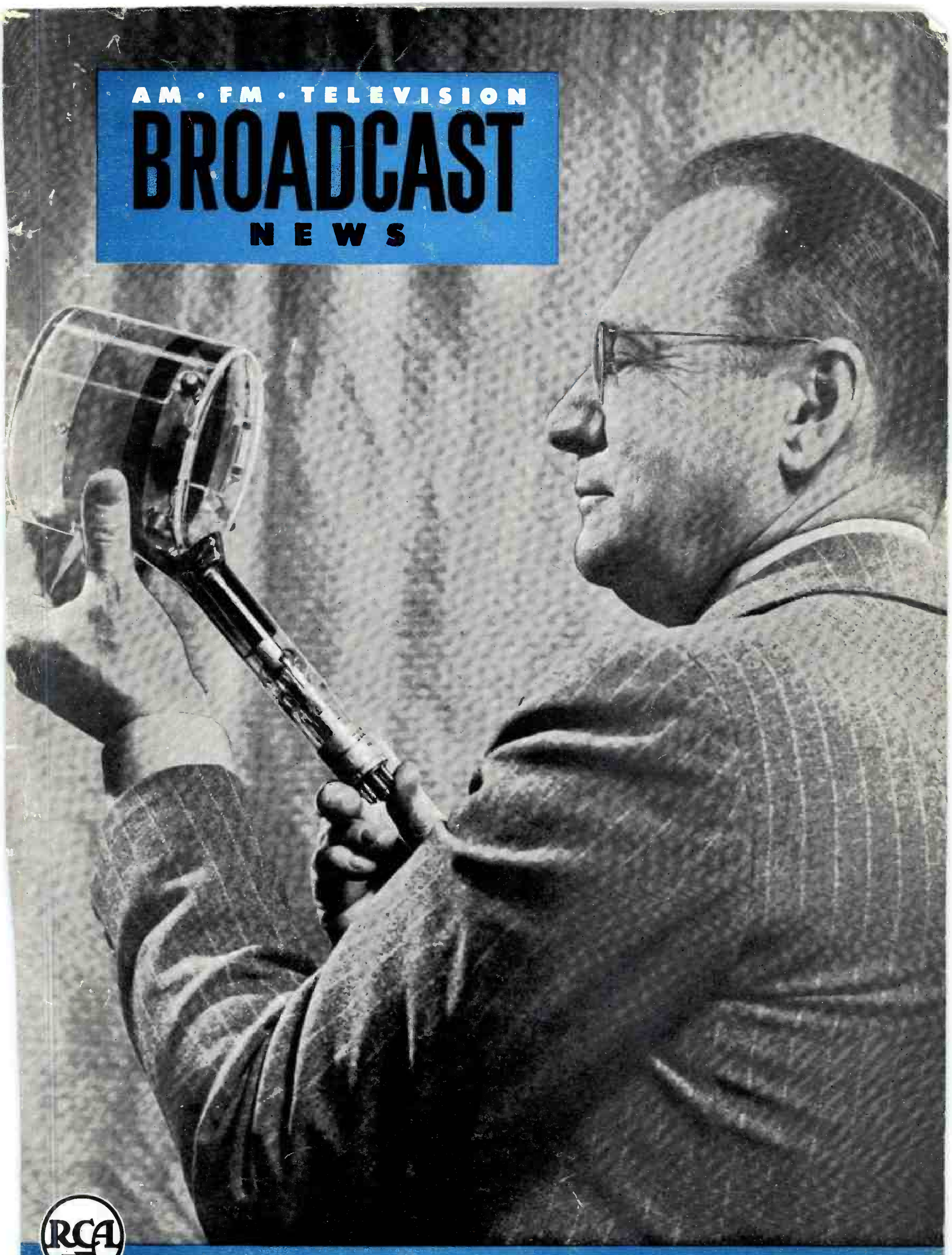
AM · FM · TELEVISION

BROADCAST NEWS



RCA

DR. V. K. ZWORYKIN · · · Television Genius

IN

TELEVISION

BROADCASTING...

RCA pioneered the development of electronic television.

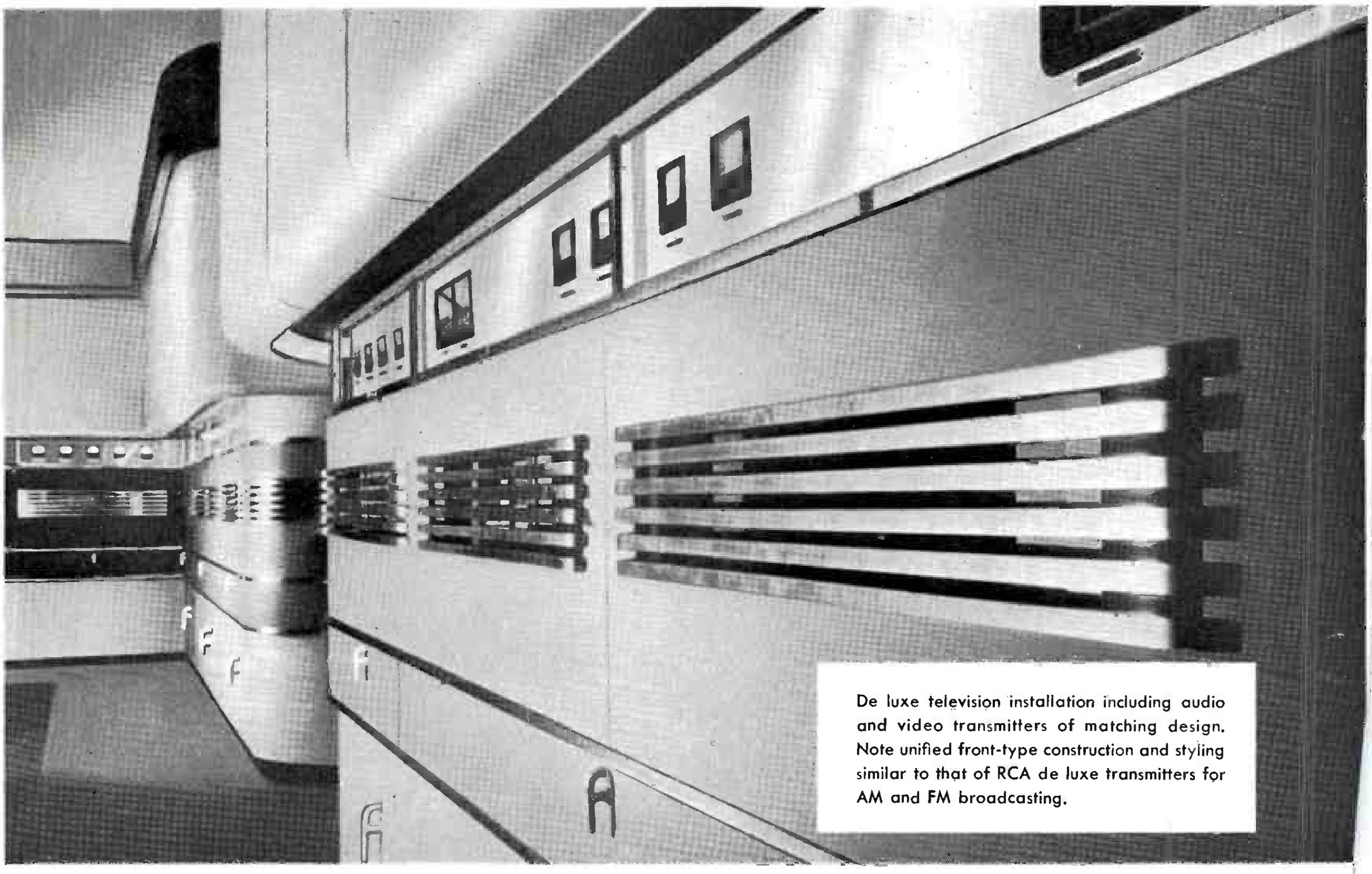
RCA engineers developed the Iconoscope, the Kinescope and the Orthicon, as well as circuits for their use.

NBC, a member of the RCA family, operates a commercial television station which has pioneered program development—a station whose programs are rebroadcast by other stations.

RCA had developed a full line of commercial television transmitting equipment before the war and had offered it to broadcasters.

RCA is now utilizing its engineering experience by building for the armed forces a large quantity of equipment.

RCA will be prepared to offer for postwar service a full line of new and improved television equipment, including studio equipment, film equipment, portable equipment, relay equipment, studio-transmitter-link equipment, and, of course, audio and video transmitters.



De luxe television installation including audio and video transmitters of matching design. Note unified front-type construction and styling similar to that of RCA de luxe transmitters for AM and FM broadcasting.

RCA installations now in operation

The de luxe-type installation shown above is one of several RCA Television Transmitters installed before the war.

All of these installations are standard transmitter models, designed and constructed to broadcast specifications and installed for regular television stations.

They are in addition to a number of experimental and relay-type television installations made by RCA as part of its own television development program.

RCA's experience in this field is unequaled.

RCA BROADCAST EQUIPMENT

BUY MORE WAR BONDS

RCA

RADIO CORPORATION OF AMERICA

RCA VICTOR DIVISION • CAMDEN, N. J.

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Broadcast News

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Contents

OUR COVER for this issue is a recent study of Dr. V. K. Zworykin examining a model of a new, small-size iconoscope. Pictures of this kind are hardly new. There have been pictures of Dr. Zworykin and the kinescope, Dr. Zworykin and the electron multiplier tube, Dr. Zworykin and the earlier models of the iconoscope and many others. In fact, the history of electronic television could be illustrated with such pictures. Nevertheless, when it came to choosing a cover illustration which would symbolize television's coming of age, nothing seemed quite as appropriate as a picture of the man whose imaginative iniative and driving energy did more than any other single thing to bring all-electronic television to its present advanced state.

For more than twenty years, Dr. Zworykin has been developing and building television equipment—particularly television tubes. In 1923, he developed the iconoscope, the "electric eye" of the television camera. In 1924, he built his first complete television system. Soon afterward, he developed the kinescope, the cathode-ray tube on which the picture appears in the receiver. In between times, with the help of associates, he developed a practical version of the electron multiplier tube and various other special-purpose and transmitting tubes.

During all of his years of work on television, Dr. Zworykin held steadfastly to the belief that television should be "all-electronic." While others were experimenting with mechanical scanners, he was working with early versions of the "electric eye." Dr. Zworykin himself attributes his belief in electronic television to the inspiration of his early teacher, Prof. Boris Rosing of the Institute of Technology at St. Petersburg in old Russia. Prof. Rosing, as early as 1907, had the vision of television using cathode rays. His dreams were years ahead of his contemporaries — and of available equipment. But, he so inspired his pupil, that the latter went on to become the world's acknowledged leader in television research and the developer of a television system which is electronic's proudest accomplishment.

Today, Dr. Zworykin is Associate Research Director of RCA Laboratories and heads a large group of scientists conducting research, not only on television, but in allied fields of electron optics. During the war, the work they are doing cannot be disclosed. It is safe, however, to predict that their contributions to the future of television may well equal the remarkable advances already made.

HARRY SADENWATER has recently been appointed manager of RCA broadcast equipment sales for the eastern region. He will make his headquarters in RCA sales offices at 411 Fifth Avenue, New York City.

Harry needs no introduction to old-timers in broadcasting for he has been connected with broadcasting and television from the earliest crystal set days. Active in radio since 1914, he served in Navy radio during World War I and made headlines as radio officer of the NC-1, one of the four Navy flying boats that made the first trans-oceanic flight.

In 1923, as engineer in charge of technical operations of GE broadcasting stations, he built KGO at Oakland, Calif. and a year later, KOA at Denver.

In 1930, Harry joined RCA at Camden. During the following ten years he had important roles in the development of the first ultra-high frequency walkie-talkies, U-E-F Aviation Radio, Navy receivers and television equipment. From 1941 until the present time he has been manager of services at RCA Laboratories.

Broadcasters in the eastern region will find that Harry knows their problems, knows the broadcasting business and knows broadcast equipment. Moreover, he is an expert on FM and television—having been in on the early days of both.

NEW INTERNATIONAL STUDIOS OF ASSOCIATED BROADCASTERS SAN FRANCISCO, CALIFORNIA

FIG. 1. (Top left) *Master Control Room. From his position at the control desk, the engineer can view the operations going on in the eight studios which are grouped around the master control room.*

FIG. 2. (Center left) *Another view of the master control desk. The equipment room can be seen directly behind the operator. The equipment is completely enclosed behind and is "pressurized" with filtered, refrigerated air.*

FIG. 3. (Bottom left) *The Recording Laboratory. International broadcasting entails a large amount of recording. At KWIX, six RCA Type 73-A Deluxe Recorders installed in special room handle all requirements.*

FIG. 4. (Below) *One of the control booths associated with the smaller "announce and play-back" studios. RCA 70-C Turntables and special control consoles are used.*

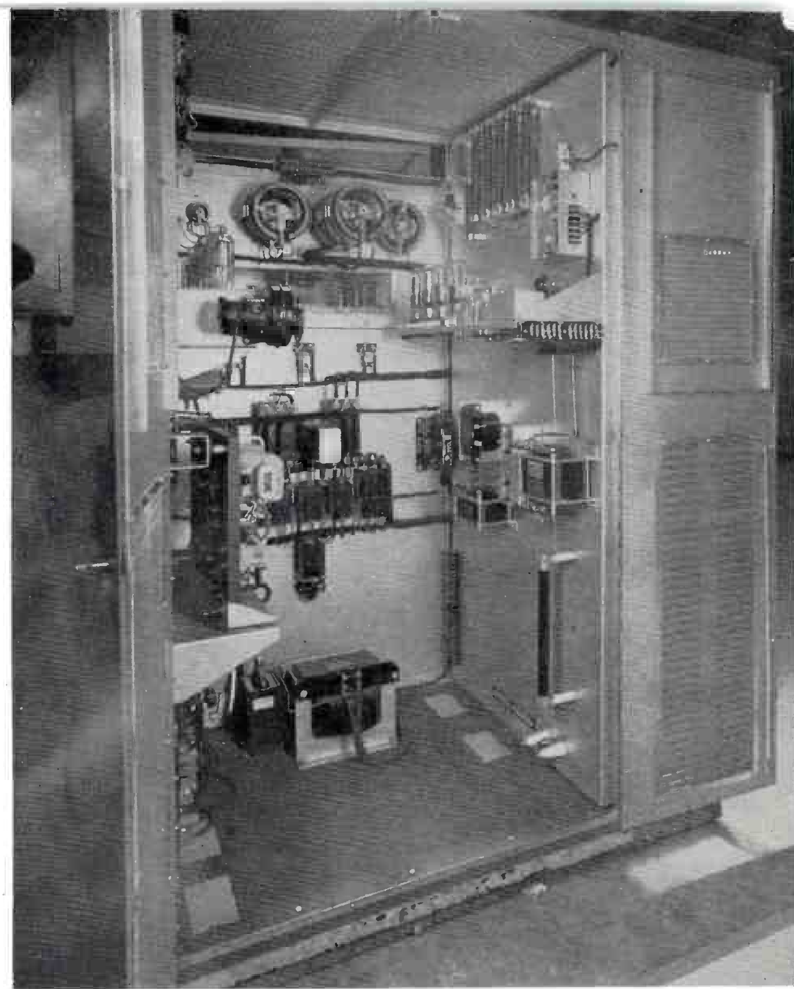
POWER AND CONTROL SECTION

Two views of the interior of the power and control section of the FM-10-A transmitter are shown on this page. All of the power controls of the transmitter are mounted on the front panel of this unit. This panel is directly behind the non-interlocked door of the outer front enclosure. (See photos on preceding pages). These controls include circuit breakers—main line, filament, plate, etc.—the starting and overload relays and the filament rheostats.

Mounted on the outer front enclosure, so that they are in view at all times, are the plate start and stop button and all of the meters, including line, filament, plate voltage and plate current.

Inside the power and control unit, and mounted on the left side, (as seen from the rear) are the various relays and contactors and the main high voltage rectifier. The latter consists of six RCA 872-A's in a three-phase full-wave connection. These tubes are mounted on a shelf near the top left of the unit. A small blower and a bakelite duct direct an air blast on the base of each of these tubes. The plate transformer primary connections are brought through a knife switch (lower left) which allows either delta or wye connection to be used. Thus the amplifier can be tuned up in the low-voltage position, then changed to full plate voltage (7000 volts) for operating.

Just above the rectifier, on the left side panel, are the various control relays. These include, among others, the carrier-off relay and the re-cycling relay. The carrier-off relay operating coil is in the plate



circuit of the AM detector located in the feedback unit. If the carrier is lost for any reason, this relay operates and takes the plate contactor out. This provides valuable protection in case of short in the output circuit, lightning or similar failures. The "re-cycling" relay functions in the "three-strike" manner. Thus, in case of a failure which operates the overload relay and takes out the plate contactor, this relay brings plate power back on. If there is a third failure, the power remains off until the system is reset by hand.

At the bottom of the left panel in the far corner is the condenser shorting relay. When power is disconnected, power is removed from this relay which allows a bar to fall by gravity which shorts the filter condenser and thereby protects the operating staff from condenser discharge voltages.

On the right hand panel, near the top, is the chassis which contains the feedback unit. This chassis contains an AM detector which rectifies any AM component in the output of the transmitter (a small amount of R.F. energy is fed to it by a coaxial cable from the output of the amplifier). The rectified audio output of this detector is amplified and used to drive a "modulator" consisting of four RCA 845's. These modulators are so connected as to produce AM modulation of the 10 KW output. This modulation is adjusted as to amplitude and phase so as to "buck" or cancel out the AM ripple in the output. By this means, the "AM noise" level in the output of the FM-10-A is reduced to an exceedingly low figure.

ANTENNAS for FM STATIONS

★

What is meant by "Antenna Gain"; How it is obtained; Types of antennas; Characteristics of various types

by JOHN P. TAYLOR
Engineering Products Department

Assuming that a site has been selected, the next step in planning an FM station is to decide on the type of antenna to be used. Considerable importance is attached to this decision because of the increased coverage (for the same transmitter power) which can under some circumstances be obtained by using an FM antenna of one of the so-called "multi-element" (or "multi-layer") types.

ADVANTAGES OF MULTI-LAYER ANTENNAS

The desirability of carefully considering the possibilities of multi-layer can hardly be overstressed. An example is probably the best way to illustrate this. Assume a 1 KW FM transmitter feeding power to an antenna on the top of a 300-foot building. If this antenna is of simple "single-layer" design, for instance, a one-bay turnstile, coverage (i.e., distance to the point where the signal has fallen to 50 microvolts per meter) will be approximately 31 miles. Now suppose that there is substituted for this "single-layer" antenna an antenna of the same type but having six layers. By this substitution the 50 microvolt line will be moved out to 44 miles and the area covered increased from 3017 square miles to 6079 square miles. In terms of equivalent power the difference is even more striking. To obtain the same increase in coverage by increasing power (while retaining the "single-layer" antenna) would have meant going to a power of 8.6 KW. In terms of cost this makes an interesting comparison. Depending on the mechanical difficulties of installation a six-bay turnstile (installed) may cost from three to six or eight thousand dollars more than a single-bay turnstile. But a 10 KW transmitter (installed) will cost at least fifteen thousand dollars more than a 1 KW transmitter. Moreover, the larger transmitter will require more space, involve greater installation problems and cost more to operate. *Thus, other things being equal, obtaining increased coverage by use of a higher gain antenna is usually preferable to an increase in power.*

LIMITATIONS OF MULTI-LAYER ANTENNAS

There are, however, some definite limitations which must be reckoned with in considering the use of high-gain antennas. The most important of these are the mechanical limitations imposed by the supporting structure. A six-bay turnstile, for instance, is approximately 60 feet high (at FM frequencies). It is mounted on a pole which is 12 inches in diameter at the base and 5 inches at the top. The whole antenna weighs about 3500 pounds. Moreover, it presents considerable wind resistance, so that at high wind velocities the overturning moment is rather large. The supporting structure, whether building or tower, must be able to stand this weight and overturning moment and must be adaptable to mounting the supporting pole. When these requirements are combined with the desirability of having a high location, a compromise is often required. For instance, it may be found that there is available a 300-foot building which is ideal in all respects except that it will not support more than a two-bay antenna, whereas the only building on which a six-bay antenna could be located is only 100 feet high. Reference to the "coverage" curves will show that in this case the first location would be the better even though only the two-bay antenna could be used. The same consideration may apply where an FM antenna is to be mounted on an existing AM tower. Most such towers will not support an FM antenna of more than two bays. However, the extra height afforded by such mounting may be an advantage that outweighs this.

INTERRELATION OF HEIGHT, GAIN AND POWER

Even an elementary consideration such as the above serves to show that it is not always possible to follow the logical course (in FM station planning) of first, determining coverage required; second, selecting a site; third, deciding on antenna type and, finally, determining the necessary power. In many cases the site and type of antenna must be considered together. In not a few cases transmitter power will also enter into this consideration. And, in a few extreme cases, the limiting conditions may be such that the coverage originally set up as desirable may have to be scaled down to meet practical conditions. This, in turn, may involve a change in the type or classification of station to be applied for. Thus, considerations of antenna type and design which at first thought seem to be chiefly of engineering interest, may actually turn out to be matters affecting station policy. As such, they are of interest not only to the station engineer but also to the station manager and the station owners.

HOW ANTENNA GAIN IS OBTAINED

The increased effective power and the increased coverage referred to above are obtained by the use of what are called multi-element antennas. These consist essentially of from two to ten

Obviously this would not be satisfactory for broadcasting practice where, as a rule, uniform transmission in all directions is desired. This is the reason for the second set of rods in each layer. When this second set is fed an equal amount of power which is, however, of opposite phase, the patterns of the two radiating dipoles are as shown by the dotted lines of Fig. 5 and the combined field is the solid line. The latter, it will be noted, is very nearly a circle.

