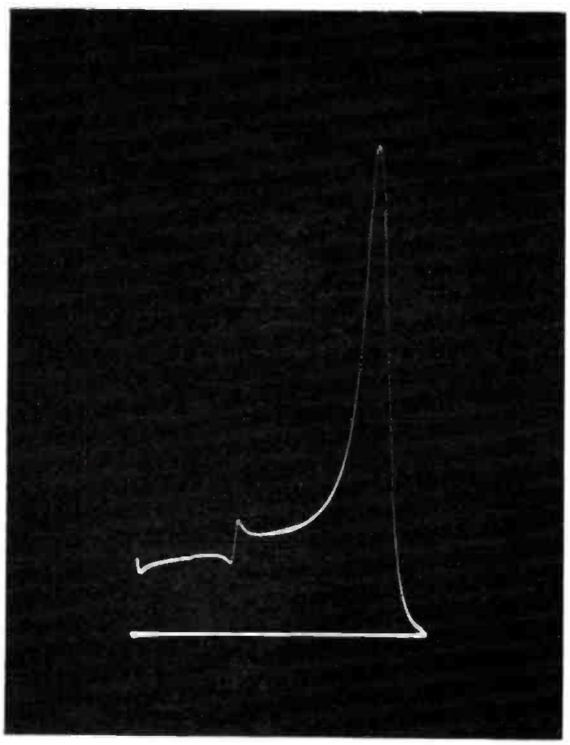


FIG. 22. R[1] completely removed permitting characteristic resonant peak at cutoff frequency. Small resonance at mid-range caused by the second harmonic content of the sweep oscillator signal. This latter is characteristic of most signal generators, and the result is not caused by a fault in the amplifier.

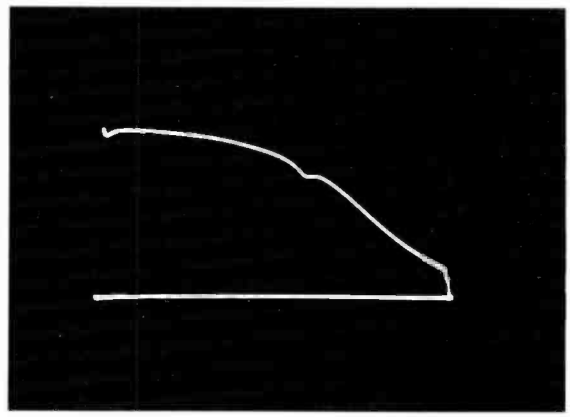


FIG. 24. R[1] too small. Note overdamping of fundamental resonance and long downward slope of curve with absence of pronounced cutoff.

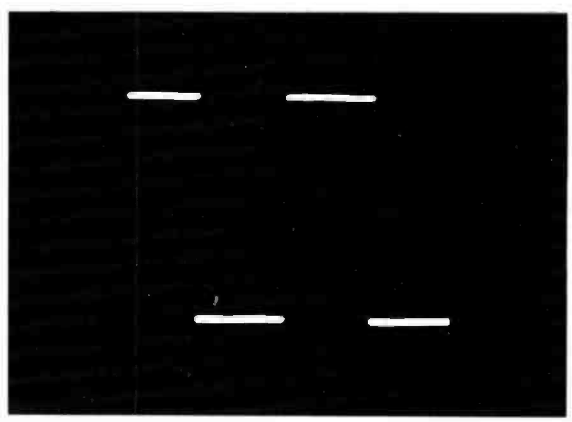


FIG. 25. 30 cycle square wave at output of amplifier of Fig. 9. This picture illustrates the input signal equally well as there was no observable difference in wave shape.

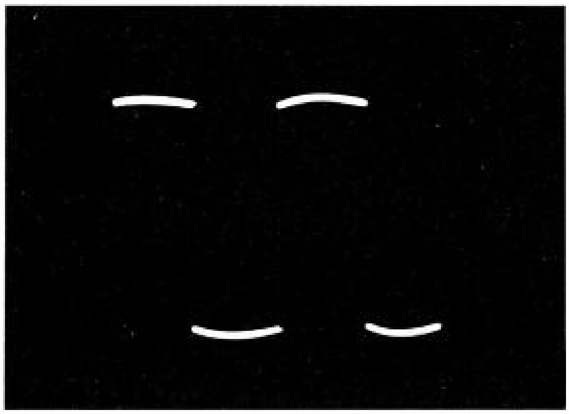


FIG. 26. Distortion resulting when R_c shunt across C_c is opened. R_g readjusted to give optimum results.

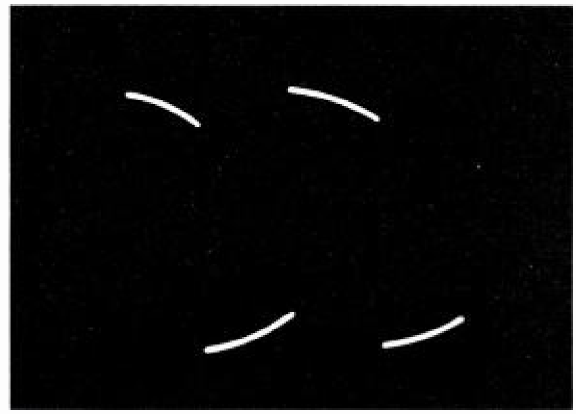


FIG. 27. R_g made too large resulting in rising slope of positive peaks, or "gain in lows."

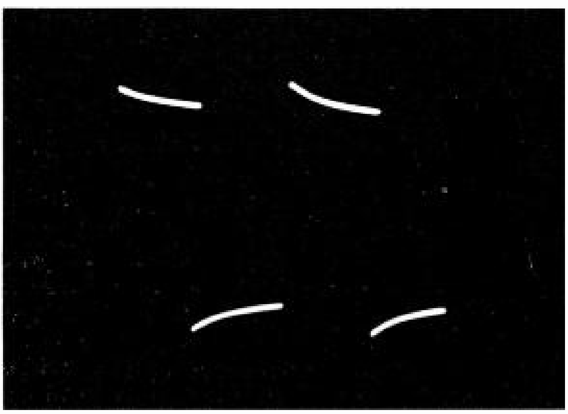


FIG. 28. R_g made too small producing "loss in lows."

