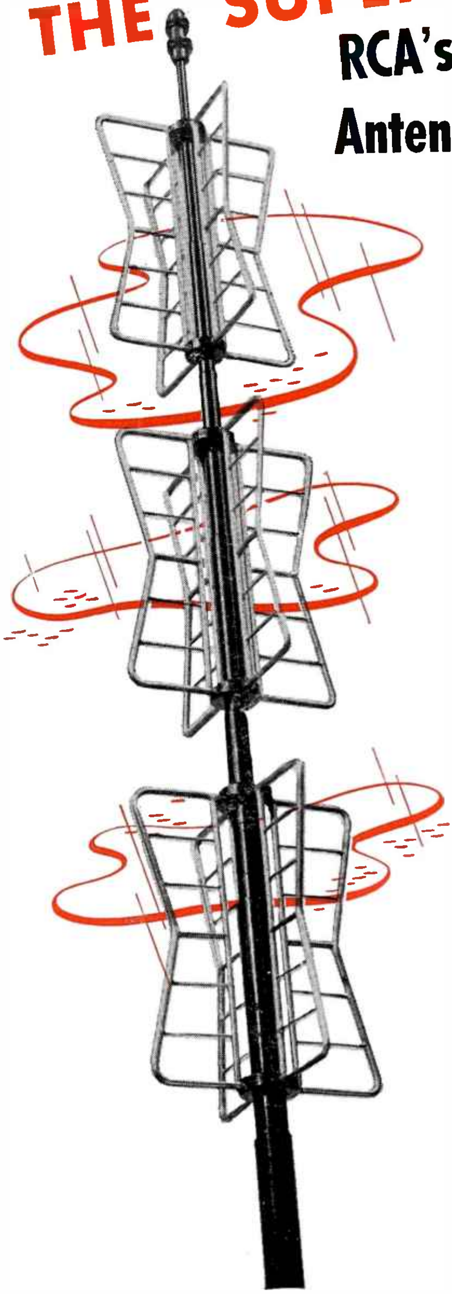
AM · FM · TELEVISION

BROADCAST NEWS

RCA Antennalyzer solves directional problems . . . see Pg. 6

THE SUPER TURNSTILE–

RCA's New, Wide-band, High-gain Antenna for FM and Television Stations



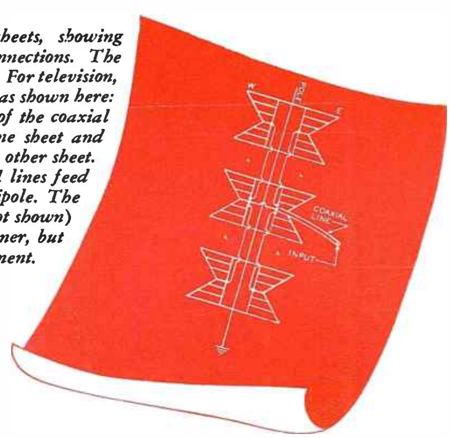
- Extremely broad frequency characteristics
- High gain (approximate power gain: 1.25, 2.5 and 4 for one-, two- or three-section antennas)
- Lower transmitter power for a given coverage
- One size operates at any frequency from 88 to 108 mc
- Handles up to 20 kw—which can be increased very simply by substitution of larger feed line
- Easy and inexpensive to install—single-pole mounting
- Fewer feed points and end seals
- Pretuned at factory
- No field adjustments required
- A standardized, "packaged" item—comes complete
- Entire structure can be grounded
- Circular field pattern (easily modified for FM to "figure-8" or in-between patterns)
- Withstands high-wind conditions and ice
- Two FM transmitters can be diplexed into a single antenna
- Both sound and picture television transmitters can be diplexed into a single antenna.

This new RCA antenna, we believe, is a real step forward in the art of FM and Television Broadcasting.

Its most notable feature is the use of bat-wing-shaped "current-sheet" radiators in place of conventional dipole arms.

These "current sheets" broaden the antenna's operating characteristic so that the impedance reflected on the transmission line is almost equal to that of the line itself over a frequency range of 20 per cent—nearly twice the entire FM band! Hence, there are no tricky field adjustments to worry about.

Ask today for a copy of our new leaflet which fully explains how this unique antenna works, and why it assures you the long list of advantages summarized above. Write c/o Dept. 24-D.



The West-East *current sheets, showing the transmission-line connections. The sheets are fed in push-pull. For television, the connections are made as shown here: i.e., the outer conductor of the coaxial line is attached to the one sheet and the inner conductor to the other sheet. For FM, separate coaxial lines feed the two sheets of each dipole. The North-South radiators (not shown) are fed in a similar manner, but with a 90° phase displacement.*

BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

Broadcast News

AM • FM • TELEVISION

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Contents

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OUR COVER for this issue shows Dr. G. H. Brown (standing) and W. C. Morrison (seated) of RCA Laboratories with the Antennalyzer, which they demonstrated at the Broadcast Engineers' Conference on March 19th. This is reproduced from a color photograph made by Normal Newell, photographer at RCA Laboratories, Princeton. The trace on the scope was rather faint and had to be touched up—which accounts for the somewhat unrealistic appearance.

THE ANTENNALYZER itself is described in the article which begins on Page 6. This is the first one of Dr. Brown's articles we've had since before the war, and we're naturally very pleased to have him back—as a regular contributor, we hope.

Incidentally, Brown and Morrison are very modest about the possibilities of the Antennalyzer. They don't think it will put consultants out of business, or even make mechanical computors obsolete. In fact, they frankly admit that they are building a mechanical computor themselves. Their idea is that the Antennalyzer should be used to determine approximately the type of array required to produce the desired pattern—after which a mechanical computor would be used to determine the exact constants.

At the present time it is not our intention to manufacture Antennalyzers for sale, since it is felt that the cost would be prohibitive. However, one of the two which have been built in Dr. Brown's Laboratory will be set up at Camden and will be available for the use of consultants and other qualified engineers.

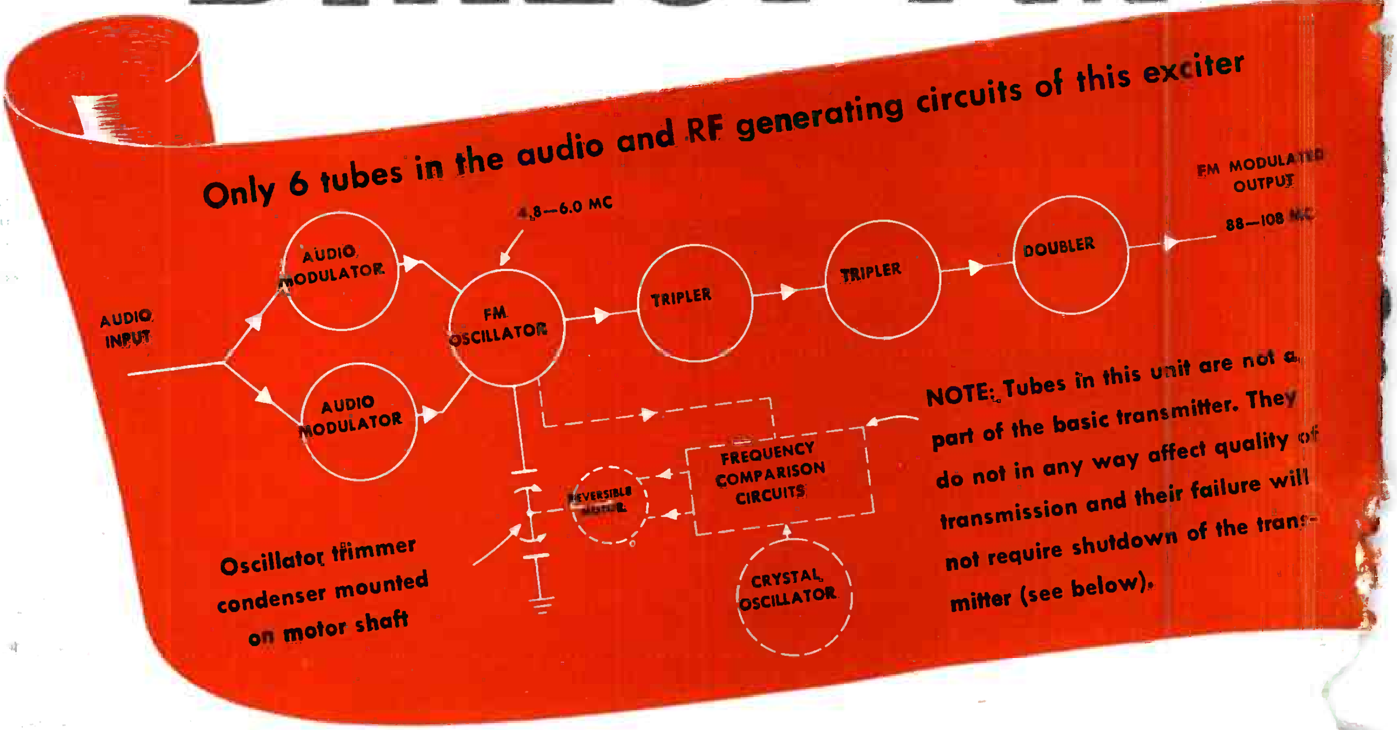
AIRBORNE TELEVISION may or may not be of direct future interest to the broadcaster. Certainly it has been much discussed of late. Unfortunately, most of this discussion overlooked, or was ignorant of, the very real war-time accomplishments in airborne television. It is, therefore, not only a pleasure, but a satisfaction to set the record straight with the comprehensive article on Page 26.

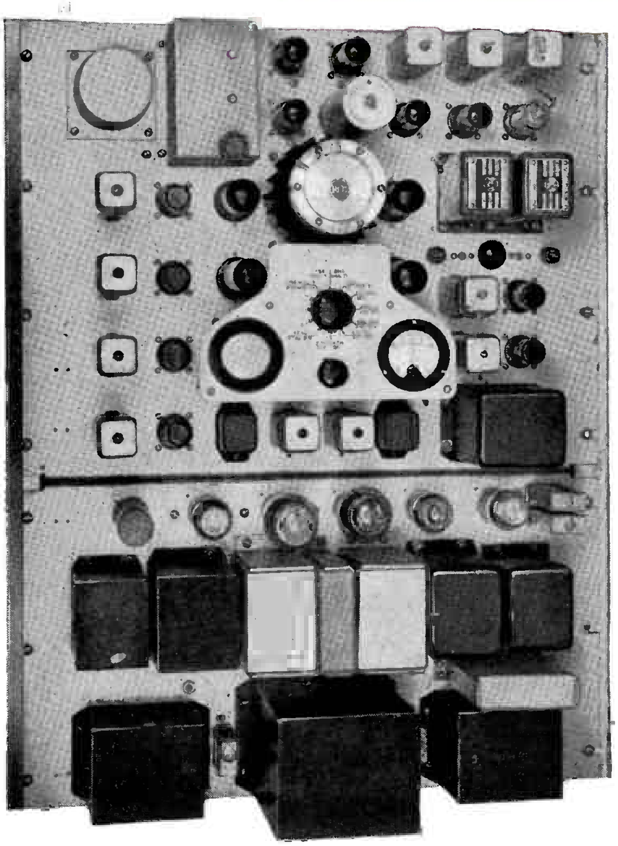
Simply as a matter of giving credit where due, we would like to emphasize a few points from this article. First, as to historical development, RCA engineers (a) first proposed airborne television for military use in 1934 (b) built at RCA's expense, and without contract, the first television equipment for guided-missiles (c) sold NDRC on the idea and received the first contracts for quantity production. Second, as to actual production, RCA engineers and factories (a) did perhaps ninety percent or better of all wartime work on television (b) actually built 4,400 complete television camera and transmitter equipments for airborne use, *of which 250 were Image Orthicon cameras* (c) trained other manufacturers in order that the military services might have alternate sources of supply (d) designed and built an airborne system (i.e. RING) which *broadcasts a 587-line picture from a plane with a power of* 1,200 *watts at* 100 *megacycles*. Two of the latter installations have been in operation in Navy planes (see Page 40) for nearly a year.

THE FM CALIBRATOR for disc recording heads, which is described on Page 42, is one of a number of devices which H. E. (Ed) Roys has developed for use in the study of recording characteristics. Equipments of this type have been used in perfecting the new RCA temperature-controlled recording head which will be described in our next issue. In the present article Ed describes the construction of the ingenious FM Calibrator and gives some examples of its use. Next issue we hope to have more from him along the same lines.

FM FIELD SURVEYS are something many station engineers are going to have to bone up on. And there isn't too much information available on the subject. So-o-o, we've collected all we could find in the four articles starting on Page 52. To begin with, we have articles by Klingaman and Laeser relating their experiences in making prewar surveys. Experience, in this kind of work, is of the essence (as the lawyers say) and the two authors have had a lot, as their articles will indicate. George, who is now in our own engineering department, was with WOR at the time the survey described by him was made—while Phil, of course, is FM and Television Director of the Milwaukee Journal Station and an acknowledged authority on the subject. Since both surveys were made before the present FCC Standards were issued we've added a little discussion of the changes these Standards will make necessary.

"DIRECT FM"





BASIC CIRCUITS are mounted on this part of the exciter panel. They include two audio modulators, an FM oscillator, and three frequency multiplying stages (see diagram above).

AUTOMATIC FREQUENCY CONTROL is provided by the circuits in this part of the exciter panel. Two temperature-controlled, precision-ground crystals (one a spare) are provided. Sub-harmonics of the crystal oscillator and FM oscillator are compared. Any difference between these frequencies operates a reversible motor with a vernier condenser mounted on the motor shaft. The motor never turns more than 90 degrees either way. No gears, counter circuits, or compensating voltages are involved. Failure in this section does not take the transmitter off the air, since operation may be continued by making occasional manual frequency corrections.

REGULATED POWER SUPPLY is contained on this panel. Provides close control of plate voltages regardless of changes in a-c supply voltages.

GROUNDED GRID FM

provides the lowest distortion!

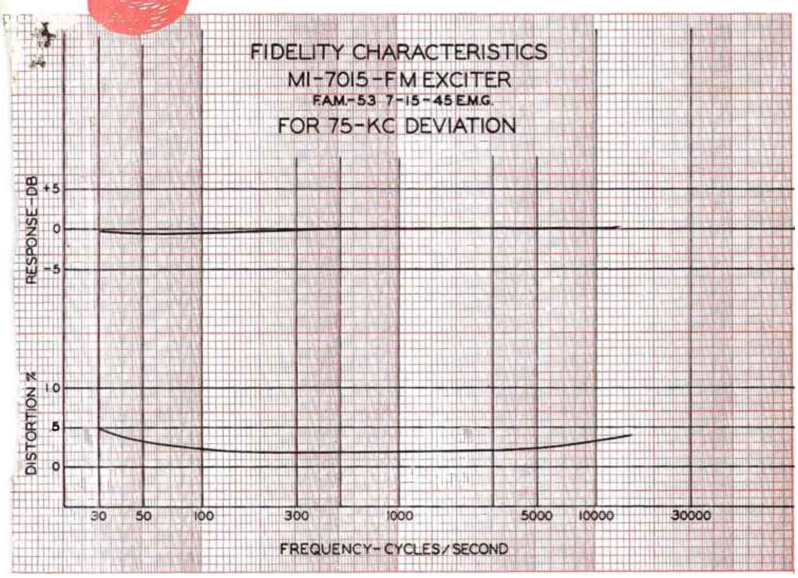
COMPARE these laboratory performance measurements on one of the new RCA "DIRECT FM" EXCITERS

✓ Distortion:

Less than ½% from 30 to 15,000 cycles

✓ Frequency Response:

Within ±½ db from 30 to 15,000 cycles



THE CURVES at the left show the distortion and response versus frequency as actually measured on one of the first of the new RCA "Direct FM" exciter units. Distortion has been measured at less than one-half of one per cent over the whole "FM range" of 30 to 15,000 cycles, with frequency response varying less than ½ db over the same range.

The fidelity which can be obtained in an FM transmitter is basically limited by the distortion and noise introduced in the FM generating circuits located in the exciter. The simple, straightforward circuits used in the RCA exciter are inherently capable of lower distortion and lower noise level than any other type yet developed. The curves at the left prove this!

The station which proposes to provide true "FM Quality" should start with the best exciter available. We believe that the RCA "Direct FM" exciter is just that!

BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

How to buy an FM TRANSMITTER

RCA's new "add-an-amplifier" designs help you cut costs today, make power increase easy tomorrow

The new RCA 10-kw FM transmitter, showing how the equal-size units fit together. Curved end pieces and continuous trim strips (not shown) add to transmitter's unified appearance.

THE matched units which make up RCA's new line of FM transmitters are *all the same size* (25 by 25 by 84 inches) —a big help in reducing installation problems and expenses.

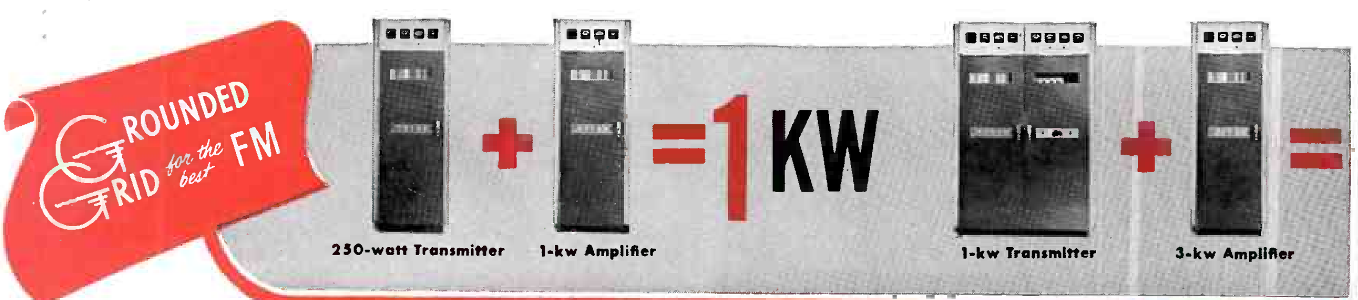
Each unit is relatively light and can be easily handled by two men using a small "dolly" or hand truck. They can be taken through an ordinary door or carried up on a passenger elevator.

As indicated below, higher power units can be easily added at any time without making any of the original equipment obsolete, and without spoiling the transmitter's unified appearance. Thus you can get your FM station started *now*—even if you do not know what your ultimate power requirements will be.

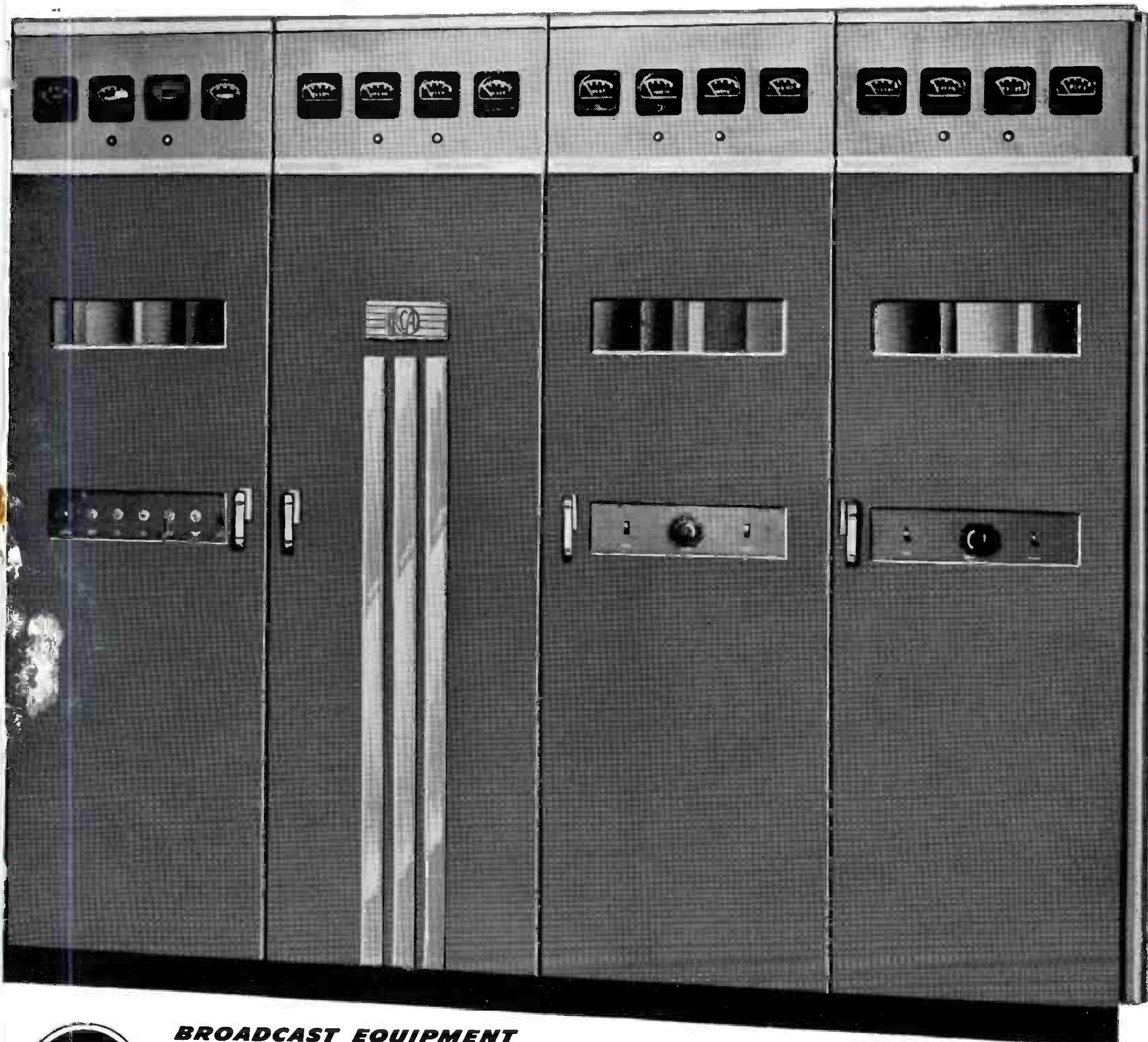
A new-type, hollow base frame provides space for inter-unit wiring, and eliminates the need of wiring through units or conduits in the floor.

New "Direct FM" and "Grounded Grid" circuits (simpler and more stable than any heretofore employed) offer other advantages such as easier tuning, smaller, less-expensive tubes, lower operating costs, less distortion, and better frequency response.

We believe that these FM transmitters are the finest ever offered to broadcasters. Write today for full information. Radio Corporation of America, Dept. 18-DI, Engineering Products Department, Camden, N. J.



with an eye to the future . . .



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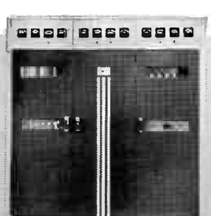
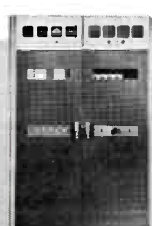
3 KW



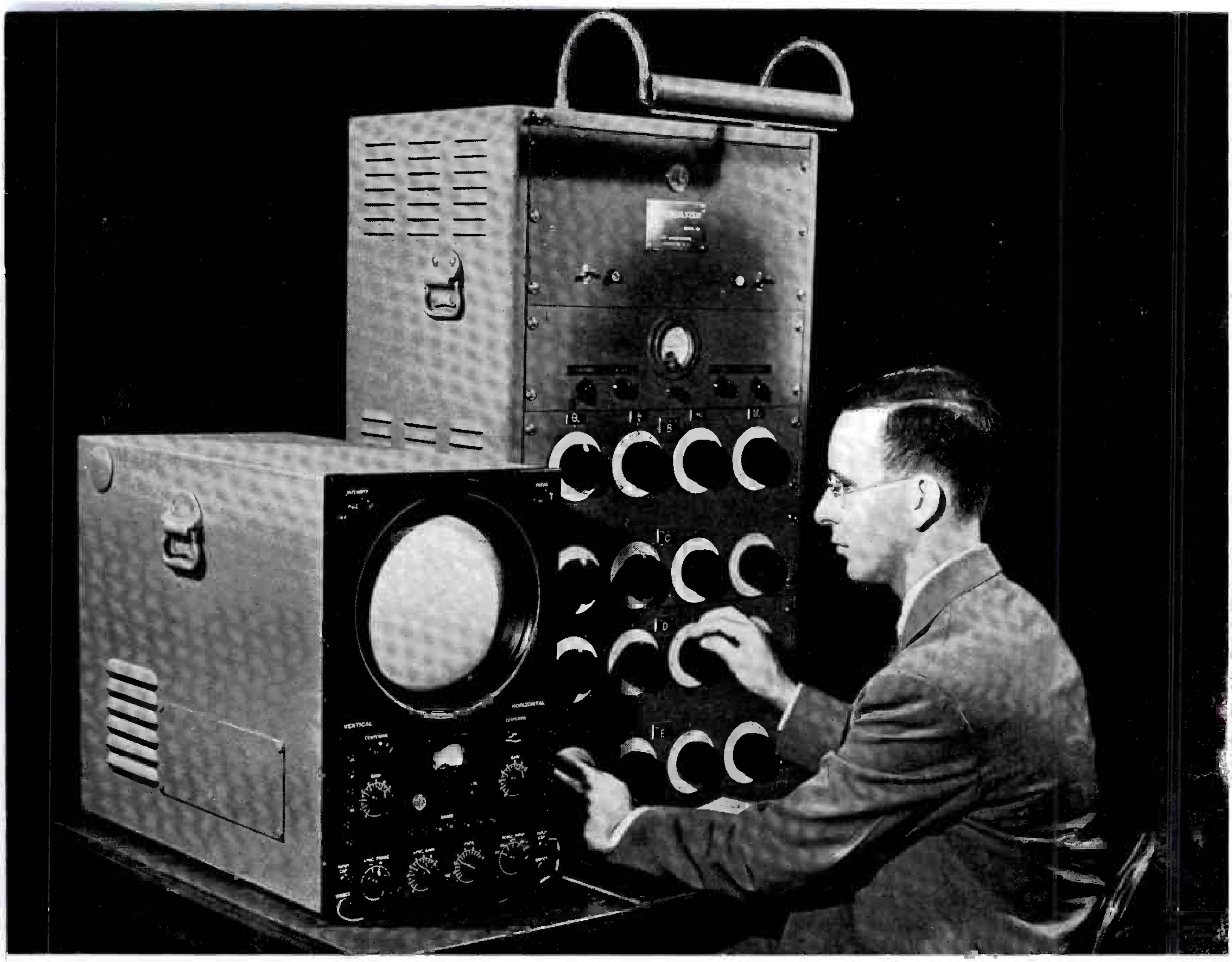
3-kw Transmitter

+



10-kw Amplifier

= 10 KW



(Above)—*The RCA Antennalyzer in operation. The analyzing circuits are housed in the cabinet at the right. The unit at the left is an RCA Type 327-A Oscilloscope on which the pattern is portrayed.*

The RCA ANTENNALYZER

A New Device with Which it is Possible to Observe on an Oscilloscope the Total Radiation Patterns of Two, Three, Four or Five Tower Antenna Systems

by

GEORGE H. BROWN and WENDELL C. MORRISON

RCA Laboratories, Princeton, N. J.

When directional antennas were first used in broadcasting, it was generally possible to obtain an appropriate and suitable directional radiation pattern with rather simple arrays, consisting usually of two towers or radiators. The radiation patterns that could be obtained by varying the spacing between two antennas, as well as changing the phase relationship between the antenna currents, were published in the form of useful charts and a pattern which met the requirements of a particular station could be readily selected. As the channels became more crowded and as more stations attempted to obtain authority to increase power on regional channels, more complex radiation patterns became necessary. In turn, this meant directional antenna systems using three or four or more towers.

The equations for the radiation patterns of a multi-element array are well known, so it is possible to calculate the pattern for a given configuration in a reasonable length of time. However, to say that the procedure is tedious is to apply an adjective of

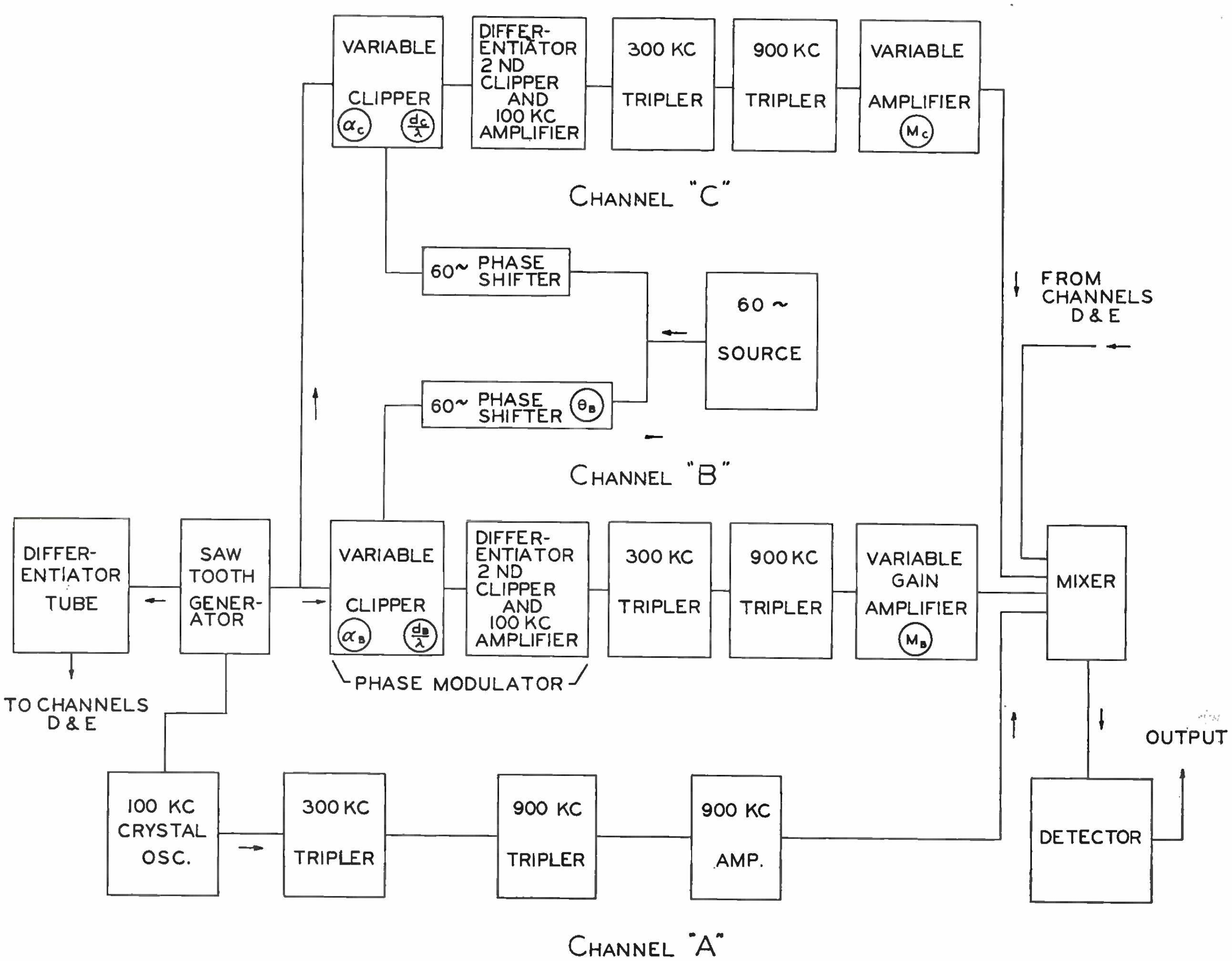


FIG. 1. *Block diagram of the Antennalyzer shown on the preceding page. Channels D and E, which are not shown here, are similar to Channels B and C. The "OUTPUT" from the circuits shown above is fed to the RCA Type 327-A Oscilloscope which is used as an indicator.*

the mildest sort. A number of mechanical and electromechanical calculators were developed and have been described in the literature. These calculators effectively eliminated the drudgery involved in calculating the performance of a specified configuration of towers. If the problem were simply that of finding the radiation pattern for a given set of radiators, fed with specified currents at certain phase angles, the existence of a few electromechanical calculators would have taken care of the directional antenna design problem and no need would have existed for the Antennalyzer described in these pages.

Actually, we usually know the shape of the desired radiation pattern and the problem consists of finding where to place the towers, what currents to feed into the towers, and what phase relationships should exist between these currents. If we were using a mechanical calculator, we would set the gears, wheels, and possibly potentiometers to correspond to an antenna system which our experience tells us is most likely to succeed. Then the driving mechanism is actuated and a curve traced. Since it is rather unlikely that this first trial will yield a suitable pattern, one next changes one of the many parameters slightly and a new curve is traced. This changing of parameters and tracing of curves continues until one finally sneaks up on the desired solution. When the designer does not have the luxury of a calculator and wields a slide rule to get his answers, he is usually ready and willing to make a few compromises here and there, even though the pattern may bulge where it should shrink.

Several years ago the authors set as their goal the development of a calculator which would permit the operator to observe the total radiation pattern or plot at all times with controls so flexible that the parameters could be changed at will while one watched the pattern change. These requirements practically postulated that an oscilloscope would be used. Soon it became apparent to us that it was possible to accomplish our purpose through electrical and electronic means, without resorting to mechanical devices at all. The development has been carried out over a period of several years, with lengthy interruptions due to a war, shortage of materials, and sometimes because an invention or investigation of a particular detail was needed.

Before proceeding with a description of the equipment, it seems appropriate to briefly review the radiation pattern equation. For the sake of simplicity, we shall talk about the radiation pattern in the horizontal plane. First, we select a reference point in this plane. Then we may locate a tower at any point in the plane by specifying the distance between the tower and the reference point and by specifying the angular bearing of a line drawn from the reference point to the tower. That is to say, we have used a

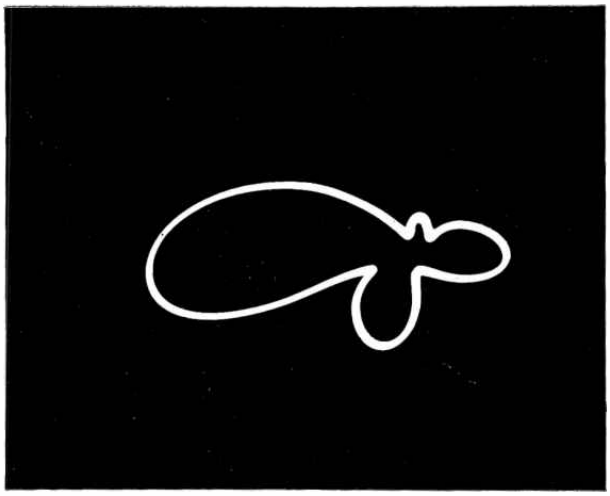


FIG. 2. *Radiation pattern of Radio Station WTAR shown in polar coordinates.*

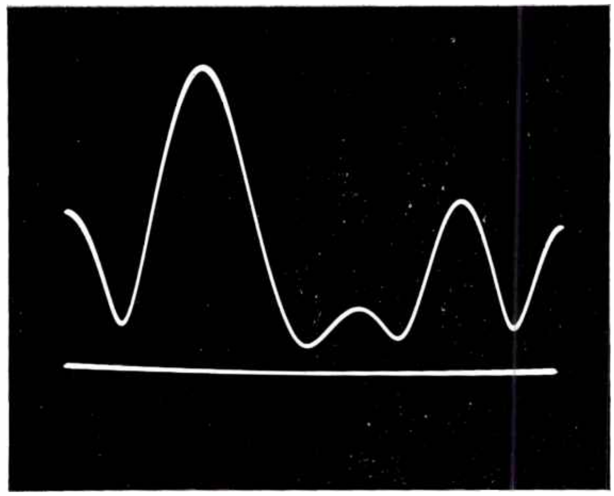


FIG. 3. *Radiation pattern of Radio Station WTAR shown in rectangular coordinates.*

system of polar coordinates. Then we may feed this same tower with a certain amount of current at a iven phase angle.

It is convenient to place the first antenna, which we may call Antenna A, at the reference point. This antenna carries current which is unity in magnitude and is of zero phase. Then the current in any other tower is expressed as a fraction of the current in Antenna A and its phase angle is relative to zero phase. The shape of the horizontal radiation pattern of five identical towers or radiators is given by the following relation.

$$F = KI_A \cdot \sqrt{\begin{aligned} &\Big\{ 1 + M_B \cos\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos[\phi - \theta_B]\right) \\ &\quad + M_C \cos\left(\alpha_C + \frac{2\pi d_C}{\lambda}\cos[\phi - \theta_C]\right) \\ &\quad + M_D \cos\left(\alpha_D + \frac{2\pi d_D}{\lambda}\cos[\phi - \theta_D]\right) \\ &\quad + M_E \cos\left(\alpha_E + \frac{2\pi d_E}{\lambda}\cos[\phi - \theta_E]\right) \Big\}^2 \\ &+ \Big\{ M_B \sin\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos[\phi - \theta_B]\right) \\ &\quad + M_C \sin\left(\alpha_C + \frac{2\pi d_C}{\lambda}\cos[\phi - \theta_C]\right) \\ &\quad + M_D \sin\left(\alpha_D + \frac{2\pi d_D}{\lambda}\cos[\phi - \theta_D]\right) \\ &\quad + M_E \sin\left(\alpha_E + \frac{2\pi d_E}{\lambda}\cos[\phi - \theta_E]\right) \Big\}^2 \end{aligned}}$$

Here using the generic subscript *X*, we may define the various quantities as follows:

M_X = the ratio of the current in Antenna X to the current in Antenna A.

α_X = the angle by which the current in Antenna X leads the current in Antenna A.

d_X = the distance from Antenna A (the reference point) to Antenna X.

θ_X = the azimuth bearing angle of a line drawn from the reference point to Antenna X.

λ = the wave length.

The quantity K is a factor depending on the antenna height while I_A is the value of the current in Antenna A. These two factors are of no importance to us in operating the Antennalyzer, since the quantity included by the square-root sign determines the *shape* of the pattern. The angle ϕ is the angle through which we progress from zero to 360 degrees as we move on the circumference of a large circle whose origin or center coincides with the reference point. It should be noted that the distances between towers are measured in terms of wavelengths, thus providing us with a dimensionless ratio, d_X/λ.

To obtain the expression for an array consisting of four towers, we simply set the ratio M_E to zero. In like fashion, we can readily alter the expression to handle the case of two towers or three towers.

The ability to develop an electronic pattern calculator depended on recognizing the similarity between this equation and another equation obtained in an entirely different fashion. Let us speak in terms of the actual construction used in the Antennalyzer. Suppose that we have a crystal oscillator which is

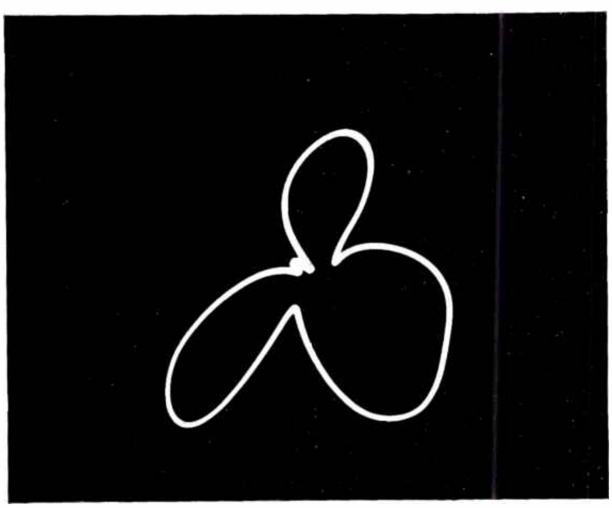


FIG. 4. *Horizontal radiation pattern of Radio Station WMAL.*

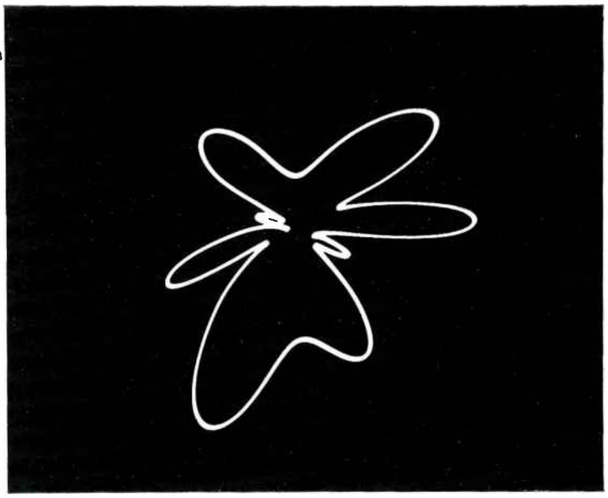


FIG. 5. *Pattern observed when five towers are used with random settings of the dials.*

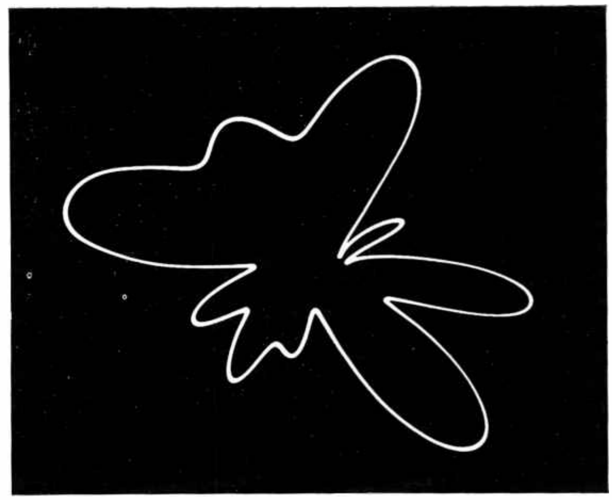


FIG. 6. *Another random pattern which may be obtained with five antennas.*

operating at a frequency of 100 kilocycles. We divide the signal coming from this oscillator into two channels. In Channel A, the signal is a simple sine wave with an amplitude of unity. In Channel B, the signal starts as a sine wave but we provide means of adjusting the amplitude. In addition, we provide a fixed phase shift. Next, we phase-modulate the signal with a 60-cycle voltage. Means are provided for varying the amplitude of the 60-cycle voltage, which in turn controls the degree of phase modulation. A phase shifter is also provided in the source of the 60-cycle voltage. The output of Channel B is then added to the output of Channel A. It may then be observed that the equation of the envelope of the combination has a form identical with the radiation pattern of a two-tower array with the following correspondence of parameters.

Current ratio	Ratio of voltages
Phase angle between antenna currents	Radio-frequency phase angle
Tower spacing	Phase modulation angle
Azimuth angle of tower	Sixty-cycle phase shift
Azimuth angle of measuring point	Instantaneous angle of modulating voltage

The combined signal may then be rectified to obtain the envelope and the resulting pattern displayed directly on a cathode ray oscilloscope, in rectangular coordinates with the angle ϕ as the absoissa and relative field intensity as the ordinate.

A block diagram of the Antennalyzer is shown in Figure 1. The saw-tooth generator, as well as the clipper circuits and differentiators, furnishes the means of securing wide-angle phase modulation with a crystal-controlled oscillator. This method was developed by Ray D. Kell for an entirely different piece of equipment. Without this valuable tool, the authors feel that the Antennalyzer would not have been possible.

It may be noted that in each channel, two tripler stages are used so that the final signal has a carrier frequency of 900 kilocycles. This tripling procedure was used to secure wide-angle phase modulation. Where tower spacings of two wavelengths are required, it is necessary to phase-modulate both plus and minus 720 degrees.

The RCA Antennalyzer shown on the preceding page gives the radiation pattern for arrays consisting of five or fewer towers. Since Tower A is at the reference point, it is not necessary to provide controls. For each other tower we have a dial which controls current ratio, a second which takes care of antenna current phase angle, while a third control varies the spacing of the tower from the reference point. A fourth dial regulates the azimuthal position of the tower. Thus, for the five tower combination we have sixteen dials to manipulate. In practice, we usually mark out in crayon the desired pattern. This is done directly on the face of the oscilloscope. Then the dials are twiddled until the pattern on the oscilloscope corresponds to our crayon markings. The dial readings are next jotted down, and the desired array has been found.

Circuits are provided in the Antennalyzer so that the pattern may be displayed in either polar or rectangular coordinates. It is generally helpful to rough out the pattern in the more familiar polar coordinate system and then switch to rectangular coordinates. This is desirable for two reasons. First, we have not secured the circuit precision in our polar system that we have achieved in rectangular coordinates and secondly, even with equal perfection it is possible to observe more detail in the null points when the plot is made in rectangular coordinates. Figures 2 and 3 were prepared to demonstrate this point. Figure 2 shows the radiation pattern of a three-tower directional antenna system once used at Radio Station WTAR, Norfolk, Virginia. The tower configuration and the calculated pattern are shown elsewhere.[1] Figure 2 was photographed directly from the face of the oscilloscope. The same pattern displayed in rectangular coordinates is shown in Figure 3. The increase of detailed information is apparent.

The radiation pattern of Radio Station WMAL, Washington, D. C., is shown in Figure 4. This pattern is obtained by a combination of four towers.

Figures 5 and 6 were obtained as we casually turned the various dials when five towers were included in the circuit. It is interesting to change the controls at random and watch the variety of patterns which appear. The writers have found it worthwhile

[1] George H. Brown, "Directional Antennas", PROC. I.R.E., vol. 25, pp. 101-103; January, 1937.

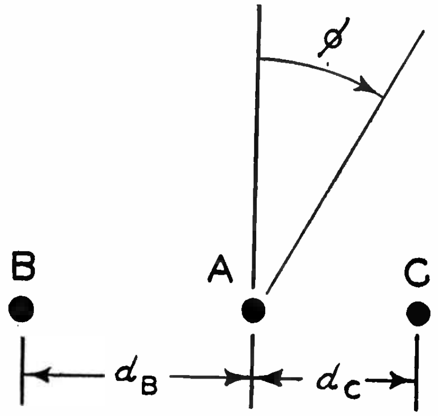


FIG. 7. *Three towers placed in a row.*

to spend hours watching the patterns change in order to appreciate the wide variety of patterns that may be obtained with three to five towers.

The configuration of antennas shown in Figure 7 was investigated. Here the towers were placed in line. The current in Tower A was taken as unity. Then the other parameters were as follows.

$$M_B = M_C = 0.48$$
$$\alpha_B = \alpha_C = \text{zero degrees}$$
$$d_B/\lambda = 0.71$$
$$d_C/\lambda = 0.53$$

The shape of the horizontal radiation pattern was calculated from the relation

$$0.51\ [0.96 \cos(230^\circ \sin \phi) + \cos(39.5^\circ \sin \phi) + j \sin(39.5^\circ \sin \phi)] \qquad (1)$$

and the results were plotted to yield Figure 8. The conditions for this array were set up on the Antennalyzer and Figure 9 was obtained. Then with all the other conditions remaining constant, we set d_B/λ equal to 0.53 and calculated Figure 10 from the relation

$$0.51\ [1 + 0.96 \cos(190^\circ \sin \phi)] \qquad (2)$$

The corresponding trace shown by the Antennalyzer is shown by Figure 11. The agreement is rather good. Next the parameter

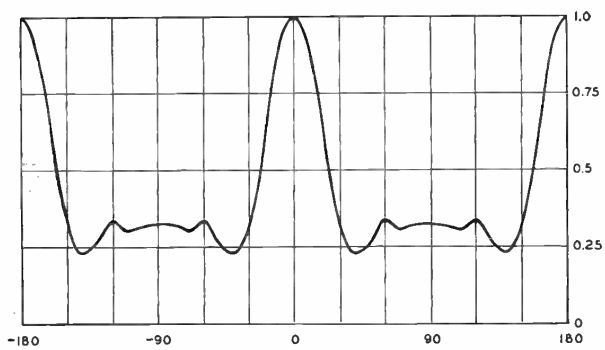


FIG. 8. *Calculated horizontal radiation pattern obtained from relation (1).*

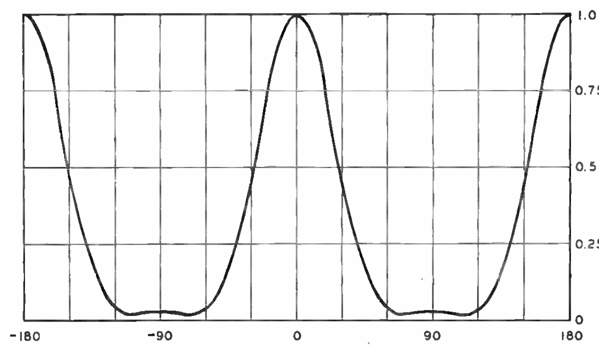


FIG. 10. *The calculated pattern obtained from relation (2).*

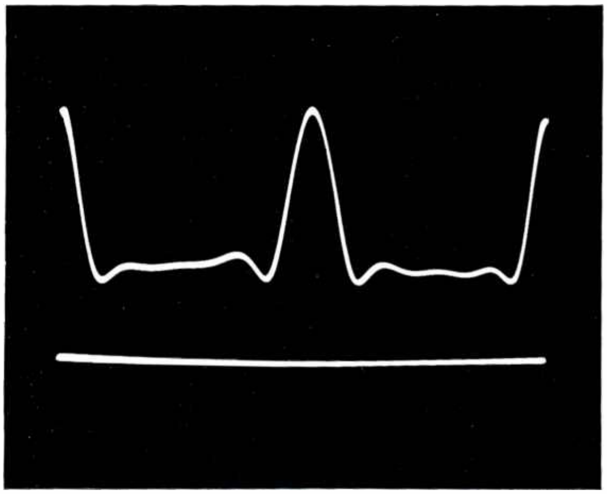


FIG. 9. *The pattern shown by the Antennalyzer, corresponding to the calculated pattern shown by Figure 8.*

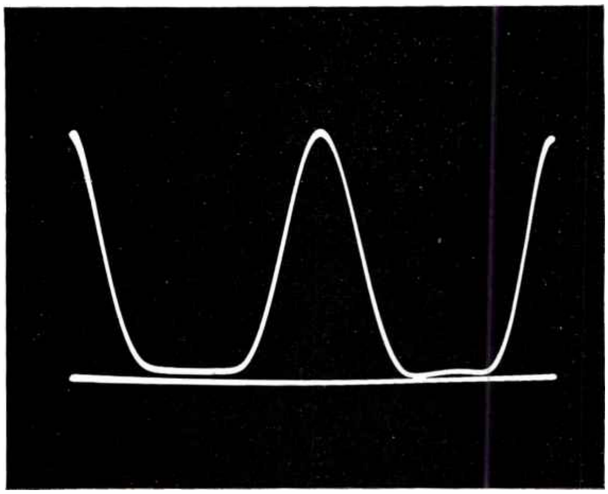


FIG. 11. *The Antennalyzer trace corresponding to the calculated pattern shown by Figure 10.*

d_B/λ was altered somewhat with the result shown by Figure 12. A further adjustment of the phase of the two end towers yielded the pattern of Figure 13, while Figure 14 shows the trace obtained when the phases were shifted somewhat in the opposite direction.