In order to achieve the kind of horizontal directivity noted in Fig. 5, all of the dipoles in one plane must be fed equal amounts of the same phase. If the layers are spaced a half-wave apart, this can be conveniently done with a transmission line which is crossed over between each layer, thereby counterbalancing the phase shift that occurs along this line between layers. Two such lines, one for each set of dipoles, run up the tower, twisting around it as they go and being set off from the tower by stand-off insulators. At the base of the tower the two lines are fed oppositely phased currents by one of several methods.

The first model of the turnstile antenna was carefully tested and a large number of field measurements made of signals transmitted with it. These tests indicated that the turnstile met the primary requirements of a good high-frequency broadcast antenna in that it, first, had a uniform directivity pattern in the horizontal plane (i.e., the same signal in all directions) and, second, offered a convenient and easy means of obtaining high directivity in the vertical plane (i.e., high-gain in "useful" signal strength). In addition, it was obvious that such an antenna had the other necessary qualities of simple mounting and rugged construction.

Because of its unique qualities, the turnstile was adopted by almost all of the pioneer FM broadcast stations and its familiar contour has become a symbol of FM to engineers and laymen alike.

THE IMPROVED BROWN TURNSTILE

Field experience with the original turnstile antennas brought out two minor drawbacks. One of these was that the matching of the feeder lines was extremely critical and required that adjustments be made in the field (which, as most stations lacked experienced personnel, was a major difficulty). The second was that the open wire transmission lines invited the formation of ice which tended to increase the wind resistance of the antenna and to detune the radiating system.

To overcome these difficulties, Dr. Brown and his associates, at RCA Laboratories, developed a modification of the original turnstile in which coaxial transmission lines replaced the open wire lines previously used.

A photograph of the improved version of the turnstile using coaxial feed lines is shown in Fig. 6. It will be noted that the two coaxial transmission lines twist around the tower between layers exactly as did the open lines in the original design. Since the impedance of the lines is lower—and they are single-ended instead of balanced—a different feed arrangement is used. Fig. 7 shows a close-up view of two of the layers. Each radiating element consists of a rod rigidly mounted to the tower by means of a steel band, an outer sleeve which is insulated from the rod and a section of concentric line which acts as a phase shifting and impedance matching device. This concentric matching section is fastened along the sleeve which is the actual radiator.

The arrangement of radiators and lines in the new turnstile has several advantages. The first is that the antenna can be completely "pre-tuned" during fabrication. It comes as a finished assembly with no engineering required in its erection. The second

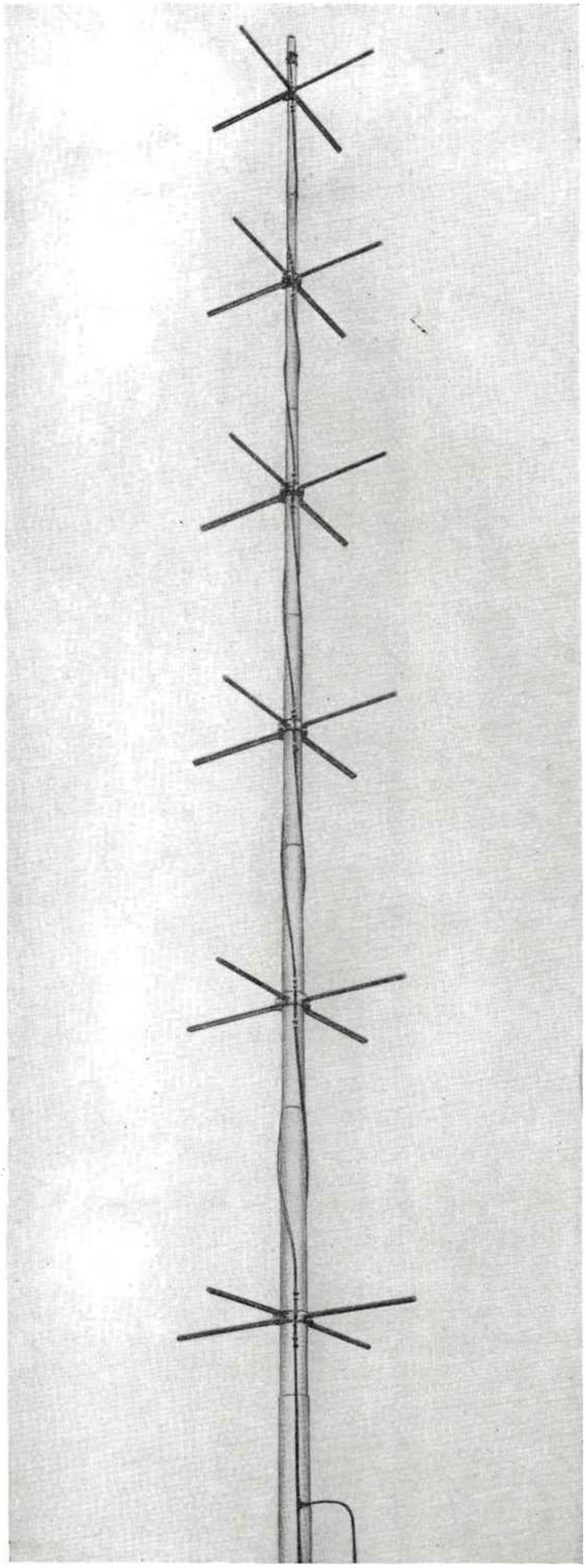


FIG. 6. *Six-layer turnstile of the improved type. Two coaxial lines feed all of the elements. Sleet-melting units are incorporated where required.*

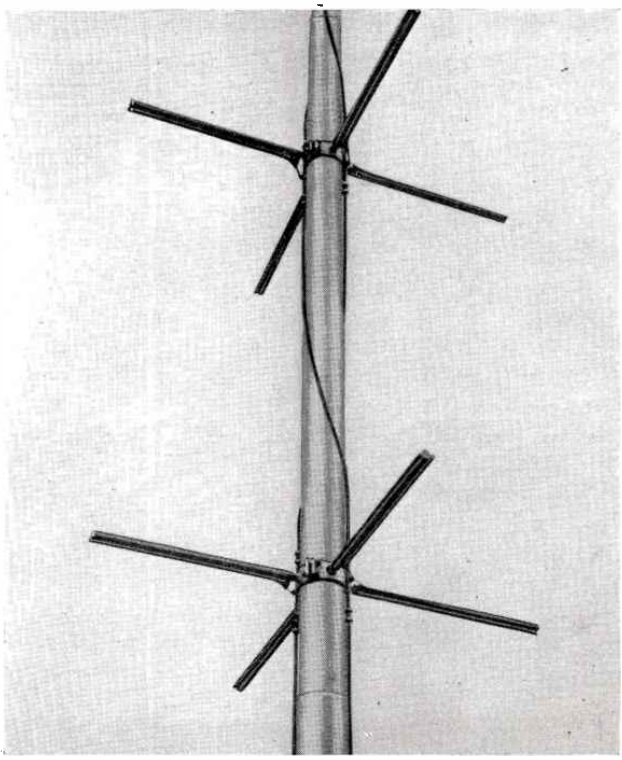


FIG. 7. ***A closeup of the two layers of the coaxial turnstile showing the manner in which the two lines twist around the pole between layers to provide proper phasing of elements.***

is that since phasing is accomplished at the radiators, there are no phasing adjustments to be made at the bottom of the tower, all line impedances are exactly matched and there are no standing waves on the lines. The third is that the frequency range, both as to line termination and field intensity, is much wider than is required for wide band FM so that the system is not critical in any respect.

Insofar as the radiating properties of the new turnstile are concerned, these are the same as in the original design. The field is very nearly symmetrical; the gains achieved compare favorably with the theoretical values. In the gain that can be achieved within practical limits, the new turnstile exceeds any FM antenna yet devised. RCA engineers believe that wherever the supporting structure will allow the use of a multiple-layer turnstile, this antenna is to be preferred over all other types.

The new turnstile is furnished as a "package" item including pole, radiators, transmission lines and, if desired, lights, steps and sleet-melting units. This is of great advantage since the cost and labor of cutting and fabricating all the necessary parts of an FM antenna is one which few stations will wish to undertake. While this new design was introduced just previous to the war, and hence not many were built; nevertheless, the some half-dozen which were installed have given excellent performance.

Some of the characteristics of the new turnstile as manufactured by John E. Lingo & Son are shown in the table of Fig. 8. Power gains of the turnstile as compared to other types are shown in Fig. 9.

MODIFICATIONS OF THE TURNSTILE

A number of variations of the original turnstile are in use and deserve to be mentioned briefly. The best known of these is the DeMars turnstile used by the Yankee Network and others. The essential difference between this antenna and the turnstile is in the use of a separate coaxial feed line for each radiator. Thus, for a six-bay antenna there are 24 feed lines. These lines run all the way down the tower to a "phasing room" at the base. The

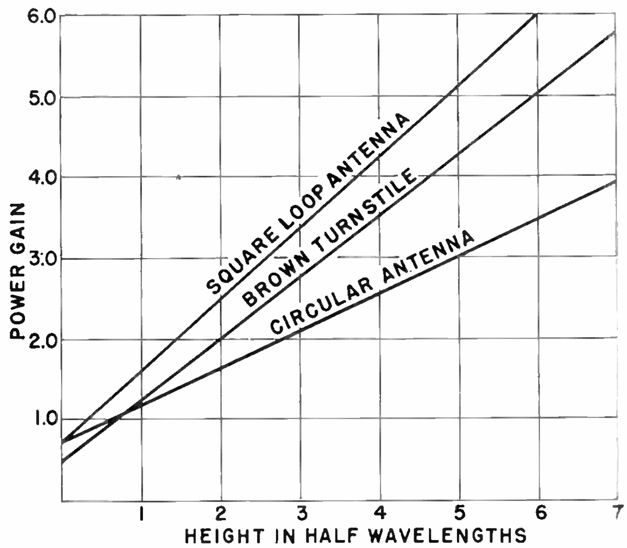


FIG. 8. ***Power gains of several types of FM antennas plotted against required height of supporting pole (note that this height usually determines the size of the antenna that can be mounted on a given structure).***

advantages claimed for this system are that it enables the phasing to be done at a sheltered and convenient point and a more accurate match is obtained. As compared to the original turnstile, these were quite important advantages. It is believed, however, that they represent no advantage over the new design turnstile. On the side of disadvantage there is the cost and work of installing the greater number of lines and the extra wind resistance and ice hazard which they form.

The antennas designed by DeMars also incorporate a number of structural innovations. The most notable of these is the antenna on Mt. Washington in which, because of the extreme weather conditions and continual ice formation, truck springs were used as the radiating elements.

FIG. 9. - CHARACTERISTICS OF THE COAXIAL TURNSTILE

Number of Layers	*Power Gain*	*Field Gain*	*Maximum Pole Height Above Tower or Roof*	*Minimum Distance in Tower or Roof*	*Outside Diameter Pole Butt*	*Estimated Complete Weight of Pole, Elements, Transmission Lines on Turnstile, Etc.*
2	1.25	1.12	20′	4′	5″	725 lbs.
4	2.75	1.64	42′	8′	8⅝″	2100 lbs.
6	4.24	2.037	64′	10′	11¾″	3500 lbs.
8	5.75	2.38	87′	13′	14″	6000 lbs.
10	6.70	2.6	110′	18′	16″	8700 lbs.

Another variation of the turnstile which had a short vogue employed a between-layer spacing of three-quarters of a wavelength (instead of the half wavelength spacing of the original). It can be shown mathematically that a three-quarter wave spacing gives a slightly greater gain than the half-wave spacing and, therefore, an antenna of this type has more *gain per layer*.

It should be noted, however, that gain per layer is not the true criterion of worth. Actually, extra layers add little to cost or weight; what is most important, is the overall height of the supporting pole, since it is the weight of this pole and the means of mounting it that determine what can and what cannot be used on a given structure. In this respect, the three-quarter wave spacing offers no advantage. For instance, a three-layer antenna of this type requires a total pole length of one and one-half wavelengths (30 feet at 45 mc.) and has a gain of 1.6, whereas a four-layer antenna of one-half wave spacing also requires one and one-half wavelengths and has a gain of 1.65. Moreover, the three-quarter wave spacing requires either separate feed lines for each radiator, as in the DeMars antenna, or else a full wavelength of line between layers (which is an unwieldy alternative). For these reasons this type of antenna is not widely used.

CIRCULAR OR "RING" ANTENNAS

The circular or ring antenna which has recently achieved some prominence is essentially a folded dipole antenna bent around into a circle.

Folded dipole antennas have been used for some time for communications purposes. They have been used for a number of years for television transmission at the Empire State Building (Lindenblad, RCA REVIEW, April 1939). The general advantages of this type of antenna are discussed by P. S. Carter of RCA Communications in an article entitled "Simple Television Antennas" published in the RCA REVIEW for October 1939. In Fig. 10(a) the folded dipole is shown in its simplest form. Essentially it consists of two half-wave radiators, one of which is broken at the center and the system fed at this point. Since the two radiators are mounted very close together, the currents in them flow in the same direction and the current distribution on both is a sine wave as shown by the dotted line. As the voltage to ground at the center is zero, the unbroken radiator can be attached directly to the supporting pole at this point. The ends of the lower radiator can be fed power by an open balanced line or by a pair of concentric lines (oppositely phased) as shown in Fig. 10(a).

The radiation characteristics of the dipole as shown in Fig. 10(a) are the same as that of one pair of radiators on the turnstile. The pattern in the horizontal plane is a figure 8 which, of course, is undesirable for broadcast purposes. To overcome this and attain an approach to uniformity of transmission in all directions, the dipole is bent around into a circle as shown in Fig. 10(b). This, however, will not of itself give a circular pattern as the current distribution is not uniform around the radiator. To improve on this situation, therefore, a pair of large metal plates are fastened at the folded points as shown in Fig. 10(c). These plates have the effect of adding end capacity to the radiators and change the current distribution something as shown in Fig. 10 (d). The current is now approximately uniform around the loop and the signal radiated approaches a circular pattern to the same degree.

The circular antenna presents a neat appearance and has a higher gain per layer than the turnstile. However, in order to keep down the mutual impedance the layers must be placed a full wavelength apart. Thus, the *gain per height* is less than with

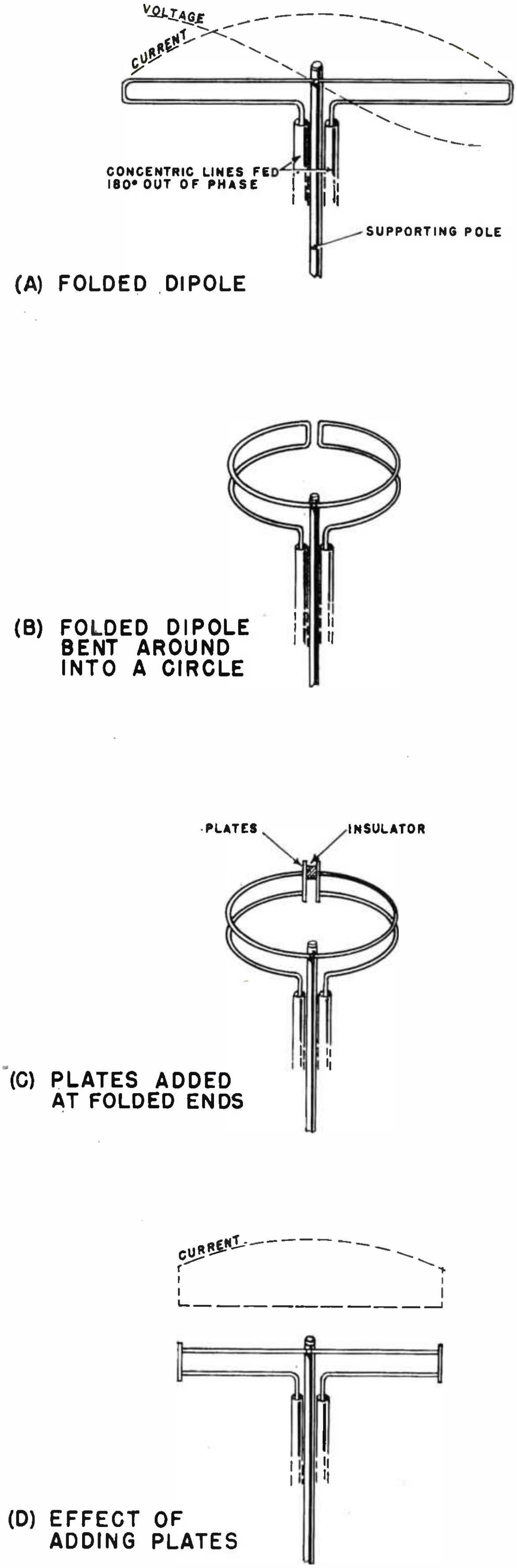


FIG. 10. (Right) *Evolution of the circular antenna.*

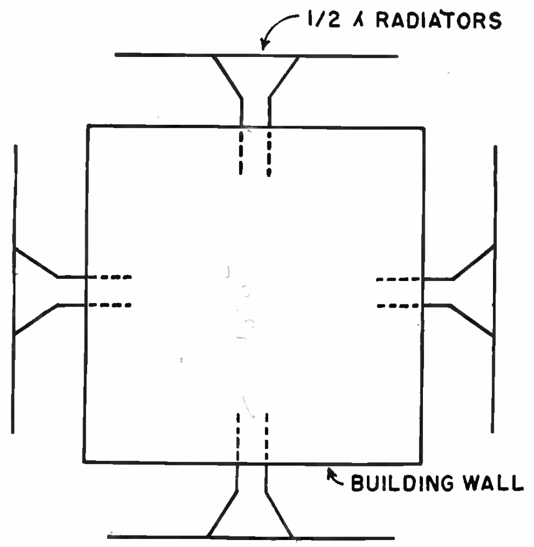


FIG. 11. *A square-loop antenna built around a building.*

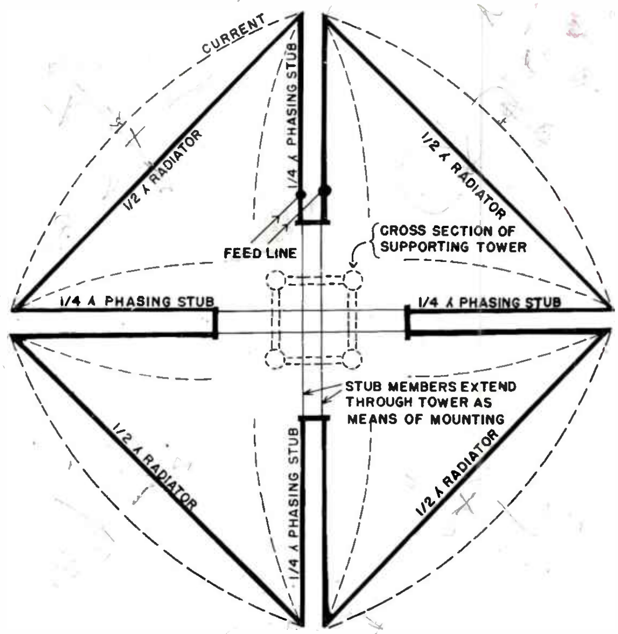


FIG. 12. *Arrangement of "square-loop" mounted on a tower.*

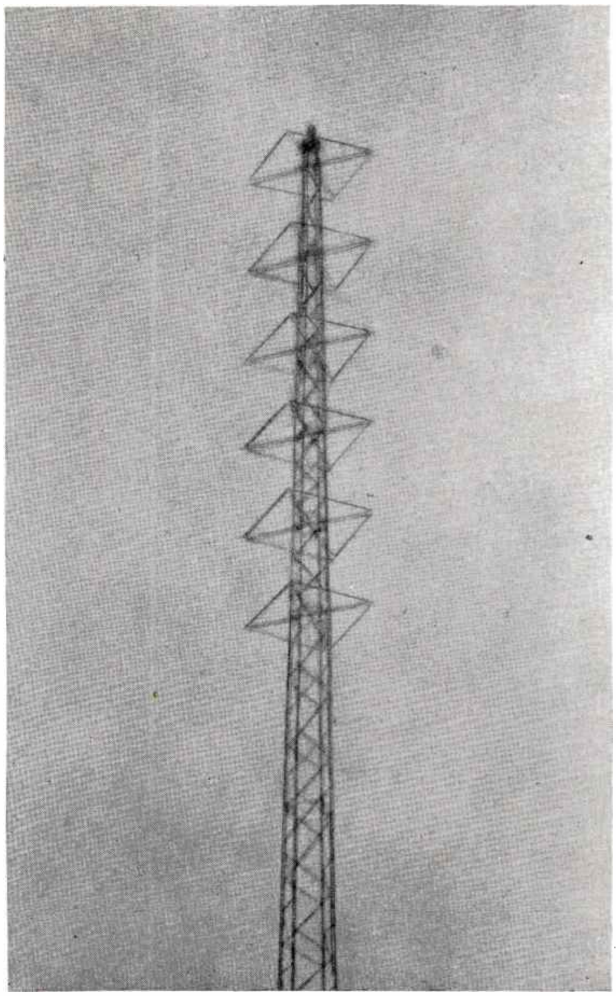


FIG. 13. *A six-layer antenna of the "square-loop" type mounted on an AM tower which has been in use at WBRL, Baton Rouge, for the past three years.*

the turnstile for cases when more than one layer is used. For instance, a three-bay circular antenna which is two wavelengths high (40 feet at 45 mc.) has a power gain of 2.6, whereas a five-bay turnstile having the same height has a power gain of 3.5. As noted before, it is the height which is the important parameter since it is the weight and upsetting moment of the supporting pole which determine the practicality of a given design.

The off-center mounting of the rings is also a disadvantage in that it makes for mechanical and electrical dissymmetry. Thus, while the loops are of the same approximate weight as the turnstile elements, the fact that they are off-center requires a stronger supporting pole. The dissymmetry also affects the electrical properties in that there are induced in the pole currents which are opposite in phase to those in the radiators. Because of these mechanical and electrical difficulties, it is believed impractical to go beyond three or four layers in this type of antenna.