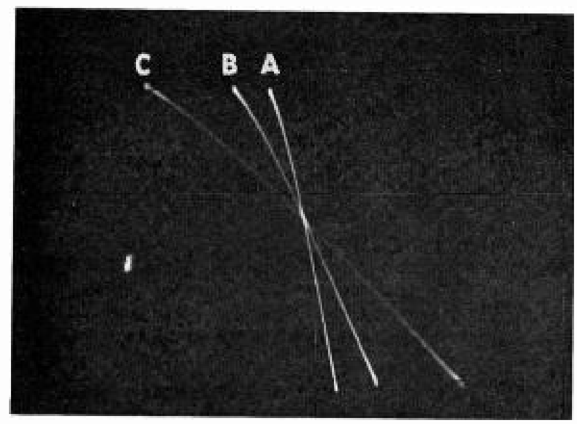


FIG. 29. (a) Z_k nearly zero (R_k by-passed by large C).
(b) R_k = 560 ohms.
(c) R_k = 1700 ohms.
Abscissas indicate input voltage; ordinates indicate output voltage with circuit of Fig. 30-A.

In making both high and low-frequency tests it is imperative to guard against saturation either in the amplifier under test or in any of the test equipment including the oscilloscope. Even partial saturation can result in serious misinterpretation of actual conditions. Furthermore, in making high-frequency tests with the sweep generator, it is important to be sure that a stage already adjusted does not cut off at a frequency lower than the stage under test. If this happens, the operation of this latter stage will be partially masked by the cutoff of the first circuit.

TYPICAL RESULTS AND THEIR INTERPRETATIONS

High-Frequency Tests

The oscillograms shown in the illustrations were photographed from tests of a circuit of the type shown in Figure 9. This circuit was chosen for discussion because it is the most commonly used circuit, and because the number of variables is rather large and confusing. The story of each oscillogram is given in its legend in order to facilitate use of the illustrations for reference. Normal adjustments are illustrated first, while succeeding pictures show the results of misadjustments of the various circuit elements. In each such case only one element has been changed from the normal value of Figure 15 unless otherwise indicated.

Low-Frequency Tests

Reference should be made to Figure 9 in this case also. The fundamental frequency of the square waves used in producing the oscillograms was 30 cycles. This low frequency was chosen to accentuate the effects shown. It also indicates the excellent performance which may be obtained when the circuit is properly adjusted. As before, each oscillogram illustrates the effect of misadjusting only one circuit element as compared to the correct result of Figure 25, unless otherwise noted.

Linearity of Amplifiers

Maintenance of a linear relationship between input and output voltages in a video amplifier is important. One of the best methods for securing such a relationship is the use of negative (degenerative) feedback. An unbypassed resistance in the cathode of an amplifier is a simple and effective way of obtaining negative feedback which is satisfactory over a wide frequency range. This type of feedback is useful in wide-band television amplifiers because the cathode circuit impedance is so low (when tubes of high transconductance are used) that no frequency compensation in the cathode circuit is required even though the resistor used is relatively large. Negative feedback of this kind is indicated in the circuit of Figure 9 by the resistor R_K.

In addition to its inherent low impedance a degenerative cathode circuit has the usual properties of all negative feedback circuits such as:

(a) increasing loss of gain with increasing degeneration.

(b) more nearly linear operation as the degeneration increases.

The oscillogram of Figure 29 shows the change in gain when three different values of cathode circuit impedance are used with a 6SN7-GT tube. The curves were obtained by applying the voltage from the signal generator to the horizontal deflection plates of the oscilloscope, and the output of the amplifier being tested to the vertical deflection plates as illustrated in Figure 30-B.

In order to show the effect on linearity, which is not easily discernable in Figure 29, the curves are repeated in Figure 31 with the horizontal deflection of the oscilloscope adjusted in each case to give the same amount of deflection. The improvement in linearity with increasing R_K is obvious.

As a matter of interest, the curves of Figure 32 are included to verify the previous statement that the internal impedance of a cathode circuit is low. As indicated in the legend for case (a), the (a) curve shows the cathode signal voltage produced across a cathode resistor of 1700 ohms. The circuit is illustrated in Figure 33. For case (a), both switches, S_1 and S_2, are open. For case (b), S_1 is closed connecting plate and cathode *only* of the second triode in parallel with the first. Note that the signal voltage on the cathode is seriously compressed and distorted just as though the cathode resistor had been reduced to a low value. In fact, this is just what has been done by shunting the cathode of the second triode across that of the first. The internal cathode resistance of a tube is approximately equal in magnitude to $\frac{1}{g_m}$, where g_m is the transconductance of the tube. Published data on

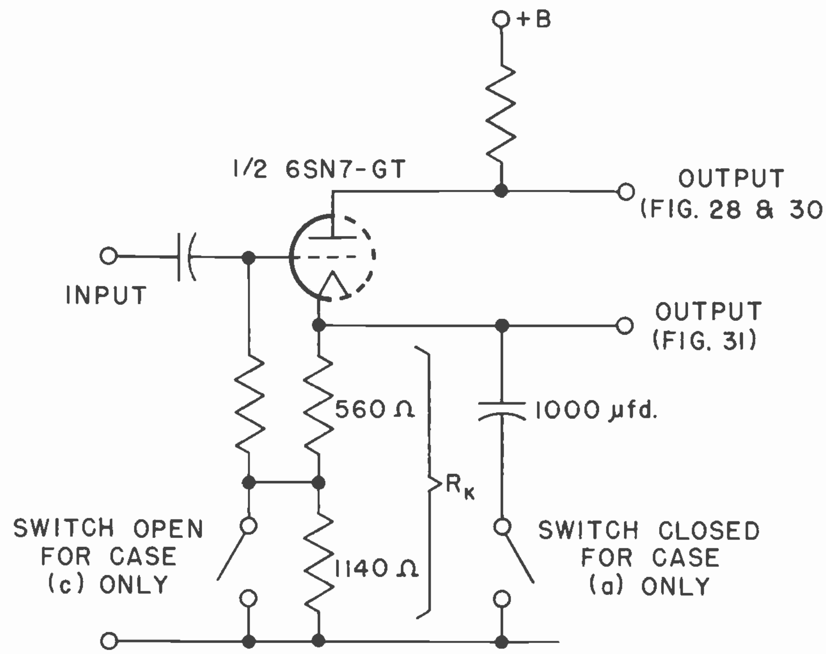


FIG. 30-A. Circuit used in obtaining the oscillogram shown in Fig. 29.

the 6SN7-GT gives $g_m = 3100$ mircomhos, which in turn gives a value of about 325 ohms for the internal cathode resistance. Thus, closing S_1 has changed the cathode resistor for the first triode from 1700 ohms to a parallel combination of 1700 and 325, or about 275 ohms. Case (c) was obtained by closing S_2 (leaving S_1 closed) which causes the second triode to contribute to the output signal by driving its grid with input signal. The two triodes now function as a single triode having twice the transconductance of one, giving a slight increase in output as indicated by the increased length of the slanting line.