The lengthy expression given earlier in this paper applied only to the horizontal radiation pattern. However, it is possible to determine the vertical radiation pattern with the Antennalyzer in either of two ways. First, we may find the pattern as the angle ϕ varies through 360 degrees, at a given elevation angle. This plot might be termed the horizontal radiation pattern at a fixed elevation angle. The procedure is to multiply the spacing from the reference point to a given antenna by the cosine of the elevation angle. This product is the value set up on the dials which indicate tower spacing. A procedure slightly more involved will yield a plot of the vertical radiation pattern at a given azimuth angle.

As a rough means of obtaining the scale factor for a directional pattern, the designer often resorts to obtaining the r.m.s. value of the pattern. This is done by running a planimeter around the polar plot to determine the area of the diagram. From this the radius of a circle which has the same area is found. A metering circuit is incorporated in the Antennalyzer so that the factor is read directly from a meter on the face of the instrument.

The authors have used the RCA Antennalyzer to explore a number of antenna situations and in addition have used it to assist other engineers in the design of directional antenna systems. From this experience, we conclude that the present accuracy of the equipment is sufficient to make it a valuable research tool. In addition, in skilled hands, it is possible to arrive quickly at a desired directional pattern and accompanying antenna configuration in a remarkably short time. The instrument must be regarded as a tool to be used with understanding and discretion. After the desired pattern is obtained on the oscilloscope, it is desirable to calculate the pattern corresponding to the parameters found with the Antennalyzer. Two or three such calculations, with slight readjustment of parameters, may be necessary when the pattern needed is critical. If the Antennalyzer were used in conjunction with an extremely accurate mechanical calculator, the two instruments would supplement each other beautifully. First, we might use the Antennalyzer to quickly arrive at the configuration of towers and the currents in the towers. Then we would feed the parameters obtained from the Antennalyzer into the mechanical calculator to obtain an accurate plot of the pattern. If it were found that the pattern deviated somewhat from that desired, the next step would be to consult the Antennalyzer for a few moments to get an idea which way to readjust the parameters and a new trial run would then be made with the mechanical calculator.

In addition to furnishing a rapid means of solving specific design problems which, of course, was the primary purpose of the development, a study of the variety of liriodendron shaped figures may reveal useful directional antenna systems not ordinarily considered.

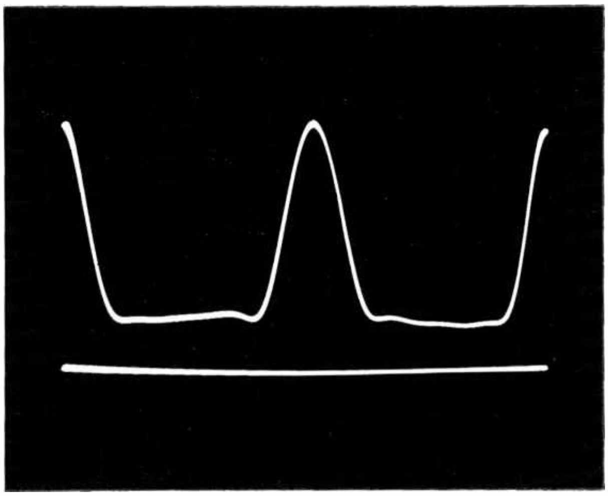


FIG. 12. *The Antennalyzer trace corresponding to a change in the position of one tower in Figure 7.*

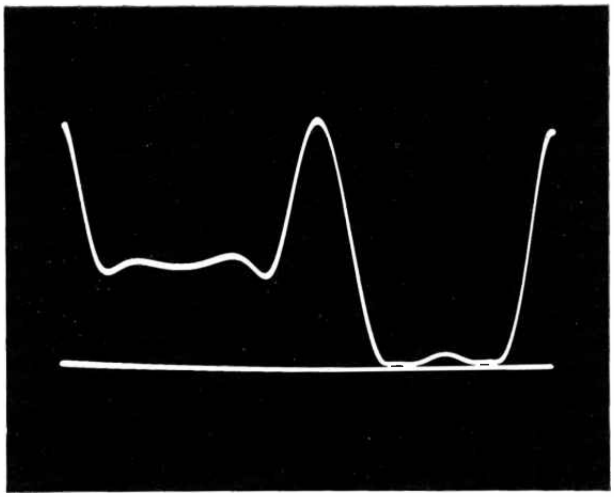


FIG. 13. *The phase of two currents has been altered from the values used to obtain Figure 12.*

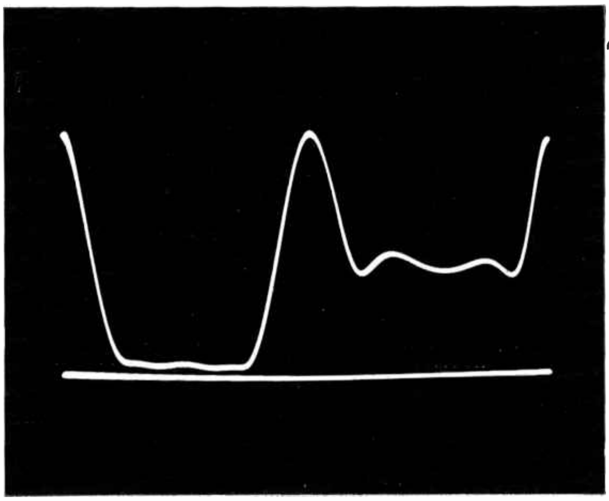


FIG.14. *The phase of the currents in Figure 13 has been changed in the opposite direction.*

HOW A TELEVISION STATION CAN GROW IN EASY STAGES

STAGE ONE: a minimum layout providing facilities for film and network programs only

Many broadcasters, particularly in the smaller market areas, will want to start in television on a small scale. It will obviously be desirable for them to make their plans in such a way that investment and operating costs are relatively low during the initial period—increasing later as the scope of operations is broadened in accordance with the growth of the local television audience.

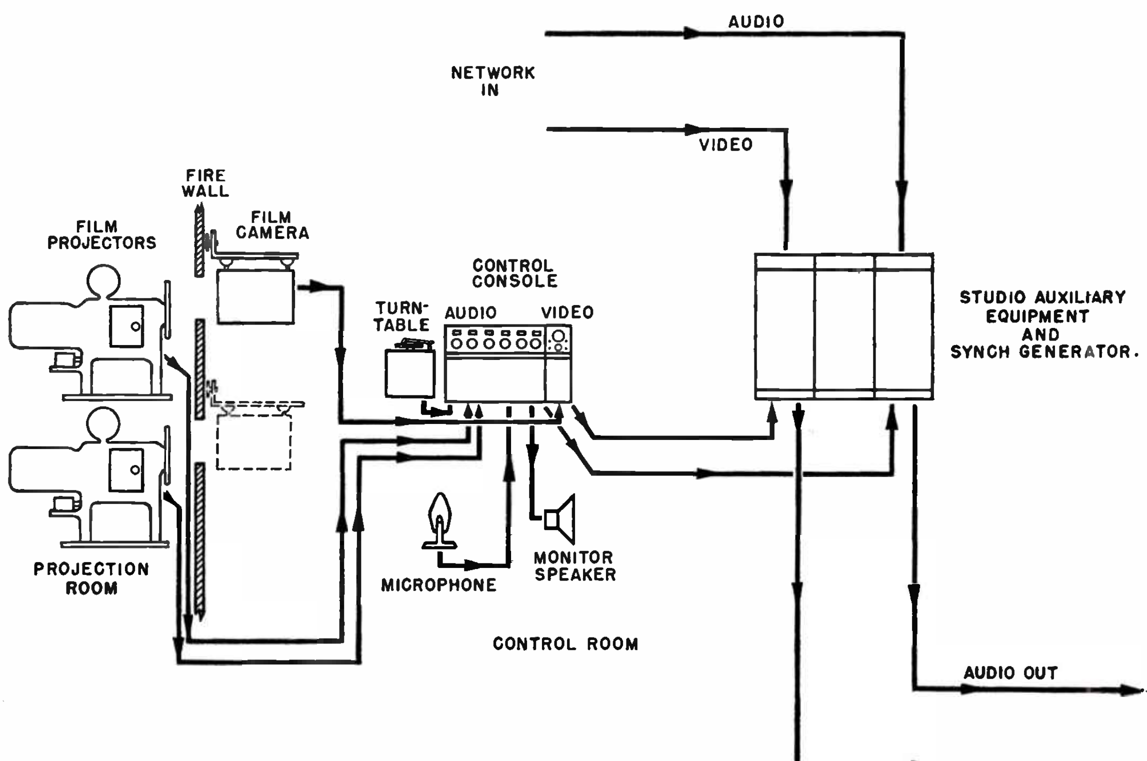
RCA television studio and transmitting equipment units have been designed to facilitate this normal expansion by making it easy and economical to add additional units as they are required. Two features are of outstanding importance. The first is that the basic units used in all RCA systems, large or small, are identical. The second is that the breakdown of the equipment into individual units has been carefully planned so that adding additional units does not make obsolete or useless any of the original units. The manner in which these features enable a television station to "grow" by easy stages is indicated by the illustrations on this and the following pages.

The diagrams below and the photograph on the opposite page show the minimum equipment required for satisfactory operation of an independent (i.e., not a satellite) television station. Such a station would have all of the facilities necessary to transmit network programs or film programs originated locally. Live talent local programs would not be provided for during the initial period of station operation because of the relatively high cost of the additional facilities and staff required.

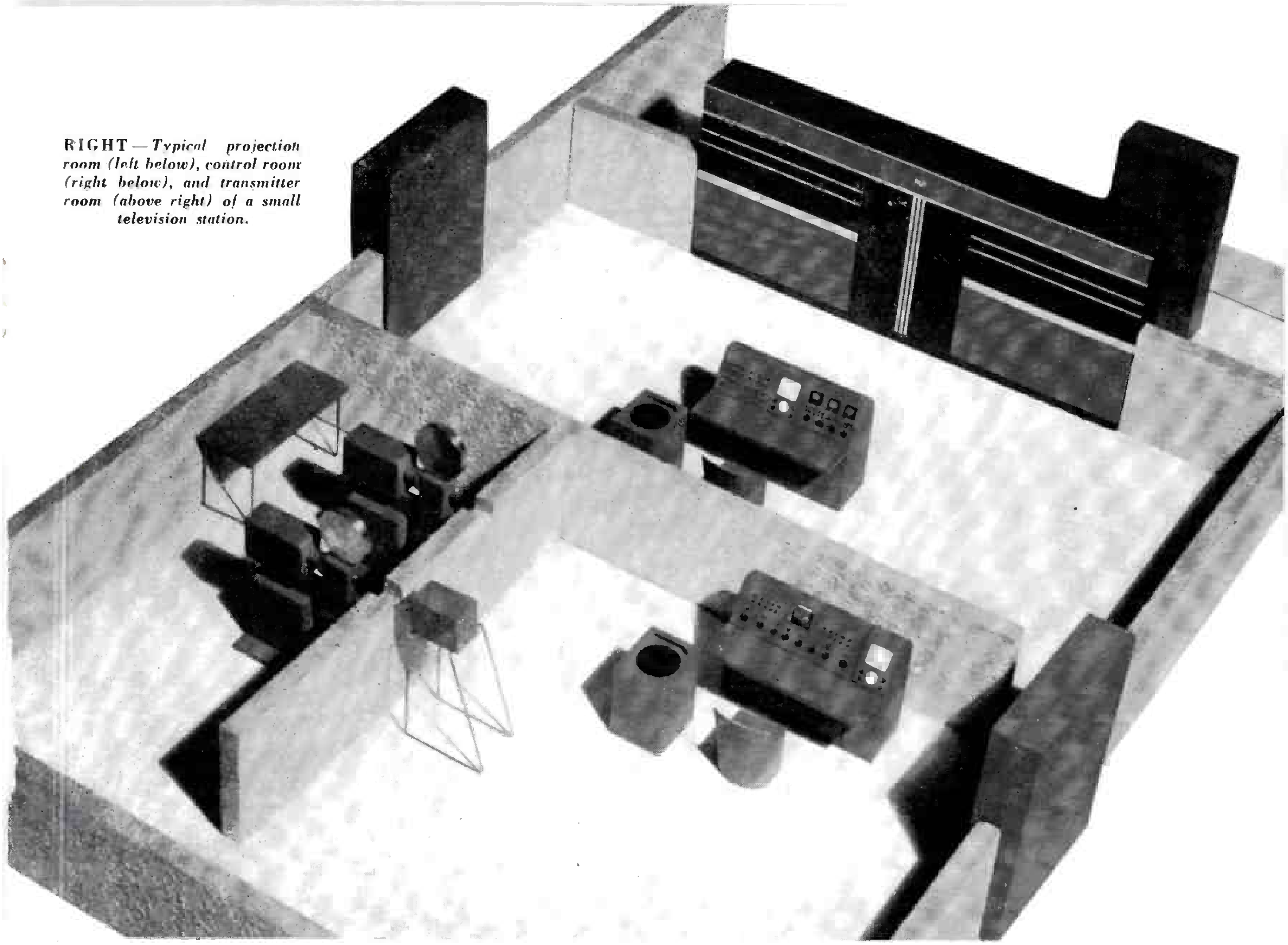
The studio and control equipment for a station of this type is relatively simple. Two 35 mm projectors are provided in order that continuous film programs (i.e., no break for rewinding) will be possible. A single film camera suffices, as it may be moved easily to face either projector port. The control console consists of a standard audio unit (the same unit is used in all sizes of stations), and a single video control unit (a second video unit is easily added if it is desired to have a means of previewing a program coming up). Auxiliary items include a transcription turntable, announce microphone and monitoring loudspeaker. Station identification with this setup may be by audio announcement only, or a slide projector may be added for this purpose.

By contrast, the equipment shown in the transmitter room (opposite page) is fairly complete. It includes practically all of the units which would be found in even the largest stations. This is necessarily so because even in the smallest station there can be no compromise in transmission quality or in compliance with FCC standards. The only marked difference in larger stations is that in these the transmitter and studio will nearly always be at different points (thereby requiring a coaxial or VHF link circuit).

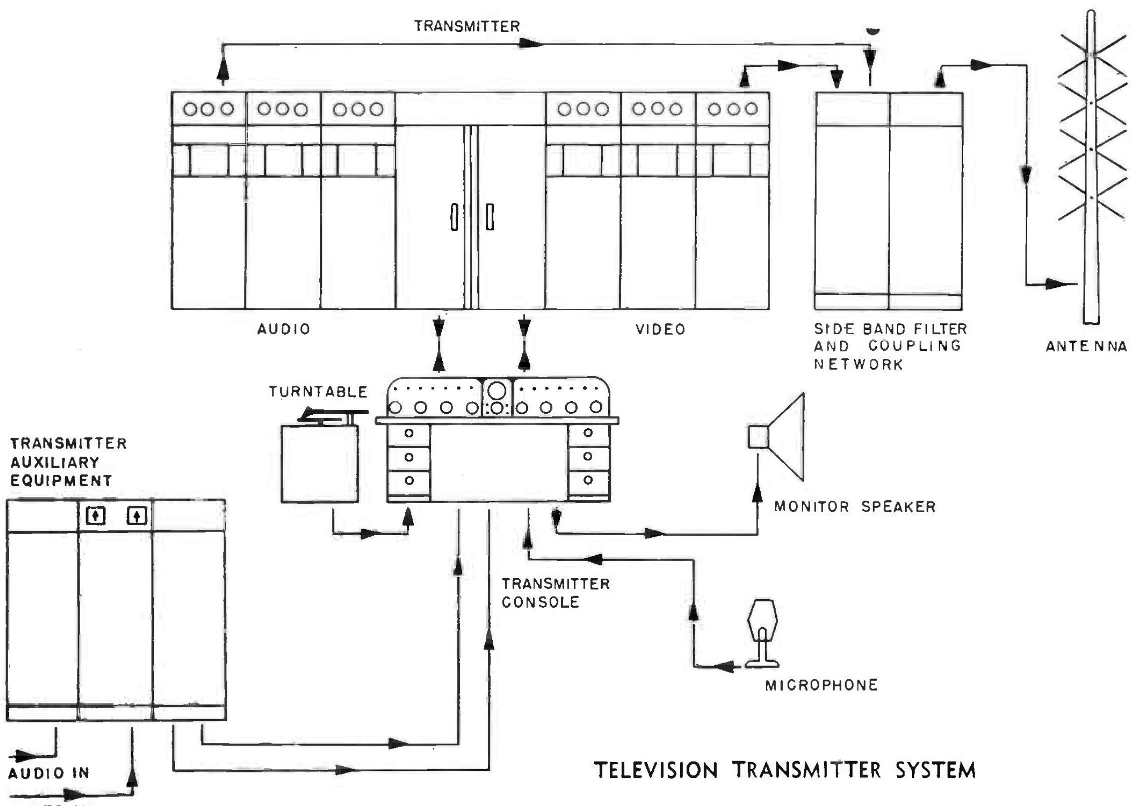
Since the transmitter room is much the same for all stations it is not shown in the other equipment layouts which follow.



SMALL TELEVISION STATION STUDIO SYSTEM



RIGHT — *Typical projection room (left below), control room (right below), and transmitter room (above right) of a small television station.*



TELEVISION TRANSMITTER SYSTEM

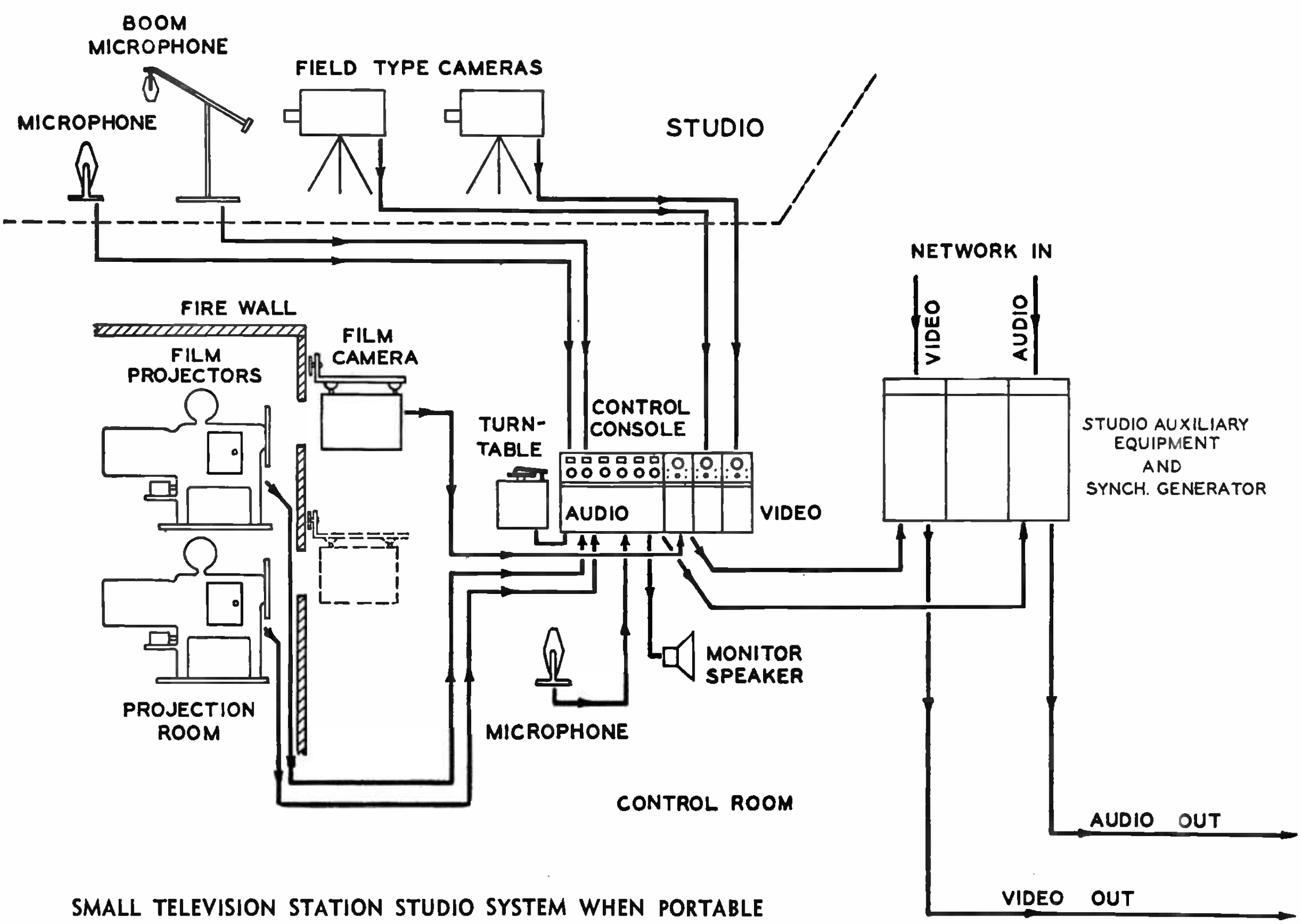
STAGE TWO: addition of portable equipment provides for field pickups and live talent studio shows

When it is desired to increase the facilities included in Stage One (described on the two preceding pages) this can be most easily and economically done by adding a set of RCA portable pickup equipment. This equipment consists of one or more cameras, an equal number of camera control units, a video master monitor unit, and audio and power supply units—all of which are designed and constructed in such manner as to be easily portable. While this equipment is intended primarily for field use its flexibility is such that it can easily be set up in the studio to produce the simple types of live talent shows. Thus, in Stage Two of the television plan outlined here, a set of this portable equipment will double as field and studio video equipment. This will make it possible for the station to put on a remote pickup—such as a football or basketball game—one night, and a local studio show the next night. Together with network and film programs this will make possible a reasonably varied program schedule.

The diagram below, and the picture at the top of the opposite page, illustrate the use of the portable equipment in the studio. From one to four cameras may be used with this equipment. Since each camera "chain" (i.e., camera plus camera control unit) is independent of the others, it is entirely practical to start with one or two cameras and add others as required. When the field cameras, with their collapsible tripod mountings, are used in the studio they are placed on "crowfeet" which are T-shaped frames provided with rollers. This allows them to be moved easily when following action or changing from one scene to another.

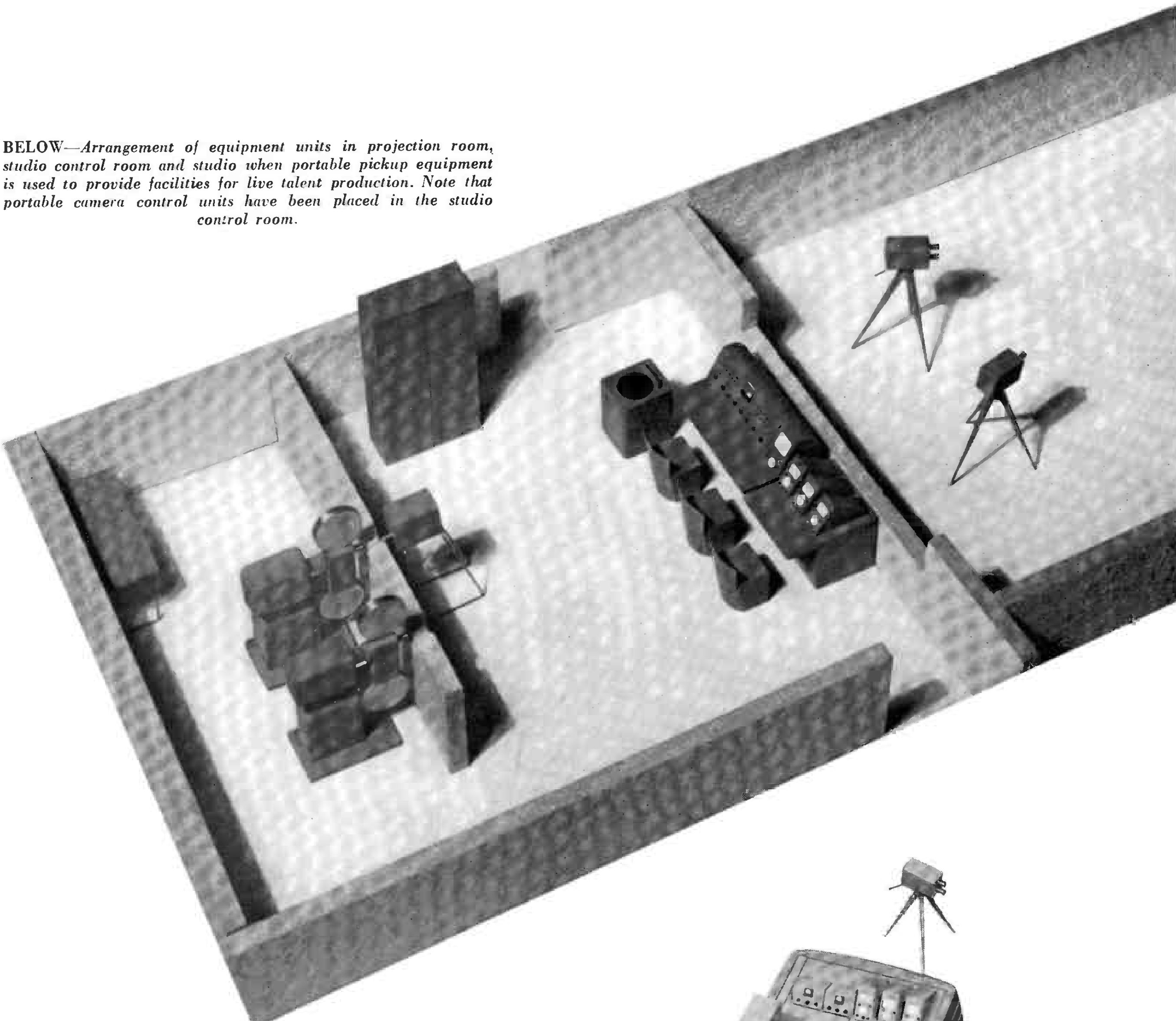
When the cameras are set up in the studios, the camera control units and the video master monitor unit are placed on a desk in the control room immediately adjacent to the control console. This desk is recessed so that the suitcase-type field units sit at an angle which brings their front panels flush with the panel of the control console. This gives the assembly the appearance of having been "built-in-one-piece," and provides a compact and convenient operating unit. The portable synchronizing generator, and the power supply units may be placed beneath the desk or in any convenient nearby location.

When the portable equipment is used in the field it may be installed in a light truck, as shown in the cutaway view at the



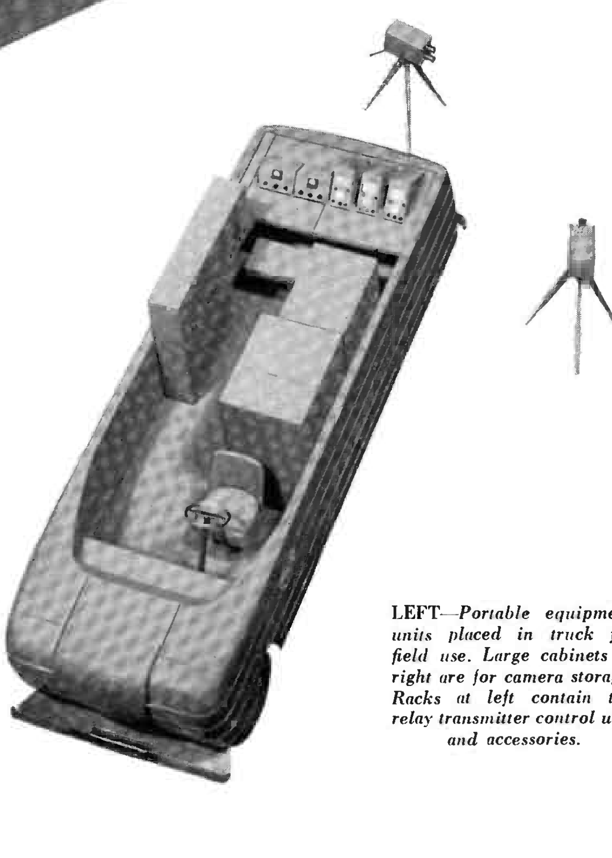
SMALL TELEVISION STATION STUDIO SYSTEM WHEN PORTABLE EQUIPMENT IS USED FOR LIVE TALENT STUDIO PRODUCTIONS

BELOW—*Arrangement of equipment units in projection room, studio control room and studio when portable pickup equipment is used to provide facilities for live talent production. Note that portable camera control units have been placed in the studio control room.*



right, or it may simply be transported in a station wagon or a car to the location and there set up wherever convenient (as for instance in the broadcasting booth at a football field). When it is to be operated in the truck it is handy to have a recessed desk similar to that used in the studio. The view at the right shows two camera control units and a video master monitor unit mounted on such a desk, along with two portable audio units (which are standard broadcast-type units). Cabinets in the truck provide storage space for cameras, cables, microphones, etc. With a truck setup, such as that shown, the cameras may be as much as 500 feet away with interphones providing communication between camera men and the control position. Where the truck cannot be brought within 500 feet of the camera positions it is necessary to set up the control units at some other convenient location.

In many cases it will be possible to send the video signal to the studio by means of specially-equalized telephone lines. When this is not feasible an RCA Microwave Relay Transmitter can be used. This transmitter is also constructed in portable form so that it too can be transported easily to any point where it is desired to make a television pickup.



LEFT—*Portable equipment units placed in truck for field use. Large cabinets at right are for camera storage. Racks at left contain the relay transmitter control unit and accessories.*

STAGE THREE: studio-type cameras and video equipment added to form a permanent studio system

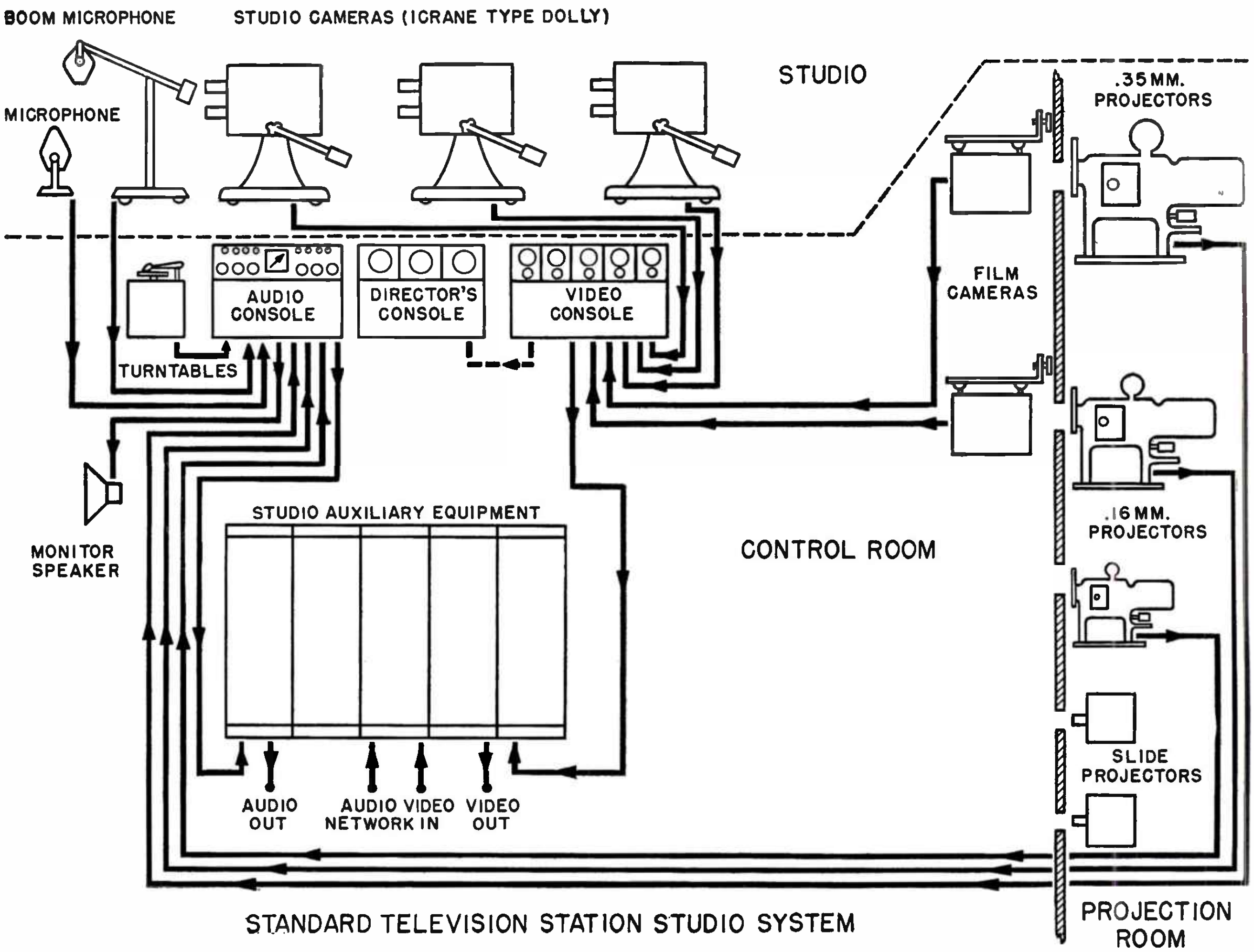
The equipment facilities included in Stage Two (see preceding pages) will provide for simple types of live talent studio programs in the early stages of station operation. However, as the station activities increase, several disadvantages will become evident. It will not, for instance, be possible to switch from a remote pickup to a studio show. Moreover, the equipment will not always be available for studio rehearsals and, in general, it will be less convenient to operate and maintain than would a permanent setup. When these drawbacks become a definite handicap to further progress, it is time for the station to consider the installation of regular studio-type cameras and video equipment. This step is envisioned in Stage Three of the television plan outlined here.

Stage Three differs from the preceding stages in that, whereas the earlier stages were admittedly temporary expedients, Stage Three may well represent a relatively permanent arrangement for stations of small to medium size. In going to this stage (which is illustrated by the diagram below and the photograph on the opposite page) permanent equipment of fairly elaborate nature is installed in the live talent studio; the film equipment is greatly increased, and the control room facilities are expanded to include a large video console, a director's console (which was not a part of earlier plans) and various additional auxiliary items.

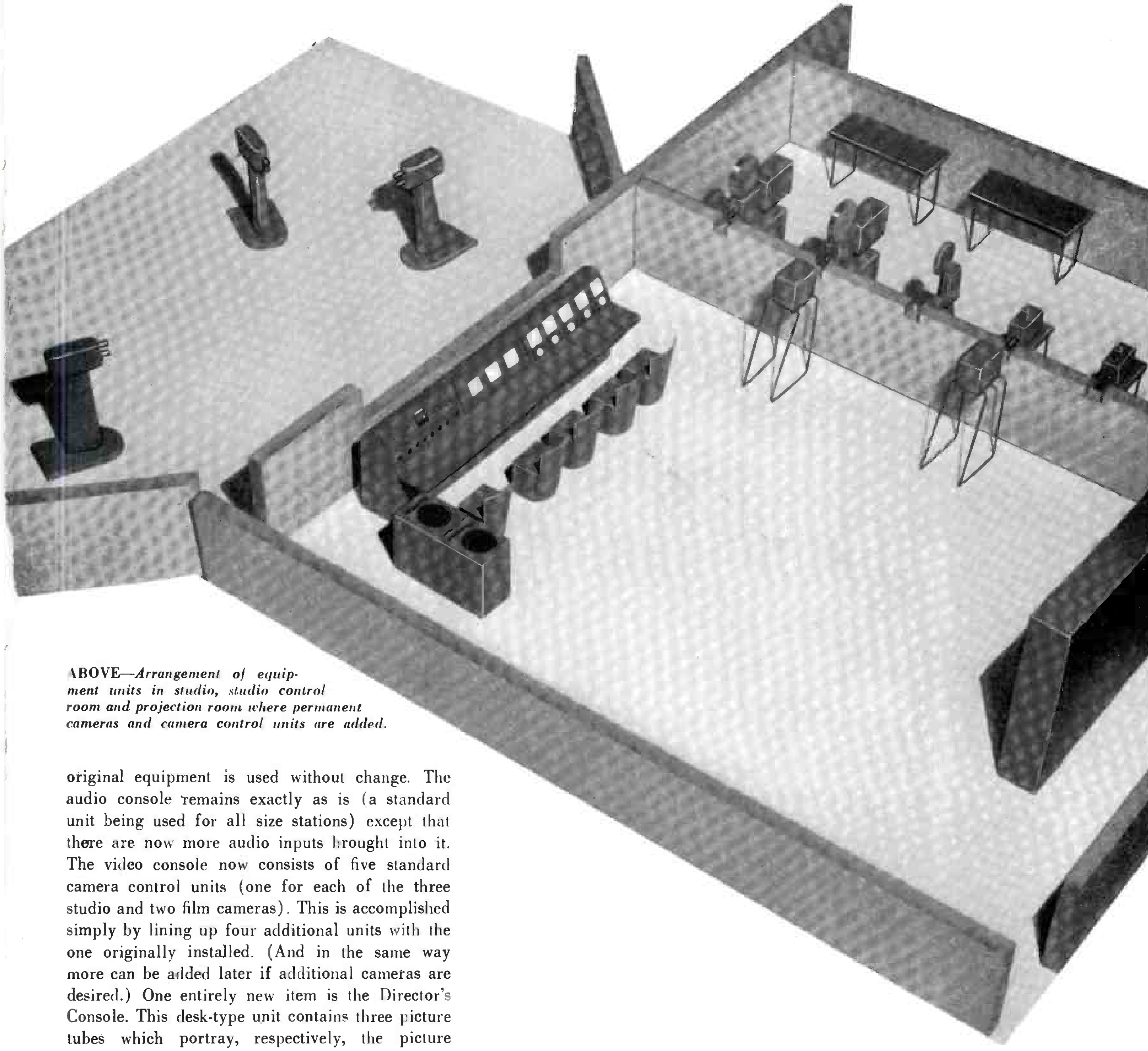
The equipment in the studio (which, of course, can be varied to meet individual needs) includes three deluxe-type cameras. Two of these are usually mounted on small dollies while the third is mounted on a large crane-type dolly to provide for angle shots and shots from above. Two microphones are included (usually a number of additional microphone outlets are provided for). One of these is usually mounted on a large boom-type stand while the other is suspended from overhead.

In the film projection room a 16 mm projector and two slide projectors are added to the two 35 mm projectors previously installed, while in the control room a second film camera is installed. These extra facilities provide for all possible types of film programs and for switching smoothly from one type to another, fading in of station breaks or commercials made up on slides, etc. It will be noted that in thus enlarging the film facilities all of the original equipment is used—none is wasted. In fact, if space was originally provided, it would not even be necessary to move, or change the connections to, the original units.

In the control room proper the video and control equipment is, of course, greatly expanded. Here again, however, all of the



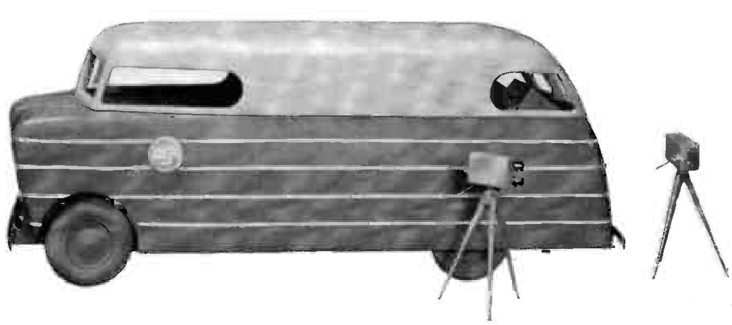
STANDARD TELEVISION STATION STUDIO SYSTEM



ABOVE—*Arrangement of equipment units in studio, studio control room and projection room where permanent cameras and camera control units are added.*

original equipment is used without change. The audio console remains exactly as is (a standard unit being used for all size stations) except that there are now more audio inputs brought into it. The video console now consists of five standard camera control units (one for each of the three studio and two film cameras). This is accomplished simply by lining up four additional units with the one originally installed. (And in the same way more can be added later if additional cameras are desired.) One entirely new item is the Director's Console. This desk-type unit contains three picture tubes which portray, respectively, the picture being transmitted, the picture on the second camera, and the "cue" picture on a program coming up. Other arrangements are, of course, possible. In smaller stations the Director's Console is not necessary. However, it is felt that larger stations will usually wish to have it available. It may be located between the audio and video consoles, as shown above, or it may be placed in an elevated position just behind the two operators' consoles.

In Stage Three the portable equipment is, of course, assigned entirely to field duty. The availability of special equipment for remote pickups, which is always ready (and preferably stored permanently in the field truck), is an advantage any broadcast engineer will appreciate.



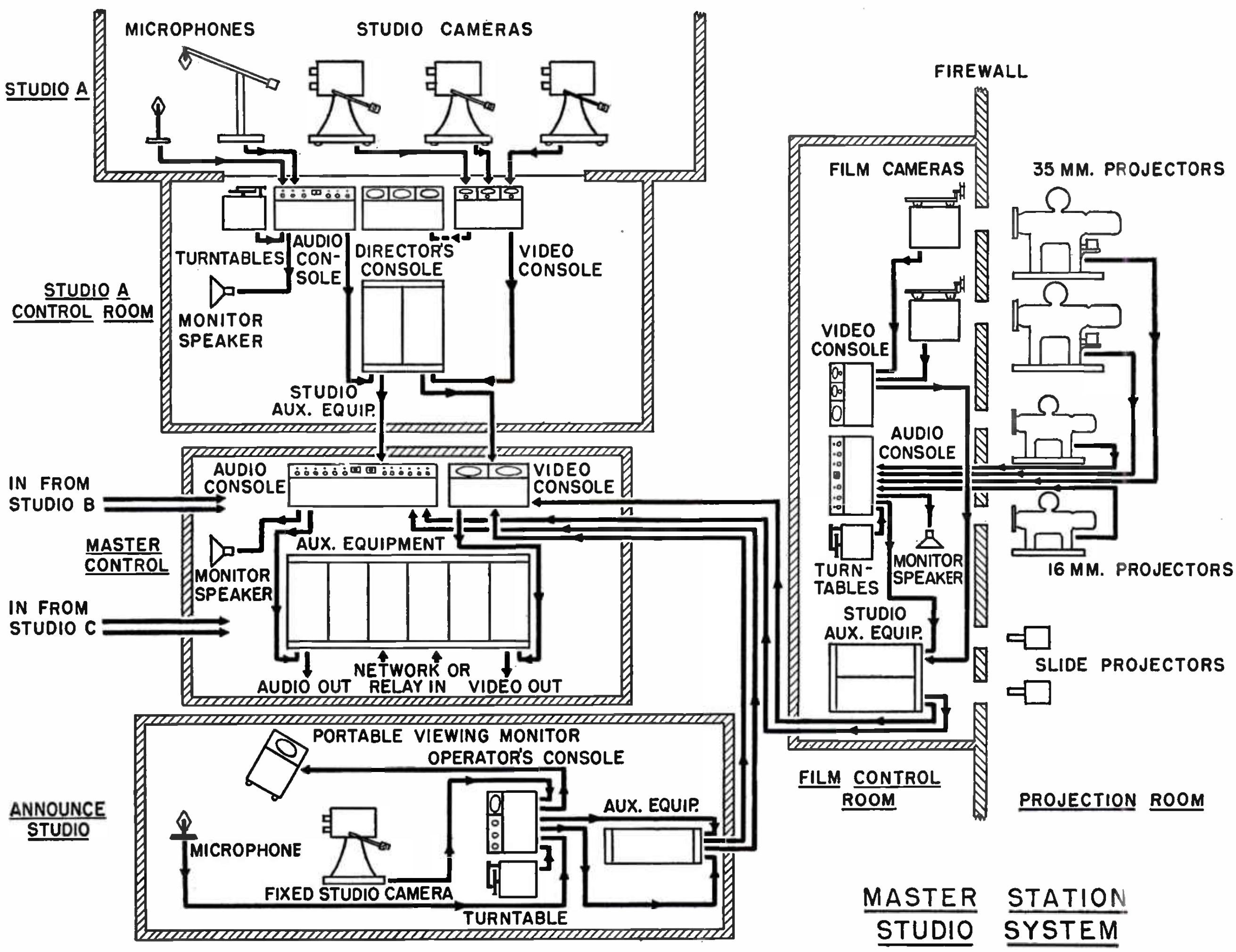
ABOVE—*Truck in which portable equipment can be placed for field use. When desired, portable units can be removed and carried to scene of action in light truck or station wagon.*

STAGE FOUR: additional studios provided and master control room added to form a "master television studio system"

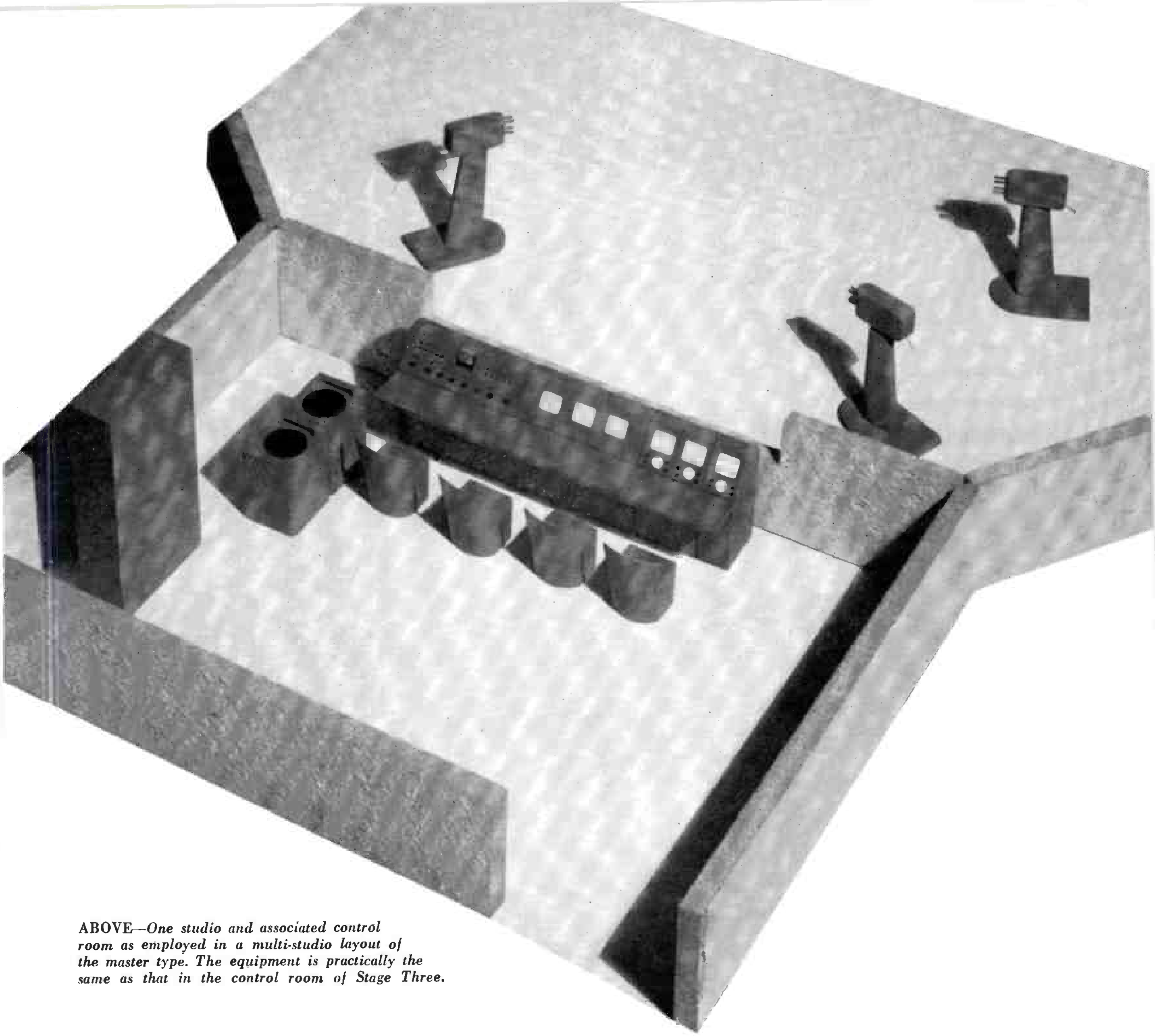
The equipment facilities included in Stage Three (preceding page) will provide for the requirements of most stations during at least the initial period of station development. Moreover, the unit plan on which RCA equipment is based makes it possible to add additional equipment, for example extra cameras, as these are required. It is even possible to add on additional studios which can be handled from the original control room by the provision of additional camera control units. However, it is felt that major stations in large cities, and certainly all network stations that must originate many studio programs, will eventually require a master control setup in which each studio has its own individual control booth and a separate master control room is provided for centralizing all operations. Such an arrangement, which is similar in principle to that presently used in large broadcast stations and network studios, is the next stage in the television plan outlined here.