SQUARE-LOOP ANTENNAS

The antennas previously described are all mounted on supporting poles of the "flagpole" variety. Where such a pole can be mounted on an existing structure or where the ground height is in itself sufficient, one of these standard types of antenna should definitely be used.

In some cases, it will not be possible to mount a flagpole on the building chosen—either because the building structure will not support it, or because of the configuration of the building itself. Similar difficulties sometimes arise when it is desired to mount an FM antenna on an existing AM tower. Most such towers were not built for and will not support the heavy pole used with multi-element turnstiles or ring antennas. In such cases, several variations of what, for want of a better term, may be called a square loop antenna have been used with some success.

The square loop antenna consists of four dipole radiators arranged in the form of a square which may or may not be closed at the corners. In the case of a large building tower, the dipoles may project from the four sides somewhat as shown in Fig. 11. They may take the form of folded dipoles or of simple dipoles fed at the center, according to how impedance matching is to be obtained. Several antennas of this type have been designed by RCA engineers and are now in operation.

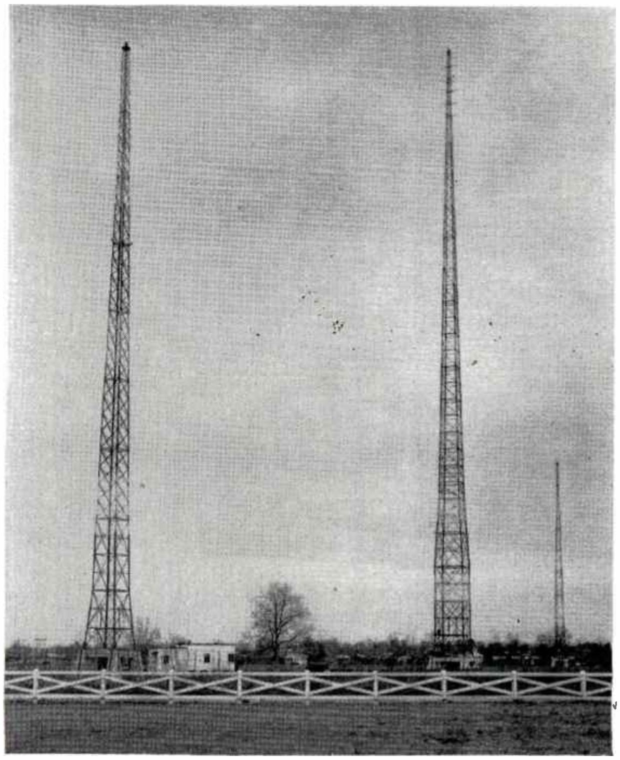


FIG. 14. *The three element array of AM station WJBO, Baton Rouge. The six-layer FM antenna of WBRL is mounted at the top of the 500 ft. tower in the center.*

A type of square loop antenna which can conveniently be mounted *around* a standard AM broadcast tower has been designed by Dr. G. H. Brown of RCA Laboratories (U. S. Patent No. 2,207,781). While various configurations are possible (including a three-sided type), the most usual arrangement is that shown in Fig. 12. The radiators are half wavelength sections supported at the ends by pieces of tubing which run diametrically across the square and are attached near the center to the framework of the AM tower. These supports have shorting bars placed at points a quarterwave in from the corners. The current distribution is shown by the dotted line. Since the points where the shorting bars are located represent voltage nodes, the supports can be at ground potential.

Several one and two layer arrays of this kind have been built and at WBRL, Baton Rouge, La., there has been in operation for the past three years a six-layer antenna of this type, a closeup of which is shown in Fig. 13. In this case, the whole FM antenna is mounted at the top of a 500 foot AM tower, as shown in Fig. 14. The original intention had been to put a six-bay turnstile at the top of this tower. However, querying the tower manufacturer brought out the fact that to provide adequate support for the turnstile, some 150 feet of the tower would have had to be removed. The saving in tower height effected by this use of the square-loop antenna is illustrated in Fig. 15.

The *gain per layer* of the square-loop antenna is greater than that of either the turnstile or the ring antenna. The reason will be evident when it is noted that each layer has effectively twice as many radiators as the turnstile. Moreover, because the vertical radiation is very low, the layers can be mounted at half-wave intervals. Comparative gains of the several types of antenna are shown in Fig. 9.

Despite its high gain and mounting advantages, however, the square-loop antenna should be considered only when the other types cannot possibly be used. There are three reasons for this statement. First, such an antenna must be laid out and probably built on the location. This is because each one will be slightly different as to arrangement and mounting details. Second, the tuning is quite critical and must be done with the radiators in place. (In the case of WBRL the top section of the tower was set up on the ground and preliminary adjustments made before it was raised to the top of the tower.) Third, it is very difficult to design such an antenna to withstand a heavy ice load—although this, of course, does not mitigate against its use in the South.

SUMMARY

In summing up the information on FM antennas developed out of experience to date, the best advice that can be given to station engineers setting out to plan an FM station is:

(a) Choose an antenna which can be purchased complete—a "packaged" item.

(b) Select an antenna type which can be "pretuned" so that engineering adjustments will not have to be made at the time of installation.

(c) Get as much "antenna gain" as possible, but remember that the building or structure on which the antenna is to go may set a definite limit.

(d) Note that it is the height of the supporting pole which determines the type of antenna that can be erected—hence "gain per height of pole" is the true figure of merit.

(e) Remember that wind-resistance and icing conditions (where they exist) must be adequately provided for.

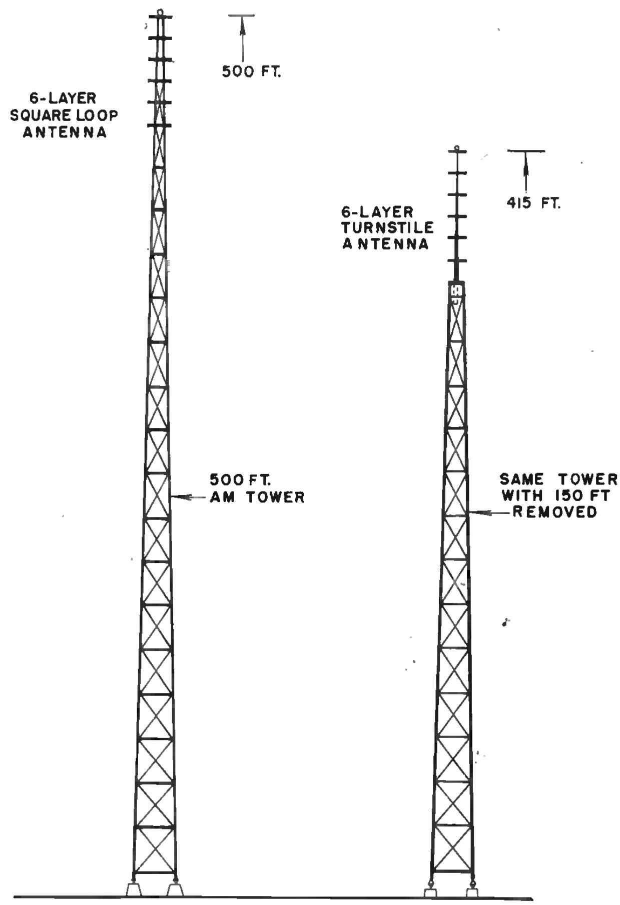


FIG. 15. *Diagram showing how 85 ft. in height was saved by use of square-loop type antenna.*

NBC's EXPERIENCE with PORTABLE TELEVISION EQUIPMENT

by ROBERT E. SHELBY & HAROLD P. SEE
Development Engineering Section
National Broadcasting Company

EDITOR'S NOTE: *The last issue* (Vol. No. 38) *of BROADCAST NEWS featured an article by Henry Rhea describing in some detail the RCA Portable Television Pickup Equipment. In this second article of our series on television remotes, Mr. Shelby and Mr. See describe the experience of NBC's technical staff in using this equipment—as well as their experience with earlier type equipment which led up to the design of the present orthicon-camera type units. In a third article, which will appear in a forthcoming issue of BROADCAST NEWS, we hope to present a discussion of the programming ideas which have evolved from NBC's work in this field.*

The recent announcement of tentative plans for a coaxial cable from coast-to-coast is indicative of the planning in all allied fields to bring about a great new television broadcasting industry. This schedule envisages a series of national coaxial cables linking a substantial portion of the east coast, some inter-city connection in the central part of the country, the completion of a southern transcontinental coaxial cable route, and extensive linkage of other cities within a reasonable period following the end of the war.

In the meantime, the development of the local television market and the creation of an established local television audience, must take precedence in the plans of a majority of potential station operators over eventual participation in a television network service. It is essential that local development proceed toward the goal of providing interesting programs within the allowable cost framework. Fortunately, a wealth of television program material exists in most of those communities which will have an early place in the establishment of a television broadcasting industry. While a considerable portion of the program material now

FIG. 2(a) *The iconoscope-type field camera used in early remote television pickups.*

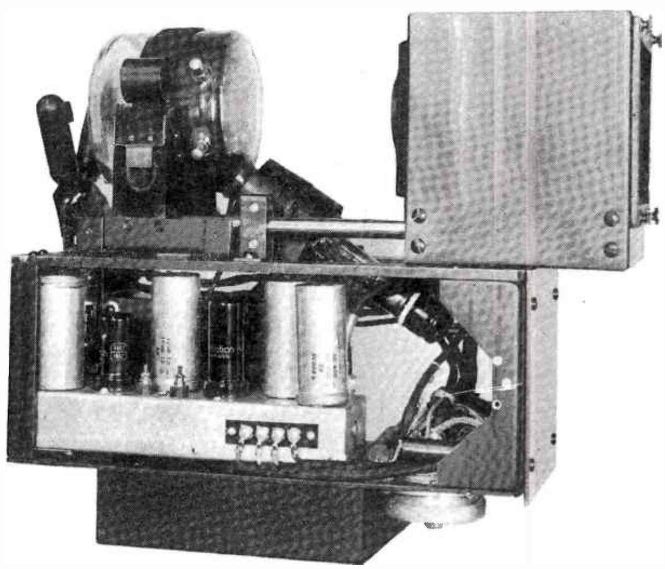


FIG. 2(b) *Interior of the iconoscope-type camera shown at the left.*

FM AUDIO MEASUREMENTS with an AM RECEIVER

★

How to determine modulation level and make audio response measurements by the "Bessel Zero" Method

by R. J. NEWMAN
Transmitter Engineering Section

The best and, of course, the easiest method of checking frequency swing and making frequency response measurements is with an RCA 322-A FM Modulation Monitor. However, when such a monitor is not available, or when an independent check is desired, the so-called "Bessel Zero" system of measuring can be used to advantage. No knowledge of Bessel functions nor even of FM modulation theory is necessary providing the operator understands what he is trying to do and goes about it carefully. The only equipment required is a beat frequency oscillator of good stability (such as the 68-A or 68-B) and an AM receiver which has a "cw" or beat oscillator and is capable of tuning through the range up to 50 megacycles.

WHAT IS MEANT BY "BESSEL ZERO" POINTS

The "Bessel Zero" method of measurements is based on the fact that the amplitude of the center frequency component of the energy emitted from an FM transmitter, varies as the *amplitude or frequency* of the audio modulating signal is changed. Thus, if the frequency of the modulation is held constant and the amplitude varied, the amount of energy radiated at the center or "carrier" frequency will vary through wide limits. The reason for this variation is that the modulation energy is distributed over the frequency spectrum; diversion of energy to "side current" frequencies takes center frequency power. These variations in the center frequency power can be calculated by means of Bessel functions. Ordinarily, they are plotted as a curve of amplitude against "Modulation Index" as shown in Fig. 1. (In order to use this method, it is not necessary for the operator to know how to make these calculations—but simply how to use the resulting curve). The "Modulation Index", which is the abscicca on the curve of Fig. 1, is the ratio of the Frequency Swing (usually designated F_d) to the Modulating Frequency (usually designated F_m). It will be noted in Fig. 1 that the amplitude becomes zero at several points. The first point at which this occurs (when the audio modulating voltage is increased from zero up) is at the point where the "Modulation Index" equals 2.405. If we can identify this point, and if we know the modulating frequency, we can figure out how much "frequency swing" is occurring, because: Mod. Index $= 2.405 = F_d / F_m$

hence: $F_d = 2.405 \times F_m$

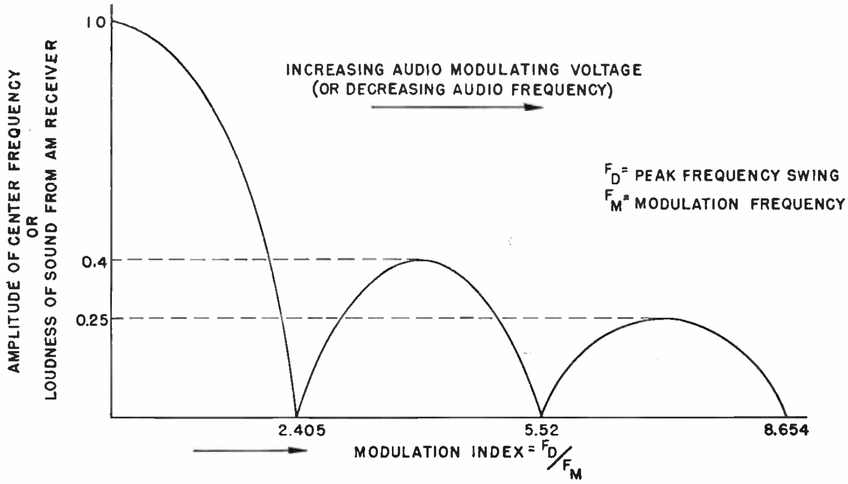


FIG. 1. *A diagram showing how the "Bessel Zero" points may be found. As level of audio input is increased, the amplitude of the "center frequency" decreases and becomes zero when* $F_d/F_m = 2.405, 5.52$, *etc.*

HOW THE "BESSEL ZERO" POINTS ARE FOUND

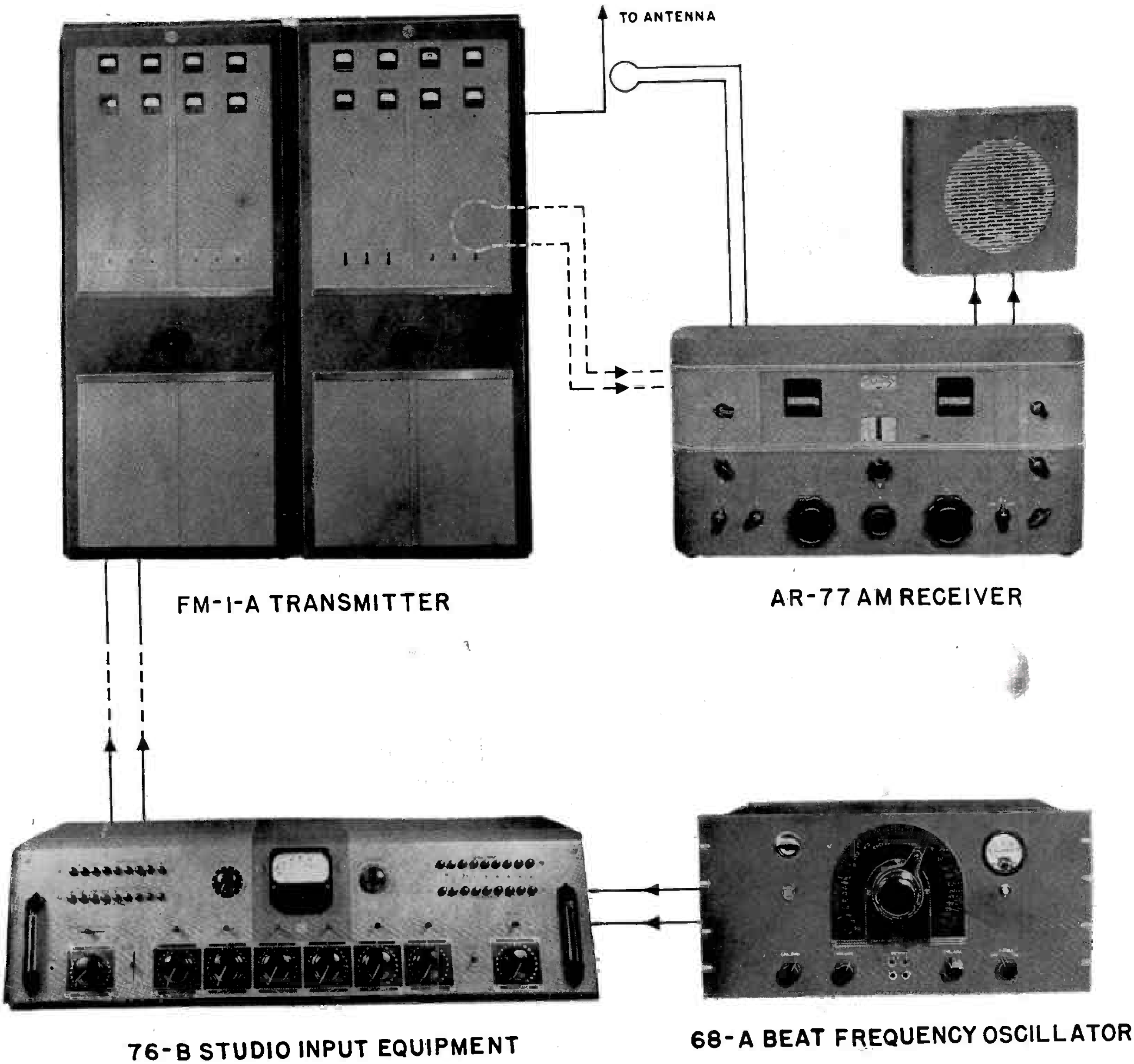
The disappearance of the center frequency of the FM transmitter may be observed with the equipment arranged as shown in Fig. 2. The procedure is as follows:

1. Tune the superheterodyne receiver (with its cw oscillator operating) near the *unmodulated* FM transmitter frequency obtaining a low pitched beat note (about 500 cycles) in the headphones. It is important that the center frequency beat note heard in the headphones not be confused with that of the side frequencies. The side frequencies increase in intensity and number as the deviation increases. Care in making the adjustments, and a little practice will attune the ear to the proper beat note. A low pass audio filter may be used in the receiver, if desired.
2. Slowly increase the amplitude of the audio modulating voltage; the transmitter frequency deviation will increase causing the "Modulation Index" to increase. Note that:
   (a) Increasing the modulating index will cause more side frequencies.
   (b) Energy moves into the "side current" frequencies and finally the center frequency (audio note in the headphones) decreases to zero.
   (c) As the modulation index is increased further by a higher modulating level, the carrier (and audio note) will reappear.

HOW THIS INFORMATION IS USED

Suppose that it is desired to establish the audio level necessary for a given percentage of modulation. The following examples will illustrate how this can be done:

FIG. 2. *Arrangement of equipment for measurements by the "Bessel Zero" method.*



Example 1

(a) Assume that it is desired to establish the audio level for 40 percent modulation (±30 kc. deviation).

(b) First it is necessary to find the audio modulating frequency "^{F}m" which will give 40 percent modulation at the first "Bessel Zero." This can be obtained from the relation $^{F}m = {}^{F}d/2.405 = 30/2.405 = 12.058$ kc.

(c) Next the 68-B is set at 12,058 cycles and the level of the 12,058 cycle frequency increased until the center frequency component of the emitted R.F. energy disappears. At this level the modulation is 40 percent.

Example 2

(a) Assume that it is desired to establish the audio level for 100 percent modulation or ±75 kc. deviation.

(b) It is first necessary to find the audio frequency "^{F}m" which will give 100 percent modulation at the first Bessel Zero. Using the same relation as before, it is found that, $^{F}m = 75/2.405 = 31.2$ kc. or 31,200 cycles.

This value is impractical since the modulation frequency is too high for the audio system of the transmitter. However, in FM transmitters employing the reactance-tube type of frequency modulation, both the carrier-frequency deviation and the frequency of the carrier itself are directly proportional to the number of times the frequency of the modulated-oscillator is multipled before reaching the output stage of the transmitter. If the transmitting equipment is tuned so as to triple the modulated oscillator frequency in the modulator or exciter unit, and if this exciter output frequency is again tripled in one of the succeeding R.F. amplifier stages, the carrier frequency will be 3 x 3 or nine times the modulated-oscillator fundamental frequency. The frequency deviation at the oscillator frequency will, therefore, be one-ninth of the 75 kc. deviation of the carrier frequency or ±8.33 kc., and the first "Bessel Zero" will occur at a modulating frequency of 8.33 divided by 2.405 or 3.46 kc.

Thus, if the receiver is coupled to the modulated-oscillator stage (instead of the output of the transmitter) and the transmitter is modulated with a 3,460 cycle sine-wave signal, the heterodyne note will disappear when the deviation of the carrier is ±75 kc. This provides a method of solving Example 2, above, as follows:

Example 2 (cont'd)

(c) The AM receiver is coupled (by means of a small pickup coil) to the modulated-oscillator stage.

(d) The 68-B is set at 3,046 cycles and the level of the 3,046 cycle frequency increased until the center frequency component disappears. At this level, the modulation is 100% (i.e., deviation is ±75 kc.).