Output Circuits

Output amplifier stages in wide-band video amplifiers are not usually spoken of as power amplifiers because it is not possible to match the internal tube impedance for maximum power output. The load has very low impedance to accommodate the wide frequency band, and as a result the amplifier operates very inefficiently. In fact, this statement applies equally well to all types of video amplifiers. In television terminal equipment, output stages are used to feed signal to low impedance transmission lines, usually coaxial lines of 75 ohms characteristic impedance. A properly ter-

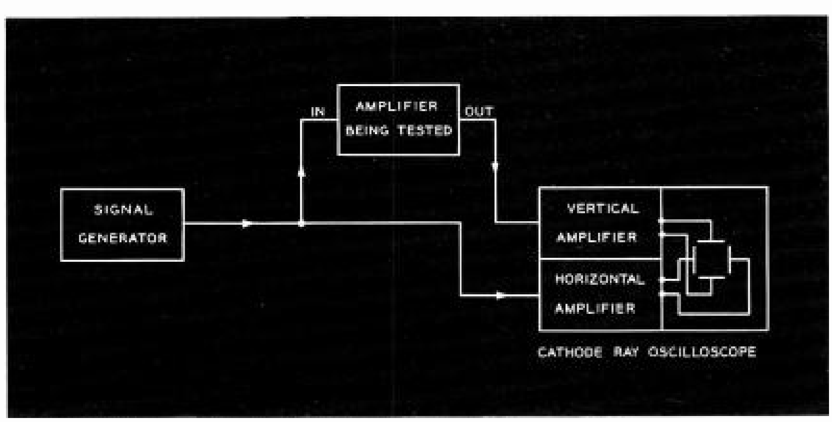


FIG. 30-B. Arrangement of equipment for obtaining linearity curves.

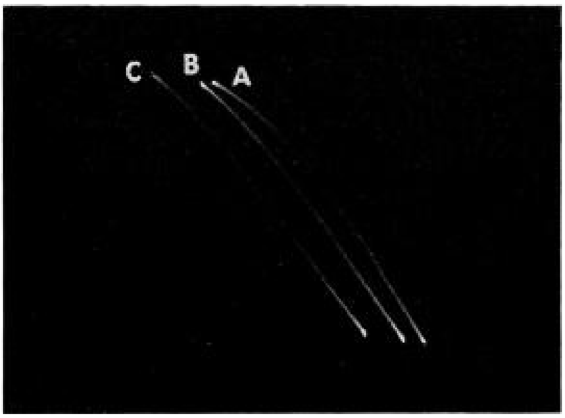


FIG. 31. Same conditions as Fig. 29, but with equal horizontal deflection in each case to show change in linearity.

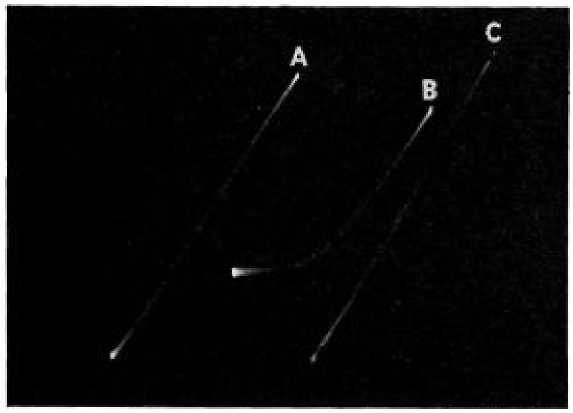


FIG. 32. Loading effect of internal cathode impedance:
(a) Cathode signal voltage with one triode, $R_k = 1700$ ohms.
(b) Second triode added in parallel, cathode and plate only.
(c) Grid of second triode also added in parallel.

minated transmission line acts as a purely resistive load and therefore accepts all frequencies equally well. To the amplifier the line appears simply as a resistance. Therefore, the problem becomes one of providing proper coupling to the low resistance presented by the line.

The cathode follower is often regarded as the most acceptable circuit arrangement for feeding a line. Where direct coupling to the line is possible, it has some advantages, namely, excellent low frequency response all the way down to zero (dc), general simplicity, and the property of providing (with slight modification) a termination at the sending end of the line which helps to minimize reflections. However, it has one disadvantage which is rather serious; with direct coupling, the d-c component of the cathode current of the amplifier tube flows in the transmission line. This is an objectionable feature because many of the transmission circuits now provided by the common carriers, such as the A. T. and T. Co., include wide band transformers which cannot accommodate any d-c. If direct coupling is to be avoided, very large coupling capacitors must be used. Because of this situation, it has become customary to avoid the use of cathode followers for line driving, and to resort to plate output circuits in their stead.

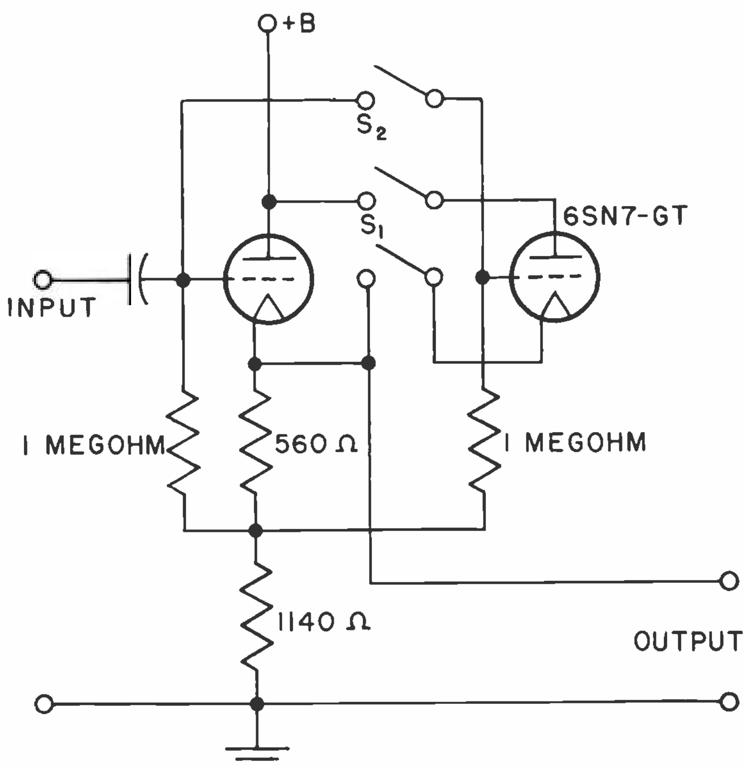


FIG. 33. Schematic of test circuit of a typical cathode follower used in obtaining the curves of Figs. 28-31.