The diagram below and the photographs on the three following pages illustrate this next stage. The arrangement depicted is a multi-studio installation in which each studio, whether film or live talent, is a complete operating unit in itself. Thus, while a program is being aired from one studio, rehearsals may be carried on in others. Moreover, such rehearsals can be complete with the whole staff, including control room operators, in their final positions (which would not be possible if there was but one control room for all studios).

The number of live talent studios in an installation of this kind is not limited. A possible arrangement would be to provide space for as many as five or more, but to install equipment initially in only two or three. Each of these studios, with its associated control booths, would be equipped approximately as indicated in the illustration on the opposite page (and as shown for "Studio A" in the diagram below). It will be immediately noted that this equipment is the same as that provided in the studio and control room of Stage Three (except that film equipment has been moved to a new location, as explained later). In fact, in progressing from Stage Three of this plan to Stage Four, it will often be possible to leave the original studio and control room intact. The transition can be made in easy steps by adding,



MASTER STATION STUDIO SYSTEM

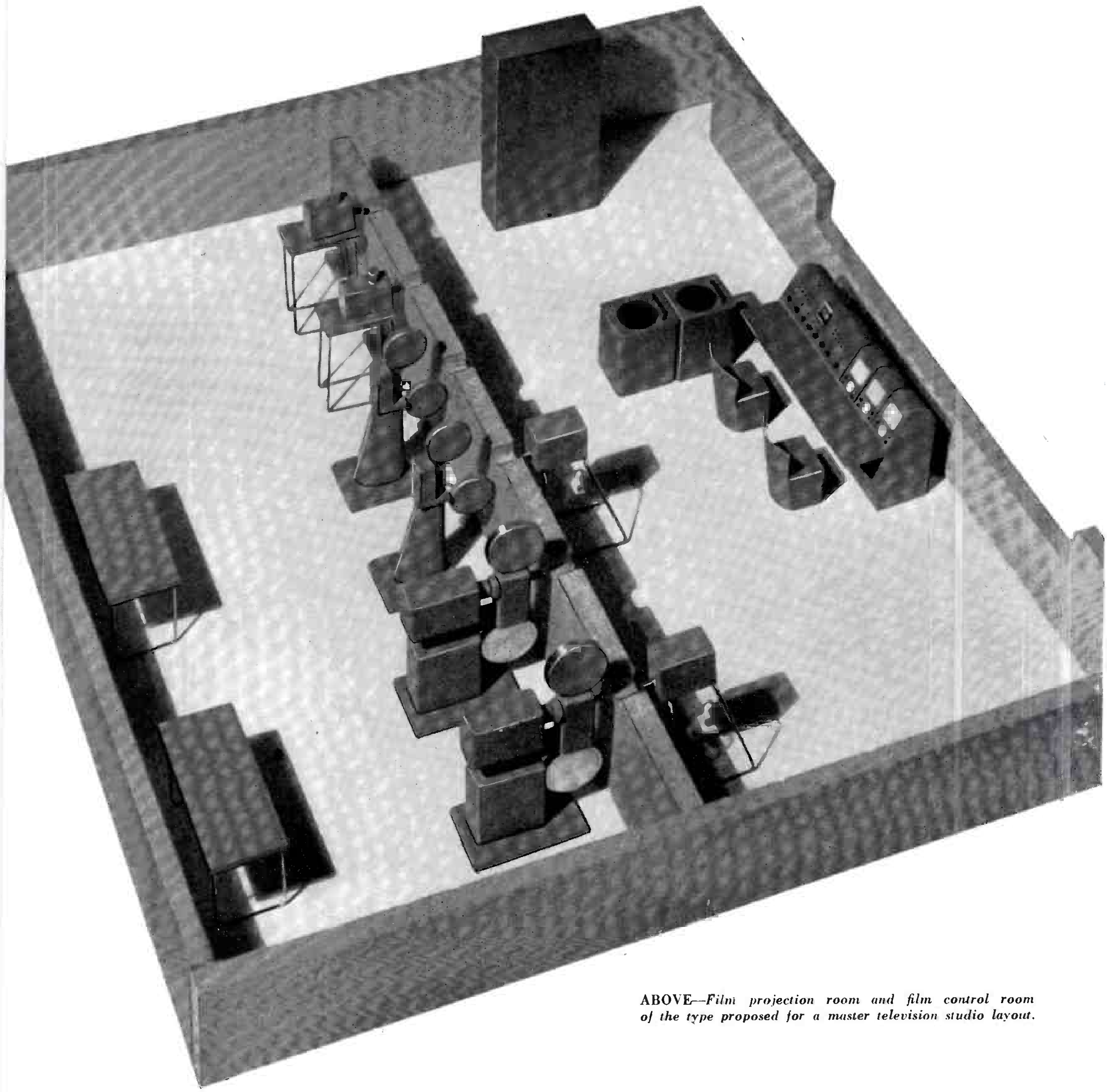


ABOVE—*One studio and associated control room as employed in a multi-studio layout of the master type. The equipment is practically the same as that in the control room of Stage Three.*

one at a time, additional studios (each with control booth). These studios do not need to be adjacent. They can be on separate floors of the building—it is even possible that television stations may evolve along the lines of present-day motion picture production plants with the individual studios being separate one-story buildings comparable to the "stages" of motion picture lots. However, regardless of the form they take, each of these studios will require equipment approximating that shown here. This will include three or more cameras and a number of microphones of various types in the studio proper, plus an audio console, a director's console and a video console, together with auxiliary equipment in the control room. The audio consoles and the video consoles are basic units which are the same in all studios and they are the same as those used in smaller equipment layouts discussed previously. The video consoles are made up of a number of standard camera control units (this being the basic unit in all installations). Thus, they are all similar in nature, but will vary in number of units included according to the number of cameras in the associated studios.

The film "studio" and its associated control room are shown in the illustration on the following page. This "studio" is actually a projection room which is similar to the projection rooms indicated for the smaller station layouts, except that it is considerably larger and includes at least two 35 mm, two 16 mm and two slide projectors. Some stations may eventually have an even greater number of projectors in order to provide for smooth fading from one film to another, for previewing, and as spares in an emergency.

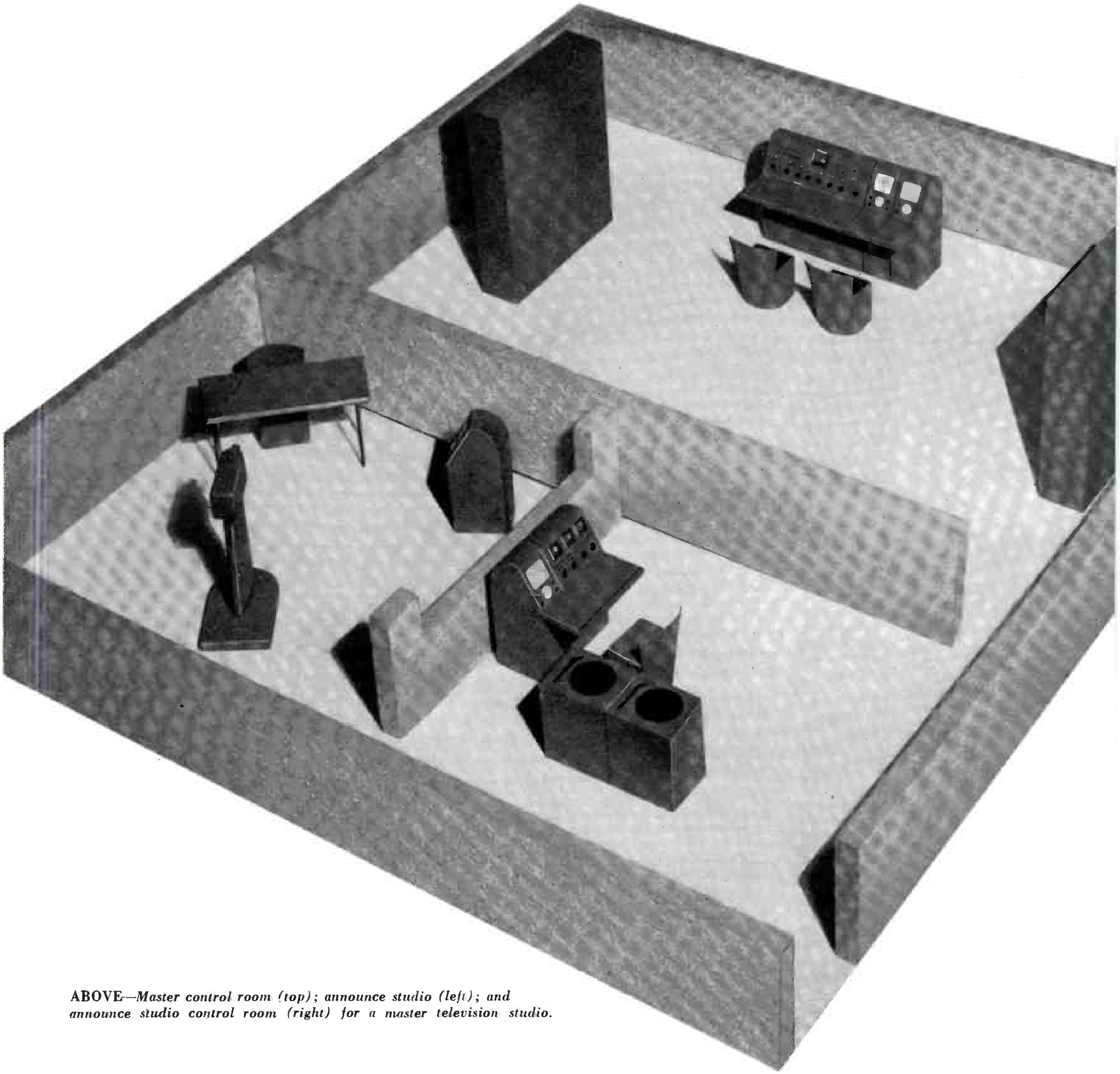
The film control room, which is located adjacent to the projection room, contains an audio console, a director's console and auxiliary equipment. The film cameras, of which there will be at least two, are mounted either on movable supporting bases or on a track which enables them to be moved easily to a position in front of any of the projection ports. The audio console is the same as that used in the other studios, as is also the video console. The latter contains one standard video control unit for each of the film cameras, plus an extra unit which is used for taking "cue" from the master control room.



ABOVE—*Film projection room and film control room of the type proposed for a master television studio layout.*

The illustration on the opposite page indicates the arrangement of equipment in the master control room and in the small "announce" studio and its control booth. The master control room is the "brain center" of a large station, the point from which all of the station operations (and often those of an associated network) are directed. To this point are brought lines from all of the individual studios as well as lines from remote pickup points and from the network. The operator at the master control position selects the program to be fed to the transmitter (and to the network, if the station is originating on a net program). He switches from one studio to another as required, feeds "cue" to various points, and in general "master minds" the whole programming operation.

The equipment required in the master control room will vary with the size and particular requirements of the station. The illustration above shows a small audio console of the standard type and a video console consisting of two units (one for "on-air" and the other for previewing the program coming up.) However, it is likely that a much larger console will be necessary to incorporate the required switching facilities, particularly in a network station. Such a console ordinarily will be custom-built. The various program, distribution and monitoring amplifiers, which make up essential parts of the master control system, will be mounted in standard cabinet racks which may be installed in the master control room as shown above, or in a separate equipment room.



ABOVE—*Master control room (top); announce studio (left); and announce studio control room (right) for a master television studio.*

Immediately adjacent to the master control room (in the installation shown above) is a small "announce" studio with an associated control booth. This studio contains an announce microphone; an unattended studio camera, which may be used in televising news commentators, interviewing celebrities, etc.; and a portable picture monitor which is useful when it is desirable to add oral comments to visual program material (for instance, 16 mm films made of local news events and which ordinarily do not have sound track). In the control booth associated with this announce studio is a small operator's console consisting of a single standard camera monitoring unit and a simplified audio control panel, also a transcription turntable which can be used in audio testing or for emergency fill-ins.

SUMMARY

The four stages in the development of a television station which have been outlined in the preceding pages could, of course, be varied in many ways. In most stations the additions indicated will probably be made in smaller steps than those shown. However, the arrangements shown here serve to illustrate the main stages and to indicate how the station may grow in accordance with its audience, starting in a small way with a minimum investment and operating staff, and adding facilities and personnel as the economics justify. The design of RCA Television equipment units makes it possible to do this without making original equipment obsolete, and with a minimum of interference to station operation during periods of equipment expansion.

WMT INSTALLS 5-F TRANSMITTER

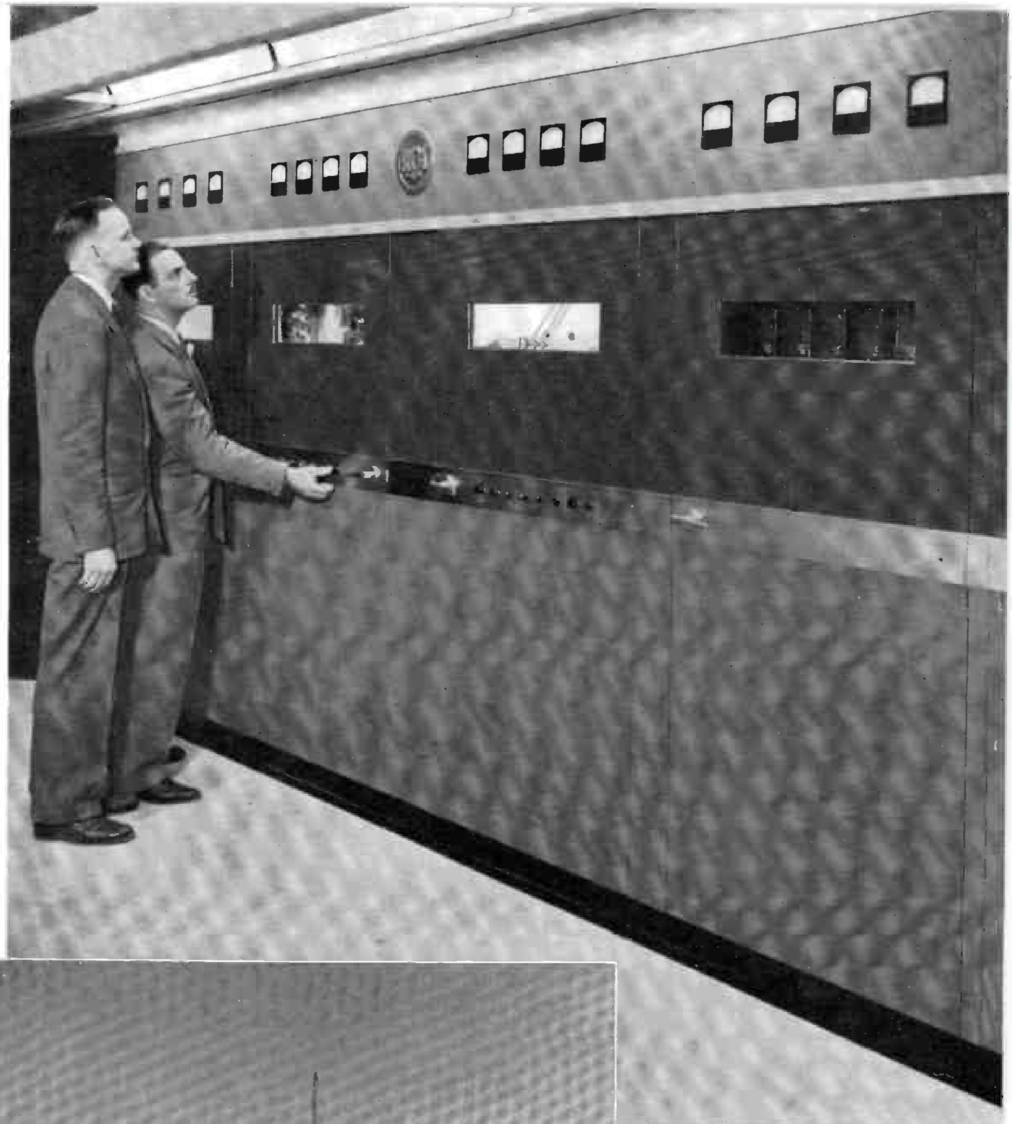
Cedar Rapids Station Proud Owner of First RCA Postwar Installation

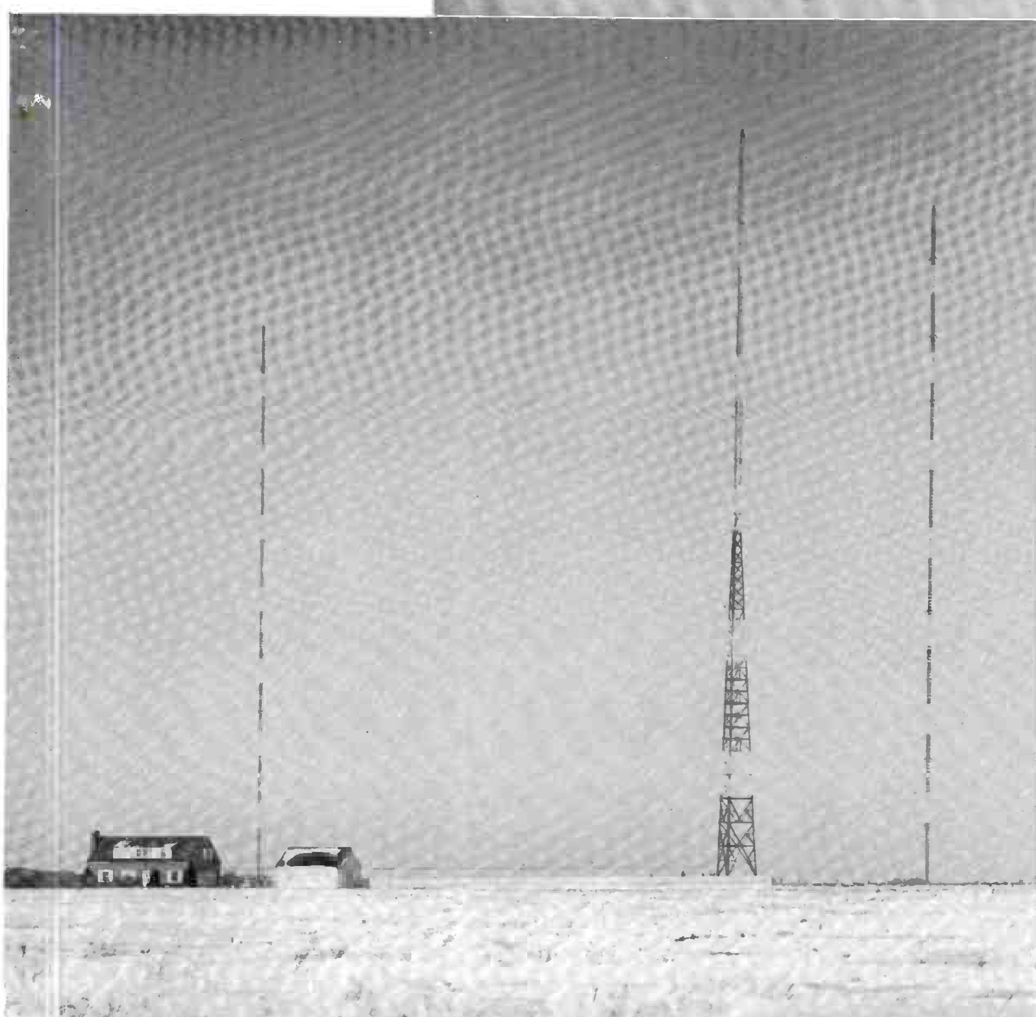
WMT, Eastern Iowa's progressive station with studios in Cedar Rapids and Waterloo, won the race to have the first postwar transmitter on the air. RCA completed and shipped six Type 5-F 5000-watt Transmitters during November and December of 1945. George Hixenbaugh, WMT Chief Engineer, and his staff received theirs in the middle of November. By installing it in the very good, if not record time of three weeks, they managed to get it on the air by December 10th, thereby making theirs actually the first "on-the-air" with a postwar job. Final testing and tuning of the new transmitter were done by Tom Hall and Ellis King of the RCA Service Company.

WMT, which is owned by American Broadcasting Stations, Inc., has been operating with a power of 5000 watts on the favorable 600 kc frequency for the past ten years. Providing primary coverage to all of Eastern Iowa, it has established an enviable reputation for service throughout Iowa's rich farmland. The new RCA 5-F Transmitter is only part of the modernization which William B. Duarton, General Manager and George Hixenbaugh, Chief Engineer have planned for WMT. New monitoring, test, and audio equipment have been ordered from RCA and will be installed as soon as available. Old equipment, located in another room of WMT's spacious transmitter building, will be retained as auxiliary equipment for use during maintenance or in an emergency.

(Left): WMT's promotion features their new RCA transmitter. Shown here is the cover of the unusually attractive weekly program schedule mailed to listeners in WMT's coverage area, which includes all of Eastern Iowa. This is a 2-color, 4-page job, 9" x 12" in size.

(Right): *George Hixenbaugh, Chief Engineer (left) and Ellis King, RCA engineer, put WMT's new 5-F Transmitter on the air for the first time.*





(Left): *Three tower directional array and transmitter building of WMT are located in Merion, approximately 9 miles northeast of Cedar Rapids.*

In 1934 *Dr. V. K. Zworykin of RCA Laboratories predicted Kamikaze warfare and suggested the radio-controlled television-equipped aerial bomb as a means of obtaining equal effectiveness without the terrible cost in pilots' lives. In the photo above, Dr. Zworykin is examining the latest RCA pickup tube, the Image Orthicon. This new tube, which solved the problem of television pickup under conditions of poor visibility, was developed at the RCA Laboratories by Drs. Albert Rose, Paul K. Weimer, and Harold B. Law, of the RCA research staff.*

AIRBORNE TELEVISION

by HENRY E. RHEA, Manager

TELEVISION TRANSMITTING EQUIPMENT SALES

Engineering Products Department

A Navy TBF Avenger was slowly circling at a thousand feet above the blue waters of the South Pacific. In the after cockpit an officer was seated in front of a special instrument panel. Between his knees was a small metal box with a miniature control tick mounted on top. In the instrument panel before him was a cross-haired television screen on which was reproduced an image which the officer was intently studying. As he watched the outlines a large harbor came into view. Near the entrance of the harbor, protruding from the water, was a small vertical column. The shifting of the scene and the gradual enlarging of individual objects showed that the television camera scanning the area was approaching closer and closer. The column in the center grew larger and larger. From time to time, as the pitching and sidewise motion of the camera displaced it from the cross hairs on the screen, the officer manipulated the control stick to bring it back on center. The column increased in size until it eventually became recognizable as a lighthouse. Then, as the seconds passed, the increase in size became more and more rapid.

In 1937 *the first television system designed specifically for aircraft use was built and tested by RCA engineers. The photo below shows this equipment installed in a Ford Trimotor. The camera in the foreground points downward through a hole in the bottom of the fuselage.*

In 1940 *in cooperation with United Airlines, RCA engineers installed the then newly-developed RCA television field pickup equipment in a Boeing 247 and successfully transmitted pictures to a receiver in Radio City. This picture in turn was broadcast by NBC's Television Station.*

IS AN RCA DEVELOPMENT

"BLOCK" and "RING" Equipments Demonstrated by RCA and the Navy at Anacostia in March are the Culmination of Ten Years Work on Airborne Television

The windows of the lighthouse became visible and a "bedspring" antenna could clearly be observed on the tower's peak. The last intervening space between the flying camera and the lighthouse was closed with a rush . . . the image of the target completely filled the screen—and then, oblivion.

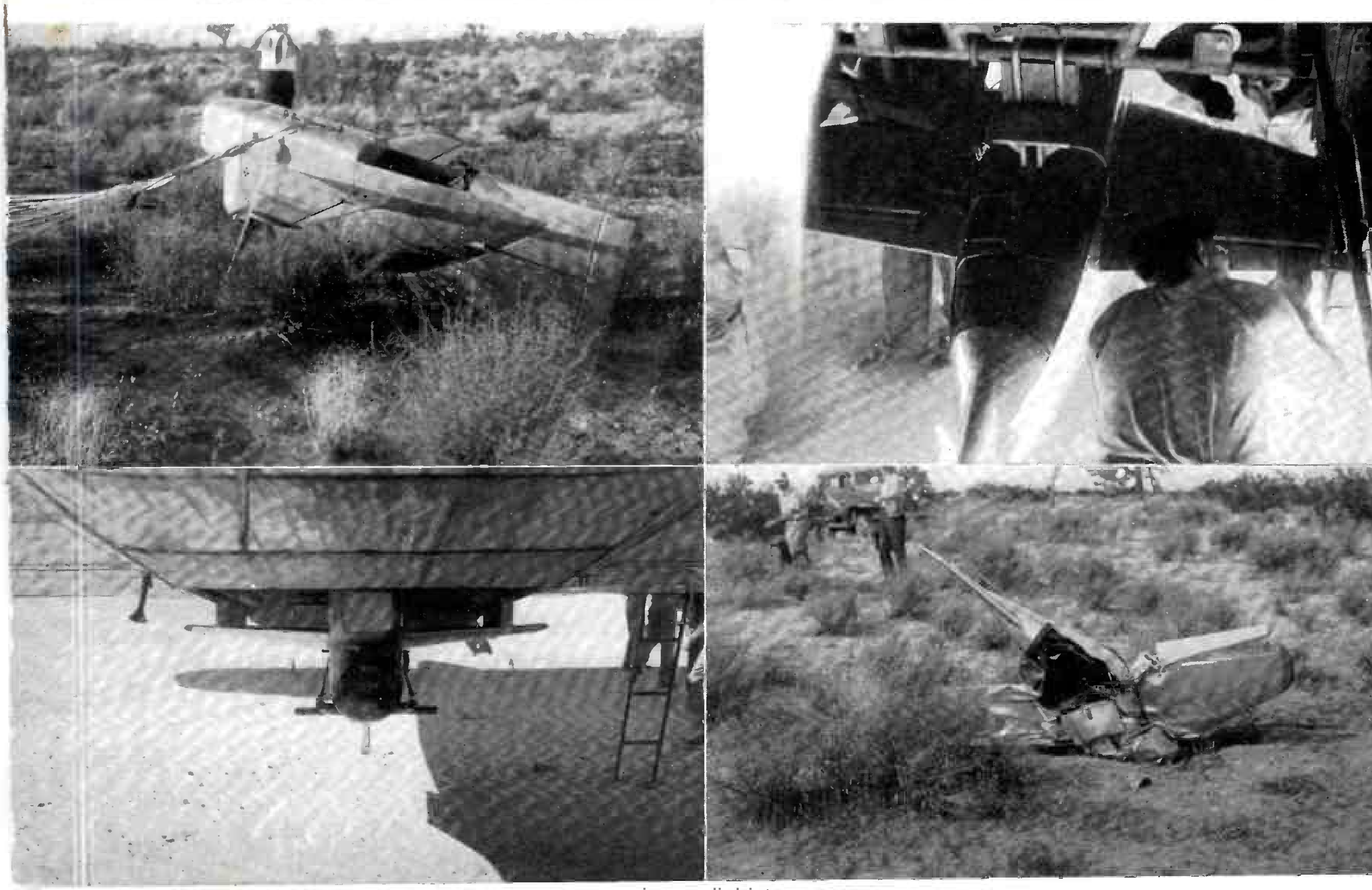
The pilot glanced out the side window of the cockpit. Several miles away, in the lower entrance of Rabaul Harbor, could be seen a tall geyser of water and debris, which quickly settled leaving nothing in sight but the smooth surface of the bay. The lighthouse was gone—the victim of a new type of flying bomb.

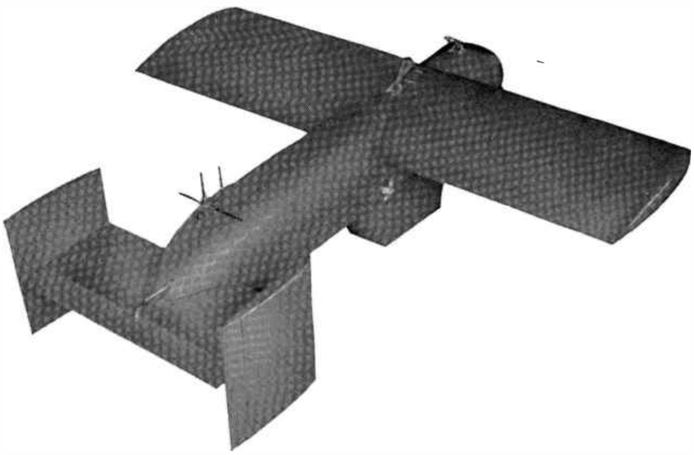
The "bomb", which destroyed the Rabaul lighthouse, differed considerably from any that had been used before in those waters. It was one of the Navy's new guided missiles—in this case, a twin-engined TDR pilotless drone controlled remotely by radio. Radio-controlled drones, of course, were not new—but the unique feature of this drone was that it could "see". A television camera in the nose of the drone was adjusted to produce an electronic image of the target and surrounding area along the forward extension of the plane's longitudinal axis. A high-frequency transmitter and antenna were provided to transmit the signal to a television receiver located in the TBF "mother" plane fifteen miles away. The image had the unusual, but very valuable feature of containing more and more visual detail as the distance between the drone and the target diminished, thereby permitting greater accuracy of control. This image was reproduced on a screen located in the instrument panel directly in front of the control pilot. As the target moved away from the cross-haired center of the screen, it was quickly brought back by the pilot's stick controlling the direction of flight of the drone. Several tons of RDX in the drone's belly did the rest.

A 1934 IDEA

At the time of this Rabaul mission the idea of a guided missile with a television eye was just ten years old. Dr. V. K. Zworykin of RCA Laboratories first proposed the notion in 1934 when he

In November 1941 *the first three television-guided missiles on record—built by RCA under an NDRC contract—were tested at Muroc Lake, Calif. This early missile was designed entirely by RCA engineers; the fuselage was built under their direction by a well-known aircraft company. The pictures below show the missile itself (top left) with cords to the landing parachute which permitted repeated flights; the bomb being attached to the plane (top right); the bomb in position for flight (lower left); and one of the bombs after an accidental crash (lower right).*





GB-4

A TELEVISION-GUIDED, RADIO-CONTROLLED GLIDE BOMB

In June 1943 *a new type of Glide Bomb, equipped with RCA television equipment, was tested under operating conditions at Eglin Field, Florida. This bomb, the result of an extended period of development carried out by the Army Material Command, Wright Field, consists essentially of a standard 2000-pound bomb to which is attached a vestigial air frame which makes the glide path of the missile approximately 8-to-1. The drop is made some distance from the target. Additional pictures of this bomb are shown on following pages. At about the same time the Army also began using this television equipment for guiding explosive-laden "war-weary" B-17's in the ETO.*

became worried about Japanese plans for training suicide or Kamikaze pilots. Dr. Zworykin was Russian born and decidedly did not trust the sons of Nippon. In a report disclosing his new proposal the Doctor made some astoundingly accurate predictions. The following paragraphs are quoted from this report:

"There have been quite a number of attempts to devise an efficient flying weapon. The aerial bomb is the simplest form, and the recent improvements in aerial ballistics make these bombs a most formidable modern weapon. But the use of such a bomb usually requires a close approach of the bombing airplane to the target, thereby subjecting the plane to the barrage of the anti-aircraft batteries. It follows that simultaneous improvement in anti-aircraft artillery, as aerial bombing is developed, has considerably lessened the effectiveness of the latter weapon.

"Considerable work has been done also on the development of radio-controlled and automatic-program controlled airplanes having in mind their use as a flying torpedo. The possibilities of such airplanes were demonstrated repeatedly in various countries during the past few years. Both these methods, however, have the same fundamental difficulty, viz., that they can be used efficiently only by trained personnel at a comparatively close range, thereby being subjected to anti-aircraft gunfire. Both radio and automatic-controlled planes lose their efficiency as soon as they are beyond visual contact with the directing base.

"The solution of the problem evidently was found by the Japanese who, according to newspaper reports, organized a Suicide Corps to control surface and aerial torpedoes. The efficiency of this method, of course, is yet to be proved, but if such a psychological training of personnel is possible, this weapon will be of the most dangerous nature. We hardly can expect to introduce such methods in this country and therefore have to rely on our technical superiority to meet the difficulty."

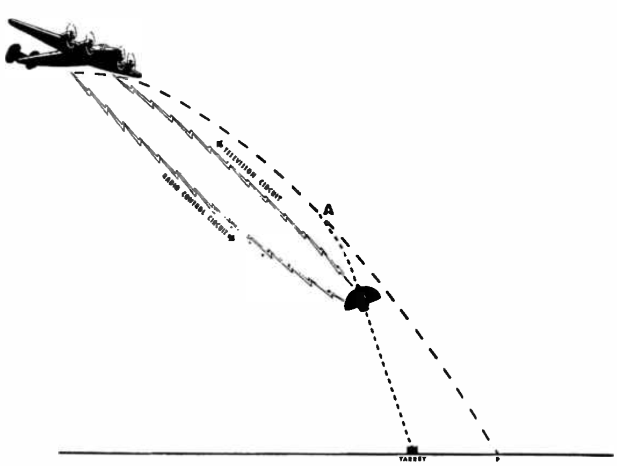
Dr. Zworykin then declared that "one possible means of obtaining practically the same results as the suicide pilot is to provide a radio-controlled torpedo with an electric eye," and added: "This torpedo will be in the form of a small steep angle glider, without an engine, and equipped with radio controls and iconoscope camera. One or several such torpedoes can be carried on an airplane to the proximity of where it is to be used, and released. After it has been released the torpedo can be guided to its target with the short-wave radio control, the operator being able to see the target through the 'eye' of the torpedo as it approaches."

"This," Dr. Zworykin commented, "introduces an entirely new principle in ballistics, since in all existing methods the operator has no way of controlling the projectile once it has been released."

The RCA television pioneer included in his memorandum details as to radio-control equipment involved in the flying torpedo, and went so far as to estimate that this entire equipment, the television transmitter and all, could be built to weigh only 140 pounds.

In that memorandum and in a supplementary memorandum written in the latter part of 1935, a year and a half later, Dr. Zworykin told how the system might be applied in more elaborate form to an explosive-carrying plane which, like the flying torpedo, could be radio-controlled and guided to enemy targets by television. Such aircraft, he pointed out, had the advantage of easy launching from land points or from vessels at sea. His estimate of the total weight of a satisfactory radio and television system for this use was 160 pounds, and that included an automatic pilot.

Television equipment in 1934 was not light enough to be used in an airplane. But in 1935 RCA, on its own initiative, started the construction of airborne reconnaissance television



(Left): *This diagram shows how the trajectory of a high-angle bomb is controlled to obtain greater accuracy. The free falling path would cause the bomb to strike point P. Radio control exerts a correction at A, the bomb traveling in a straight line shortly beyond this point.*

ROC

A TELEVISION-GUIDED, RADIO-CONTROLLED HIGH-ANGLE BOMB

In August 1944 *the Army started tests on television-guided, radio-controlled, high-angle bombs. The ROC, shown at the right, is one of these. Bombs of this type are provided with only such wing surfaces as are required in order to exercise some control of the path. Thus, instead of gliding into the target (like the GB-4), these high-angle bombs fall approximately as would an uncontrolled bomb. The bombardier releases them as he would a regular bomb and uses the radio control feature simply to obtain greater accuracy. The plane must fly over the target, as in regular bombing, but television allows the bomb to be dropped from great heights and still obtain a high degree of accuracy.*

equipment and this apparatus was completed and successfully demonstrated in 1937—the first television apparatus for aircraft use, but still not light enough for guided missile use. Two more years passed before the next significant step in airborne television development. This came in 1939, when RCA in cooperation with the United Air Lines (in order to determine the program possibilities of airborne television) installed the newly designed RCA television field equipment in a Boeing 247 and successfully transmitted pictures of New York City from several thousand feet above and around Manhattan, to a battery of receivers installed in Radio City. This demonstration was witnessed by Army and Navy officials. At this point, the RCA management authorized a development program on lightweight airborne equipment using RCA's own funds. In the latter part of 1939 work was started by engineering groups headed by R. D. Kell of RCA Laboratories and M. A. Trainer and W. V. Poch of RCA Victor. Within six months a complete television system, including a 15-watt, 100-mc transmitter weighing about thirty pounds and about the size of a small suitcase, was under test in the laboratory.

In July 1941, this airborne television system—named "BLOCK" for security reasons—was installed in an ancient model TG Navy plane at the Philadelphia Navy Yard and flight tested. And then the troubles began! All the difficulties Wally Poch and his fellow engineers had encountered on the drawing boards and work benches paled into insignificance. Plane power line voltages fluctuated widely, high humidity and temperatures changed circuit impedances and wrecked performance. Worst of all, multipath problems—always troublesome in high-frequency television transmission—were accentuated because of the continuously changing propagation path between the transmitting and the receiving planes.

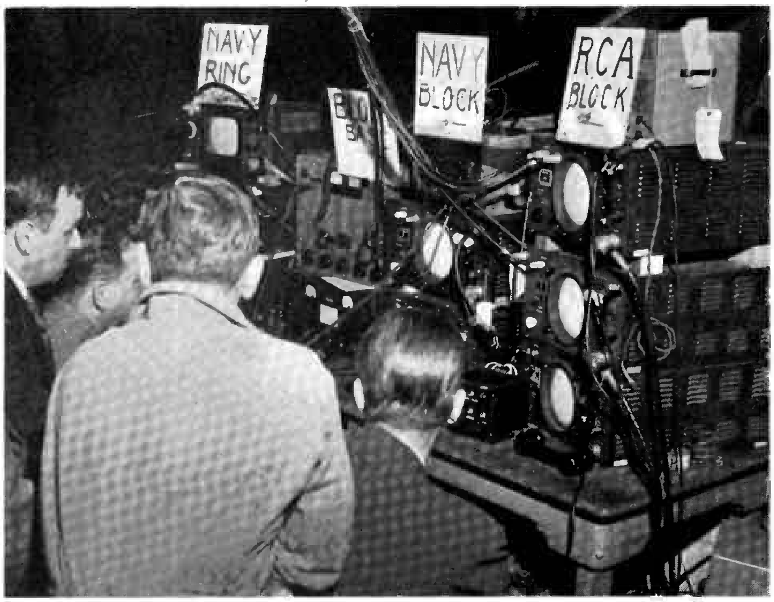
One by one these problems were solved by the diligent efforts and stubborn persistence of the engineering groups which included Antony Wright, Ed Clark, Dr. H. N. Kozanowski, John Roe, Howard Morrison, and their fellow workers. Over 500 BLOCK I transmitting equipments (the early design) were manufactured in the RCA Camden plant and delivered to the Army, Navy, and NDRC. This equipment (BLOCK I) was built to operate on any one of four 12-megacycle wide channels from 78 to 114 mc. By the latter part of 1943 the BLOCK III transmitting equipment—the third design, operating in the 300 mc band—was rolling through production. This equipment, of which 4000 were made, met specifications that were considered impossible two years earlier.

The video system, including the synchronizing generator, camera, and auxiliary circuits were divorced from the r-f transmitter which, in its own separate case, was designed to produce an output of approximately fifteen watts on any channel between 264 and 372 megacycles. The BLOCK III receiver made use of a 7-inch viewing tube and was tunable over the entire 264 to 372 mc band. The transmitter used a directional antenna, radiating towards the drone's tail, but the receiving antenna was omni-

GLOMB

A TELEVISION-GUIDED, RADIO-CONTROLLED GLIDER BOMB

In October 1945 *the Navy disclosed some of the details of the work it had been doing with RCA television-equipped guided missiles. One of the most successful of these was the "GLOMB", a television-guided, radio-controlled glider which was towed to the vicinity of the target by a tow plane which, after launching the glider, could control its course to the target. The model LBE-1 GLOMB shown at left will stand 300 miles an hour in a four-G dive. The Navy also achieved considerable success in the Pacific area with the TDR-1 Drone, a twin-engine powered aircraft which could carry a very heavy explosive load.*



In March 1946 *the Navy gave recognition to RCA's wartime television contributions by staging at the Anacostia Naval Air Station a joint demonstration, with RCA and NBC, of the latest airborne television equipment. The picture at left shows the temporary control room set up for the occasion. The receivers under the sign RCA BLOCK were used to pick up the picture from a standard BLOCK equipment mounted in an RCA plane (one of the four which make up RCA's Flying Laboratory). The receivers under the sign NAVY BLOCK picked up the picture from a similar equipment in a Navy plane. The equipment labeled NAVY RING picked up the picture from a Navy Marauder flying over Baltimore. The RING equipment, developed by NBC, uses a 1-KW, 100-Megacycle transmitter capable of covering a radius of 200 miles.*

directional so as not to interfere with maneuverability in the control plane.

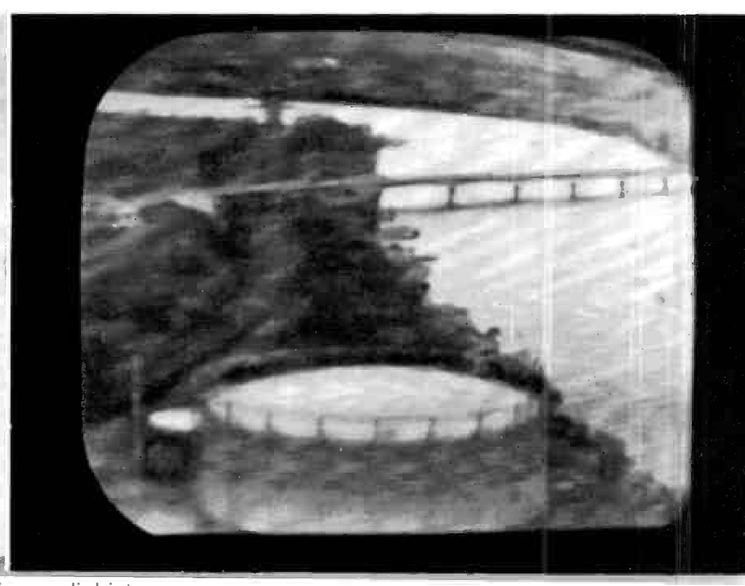
Special shock mounts were used to reduce microphonics; iconoscopes and video amplifier tubes were modified and changed dozens of times to improve life and performance under the most exacting and trying conditions. Highly stable (flywheel) synchronizing circuits were developed to reduce the possibility of loss of synchronizing in the presence of radar signals or high noise levels. Fast, "keyed" AVC circuits were used in the receivers to smooth out rapid changes in signal level caused by multipath phenomena. Components were redesigned and wiring layouts were changed to permit satisfactory operation in a temperature range from −30° C to +55° C, in humidities up to 95% and at altitudes up to 40,000 feet! Gray hairs on the engineers were rapidly cultivated.

Not least important in this development and test program was the fact that the one "must" specification was met—viz., circuits were so stable that, after installation, the entire transmitting and pickup system operated satisfactorily *without further adjustment and unattended.*

During this time the Army, the Navy, and the NDRC had become very active. Orders from the two services were of such magnitude that RCA was called upon to train and assist other manufacturers, notably Farnsworth and Remington Rand, in the program. The NDRC established Section 5.3 of Division 5, under the direction of Dr. O. E. Buckley; and later, Dr. Pierre Mertz to further the development of television for guided missile application. Extensive drop tests were made in the barrens of South Jersey; Eglin Field, Florida; Muroc Lake, California; and Tonapah, Nevada.

The Services were having their problems, too. The Navy was concentrating on the use of the TDR powered drone as a carrier, while doing some experimentation with a glider—"GLOMB", which in later tests proved very satisfactory. The Army Air

TELEVISION RECONNAISSANCE *which also has important military uses, is illustrated by the illustrations below. The picture at the left shows the television camera (BLOCK type) mounted in the nose of the reconnaissance plane. The picture picked up by this camera is sent, by a transmitter in the plane, to a receiver located at a headquarters point which may be as much as 200 miles away (see Page 40). The picture at the right (below) is a photograph made directly from the screen of the television receiver during the demonstration illustrated in the picture at the top of this page.*



AT BIKINI, IN JULY, 1946 *airborne television equipments of the BLOCK type, developed and built by RCA, will be used by the Army and Navy to provide observers located miles away with a closeup view of the action. The photograph reproduced at the left shows a Navy F6F "Drone" in a practice take off from the aircraft carrier Shangri-La. These "Drones" will have television cameras mounted in the nose. Their take offs from the carrier will be radio-controlled from a control unit of the type shown in the left foreground of this picture. After take off a "mother" plane will take control. The television picture picked up by the camera in the "Drone" will be reproduced on a receiver in the "mother" plane and on receivers in ships located fifteen to twenty miles away.*

Force's chief interest was in the GB-4 (glide bomb), capable of carrying a 2000 pound bomb, and in the use of "war-wearies," B-17's and B-24's that had performed their missions in combat service and which could be expended in carrying up to 14 tons of explosives into the target.

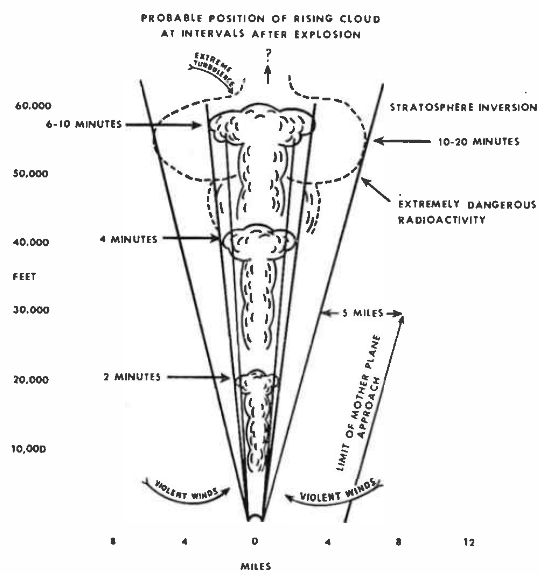
Aerodynamic and control difficulties were numerous. Visibility was sometimes a problem. The BLOCK III television camera needed good visibility conditions. It was this later difficulty that led to the accelerated development of the image orthicon—the high sensitivity pickup tube on which work had started in the RCA Laboratories several years earlier.

Had it not been for the untiring efforts of such men as Col. George Holloman, AAF; C. J. Marshall, Signal Corps Civilian Section head; Lt. Commander Paul de Mars, BuAero; Commander E. R. Piore and Mr. C. Stec of BuShips; Commodore Oscar Smith of Bureau of Operations; Commander M. B. Taylor, NAF; and their many able assistants and fellow workers, it is doubtful that the airborne television project could have progressed so rapidly.

It was in August 1944, in the Northern Solomons near Bougainville, that the Navy first used a television-equipped guided missile, when TDR-1 drones were used against Japanese shipping. The lighthouse attack occurred about two months later when the mission resulted in the destruction of an important Jap radar station and anti-aircraft position—a target that had come unscathed through many conventional bombing attacks.

The Army's first use of the missile was in the ETO where "war-wearies" were sent against the sub pens of Heligoland and some GB-4's were directed against the rocket launching sites near Calais. Shortly after that, the project was being readied for a move to the Pacific, but fortunately by that time the tide had turned and the move was unnecessary. Later some of the equipment was installed in reconnaissance planes and used by MacArthur's forces to survey battle damage in remote areas and for patrol work.