PROCEDURE FOR MAKING MEASUREMENTS OF THE AF RESPONSE

The above method may also be used in making audio response measurements by following the same outline to determine the "Bessel Zero" for each of the several audio frequencies chosen for measurement. It can be seen from the relationship $^{F}d = 2.405 \times 9 \times {}^{F}m$ that the carrier deviation is directly proportional to the audio frequency. Hence, it is possible to determine the audio level required in each case for the first "Bessel Zero" and then to compare both the audio level and the frequency deviation produced for each audio frequency back to a reference point such as the 100% modulation point. The procedure is as follows:

1. A table is set up, as shown, listing first the data for the 100% modulation condition. This becomes the reference point.
2. The audio frequencies to be used are listed in the first column and in the second column, the levels required for the first "Bessel Zero."
3. The carrier frequency deviation is determined for each audio frequency from the formula, $^{F}d = 2.405 \times n \times {}^{F}m$, where "n" is the number of times the frequency of the modulated oscillator is multiplied to produce the carrier frequency.
4. The logarithmic ratio between the deviation of the particular audio frequency and that of the reference frequency (75 kc.) is computed and set down in column 4.
5. A similar calculation is made (column 5) between the audio level required for the particular audio frequency and that of the reference (3,460 cycles/sec.).
6. The actual response in db is then the difference between columns 4 and 5 taking into consideration, of course, the proper sign.

The carrier frequency of the transmitter in this example is 45 mc. It should be noted that for the first six frequencies, the receiver was tuned to 5 mc. For the last four measurements, the formula for column 3 becomes $^{F}d = {}^{F}m \times 2.405 \times 3$. This is because for these measurements it was necessary to tune to one-third of the carrier frequency (coupled to the first tripler stage) and continue the measurements there, since otherwise, the deviating frequency would exceed 100 kc. and the carrier would be overmodulated. The 5,000 cycle measurement is repeated for the purpose of checking the accuracy of this shift.

TABLE 1

#1 Aud. Mod. Freq. Cycles	#2 Aud. Level Req. For 1st Bessel Zero DB	#3 $^{F}d = 2.405 \times 9 \times {}^{F}m$ KC	#4 $20 \log \frac{^{F}d}{75 \text{ kc.}}$ DB	#5 Aud. Level (db) — (—2.5db) DB	#6 Response DB
RECEIVER TUNED TO 5 MC.					
REF 3460	—2.5	75	0	0	0
500	—19	10.8	—16.8	—16.5	—0.3
1000	—13	21.6	—10.8	—10.5	—0.3
2000	—6.5	43.2	—4.6	—4.0	—0.6
3000	—3	64.8	—1.1	—0.5	—0.6
5000	+1	108	+3.2	+3.5	—0.3
RECEIVER TUNED TO 15 MC. (DEV NOW = 3. x 2.4 x AUD. FREQ.)					
5000	—8.5	36	—6.3	—6.0	0.3
7500	—4.5	54	—2.8	—2.0	—0.8
10000	—1.0	72	—2.0	+1.5	—0.5
15000	+2.0	104	+3.2	+4.5	—1.3

THE 2-A STUDIO CONTROL CONSOLE

by J. E. COLVIN • STUDIO EQUIPMENT SYSTEMS ENGINEER

The 2-A Studio Control Console—manufactured on special order for the Columbia Broadcasting System—is easily the most advanced equipment of this kind built to date. The refinements incorporated in the design and the facilities built into this console go somewhat beyond the immediate requirements of individual stations. Nevertheless, these features will be of considerable interest to station engineers as an indication of the trend in studio equipment design. Moreover, the console as a whole is interesting as an example of what can be achieved when careful study and thought are given to the requirements of a specific application.

The general construction and the main features of the 2-A Console were planned by CBS engineers at the time the Columbia Broadcasting System was in the process of adding several new studios to its New York facilities. Since these studios were to represent the last word in modern design, with "controlled acoustics" and other advanced features, it was considered desirable to have control equipment which would insure the ultimate in performance and which, at the same time, would be convenient, reliable, and as nearly "confusion-proof" as possible. To this end CBS engineers spent several months studying such problems as: what audio facilities would be neeeded; what operating features were desirable; and what the physical arrangement and size should be. Diagrams such as that shown in Fig. 1 were made up in order to estimate required heights, angle of vision, reflections, and the like. Finally a wooden model was built so that the operators and others concerned could pass judgment on the construction, convenience, and suitability. At this point the sketches and circuit arrangements were turned over to RCA engineers for detailing and manufacture. After these engineers had studied the requirements and made tentative plans, further conferences were held with CBS engineers. The final design combined the operating knowledge of CBS engineers with the circut and manufacturing experience of RCA engineers.

The console which resulted from this careful planning is shown in Fig. 2. Since it was desired to have the control room elevated as shown in Fig. 1, a primary requirement was that the front of the console be low enough that it would not obstruct the view of the operator. That this was achieved is indicated by Fig. 3 which shows a view looking into the studio from approximately the operator's position. Another requirement which was stressed was that all controls, plugs, jacks, etc. be within easy reach of the control engineer when seated in his normal position. To obtain this the patching lines are located in the two somewhat elevated sides of the console, with the low level lines on one side and the high level lines on the other side. There were other requirements which affected the physical layout; for example, that all components—amplifiers, power supplies, etc.—be located in the console (rather than on racks); that these be easily accessible without moving the console to get at the back; and

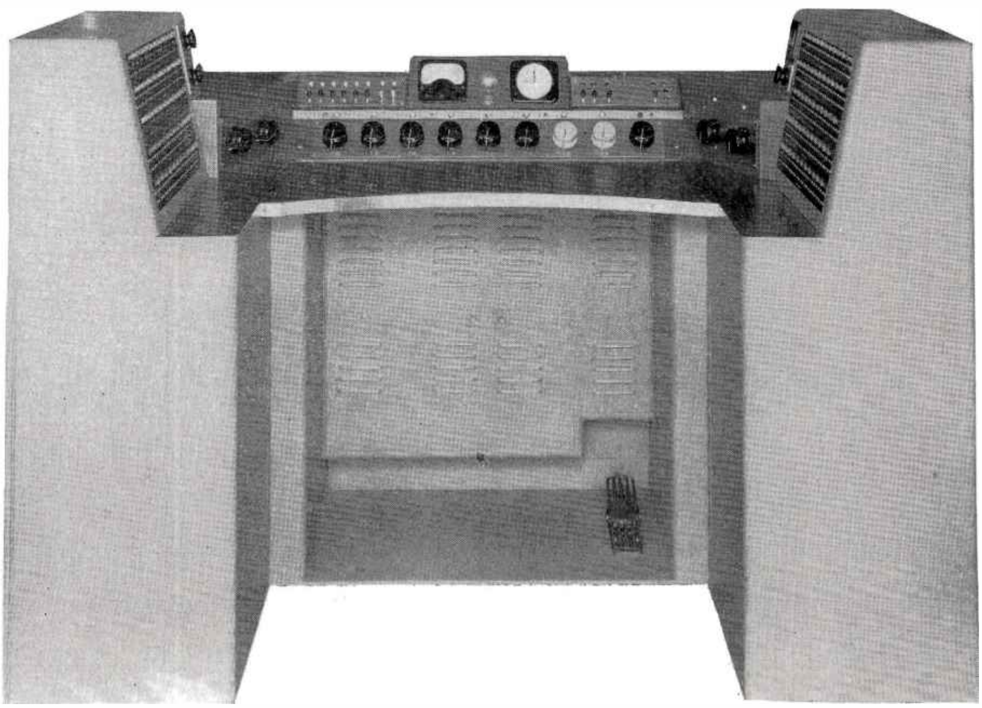
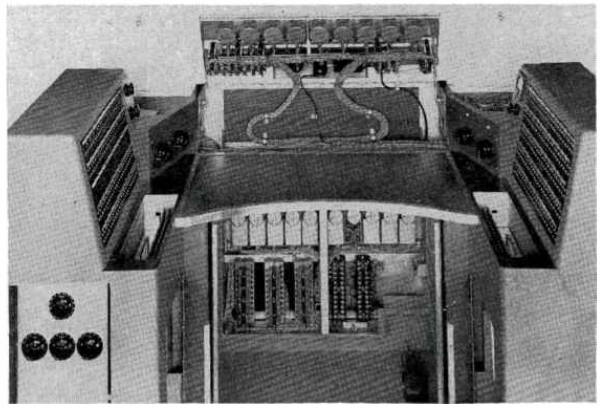


FIG. 2. *The front view of Type 2-A Studio Control Console built by RCA for the Columbia Broadcasting System.*

aiding in quick identification. The master gain control is red. The three-position "line" key switch is just above the master gain control. In the up or "Rehearsal" position of this key switch, the input of the control room monitor circuit is connected to the output of the program amplifier. This also makes the talkback circuit operative. In the center or "Cue" position of the line key switch, the input of the control room monitor circuit is connected to the cue line that comes from master control. Upon receiving the proper cue, the line key is thrown to the down or "Air" position. The control room monitor then goes back across the program circuit. If the program being carried through the console to the air comes in on a remote line and none of the studio microphone keys is thrown, the studio speaker comes on. Throwing any mic key will kill the studio speaker. All interlock circuits are so arranged as to prevent any speaker-to-microphone feedback and also to make it impossible to talk back into the studio while the studio is on the air.

Plenty of jacks through the circuit provide maximum flexibility in making up special circuit arrangements. In Fig. 7 are shown the various "circuit accessories" features included in the desk, in addition to the straightforward program equipment shown on the block diagram. The function of these features and the various uses to which they can be put can be understood from their titles and their diagrammatic figures. With the exception of the regular and emergency power supply circuits, the clock, and the tube

FIG. 5. *The control panel is hinged for easy servicing. Preamplifiers and terminals are readily accessible.*



checking meter, all other devices and circuits shown in this figure can be inserted into the regular program circuit by means of patch cords. The entire arrangement of the desk provides means and facilities to create a setup that will meet the requirements of any type of program, and all of these are within arm's reach of the operator.

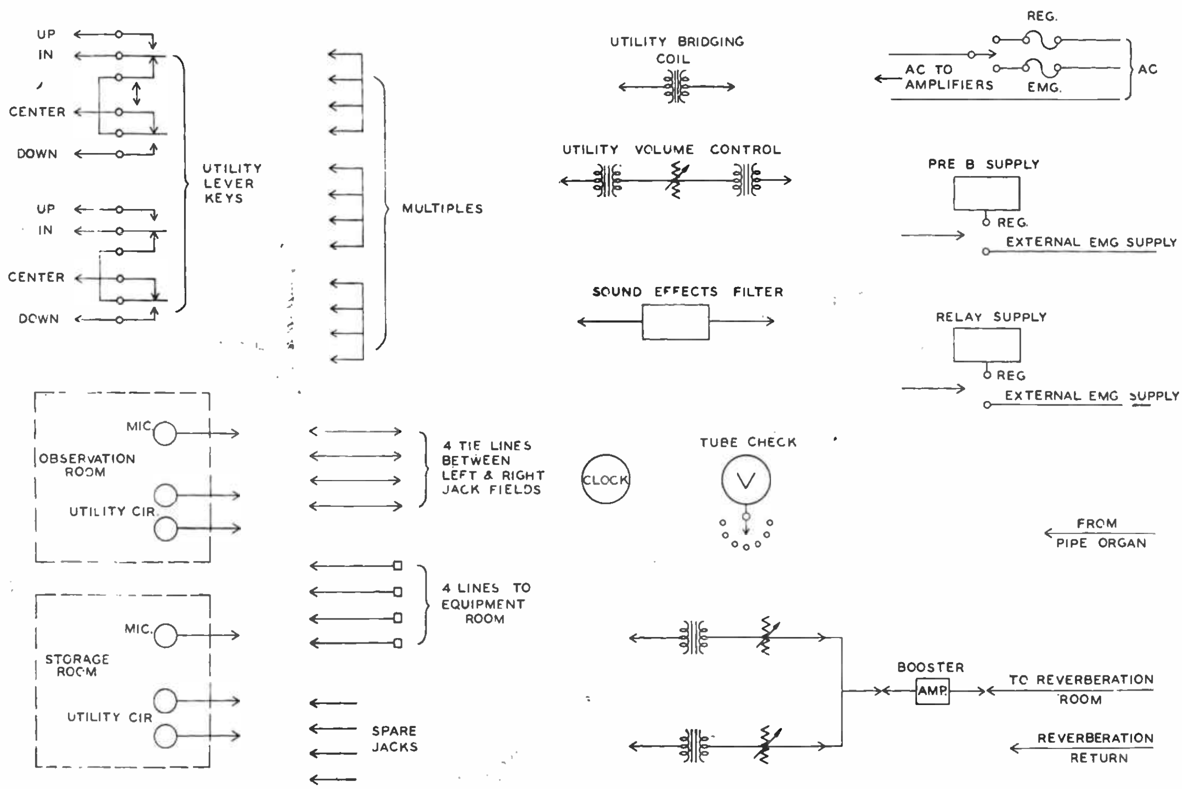


FIG. 7. *Diagram illustrating the "extra" circuit features in the 2-A Console.*

"DC" PICTURE TRANSMISSION

by **H. N. KOZANOWSKI**
Television Engineering Department

In "DC" picture transmission, no DC is transmitted in the ordinary sense of the term. What the television engineer actually means when he speaks of "DC" picture transmission, is that the DC component of the picture signal is transmitted. This component represents the background or average illumination of the original scene. It varies with the overall illumination of the original scene, whereas the video signal (a.c. component) varies with the brilliance of the small area of the scene which is being scanned at the moment.

To understand why "DC" picture transmission is used and how it is accomplished, it is necessary to consider in some detail the inner workings of the television system.

To begin with, we can imagine a general television pickup tube. All that we have to know about this tube at the present time is that in some way it is able to translate light variations into corresponding variations of electrical voltage. In practically all such tubes in use at the present time, this translation process is carried out by focusing an optical image of the scene to be televised on a light-sensitive area of an electronic tube. Photoelectrons are emitted from various regions of this area in direct relation to the illumination of these regions. By the process of scanning, an electron beam, deflected from left to right and from top to bottom of this rectangular surface, replaces the electrons which were emitted under the influence of light by new electrons from the electron stream in an orderly fashion. The electrons replaced by this orderly scanning procedure actually form a complex electrical wave whose amplitude at any instant is directly related to the brightness at that instant of the definite region of the picture being televised. In general, one can think of the process as that of dividing the picture area into a series of very narrow strips, each a scanning line long, and of marking on each strip the effective illumination of the area from which it was taken. This strip-series in television is the succession of elementary scanning lines and the markings are the instantaneous voltages along these lines.

Assume for the moment that we know how to make an electrical signal which will vary in time in such a manner that its voltage at any instant corresponds precisely to the brightness of the scene element from which this voltage was formed by photoelectric action. Assume also that we know how to put in at the end of each scanning line and at the end of each frame the synchronizing signals which we shall need in re-assembling this electrical information faithfully into a visual scene or picture. A device which is practically universal at the present time for reproducing an image from an electrical signal is the kinescope. The kinescope contains an electron gun which shoots a stream of electrons at a fluorescent screen under the influence of a high DC voltage. The electron stream is deflected from left to right and from top to bottom either magnetically or electrostatically. By means of the synchronizing signal which we introduced into the system, it is possible to make the electron beam start at the left of the kinescope, continue to the right side, return to the left and so on, exactly in synchronism with the original scanning at the pickup device. When electrons strike the screen their energy is converted into a fluorescence of the screen itself, the screen brightness at a given region depending directly on the number of electrons striking it at a given instant. In the kinescope the grid which surrounds the electron gun acts as a valve controlling the number of electrons in the electron stream. A high negative bias will cut off the beam completely and produce no light on the end of the kinescope while a grid voltage close to zero will allow full beam current to flow and produce the maximum possible illumination. Intermediate brightness will be produced by voltages located between the two extremes, zero bias for full white, and cutoff bias for full black.

If the signal which is obtained from the pickup device is magnified without any distortion and applied to a kinescope grid, we see that a sufficient mechanism exists to produce a picture which is a faithful reproduction of the object being televised. If this signal has a polarity such that black is represented by a definite negative voltage and white by a voltage practically zero, this voltage magnified and applied to the kinescope grid will cause the light intensity to change so as to follow the change of illumination in the object being scanned.

It is now necessary to explain the meaning of black level, white level, synch. pulse, (blacker than black) and to consider intermediate illumination values. Figure 1 shows one-cycle samples of simplified typical signals for various types of scenes. Black level, B, white level, W, a stair-step wedge, a white bar on black background, and a black bar on white background are shown successively. Each wave includes blanking and synchronizing pulses. To get a true picture at the kinescope, these voltages, correct in absolute value, must be applied to the grid of the kinescope after all the intermediate processes of modulation, transmission, and reception in the various circuits have been accomplished. In other words, a kinescope has only one value of grid voltage at which it is dark, and another voltage at which it delivers full illumination, and it is the duty of all the intermediate transmission and reception processes to translate the television signal into absolute voltage levels at the kinescope grid. If we amplify a television signal which is a series of wave trains of the elementary forms shown in Figure 1, it is obviously impractical to use multi-stage DC amplifiers. However, as soon as a wave of this type is applied to an amplifier grid through a condenser, it is changed electrically; in fact, we must now talk about an AC signal axis. By its very concept, the AC axis is located so that during any given cycle the area of the wave above it is equal to the area below it. This is just another way of saying that the product of current and time in one direction is equal to the product of current and time in the opposite direction during one cycle and there is no finally, that the unit as a whole be good-looking, sturdy, and free from projections and sharp corners. The latter was achieved by making the cabinet entirely of muntz metal (brass and aluminum alloy) with all the joints being welded or brazed and all corners and edges rounded on a half-inch radius.

Not only the arrangement and construction of the 2-A Console but also the layout of the various controls and the mechanical mounting of the amplifiers and other components were the subject of much study. As can be seen in the photographs, the primary studio controls consisting of faders and lever keys are located on sloping panels directly in front of the operator. Centrally located on this main control panel is the talkback microphone. This microphone is turned on by pressing a foot-operated switch. A small but interesting feature is the provision of small, celluloid temporary note pads located above each fader (as can be seen in Fig. 3). While setting up for a program, the operator can jot down pertinent notes on the pad relating to the mic or circuit controlled by the fader immediately below. After the show the notes are quickly erased by lifting the celluloid.

The height of the center part of the console, as mentioned above, was kept as low as possible in order to allow a maximum view of the studio. Side wings of the console were made higher

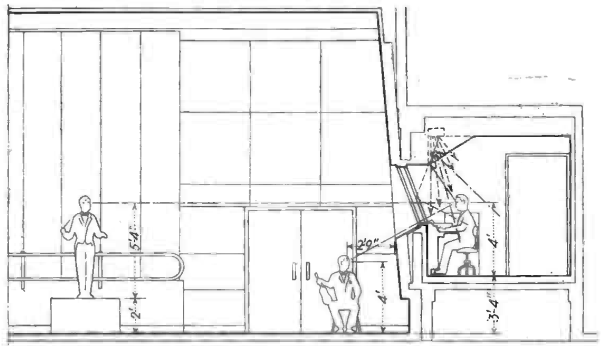


FIG. 1 *Diagrams of this kind were used in planning the arrangement and dimensions of the 2-A Console.*

to provide jack field space. Patch cords are suspended from a disappearing tray that is mounted in a compartment below the jacks. They are readied for use by opening a sliding door and pulling up the counterbalanced tray. Weights on the patch cords return them to place after using. The sound effects filter controls, reverberation controls, utility volume controls, and the tube checking meter are located on the small side and corner panels.

FIG. 3. *The 2-A Console in one of the booths at CBS, New York. Note how the low front gives the operator an unobstructed view of the entire studio.*

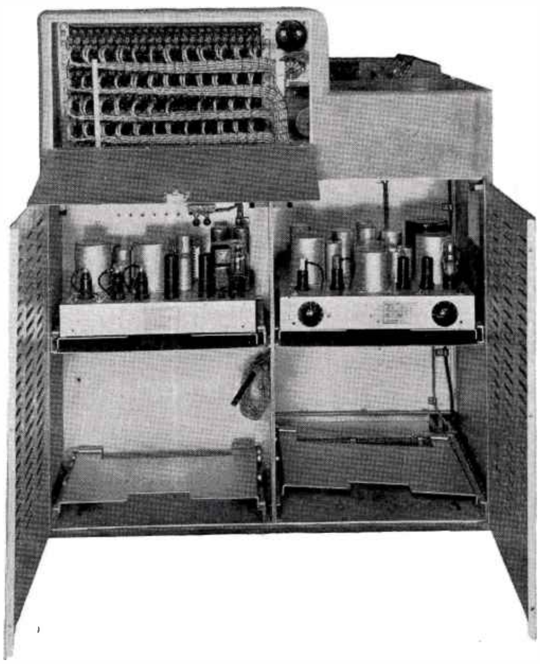


FIG. 4. *Monitoring and program amplifiers are mounted on sliding shelves in the right side of the console.*

All component parts of the equipment are easily accessible for servicing. Lifting the front panel exposes all faders and key switches. Doors in the knee hole of the desk reveal all pre-amplifiers and booster amplifiers, as well as the terminal blocks. (It is not necessary to get at the back of the console for any servicing or checking.) Mounted on sliding shelves in the right end of the desk are the program and monitoring amplifiers. (See Fig. 4.) These amplifiers can be tilted after the shelf has been pulled out, thereby giving access to the chassis wiring. Although this illustration shows only one each of the monitor and program amplifiers on the top shelf, space and wiring has been provided for emergency amplifiers on the bottom shelf. Power supply and speaker relays are located in the left-hand side of the desk. Opening a door on the front of the left pedestal gives access to the speaker and monitor gain controls, regular and emergency power switches, and power circuit fuses.