Plate coupled output amplifiers require blocking capacitors too, but much better low frequency performance can be obtained as will be seen from the following discussion. Figure 13 includes a plate-coupled output stage which is redrawn in Figure 34 for convenience. The low frequency performance of a network like this may be measured in terms of the time constant of the loop which includes the coupling capacitor; i.e., the product, RC, where R is the total resistance around the loop. In Figure 34, $R = R_p + R_o$, assuming negligible resistance in the power supply. For good performance, RC should be as large as possible. By adding the frequency, f, at the low end of the band as a third factor, a figure of merit for low frequency performance may be determined, i.e., RfC. Circuits having values of RfC less than 20 are usually not considered satisfactory, and larger values are desirable.

In cases of coupling between amplifier stages, the same rule applies, and, in the terminology of Figure 1, the time constant becomes $(R_L + R_g) C_c$. In this case, however, R_L is usually negligible compared to R_g, so that the time constant becomes practically $R_g C_c$. On the other hand, in Figure 34, R_p is not negligible; it is the principal resistance as compared to R_o. Therefore, it may be seen that the low frequency performance is almost entirely dependent on the size of R_p and C, and almost independent of how small R_o becomes.

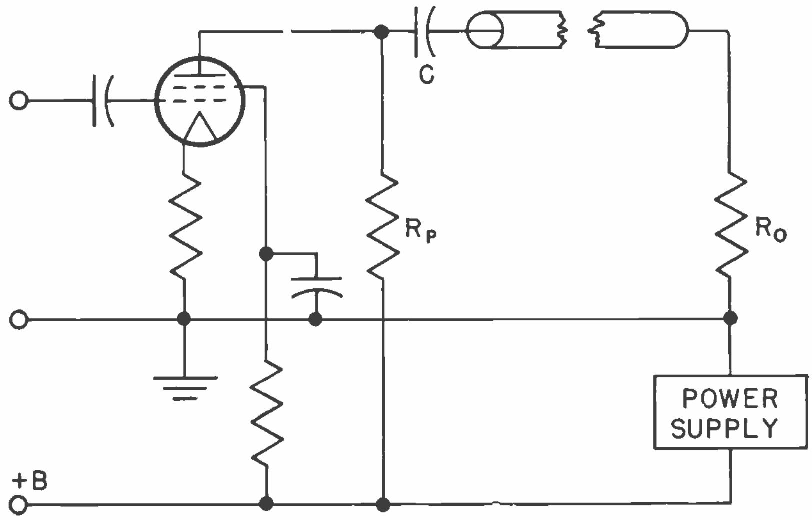


FIG. 34. Schematic of typical plate output stage for coupling to a low impedance transmission line.

In practical cases, R_o is usually 75 ohms, and R_p is made as large as the plate supply voltage will permit. Let us say, for example, that R_L is 3000 ohms for a 6AG7 tube and a plate supply of 280 volts. At 60 cycles, if we choose 20 for the minimum figure of merit, then C must be

$$\frac{20}{Rf} = \frac{20}{3075 \times 60} = 108 \times 10^{-6} = 108\text{MFD}.$$

Obviously if R_o is reduced to 50 ohms or even less, there will be almost no change in the capacitance required to give equally good performance.

Figures 35 and 36 are oscillograms showing the low-frequency performance of a plate coupled output stage with adequate and inadequate values of R_p respectively, no other circuit changes being made.

Considering the cathode follower in the light of the expression for figure of merit, it becomes obvious that a very large capacitor is needed. For example, again using a 6AG7 for illustration,

$$R_k = \frac{1}{g_m} = \frac{1}{.011} = 90 \text{ ohms}.$$

Let us choose C = 2000 MFD.
Then the figure of merit

$$= (R_o + R_k) fC = 165 \times 60 \times 2000 \times 10^{-6} = 19.8,$$

a satisfactory figure. However, it would be difficult to attain this in practice because the cathode circuit would have to be shunted with a resistor (not considered above) to provide a d-c path for the cathode current. This resistor would have to be small to limit the voltage applied to the 2000 MFD capacitor to its rated value. The shunt resistor would reduce the figure of merit appreciably. Such a circuit would be used only in cases where other considerations are controlling.

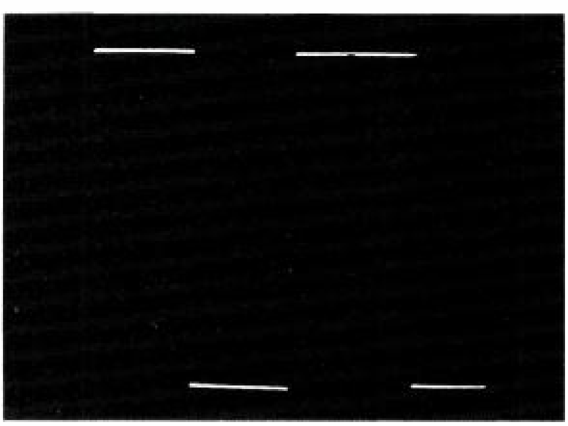


FIG. 35. Signal across R_o with 6SN7 plate coupled output.
R_o = 100 ohms R_L = 10,000 ohms C = 125 MFD

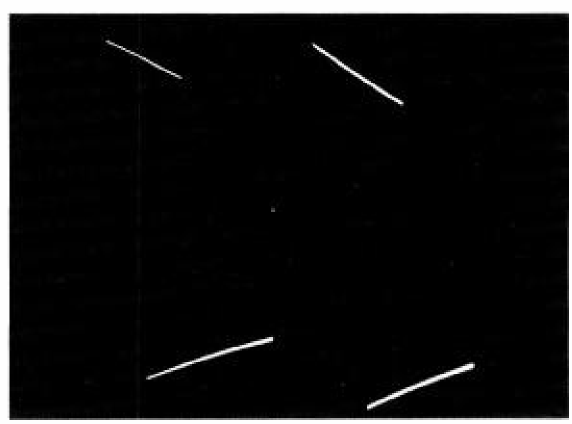
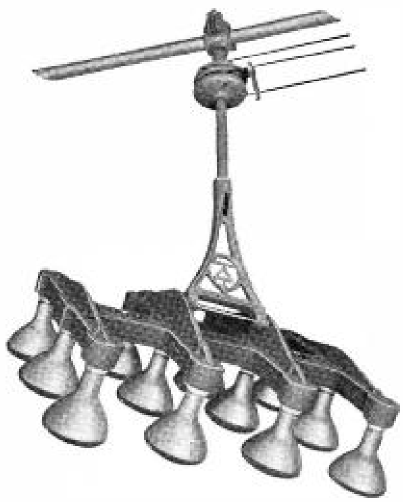