In the forthcoming atom bomb tests at Bikini, many observers will witness the explosion and its devastating effects from a safe distance of many miles, by means of BLOCK III equipment.

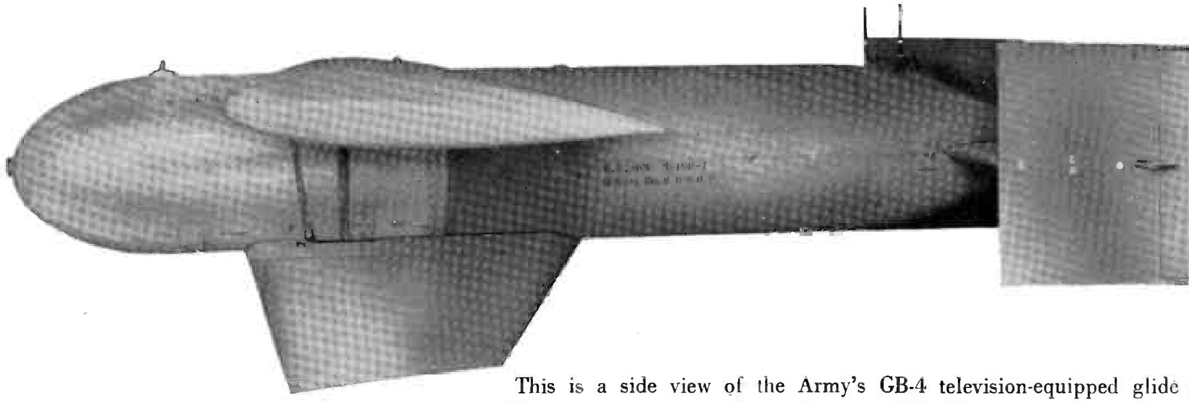


ATOMIC CLOUD — *This sketch of the atomic clouds which will rise after the bombs are dropped in the Bikini experiments has been released by the Joint Army-Navy Task Force, Inc. Note the region of violent winds at the bottom of the mushroom and the extremely dangerous radioactivity at 50,000 feet. Mother planes will stay outside this area as indicated in the diagram above. Radio-controlled, television-equipped planes will presumably be flown into it in order to provide watchers with a closer view.*

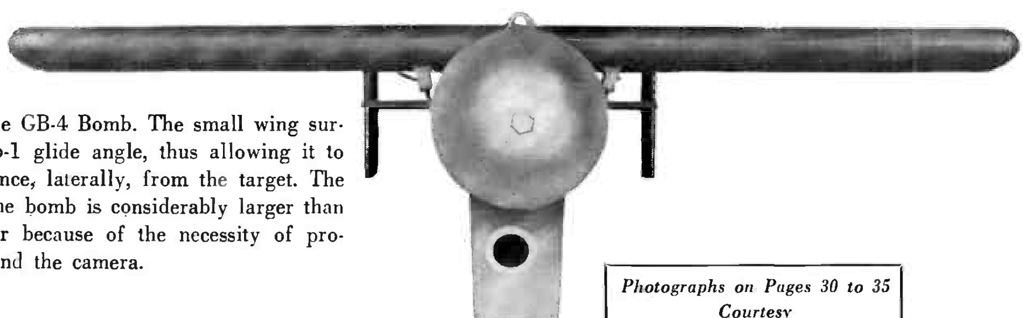
Cameras and transmitters will be located at strategic points near the target area while receivers and auxiliary monitors will bring the action to witnesses comfortably reposing in ships circling safely outside the danger zone.

For more details of the Television Bomb see the photo story on the following pages.

This is what a Television Bomb looks like-

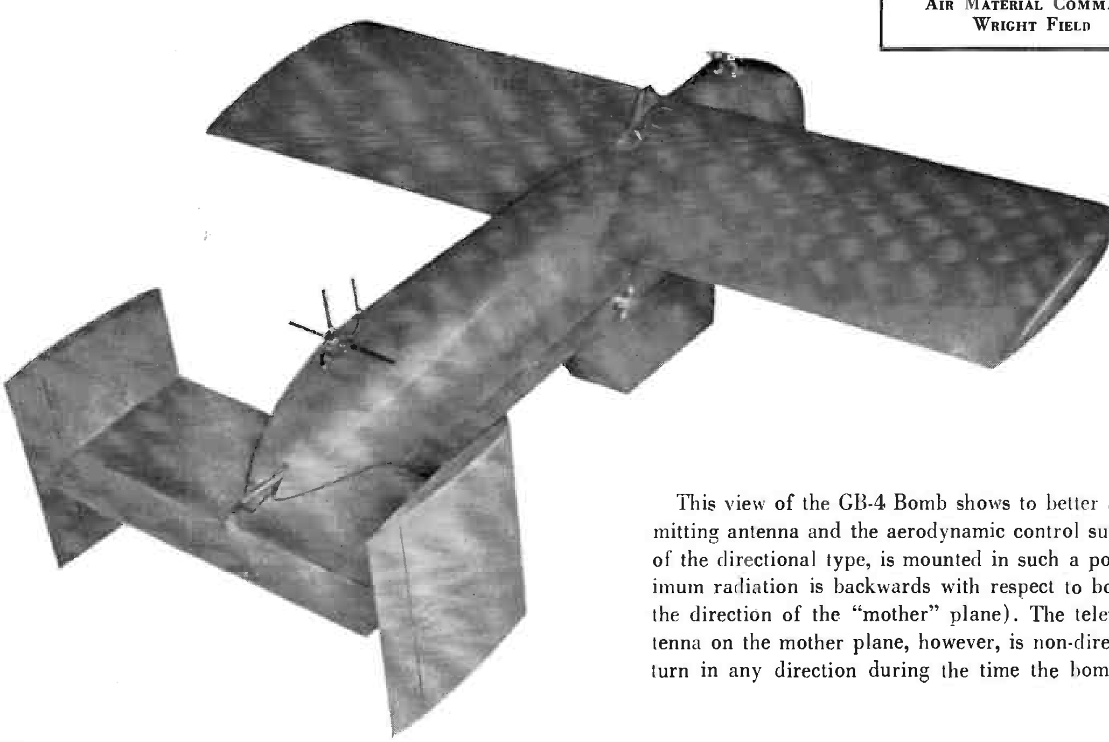


This is a side view of the Army's GB-4 television-equipped glide bomb. The television camera is in the nacelle suspended below the main section of the bomb. The front third of the cylindrical body (light-colored) is a standard 2000-lb. demolition bomb. The rear part of the body contains (a) the television transmitter, which sends the picture back to the mother plane, (b) the radio receiver, which picks up the control signals from the plane, and (c) the servo control mechanism, which employs the received signals to control the bomb's course.



This is a front view of the GB-4 Bomb. The small wing surfaces give the bomb an 8-to-1 glide angle, thus allowing it to be "dropped" at some distance, laterally, from the target. The nacelle below the body of the bomb is considerably larger than the television camera proper because of the necessity of providing acoustic-packing around the camera.

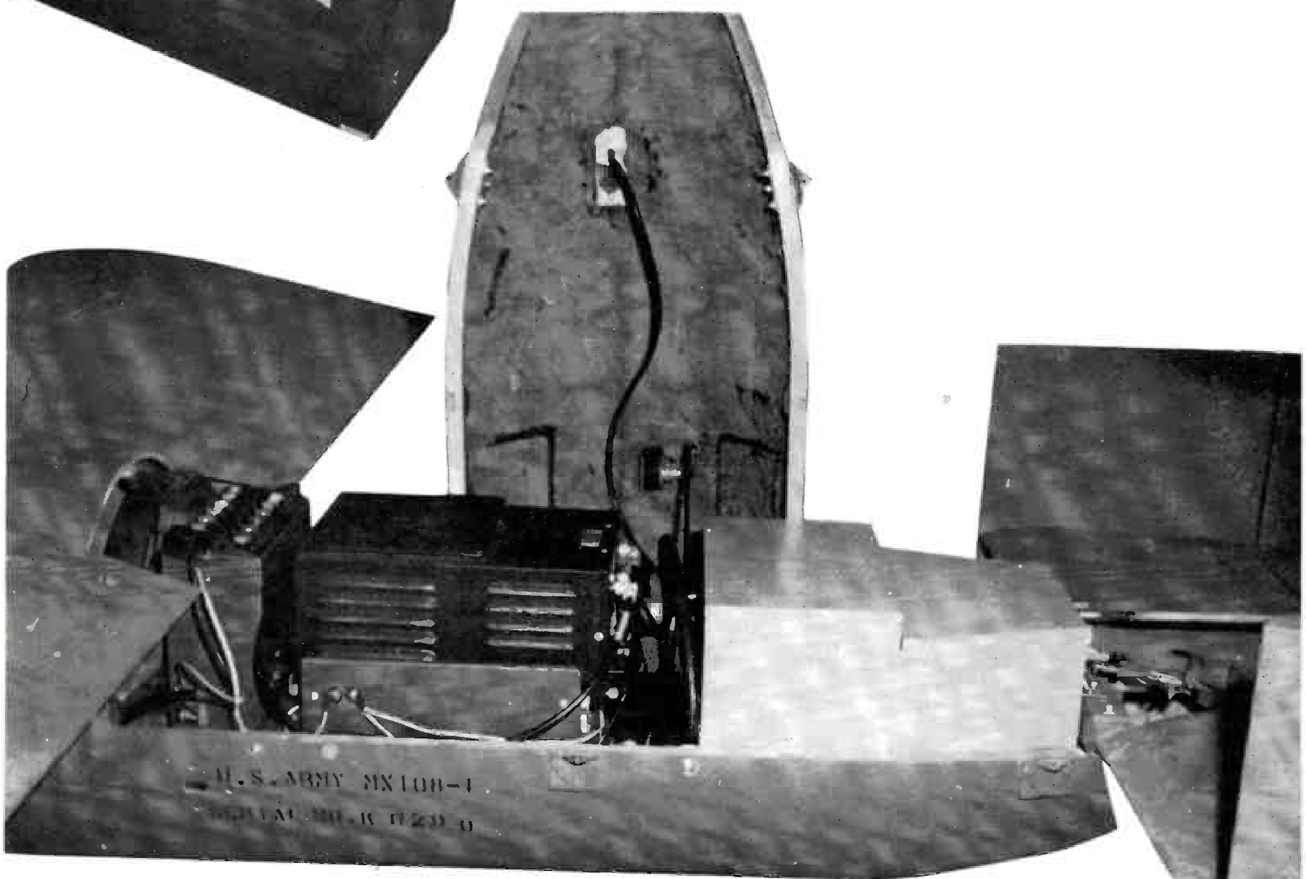
Photographs on Pages 30 to 35
Courtesy
ENGINEERING DIVISION
AIR MATERIAL COMMAND
WRIGHT FIELD



This view of the GB-4 Bomb shows to better advantage the transmitting antenna and the aerodynamic control surfaces. The antenna, of the directional type, is mounted in such a position that the maximum radiation is backwards with respect to bomb's flight (i.e., in the direction of the "mother" plane). The television receiving antenna on the mother plane, however, is non-directive so that it may turn in any direction during the time the bomb is under control.

This is the Television Equipment in the Bomb -

This is the television camera which is mounted in the underslung nacelle of the GB-4 Glide Bomb in such a position that it picks up the scene in the direction in which the bomb is headed. The camera unit shown here is an early type which used a small-size Iconoscope as a pickup tube; it weighed 33 lbs. Later camera-unit designs used successively the Orthicon, the Image Orthicon and the Miniature Image Orthicon. The camera unit using the latter (dubbed the "MIMO" equipment) weighed only 26 lbs. A description is given on page 38.



Rear section of the GB-4 Glide Bomb with upper half of the fuselage removed to show the arrangement of transmitting and control equipment. The storage battery and dynamotor power supply are at the front. The transmitter is in the louvred cabinet in the center. The flexible coaxial line to the antenna can be seen. The box in the tail of the fuselage contains the receiver for picking up control signals from the mother plane and the servo-mechanism which controls the positions of rudder and tail fins according to the received signals.

This is how the Bomb is Launched-

On combat missions two GB-4 Glide Bombs were carried by each B-17. The view at left shows a B-17 so equipped. This photograph was taken on a tactical mission over Europe. B-17's carrying GB-4 Glide Bombs were able to fly a thousand miles or more to a target area, drop their bombs in relative safety.

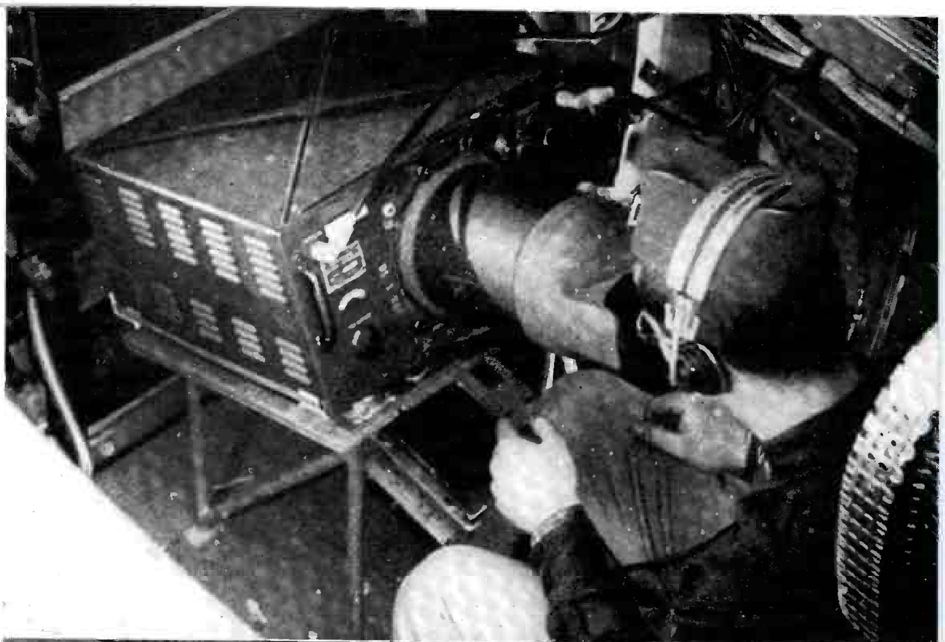
During the flight from the base to a point within 10 to 15 miles of the target the GB-4 Glide Bomb is suspended on an external bomb rack attached to a standard bomber. Some other types of television bombs were designed to be carried in the bomb bay. The view at left shows a single GB-4 attached to the bomb rack of a B-17 Flying Fortress.

This photograph shows a GB-4 Glide Bomb just after drop away from the B-17 mother plane. After dropping the GB-4 the mother plane need not continue on a straight run, but may circle at a distance of 10 or 15 miles from the target while controlling the course of the bomb to the target.

GB-4 Glide Bomb in flight. The television camera in the nacelle is tilted slightly downward to compensate for the fact that the centerline of the fuselage is always tilted slightly upward with respect to the actual direction in which the bomb is traveling. (Spottiness in these pictures is due to the fact that they are enlargements of single frames of a 16 mm movie made under difficult conditions.)

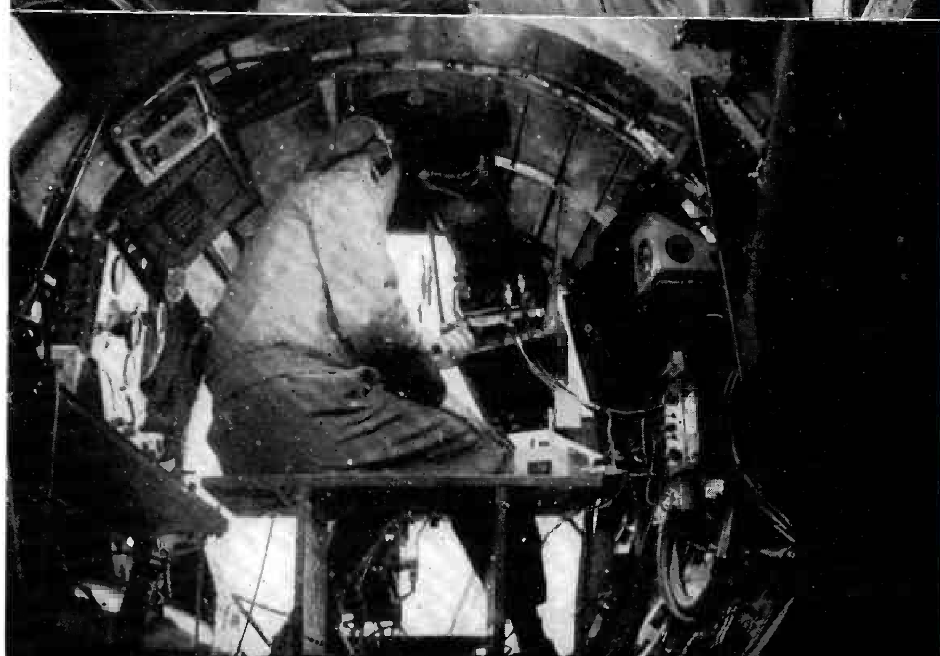
This is how its course is Controlled-

The television picture from the bomb is picked up by the receiver shown in this view. This receiver is installed in the radio compartment of the mother plane (in this case a B-17 Bomber). The television operator sits in the position shown and observes the picture on the screen of a 7-inch kinescope (shown here with viewing hood over it). The operator's job is to monitor synchronizing, contrast, and carrier frequency control so that the co-pilot or bombardier, who controls the bomb, will not have to touch these controls.



The actual control of the bomb—both launching and guiding—is exercised by the co-pilot in smaller planes, or the bombardier in larger planes. The picture at the right shows the co-pilot's installation on a B-23. The co-pilot watches the picture reproduced on the 7-inch kinescope in the monitor unit. This picture is a duplicate of that in the receiver kinescope. When the picture on the screen indicates that the bomb is turning away from a direct line to the target, the operator can bring it back by manipulating the miniature "control stick" on the box in front of him. Movement of this stick causes radio signal to be sent by a transmitter in the bomber to a receiver in the GB-4 bomb. These signals cause the position of the aerodynamic control surfaces of the bomb to be altered so as to bring the course of the bomb back on the target.

When the mother plane is a larger type, such as the B-17 shown in most of these pictures, the bomb-course control equipment is installed in the bombardier's compartment as shown here. The monitor unit and the control box (in this picture on the seat beside the bombardier) are the same as in the picture above. The bombardier in this view is holding in his left hand a control switch which is used to release the bomb. After release he follows the course of the bomb and guides it to the target as described above.



This is what the Bombadier sees-

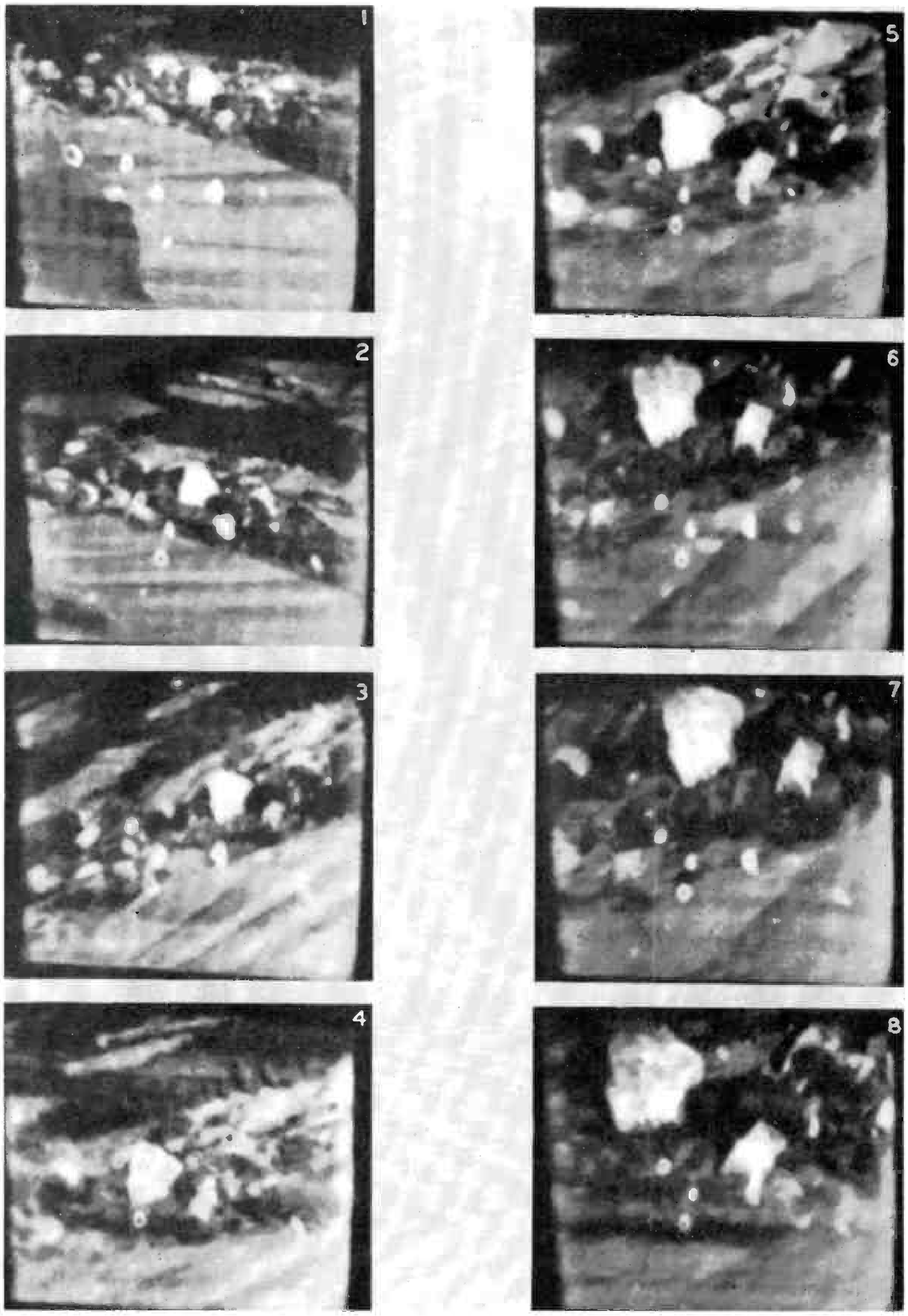
The series of pictures on this and the opposite page provide some idea of the constantly changing scene the bombardier sees on the picture in his monitor unit. It should be noted that these pictures are enlargements of single frames from a 16 mm movie made directly from the screen of the tube. Photographing a kinescope screen is difficult at best. Enlargement of the single frames tends to bring out the grain in the film, and the screening process employed in making printing plates still further reduces the apparent resolution. Thus, while these pictures indicate the type of scene they do not do justice to the clarity of the image.

The scene at the left, as in the other pictures of this series, shows the target area at the Eglin Field, Florida, as picked up by the camera in a GB-4 Glide Bomb. The target is a small pyramid in the center of the white circle. The large triangle, within which the circle lies, is approximately 1800 feet on a side.

In this view the GB-4 Glide Bomb has approached much closer to the target and only a portion of the circle is visible on the screen. As this photograph was taken the direction of the bomb had deviated from the true course to the target and the control operator was bringing it back on the target. This accounts for the tilted effect of the picture with relation to the others of the series.

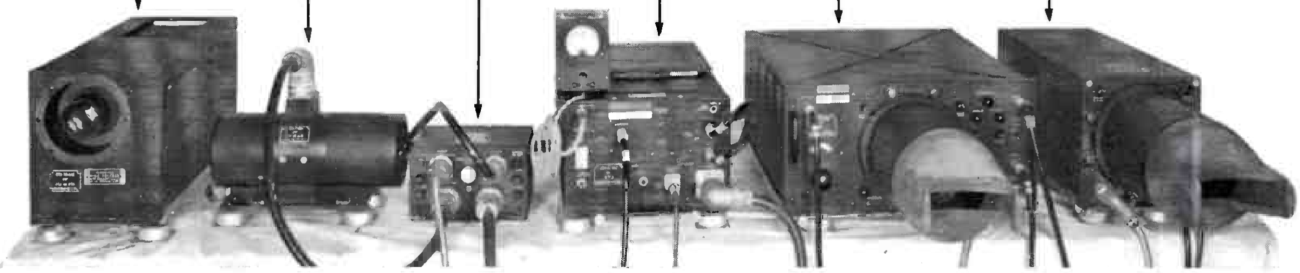
This is a frame of the same movie just before the bomb struck the target. A feature of the television bomb, which is of great advantage, is the fact that as it approaches the target the area portrayed on the screen becomes smaller and the target increases rapidly in size. This makes for great accuracy.

This is a series of pictures taken from the screen as the Bomb approached a target in Germany

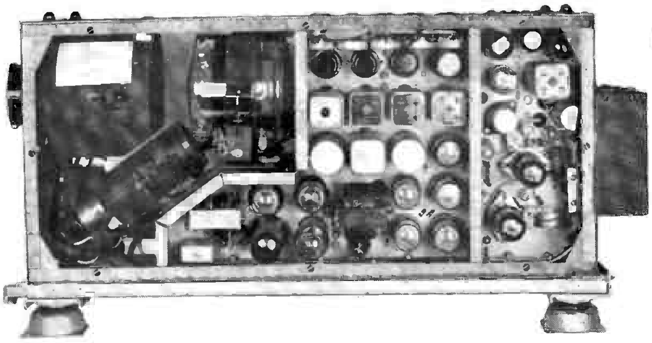


The series of pictures above (note sequence number in upper right corner) are single frames enlarged from a 16 mm movie showing a GB-4 Glide Bomb approaching a target in Germany. The rate of approach can be judged by noting the increase in size of the white splotch (apparently a plowed field) near the center of the scene. Here again the reproduction leaves much to be desired. However, the series is of interest as representative of an actual bombing run.

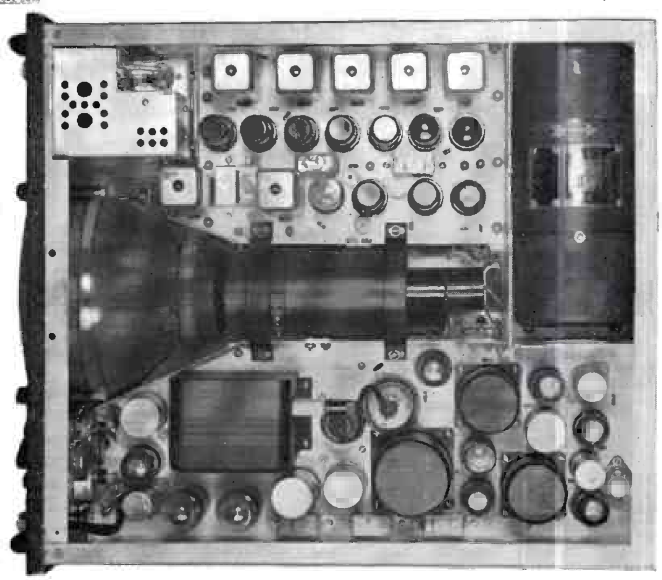
Closeups of the Television Equipment used in the Bomb and the Control Plane



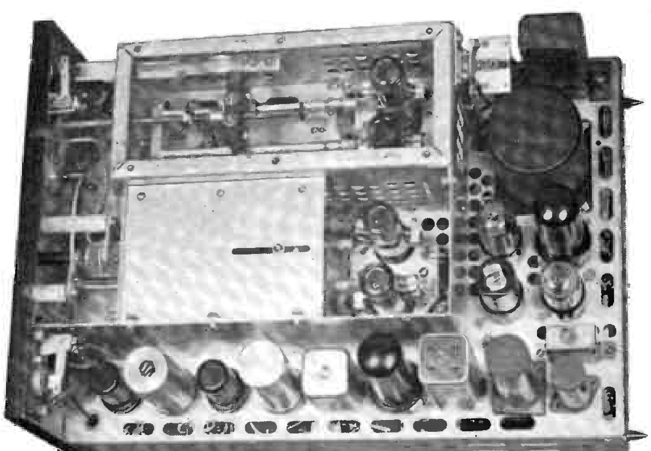
The complete television transmitting-receiving system used with GB-4 Bomb is shown above. The camera, dynamotor, junction box and transmitter are mounted in the bomb. The receiver and one or more monitor units are located in the mother plane.



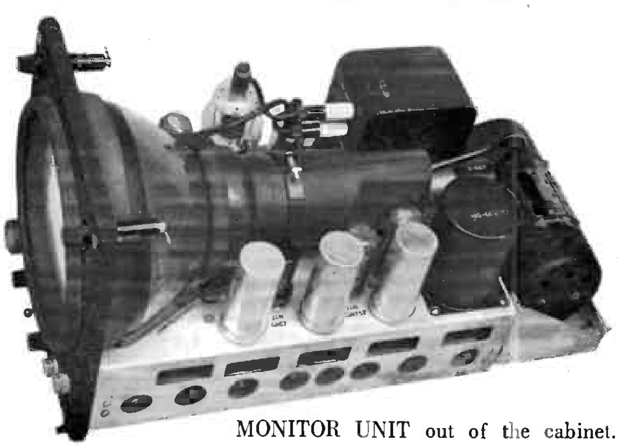
CAMERA of the "BLOCK" equipment with side shield removed to show the interior construction. The GB-4 equipment was the early type using the Iconoscope pickup tube. Later equipments, of generally similar design, used successively the Orthicon, the Image Orthicon, and the Miniature Image Orthicon. The later equipments are shown on the following pages.



RECEIVER is completely self-contained (note built-in dynamotor) and requires only r-f input and battery connections to be ready for installation. Total weight is 54 pounds.



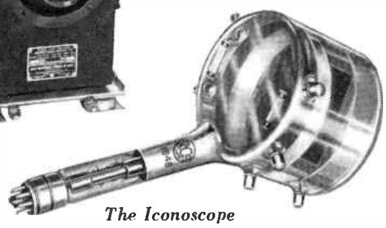
TRANSMITTER unit used in the GB-4. This view shows a top view of the chassis removed from the cabinet. Circuit is of the master oscillator power amplifier type using two RCA-8025's in each stage. Output is about 15 watts unmodulated at frequencies of the order of 300 megacycles. Weight, including shock mounts, is 26 pounds.



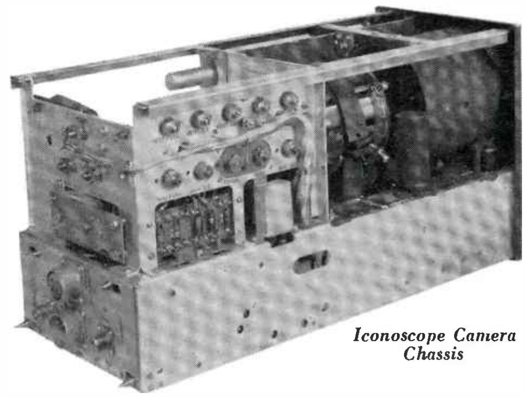
MONITOR UNIT out of the cabinet. It contains a 7-inch picture tube, video amplifiers, and deflecting circuits. Driven by video signals obtained from the receiver, it provides a picture duplicating that on the receiver picture tube.

The development of smaller, more sensitive Television Cameras was greatly accelerated by war requirements—here are three stages

Iconoscope Camera



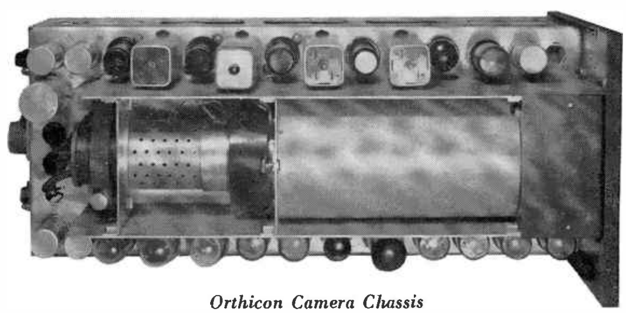
The Iconoscope



Iconoscope Camera Chassis

ICONOSCOPE CAMERA, using an iconoscope-type pickup tube similar to prewar studio type, but smaller in size, was the first camera used with BLOCK equipment. Illustrations above show, left to right, the camera case, the iconoscope and the camera chassis with cover removed. More than 4000 of these cameras were manufactured by RCA during the war.

Orthicon Camera



Orthicon Camera Chassis

The Orthicon

ORTHICON CAMERA was the second step in the evolution of BLOCK cameras. This camera used the relatively more sensitive ORTHICON, a pickup tube developed just before the war by RCA engineers. This camera was an intermediate type which was quickly superceded and hence only a few were made.

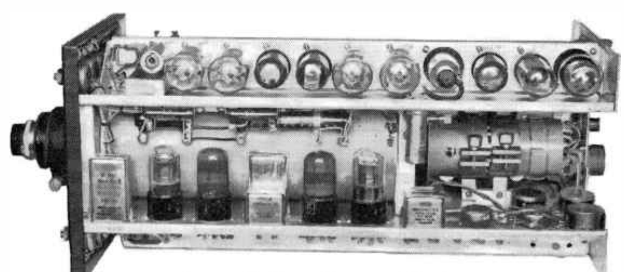


Image Orthicon Camera Chassis

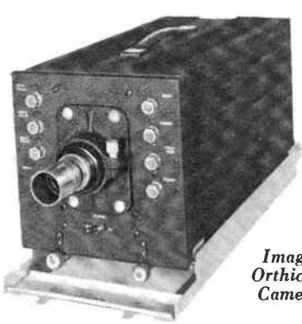


Image Orthicon Camera

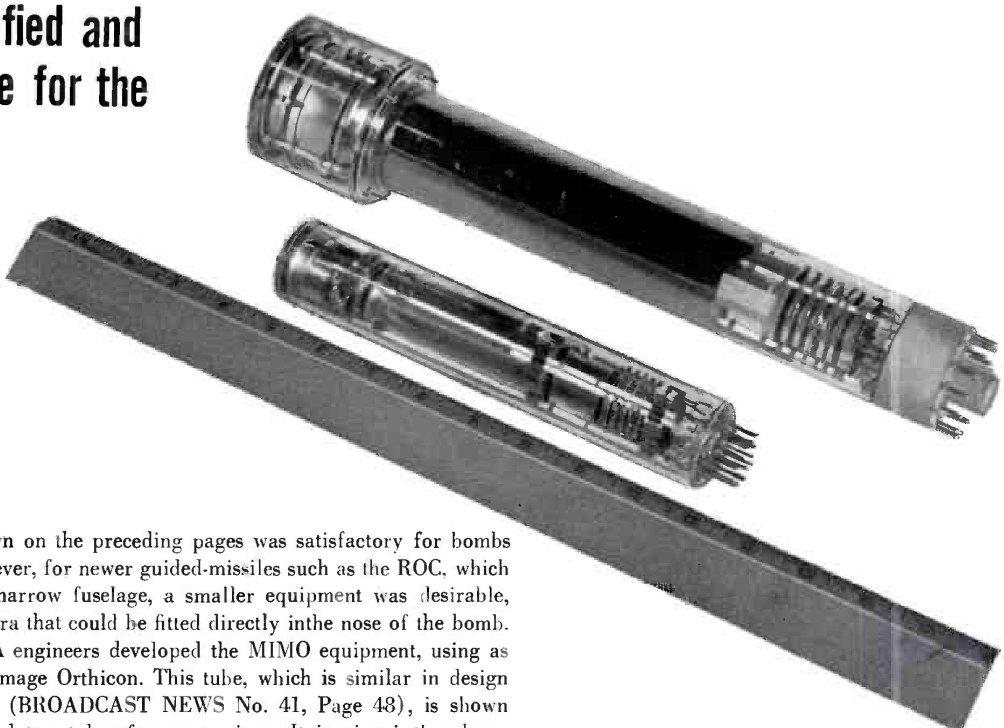
The Image Orthicon

IMAGE ORTHICON CAMERA represented the third step in camera development—and the final step as far as the BLOCK equipment was concerned. This camera, using the Image Orthicon, which is 100 times as sensitive as the Iconoscope, made it possible to use the BLOCK equipment under conditions of poor lighting, as on dark, cloudy days or at twilight.

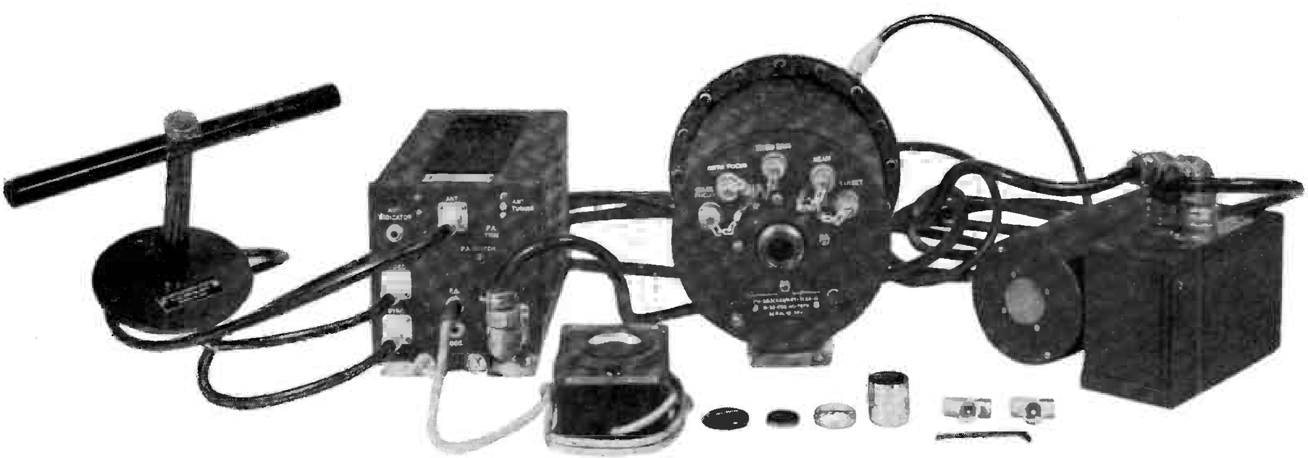
FOR DETAILS OF A NEW STILL SMALLER CAMERA SEE NEXT PAGE

THIS IS "MIMO" THE NEW STILL SMALLER AIRBORNE TELEVISION EQUIPMENT

This equipment has just been declassified and is shown here for the first time

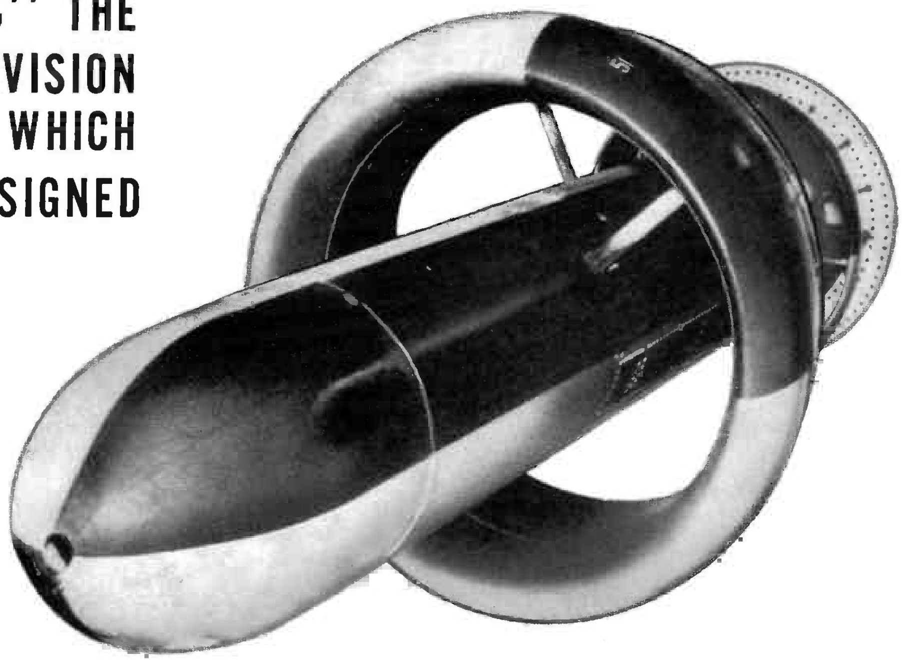


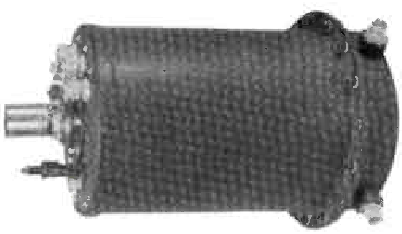
The equipment shown on the preceding pages was satisfactory for bombs such as the GB-4. However, for newer guided-missiles such as the ROC, which has a relatively long narrow fuselage, a smaller equipment was desirable, preferably with a camera that could be fitted directly inthe nose of the bomb. To meet this need RCA engineers developed the MIMO equipment, using as a start the Miniature Image Orthicon. This tube, which is similar in design to the Image Orthicon (BROADCAST NEWS No. 41, Page 48), is shown above with one of the latter tubes for comparison. It is nine inches long, only two inches in diameter; i.e., about the size of an ordinary flashlight.

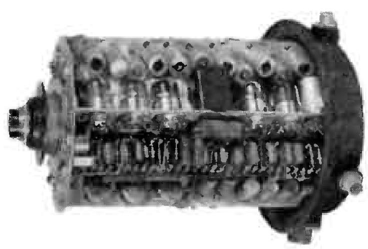


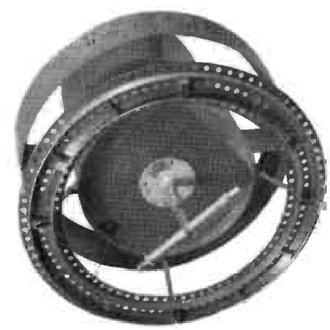
This is the complete MIMO equipment which goes in the ROC. The camera, transmitter and antenna are shown separately in the pictures on this page. The MIMO junction box (right) has the dynamotor mounted inside, and yet is little larger than the BLOCK junction box (which is required in addition to the dynamotor). The large weight savings in main units, together with some savings in weight of cables, result in a total weight of the MIMO equipment (in the bomb) of 50 pounds as compared to an equivalent weight of 100 pounds for the BLOCK equipment. In addition all of the MIMO units are smaller so that they may be more easily fitted into the slender fuselage of the ROC.

THIS IS THE "ROC" THE HIGH-ANGLE TELEVISION GUIDED BOMB FOR WHICH "MIMO" WAS DESIGNED



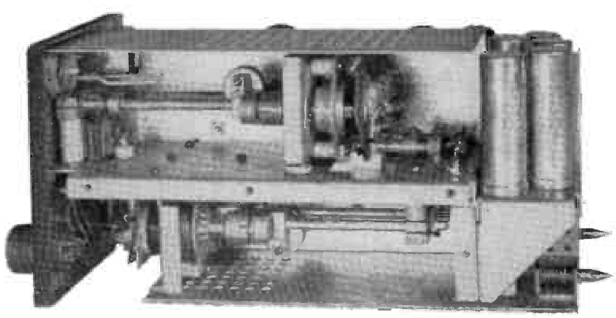


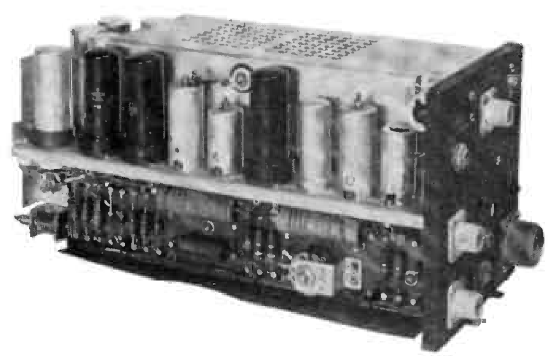




MIMO CAMERA from the side, with and without case, is shown in the above views. Only 8 inches in diameter and 14 inches long, this unit fits easily into the streamlined nose of the ROC (see illustration above). The Miniature Image Orthicon and the optical system are enclosed in a steel center tube. Components, which make up the deflecting circuits and video amplifiers, are mounted around this tube as shown above. The complete unit weighs only 26 pounds.

MIMO ANTENNA is a dipole mounted on the rear or tail end of the ROC, as shown in the illustration above. In this position it always "faces" in the general direction of the control plane.





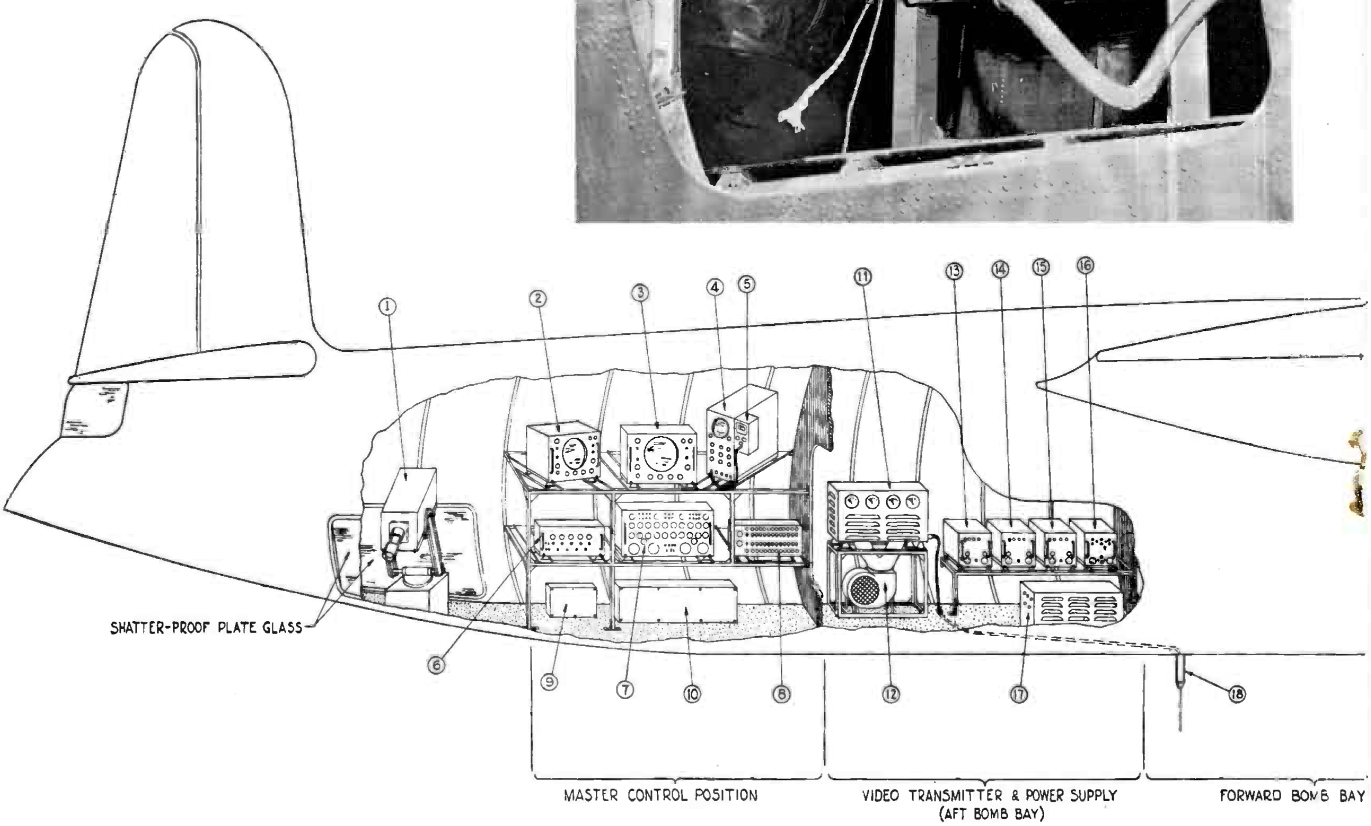
MIMO TRANSMITTER out of the case is shown in illustrations above and at right. MOPA circuits, which make up the r-f part of the transmitter, are shown in right side view (above) and audio and modulator components in the leftside view (right). The whole transmitter is approximately 6 inches square by 12 inches deep. It weighs only 7 pounds as compared to the 26 pounds of the BLOCK Transmitter. Output is approximately 5 watts at 300 megacycles.