The normal program circuit is straightforward, as a study of the block diagram (Fig. 6) will show. Six microphone circuits and two remote line circuits make up the eight-channel mixing system. A master gain control is located at the right of the mixers. Electrically this is between the booster and program amplifiers. The eight input or microphone key switches are located on the small panel at the left of the volume indicator meter. The two "remote" keys are white, as are the associated mixers, thus

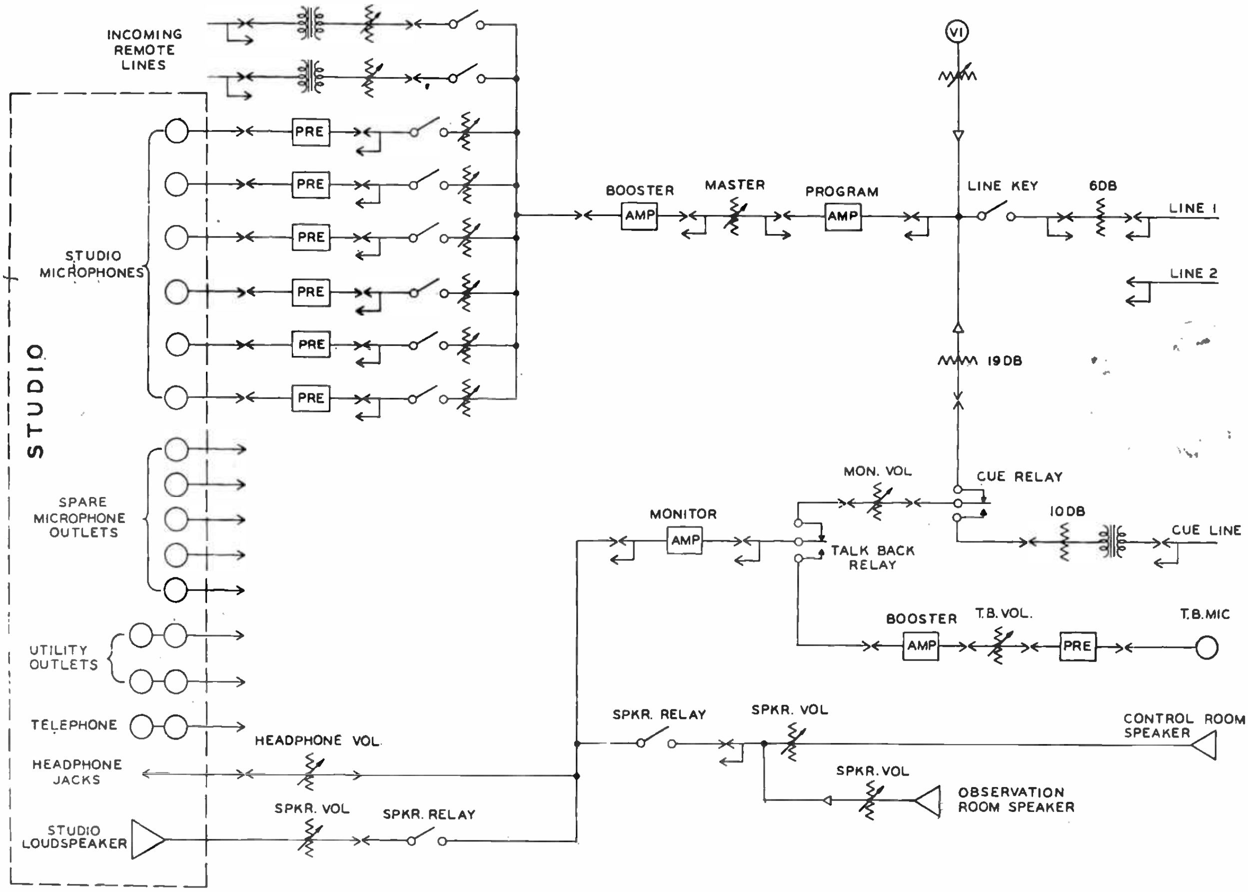
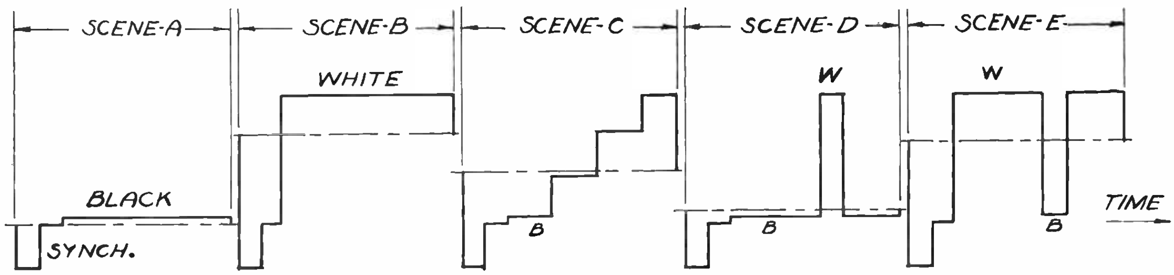


FIG. 6. *Block diagram of the circuits incorporated in 2-A Console.*



—— - —— INDICATES A-C AXIS IN FIG 1 & 2

FIG #1

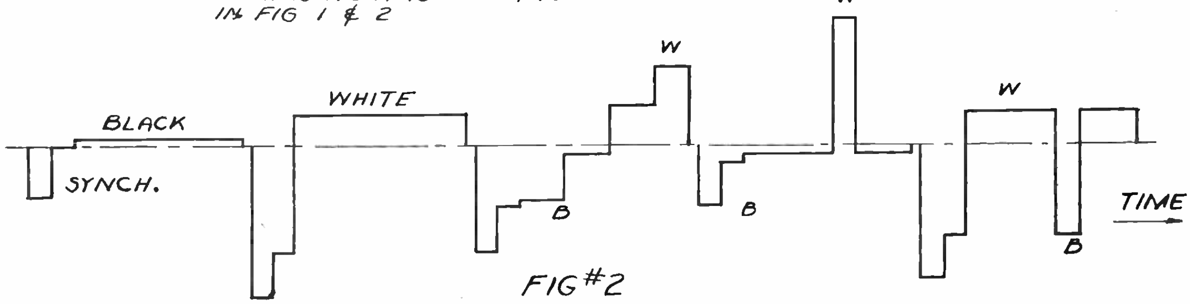


FIG #2

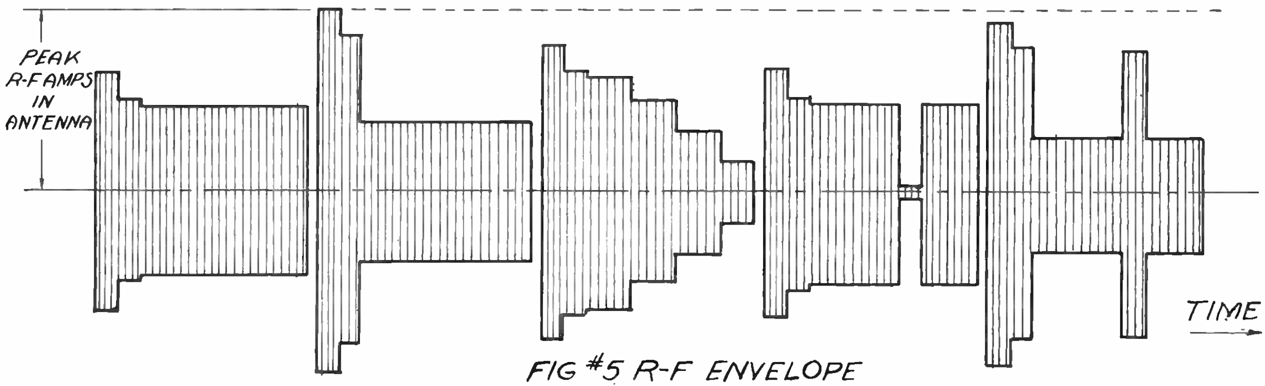


FIG #5 R-F ENVELOPE
A.C. TRANSMISSON

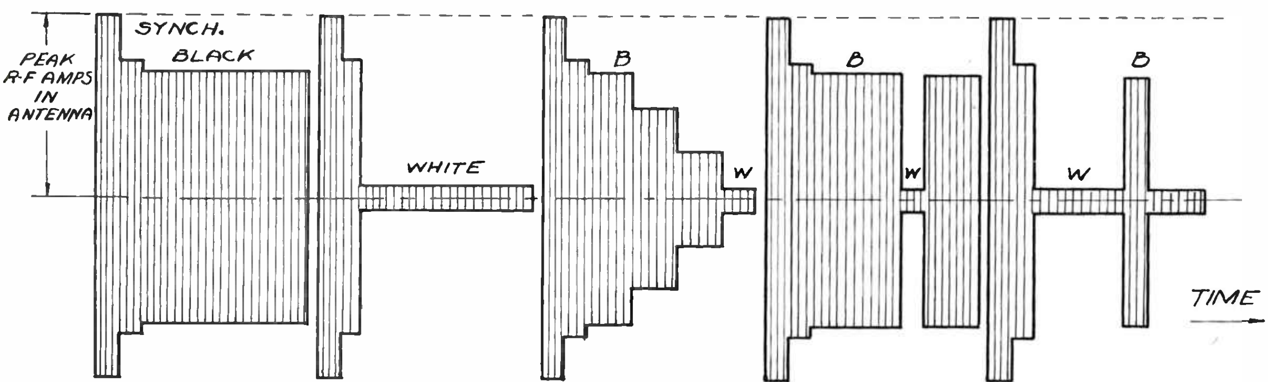


FIG #6 R-F ENVELOPE
D.C. TRANSMISSON

DC component. The DC wave forms of Figure 1 balance themselves about the AC axis to give the symmetry shown in Figure 2. It is important and essential to point out that peak-to-peak voltages values are completely and faithfully preserved in the process. If the wave forms shown in Figure 1 are applied to a kinescope grid through a coupling condenser from the output circuit of a video amplifier, the instantaneous voltage of the grid varies about the AC axis as shown in Figure 2.

It is immediately apparent that although the peak to peak values of the wave forms are maintained, the absolute value measured at the grid changes with time depending entirely on the picture content. On the kinescrope this will mean that, with an arbitrarily selected grid bias voltage which is varied by the picture signal, either the white components or the black components can be compressed as the average picture content changes. As a simple illustration, let us consider the stair-case wave form "C" of Figure 2. If the DC grid bias is adjusted to the value given by the AC axis, white, gray and black will be quite truly represented because the picture of the stair step wedge is practically symmetrical. If, without changing the DC bias, the wave form "D" is applied, the white will be saturated and what should be black will appear as gray. If the wave form "E" is applied, the black will be saturated and what should be white will appear as gray. This state of affairs can be summarized by saying that the picture will "bloom" in the highlights or "squash" in the blacks and, only accidentaly, as in the relatively symmetrical wave form "C", will the correct illumination range of the picture be faithfully reproduced.

It is easy to go a step further in the analysis by noting that the absolute wave forms of Figure 1 can be obtained from the AC wave form of Figure 2 by a simple process known as DC setting. This DC setting process merely pushes all synchronizing or blanking pulse peaks to the same operating point on a vacuum tube characteristic. One method of DC setting is to allow the amplifier tube to take grid current at the peak of the synchronizing portion of the wave. A circuit which can be used for this purpose is shown in Figure 3. In this case the video signal, with synch. pulses having positive polarity, is applied to the grid of the video output tube. On initial application of the signal, the grid is driven positive by the synch. pulse peaks. Electrons flowing to the grid will charge the grid side of the coupling condenser negatively. During the interval between successive synch. pulses, this charge can leave the coupling condenser only through the high resistance grid leak, developing a negative bias which is practically constant. Successive synch. pulses, by repetition of the grid current process, restore the small amount of charge that is lost during the intervals between pulses.

If a change in the symmetry of the signal about the AC axis produces a new synchronizing reference height, the amount of charge on the condenser will change correspondingly. In other words, the DC grid bias on the tube automatically varies in accordance with the amplitude of the video signal and thus the peaks of synch. will always fall at the same point of the operating characteristic of the tube indicated by "P" in Figure 3. This effectively ties the synch. level definitely to a fixed video amplifier plate current which results in a fixed value of DC

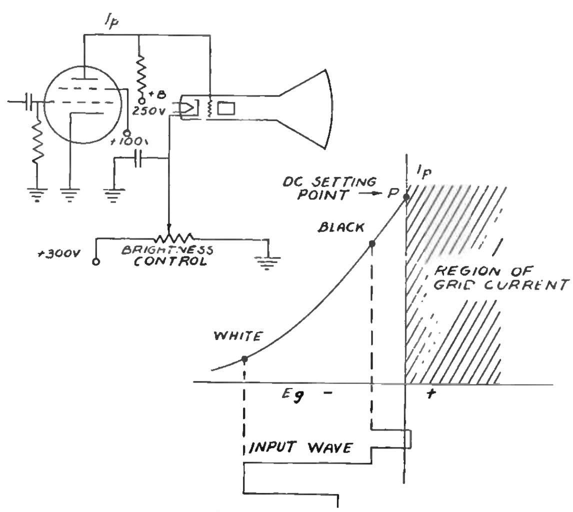


FIG..3 *Circuit for "DC Setting."*

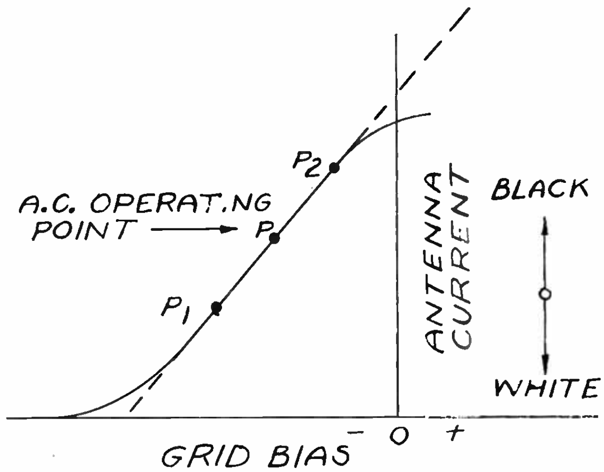


FIG. 4. *Operating curve for grid-bias modulated amplifier.*

voltage on the kinescope grid. *It should be kept in mind that the illustrations of wave forms given in the samples generally occur several frames apart and the transition in DC setting is much more gradual than indicated in this approximate analysis.*

Having shown the advisability and necessity of introducing DC setting at the receiver, it will be interesting to review the process of transmitter modulation. In television transmitters where we deal with modulation frequencies from practically DC to 5 Mc. depending on picture content and rate of change of scene, it has been found most feasible to grid-bias modulate the transmitter, as such a system represents the most practical way at the present time of obtaining satisfactory modulation without the expenditure of prohibitively large modulating power. Grid bias modulation merely varies the DC operating bias of the output RF amplifier at video frequencies under conditions where the RF grid driving voltage is held constant. If the output tubes did not take grid current, bias modulation could be considered as practically electro-static and hence wattless. Straight forward comparisons of grid and plate modulation, well-known to all broadcast engineers, bring out the fact that grid-bias modulation can be accomplished with smaller tubes in the modulator at the expense of RF output stage efficiency, while plate modulation gains in output stage efficiency at the expense of large modulating power.

The familiar curve of grid voltage vs. antenna current for constant RF excitation of a grid-bias modulated amplifier is shown in Figure 4. It is apparent that in order to modulate the transmitter successfully with a video signal of the type shown in Figure 2, the no-signal or AC operating point must be chosen so that any of the AC wave forms indicated will fall on the linear portion of this curve. Again it can be seen that if the operating point is incorrectly chosen, for example, Point P_1, it is very easy to saturate white portions of the picture by cutting off the output tubes, or to compress the synchronizing signal by operating too close to the curved high power output portion of the curve, as for example at point P_2.

Figure 5 shows the RF envelope of the picture wave when AC transmission is used. In this representation it can be seen that synchronizing always represents an increase in radiated power, as does black, whereas white represents a decrease in radiated power. The peak power output depends entirely on the AC symmetry of the signal and the only invariant in the system is the AC axis of the modulation as previously discussed. As in sound transmission, with a symmetrical wave, the peak power radiated is four times the carrier or no-signal radiation.

(Continued on page 44)

for exhaust tubes, this metal tube is pinched off cold by hydraulic pressure. Sufficient pressure is employed to obtain a vacuum-tight, cold weld.

The copper plate in these new tubes is designed to provide uniform heat dissipation and has a wall thickness of one-quarter inch, a diameter of four and one-half inches, and a length of thirteen inches.

The height of the 9C21 is twenty-one inches while that of the 9C22 with radiator is twenty-one and three-quarter inches, neither dimension including filament terminals. The radiator has a diameter of thirteen and three-quarter inches and a height of fifteen and three-eighth inches.

Both tubes are of the high-perveance type. They have the ability to deliver a large amount of power at relatively low plate voltage and with a small amount of grid excitation power. For example, a pair of 9C21's or 9C22's operated as class B audio modulators at a plate voltage of 14,000 volts will deliver a total audio output of 61,000 watts with a total driving power of only 150 watts.

These tubes may be operated at maximum ratings in all classes of service at frequencies as high as 5 megacycles and at reduced ratings up to 25 megacycles. They are useful, therefore, in both standard and international-band broadcast transmitters and in electronic heating oscillators of both the low and high-frequency types.

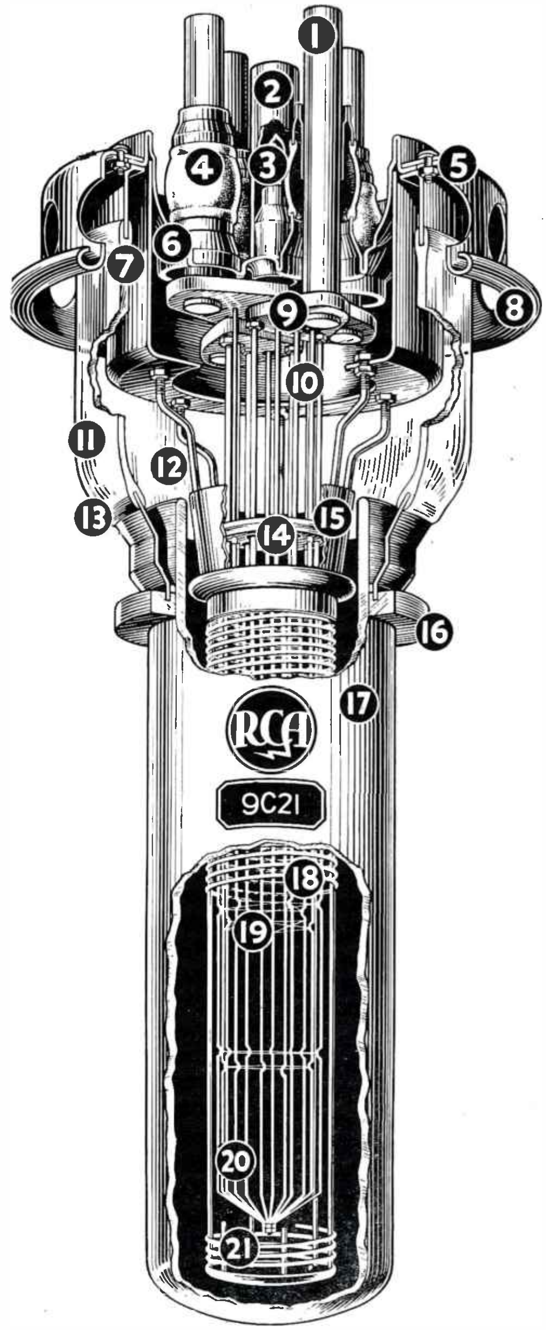
The relationships between operating frequency and maximum rated plate voltage and plate input are shown in the following table:

Frequency	5	12	25	Mc
Max. permissible percentage of max. rated plate voltage and plate input:				
Class C telephony	100	90	81	Per cent
Class C telegraphy	100	84	70	Per cent

Ratings and electrical characteristics of the 9C21 and 9C22 are shown below and are per tube unless otherwise specified:

Filament	Single-phase	
Voltage (A.C. or D.C.)	19.5 volts	
Current	415 amperes	
Amplification Factor	38	
D-C Plate Voltage (Max.)	*9C21*	*9C22*
Class B audio	15,000 volts	15,000 volts
Class C R-F plate modulated	12,500 volts	12,500 volts
Class C R-F oscillator	17,000 volts	17,000 volts
Plate Dissipation (Max.)		
Class B audio	40 kw	20 kw
Class C R-F plate modulated	28 kw	14 kw
Class C R-F oscillator	40 kw	20 kw
Driving Power (Typical, Approx.)		
Class B audio (max. signal)	150 watts*	150 watts*
Class C R-F plate modulated	1570 watts	1570 watts
Class C R-F oscillator	1800 watts	1450 watts
Power Output (Typical, Approx.)		
Class B audio	61 kw*	61 kw*
Class C R-F plate modulated	38 kw	38 kw
Class C R-F oscillator	100 kw	65 kw
Water flow around plate	15 to 20 gals. per min.	———
Air flow through radiator	———	1800 cubic feet per minute
Air flow to filament seal	10 cubic feet per minute	10 cubic feet per minute

* These values are for two tubes.



1—Filament Posts
2—Exhaust Tube Protective Cap
3—Metal Exhaust Tube
4—Filament Lead Seal (metal-to-glass)
5—Low Inductance Grid Terminal
6—Entrant Metal Header
7—Grid Seal (metal-to-glass)
8—Corona Ring
9—Filament Terminal Blocks
10—Filament Support Rods
11—Hard Glass Bulb
12—Grid Support Rods
13—Anode Seal (metal-to-glass)
14—Filament Heat Shield and Rod Enforcement
15—Electrostatic Shield
16—Anode Flange
17—Anode (¼-inch thick copper)
18—Grid Welded to Supports
19—Tie Wires for Self-Supporting Filament Assembly
20—Filament Strands
21—Common Tie of Self-Supporting Filament Assembly

TELEVISION LINEARITY CHARACTERISTICS

by C. D. KENTNER
Television Engineering Department

In simplest terms, amplitude linearity of a television transmitter system may be defined as a plot of input voltage against output voltage. The deviation of such a curve from a straight line is a measure of the non-linearity of the amplitude characteristic. In these respects, this characteristic is comparable to the "dynamic" characteristic of a sound modulated transmitter as shown in Fig. 1.