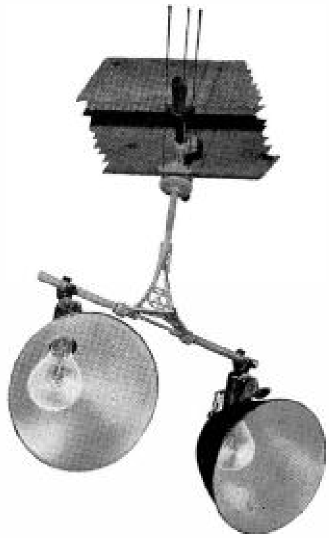
FIG. 36. Same as Fig. 35, except R_L = 500 ohms.

EVERYTHING IN LIGHTING—



Incandescent Lamp Bank, Type TL-5A

The standard 12-lamp light source for normal studio operation. Ideal for slow fades. Provides equal light distribution on "douses." Maximum load per circuit, 3 kw; Per unit, 6 kw. Single cast aluminum-grille construction. Rotates 360 degrees. Tilts 170 degrees. Noiseless controls.



Rotatable Lamp Mount, Type TL-15A

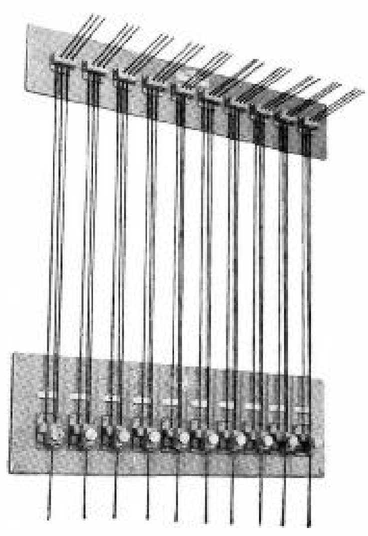
With extension bars for mounting individual or multiple flood lamps. Control spindle can rotate 360 degrees—tilt 170 degrees about the point of support.

Fairleads, Type TL-32A

A practical way to guide mechanical control lines to control board without noise. 170-degree tilt and 360-degree angle of rotation around its point of support provides maximum flexibility for mounting anywhere. Equipped with quick-release gridiron clamp. Nine chromed bushings reduce control-line friction.

High-Intensity Light Dolly, Type TL-26A

The ideal mobile floor unit that puts high-intensity side illumination where you want it. Uses the TL-1A High-Intensity Fluorescent Bank. Rotates the bank from horizontal to vertical position; tilts it through 90 degrees. No high-voltage floor cables, because lamp ballast is right on the dolly.



Light-Control Panel, Type TL-31A

Includes ten headlocks and ten rope locks for controlling ten light banks. Available in single units or on ready-to-operate panels, as illustrated.

Spot-Light Fixtures, Type TL-10A—TL-11A

Standard control spindle for use with a Mole-Richardson or Oleson 2-kw Solar Spot, or a 750-watt Baby Spot. Rotates 360 degrees. Tilts 170 degrees about its point of support.

— FOR TV STUDIOS...

New silent-control lighting equipment enables you to "tailor" the lighting system to fit your studio —correctly, without expensive experimenting.

AVAILABLE for the first time—a complete line of studio-tested lighting equipment from a single manufacturer. Available for the first time—packaged studio lighting systems to match the response curves of modern studio cameras.

Combining high-intensity fluorescent banks, high-intensity spots, and incandescent banks for handling any studio set-up, RCA lighting systems are capable of delivering more than 200 foot candles of light energy. All lights can be rotated 360 degrees horizontally and 170 degrees vertically. All lights are designed for pyramid-mounting on studio ceilings. All lights are mechanically controlled through silent-operating fairleads that terminate in a central control board.

With this lighting equipment you can swing each light for basic work, modeling, or back lighting. You can direct each light to more than one acting area. You can "dim" by tilting, rotating, or cutting off half banks—and without upsetting light distribution. All equipment and wiring is off the floor. No ladder hazards or expensive catwalk installations. No danger of burning artists or technicians.

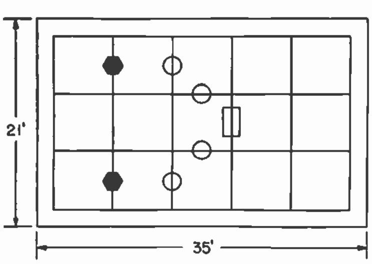
Here is the system that delivers correct illumination with as little as two-thirds to one-half the usual amount of equipment—and with proportionate savings in power. No more experimenting for the individual studio. No more junking of extensive lighting installations.

For help in planning your studio lighting—correctly—simply call your RCA Broadcast Sales Engineer. Or write Dept. 19IA, RCA Engineering Products, Camden, N. J.

High-Intensity Fluorescent Bank, Type TL-1A

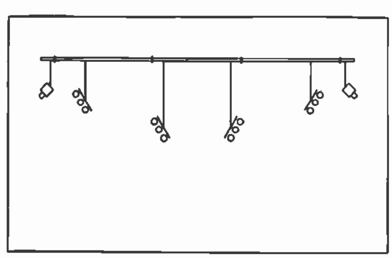
Assures optimum light response from TV studio Image Orthicon cameras. Uses six 3500-4500 Kelvin slim-line tubes. Only 600 watts connected load. Includes noise-free, double-rubber cushioned, built-in ballast units; heavy-duty jumper cord connections; instant start high-voltage striking circuit. Uses pre-focused individual alzac parabolas. Rotates 360 degrees. Tilts 170 degrees. Noiseless controls.