This is "RING" - a deluxe naissance Equipment with

The airborne television equipments (BLOCK and MIMO) described on the preceding pages were intended chiefly for use in guided missiles, therefore were made just as small and light as human ingenuity could make them. The 15 watts or so which they put out provided ranges up to 20 miles and this was sufficient for the purpose. However, when television equipment of this type was mounted in scout planes and used to transmit a picture back to headquarters (i.e., television reconnaissance) a greater range was obviously desirable. Since the weight and size requirements for this use were less critical, a transmitter of greater power was indicated. Such an equipment, given the name RING, was developed for a Navy project on which RCA was

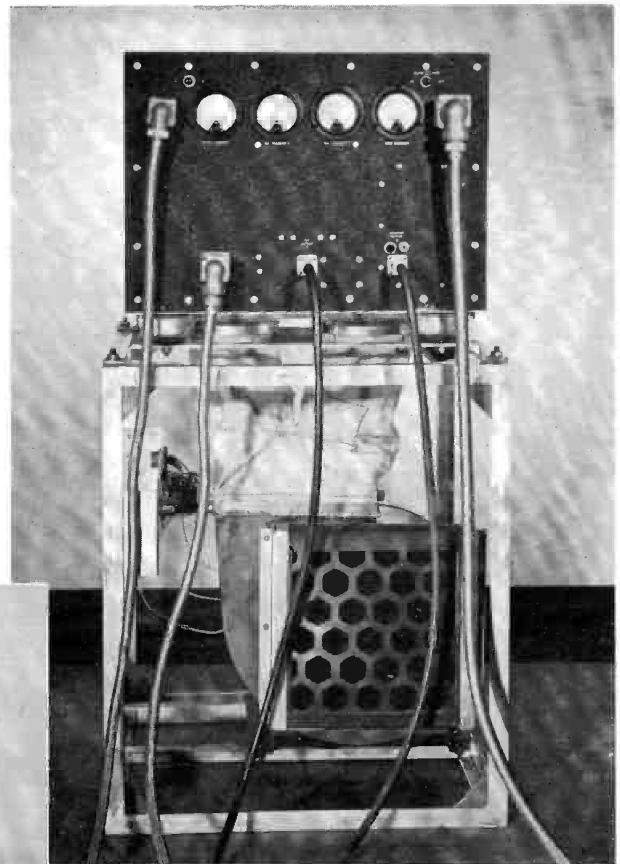
One of the RING television cameras is located in the nose of the plane as shown here. (Item 19 on diagram below.)

The second RING television camera mounted in the side porthole of the Navy JM-1 Marauder used for television reconnaissance demonstration. (Item 1 in diagram below.)

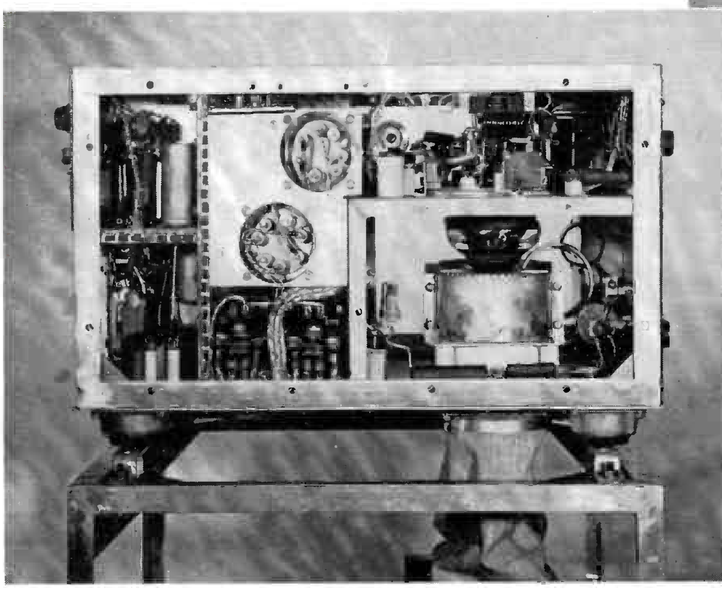


Airborne Television Recon- a range of 200 Miles

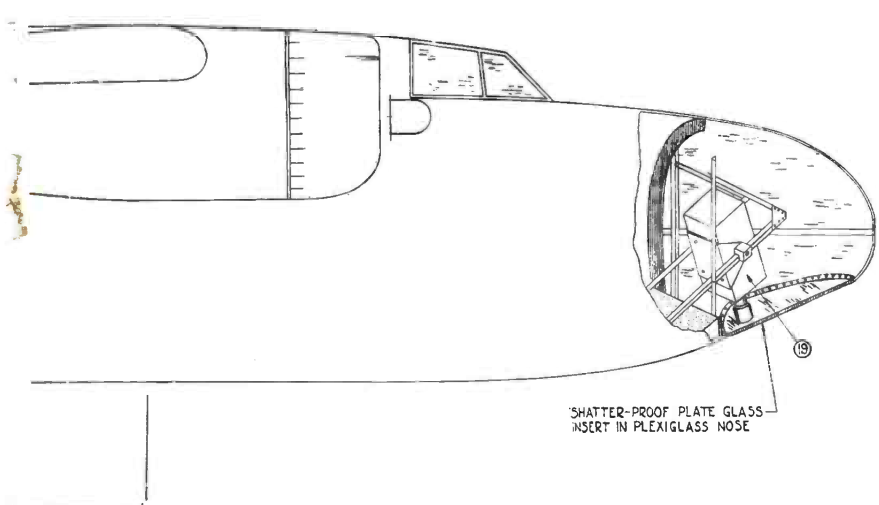
the contractor and the NBC engineering department the sub-contractor. The arrangement of this equipment in a Navy JM-1 Marauder is indicated in the diagram below and the photos on these pages. Two cameras are provided, one in the nose and one in the fuselage near the tail. Associated equipment is generally similar to BLOCK, but somewhat more elaborate. The most important difference is the transmitter (see photos below) which puts out approximately 1000 watts at frequencies of the order of 100 megacycles. This power, radiated from a non-directive antenna mounted on the under side of the fuselage, provides good reception up to 200 miles away (from an altitude of 22,500 feet).



The 1 KW, 100 mc transmitter, and associated air blower used with the RING equipment.



Interior (side view) of the transmitter is shown here. Two RCA-827-R's in the output stage provide a power of one kilowatt at 100 mc. Power supplies and modulators are separate units.



(Left.) Installation of RING equipment in a Navy JM-1 Marauder. Components are indicated by numbers on diagram, as follows:

1. Conversion Unit
2. Flight Monitor No. 1
3. Flight Monitor No. 2
4. Oscilloscope
5. Oscilloscope Calibrating Unit
6. Synchronizing Generator
7. Control Unit and Line Amplifier
8. Power Panel for Video Equipment
9. A-C Junction Box
10. D-C Junction Box
11. Radio Relay Transmitter
12. Blower
13. Plate and Bias Supply for (19)
14. Plate and Bias Supply for (2)
15. Plate and Bias Supply for (7)
16. Plate and Bias Supply for (1)
17. Transmitter Plate and Bias Supply
18. Transmitter Antenna
19. Conversion Unit

AN FM CALIBRATOR FOR DISC RECORDING HEADS

by H. E. ROYS, Engineering Products Department

Since the beginning of disc recording, a device has been needed which would permit the calibration of a recording head under actual cutting conditions. For years the head has been calibrated by mounting it under a microscope and measuring the amplitude of the stylus vibration in air at different frequencies. The correctness of this procedure was based upon the assumption that the load imposed upon the stylus by the recording material during cutting was small in comparison with the mechanical impedance of the recorder and therefore introduced no appreciable error. This assumption was justified by showing that the width of the reflected sunlight pattern of a frequency record, recorded at constant stylus velocity, appeared constant in width across the disc, as theoretically it should when viewed under suitable light conditions.

SUNLIGHT PATTERN METHOD

The sunlight or Christmas tree pattern, as it is sometimes called, is a satisfactory means of making an overall calibration and is in common use. It is accurate providing certain precautions are taken; such as having a small source of light located some distance away so that the light rays are parallel (if the sun is not used), having the rays strike the disc nearly parallel to its surface, and observing the reflected pattern at right angles to the plane of the disc some three or four feet away while viewing with only one eye.

At the center of the pattern an unmodulated groove makes an angle of 90° with the incident ray, and reflects a beam of light to the eye. Elsewhere the unmodulated groove appears dark. With modulation present visible reflections occur because, despite the departure of the groove axis from the 90° direction, some point exists on each wave where the angle due to modulation cancels the angle due to the change in mean direction. Hence, for a very short distance within each wave the groove is again at the 90° position (or parallel to the tangent at the center of the pattern). Beyond a certain distance from the center, the groove axis angle has become so large that this cancellation of angles can no longer occur. This condition marks the edge of the pattern. As the groove diameter decreases, its mean curvature increases, but at the same time the waves get shorter and the modulation slopes (for a given amplitude and frequency) increase in the same proportion; hence the width of the pattern is not altered by a change in groove diameter.

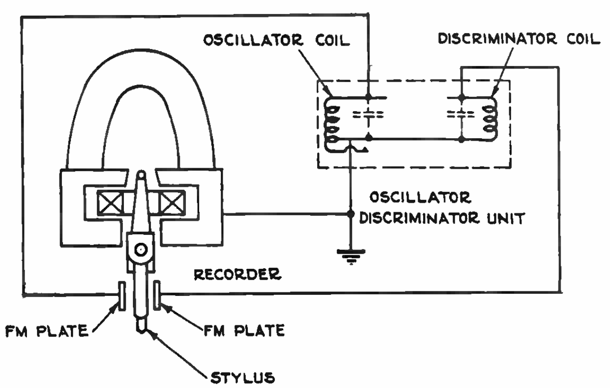


FIG 1. *Basic arrangement of the FM Calibrator. Small plates on either side of the stylus bar are connected to an oscillator discriminator unit mounted on the carriage.*

The method is mainly one of comparison; the width of one frequency band being compared to that of another and it does not lend itself readily to quick, accurate checks needed during initial calibration. It is valuable, however, in making a final test on the recording head and in checking the flatness of the constant velocity portion of a frequency recording.

MICROSCOPE METHOD

The microscope method is suitable for initial calibration, especially if adjustments can be made without removing the head. But the method is slow and tedious and is inaccurate at the higher frequencies where, due to constant stylus velocity, the amplitude of motion is small and the spot of light is no longer small in comparison with the amplitude of movement. Most recorders maintain constant amplitude stylus motion below a frequency, known as the cross-over frequency, and constant velocity above, so that, at the higher frequencies the amplitude decreases, since the product of frequency and amplitude must remain constant for constant velocity motion. Constant amplitude at the lower frequencies is of course necessary to prevent overcutting, unless excessive spacing of grooves is resorted to with the accompanying loss of playing time.

PHOTOELECTRIC CELL METHOD

The microscope method was improved upon by substituting a photoelectric cell for the eye and having the stylus modulate a light beam being transmitted to the cell. Calibrators of this type have been in use for some years and in general have proven to be accurate and reliable. They do not, however, permit calibration while cutting a disc.

FM METHOD

The problem of being able to calibrate the recorder under actual cutting conditions was finally solved by an FM system. Here was a device which could be attached to the recorder without requiring much space or adding mass to the moving system, one which would not couple electrically to the driving coils of the recording head, and which could be so arranged as not to interfere with the cutting action of the stylus.

Figure 1 shows the arrangement.* Two tiny plates, one on each side of the stylus shank or stylus bar, insulated from each other

* The FM Calibrator described here was developed by Mr. Alexis Badmaieff, RCA engineer.

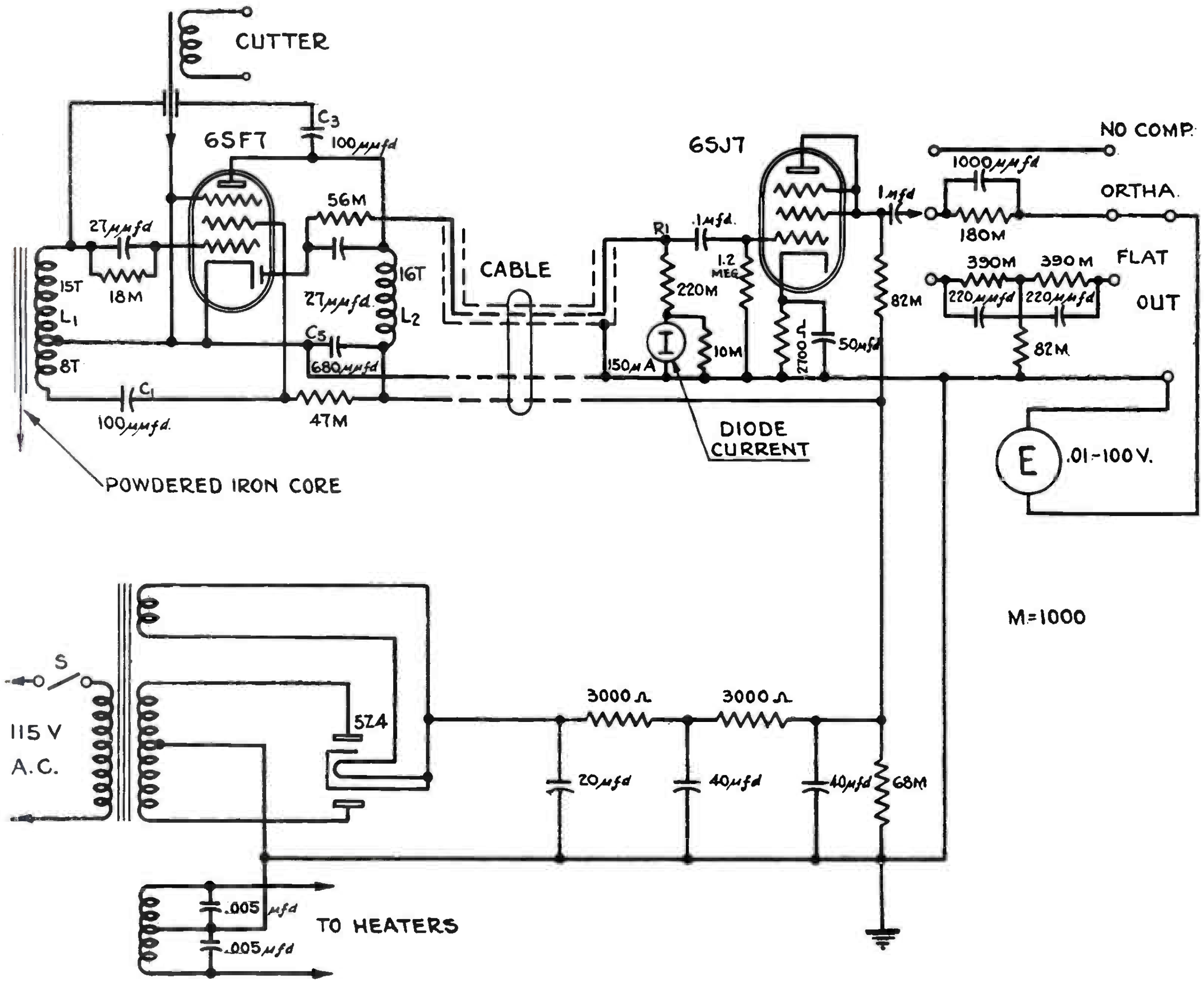


FIG. 2. *Schematic diagram of the complete quipment used for calibrating disc recording heads by the method described in this article.*

and from the recorder are spaced a few thousandths of an inch from the stylus. Neither mass nor stiffness is added to the moving system so there can be no change in its mechanical action. Flexible leads from these plates connect to the oscillator-discriminator unit mounted on the carriage located close to the recorder. Variation of capacitance between the plates and the stylus due to its motion changes the oscillator frequency and tuning of the discriminator.

The complete circuit is shown in Figure 2. An RCA 6SF7, pentode-diode tube is used and the control and screen grids, with a coil and one of the capacitor plates mounted on the recording head, form the oscillator circuit. The discriminator circuit consists of a coil across which the other capacitor plate, mounted on the recording head, is connected and is electronically coupled to the oscillator by means of the plate of the 6SF7. The diode is connected as shown, and a short, low capacitance, shielded lead couples the diode circuit with the audio amplifier mounted on a separate chassis.

The frequency of oscillation is approximately 45 megacycles, and the coils consisting of the number of turns indicated are wound on forms about ½ inch in diameter. These coils have adjustable powdered iron cores for tuning purposes. To obtain maximum sensitivity and consistent readings, it is necessary to have the oscillator tuned to a frequency relative to the optimum operating point of the discriminator circuit. To accomplish this, a meter is provided in the diode circuit and the oscillator is tuned for maximum diode current and then backed down, in the same direction each time, to 75% of the peak current.

The audio amplifier coupled to the diode consists of a 6J7 connected as a triode. A three-position switch in the output of the amplifier permits a selection of compensation for monitoring and measuring purposes. For measurements, the position marked "No comp" is used. Since the FM system is an amplitude device, the output voltage is proportional to the amplitude of the stylus motion. This must be taken into account when plotting velocity curves, the usual way of showing response characteristics of disc recording and reproducing heads. The other two positions are used primarily for monitoring purposes where either a tip up, orthacoustic, or a flat input characteristic is used at the recording head.

The FM capacitor plate assembly which is attached to the recording head and couples electro-statically to the grounded stylus is shown in Figure 3A. The complete equipment with the stylus assembly mounted on the bottom of a recording head as shown in Figure 3B, and Figure 3C, shows the equipment on a recording lathe with the oscillator-discriminator unit mounted on the carriage directly above the recording head.

COMPARISON OF FM AND OPTICAL CALIBRATORS

One of the first tests was a comparison of results obtained with the FM and optical calibrators using the RCA MI-11850 recorder which has the same performance as the MI-4887 recording head. Due to the small size of the FM plates it was possible to have them in place while the recorder was mounted in the optical calibrator so that a direct comparison was easily made. The re-

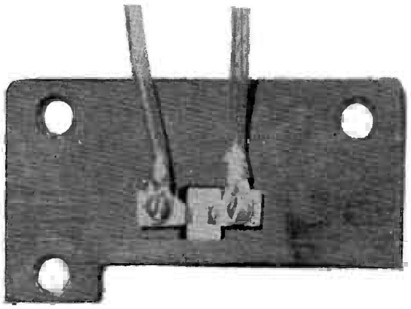


FIG. 3a. *The small capacitor plates are mounted on an insulating plate which is fastened to the bottom of the recording head.*

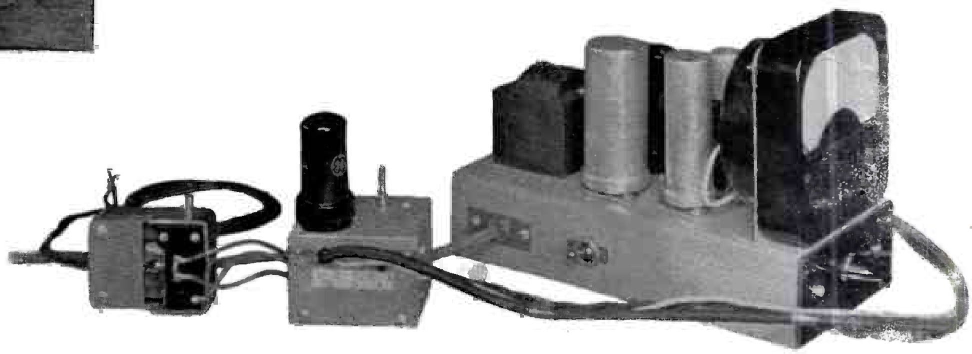


FIG. 3b. *Complete equipment. Note stylus assembly mounted on the bottom of the recording head.*

FIG. 3c. *The equipment mounted on standard recorder. Note oscillator unit mounted directly on the carriage.*

sults of frequency response measurements made in this manner are shown in Figure 4. A very close agreement is noted between the two methods, except at the low frequency end where the characteristics of the amplifier used in the optical calibrator caused some increase in the response.

CHANGE IN FREQUENCY RESPONSE DUE TO CUTTING LOAD

The most important advantage of the FM calibrator is realized when investigating the change in frequency response due to cutting load, for with it measurements can be made under actual cutting conditions. Several factors must be considered when making these measurements, such as the record material, the stylus with its burnishing edge, the turntable speed and recording diameter, and the test frequency. Early tests showed what had been predicted, that the greatest effect of the cutting load would be at the resonant frequencies of the mechanical system. Figure 5 shows the response characteristic, in air, of an undamped recording head and also the response after the viscoloid damper block has been added. It will be noted that there are two resonant frequencies, one about 1000 cycles and the other about 10,000 cycles, and that the damper block has little effect on the frequency response between 5000 and 8000.

Figure 6 shows the cutting load loss as a function of groove velocity, at several different frequencies, the groove being cut in lacquer with a sapphire stylus having a tip radius of approximately 2 mils, a 90° included angle, and the usual burnishing edge. For this particular recorder, which had the high frequency peak at [illegible]000 cycles instead of 10,000, the greatest loss due to the cutting load occurred at 1000 cycles, the fundamental resonant frequency of the mechanical system. The least loss occurred at the lower frequencies and in the region from 5000 to 8000 cycles, which was predicted from the damped and undamped curves. The curves of Figure 6 show that over the diameters and turntable speeds normally covered in $33^1/_3$ and 78 rpm recordings, the loss is small. For a $33^1/_3$ rpm recording at the innermost diameter, the 1000 cycle loss, when compared to that of the maximum diameter is approximately 1.2 dbs. which is not very great. Styli with larger burnishing surfaces may increase this loss, and tests with ten new styli showed an average loss of about 1.7 db or one half a db more than the previous test. At 78 rpm, the loss at 1000 cycles between the inside and the outside of the disc is approximately 1 db.

The effect of loading is also shown in Figure 7 in which the results are plotted in the usual frequency response manner. Curve B shows the response that can be expected near the outside of a 12 inch disc at 78 rpm. The lower curve C shows the response—near the inside of a $33^1/_3$ rpm disc. At 1000 cycles a difference of 2 db was measured and at the upper resonance a greater loss, 3 db in this case, was observed. Elsewhere the loss was less, and between 4000 and 6000 cycles no loss was experienced; likewise no loss was observed at 50 and 100 cycles. The upper curve A is an air calibration, that is with the stylus vibrating in air and not cutting the lacquer. The two lower curves B and C show the extreme losses to be expected between the inside of a $33^1/_3$ rpm disc and the outside of a 12 inch diameter 78 rpm disc.

CHANGE IN RECORDING LEVEL WITH GROOVE WIDTH

Previous tests have shown that the greatest loss due to loading occurs at the resonant frequencies of the mechanical system. Since the peak is broader at the 1000 cycle resonance, there is

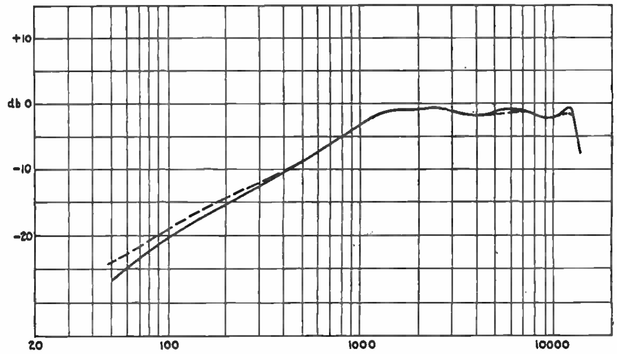


FIG. 4. *Comparison of FM Calibration (solid line) and optical calibration (broken line) of MI-11850 Head.*

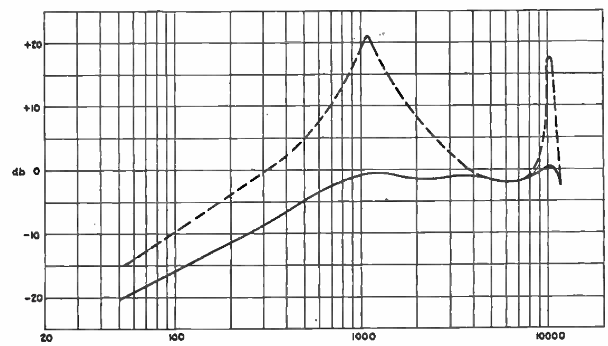


FIG. 5. *Frequency response of recorder with damper (solid line) and without damper (broken line).*

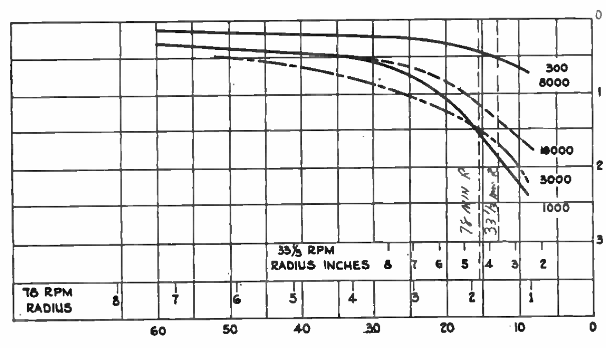


FIG. 6. *Cutting load versus grove velocity for several different frequencies.*

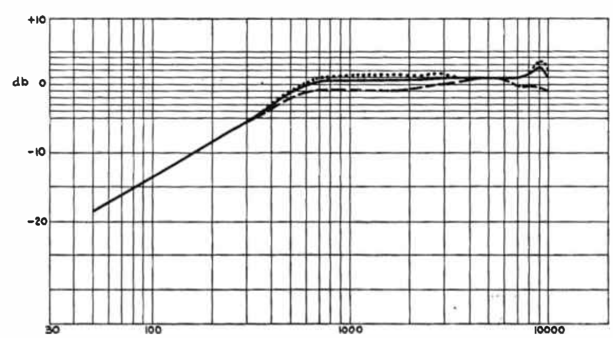


FIG. 7. *Effect of diameter and speed on response. Curve A (dotted) air calibration; Curve B (solid), 78 rpm; Curve C (broken), 33⅓ rpm.*

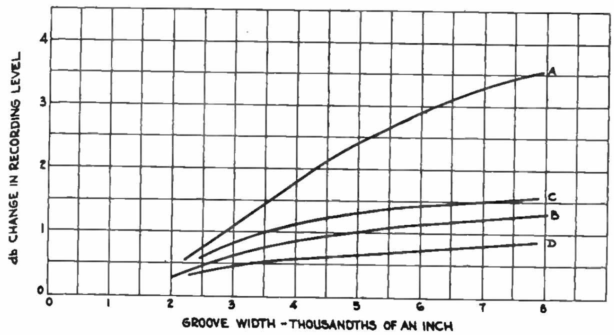


FIG. 8. *Change in recording level at 1000 cycles with change in groove width (depth).*
A. Inside of 33⅓ rpm disc sapphire stylus.
B. Outside of 78 rpm 12" disc sapphire stylus.
C. Inside of 33⅓ rpm disc, steel stylus.
D. Outside of 78 rpm 12" disc, steel stylus.

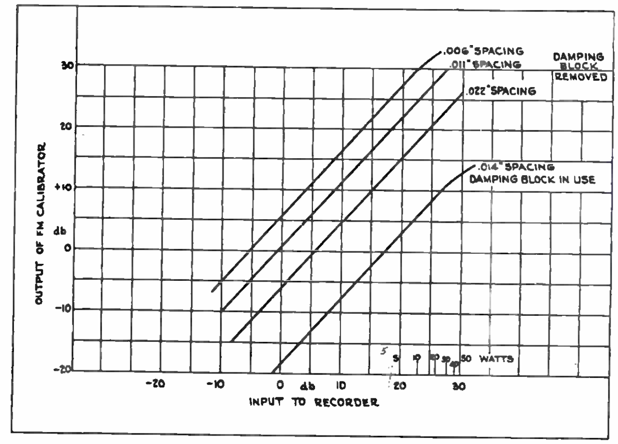


FIG. 9. *Input versus output curves of the FM calibrator and recorder.*

less likelihood of errors due to frequency shift of either the applied signal or the mechanical system; therefore, the change in recording level with depth of cut was investigated at 1000 cycles. Ten styli were measured for level loss at 1000 cycles and an average one chosen. Of these ten the average load loss for a groove five mils in width was 2.9 db; the maximum loss was 3.2 db; and the minimum 2.7 db. The sapphires had a tip radius of approximately 2 mils and an included angle of 90°. Figure 8 shows the results of changing the depth of cut which is expressed in groove width since this is easy to measure with a microscope. Curve A shows the loss obtained at the outside of a 33⅓ rpm recording. Curve B shows the loss obtained at the outside of a 12 inch disc at 78 rpm. Curves C and D are the results of similar tests with a steel stylus instead of a sapphire. The steel stylus has no burnishing edge or tip radius and had an included angle of 90°. The change in level is not very great except at the lower groove velocities such as occur at the inside diameter (7½ inches) of a 33⅓ rpm recording. At this diameter a groove variation from 4 to 5 mils resulted in an amplitude reduction of approximately .6 db. The variation in groove depth could be caused by cutter bounce or flutter which fortunately is usually less at 33⅓ than at 78 rpm or by the irregular surface of the recording blank.

DISTORTION

Another requirement of a good calibrator is that it be free from distortion so that accurate measurements of the recording head distortion may be made. An overall distortion measurement which includes the disc and pickup is not satisfactory since it does not permit segregation of the amounts introduced by the recording and reproducing heads. Since the FM calibrator is an amplitude device, it is only necessary to limit the range over which the FM system operates in order to keep the distortion at a low value so that accurate measurements may be made.

To determine what spacing between the FM plates and the stylus was necessary to fulfill this requirement, tests were made using the recording head with the viscoloid damping block removed, so that at the fundamental resonant frequency, about 1000 cycles, very little electro-magnetic energy was required to give normal amplitudes of vibration. Therefore the distortion introduced by the recorder under these conditions would be quite low. Numerous distortion measurements at 1000 cycles were made at various amplitudes of vibration and plate separation. In addition, input-output or linearity measurements were made and as a result a plate separation of .015 inch is recommended for distortion measurements at the lower frequencies, where the maximum amplitude of the stylus should not exceed plus or minus 3 mils. For higher frequencies where the amplitude of motion is less the spacing may be decreased. With a plate separation of 0.015 inch the distortion at 1000 cycles was less than one per cent for the entire system, which included the recording amplifier and the one used to amplify the output of the FM calibrator. These amplifiers measured somewhat less than one-half of one per cent each, so that the distortion of the FM system was of the same order for the highest amplitudes of vibration likely to be encountered. The results of the input-output curves are shown in Figure 9. Some curvature will be noted with the 0.006 inch spacing and likewise with the 0.014 inch spacing when the damping block was in place, the non-linearity being chargeable to the recording head in this case. With the damper block in place the overall measured distortion at 1000 cycles was about 1.5 per cent at normal recording level. The distortion measurements were made using the RCA distortion meter in which a signal is used, directly from the oscillator, to balance out the fundamental of the signal being measured, the residue being the total harmonic distortion.

MONITORING

The FM calibrator was designed primarily for calibrating purposes, but may also be used for monitoring. As such it is ideal when cutting frequency records for reproducer tests. The recorder can be carefully calibrated beforehand and the correct input level for each band determined. Then when cutting the final disc the calibrator may be used as a check on the recording level, making slight corrections if necessary, or if it is undesirable to change the level during recording, the correction can be noted and applied afterwards when using the disc. A test frequency record was made using the latter procedure and a photograph of it taken in the sunlight is shown in Figure 10. The variation of the constant velocity section from true flatness is only a few tenths of a db.

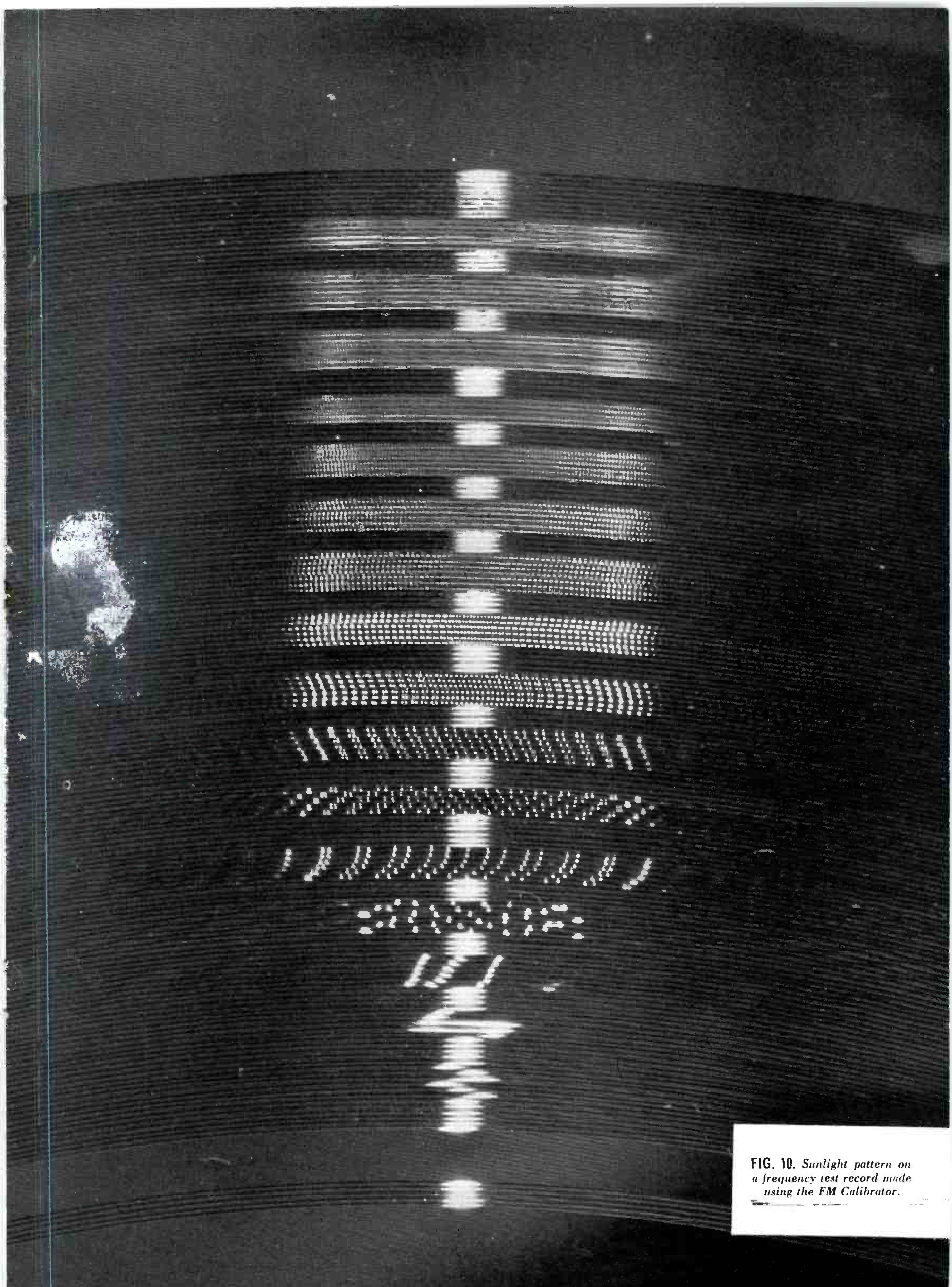


FIG. 10. *Sunlight pattern on a frequency test record made using the FM Calibrator.*

WMC MEMPHIS INSTALLS RCA 10-F

WMC, one of the oldest and best known stations in the South, now has a brand new RCA transmitter of the latest postwar design. Operating with 5000 watts on the 790 kc channel, and using a 615 foot tower, WMC is the dominant station in its area.

Known to its listeners as the "Commerical Appeal Station," WMC is owned and operated by the Memphis Publishing Company. Its General Manager is H. W. "Hank" Slavick, who has taken an active part in NAB affairs and is well-known to most broadcasters. Much of the credit for WMC's growth and its present outstanding position is due to Hank's enterprise and management. When he became manager in 1930 WMC was operating with 500 watts. He immediately built a new plant and increased power to 500/1000 watts. In 1935 WMC went to 1000/2500, in 1936 to 1000/5000, and in 1942 to 5000 watts day and night. The new RCA transmitter replaces a composite job in use for the past ten years. Power is fed to the antenna by a 2⅝ inch coax line. The antenna array consists of one 615 foot tower and three 315-foot towers, all arranged in a parallelogram. The directional array is used only at night; during the day, the big tower is used non-directively. WMC's installation, an outstanding job, was planned and supervised by E. C. Frase, Jr., Chief Engineer; L. L. Covington, Transmitter Supervisor; and H. W. Zimmerman, Studio Supervisor.

(Right): *H. W. "Hank" Slavick, genial General Manager of WMC. Hank joined WMC as an engineer in 1925, became Chief Engineer in 1927, and General Manager in 1930. WMC's steady growth and its present outstanding position are largely due to his enterprise and efficient management.*

(Left): *E. C. "Ed" Frase, WMC's Chief Engineer, planned and supervised the new transmitter installation. Ed joined WMC as an engineer in 1933, was appointed Assistant Chief Engineer in 1939 and Chief Engineer in 1942. As this issue of BROADCAST NEWS goes to press Ed and his wife are celebrating their 25th Anniversary.*

(Left): *Control Room of WMC's studios located in the Goodwyn Institute Building. Amplifiers, which are all RCA, are located on four racks just out of sight to the left in this picture. Turntables and main recorder unit are also RCA. Control desk was built by WMC staff.*

(Right): *Transmitter Room in WMC's plant located on Thomas Road, 12 miles east of Memphis. New RCA 10-F Transmitter (right), the 10-F Control Console (center) and a corner of the 500-watt auxiliary transmitter (left) are shown. Audio, monitoring, and test equipment are on a rack to the right of the 10-F and are not visible in this view.*

FILAMENT SUPPLY IN THE BTA-50F TRANSMITTER

by

T. J. BOERNER

Transmitter Engineering Section, Engineering Products Department

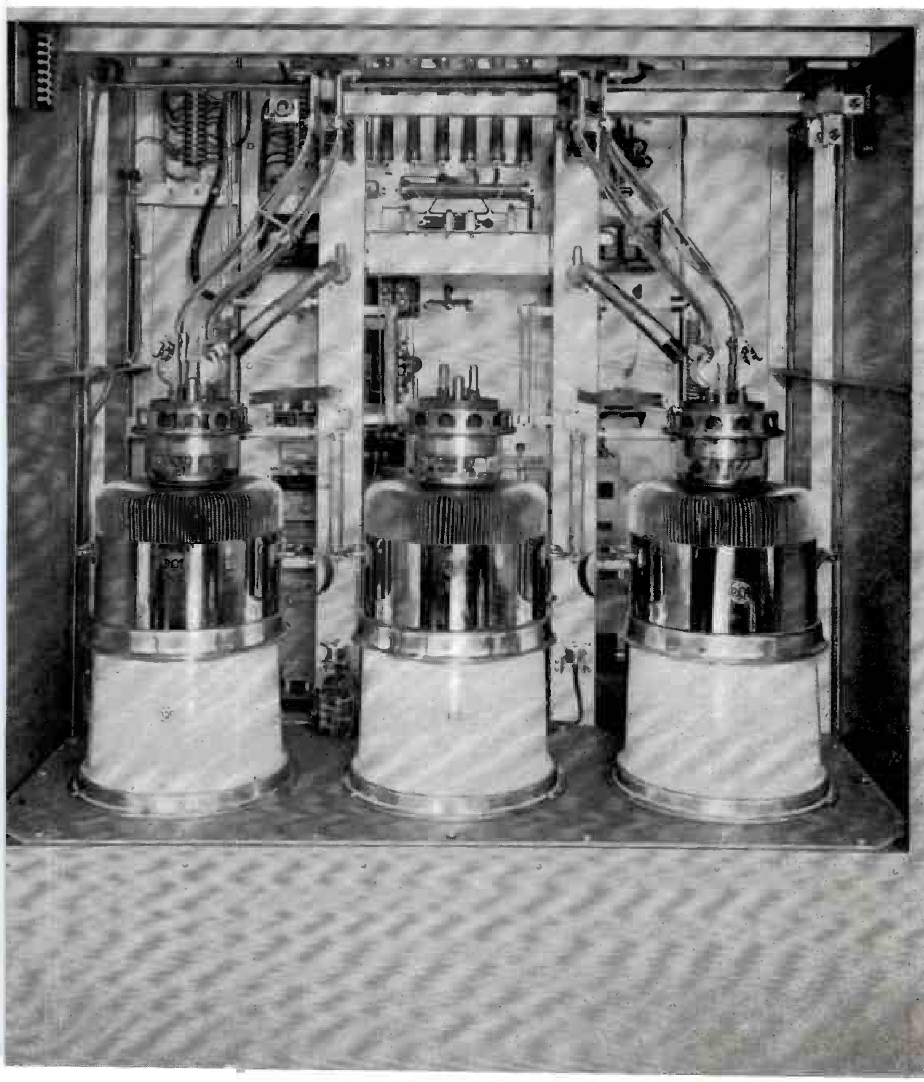
The Type BTA-50F is the newest RCA 50 KW amplitude-modulated broadcast transmitter. In this transmitter RCA 9C22 air-cooled triodes are used in the final radio-frequency and audio-frequency amplifiers. The modulating system is "high level", similar to that used in the RCA Type 50-E Transmitter in which the output of a Class B amplifier modulates the plate voltage of a high efficiency Class C output stage. The transmitter design was preceded by a comparative study of single-phase and three-phase filament heating for the output tubes. Some results of this study are presented below.

Tests were made with two types of experimental tubes in a Type 50-E Transmitter. One of these tubes, designed for single phase filament excitation, was released later as the RCA 9C22. The other experimental type was similar in mechanical structure, number of filament strands, and rating in all respects except that the filament was designed for three-phase heating. Both types of tubes were tested in modulator and power amplifier service in the 50-E Transmitter. Hum levels were measured with an RCA 69-C distortion meter against a reference level of 100% modulation at 1000 cycles.

The approximate relative magnitudes of the various hum frequencies from 60 to 720 cycles were checked by noting the decrease in rms noise level when each hum frequency was cancelled by an equivalent frequency fed into the audio system in proper phase and amplitude. Hum measurements on the tube with three-phase filament heating were made with only one tube having its filament lighted, but with the other tube in the circuit to maintain the same neutralizing adjustment as would be used on normal two-tube operation. Under these conditions, output was adjusted to 26.5 KW on carrier at 1 megacycle.

The rms hum level of the modulator alone was 66 db below 100% modulation. The rms hum level on the r-f output under the above three-phase conditions was 50 db below 100% modulation. The major hum component was 120 cycles as indicated by a reduction to 53 db when the 120-cycle hum was cancelled in the manner described above. Other hum frequencies having appreciable magnitude were 180, 240, and 360 cycles with perceptible amounts at 480 and 720 cycles. Two three-phase tubes were available and a similar check on the second tube yielded approximately the same results.

A similar test run was made using the tubes with single-phase filament heating. Operating conditions such as grid current, plate current and efficiency were identical. Hum level with either single-phase tube operating alone at 26.5 KW output was found to be 41 db below 100% modulation. The predominant hum frequency was 120 cycles and when this was cancelled, the hum level decreased to —54 db, mostly 240 cycles. The same hum level of —54 db was obtained by operating with the two single-phase power amplifier tubes at 53 KW carrier output and with the filament of one tube operated 90 degrees out of phase with the other. In this case the predominant hum frequency



(Left) —*Modulator compartment of the BTA-50F Transmitter contains three RCA-9C22 Tubes, one of which is a spare. The r-f power-amplifier compartment (not shown) has positions for four RCA-9C22's, two of which are spares.*

was 240 cycles and, when this was cancelled the hum level decreased to —52 db, mostly 480 cycles.

Significant results of these tests are summarized below:

THREE-PHASE FILAMENTS

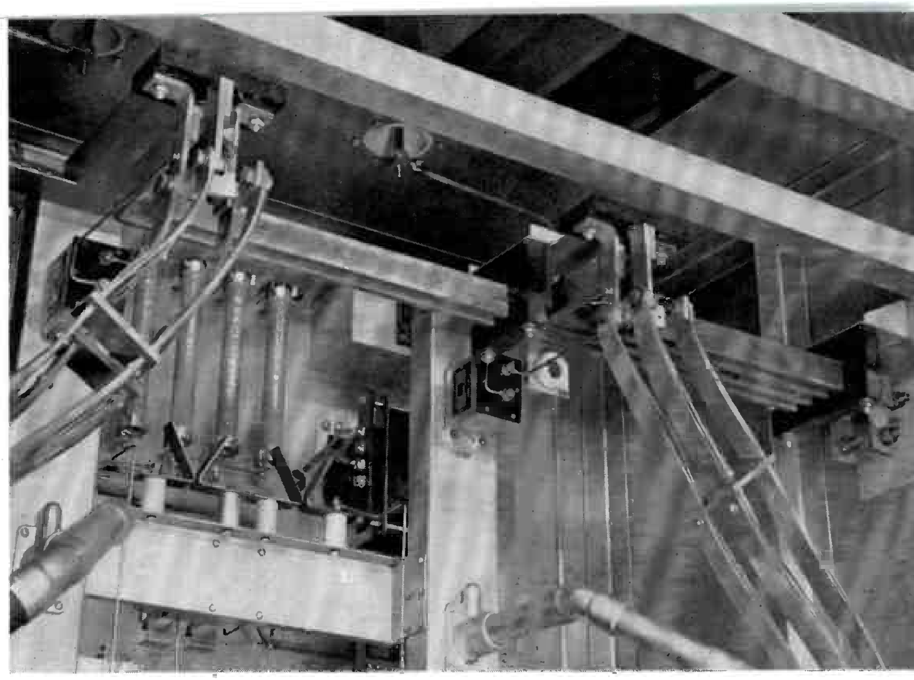
The predominant hum frequency was 120 cycles rather than 360 cycles. Other hum frequencies such as 180, 240, 360, and 480 were present in appreciable amounts so that cancellation of three frequencies simultaneously was necessary to obtain a hum level of —60 or lower.

SINGLE-PHASE FILAMENT

The predominant hum frequency was 120 cycles as expected. A hum reduction of 13 db was obtained by operating two tubes with filaments quarter-phased. A further reduction of 8 db was obtained by cancellation of the 240-cycle hum. The reductions noted are in fairly close agreement with calculated amplitudes for the various components of a full-wave rectified sine wave such as would be developed due to the magnetic effect of the filament current.

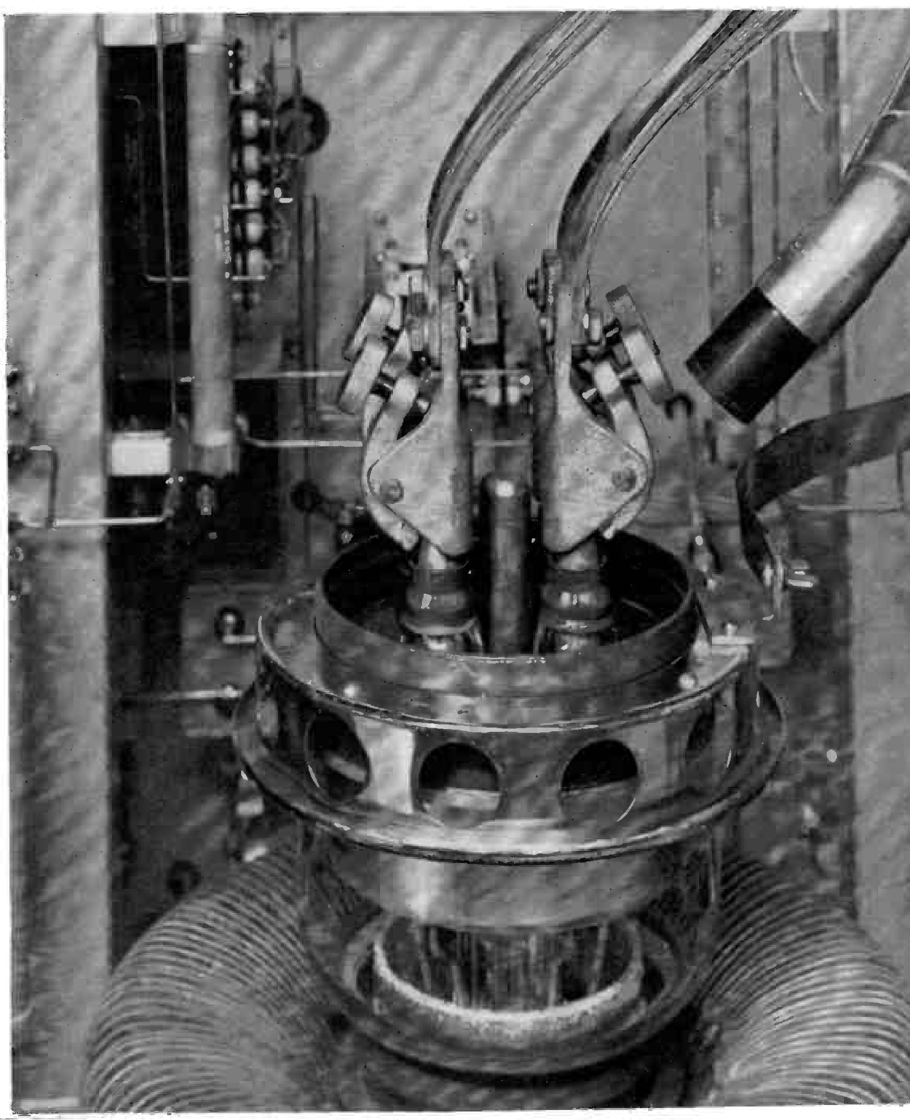
Means for cancellation of a single hum frequency was successfully applied on the Type 50-E Transmitter through the use of a hum frequency feedback amplifier. This unit provides overall feedback at one sharply tuned frequency, 240 cycles, without encountering any of the phase shift complications introduced by a broad band overall feedback system. It was obvious that the same hum cancellation system applied to the BTA-50F transmitter would achieve a hum level of —60 db. An attempt was made to incorporate a similar hum cancellation system for the three-phase tubes by modifying the hum frequency feedback amplifier to include circuits for cancellation of more than one frequency. It was possible to achieve a hum level of —60 db with the modified unit, but the adjustments were critical and difficult to maintain. Thus, one of the important arguments in favor of three-phase filament heating on high-power tubes appeared to be of doubtful benefit.