If it is attempted to carry the comparison further, however, the equivalence soon ceases to exist. In sound equipment, the reproducing device is the ear, and hence the non-linearity limitations may be defined in terms of the amount of distortion perceivable by the ear. The methods and technique involved are well known, and satisfactory limits have for some time been established.

Fundamentally, in a television amplifier chain, a change of voltage represents a change in gradation between black and white. The eye, then, is the "ultimate consumer." When the eye is the reproducing device, an entirely different set of considerations is involved, since the criteria governing the acceptability of the reproduction must be evolved with regard to characteristics of the eye. These characteristics are described in an approximate manner by the Weber-Fechner law. This law states that the eye produces in the mind of the observer a sensation which varies as the logarithm of the brightness of the viewed image. Theoretically, then, if a proportional relationship is made to exist between the logarithm of the subject brightness and the logarithm of the image brightness in an overall system, the eye will receive a faithful reproduction of the original.

If we are to specify what is and what is not a faithful reproduction, consideration must be given as to how the amplitude linearity characteristics are related to the above proportionality. The consideration must include the whole television system from iconoscope to kinescope. Between these two end devices, there are many component units, each having its own kind of amplitude linearity characteristics, as shown in Fig. 2. These include camera tube to video amplifier, modulator to r-f amplifier, receiver r-f to detector and receiver video amplifier to kinescope. The overall characteristic is a combination of the individual characteristics. It will be found in general that if an amplitude characteristic is plotted for the camera (object brightness vs. voltage output), as in Fig. 3, the relation will be non-linear in that a given change in object brightness causes a smaller change of output voltage in the high brilliancy region than in the low brilliancy region. The video amplifier to r-f unit, and the receiver, will generally tend to have an "s" shaped characteristic, as shown in Fig. 2. The kinescope will have a non-linear characteristic such that a given change in input volts causes a greater change in output brilliance in the high brilliancy region than in the low brilliancy region.

If now these various non-linear amplitude characteristics are plotted and examined, it will be found that in most cases, the

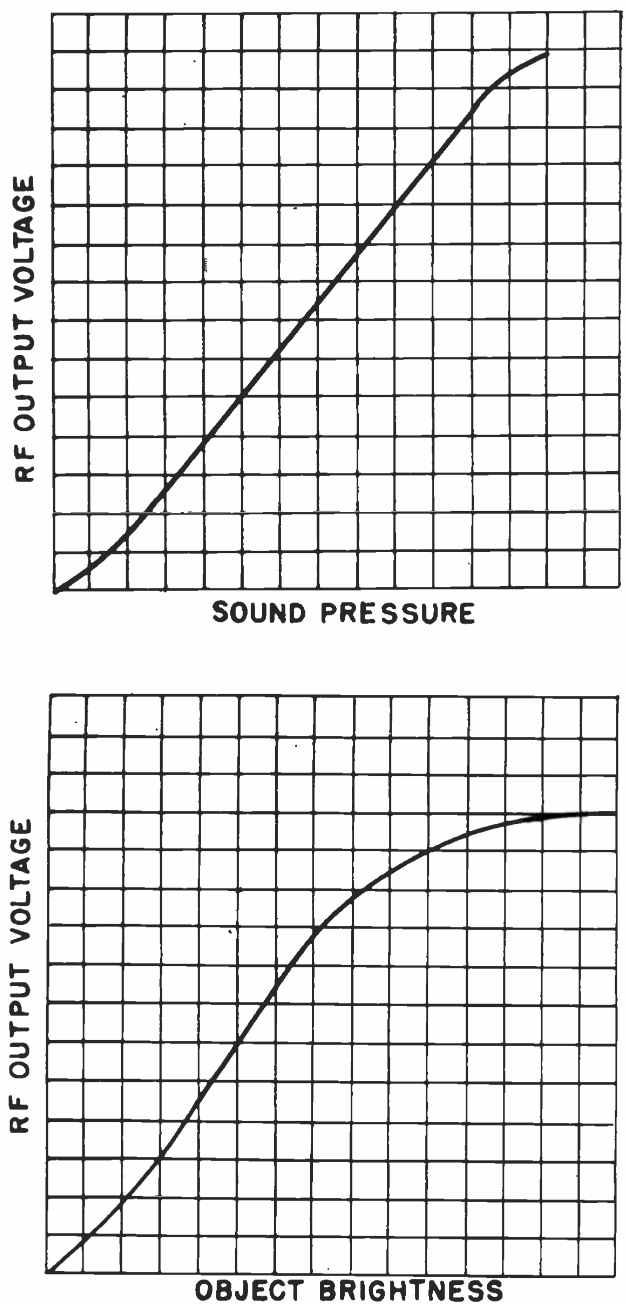


FIG. 1. *Comparison of amplitude characteristics of audio system* (above) *and video system* (below).

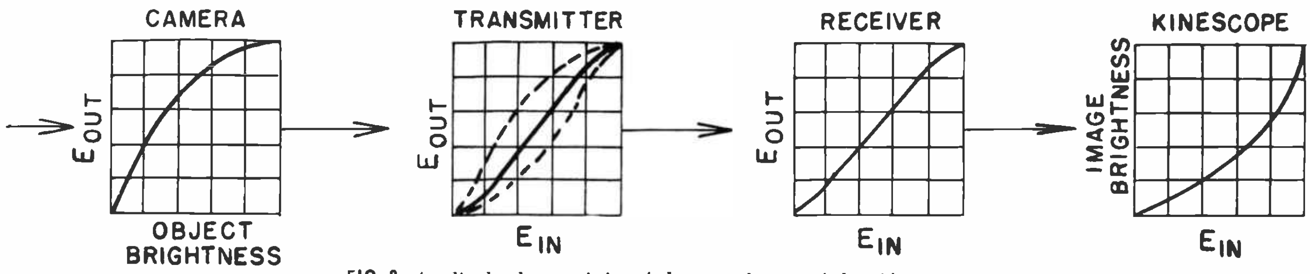


FIG. 2. *Amplitude characteristics of the several parts of the video system.*

curves may be approximately described by a relationship in the form of:

$$A = KB^{\gamma}$$

where A and B are the input and output parameters, K the proportionality factor, and gamma the exponent which describes to what extent the two parameters depart from linearity. It is evident, from Fig. 4, that a unit which has a linear relationship between input and output has a gamma of 1, a unit with a non-linear characteristic, like the camera, has a gamma of less than 1, and units like the kinescope, considerably greater than unity. Furthermore, the gamma of an overall system is the product of the gamma values of all of the component units.

It is now possible to draw a relationship between these linearity characteristics and the conditions defined above which are necessary for the eye to perceive a faithful reproduction. These conditions stated that, theoretically, reproduction was faithful when the logarithm of the object brightness was proportional to the logarithm of the image brightness. If, then, the non-linear curves of the various units which, it is assumed are of the form $A = KB^{\gamma}$ are re-plotted in the form $A = \log K + \gamma \log B$, it will be seen that all are straight-line relationships differing only in their slope and point of origin. This is true of the overall system characteristic as well as for the individual components. Thus, the theoretical considerations for faithful reproduction are fulfilled, and this conclusion holds true within the error incurred above wherein it was assumed that the relation $A = KB^{\gamma}$ describes the non-linear amplitude responses in the equipment.

If the discussion were ended by the conclusions drawn from the theoretical considerations outlined above, it would be necessary to make the general statement that any amount of non-linearity (or any value of gamma) in the overall system or any of its component units is permissible as long as the overall object brightness vs. image brightness curve follows, at least approximately, the law of $A = KB^{\gamma}$. Actually, practical considerations do not allow the termination of the analysis here, and this is probably due in part to the fact that the Weber-Fechner law is at best an approximation.

By inspection of the above relation, it is seen that gamma is a term which sets the "rate of going" from black to white. This "rate of going" ties in intimately with "contrast," the practical factor, and has an important bearing on the effective contrast even though the range, or ultimate excursion, from black to white, is the same at the image as for the object. It has been shown above that, theoretically, a gamma of unity is not a requisite to faithful reproduction. In fact, greater contrast may be obtained with higher (greater than unity) values of gamma. The amount of investigation on the importance of gamma in television systems has been limited. It appears that gamma values ranging from 0.5 to 2.0 are in use at present. Maloff[1] has suggested

[1] Maloff, I. G., "Gamma and Range in Television"—RCA Review 3 (4) 409, April, 1939.

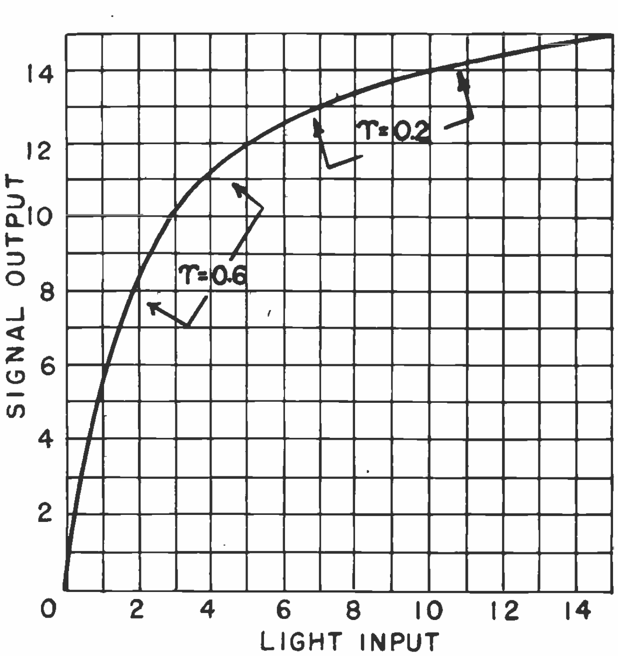


FIG. 3. *The amplitude characteristic of the camera is non-linear, the signal output varying with light input somewhat as shown above.*

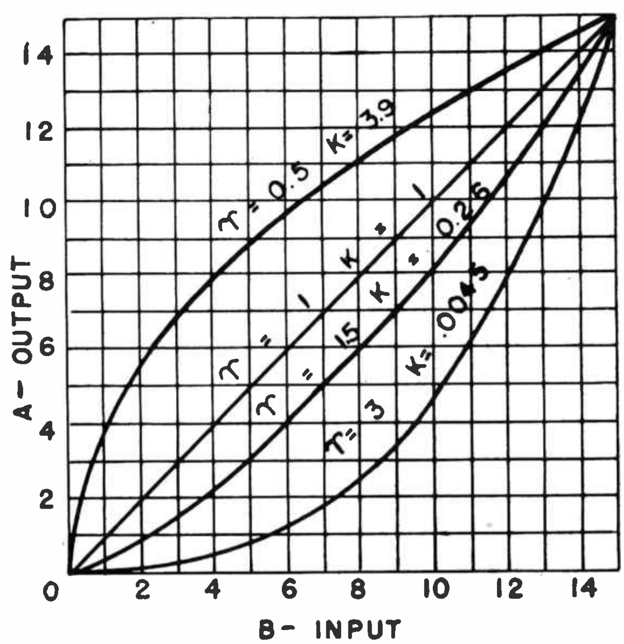


FIG. 4. *Linearity characteristics for various values of "gamma" and K. A linear characteristic corresponds to a gamma of one.*

that commercial motion picture practice be followed, in which gamma values from 1.2 to 1.7 seem optimum. It is apparent that if one value of gamma were to be designated based on present experience (1) it would be greater than unity and hence dictate deliberate overall aplitude distortion and (2) it would be a compromise value, since monotone program material such as animated cartoons and landscapes with a sky background and dark foreground require low contrast, while shots involving facial features or scenes which in natural life obtain contrast by color difference require high contrast for optimum reproduction. For example, the $\gamma = 1.5$ curve of Fig. 4 might be optimum for the former, and the $\gamma = 3$ curve optimum for the latter scene.

Having set down briefly some of the basic considerations, attention can be turned to the specific problem which confronts the transmitter engineer; namely, that of specifying the amplitude linearity for the portion of a television system between studio and transmitting antenna. If it is assumed that a satisfactory compromise value of gamma, G_o, can be designated, then it is true that:

$$G_c\, G_t\, G_r\, G_k = G_o$$

or

$$G_c\, G_t = \frac{G_o}{G_r\, G_k}$$

where G_c, G_t, G_r and G_k represent respectively the gamma values of camera, video transmitter, video receiver and kinescope. This expression tells the obvious story that the studio-transmitter gamma is dependent upon the receiver-kinescope gamma. If the product $G_c\, G_t$ is made a constant (with tolerances) then $G_r\, G_k$ must be a constant. This is undesirable since kinescope development may be arrested unless the television set owner can be trusted to manipulate a control to vary G_r, which does not appear feasible. If both G_t and G_r were made equal to unity, the camera and kinescope gamma would be inter-dependent. In general, camera gamma is less than unity and kinescope gamma is greater than unity, but the absolute values must be of the right magnitude to achieve a given G_o. In this connection, it must be recognized that, in the present state of the art, both camera and kinescope gamma will vary independently over relatively wide ranges.

It appears, therefore, that G_r should be a constant and equal approximately to unity. G_t should be made a variable so that it can act as a proportionality factor between G_c and G_k. Thus, the product $G_t\, G_c$ can be held to within reasonable limits when a change of cameras involving a change in type of pickup tube is made, and in addition, with a given camera, G_t can be adjusted to give the best contrast for the program material to be transmitted.

A summary of the most important considerations relating to television transmitter amplitude linearity characteristics may be made as follows:

1. Sound transmission and video transmission are basically different with respect to allowable amplitude distortion. In sound transmitters, appreciable amplitude distortion cannot be tolerated. In television, the opposite is true; amplitude distortion can be tolerated, and even invited in order to improve contrast.
2. Amplitude linearity characteristics for a chain of video amplifiers in general take the shape of an "s" curve. Within limits, such characteristics are not detrimental to good reproduction, but care must be taken to prevent overloadin or saturation.
3. The greatest amplitude distortion in a television system occurs in the pickup tube and the reproducing tube. These have opposite types of distortion, and hence tend to compensate in the overall system. The characteristics of each, however, vary over wide limits with various kinds and types of tubes.
4. A fixed value of gamma in a video amplifier chain is not required or necessarily desirable. It is becoming standard practice to install a "gamma control" in the terminal equipment amplifier to at least partially compensate for the wide range of gamma found in various types of camera tubes.

D. C. PICTURE TRANSMISSION

(Continued from page 38)

The RF envelope of Figure 5 shows transmission which has negative polarity, now standard in American television practice. The term negative polarity signifies that with an increase of illumination of the object being televised, there is a *decrease* in the radiated power. Positive transmission, used in England before the war, gives an *increase* in radiated power corresponding to increase in illumination. It is evident that with the AC system of transmission one must provide sufficient leeway on the modulation characteristic to allow for shift of black and white signals so that they always fall within the linear portion of the modulation curve and are neither compressed nor saturated.

By the use of devices very similar to the DC setter described for the kinescope circuit, it is possible to transmit the DC component of picture. *In this case, the peaks of the synchronizing pulses always correspond to the instantaneous peak radiated antenna current* no matter what the picture content of the signal may be. Black level is specified to be 75% of the peak (synch.) RF current in the antenna and full white, which corresponds to 100% down modulation, gives zero or nearly zero antenna current. This system has several readily apparent advantages. First, the full modulation characteristic is used to complete advantage as it is not necessary to allow any leeway for shift of black and white about an AC axis. There is a definite RF power radiation for every illumination level being transmitted. It can be shown that by the use of the DC transmission there is an effective gain in the useful radiated signal power. Figure 6 indicates the appearance of the RF envelope with DC picture transmission. The salient points which can again be emphasized are: the peak of synchronizing is always given by a constant peak radiated power, black and white also have unique values of radiated power as indicated in the figure. Moreover, it is possible to use the curved portion of the modulation characteristic to obtain synchronization power, since operation over this curved portion merely means that there is amplitude compression of synchronizing. By pre-emphasis of the synch. pulse, making it larger than the 25% synchronizing pulse to be radiated, it is possible to increase the radiated power of a given transmitter.

In addition to providing for the correct average or background illumination in the reproduced picture, the use of DC picture transmission also improves conditions in the receiver, allowing for efficient operation without the possibility of IF overload and making possible higher video levels at the output of the second detector. Moreover, AVC operation from peaks of synch. can be satisfactorily used in receivers when a DC picture transmission system is used. Thus, the use of DC transmission leads to higher standard of television performance, resulting in more effective utilization of transmitter power, and in improved receiver performance over the complete video modulation range.

Today Radio Brazzaville has a staff of nearly 50. It is broadcasting 12 or more hours a day with newscasts every hour in French, English, Spanish, Portuguese, Italian and Roumanian. It has six directional antennas beamed to France, Central Europe and North Africa, Syria, Indo China, Madagascar and North and South America. Letters lauding the station's performance have reached the French National Committee from Sydney, Rio de Janeiro, Moscow, Ottawa, Trinidad, London and many other parts of the world. Some listeners have reported "strong reception despite Axis efforts at interference" with the signals.

The broadcast day at Brazzaville begins at 6 a.m. and ends at one in the morning, but of course, the news desks are manned every hour of the twenty-four. Radio Brazzaville is dedicated to the mission of giving the people of France the truth, to better arm them in their fight for freedom. Facts are the important things; facts for people who, for years, have been shut away from the truth.

Mrs. Helen Scott, the English program editor at Radio Brazzaville, who recently returned to the United States after a year at the station, adds interesting sidelights to the Brazzaville operation.

"News came first," Mrs. Scott explained, "but of course we had a large library of recorded music too. Our theme song was an oddly haunting refrain played on a native African instrument. The news broadcasts were always followed by a commentary."

Mrs. Scott felt that the commentaries occupied a very important place as they helped listeners to grasp the significance of what had happened and give it its proper place in the changing pattern of military oerations.

"Of course we couldn't fill our day with only news broadcasts," Mrs. Scott continued. "People would have lost interest in the station, so we racked our brains for new ideas. We wrote skits and tried to make them as amusing as possible. Sometimes we had instructions to transmit for the Underground. Once we rebroadcast instructions for the use of new weapons. We picked this up from BBC and a secret radio station operating in France. We put on a special 15 minute broadcast for American soldiers in the Near East. That was after an American officer had visited our station and asked that we do what we could for the American troops in that area."

Mrs. Scott believes that Radio Brazzaville has pioneered two daily programs of special interest. The first was their program

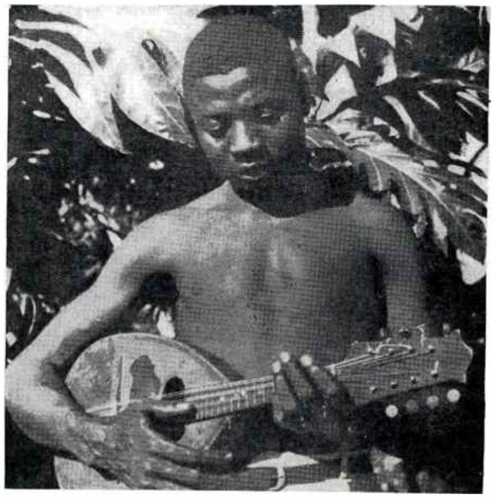


FIG. 4. *Native talent as well as recordings and news make up the programs of Radio Brazzaville.*

on French spiritual resistance. Radio Brazzaville recognized, very early, that one of its most important missions was to foster and keep alive the will to resist in the hearts of the people of France.

The second type of program was its broadcasts to French war prisoners.

"Do not come back dragging your wounds" the station constantly exhorted. "Do not come back resentful toward civilians of France who, you may feel, have had things easier than yourselves. Come back prepared to work for a united France. Only when all Frenchmen are welded together will France be strong once more."

A professor, a collector of antiques, a former financial writer on a French daily and a dreamy, mild-mannered engineer were among the first members of the Radio Brazzaville staff. Their first big job was to hire workers to take down radio Morse code messages on the typewriter. They could, of course, have contented themselves with repeating what other stations had said, but they were determined that Radio Brazzaville should go to the source of the news.

They hired natives. The natives couldn't read or write, let alone operate a typewriter and take down the chatter of code. The natives still cannot read or write, but they have been taught to transcribe Morse code. They have no idea what they are writing, of course. They merely know that if, for example, they hear two dots and a dash, they must hit a certain key on the typewriter. These illiterate natives have copied down millions of words in French, English and other languages, and the news editors have been able to correct their unbelievably few mistakes.

Some of the people who joined the Brazzaville staff in the early days of the station's operation had amazing backgrounds. They included a Parisian bank clerk, a man who had taught law at Singapore, an American girl reporter who had thrown up her job on a Washington newspaper, a French girl from South Africa and a girl stenographer who had escaped from Alsace.

This is Radio Brazzaville! With RCA equipment supporting a great concept of radio.

FIG. 5. *Natives transcribe code messages received at Radio Brazzaville.*

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* See "The 50 SW—A New Transmitter For International Broadcasting," BROADCAST NEWS, January, 1944—page 24.

COVERAGE CURVES for FM ANTENNAS

★

How to determine the distance to the 50 uv and 1000 uv contours for various combinations of height, gain and power

by R. D. DUNCAN, Jr.
Engineering Products Department

In the Standards of Good Engineeering Practice for FM Broadcasting issued by the Federal Communications Commission, June, 1940, propagation curves were provided to enable computation of the expected coverage of a station. The curves were based on theoretical considerations, assumed transmission over land, horizontal polarization, a spherical earth of specified conductivity and dielectric constant, and a receiving antenna height of 30 feet. They were for a frequency of 46 megacycles, which is the mean of the FM broadcast band.

All curves involve a quantity called the "Effective Signal Radiated," abbreviated "ESR," which is a function of the height of the transmitting antenna, its field-strength gain, the square root of the antenna power and the field-strength with respect to a specified field-strength. The value adopted for the latter was 50 microvolts per meter ($\mu v/m$). Assuming values of transmitting antenna power, its height and field-strength gain, the distance to a specified field-strength contour is obtained from the curves. A wide range of values of the ESR factor, antenna powers and heights is covered by the curves and in general it is necessary to interpolate between fairly wide values of antenna power and height with some consequent loss in accuracy.