TYPICAL TV STUDIO-PROVED FLOOR PLANS AND CEILING ARRANGEMENT FOR RCA LIGHTING SYSTEMS

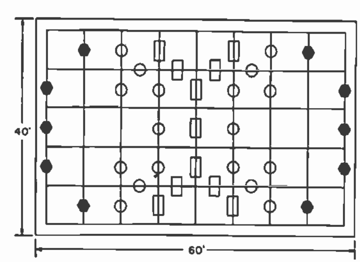


For a small interim-type studio, 21 feet x 35 feet. This plan more than meets the minimum lighting requirements of 200 foot candles and a contrast range of 2-to-1.

NO. REQD.		SYMBOL
1	HI-INTENSITY FLUORESCENT BANK	▯
4	INCANDESCENT FLOOD-LITES	○
2	CONTROLLABLE SPOT-LITES	●



Cross-sectional view of a TV studio, showing RCA's inverted pyramid-type of lighting. This system delivers unobstructed light to every point in the studio.



For the average-size studio, 40 feet x 60 feet. This plan more than meets the minimum lighting requirements of 200 foot candles and a contrast range of 2-to-1.

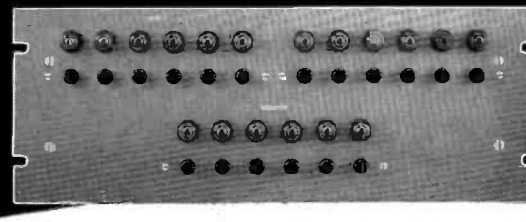
NO. REQD.		SYMBOL
11	HI-INTENSITY FLUORESCENT BANKS	▯
18	INCANDESCENT FLOOD-LITES	○
10	CONTROLLABLE SPOT-LITES	●

TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

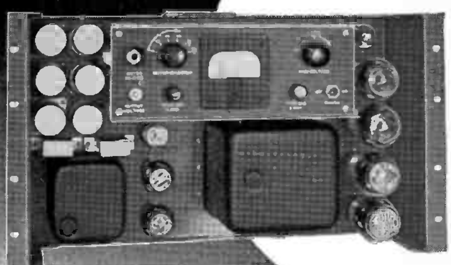
ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal



Switching Panel, TS-1A. A convenient way to switch any one of 6 different input video signals to TV transmitter, or to local and remote monitors.

Regulated Power Supply (Heavy-Duty) WP-33B. Provides well-regulated d-c voltage at loads of 200 to 600 ma. Adjustable output, 260 to 295 volts. Voltage variation, less than 0.2 volt between minimum and maximum load.

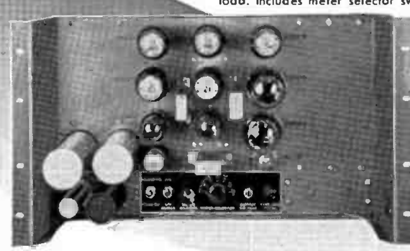


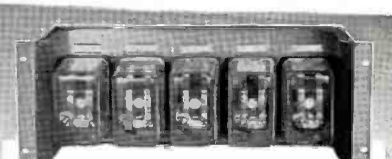
Everything in

Regulated Power Supply, TY-25A. Provides well-regulated d-c source at loads from 200 to 300 ma. Output is adjustable between 260 and 290 volts. Less than 0.5% variation between minimum and maximum load.

Current Regulator, MI-26090. Maintains constant current in focus coil of Studio Camera TK-10A. Current can be adjusted over a range of 65 to 85 ma.

Regulated Power Supply, 580-C. Output adjustable between 260 and 295 volts—at 50 to 400 ma. Less than 0.25-volt variation between min. and max. load. Includes meter selector switch and meter jack.

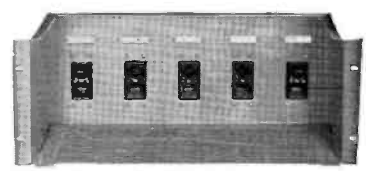




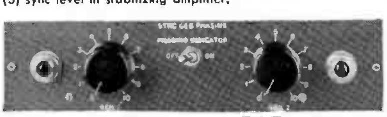
Power Relays MI-26761. Provides remote power switching in conjunction with Power Control Panel MI-26251. Includes 5 separate power relays.

Stabilizing Amplifier Control, MI-26250. Includes three potentiometers. Controls: (1) picture gain; (2) picture clipper; (3) sync level in stabilizing amplifier.

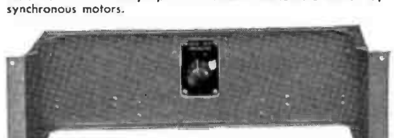
Elapsed Time Indicator, MI-26760. Provides constant record of "hours on" life of tubes, etc. Includes 5 individually-operated counter indicators driven by synchronous motors.



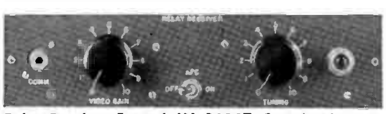
Circuit Breaker, MI-26240. Designed as main switch breaker between power line and TV studio equipment. Accommodates up to 5 breakers (choice of breakers available, extra).



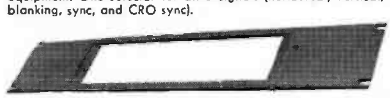
Sync Generator Phasing Control, MI-26249. Provides for phasing one of two local synchronizing generators with one remote synchronizing generator.



Sync Generator Switch, MI-26285. Used to switch outputs of either of two sync generators over to studio equipment. One selector for all 5 signals (horizontal, vertical, blanking, sync, and CRO sync).



Relay Receiver Control, MI-26247. Controls video gain and receiver tuning. Includes 2 potentiometers, AFC "on-off" switch, tally light, and telephone jack.

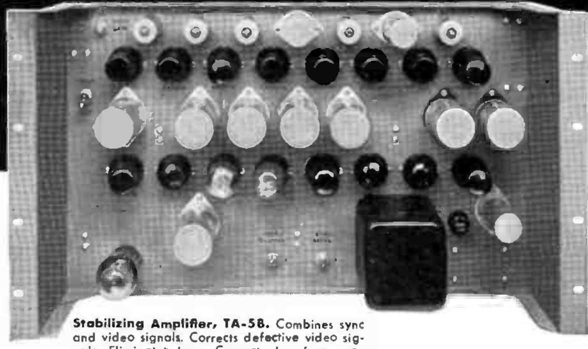


Panel Adapter MI-26254. Enables you to mount control panels (shown in left column and below) in any standard rack.