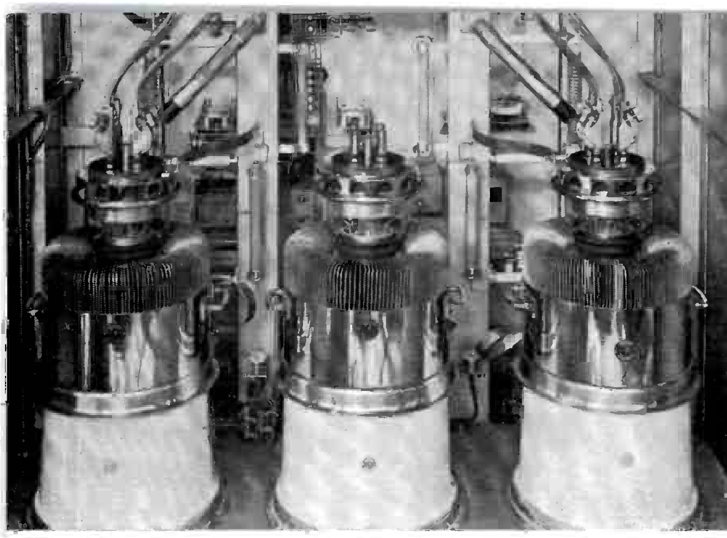
The same high-power tubes were also checked in the modulator circuits of the Type 50-E Transmitter. Either type was satisfactory from the hum standpoint because the normal audio feedback reduces hum to a satisfactory value. The 120-cycle component is predominant with single-phase tubes. It is easily reduced by peaking the frequency characteristics at 120 cycles at a point inside the feedback loop. No one frequency appeared to predominate



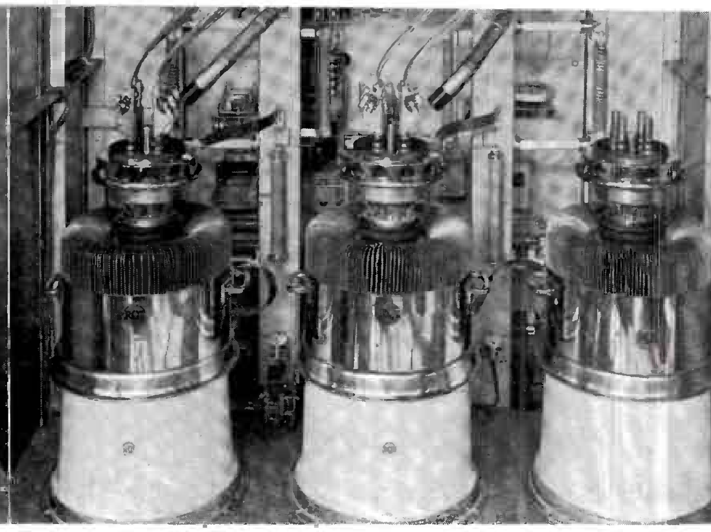
(Above)—*Closeup of the overhead filament bus connections in the modulator unit shown on the preceding page.*

(Below)—*Closeup of the filament connections on one tube. The connectors are copper-bronze castings with thumb-screw tightening arrangement.*





(Above)—*Modulator filament connections in the standard operating position (center tube is the spare).*



(Above)—*Modulator filament connections changed to use spare tube in place of the tube in the right.*

with the three-phase tubes, but the normal feedback without peaking reduced all components satisfactorily.

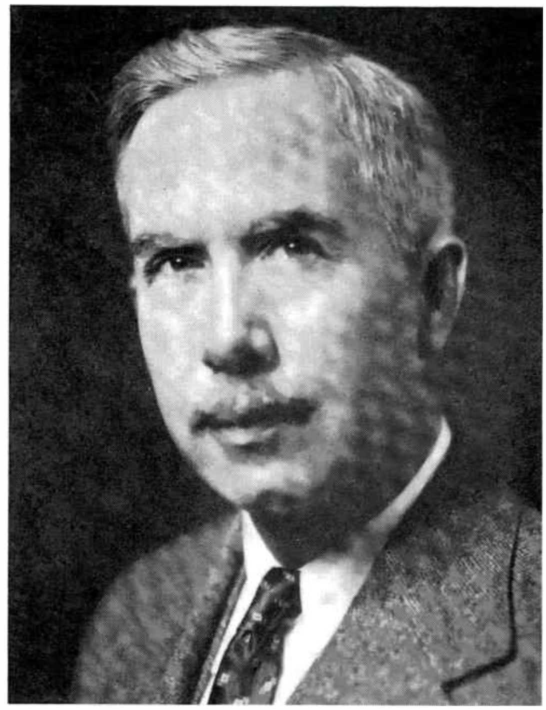
While it is true that filament transformer cost and weight are less with three phase tubes than with single-phase tubes of equal rating, other factors enter in to make up some of the difference. These factors are well known and have been pointed out by others, but are reviewed here briefly. Three-phase tube design requires that filament strands for each phase must be separately supported so that phase voltage unbalance, or loss of one or two phases, will not cause distortion or fracture of filament strands due to thermo-mechanical stresses. The complications introduced by such a filament structure inevitably result in a weaker assembly both mechanically and electrically than with a simple, single-phase filament. Even if all the precautions are taken in design of the tube, early filament failure may result unless complicated means are provided to maintain phase-to-phase voltage balance and to cut off filament power immediately if one phase drops below a point at which any practical voltage regulating device can maintain the balance. The additional complications just about offset the increased cost of single-phase filament heating. In the BTA-50 Transmitter, three-phase load balance for filament power is obtained easily with a quarter-phasing autotransformer.

Careful consideration of all the factors noted above led to the choice of single-phase filament tubes, Type 9C22, for the power amplifier and modulator of the Type BTA-50F Transmitter.

(Right)—*Carlyn Praux, Conover model, compares for spectators at the recent IRE convention, the miniature radio and television tube to the new, giant RCA 9C22 power tube—largest air-cooled power tube in existence which is used with Type BTA-50F Transmitters.*

ENGINEERING PRODUCTS EXECUTIVES

W. W. WATTS, *Vice President*



M. C. BATSEL, *Chief Engineer*

W. W. Watts has been elected Vice President-in-Charge of the Engineering Products Department. Previously Mr. Watts had been General Sales Manager of this department. He comes to RCA after serving as a Colonel in the Signal Corps for three and one-half years.

He was Commanding Officer of the Signal Corps Distribution Agency at the time of his release from the Army and formerly was Director of a Procurement Division of the Philadelphia Signal Corps Procurement Dilstrict. In recognition of his contributions to the Procurement and Distribution of Signal Equipment during the war he has been awarded the Legion of Merit.

Mr. Watts, whose headquarters are at Camden, N. J., will direct the engineering, manufacturing, merchandising, advertising, and sales activities of the Engineering Products Department. Products of this department include: Broadcast and Television Station Equipment, Industrial and Scientific Electronic Equipment, Motion Picture and Sound Products, Aviation Radio Equipment, Communications Equipment, and Test and Measuring Equipment.

Prior to his service with the Army, Mr. Watts was connected with the Montgomery Ward & Co., and the Zenith Radio Corporation. At Montgomery Ward & Co. he was Mail Order Sales Manager for radio and electronic equipment and major electrical appliances. With Zenith he held the position of Vice President-in-Charge of the Wincharger Corporation, a Zenith subsidiary located in Sioux City, Iowa.

Mr. Watts' association with the radio industry began with amateur and experimental work in 1912. He has been directly connected with the sales and distribution phases of the industry since 1923. In his new position he expects to use his wide knowledge of the business and technical phases of radio to advantage in directing the far-flung activities of RCA's Engineering Products Department.

Max C. Batsel was appointed Chief Engineer of the Engineering Products Department on September 1, 1945. Mr. Batsel brings to his new position thirty years of engineering experience, twenty-five of which have been spent with RCA or its affiliated companies.

Following his graduation from the University of Kentucky in 1915, Mr. Batsel was employed by the Western Electric Company as a student engineer. Completing this course he joined the staff of the Bureau of Standards where he remained until his enlistment in the Signal Corps in 1917.

While stationed at Camp Vail (later Ft. Monmouth), Mr. Batsel was engaged in the development of tubes, transmitters, and direction finders. During this time he also participated in the first tests of radio communication conducted between ground stations and aircraft.

Following his discharge in 1920, Mr. Batsel joined the Westinghouse Co. where, as a section engineer, he was responsible for the development and design of some of the first commercial radio receivers to be placed on the market. While still engaged in receiver development he became keenly interested in electronically producing sound on films for motion pictures, which resulted in his appointment in 1929 as Chief Engineer of the Photophone Division of RCA (which later became the Photophone Department). In 1936 this department was expanded to include Broadcast Audio Equipment and Sound Products. In 1945 it became a part of the Engineering Products Department and Mr. Batsel was appointed Chief Engineer of the combined department.

Mr. Batsel is a member of Tau Beta Pi, a Fellow of the Institute of Radio Engineers, and a Fellow of the Society of Motion Picture Engineers. In his new position he directs engineering activities on all types of broadcast station equipment, as well as associated types of equipment.

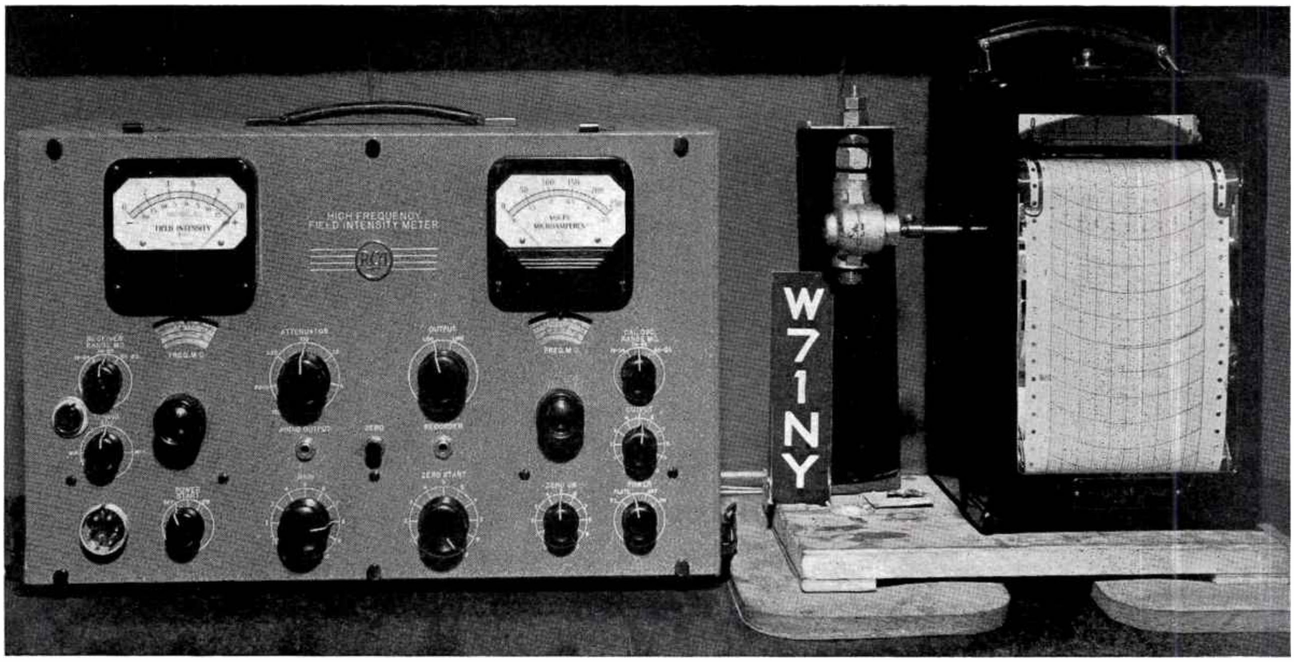


FIG. 1. *Field Strength Recording Equipment used by W71NY (now WBAM) Engineers.*

HOW TO MAKE A FIELD SURVEY OF AN FM STATION*

by G. W. KLINGAMAN
Transmitter Engineering Section
Engineering Products Department

Although a great deal has been written about the behavior of radio waves at high frequencies, the available information on methods of making a practical field survey is widely scattered. It is the purpose of this article to discuss some of the mechanics involved and to present typical data from surveys which have been made.

METHODS

In the past, some surveys have been made at broadcast frequencies by the "follow-the-contour" method which consists of circling the station with measuring equipment while weaving back and forth across the particular contour desired. This is a very approximate method and is now obsolete.

A better, and now almost universally used, procedure is the radial method. At broadcast frequencies this consists of taking "spot" readings of field intensity along at least eight radials spaced approximately 45 degrees about the transmitter. Readings are taken well away from power lines, wires or other obstructions, and are spaced about a mile (or less) apart near the station. At 30 miles or more the spacing can be increased to 5 miles. For these frequencies, reflecting surfaces are usually electrically small and a single reading at a good location will be very close to the average field for that distance.

On the other hand, a few readings by the "spot" method at FM frequencies will speedily convince anyone that a more accurate procedure is called for. Reflections are frequent and intense. Objects such as trees, poles, automobiles, and even a person walking close to the receiving antenna, can cause large variations in field intensity. Furthermore, the received field is very sensitive to antenna height, a factor which is unimportant at broadcast frequencies. Recognizing these factors, the FCC has specified that continuous mobile recordings of the field of an FM station must be made along each of eight radials and that this data must be translated to a height of 30 feet. The latter is based on the assumption that 30 feet is a height which is typical of the average home installation.

EQUIPMENT

The arrangement of the pickup antenna used will depend on whether the signals to be measured are vertically or horizontally polarized; otherwise the equipment is the same in either case. On Page 62 (Figure 1) is shown a survey car equipped for receiving horizontally polarized signals. The antenna used is the short doublet furnished with the 301-A Field Intensity Meter.

A somewhat different arrangement used for measuring the vertically polarized signals of W71NY (now WBAM), the FM station of WOR, has been described by Charles Singer.[2] In this case a 124-inch vertical antenna was mounted on the front bumper of the car as shown in Figure 2. It was supported on a maplewood pole with the center of the antenna 10 feet off the ground. The receiver used with this installation was an RCA

* The survey described in this article was made before the present FCC Standards of Good Engineering Practice were issued. The procedures followed, however, are the same as those suggested in the Standards with the exception that the Standards require a different method of determining the 50-microvolt contour. This difference is explained in the discussion on Page 72.

FIG. 2. (Right) *In the W71NY survey the antenna was a vertical dipole mounted on the front bumper of the car.*

FIG. 3. (Left) *Closeup of the vertical dipole showing the connecting cable.*

Type 301-A Field Intensity Meter which, however, was somewhat hampered by inadequate bandwidth. (The 301-A has since been replaced by the improved 301-B in which special provision is made for FM measurements). The antenna lead-in was a two-wire shielded cable regularly supplied with these units. The output of the field intensity meter was used to operate both an Esterline-Angus recorder and a monitoring amplifier and loudspeaker.

Probably the most difficult part of the installation of measuring equipment in a car is a means for driving the recorder from the motion of the car. This is not an absolute necessity since a spring-drive is usually supplied with the recorders. This is acceptable provided distances and identifying landmarks can be readily noted on the chart. However, personal experience with both methods has shown the former to be by far superior. A very satisfactory arrangement was devised for the W71NY survey. The regular speedometer was removed from the drive-shaft and replaced with a taximeter drive having two outlets—one to drive the speedometer, and the other with a gear reduction of 1009 revolutions per mile to 48 revolutions per mile. This drove an 8 foot flexible shaft attached to a second reduction gear bringing the speed down to 4 inches per mile. This last was attached to the recorder by means of a set-screw clutch. The recorder was then geared to record at 6½ inches of paper per mile. This arrangement is shown in Figure 4.

Close to the transmitter it may be found desirable to increase the paper speed to about 20 inches per mile. The clutch mechanism described should be incorporated so that the paper can be stopped instantly for backing the car, retracing a route, etc. Other refinements of the method may suggest themselves.

The recorder used with the RCA Type 301-B Field Intensity Meter should have a 5 ma movement and an internal resistance

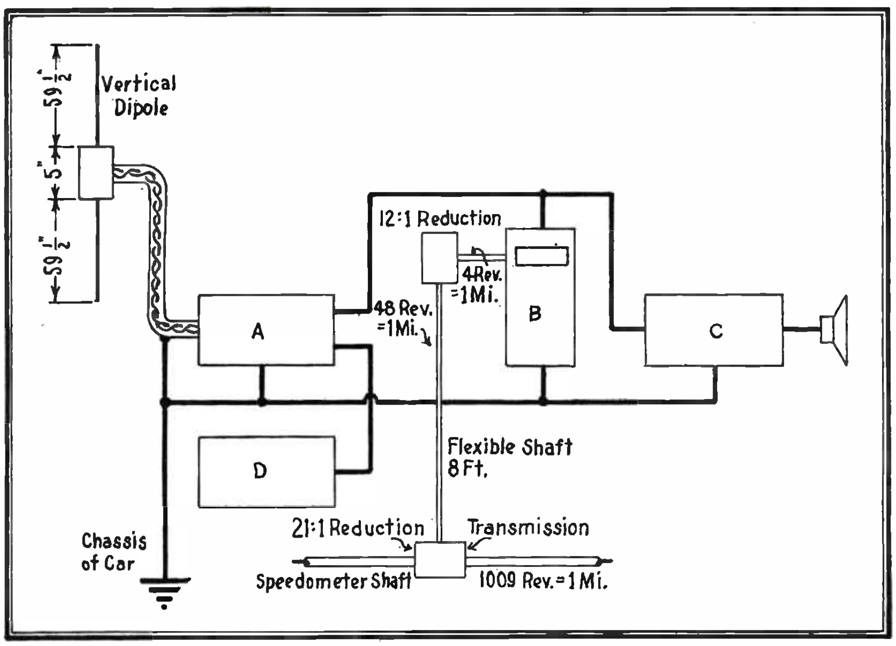


FIG. 4. *Arrangement of equipment. Components are as follows: A, Field Intensity Meter; B, Recorder; C, Amplifier; D, Power Supply.*

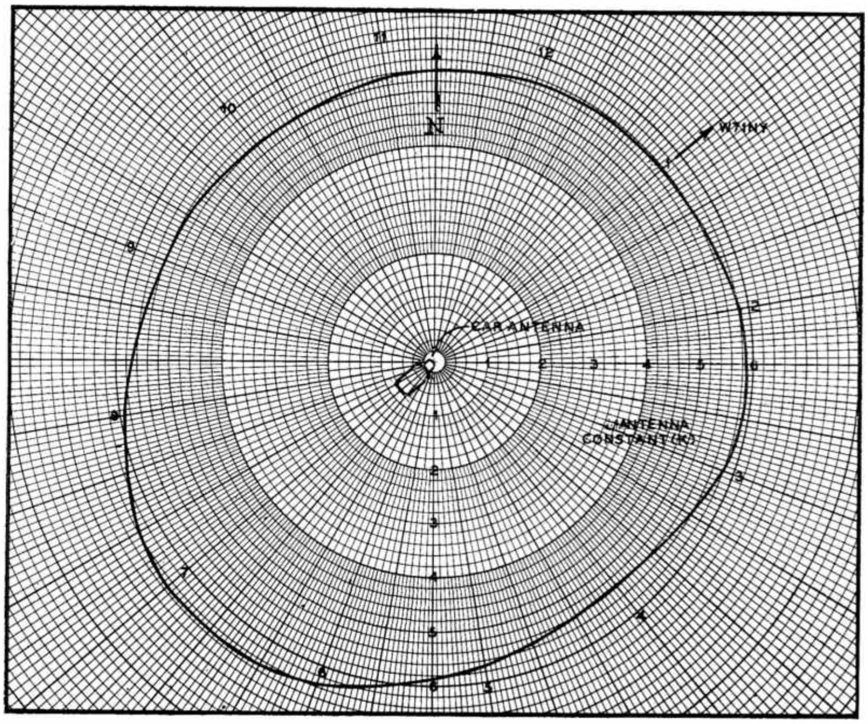


FIG. 5. *Graph of the antenna constant K for various orientations of the survey car with respect to the station.*

not greater than 560 ohms. Either a logarithmic or a linear record can be made with this meter.

Ignition noise in the car must be as nearly eliminated as possible. The usual devices, such as spark-plug suppressors, by-pass condensers, etc., are uually effective if installed properly. A wide copper ground strap running the length of the car, to which all the equipment components are bonded, has been found helpful. The strap should be connected to the car frame in several places and form the ground point for the electrical system of the car. Electrical noise will be found very disturbing when field intensities of a few microvolts per meter are to be measured near the end of a radial.

It is recommended that a heavy-duty 6-volt storage battery be used to operate the field intensity meter. It should be fully charged at the start of each radial. If smaller batteries are used it is wise to carry a fully charged spare.

It will be observed that dipole antennas are shown in Figures 2 and 3 in place of the usual loop antennas used at broadcast frequencies. The reason for this is the low effective height of loop antennas at high frequencies. For example, at 46 mc the effective height of a half-wave dipole is 6.8 feet, whereas the effective height of a single-turn 12 inch loop is only 2.8 inches! The chief drawback to dipole antennas on mobile equipment is their size which makes them somewhat clumsy to maneuver, especially in wooded country or on streets with many overhead wires. One expedient is to reduce its length close to the transmitter so that it is no longer than necessary. However, near the end of a radial it will be desirable to extend the elements in order to receive extremely weak signals. Of course, each time the antenna length is changed a new antenna constant must be determined for the equipment. The antenna should be made readily removable, or at least capable of being telescoped to a small size. This will be found particularly helpful where the going is rough, as in wooded sections. It is well to carry elements in case of breakage. The usual source of trouble is where the rods are screwed into the studs in the bakelite centerpiece. They should always be tightened with a wrench to prevent movement which eventually breaks the studs.

All equipment should be shock-mounted and firmly strapped in place so that it will not be broken by sudden severe jolts as may occur in heavy traffic. A number of tools for making emergency repairs should be taken along. A voltmeter of the common "analyzer" type is essential.

MAKING THE SURVEY

The routes followed by the car should lie as close as possible to the radials originally used in the construction permit application. They should be carefully planned in advance and marked on automobile road maps. Records should be taken well beyond the opitcal horizon, preferably to a point where the signal has entirely disappeared, in order to accurately locate the 50 microvolt-per-meter contour.

The importance of keeping a detailed log throughout the survey cannot be too strongly emphasized. Data can be written directly on the recorder chart, but it is much more satisfactory to make all notations in a notebook and refer them to numbers on the chart. These numbers can be marked while the recording is being made or before the start of the trip. Information that should be noted is as follows:

1. All landmarks which appear on the road maps.
2. Car mileage.
3. Time and date.
4. All changes in the receiver sensitivity, attenuator settings, re-calibration of equipment, etc.
5. All changes in antenna length.
6. Direction of making the survey (whether approaching or going away from the station).
7. By whom the survey was made.
8. Any unusual conditions or other pertinent data to explain and aid in the interpretation of the charts.

Making a survey is at least a two-man job. One man acts as observer to keep the logs and mark the chart. The driver usually is kept extremely busy watching overhead obstructions, trees, traffic, and other details.

At some point near the end of a radial, a stationary fading and interference test should be made. The self-contained spring-drive in the recorder may be used for this purpose. Another interesting test is a record of other stations which can be heard at the location.

ORGANIZATION OF DATA

The rules[7] of the Federal Communications Commission require that data submitted include a topographic map similar to that submitted with the application for a construction permit. On the map should be plotted the original radials, together with the actual paths followed by the car in making the measurements and a plot of the 50 and 1000 microvolt-per-meter contours. The field intensity for each sector should be marked either directly on the map or in tabular form, with notation to identify the sector to which each reading applies.

The first step in the reduction of the survey records to a suitable form is to correct the calibration of the field intensity meter for the presence of the car body and for any changes in antenna length from that specified for the instrument at the frequency of measurement. In the 301-B meter the field is given as:

$$F = S \times A \times K \qquad (1)$$

where

F = field in microvolts per meter
A = attenuator setting
K = calibration (or antenna) constant
S = scale reading

It is the constant (K) that must be modified. The simplest wav of doing it is as follows:

The survey car is driven to the middle of a large, clear, flat field. Stakes are then driven into the ground to form a circle with the antenna at the center. The stakes are spaced 30 degrees apart about the circumference. The car is faced toward each of the stakes successively and a reading of the station field intensity is made at each position for each of the several antenna lengths used in the survey. The field intensity will be:

$$F = S^1 \times A^1 \times K^1 \qquad (2)$$

where the primed letters are values modified by the car body and changed antenna lengths. The equipment is then removed from the car and set up on the ground with the antenna on its tripod at the center of the circle. The car is driven well away from the field of the antenna. A reading of the true field intensity is made and recorded as F_T. The ratio of Equation (2) to the true field intensity (F_T) is used to obtain K^1

$$\text{thus,} \quad K^1 = \frac{F_T}{S^1 A^1} \qquad (3)$$

where K^1 is the corrected antenna constant.

A plot of K^1 for W71NY is shown in Figure 5. When recording a radial approaching the transmitter, positions 10, 11, 12, 1, 2, 3 and 4 were averaged. When the radial was recorded going away from the station, positions 4, 5, 6, 7, 8, 9 and 10 were averaged. Instead of the station signal a local field generator may be utilized.[2,3,4] It consists essentially of a thoroughly shielded oscillator with a balanced loop antenna, and a thermo-milliameter for measuring antenna current. The generator, as illustrated in Figure 2, is set up at the same height as the antenna center and half-wave length away from it. The device is used to generate known fields for calibration purposes.

Once the calibration of the receiving equipment has been accomplished, data on the various survey records can be reduced to actual field intensities along the radials. The records are divided into sections which increase in length as the dis-

RADIAL NO. 1 - N. 29° E.

Section Number (1)	Attenuator Setting (2)	Distance to End of Sector MILES (3)	Median Field Reading (4)	Median Field at 10 mv/m (5)	Median Field at 30 mv/m (6)	Max. Field Reading (7)	Max. Field at 10 mv/m (8)	Max. Field at 30 mv/m (9)	Location of End of Sector. (10)
1	10,000	0.6	10.0	600,000	1,200,000	10.0	600,000	1,200,000	64 St. & Madison Ave.
2	10,000	0.9	4.0	240,000	480,000	6.4	348,000	768,000	67 St. & Madison Ave.
3	10,000	1.16	1.8	108,000	216,000	3.9	234,000	468,000	
4	2,000	2.0	1.6	192,000	38,400	4.0	48,000	96,000	88 St. & Madison Ave.
5	500	2.26	2.0	6,000	12,000	4.8	14,400	28,800	
6	100	2.8	1.0	3,000	6,000	1.7	5,100	10,200	
7	100	3.10	5.4	3,240	6,480	10.0	6,000	12,000	109 St. & Park Ave.
8	100	3.8	6.0	3,600	7,200	10.0	6,000	12,000	124 St.
9	100	5.0	6.0	3,600	7,200	10.0	6,000	12,000	149 St. & Grand Concourse
10	500	6.0	1.8	5,400	10,800	5.3	15,900	21,800	
11	500	6.6	1.2	3,600	7,200	2.6	7,800	15,600	170 St. & Grand Concourse
12	100	7.4	4.4	2,640	5,280	5.0	3,000	6,000	
13	100	8.4	5.0	3,000	6,000	8.8	5,280	10,560	Fordham Rd. & Grand Con
14	100	9.2	2.8	1,680	3,360	2.6	1,560	3,120	
15	100	9.7	1.4	840	1,680	3.0	1,800	3,600	Jerome Avenue, Bronx
16	100	11.2	3.0	1,800	3,600	4.3	2,580	5,160	
17	100	11.8	5.0	3,000	6,000	6.3	3,780	7,560	Yonkers, New York
18	100	12.6	4.0	2,400	4,800	6.2	3,720	7,440	
19	100	13.4	1.0	600	1,200	3.8	2,280	4,560	
20	100	14.9	1.2	720	1,440	3.1	1,860	3,720	Bronxville, New York
21	100	16.8	1.8	1,080	2,160	2.5	1,500	3,000	
22	100	18.8	0.6	360	720	.83	498	996	Near Hartsdale, N. Y.
23	20	21.9	4.0	480	960	15.0	1,800	3,600	White Plains, N. Y.
24	20	24.7	1.0	120	240	4.2	504	1,008	Kensico Dam, N. Y.
25	20	28.8	3.0	360	720	3.2	384	768	Armonk, N. Y.
26	20	31.4	1.0	120	240	.95	114	228	
27	20	33.5	4.0	480	960	6.0	720	1,440	
28	20	34.4	0.4	48	96	.91	109	208	Near Bedford
29	5	37.4	2.0	60	120	4.9	145.0	290	
30	5	43.0	2.0	60	120	9.4	285.0	570	Grant, Conn.
31	1	46.2	2.0	12	24	9.7	582	116.4	Intersection 121-206
32	1	50.6	5.0	30	60	4.0	24	48	Danbury
33	1	56.6	1.6	9.6	19.2	2.3	13.8	27.6	Brookfield
34	1	62.2	1.2	7.2	14.4	2.2	13.2	26.4	New Milford, Conn.
35	1	67.1	0.6	3.6	7.2	1.5	9.0	18.0	

tance from the station becomes greater. In determining the distance to the start and end of each section, it is projected upon the radial on the topographic map along which the survey was made. This is done by measuring the airline distance to the extremities of the section. The projection thus becomes a sector of the radial. The average recorder reading throughout the section is then obtained, usually by inspection (although, more exact methods can be used) and translated to field intensity. Although not required, it is interesting to note also the maximum and minimum intensities encountered throughout the section.

The length of the sections are so chosen that their projected sectors vary from approximately one-tenth the service radius near the station to no greater than five miles at the end of the radial. The distance to the *end* of each sector is associated with the field intensities noted above and arranged in tabular form, together with notation to locate it on the route followed by the car. An example of this is given in Table I for W71NY between New York and New Milford, Connecticut.

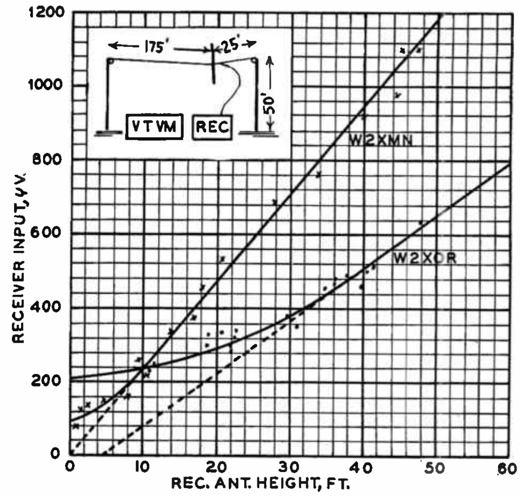


FIG. 6. *Graph illustrating method of experimentally determining correction factor.*

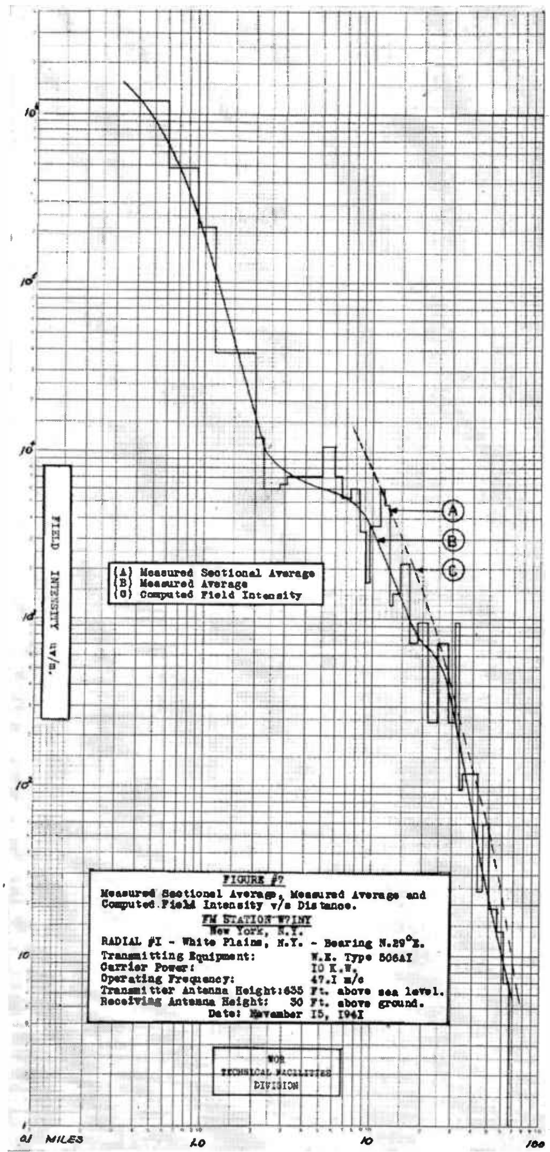


FIG. 7. *Field Intensity versus distance for one radial.*

All of the data tabulated so far is for the particular antenna height used in the survey car, usually about 10 feet. The average home receiving antenna is considerably higher and the FCC therefore specifies a height of 30 feet. The necessary correction factor may be experimentally determined as shown in Figure 6 or it may be determined theoretically. In general the correction factors for vertical and horizontal polarization will be different. Assume a transmitter operating on 46 mc with a half-wave dipole 500 feet above the *average* elevation between the state and the receiver. It is radiating 1000 watts. The dielectric constant at the point of reflection is 15 and the ground conductivity is 5×10^{-14} emu. The distance to the receiver is 10 miles. The field intensities are given[5, 6] for a simple half-wave radiator by

$$F_v \doteq \frac{7\sqrt{w}}{d^2}\left[\frac{2\,\epsilon_o\,(h+a)}{\sqrt{\epsilon_o - 1}} + j\,\frac{4\,\pi\,ha}{\lambda}\right] \quad (4)$$

$$F_h \doteq \frac{7\sqrt{w}}{d^2}\left[\frac{2\,(h+a)}{\sqrt{\epsilon_o - 1}} + j\,\frac{4\,\pi\,ha}{\lambda}\right] \quad (5)$$

where

F_v = vertical field intensity in volts/meter
F_h = horizontal field intensity in volts/meter
W = radiated power in watts
d = distance to receiver in meters
h = transmitter antenna height in meters
a = receiver antenna height in meters
f = frequency in cps
ϵ_o = complex dielectric constant
$= \epsilon - j\,\dfrac{18 \times 10^{20} \times 6}{f}$
ϵ = dielectric constant of the earth
6 = earth conductivity in emu
λ = wavelength in meters

These formulas apply with good accuracy to distances greater than a mile or more and almost to the optical horizon. Using the above constants, values have been computed for several receiving heights:

a	F_v	F_h
0 Ft.	1050 v/m	69.4 v/m
10 Ft.	1275 "	770 "
30 Ft.	2480 "	2290 "

In the example, therefore, the correction factor for vertical polarization to translate field intensities from 10 feet to 30 feet is 1.95. For horizontal polarization it is 2.97.

Having completed the tabulation of survey data it is possible to prepare a plot of field intensity against distance. One suggested method is to plot the median value for each sector against distance as shown in Figure 7. (Editors Note: for additional information on plotting values see the discussion on Page 66.

With data for all the radials plotted, a contour map may be drawn as in Figure 8. In transferring average field-strength curves to coverage maps some irregularities will have to be smoothed out, as was done in Figure 7, Curve B. Averaging the curves in this way avoids the difficulty of attempting to plot "pools" or isolated contours which have little practical significance anyhow and require much more data for accurate determination than that available from the survey.

Contours should be plotted on a suitable map such as Sectional Aeronautical charts or their equivalent. They may be obtained from the U. S. Coast and Geodetic Survey, Department of Commerce, Washington, D. C., for forty cents. In addition to the contours these maps should show the original radials, car routes, and section data as pointed out previously.

The area within the 1000 and the 50 microvolt-per-meter contours should be measured by planimeter or other approximate means to determine the area actually served by the station. In computing these areas large bodies of water such as oceans, gulfs, sounds, bays, large lakes, etc., but not rivers, should be excluded.

A practice followed at broadcast frequencies is to evaluate the effectiveness of the antenna by determining the unattenuated or free space field at one mile. Although not required for FM stations by the Commission it may be of interest, particularly in checking the antenna gain in the horizontal plane when turnstile or other directional antennas are used. A method is described in FCC Mimeograph #40004, "Field Intensity Survey of Ultra-High-Frequency Broadcasting Stations," and may be obtained from the Secretary of the Federal Communications Commission, Washington, D. C.

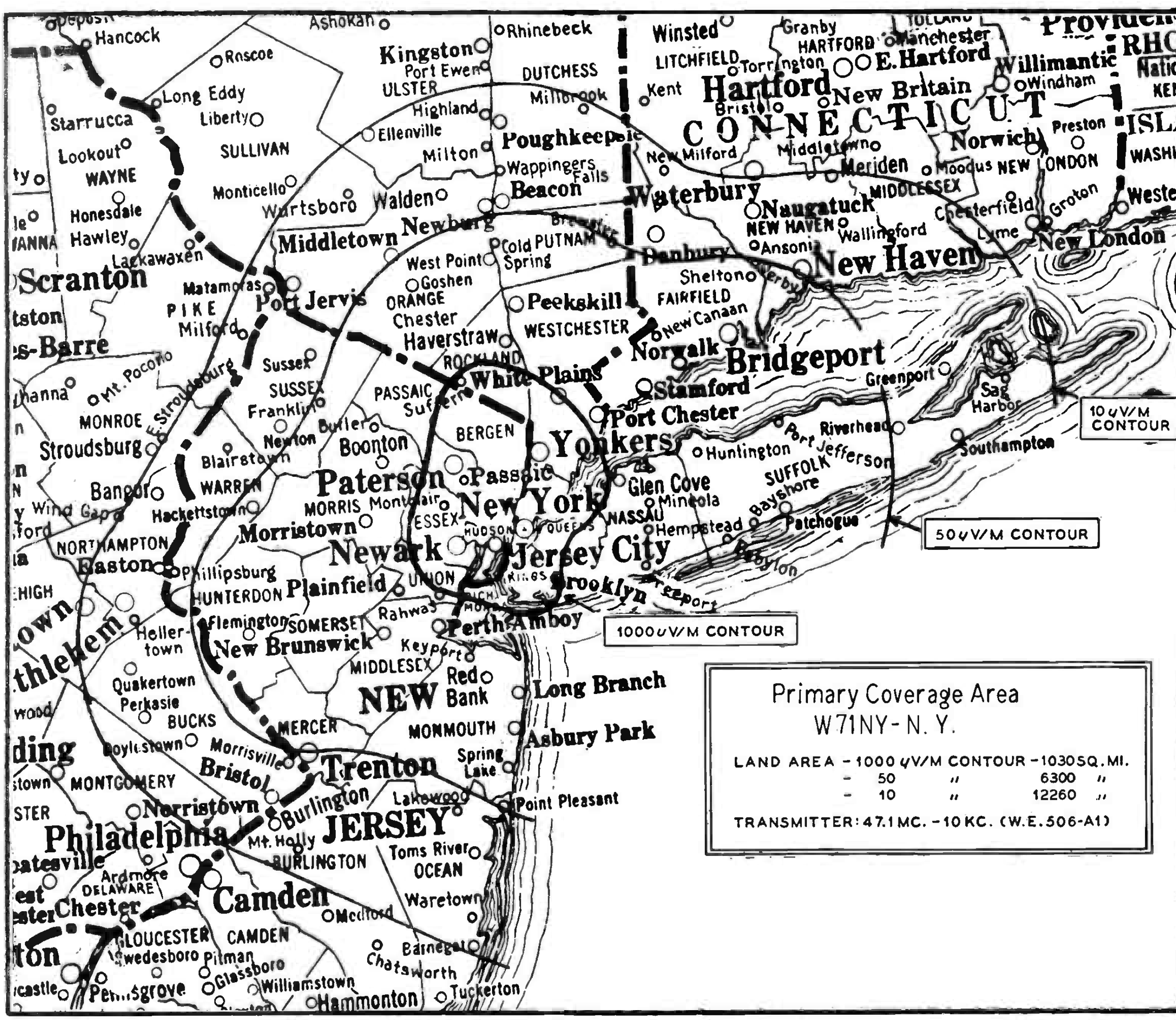


FIG. 8. *Map showing 1000-microvolt, 50-microvolt, and 10-microvolt contours as plotted from data taken from Curve B of graps similar to Figure 7 which are drawn for each of the eight radials.*

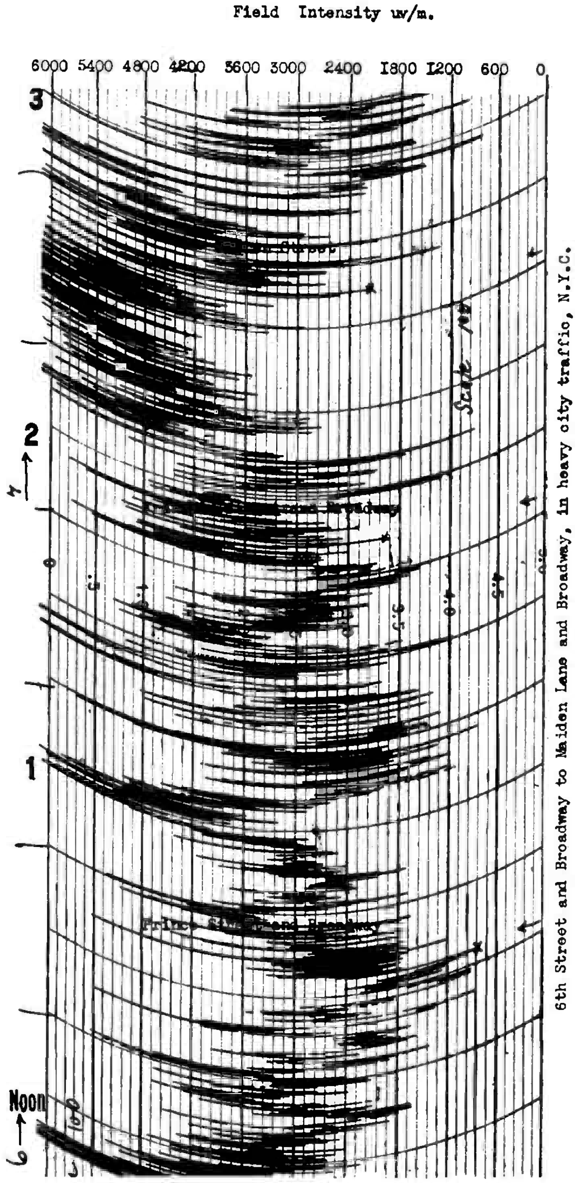


FIG. 9. *Section of a recording made in an area where traffic was heavy and buildings crowded.*

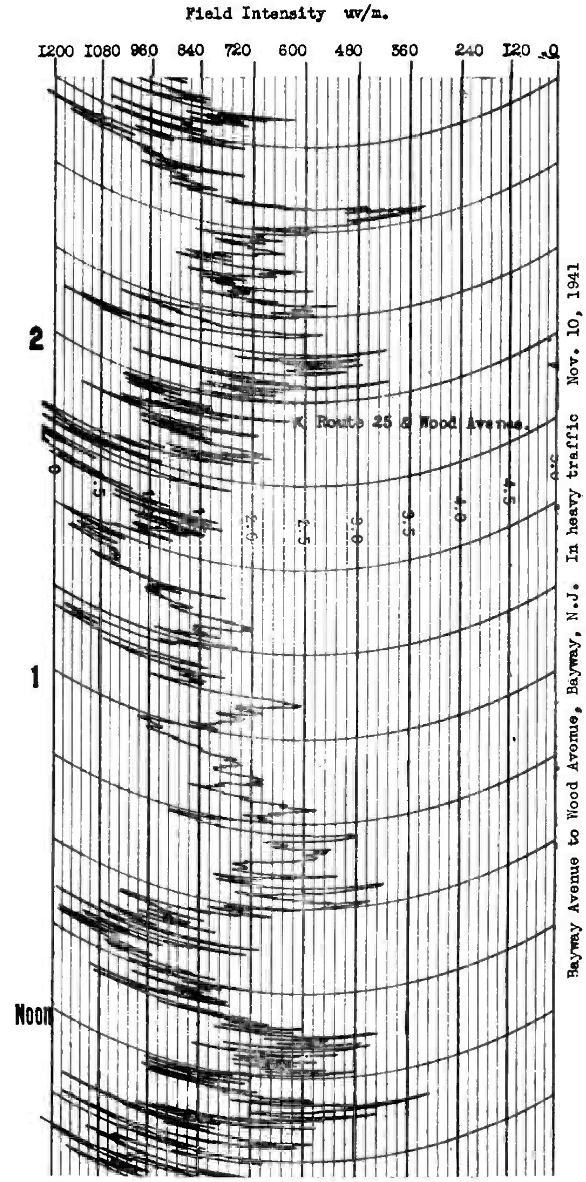


FIG. 10 *Section of a recording made in an area where traffic was heavy, but fewer buildings were present.*

DISCUSSION

Some sample records taken from the W71NY charts are shown in Figures 9 to 12. Figure 9 shows the variations in signal level under the worst conditions—heavy traffic and buildings crowded together. Variations were less severe in Figure 10 where traffic was heavy but fewer buildings were present. Figure 11 shows the relatively steady signal received over flat, open, country. The rise of signal strength as the crest of a hill was approached in Figure 15 indicates the desirability of such a location for the reception of ultra-high-frequency signals. As the antenna dropped behind the hill the intensity fell sharply.

One very interesting instance which the writer recalls was on a radial to Port Jervis, New York. For some time, as the car approached High Point State Park (which was 1800 feet above sea level and was 52 miles distant from W71NY) the signal had been very weak. As the mountain was climbed, the signal rose steadily until at the crest it had gained almost 40 decibels and the FM band became practically crowded with signals.

It will be found that beyond the optical horizon the signal decreases at a much higher rate with distance than before. This is evident in the sample plots.

Pattern distortion is usually found when contour maps are plotted. This may be due to a number of reasons:

1. Intervening hills may effectively screen the transmitter in a given direction and greatly shorten the distance to the optical horizon.
2. Ground areas at the point of reflection may have poor electrical characteristics.

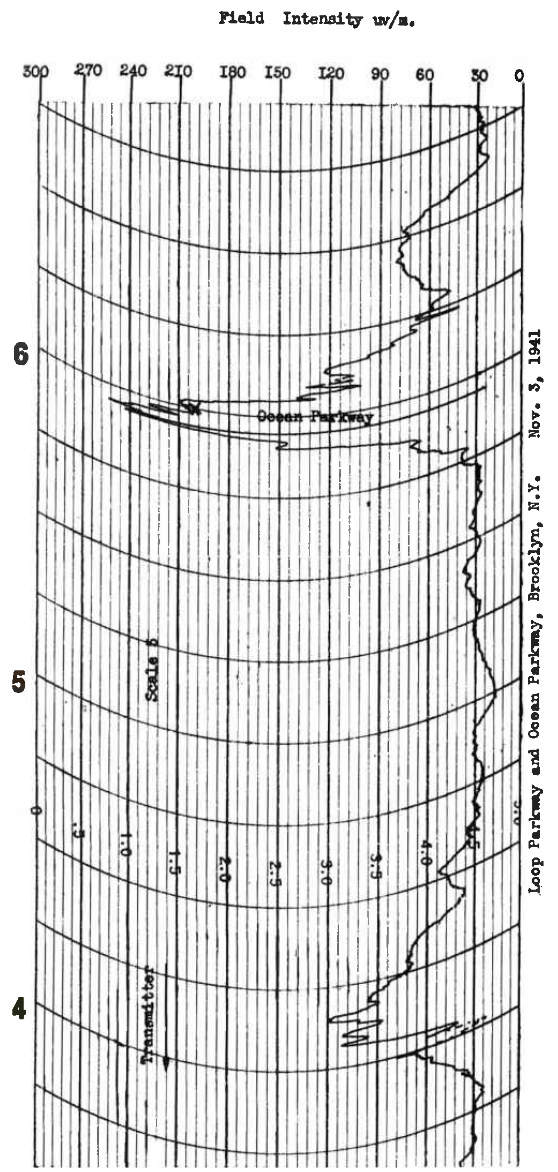


FIG. 11. *Section of a recording made in flat, open country. Note relatively steady signal received.*

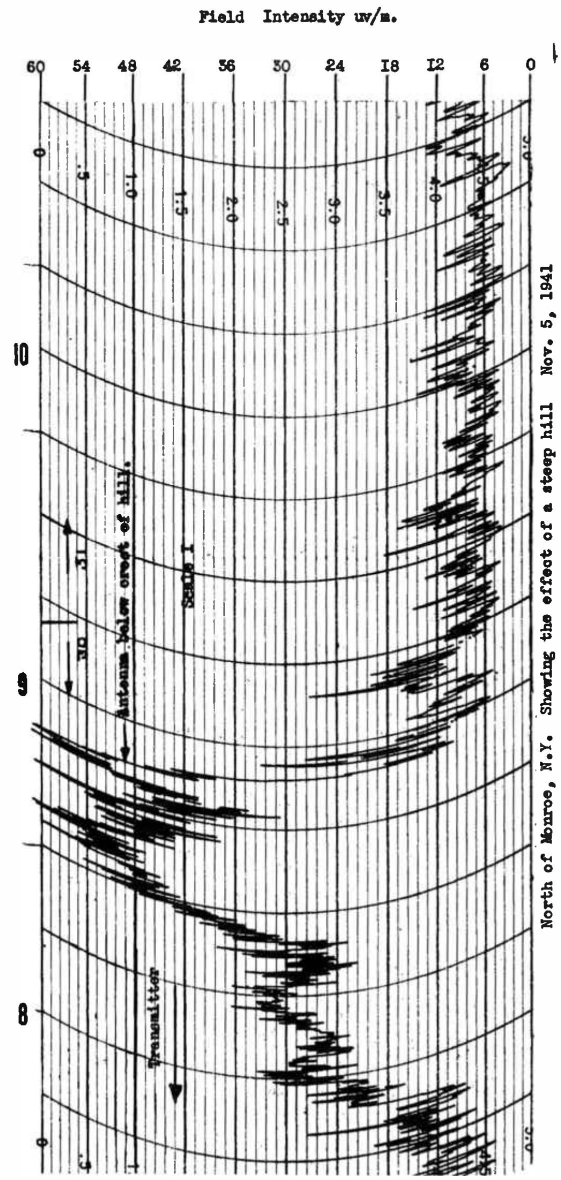


FIG. 12. *Section of a recording showing the rise in signal as the crest of a hill was approached.*

3. When the antenna is located on a high steel building considerable distortion may result, for example, if it is located near a corner of the building.
4. A tall building in the immediate vicinity of the antenna may produce a deep "shadow."
5. Supporting towers, guy wires, etc., near the antenna may be parasitically excited.