COVERAGE PROBLEM

The problem faced by the engineer in specifying the transmitter and antenna equipment for an FM station is that of working out a suitable combination of transmitter power, type of antenna, its gain and height, which will permit laying down the necessary values of field-strength at the required distances. Of these three factors only the transmitter power and the antenna-gain are under complete control. The maximum antenna height practically possible is usually governed by terrain and building heights available in the vicinity where it is desired to locate the antenna.

Knowing the transmitter power available and the gain characteristics of the antenna to be used, it is possible to superimpose a simple system of graphs upon the propagation curves furnished by the Federal Communications Commission, and provide a simplified and convenient method for estimating FM coverage. Such a set of graphs are given in accompanying Figs. 2 through 16, for the "Turnstile" type of transmitting antenna which is described later on. Similar graphs have been prepared for estimating Television coverage and will be presented in a later issue of Broadcast News.

TRANSMITTER POWER RATINGS

Subsequent to the issuance of Standards of Good Engineering Practice, power ratings of FM transmitters were informally agreed upon and put into effect by the Commission and by equipment manufacturers. These were the following:

Transmitter Power Rating	*Power Range*
250 Watts	10 to 250 Watts
1 KW	250 to 1000 Watts
3 KW	1000 to 3000 Watts
10 KW	3000 to 10,000 Watts
50 KW	12,500 to 50,000 Watts

In addition 25 KW and 100 KW ratings were considered but not adopted. The different ratings are maximum and should more power be necessary to achieve a specified coverage, a transmitter of the next higher rating would have to be employed.

It is noted that the ratings are in terms of the transmitter output, that is the power delivered to the transmission line. The antenna power, which is the power received from the transmission line is less than the transmitter power by the losses incurred in the line. These losses should be and normally are low. However, where extremely high antennas are involved, or with the transmitting equipment at a relatively great distance from the radiating elements requiring a long run of line, the line losses become an appreciable factor. Under any condition they must be taken into account in estimating coverage or compensated for either by variation in transmitter power output or in antenna height.

ANTENNA-GAIN

The "gain" of a transmitting antenna represents a measure of directivity of radiation in the vertical plane. Stated otherwise it represents a measure of reduction of radiation at high angles or away from the earth's surface where no useful purpose is served, and of the concentration of radiation towards the horizon or in directions where it is useful in producing signals in distant receiving antennas.

In speaking of antenna-gain it is necessary to distinguish between power and field-strength or voltage gain as the former is equal to the square of the latter. The term "antenna field-gain" used in the Standards of Good Engineering Practice refers to field-strength gain.

It is customary to express the gain of a UHF antenna in terms of the increase in radiated power or field-strength produced relative to a single half-wave antenna or dipole. By "power-gain" is meant the number of times the power fed to a half-wave antenna must be increased to yield the same value of field-strength as the antenna in question. A vertical reference half-wave antenna is either implicitly assumed or in the case of a horizontal reference antenna, it is assumed that the latter is so oriented as to produce its maximum field-strength in the direction in the horizontal plane, that is in question.

One of the simplest forms of UHF antennas available for obtaining gain in the vertical plane, and which has received wide usage, is the so-called "Turnstile Antenna" developed by Dr. G. H. Brown of the Radio Corporation of America.* In its basic form it consists of a pair of half-wave antennas or dipoles crossed at right angles and fed equal currents differing in time phase by 90 degrees. Because of this phasing a substantially uniform radiation field is produced in all directions in the horizontal plane as distinct from the well known figure eight field pattern of a single half-wave antenna.

To obtain the desired gain, layers of these crossed dipoles are employed, stacked vertically and spaced a half-wavelength, the number of layers determining the exact gain. The layers are disposed symmetrically around a central supporting pole in such a manner that one dipole of each layer lies in a common vertical plane while the other right angularly positioned dipoles lie in a second vertical plane. The currents in all dipoles are of equal strength; those in the dipoles in each vertical plane are in phase with respect to each other but are 90 degreees out of phase with the currents in the dipoles in the right-angularly intersecting plane. Because of the half-wavelength spacing between layers, the voltages impressed on successive layers would if not corrected be out of phase by 180 degrees. This correction is simply effected and in-phase voltages obtained for all dipoles in one plane by transposing the transmission line between layers. A single transmission line extending from the transmitter supplies power to the antenna array.

In the early commercial form of Turnstile Antenna the two halves of each dipole were formed by metallic rods which were fixed to and projected from a central metallic supporting pole. The elements were fed over open wire transmission lines with transposition between layers effected by twisting the wires around the supporting pole. Adjustment of phase relations and current strengths was accomplished by properly connecting matching stub lines to the branch lines supplying the two sets of radiators and to the main line connecting the two branch lines with the transmitter. This adjustment was rather critical and was made at the time of erection of the antenna.

With the new FM Turnstile Antenna, hollow sleeve type radiators and concentric transmission lines are employed. The antenna is completely pretuned to the required carrier frequency when fabricated and no subsequent adjustments or measurements are required at the time of its erection. The antenna elements are so constructed that though insulated from the central supporting pole at radio frequencies, they are otherwise grounded to the pole and so assist in affording lightning protection. Because of the hollow radiator construction and of this grounding feature sleet melting units may be included in each radiator, an important and desirable feature for certain sections of the country. Concentric type transmission lines interconnect the radiating elements. These are properly matched to a single concentric line which runs back to the transmitter.**

Vertical spacings between turnstile layers other than a half-wavelength may be and have been used. For example it may be shown that a three-quarter wavelength spacing gives a somewhat higher gain for a given number of layers, than a half-wavelength. However, with the former spacing a taller central supporting pole is required, and it is no longer possible to employ simple transposition of lines between layers to effect proper phasing of voltages that are impressed on the radiators. Instead it is necessary

* "The Turnstile Antenna"—G. H. Brown. ELECTRONICS, April, 1936, pages 14, 17.

** A description of the FM Turnstile Antenna was presented by Radio Corporation of America in information filed with Panel 9 of the former National Television Systems Committee.

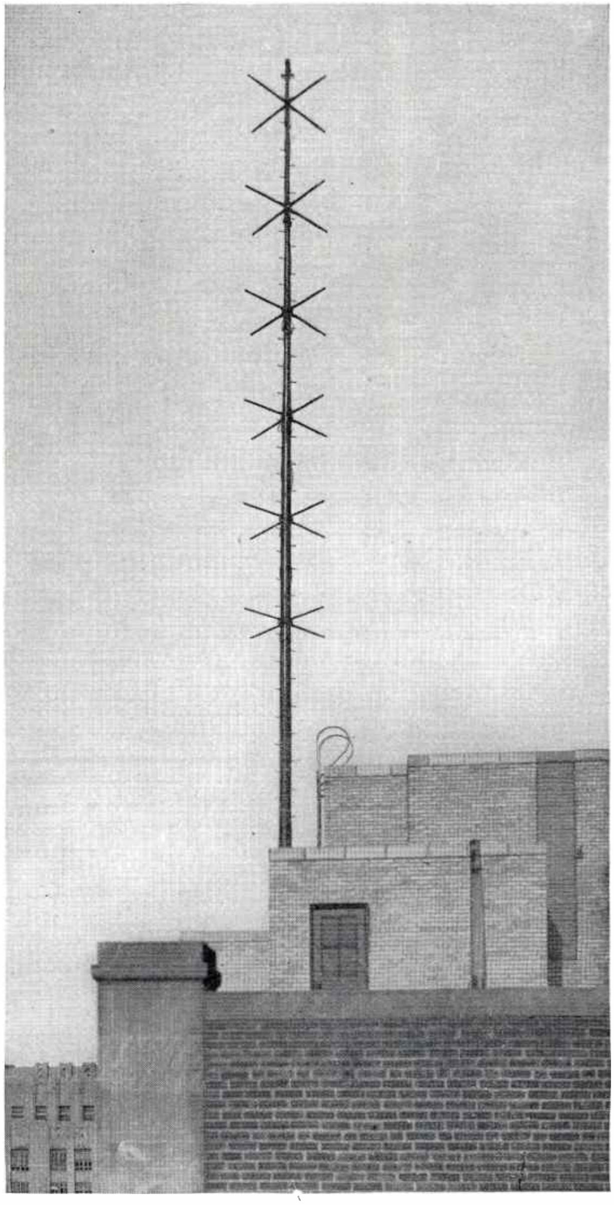


FIG. 1. *The six-layer "coaxial" turnstile at WCAU-FM, Philadelphia.*

to include additional lengths of transmission line between layers in order to obtain suitable time delay or phasing of certain dipole voltages.

Choice of an increased layer spacing to obtain a slight increase in gain must be weighed against the requirement for a taller and more costly supporting pole and a somewhat more complex transmission line system. FM antennas will normally be mounted at a considerable height above the ground and will be subject to high winds and in some sections of the country, to ice formation. The more simple and compact the array structure and transmission line system are the less likely it is there will be trouble after the antenna is placed in operation.

The following table gives the theoretical values of power and field-strength gain, and the overall vertical space occupied by the array, for a Turnstile Antenna of different number of layers up to a maximum of eight, for a half-wavelength spacing between layers. At a frequency of 46 megacycles, a half-wavelength is approximately 10.7 feet.

GAIN OF TURNSTILE ANTENNA

Half-Wavelength Spacing Between Layers

Number of Layers	*Power Gain*	*Field-Strength Gain*	*Distance Between Top and Bottom Layers in Wavelengths*
1	0.50	0.707	0
2	1.25	1.12	0.5
3	2.00	1.41	1.0
4	2.75	1.66	1.5
5	3.50	1.87	2.0
6	4.24	2.06	2.5
7	5.05	2.26	3.0
8	5.75	2.40	3.5

A view of the new design six layer Turnstile Antenna in operation at WCAU-FM, Philadelphia, is shown in Fig. 1.

A SIMPLIFIED GRAPH METHOD OF ESTIMATING FM COVERAGE

50 μv/m Contour—Figs. 2 through 10

The Effective Signal Radiated, ESR, as defined in the Standards of Good Engineering Practice, is expressed mathematically as,

$$ESR = \theta = \frac{50\ H\ G\ \sqrt{P_A}}{F} \qquad (1)$$

where,

H, is the height of the transmitting antenna in feet,

G, its field-strength gain,

P_A, the antenna power in Kilowatts

and F, the required field-strength in microvolts per meter (μv/m)

The Effective Signal Radiated for a value of F equal to 50 μv/m from (1) is obviously given by ($HG\sqrt{P_A}$). The propagation curves furnished with the Standards of Good Engineering Practice give the distance to the 50 μv/m contour as a function of the transmitting antenna height and the Effective Signal Radiated. Four height curves are given viz., 500, 1000, 2000, and 5000 feet.

Referring now to expression (1) it is obvious that this may be rewritten in the form,

$$H_F = \frac{F\ \theta}{50\ G\ \sqrt{P_A}} \qquad (2)$$

For F equal to 50 μv/m (2) becomes,

$$H_{50}\ \mu v/m = \frac{\theta}{G\ \sqrt{P_A}} \qquad (3)$$

Assuming values of antenna power P_A and antenna-gain G, or what is equivalent the number of turnstile layers, the antenna height, H, may be plotted as a linear function of the Effective Signal Radiated factor, θ. By superimposing these linear graphs for a field-strength value of 50 μv/m as obtained from (3), upon the FCC propagation curves, the distance to the 50 μv/m contour may be immediately determined for a turnstile transmitting antenna, corresponding to assumed values of antenna power and number of layers.

Such graphs are given in Figs. 2 to 10 inclusive which are for the following antenna powers:

Figures	*Antenna Power*
2 & 3	250 Watts
4 & 5	1 KW
6	3 KW
7 & 8	10 KW
9 & 10	50 KW

Each of these figures has one set of abscissas and two sets of ordinates. The abscissas are values of the Effective Signal Radiated Factor, θ. One set of ordinates is the antenna height in feet, which is to be used with the straight line graphs; the other set is distance to the 50 μv/m contour in miles, which is to be used with the propagation curves. The latter were taken directly from the Commission's curves for antenna heights of 2,000, 1,000 and 500 feet. The 3,000, 2,500, 1,500 and 750 foot curves were obtained by interpolation from the FCC curves and the 300 foot curve by extrapolation. For antenna heights less than 300 feet it is necessary to estimate values of distance with reference to the 300 foot curve.

Manner of Use of Graphs

A fundamental restriction to note concerning the graphs is that the propagation curves, similar to those in the Standards, assume unobstructed transmission and only one reflection from the ground. Actually of course, hilly and often-times mountainous terrain is encountered in the propagation path and under practically all conditions, buildings. The presence of such obstructions gives rise to "shadows" or regions of decreased field-strength which may be serious in their effect on signal reception. In information presented by Radio Corporation of America at the 1940 Frequency Modulation Hearings before the Commission it was shown that the observed increase or decrease in field-strength from the uninfluenced or theoretical value, due to dispersion effects may be of the order of two to one or higher. As the horizon* is approached the effects of fading start to be felt and additional variation in field-strength results. Near and beyond the horizon fading plays an important part. Obviously theoretical propagation curves cannot take such effects into account but serve only to provide a guide to the average field-strengths that may be expected. The value of antenna height to be used in the graphs is that above the average terrain elevation between the antenna and the contour under consideration.

Terrain obstructions and buildings in the propagation path also give rise to a multiplicity of points of wave reflection which at a given receiving antenna location may result in multi-path reception. The net effect of this is that the field-strength at this point may be decreased or increased from its single-path value but what is more important, serious signal distortion may result. The phenomena of multi-path reception and its possible effect on FM broadcast reception is now being studied.

* The horizon distance of a station is proportional to the sum of the square roots of the heights of the transmitting and receiving antennas.

The manner of use of the graphs is best illustrated by the following practical examples:

Example # 1. Given the required approximate distance to the 50 μv/m contour of 60 miles, and the permissable maximum height of antenna of 800 feet. Determine the number of turnstile layers and the power size of the FM transmitter.

The antenna may be erected on top of a building or on an existing tower structure the choice to be later decided upon. In the first case a relatively short run of transmission line from the transmitter would be required whereas in the second a long run would be necessary.

Referring to Fig. 4 which is for an antenna power of 1 KW, enter the graph from the left at the 60 mile point on the DISTANCE scale and proceed horizontally to the right until the 750 foot propagation curve is encountered. This height is the one nearest to the specified maximum. Next proceed vertically downward from this point to the slant line, corresponding to a particular number of turnstile layers, and the point of intersection of which, that is closest on the low side of 750 feet, read off on the HEIGHT scale to the left. That is, with an antenna power of 1 KW either an 8 layer turnstile antenna 650 feet effective height or a 6 layer, 750 feet height would provide a field-strength of 50 μv/m at a distance of 60 miles.

Perhaps for various reasons it may be more desirable to use a turnstile having fewer layers and to compensate for the difference with an increase in antenna power. Consider next Fig. 6 which is for 3 KW antenna power. As before enter the graph at the 60 mile DISTANCE point, proceed to the right to the 750 foot propagation curve and thence vertically downwards to a point corresponding to 750 feet on the HEIGHT scale. This is seen to lie between the 2 layer and 3 layer slant lines. Obviously a 3 layer turnstile unit must be chosen; dropping down to the 3 layer line and proceeding to the left to the HEIGHT scale, is seen to theoretically require a height of approximately 670 feet.

Referring now to Fig. 2 which is for 250 watts antenna power, it is observed by following the procedure outlined that the 60 mile distance line intersects the 750 foot propagation curve (extrapolated) at a point such that on proceeding downwards the 8 layer turnstile line is crossed corresponding to a height of approximately 1250 feet. That is a turnstile antenna having more than 8 layers, is theoretically required for 250 watts antenna power.

Again going to Fig. 7 which is for an antenna power of 10 KW, and proceeding in the proper manner, it is observed that for 60 miles and a 750 foot height-propagation curve a single layer turnstile theoretically requires a height of approximately 700 feet. A single layer turnstile however does not represent a practical solution of the problem since as seen from the preceding table, its gain is less than unity. This loss in field-strength over a single dipole represents the price paid for obtaining a uniform horizontal rather than a figure eight field pattern.

It is of interest at this point to investigate the possibilities of utilizing antenna heights lower than 750 feet. For example as observed from Fig. 6, with 3 KW antenna power and a 500 foot height, a 6 layer turnstile is usable. From Fig. 7 it is further noted that a 6 layer turnstile and a 300 foot height produces a field-strength of 50 μv/m at 60 miles.

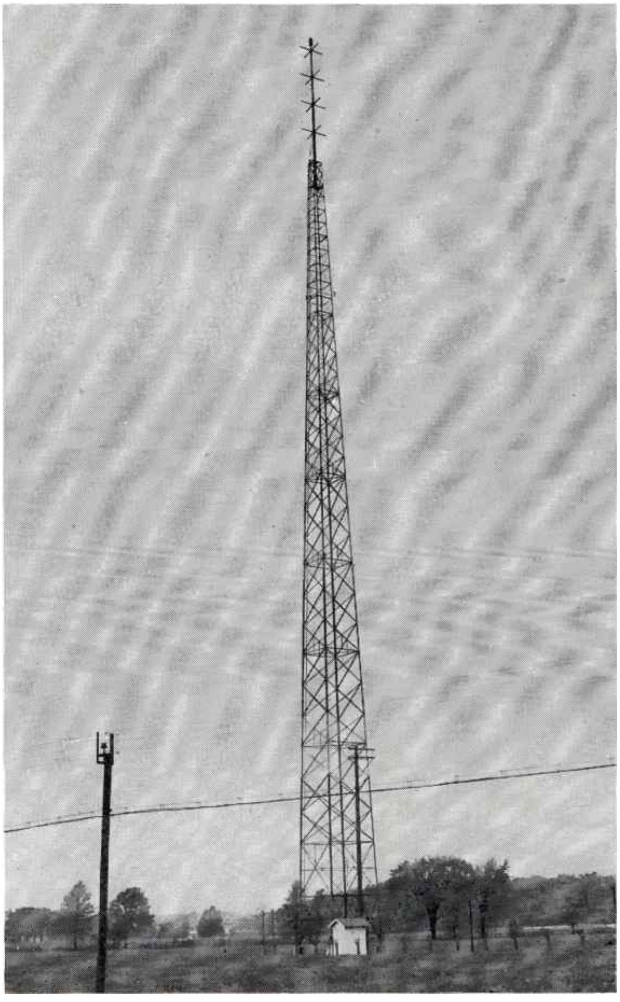
Example #2. Given a permissable antenna height of 2000 feet and an antenna power of 50 KW, determine the distance to the 50 μv/m contour corresponding to the use of 3, 4 and 6 layer turnstile antennas.

Referring to Fig. 10, enter the graph from the left at the 2000 foot point on the HEIGHT scale, proceed horizontally to the right to the 3 layer slant line and thence vertically downwards to the 2000 foot propagation curve. From this point of intersection proceed horizontally to the left and read off the distance on the DISTANCE scale. This is approximately 107.5 miles. By following similar procedures for the 4 layer and 6 layer turnstiles, approximate distances to the 50 μv/m contours of 110 and 113.5 miles respectively are obtained.

Having tentatively decided upon the antenna power, height and number of layers which theoretically will provide a field-strength of 50 μv/m at a given distance, the two problems that remain to be solved are, (1) how is this distance reduced by the losses in the transmission line connecting the antenna with the transmitter and (2) with the finally adopted antenna power, height and gain combination, what is the distance to 1000 μv/m contour? These are considered in the two following sections.

Correction for Transmission Line Losses

The antenna powers that have been assumed for Figs. 2 through 10 are the same as the maximum transmitter ratings specified by the Commission. Obviously the power delivered to the antenna is less than the power output of the transmitter by the losses experienced in the intervening transmission line. As there are almost an infinite variety of antenna height and transmission line length combinations possible it was considered impractical to attempt to account for the line losses on the graphs, but instead to provide a correction procedure which could be applied



A four-layer "coaxial" turnstile installed on an AM tower at WSBT, South Bend, Indiana.

after having tentatively adopted values of antenna power, height and gain. This would indicate how the distance to the 50 μv/m contour would be reduced after which if required a new combination of antenna height, gain or power could be worked out to compensate for the line losses.

For a field-strength of 50 μv/m expression (1) becomes,

$$\theta_{50}\ \mu v/m = HG \sqrt{P_A} \qquad (4)$$

Let it be assumed that due to line losses the antenna power is reduced to (ηP_A) where η has a value between 0 and 1. Calling θ_1 the value of the Effective Signal Radiated corresponding to the reduced antenna power, we have for the same values of antenna height H and gain G,

$$\theta_1 = H\ G \sqrt{\eta P_A} \qquad (5)$$

Combining expressions (5) and (4) there results,

$$\theta_1 = \theta_{50}\ \mu v/m \sqrt{\eta} \qquad (6)$$

The tentatively adopted values of antenna power and height and number of layers fixes the value of the Effective Signal Radiated factor θ. This is read off from the abscissa scale of the graph corresponding to the particular antenna power and gives the value $\theta_{50}\ \mu v/m$ of expression (6). It is obtained by proceeding vertically downwards from the height point on the slant line corresponding to the number of layers tentatively chosen. Then knowing the transmission lines losses per foot, the value of η is determined for the length of line it is estimated will be used. The reduced value of Effective Signal Radiated θ_1, is given by expression (6).

Using this new value θ_1 which normally is only a few percent lower than $\theta_{50}\ \mu v/m$, the coverage graph is re-entered, this time from the bottom scale, corresponding to the value of θ_1. Proceeding vertically upwards to the height-propagation curve in question and thence to the left to the DISTANCE scale, the reduced distance to the 50 μv/m contour is determined.