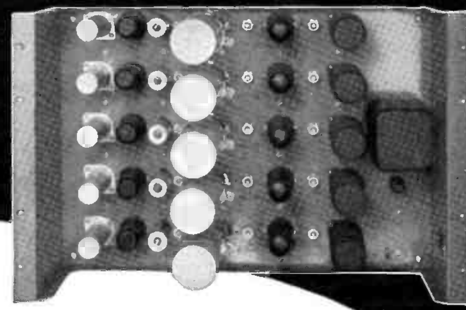
Video Jack Panel, MI-26245. For patching video and/or sync signals. Includes 12 groups of coaxial jack assemblies (3 per group). Video jack plugs and cords, extra.

Monoscope Camera Control, MI-26248. Provides remote control of video gain, and focus of monoscope camera. Includes 2 potentiometers wired to terminal board.

Power Remote Control, MI-26251. Operates up to 5 power supplies through 120-volt relays. Has 5 "on-off" toggle switches and 5 tally lights.

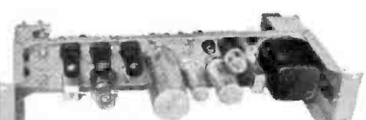


Stabilizing Amplifier, TA-5B. Combines sync and video signals. Corrects defective video signals. Eliminates hum. Corrects low-frequency response. Improves signal-to-noise ratio of sync signals.



Distribution Amplifier, TA-1A. Well-suited for use as: (1) video and sync signal mixer, (2) isolation amplifier, or (3) for feeding video or pulse signals from a single source to separate outlets.

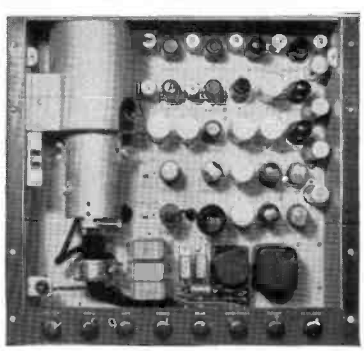
Rack-mounted Units for TV stations



Mixing Amplifier, TA-10A. Useful as mixing, fading, remote control, or isolation amplifier. Two bridging-type inputs; one output. Positive or negative polarity.

Projector Change-Over MI-26321. Designed for starting, stopping or simultaneous changeover of light and sound in 16- and 35-mm film programming. Handles two projectors in any combination (16mm or 35mm).

Sound Equalizer, MI-26313. Provides proper frequency compensation of 16-mm sound reproduction. Compensator network tilts frequencies above 1000 cps in 2-db steps. Panel and Shelf (MI-26581), available extra.



Self-contained Monoscope Camera, TK-1A. Ideal video signal source of known quality for testing: station systems, video amplifiers, picture tubes, TV receivers. Pattern shows scanning symmetry, vertical and horizontal resolution, shading, contrast, and brightness.

. . . control panels, amplifiers, projector changeover, switch panels, relay and indicator panels, power supplies, circuit breakers, jack panels

Here is your answer for ready-to-operate units that can be installed wherever you need them.

All units are identical in design and construction to those used in RCA's regular station-proved TV Broadcast Equipment—and are built with the same high-quality components. Units are built on recessed, or "bathtub" type chassis. Tubes and components are within handy reach. Controls are centralized and clearly marked.

Representing the most comprehensive line of rack-mounted TV equipment in the industry, these carefully engineered units can readily be mounted in enclosed-type racks or in standard open-type racks. Many types can be mounted conveniently in RCA console-type housings.

• • •

RCA rack-mounted units are being used in practically every television station in the country. For information about any one of them . . . or the entire line . . . simply ask your RCA Broadcast Sales Engineer. Or write Department 19KB, RCA Engineering Products, Camden, New Jersey.

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with 10-kilowatt insurance

BTA-5F. The one 5-KW AM Transmitter that insures easy increase to 10 KW at any time! Power changeover is simple . . . inexpensive . . . quick. *Because it was planned that way.*

When you install the BTA-5F Transmitter for 5-KW operation there is just one tube in the power amplifier stage (left-hand cubicle in view below). But note the additional tube socket already mounted in place. To increase power to 10 KW, you need only buy the simple modification kit (described in box at right). With the parts contained in this kit...and the few simple circuit changes required, changeover can be made "overnight." It's easy...it's inexpensive. You need lose no air time.

Naturally, you can also buy this transmitter originally for 10-KW operation (specified as Type BTA-10F). Both models—the BTA-5F for 5-KW operation, and the BTA-10F for 10-KW operation—have the same sleek, well-finished, business-like appearance shown by KOOL's installation on the opposite page. Both models have the true unified front . . . an *exclusive feature* of RCA high-power AM transmitters. This front is an integral piece *separate from the compartment enclosures.* It greatly facilitates flush-mounting...and improves appearance of the installation by several times.

And careful planning like this goes right on through. For instance, this transmitter is equipped with one of the most complete centralized control systems ever designed for *any* transmitter . . . with all the necessary controls, circuit breakers and relays needed for fully automatic operation or step-by-step manual operation. It has push-button motor-tuning for its high-power stages...and instantaneous power control reduction. It can be furnished with matching cabinet end-extensions for housing antenna phasing, monitoring, test and audio equipment. These extensions have front sections that become an integral part of the overall unified front—another exclusive RCA feature of great importance in station appearance. And note this too: the 5-KW BTA-5F uses only 24 tubes (6 different tube types); the 10-KW BTA-10F uses only 27 tubes (6 different types).