There is no secondary service area such as is found at broadcast frequencies. Only primary service is of importance, although sporadic reflections from "cold fronts" or "warm fronts" in the atmosphere and clouds may produce considerable fading near the limit of the service area.

Although this article has been concerned primarily with frequency-modulated-station surveys, it is evident that the methods outlined are almost equally applicable to television station surveys. For television, the required contours are those at 5000 and 500 microvolts-per-meter.

References

[1] "Field Strength Survey at 52.75 Mc," G. S. Wickizer, PROCEEDINGS OF THE IRE, July, 1940.

[2] "Field Strength Survey Methods," Charles Singer, FM Magazine, February and March, 1942.

[3] "Ultra-Short-Wave Propagation," Schelleng, Burrows, and Ferrell, PROCEEDINGS OF THE IRE, March, 1933.

[4] "Calibration of Short Wave Field Strength Measuring Sets," McPetrie and Pressey, JOURNAL OF THE IRE, Vol. 83, p. 210, 1938.

[5] "Propagation of Waves Below Ten Meters," Trevor and Carter, PROCEEDINGS OF THE IRE, March, 1933.

[6] "Comparison of Vertically and Horizontally Polarized Waves at UHF," G. H. Brown, WAVE POLARIZATION FOR TELEVISION, RCA Mfg. Co.

[7] "Standards of Good Engineering Practice Governing High Frequency (FM) Broadcast Stations," Federal Communications Commission.

FIG. 1. *The field car with the telescopic antenna raised. The antenna pivots on a bearing inside, permitting orientation for maximum signal.*

FM FIELD SURVEY TECHNIQUES*

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During the months of August and September 1943, a field survey was made to determine the antenna performance of WMFM, one of the Milwaukee Journal's radio stations. This survey, of course, was completed and the results analyzed and mapped before the present FCC Standards of Good Engineering Practice for FM Broadcast Stations were issued. These Standards describe in detail the proper procedure for making such a survey, and they require a different method of determining the 50 microvolt contour. However, most of the steps followed in making this early survey are still required and the techniques developed should, therefore, be of interest to engineers of new FM stations.

* Reprinted from ELECTRONICS, May, 1945.

TRANSMITTER POWER REQUIREMENTS

In order that the calculated distance to the 50-microvolt contour would conform with the map attached to the CP, an effective radiated power of 41.5 kilowatts was necessary to deliver the desired coverage of 8500 square miles.

The radiating system of WMFM consists of a two-bay turnstile antenna which has a power gain of 1.23. The required transmitter power, for an effective power radiation of 41.5 kw, is therefore 41.5 divided by 1.23, or 33.8 kw. The loss in the coaxial transmission lines to the antenna was computed to be 2.5 kw, thereby requiring an increase in the transmitter output power to 36.3 kilowatts. WMFM uses a 50-KW FM transmitter with a power input to the final stage of 60.5 kilowatts. The

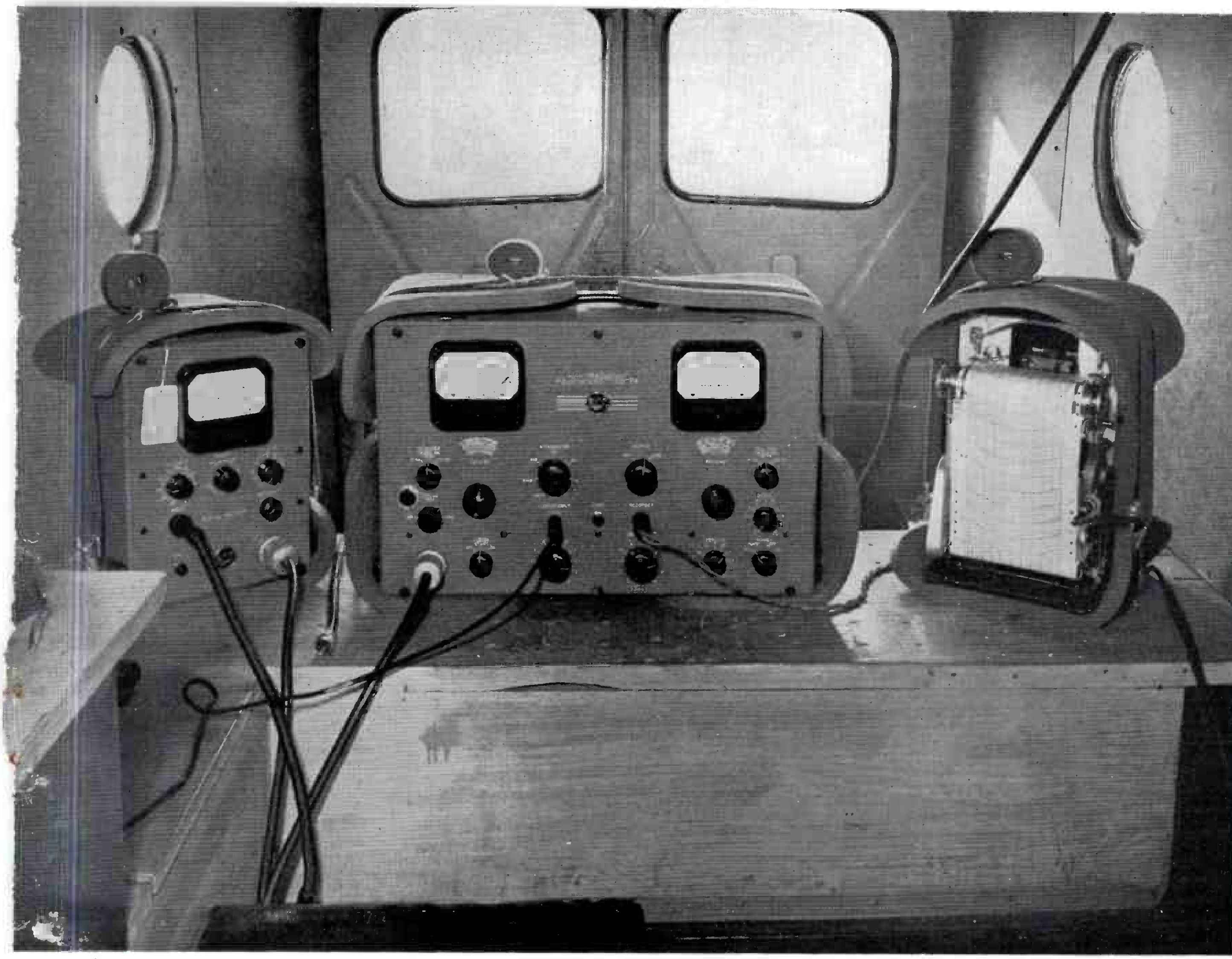


FIG. 2. *The VHF field intensity measuring set mounted in the car and ready for use. At the left is a noise meter.*

indirect method of computing the output power was used, assuming an efficiency of 60 percent for the power amplifier. The operating power then is 0.6 E_p I_p, where E_p is the plate voltage applied and I_p is the total plate current of the last radio-frequency amplifier stage. This results in 36.3 kilowatts being fed to the transmission lines and an effective 41.5 kilowatts being radiated.

The turnstile antenna is mounted on a 200-foot self-supporting tower and has a total effective height to the center of the array of 224 feet. The transmitter, located about 21 miles northwest of Milwaukee proper and about 15 miles inland from Lake Michigan, was described in a previous article.[1]

MEASURING EQUIPMENT

The 50 and 1,000-microvolt contour lines were determined by taking continuous measurements along each of eight radials spaced 45 deg. apart, using an RCA 301-A VHF field intensity measuring set with a 93-A vibrator power unit.

The field intensity meter was designed for measuring field intensities of stations operating in the high-frequency spectrum, for the purpose of checking antenna efficiency, service area and carrying out research or propagation studies. The instrument covers the band of 18 to 125 megacycles and has a range of 10 to 500,000 microvolts when used in the FM band (officially designated as the high-frequency broadcast band). It is designed particularly for field use and consists of three units—the field meter, antenna and power supply. The primary source of power to the vibrator unit is a non-spillable storage battery designed to operate continuously for eight hours without recharging. The recorder was an Esterline-Angus model AW 5-ma instrument.

The equipment was securely mounted on rubber kneeling pads in a Dodge delivery truck, as shown in Figure 2. In addition to these equipments an FM receiver was taken along to monitor the station; this proved valuable at the outer fringe of the service area.

The antenna of the measuring set was mounted on the roof of the field car and the support extended down through to the floor inside. This made it possible to control the antenna from the inside while the field car was in motion. The antenna used at the transmitter is a horizontal turnstile, and consequently similar polarization was used for the car antenna. A marker was attached to the base of the antenna mast and set up to indicate the relative position of the dipole above. This was helpful when the field car made turns along the highway, and minimized time in orienting the antenna. The output of the antenna was

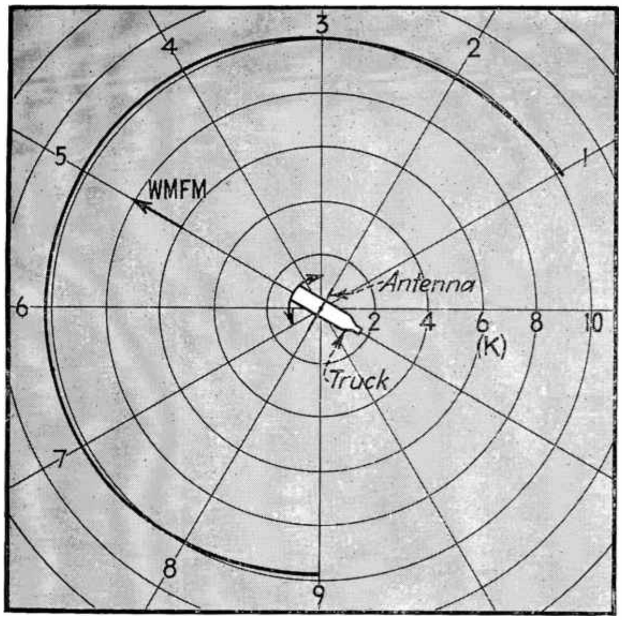


FIG. 3. *Graph showing the variation of the antenna constant with the position of the field car in relation to the direction of the transmitter as the only variable. The dipole antenna was oriented for maximum signal for each new position, and the transmitter power held constant.*

connected by means of a flexible transmission line to the field measuring set, which in turn was connected to the Esterline-Angus recording milliammeter. Figure 1 is a picture of the field car with the antenna mounted in place.

CALIBRATION OF FIELD CAR INSTALLATION

The metal in the truck body made it necessary to check and recalibrate the measuring instrument. Therefore, before the equipment was installed in the field car the measuring set was taken to a location well away from and free of power lines, fences and buildings. The nearest obstacles were more than 300 feet distant. A compass rose was laid out and readings taken to determine the field intensity in this local area. The signal intensity in this open-field area was found to be 1634 microvolts, and no fading existed here to upset the calibration. The antenna length was 54 inches, or about 0.21 wavelength each side of the dipole for the above tests. The height of the antenna was adjusted to 13.5 feet, which was the maximum height of the telescopic support.

A semi-permanent installation was then made in the field car. It was found that the top of the truck body did not present a uniform capacitance back to the antenna as it was rotated over 360 degrees. After several tests it was determined that the antenna had to be elevated slightly more than one-quarter wavelength above the steel top in order to minimize the effect of the truck body. It was deemed necessary to set up and calibrate this variation as the truck body was rotated in relation to the transmitting station. The compass rose previously laid out by driving wooden stakes in a circle was used to recalibrate the unit. Readings were taken at each 30-degree position and the antenna always oriented to deliver the maximum field intensity as the truck body was rotated through 360 degrees. The placement of the antenna with reference to the body of the truck can be seen in Figure 3, which corresponds to the 270-degree position shown in Table I.

The highest signal intensity was received at positions 2 and 8, corresponding to 1577 μv per meter. The lowest signal received was 1520 μv per meter, at positions 4-5-6-7. Prior to the installation on the field car, a signal of 1634 μv per meter was received at this identical location. This represents a reduction of 57 microvolts at positions 2 and 8 and 114 microvolts at 4-5-6-7 when introducing the metallic body of the truck in the field.

CORRECTION OF ANTENNA CONSTANT

From the data in the instruction book furnished with the field intensity instrument it was found that an antenna constant of 9.5 was needed to carry out the computation for the field intensity at 45.5 megacycles. This constant takes care of any losses in the 30-foot transmission line from the dipole to the input terminals of the field meter. Changing this constant was a very convenient way to compensate for any effect that the truck body might have on the pickup antenna. The new constant K was found by the following formula: $K = 1634\ \mu v \div$ attenuator scale $\times$ meter reading in milliamperes.

The field unit was used only for measurements while moving directly away from the transmitting station, and therefore calibrations were made for only the rear and the two sides of the truck, as shown in Figure 4. Positions 2 to 8 were averaged, and resulted in a change of the antenna constant from 9.5 to 10.0. The overall height of the antenna then was permanently fixed on the field car at 13.5 feet above the ground or 6.5 feet above the metal roof. After all the radials were run, the calibration of the measuring set was again checked under the same conditions and found to be the same.

PERCENT MODULATION WAS LOWERED

It should be realized that this method of continuous recording of field intensity is quite different from that used in the regular broadcast band. Here the measurements are generally made at isolated points free of wires and other obstructions, and under favorable conditions. The measuring instrument used was primarily meant for AM use and has a bandwidth of about 50 kc. Modulating the FM transmitter at full 100 percent, corresponding to a swing of ± 75 kc, produced an excessive variation on the field meter. Consequently, during the periods

TABLE I. EFFECT OF TRUCK BODY ON ANTENNA CONSTANT

Position No.	Position Angle	Attenuator Scale	Reading in ma	Field Intensity in uv/m, using K = 9.5	New Antenna Constant K
1	60°	20	8.1	1539	**10.08**
2	30°	20	8.3	1577	**9.85**
3	360°	20	8.2	1558	**9.96**
4	330°	20	8.0	1520	**10.21**
5	300°	20	8.0	1520	**10.21**
6	270°	20	8.0	1520	**10.21**
7	240°	20	8.0	1520	**10.21**
8	210°	20	8.3	1577	**9.85**
9	180°	20	8.3	1577	**9.85**

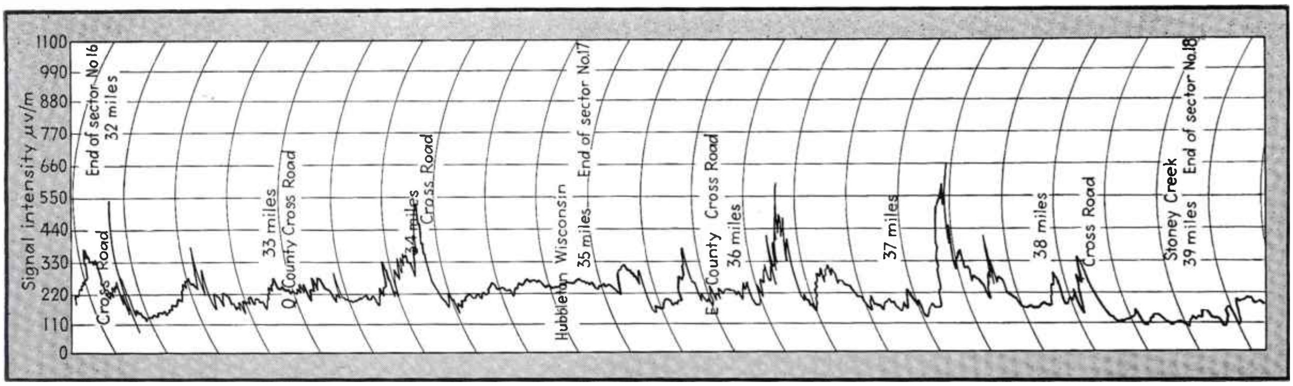


FIG. 4. *Signals recorder with equipment shown in Figures 1 and 2.*

that the measurements were being taken, the overall percentage of modulation was dropped by lowering the audio input to the transmitter until satisfactory stability was obtained. This was achieved by lowering the input 4 to 5 db. Satisfactory monitoring of the program modulation could not be obtained with this amplitude instrument so the signal was monitored on the FM receiver which was carried along. (Editor's Note: In the new RCA 301-B Field Intensity Meter a broad-band pass is provided so that measurements can be made without reducing modulation).

FIELD WORK AND ROUTES

In planning for the runs on each of the eight radials, care was taken to see that they were carried well beyond points of predicted service, so as to arrive at a sufficiently accurate determination of the contour boundary. This is particularly important at the 50-microvolt contour because of distance to be re-travelled if the field records are found to be incomplete. The radials were spaced approximately 45 degrees about the transmitter.

The survey was conducted only during the daylight hours. While driving along the radials a uniform driving speed of 15 miles per hour was maintained and a sufficient number of landmark and roadway notations were written on the record for later chart analysis. These locations were noted on the chart as often as necessary, so it was easy to determine the exact location of the field car when the chart analysis was made later on. This definitely fixed the relation of the car location to the measured field intensity. Figure 4 shows a record taken on radial 6 between sectors 16 and 18, corresponding to 32 and 39 miles from the transmitter.

In choosing the routes for the car, roads were chosen that ran parallel (or nearly so) to the radials, as deviations of the topography can cause a great difference in the recorded results. The routes traveled by the field car in relation to each radial are shown in Figure 5. In some cases wide deviations from the radials were necessary because of rivers and their lack of bridges. This was the case on radial No. 1 where it was impossible to cross the Milwaukee River. Another case was on radial No. 5 at Janesville, where the Rock River interfered. On the northwest radial a large area known as Horicon Marsh made passage impossible. Most township roads run east and west, with very few diagonal roads, hence trouble was also experienced with the radials going northwest, southwest and northeast. On the southeast radial a diagonal highway, U.S. 41, ran directly along the radial and through the city of Milwaukee.

The antenna height above the car proved to be rather awkward during the field runs and trouble was experienced, particularly on country roads. The antenna had to be replaced several times because of the driver's inability to spot electric fence wires strung rather low across the highway, or because of overhanging branches. One radial per day was all that could be accomplished. This was partially due to the regular program schedule which began at noon and therefore necessitated a late start.

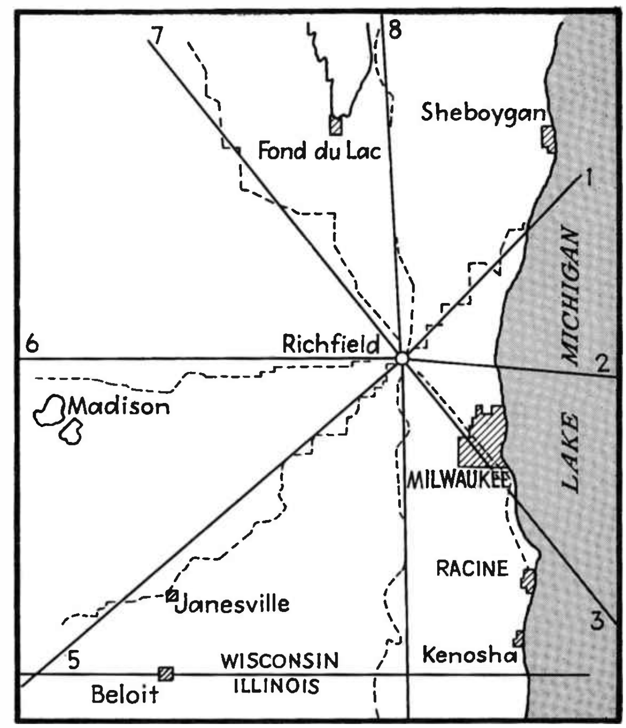


FIG. 5. *Map of the eight radials, showing the deviation of the routes traveled by the field car (dashed lines) with respect to the radials.*

PREDICTED vs. MEASURED RESULTS

After the measurements were completed, the charts from the recording meter were analyzed. The first step was to divide them into sections, each representing a sector of a radial along the topographic map. Each sector was not more than one-tenth of the service radius or not more than five miles in maximum length. The charts of the field intensities were analyzed to determine the electric field intensity obtained 50 percent of the distance along each sector. This will be referred to as the median field intensity for antenna height of 13.5 feet. The value is asso-

TABLE II. RADIAL NO. 8 — N 354.5° E

Sector Number	Attenuator Setting	Dist. to End of Sector	Median Field Reading	Median Field at 13.5 ft. = uv/m	Median Field at 30 ft. = uv/m	Max. Field Reading	Max. Field at 30 ft. = uv/m
1	2	3	4	5	6	7	8
1	10,000	0.6	8.0	800, 000	1,760,000	10.0	2,200,000
2	10,000	1.0	4.0	400, 000	880,000	7.0	1,540,000
3	10,000	2.4	2.0	200, 000	440,000	4.3	950,000
4	2,000	3.5	3.0	60, 000	132,000	7.2	316,000
5	500	5.0	4.0	20, 000	44,000	8.5	93,500
6	500	7.0	5.2	26, 000	57,400	9.5	104.000
7	500	9.0	2.5	12, 500	27,500	5.0	55,000
8	500	10.6	1.8	9, 000	19,600	3.4	37,400
9	100	12.5	3.5	3, 500	7,700	7.6	16,700
10	100	16.0	1.5	1, 500	3,300	5.6	12,300
11	20	20.0	6.4	1, 280	2,820	9.6	4,200
12	20	25.0	5.1	1, 020	2,250	9.8	4,300
13	20	27.5	4.0	800	1,760	7.6	3,350
14	20	32.5	2.6	520	1,140	9.0	3,960
15	20	36.0	1.5	300	660	3.9	1,720
16	5	40.0	4.0	200	440	10.0	1,100
17	5	42.5	5.0	250	550	10.0	1,100
18	5	45.5	1.8	90	196	6.6	722
19	1	50.0	5.5	55	121	10.0	220
20	1	55.0	6.2	62	136	9.6	212
21	1	60.0	6.0	60	132	10.0	220
22	1	65.0	1.5	15	33	4.0	88
23	1	70.0	2.0	20	44	6.1	134

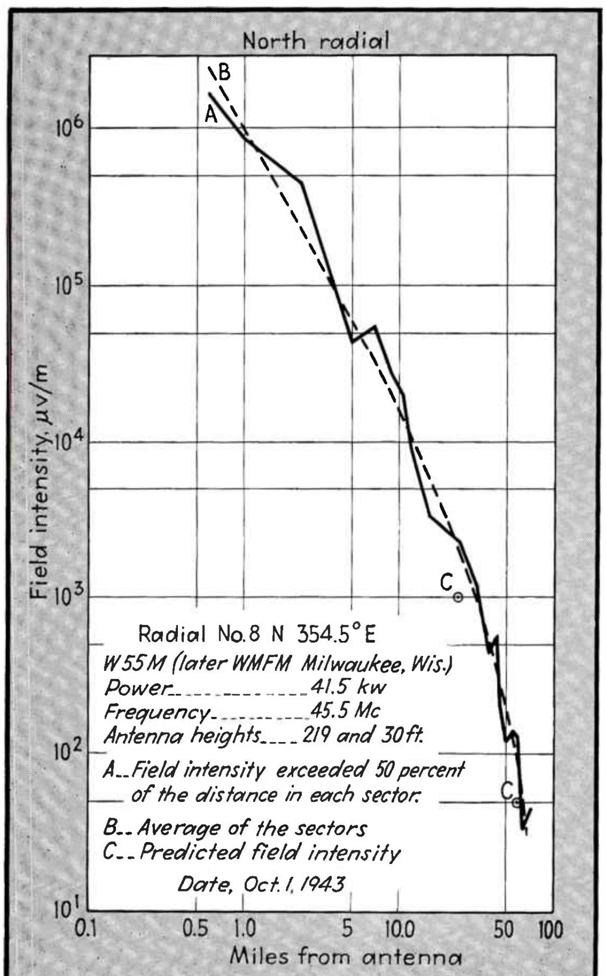


FIG. 6. *Graph constructed from data given in Table II. Similar graphs were made for each of the other seven radials.*

ciated with each particular sector and is presented in tabular form. An example of one of these tabulations, shown in Table II, was compiled from the data taken along radial 8.

Column 1 of Table II is the sector number. The next column is the attenuator setting on the field meter. Column 3 shows the distance from the transmitter to the end of each sector. Column 4 is the median field reading in milliamperes 50 percent of the distance along each sector. The fifth column is the field intensity already computed directly in microvolts at 13.5 feet. This is the product of column 2 and column 4 multiplied by the fixed antenna constant of 10.0. Column 6 is the median field intensity at 30.0 feet. Since the field intensity is directly proportional to the antenna height (above ¼ wavelength) for horizontal polarization, a factor of 2.2 was used to interpolate the field intensity values from 13.5 to 30 feet. Column 7 shows the maximum field reading in milliamperes in each sector for an antenna height of 13.5 feet. The last column is the maximum field intensity obtained about 10 percent of the distance at 30 feet, and represents the peak signal value in each sector.

For reference and comparison purposes the value of field intensity are referred back to an antenna height of 30 feet, since this is the height specified by the Standards of Good Engineering Practice. In addition, this is the receiving antenna height at which all the calculations were made for the original construction permits of the station.[3,4,5,6]

From column 6 of Table II, the values of field intensity in microvolts per meter at 30 feet were plotted graphically against distance in miles from the transmitter. One of the eight graphs is shown as Figure 6. The solid line is the measured signal intensity 50 percent of the distance in each sector. The dashed line represents an average struck to obtain the signal intensity at any intermediate distance. Indicated also are the two predicted contour points, shown by the letter notation *C*. It is evident that on this radial both contours fell inside the calculated distance.

A comparison of measured and predicted values of field intensity at WMFM for all eight radials is shown in Table III.

TABLE III. COMPARISON OF PREDICTED AND MEASURED CONTOURS FOR WMFM

Data for 1000-μv/m Contour

Radial	Bearing	Average Elev.	Eff. Ant. Height	Predicted Distance	Measured Distance
1	N 45°E	800 ft.	479 ft.	29.1 mi.	31.0
2	N 96 E	685	594	31.5	In Lake
3	N 140 E	745	534	30.8	31.0
4	N 180 E	913	366	26.5	28.2
5	N 231 E	946	333	25.5	25.6
6	N 270 E	979	300	24.8	23.0
7	N 320 E	1030	249	23.0	24.5
8	N 354.5 E	995	284	24.1	31.5

Data for 50-μv/m Contour

Radial	Bearing	Average Elev.	Eff. Ant. Height	Predicted Distance	Measured Distance
1	N 45°E			In L. Mich.	
2	N 96 E			In L. Mich.	
3	N 140 E			In L. Mich.	
4	N 180 E	837 ft.	442 ft.	66 mi.	64 mi.
5	N 231 E	891	388	64.5	64.5
6	N 270 E	932	347	62.5	58.0
7	N 320 E	982	297	60.5	59.0
8	N 354.5 E	1000	279	60.0	65.0

Each contour distance was tabulated along with the predicted distances as stated in the construction permit issued by the FCC. Notice that the 50 μv per meter contour to the northeast, east and southeast falls in Lake Michigan and could not be measured.

Figure 7 shows the map constructed from the data given in the previous chart. The solid lines on the map represent the predicted 50 and 1,000-microvolt contours, while the dashed lines show the actual measured contours.

The 5 and 2.5-millivolt contour lines are not drawn on the map, but Table IV shows the distances at which these lines fall.

TABLE IV. DISTANCES TO CONTOURS

5 Millivolt Radial	Miles	2.5 Millivolt Radial	Miles
1	17.0	1	27.0
2	14.0	2	....
3	17.5	3	22.8
4	15.0	4	20.0
5	12.5	5	17.6
6	12.0	6	16.0
7	13.0	7	17.0
8	16.6	8	22.0

The total area covered by the transmitter is about 12,000 square miles. Thirty percent of this area falls in Lake Michigan, as may be seen by referring to the map. The Milwaukee trade area extends many more miles to the north and west than it does to the south.

ANALYSIS OF DISCREPANCIES

The predicted area, not including the lake, was 8,500 square miles, which is the area specified in the present license for WMFM. The actual measured area inside the 50-microvolt per meter contour was 8,400 square miles or a decrease of about one percent. The area inside the 1,000 microvolt per meter contour was predicted at 1,860 square miles and the measured area was found to exceed this by 90 square miles or an increase of about five percent. This discrepancy between calculated and actual values is attributed to the inability to obtain accurate values of elevation of the topography to the north on radial No. 8 when the prediction was made for the construction permit. It is along this radial where the predicted signal was exceeded. This section of the state of Wisconsin had never been surveyed and therefore there were no quadrangle maps. The records available gave only such sparse data as the positions of railroad stations, airport elevations and the like. The data on the area was computed by the use of a planimeter on the original airway map.

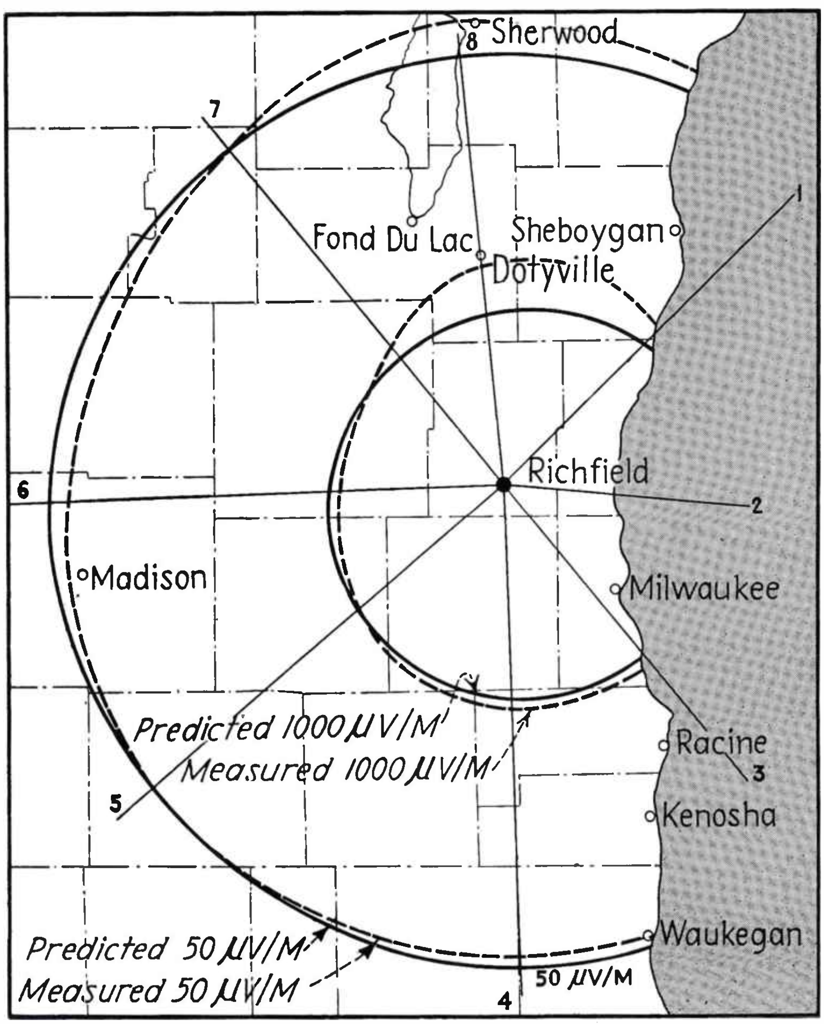


FIG. 7. *Map showing the measured 50 and 1000-microvolt contours as heavy dashed lines. The solid line represents the predicted contours. The primary service extends to the far side of the city of Milwaukee and its southern suburbs.*

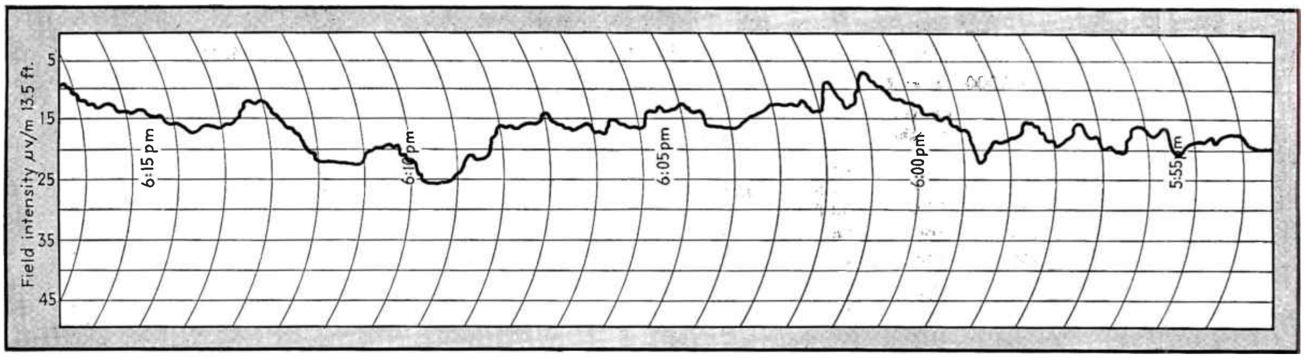


FIG. 7. *Record of the fading of Sherwood, Wisconsin, on radial No. 8 at a point 65 miles from the transmitter and just barely inside the service area of WMFM.*

Within the 1,000-microvolt contour, the population was estimated at 834,607 based on the 1930 census figures. The predicted and measured distances to the service contours on the various radials are essentially the same with the exception of radial 8. The contour distance at this point extends about 7 miles farther out but no city of any size is included in this additional area. This small variation from the predicted contour makes no appreciable change in the population served by the station.

Within the 50-microvolt contour, the population is estimated at 1,522,544. In general, the measured results show the 50-microvolt line to be 2 to 3 miles inside the predicted distance. Exception again is made in the case of the north radial 8, where the measured distance exceeded the predicted by 6 miles. This variation makes no appreciable change in the population figures within the 50-microvolt service area.

At the 50-microvolt point, noticeable fading existed on several radials. This tended to influence the analysis of the field measurements and resulted in a lower than predicted value of field intensity in some areas. Milwaukee proper and its suburbs has a population of 766,885 and makes up the major market area of the station.

"Now arch the chest . . . like *this* . . . and I *do* mean *you*."

FADING

In conclusion, a few words on the stability of the signal intensity at the outer fringe of the service area and points closer may be of interest since experience has shown that appreciable fading can exist. After reaching the end of a particular radial a few minutes were spent checking the approximate placement of the 50-microvolt contour. This was done so that on the return trip along the same route a suitable spot could be picked as close to the contour as possible for a spot check on signal fading. A position was chosen for these checks which was representative of the country traveled and which was also free of wires, rather than a position suitable for high or low signal intensity.

One recording location was at Dotyville, on radial 8, just outside the 1,000-microvolt or primary contour line. It gave a signal of 225 microvolts maximum and 160 minimum at 13.5 feet. This is an overall variation of 65 microvolts with a median signal of 200 microvolts. The distance to this point from the transmitting antenna was 34 miles.

Another location at which fading was observed is at Sherwood, also on radial 8, but near the 50-microvolt or secondary service contour. The distance here was 65 miles to the transmitter. The signal reached a maximum of 25 microvolts and a minimum of 7 with a median signal of 17 microvolts over a period of 22 minutes, as shown in Figure 8. These checks were made with an effective antenna height of 13.5 feet, and to be correct should be multiplied by a factor of 2.2. In conclusion, it would seem that in view of the variable signals at the outer fringe of the service area caused by troposhperic conditions, a cross hatched zone indicating the limits of the variations should be used, instead of a narrow line for the 50 uv/m contour. Also, because of this variation in signal voltage received at any similar fixed location, measurements on each radial should be made and averaged over a much greater period of time.

References

[1] Laeser, P. B., "Planning an FM Station," ELECTRONICS, p. 92, February, 1945.

[2] Federal Communications Commission, "Standards of Good Engineering Practice for High Frequency Broadcast Stations," Annex II.

[3] Federal Communications Commission, "Field Intensity Survey of Ultra High Frequency Broadcasting Stations," Bulletin 40004.

[4] Singer, Charles, "Field Strength Survey Methods," FM RADIO AND TELEVISION, February and March, 1942.

[5] Guy, Raymond F., "Frequency Modulation Field Tests," RCA REVIEW, October, 1940.

[6] Norton, K. A., "Ground Wave Field Intensity Over Finitely Conducting Spherical Earth," I.R.E., 29, No. 12, p. 623, December, 1941.

THE TYPE 301-B FIELD INTENSITY METER

By
K. B. REDDING
Engineering Products Department

FIG. 1. *The 301-B High Frequency Field Intensity Meter.*

The RCA Type 301-B Field Intensity Meter has been designed as a portable instrument for measuring field intensities of amplitude and/or frequency modulated signals in the range of 18 to 125 megacycles. It consists of three units; the receiver (Figure 1), an accessory case containing a dipole, tripod and associate connecting cables (Figure 2), and the power supply (Figure 4).

The receiver unit of the Field Intensity Meter is a superheterodyne employing acorn type tubes in the local oscillator, first detector and calibrating oscillator circuits. Incoming signals are fed from the transmission line to the receiver through a resistance matching network and, in turn, connected to a coupling coil which is in mutual relation with the first detector-tuned circuit. A different coupling coil is used on each band, connections to these coils being changed by means of RECEIVER RANGE switch controlled from the front panel.

Three stages of i-f amplifications are used with a capacitance attenuator between the first detector and first i-f stage. The first i-f transformer is designed to permit either sharp or broad band operation. The RESPONSE switch located on the front panel is set on SHARP for amplitude-modulated signals and on BROAD for frequency-modulated signals. Two stages of the i-f amplifier are provided with automatic volume control to obtain logarithmic response of the output meter. Gain of the i-f amplifier is controlled by varying the cathode voltage of the last stage.

The diode portion of an RCA 6R7 tube (Figure 3 symbol V5) serves as the second detector for both amplitude and frequency-

FIG. 2. *Accessory Case of the 301-B Equipment. Mounted in the lid are the sections of the extendable dipole. In the lower part of the case are the mounting tripod and the connecting cable.*

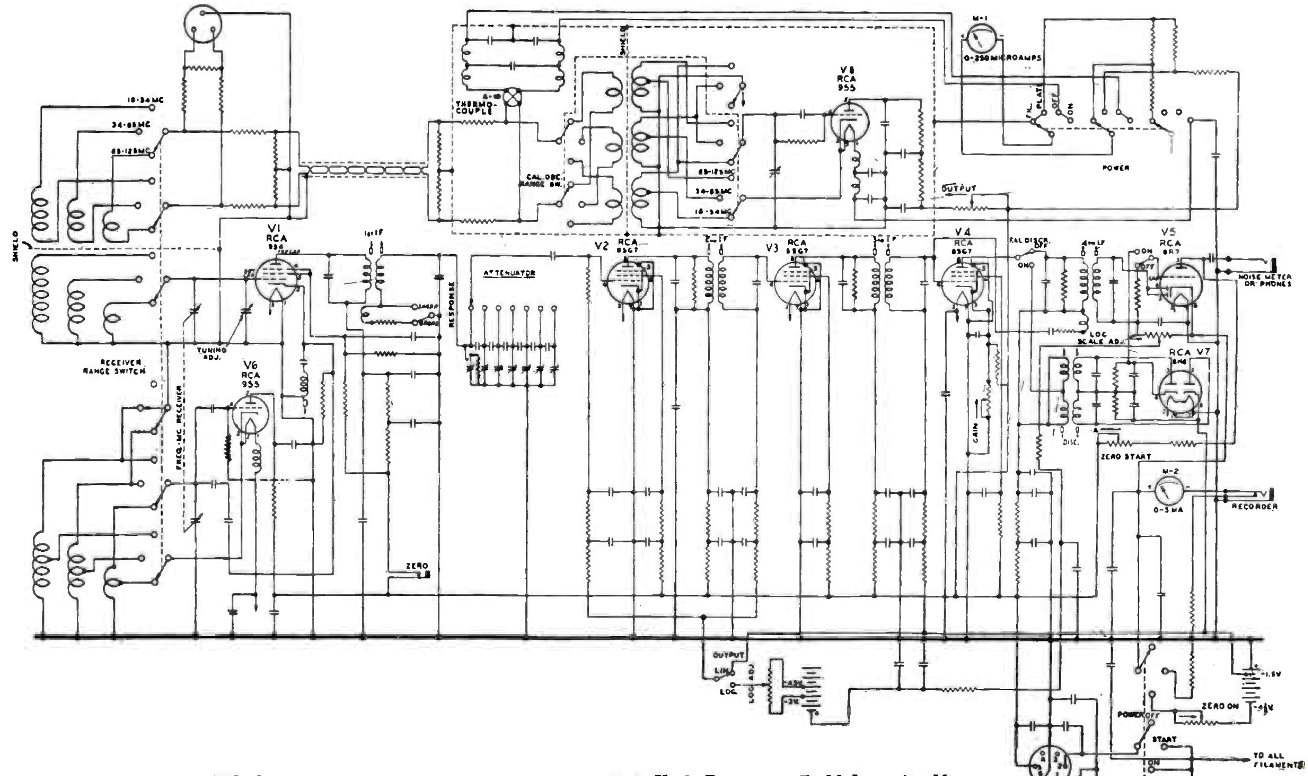


FIG. 3. *Schematic diagram of the RCA Type 301-B High Frequency Field Intensity Meter.*

modulated signals. The output of the diode is amplified by the triode section for monitoring or noise measurement. The output meter is connected in the cathode circuit of the RCA 6R7 tube. An RCA 6H6 (V7) double diode and discriminator transformer are used as a demodulator for FM signals when it is desired to tune the receiver audibly to the station.

An internal oscillator (V8) is incorporated in the receiver to supply a calibrating source of voltage. The output of the calibrating oscillator is measured with a vacuum-type thermocouple (A10) and is fed into the input coupling coil of the receiver through a resistance matching pad. With this system a standard sensitivity can be maintained over the entire frequency range.

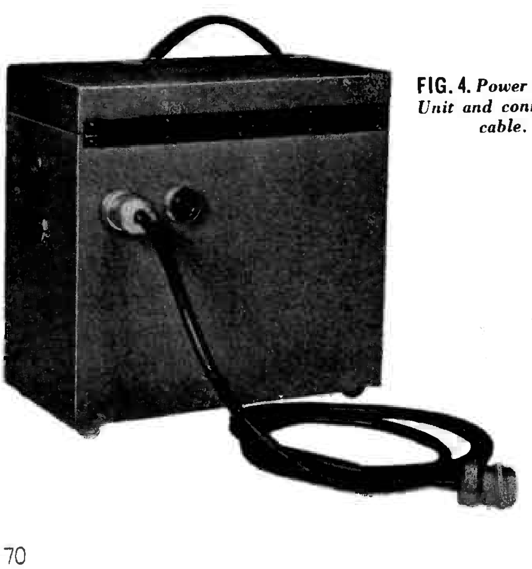


FIG. 4. *Power Supply Unit and connecting cable.*

The frequency range of 18 to 125 megacycles is covered in three bands. A single dial control and trimmer adjustment are employed to tune the receiver to the desired frequency after the range has been selected. The measurement range of field intensities of the instrument varies with frequency almost in direct relation to the effective height of the antenna. The minimum readable field strength at 18 megacycles is 5 microvolts-per-meter and at 125 megacycles it is 100 microvolts-per-meter. The highest full scale range is about 0.1 volt per meter at 18 megacycles and approximately 2.0 volts-per-meter at 125 megacycles. The output indicator is a four inch, 5 milliampere meter providing both linear and logarithmic readings. The linear scale covers a range of 20 db or 10-to-1, whereas the logarithmic scale covers a range of 40 db or 100-to-1. Derivation of field intensities from the measurement data requires only one process of multiplication.

A recording milliameter having a sensitivity of 5 milliamperes and a resistance not greater than 560 ohms may be operated directly from the instrument on either linear or logarithmic output. A jack is located on the front panel for headphones to monitor the signal. Provisions have been made to check both the d-c filament and plate voltages without the use of external meters.

A doublet comprised of 4 fixed and 2 variable sections is provided and may be adjusted in length for any frequency within the range of the receiver. For frequencies above 37.5 megacycles it is necessary to use only the telescopic sections. Since the antenna for this equipment may be fixed in a vertical position, it is equipped with an insulated supporting tripod extendable to a height of 137 inches, which is sufficient to accommodate the longest doublet required (Figure 5).

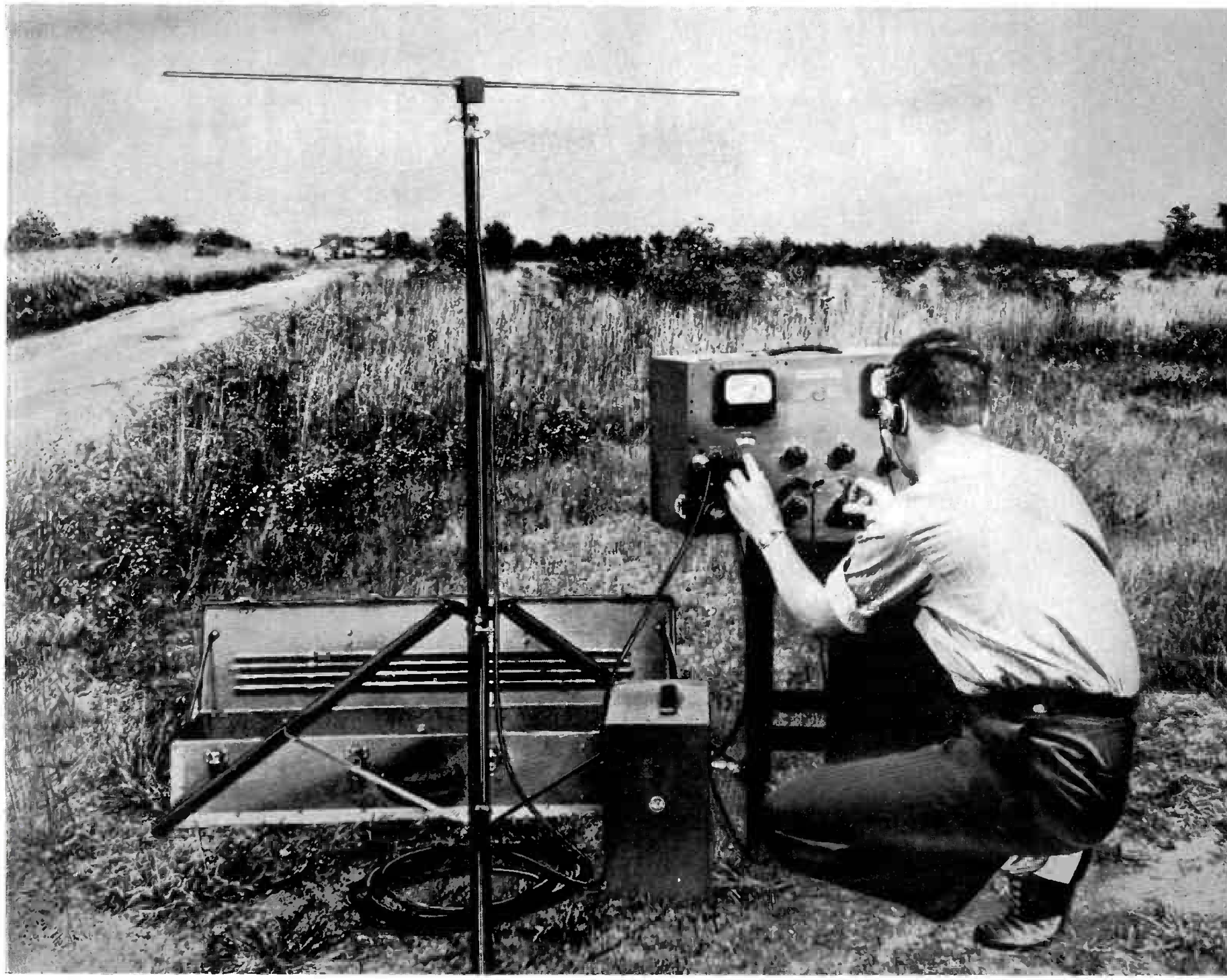


FIG. 5. *The complete 301-B Equipment set up for making a spot reading in the field.*

The dipole is connected to the receiver input by means of a specially designed weather-proof, shielded transmission line 30 feet in length.

Both the filament and plate voltages for the receiver are supplied by the RCA Type 93-A Vibrator Power Unit (Figure 6). This is essentially an energy conversion device furnishing high d-c voltage for plate excitation from a 6-volt storage battery which is contained within the case and is of the non-spillable, airplane type capable of approximately eight hours continuous operation of the receiver without recharging. Plate and filament leads are brought out to two receptacles which are wired in parallel, permitting the use of two pieces of equipment such as the field intensity meter and noise meter simultaneously. A cable for connecting the power supply to the receiver is included.

Direct-current, high potential is produced by means of a vibrating type interrupter and rectifier used in conjunction with a step-up transformer. A conventional filter in the rectified output circuit reduces the hum to a very low value.

The voltage regulator tube (RCA OD3/VR150) maintains a steady potential of 150 volts; it is connected across the output through a tapped resistor, one section of which may be short-circuited by a HI-LO toggle switch to utilize the maximum output lead current.

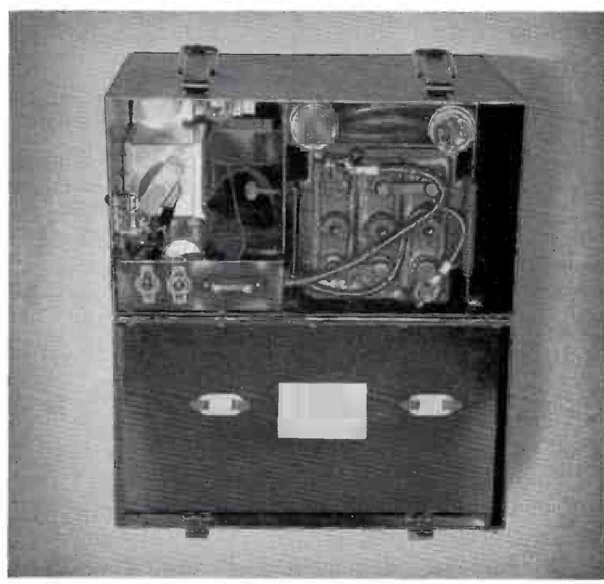


FIG. 6. *The Power Supply Unit contains a storage battery and a vibrator power unit.*

A DISCUSSION OF FM FIELD SURVEY METHODS AS OUTLINED IN THE FCC'S

"Standards of Good Engineering Practice Concerning FM Broadcast Stations"

The two articles on FM field survey methods which are printed in this issue of BROADCAST NEWS (Pages 54 and 62) are based on surveys made previous to the promulgation of the new FCC "Standards" in September 1945. Because the methods outlined are still generally applicable (and the suggestions on equipment and technique are of considerable value) it was decided to print these articles even though the procedures followed differ slightly from those outlined in the new Standards. However, the engineer proposing to make a survey now, or in the near future, should carefully note these differences and keep them in mind in making his plans. For convenience, the section of the standards referring to field intensity measurements is printed on the opposite page. It is suggested that those who have not previously read this section do so before continuing with this discussion.

METHODS OF MAKING MOBILE RECORDINGS

The second paragraph of Section 5 (opposite page) describes the equipment and procedure to be followed in making mobile

(Cont. on Page 74)

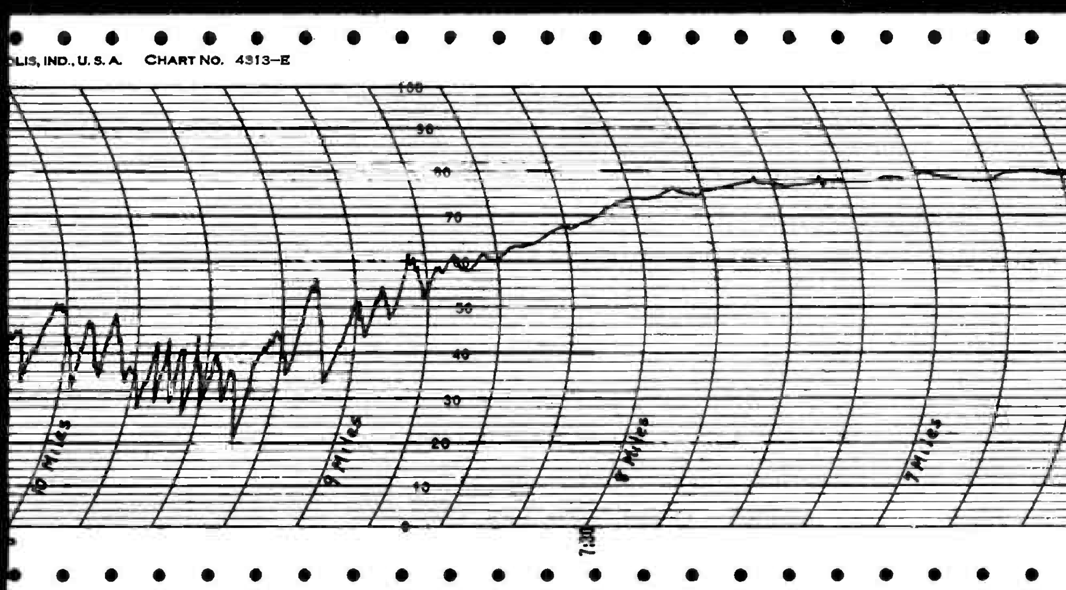


FIG. 1. *Section of a typical field intensity chart recording on an FM station.*

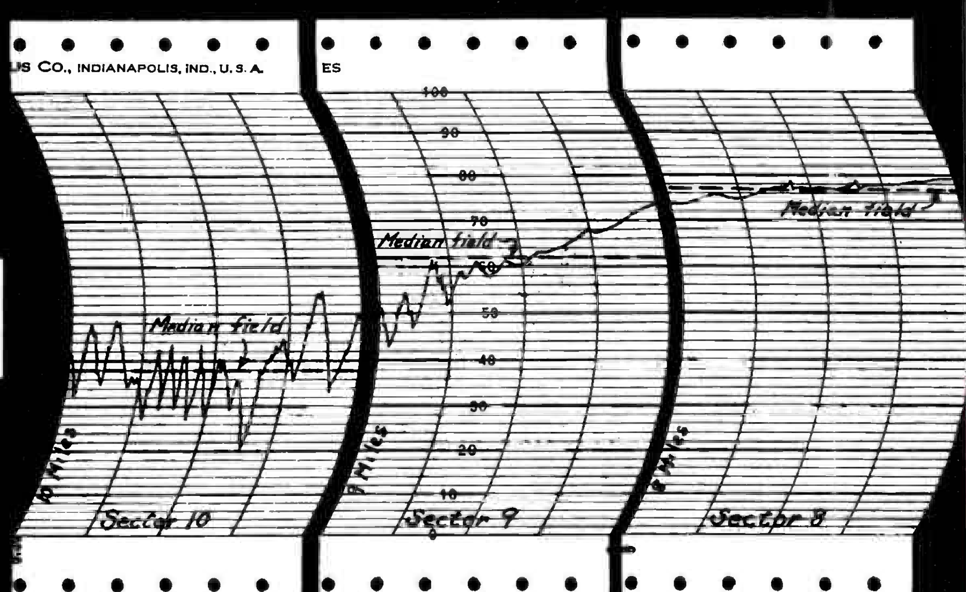


FIG. 2. *The above chart divided into sectors as described in the "Standards."*

Reprint of Section 5 of the

STANDARDS OF GOOD ENGINEERING PRACTICE CONCERNING FM BROADCAST STATIONS

5. Field Intensity Measurements in Allocation

When field intensity measurements are required by the Commission's rules or when employed in determining the extent of service or interference of existing stations, such measurements should be made in accordance with the procedure outlined herein.

Measurements made to determine the service and interference areas of FM broadcast stations should be made with mobile equipment along roads which are as close and similar as possible to the radials showing topography which were submitted with the application for construction permit. Suitable measuring equipment and a continuous recording device must be employed, the chart of which is either directly driven from the speedometer of the automobile in which the equipment is mounted or so arranged that distances and identifying landmarks may be readily noted. The measuring equipment must be calibrated against recognized standards of field intensity and so constructed that it will maintain an acceptable accuracy of measurement while in motion or when stationary. The equipment should be so operated that the recorder chart can be calibrated directly in field intensity in order to facilitate analysis of the chart. The receiving antenna must be non-directional and of the same polarization as the transmitting antenna. Mobile measurements should be made with a minimum chart speed of 3 inches per mile and preferably 5 or 6 inches per mile. Locations shall be noted on the recorder chart as frequently as necessary to definitely fix the relation between the measured field intensity and the location. The time constant of the equipment should be such as to permit adequate analysis of the charts, and the time constant employed shall be shown. Measurements should be made to a point on each radial well beyond the particular contour under investigation. The transmitter power shall be maintained as close as possible to the authorized power throughout the survey.

After the measurements are completed, the recorder chart shall be divided into not less than 15 sections on each equivalent radial from the station. The field intensity in each section of the chart shall be analyzed to determine the field intensity received 50 percent of the distance (median field) throughout the section, and this median field intensity associated with the corresponding sector of the radial. The field intensity figures must be corrected for a receiving antenna elevation of thirty feet and for any directional effects of the automobile not otherwise compensated. This data should be plotted for each radial, using log-log coordinate paper with distance as the abscissa and field intensity as the ordinate. A smooth curve should be drawn through these points (of median fields for all sectors), and this curve used to determine the distance to the desired contour. The distances obtained for each radial may then be plotted on the map of predicted coverage or on polar coordinate paper (excluding water areas, etc.) to determine the service and interference areas of a station.

In making measurements to establish the field intensity contours of a station, mobile recordings should be made along each of the radials drawn in section 2 E above. Measurements should extend from the vicity of the station out to the 1000 uv/m measured contour and somewhat beyond (at the present time it is not considered practical to conduct mobile measurements far beyond this contour due to the fading ratio at weak fields, which complicates analysis of the charts). These measurements would be made for the purpose of determining the variation of the measured contours from those predicted, and it is expected that initially the correlation of the measured 1000 uv/m with the predicted 1000 uv/m contour will be used as a basis in determining adherence to authorized service areas within the 50 uv/m contour. Adjustment of power or antenna may be required to fit the actual contours to that predicted.

In addition to the 1000 uv/m contour, the map of measured coverage shall show the 50 uv/m contour as determined by employing Figure 1 and the distance to the 1000 uv/m contour along each radial. The sliding scale shall be placed on the figure at the appropriate antenna height for the radial in question and then moved so the distance to the 1000 uv/m contour (as measured) and the 1000 uv/m mark are opposite. The distance to the 50 uv/m contour is then given opposite the 50 uv/m mark on the scale. In predicting tropospheric interference on the basis of the above measurements, such measurements shall be carried out in the manner indicated above to determine the 1000 uv/m contour. Using Figure 1 and its associated sliding scale, the equivalent radiated power shall be determined by placing the sliding scale on the chart (using the appropriate antenna height) and moving the scale until the distance to the 1000 uv/m contour (as determined above), and the 1000 uv/m mark are opposite. The equivalent radiated power is then read from the sliding scale where it crosses the lower line of the top edge of the chart. Changing to Figure 2 and using the equivalent radiated power just determined, the distance to the interfering contour under investigation is read in the usual manner.

In certain cases the Commission may desire more information or recordings and in these instances special instructions will be issued. This ma yinclude fixed location measurements to determine trophosperic propagation and fading ratios.

Complete data taken in conjunction with field intensity measurements shall be submitted to the Commission in affidavit form, including the following:

A. Map or maps showing the roads or points where measurements were made, the service and/or interference areas determined by the prediction method and by th measurements, and any unusual terrain characteristics existing in these areas. (This map may preferably be of a type showing topography in the area.)

B. If a directional transmitting antenna is employed, a diagram on polar coordinate paper showing the predicted free space field intensity in millivolts per meter at one mile in all directions. (See Section 7.)

C. A full description of the procedures and methods employed including the type of equipment, the method of installation and operation, and calibration procedures.

D. Complete data obtained during the survey, including calibration.

E. Antenna system and power employed during the survey.

F. Name, address, and qualifications of the engineer or engineers making the measurements.

All data shall be submitted to the Commission in triplicate, except that only the original or one photostatic copy need be submitted of the actual recording tapes.

(Cont. from Page 72) GROUNDWAVE FIELD INTENSITY GRAPH

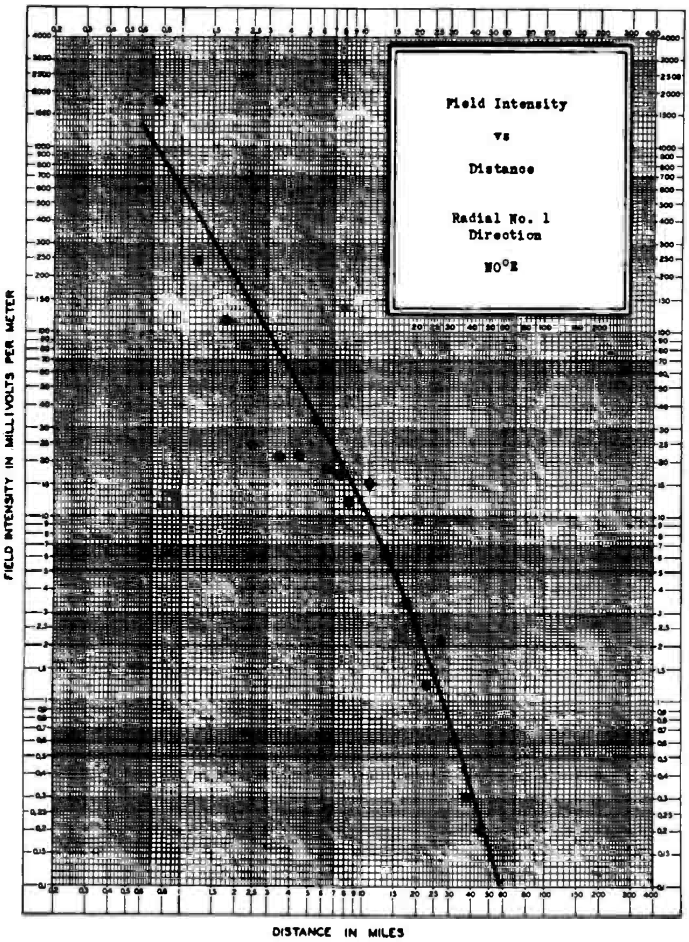


FIG. 3. *Median signal intensities for each sector are plotted against distance on log-log paper.*

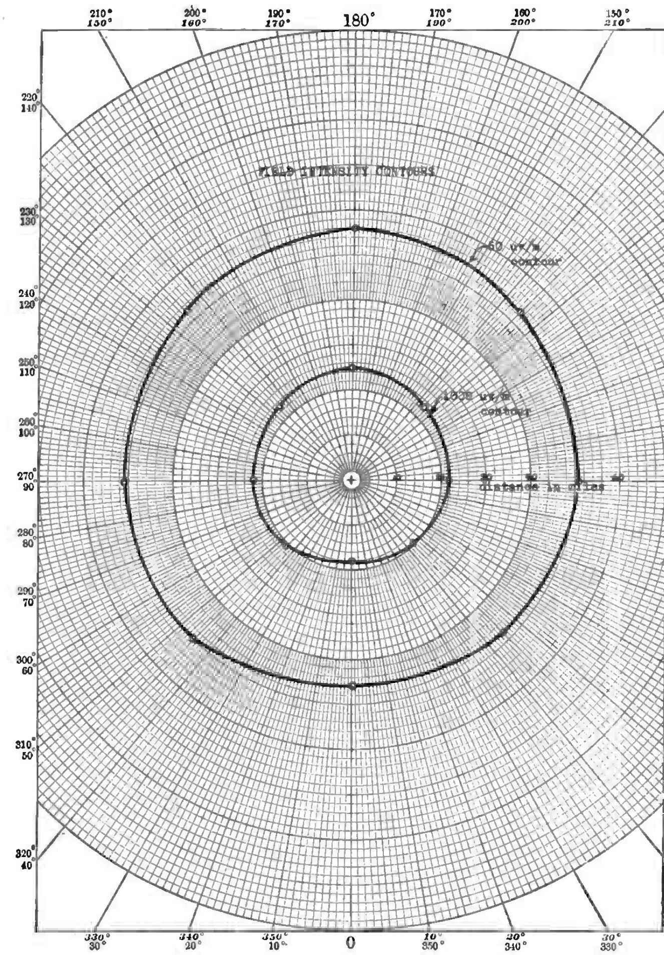


FIG. 4. *Distances to 1000-microvolt and 50-microvolt contour in various directions plotted on polar paper.*

recordings as part of an FM Survey. In general, the procedures followed by Klingaman and Laeser in the surveys mentioned above comply with the requirements specified in this paragraph. The RCA Type 301-B Field Intensity Meter (which provides for making FM measurements without necessity of reducing modulation) is the most suitable instrument for the purpose. The recorder used, and the method of driving it as described by Klingaman (Page 54), is also satisfactory. Specified requirements as to chart speed should be noted.

One new requirement in the standards is that "the receiving antenna must be non-directional." In the past, the practice has been to mount the dipole furnished with the 301-B Field Intensity Meter on the top of the field survey car and provide some means for manually keeping the broad side directed toward the transmitter. Since this apparently will not be satisfactory under the new standards it will be necessary to provide a separate antenna specially built for the purpose. For the time being, at least, such an antenna can best be constructed by the individual user (to fit whatever type of car or truck he proposes to use). Several possible constructions suggest themselves. One would be a square-loop type antenna such as that described in a previous issue of BROADCAST NEWS (August 1944, Page 14). A single loop of this type, mounted a quarter-wave above the roof top should give an approximately non-directional pattern. An antenna of this or other types can be used with the 301-B Field Intensity Meter, providing the connections to it are made in such a manner as to reflect the correct impedance (125 ohms) into the connection cable supplied with the 301-B. It will also be necessary, of course, to determine a proportionability or "calibration" factor for the new antenna by making careful comparisons and readings obtained using the regular dipole antenna. This should be done at an "open" location where the received signal is strong and steady. A procedure similar to that described by Klingaman on Page 57 should be followed in making this calibration.

METHOD OF ANALYZING RECORDINGS

The third paragraph of Section 5 of the new Standards specifies the manner in which the recordings, made as above, are to be analyzed. Previously, this was left to the discretion of the individual and several different ways are suggested by Klingaman and Laeser. Now, the FCC requires that the chart for each radial be divided into not less than fifteen sectors and the "median" signal intensity determined for each sector. A part of such a chart is shown in Figure 1. In Figure 2 this chart has been divided into three sectors. Although the Standards do not say so, it is desirable to vary the length of these sections, increasing them as the distance from the station increases (since the rate of signal decrease is much less at a distance). A practical choice is to make the sectors 1 mile each up to 10 miles, 2 miles each from 10 to 20 miles, and 5 miles each beyond 20 miles.

When the charts have been divided into sectors in this way, each sector is analyzed to determine the "median field" over that section. This "median field" is the value received or exceeded throughout 50 percent of the distance. Where the curve is fairly regular, as in Sectors 8 or 9 of Figure 2, this value can be determined with accuracy by "counting squares" or planimetering.

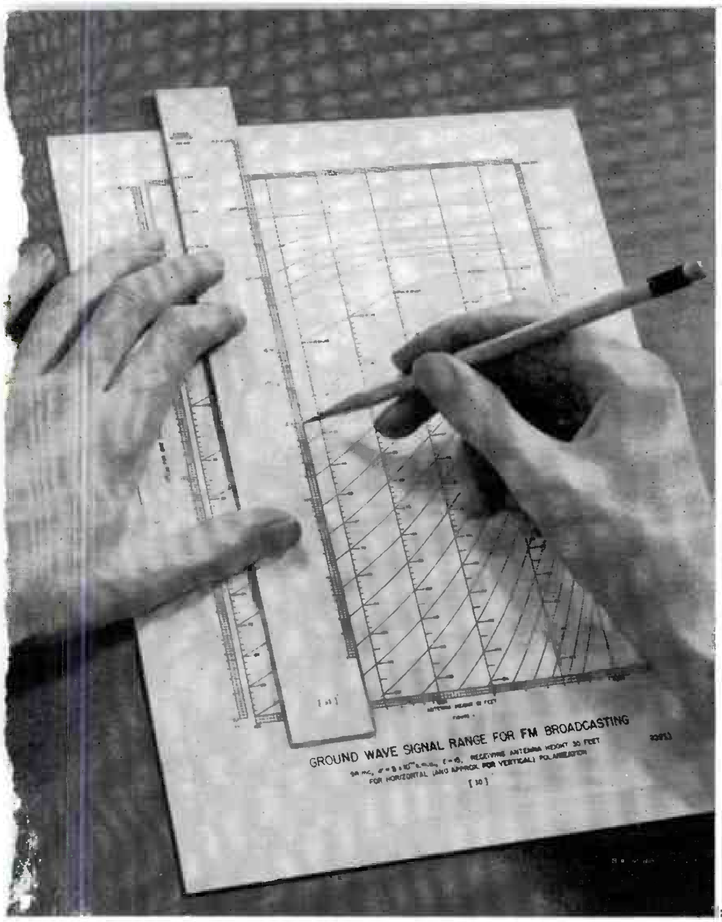


FIG. 5. *First step in determining 50-microvolt area is to set scale on vertical line corresponding to height, and move vertically until 1000-microvolt point corresponds to calculated distance to 1000-microvolt line.*

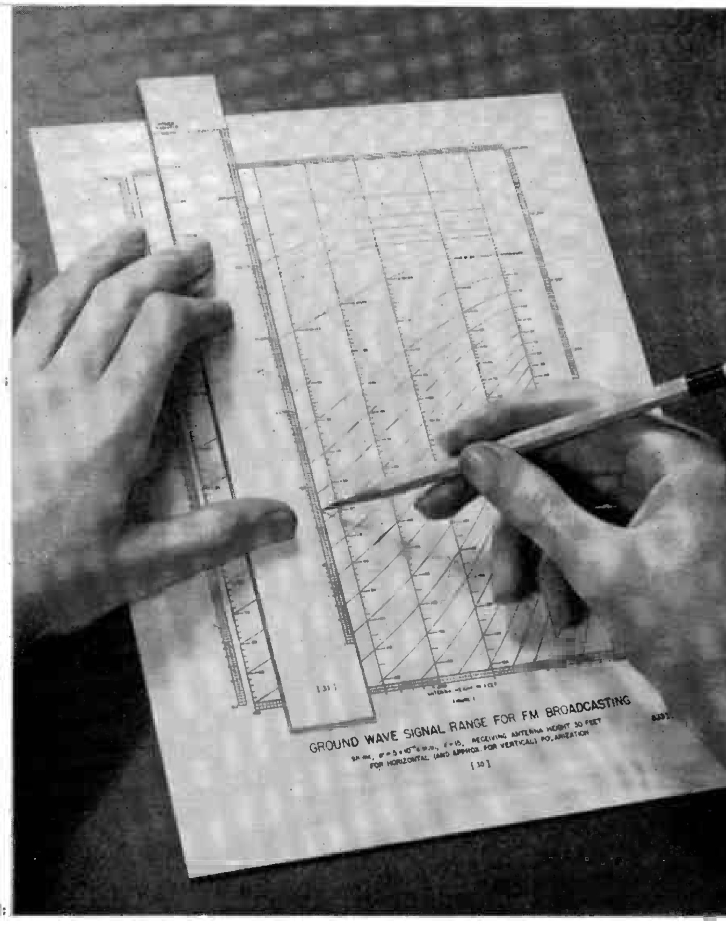


FIG. 6. *Second step is to read the distance to the 50-microvolt contour by noting the distance (curved lines) corresponding to the 50-microvolt mark on the scale (position of which was determined in Figure 5).*

Where it is very irregular, as in Sector 10 of Figure 2, a value can be approximated by inspection.

DETERMINING THE 1000 uv/m CONTOUR

When the median field values for each sector of a radial have been thus determined, these values are plotted on log-log paper as shown in Figure 3. For each point the ordinate is the median value and the abscissa is the distance corresponding to the center of the sector. A smooth curve is then drawn through these points and the point where this curve intersects the 1000 uv/m line is taken as the true distance to the 1000 uv/m contour for that particular radial. By this same procedure the distance to this contour along each of the other seven radials is determined and these values are tabulated as shown in the first column of Table 1. These values are then used to draw a contour map. This may be drawn on polar coordinate paper, as in Figure 4, or it may be drawn directly on the original map showing predicted coverage (a map of this type is shown in Figure 7, Page 67).

DETERMINING THE 50 uv/m CONTOUR

In the surveys described by Klingaman and Laeser, recordings were made to distances well beyond the predicted 50 uv/m line. From these recordings an attempt was made to establish directly the position of the 50 uv/m contour (by methods similar to those described above). In the new FCC Standards a different method of locating the 50 uv/m contour is specified. Noting that "at the present time it is not considered practical to conduct mobile measurements far beyond the 1000 uv/m contour due to the fading ratio at weak fields, which complicates analysis of the charts," the Standards specify that the 50 uv/m contour be determined by using the "Ground Wave Signal" chart included with the Standards. The method is as follows: First, the sliding scale is placed on the chart with its righthand edge on the vertical line corresponding to the antenna height for that radial. At the same time, the scale is moved up or down until the distance to the 1000 uv/m contour (as determined above) and the 1000 uv/m mark on the scale are opposite, as shown in Figure 5. Second, the distance to the 50 uv/m contour is read opposite the 50 uv/m mark on the scale, as indicated in Figure 6. When the distance has been thus determined for each of the eight radials, and tabulated as in the second column of Table 1, the 50 uv/m contour is plotted on the contour map of Figure 4.

It should be noted, however, that in determining adherence to authorized service area it is the correlation between "predicted" and "measured" 1000 uv/m contours which is compared, rather than between "predicted" and "measured" 50 uv/m contours as was previously the case.

DETERMINING INTERFERENCE AREA

When it is desired to determine interference arc the sliding scale is placed on the chart as described above, but in this case, an "equivalent power" is read by noting the point where the left-hand edge of the scale crosses the lower line of the top edge of the chart. This equivalent radial power is thus used in determining the interference contours of the station by making use of the second chart furnished with the Standards.

MAPS, EXHIBITS, ETC.

The remaining paragraphs of Section 5 describe the maps and exhibits which must be filed as evidence of the survey results. These are clearly described and require no additional discussion.

Announcing

RCA's MICROWAVE

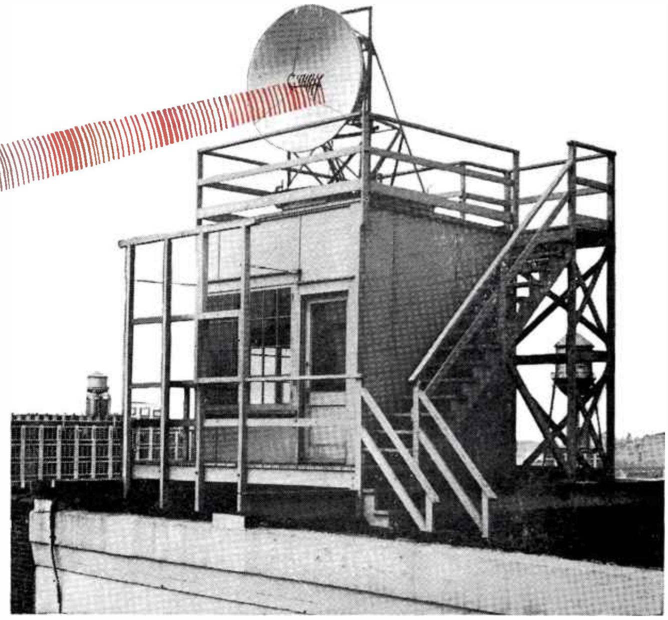
...FOR SHORT-RANGE

Brilliant Reproduction...
Low Cost... Quickly Set Up

ON LOCATION—The microwave transmitter relays the signals picked up by field cameras to the studio—recently used with excellent results to transmit scenes of the UN Conference at Hunter College to Radio City.

THE RELAY TRANSMITTER consists of a parabolic antenna with hook-shaped wave guide, an easily removed transmitter built into the waterproof cylindrical housing at the back of the reflector, and the small, suitcase-type transmitter control.

EQUIPMENT
TELEVISION RELAYING



THE VIDEO SIGNAL is picked up by the parabolic antenna and the several receiver stages mounted in a waterproof housing at the back. The signal is delivered by coaxial line to the remaining receiver and control stages shown below.

A radio link between remote pickup and studio or between studio and transmitter

AVAILABLE SOON

HERE'S ANOTHER REAL HELP to practical, low-cost television programming even in small towns and cities—a highly directional, wide-band relay link for transmitting pictures of local events to the studio or for relaying programs from studio to transmitter.

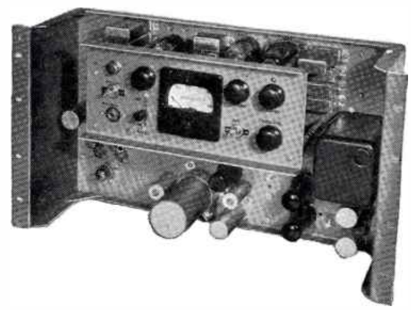
Under normal conditions, you can use this equipment within a 15-mile radius with an excellent signal-to-noise ratio assured over the entire range. *Fully developed,* it is now *in production* for early delivery.

To assure flexibility of operation, the equipment used in the field has been made relatively light in weight, and can be disassembled into easily portable units. Field setup is merely a matter of connecting the various units together by means of single plug-in cables and making the necessary adjustments.

The parabolic transmitting and receiving antennas are so mounted that they can be easily moved with a micrometer screw adjustment ±15 degrees in both horizontal and vertical directions. Proper alignment is made by scanning for maximum signal strength.

This is time-tested equipment—backed by RCA's extensive research, engineering, and manufacturing program on microwave relay systems for telegraph and other services.

Write today for complete details. Radio Corporation of America, Dept. 18-F1, Television Equipment Section, Camden, N. J.



THE RELAY RECEIVER consists of the receiver unit itself, which is mounted on the rear of a parabolic reflector (and is similar in appearance to the transmitter unit) plus the receiver control unit shown above. The parabolic and receiver can be mounted on a permanent structure as shown at the top of this page or on a tripod similar to that used with the transmitter. The control unit is assembled on a bathtub-type chassis (top) which can be mounted on a standard rack or in a portable carrying case (bottom).

TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

RCA's *Dual-purpose*

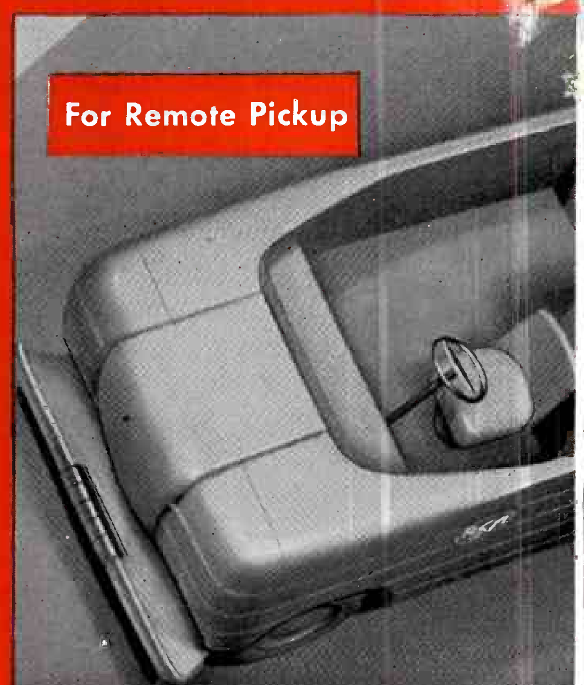
New RCA "image-orthicon" camera with sensitivity 100 times greater than conventional television cameras.

Camera control (left) with power supply

Duplicate camera control used for two-camera operation

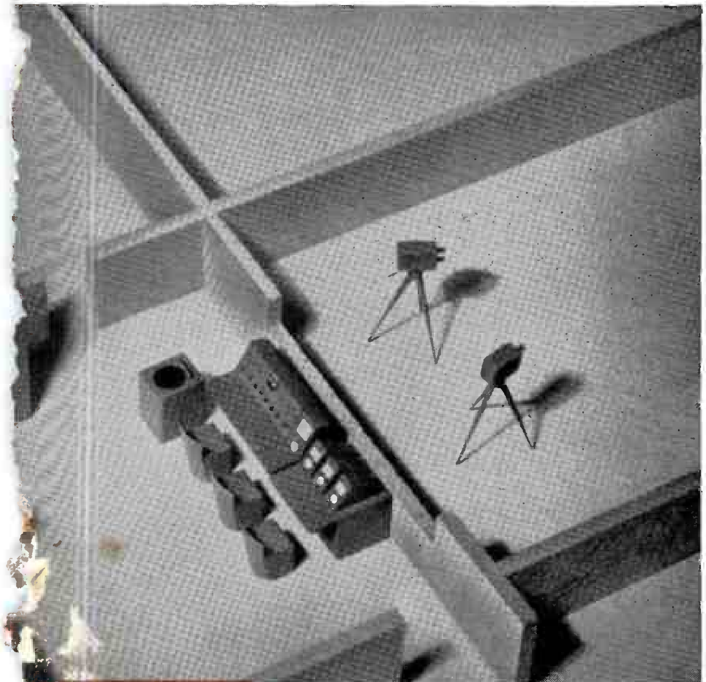
Master control (left) with power supply

Shaping unit (left) and pulse unit



The average small station starts with two field cameras, two control units (one for each camera) for monitoring the pictures picked up by each camera, a master control and switching unit which contains push buttons to permit operator to select the camera pickup desired, a field synchronizing generator (shaping and pulse unit shown above) to provide standard sweep frequencies for the cameras as well as the synchronizing pulses transmitted with the video signal, and various auxiliary switching, control and audio equipments (not shown).

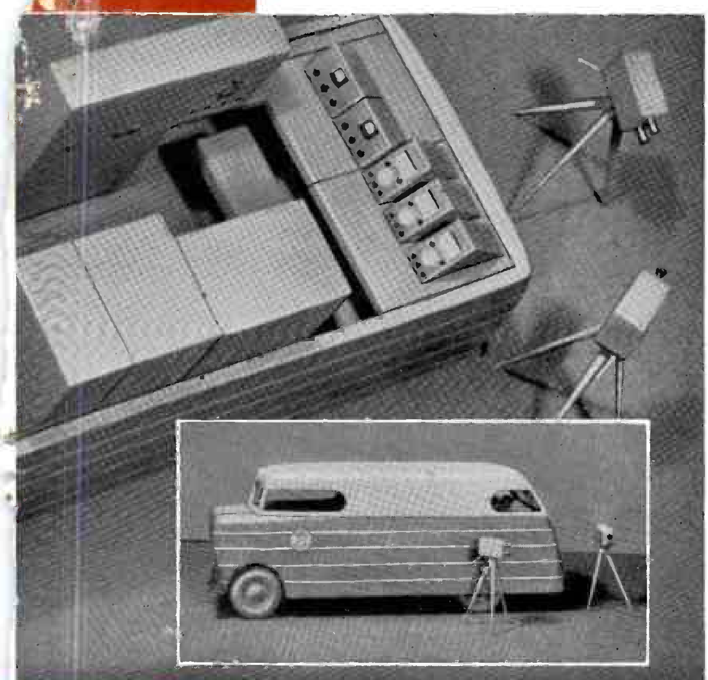
Portable Pickup Equipment...



a new, low-cost way to get started in Television

IF YOU PLAN to start a television station on a modest scale, you will find this equipment a real money-saver. With it you can enjoy the economies of using already prepared program material such as, baseball games, boxing and concerts—which do not require expensive rehearsals and where lighting is seldom a problem. And you can use it in place of *fixed studio equipment* until such time as you may want to expand your station facilities.

When used as studio equipment, the small, lightweight camera-control units can be mounted on tables or slid into console-type racks (see models) that RCA will have for this purpose. The same field cameras are used.



For remote pickup, a station wagon or light truck is used to transport the suitcase-type units to the program location. With a station wagon, the equipment is removed, carried to the program area, and connected for operation. A light truck offers greater flexibility in that the equipment can be operated from the truck if shelter is non-existent, or if brilliant illumination makes monitoring difficult. As with the station wagon, where advantageous, the equipment can be removed and set up at the program scene.

Setup can be accomplished in a short time. *Quality* is comparable to that obtained from standard studio equipment. Best of all, it's *easy to operate.*

Write for these 8 helpful bulletins:
"Locating the Television Studio," "Locating the Television Transmitter," "A Television Transmitter Building," "A Television Broadcasting Studio," "Equipment Layout for a Standard Television Station," "Equipment Layout for a Master Television Station," "Equipment Layout for a Small Television Station with Live-talent Studio," "Equipment Layout for a Small Television Station with Provision for Film and Network Programs Only." Write: RCA, Dept. 18-B4, Television Broadcast Section, Camden, N. J.

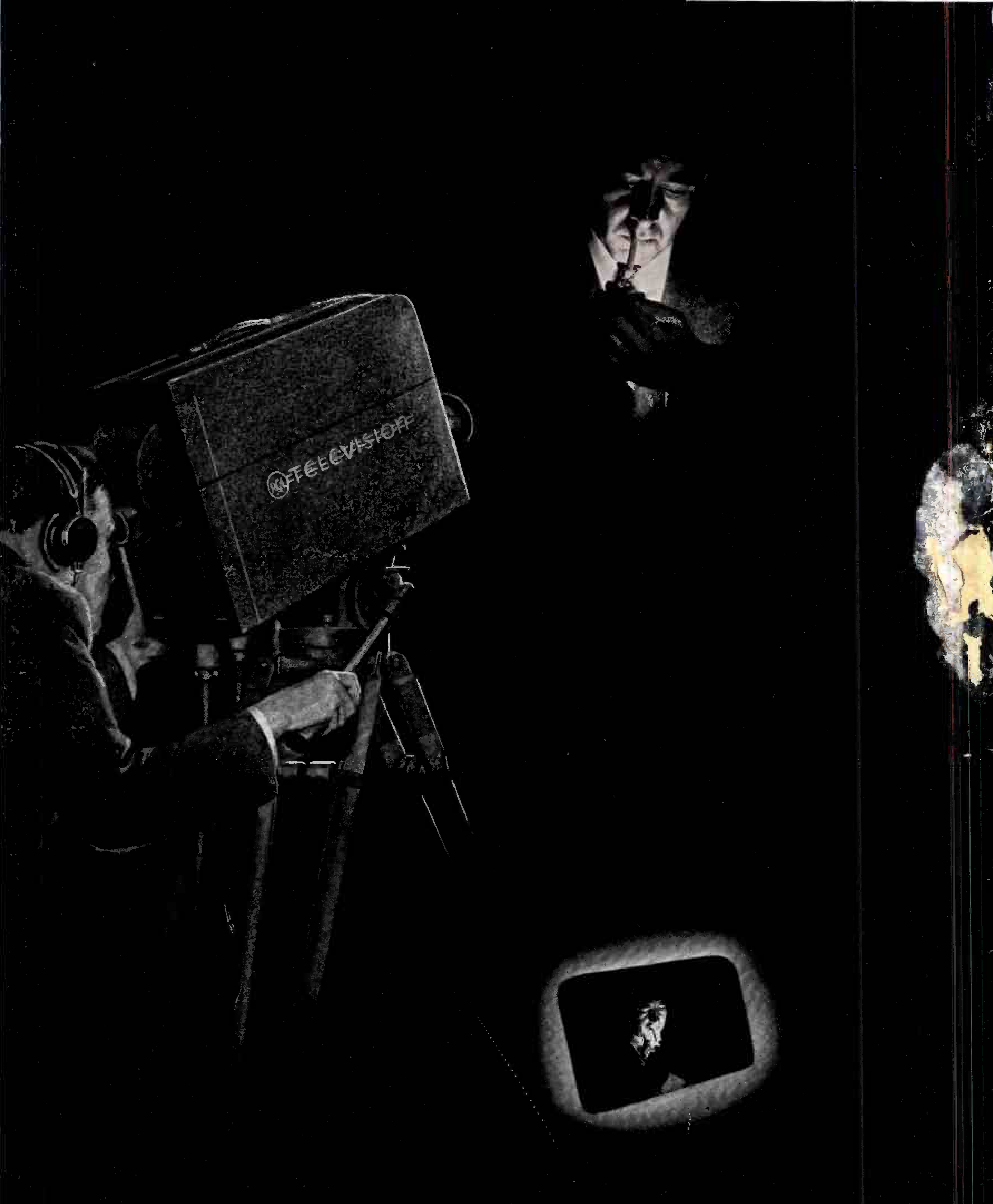
RCA

TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

Only the FLICKER of a match—yet more than



enough light for television pick-up

REVOLUTIONARY, NEW RCA "CAT'S EYE" CAMERA

- ✓ 100 times more sensitive than conventional television cameras. Provides greater depth of perception and clearer views under shifting light conditions.
- ✓ Wide sensitivity range provides unvarying transmission despite wide fluctuations of light and shadow (from the sunny to the shady end of a tennis court, for example).
- ✓ Lightweight, portable, easy to use, quickly set up. Telephoto lenses are easily applied.
- ✓ Improved stability which protects images from interference due to sudden bursts of light (such as exploding flash bulbs).

Picks up scenes in moonlight, in candle-light, and in any kind of weather

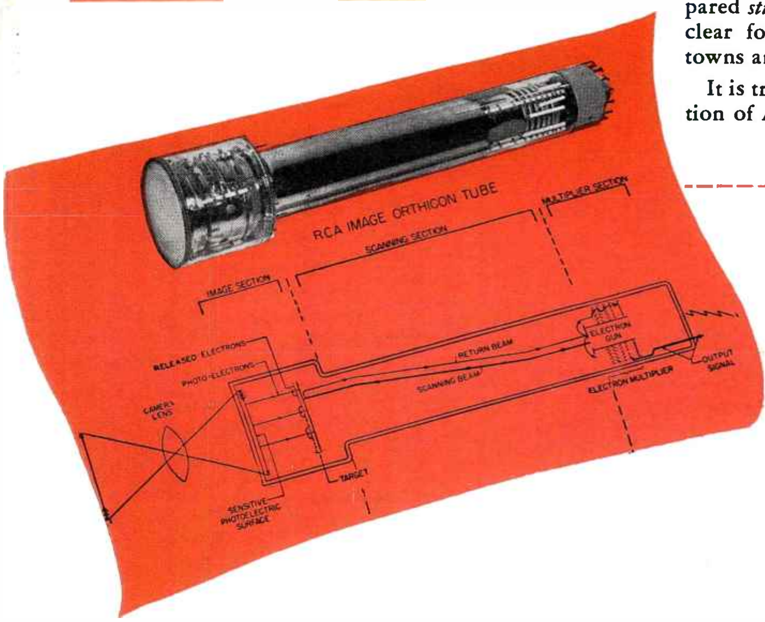
THIS television camera, utilizing RCA's amazing new electron tube—the image orthicon—opens up a wealth of new program opportunities.

Now, for the first time, round-the-clock television news coverage is possible—spot news and special events. It is now practical to televise football games, baseball games, ice hockey, boxing and other sports events, in any kind of weather, day or night. Remote indoor pick-up such as in theatres, concert halls, schools, churches, and courtrooms are other of its almost limitless application possibilities. Using infrared rays, it is even possible to pick up events in total darkness.

Equally significant are the lowered program production costs this camera makes possible. Many expensive-to-solve illumination problems are eliminated.

With such an increased source of programs, specially prepared *studio* programs can be greatly reduced. The way is now clear for practical television program production in small towns and cities.

It is truly the "Aladdin's lamp of television." Radio Corporation of America, Broadcast Equipment Section, Camden, N. J.



The new RCA image-orthicon tube—the "eye" of the camera. A light image from the subject (arrow at extreme left) is picked up by the camera lens and focused on the light-sensitive face of the tube, releasing electrons from each of thousands of tiny cells in proportion to the intensity of the light striking it. These electrons are directed on parallel courses from the back of the tube face to the target, from which each striking electron liberates several more, leaving a pattern of proportionate positive charges on the front of the target. When the back of the target is scanned by the beam from the electron gun in the base of the tube, enough electrons are deposited at each point to neutralize the positive charges, the rest of the beam returning, as indicated, to a series of "electron multiplier" stages or dynodes surrounding the electron gun, which multiply the signal many times. The output of the tube is further amplified in the camera pre-amplifiers and then carried to the television mixing circuits.

TELEVISION BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DIVISION, CAMDEN, N. J.

THE NEW RCA SINGLE-RIBBON MICROPHONE

... quickly adjustable to any pickup pattern you want

This multi-purpose, polydirectional microphone (Type 77-D) will help you add even greater balance, clarity, naturalness, and selectivity to your studio pickups.

By means of a continuously variable screw adjustment, located at the back of the microphone, an infinite number of pickup response patterns can be obtained—unidirectional, all variations of bidirectional, and nondirectional. Undesired sound reflections can be quickly eliminated merely by switching to a more suitable pattern.

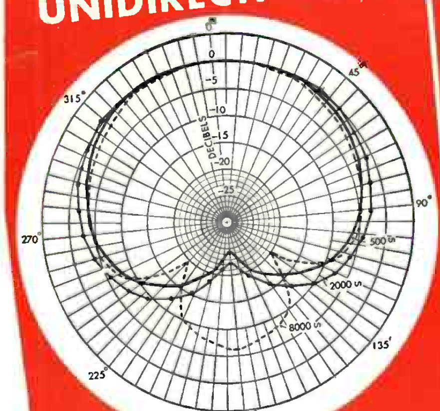
A three-position VOICE-MUSIC switch on the bottom of the microphone is available for changing the low-frequency response, thus permitting the selection of the best operating characteristic.

A unique single-ribbon unit combines the performance of the velocity-operated and the pressure-operated units used in previous designs.

Other outstanding features include: excellent frequency response, uniform directivity at all frequencies, shielded output transformer, shock mounting, spring-type cord guard, lightweight, small size, and an attractively styled umber-gray and chrome housing.

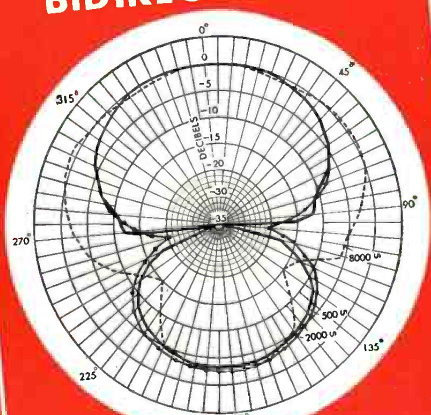
A bulletin completely describing this outstanding microphone is yours for the asking. Write: RCA, Dept. 17-B, Camden, New Jersey.

UNIDIRECTIONAL



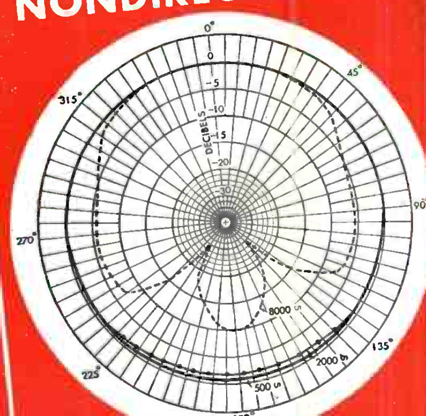
Uniform response, from operating side. At rear, sounds are attenuated 14 to 20 db for an approximate 10:1 ratio of desired-to-undesired pickup.

BIDIRECTIONAL



Pattern similar to conventional RCA 44-BX bidirectional microphone, except rear response is three db down compared with the response from the front.

NONDIRECTIONAL



The nondirectional pattern is similar to that of other pressure microphones. Many other patterns possible by varying screw adjustment.

BROADCAST EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DIVISION, CAMDEN, N. J.