• • •

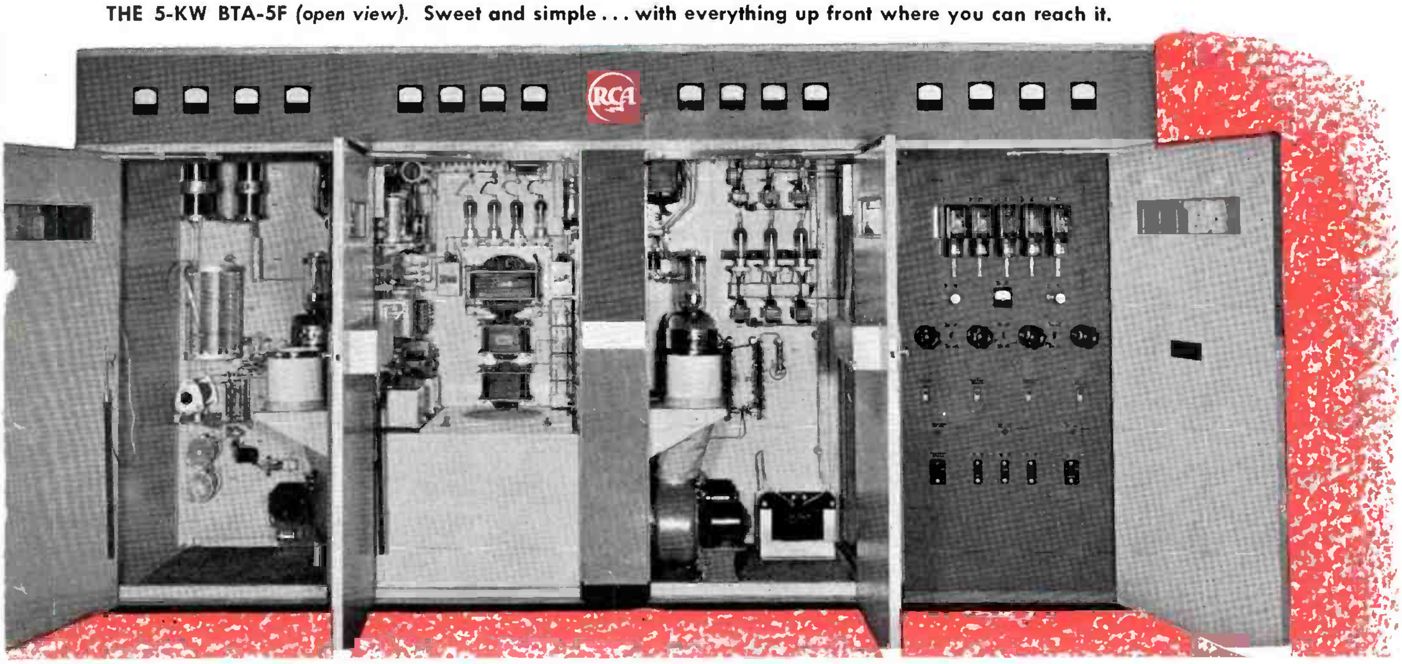
Here, we believe, is the finest streamlined station installation ever engineered for standard-band broadcasting . . . with all basic circuits proved in more than 125 transmitters of this series now operating throughout the world. Get the details from your RCA Broadcast Sales Engineer, or write Department 19AD

This simple kit (MI-7267-A) takes the BTA-5F to 10 KW . . . inexpensively and without one change in station layout.

- **One blower**
- **Two filament transformers**
- **One 10-KW modulation transformer**
- **One reactor**
- **All necessary hardware**

The Transmitter Control Console — standard equipment with every BTA-5F and BTA-10F.

THE 5-KW BTA-5F *(open view)*. Sweet and simple . . . with everything up front where you can reach it.



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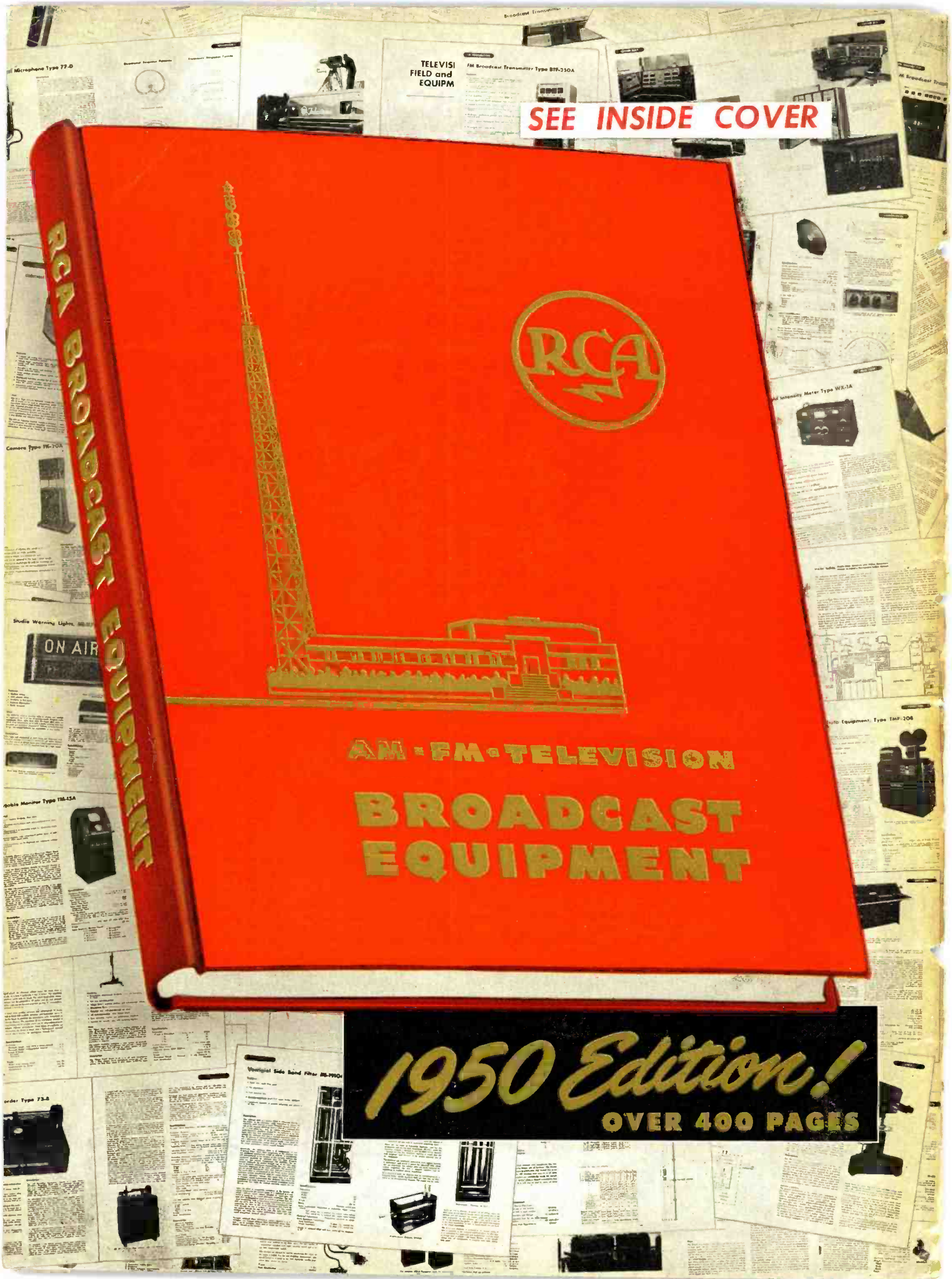
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