Distance Correction Graph—Fig. 11

To facilitate this procedure the curves of Fig. 11 have been prepared. The top abscissa of this figure represents the length of transmission line in feet. The ordinates are the ratio of the power out of, to the power into the line, viz., the ratio of antenna power to transmitter power, or the quantity η of expressions (5) and (6). Four line loss curves are given corresponding to line diameters of 2⅝, 1⅜, ⅞ and ⅜ inches. The heavy curve marked A is the quantity $\sqrt{\eta}$ or $\theta_1/\theta_{50}\ \mu v/m$ as a function of η and is read from the bottom abscissa marked DISTANCE CORRECTION FACTOR.

This graph is used as follows: Enter from the top abscissa at the transmission line length in question and proceed downwards to the loss curve corresponding to the particular line diameter. Next proceed horizontally to the left to the A curve and then downwards to the lower abscissa where the value of the correction factor $\theta_1/\theta_{50}\ \mu v/m$ is read off.

Example: Referring to the preceding Example #1 in which as alternatives a short and a long run of transmission line are under consideration. Assume the alternative lengths to be 1000 and 200 feet and a line size of 1⅜ inches.

From Fig. 11, it is found that for a 1000 foot run of 1⅜ inch line, the value of η is 0.75. The corresponding value of $\theta_1/\theta_{50} \mu v/m$ is obtained by proceeding directly to the left to curve A, and then downwards to the abscissa, is approximately 0.86. The value of the correction factor for a 200 foot line, by the same procedure is found to be approximately 0.975.

Refering now to Fig. 4 it is observed from the 750 foot propagation curve that the value of $\theta_{50}\ \mu v/m$ corresponding to a distance of 60 miles is 1550. Applying the two above correction factors to this value of θ, the two reduced values of ESR for the 1000 and 200 foot lines are respectively, 1332 and 1510. Again from the 750 foot propagation curve of this figure the corresponding reduced distance values are respectively 57.5 and 59.5 miles. That is the line losses have decreased the distances to the 50 μv/m contour to these values.

A convenient procedure is to draw a series of slant lines on the propagation graphs for each number of layers, having slopes suitably *greater* than the lines for full antenna power, determined by assuming different percentages of reduction in antenna power corresponding to assumed line loss values. For example 95%, 90%, 85%, 80% lines could be drawn. In use the graph would be entered in the usual way from either the DISTANCE or HEIGHT scales and the new slant lines used to account for the assumed transmission line losses.

1000 μv/m Contour—Figs. 12 through 16

For established values of antenna power, height and gain the Effective Signal Radiated factor for the 1000 μv/m contour, is from expression (1),

$$\theta_{1000}\ \mu v/m = \frac{H\ G \sqrt{P_A}}{20} \qquad (7)$$

That is the ESR factor for a field-strength of 1000 μv/m has a value 1/20th of that for a 50 μv/m field-strength. This obviously means that a much lower distance range on the propagation curves is involved, and the slant line graphs corresponding to the number of turnstile layers will have much steeper slopes.

Figs. 12 through 16 are a set of graphs which enable estimating the 1000 μv/m contour distance. They are for the same antenna powers and numbers of turnstile layers as the 50 μv/m graphs and are used in an identical manner. The figures are for the following antenna powers:

Figures	*Antenna Power*
12	250 Watts
13	1 KW
14	3 KW
15	10 KW & 50 KW
16	50 KW

The dashed slant lines on Fig. 15 are for 1 and 2 layer turnstiles with 50 KW antenna power.

Example: Corresponding to preceding Example #1 assume a 6 layer antenna, height 750 feet and an antenna power of 1 KW. Determine the distance to the 1000 μv/m contour.

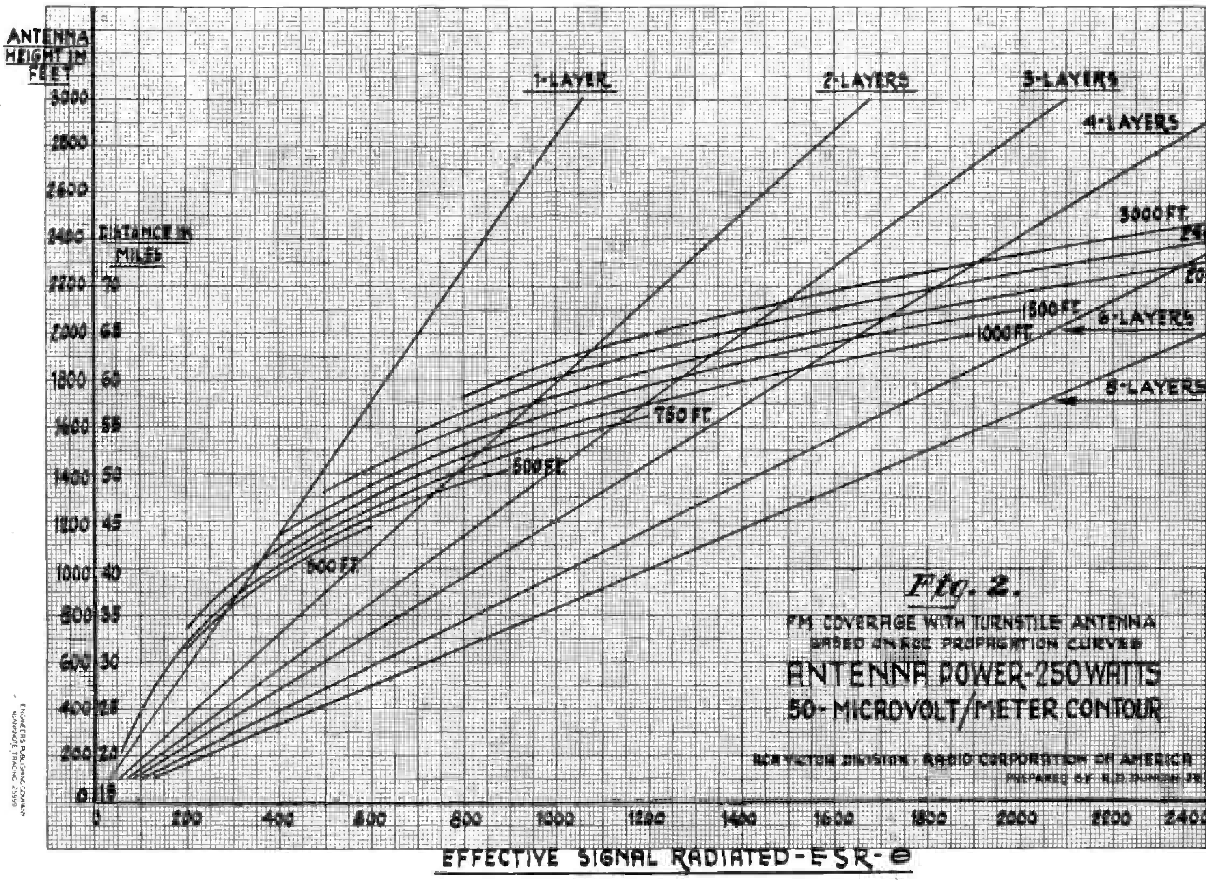
Referring to Fig. 13, enter the graph from the HEIGHT scale at 750 feet, proceed horizontally to the right to the 6 layer slant line and then upwards to a point midway between the 500 and 1000 foot propagation curves. From this point proceed horizontally to the left to the DISTANCE scale and read off the distance, 22.5 miles to the 1000 μv/m contour. Correction for transmission line loss obviously also applies to the 1000 μv/m graphs.

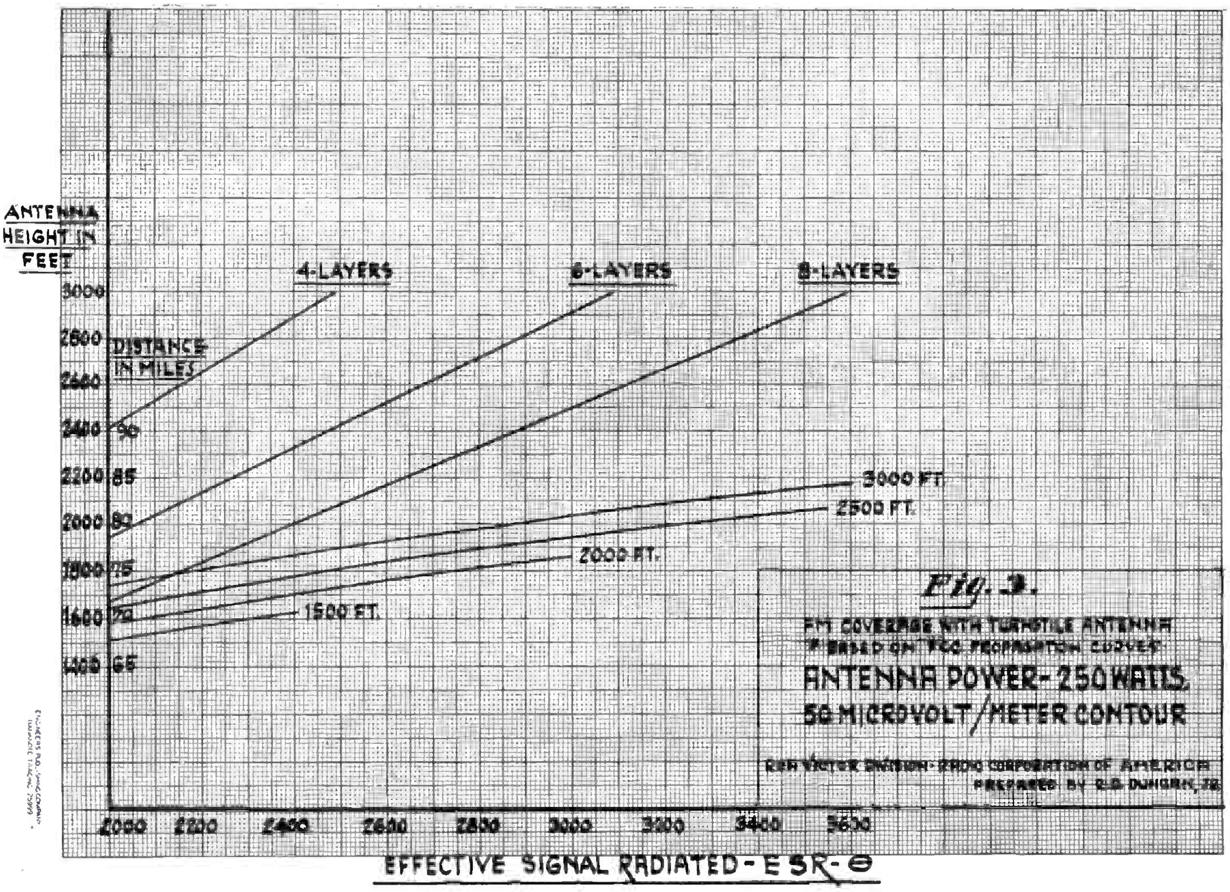
APPLICATION OF METHOD TO OTHER TYPES OF TRANSMITTING ANTENNAS

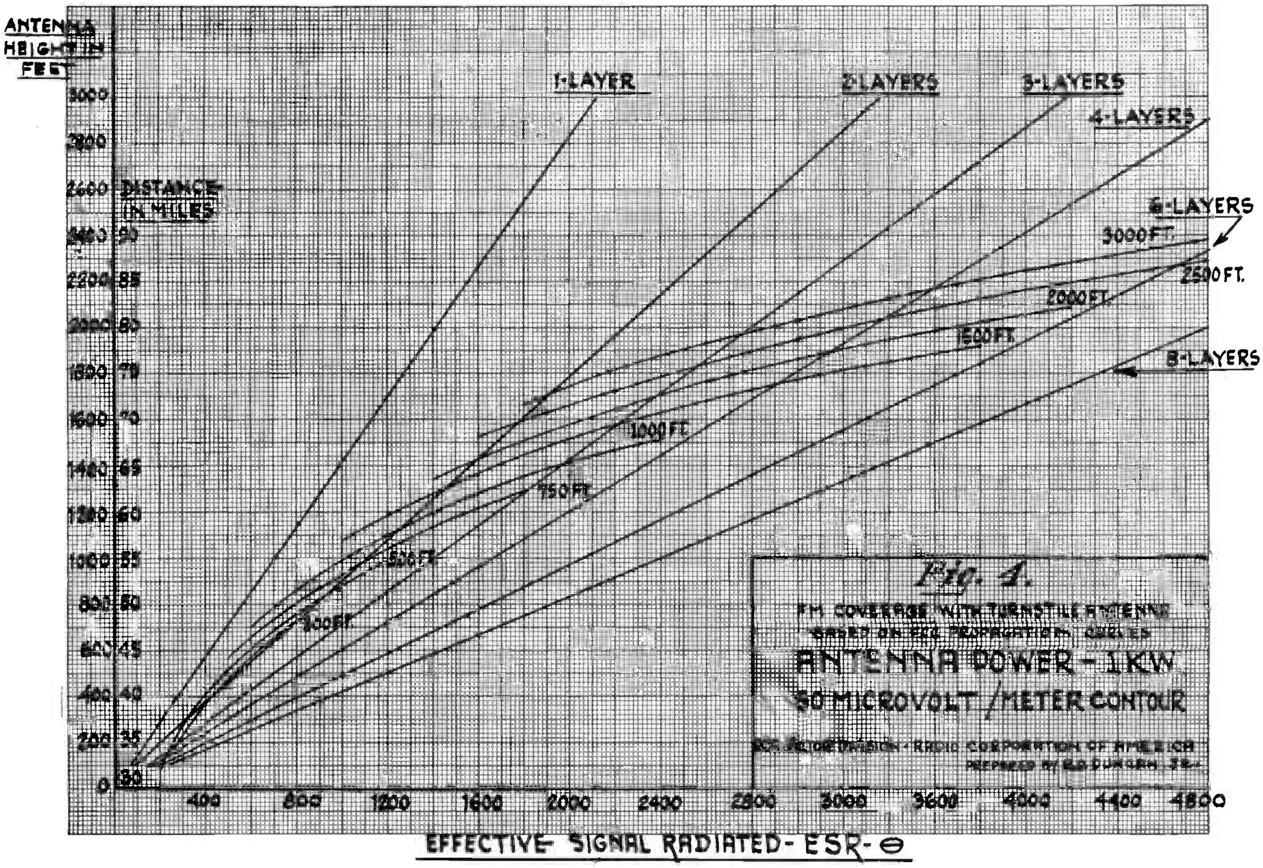
The graph method of estimating FM coverage as described in the preceding is obviously not limited to the turnstile type of transmitting antenna. All that is necessary is to know the gain characteristics of the antenna as a function of the number of layers.

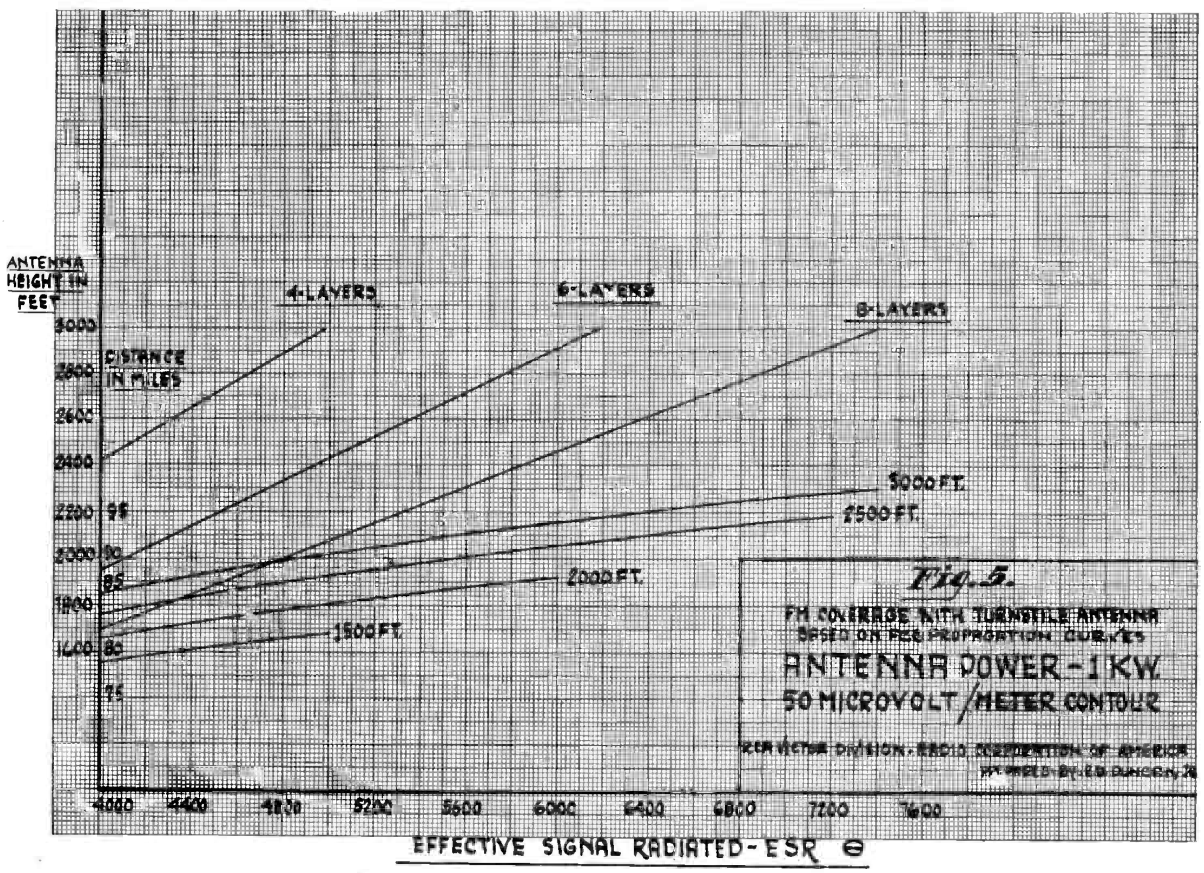
The graph of Fig. 17 illustrates this for the case of a Circular FM Antenna such as described in a recent publication.* The slant lines on this graph are based on the field-strength gain figures for a 1, 2, 3, and 4 layer antenna recorded in the published article.

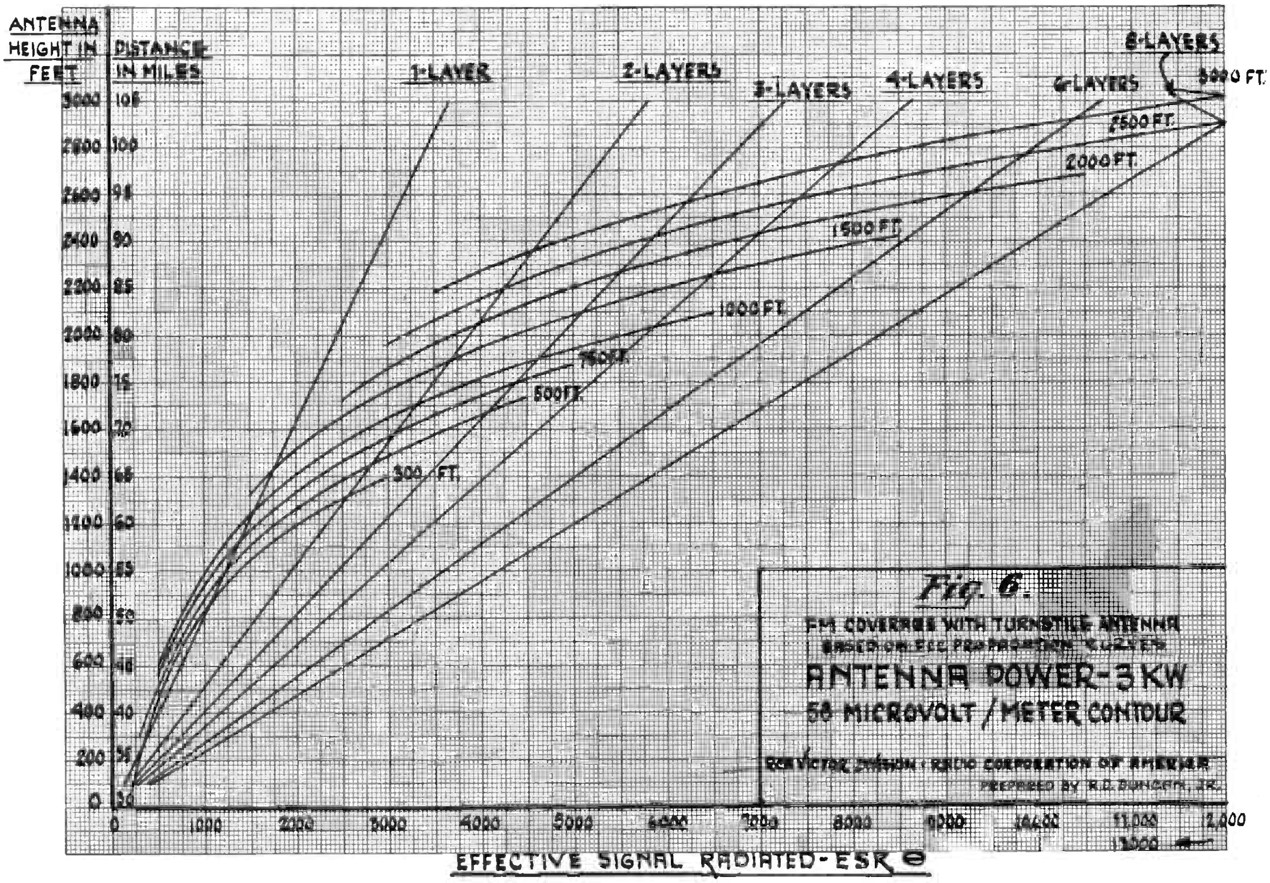
* FM Circular Antenna—M. W. Scheldorf, GENERAL ELECTRIC REVIEW—March, 1943, page 163.

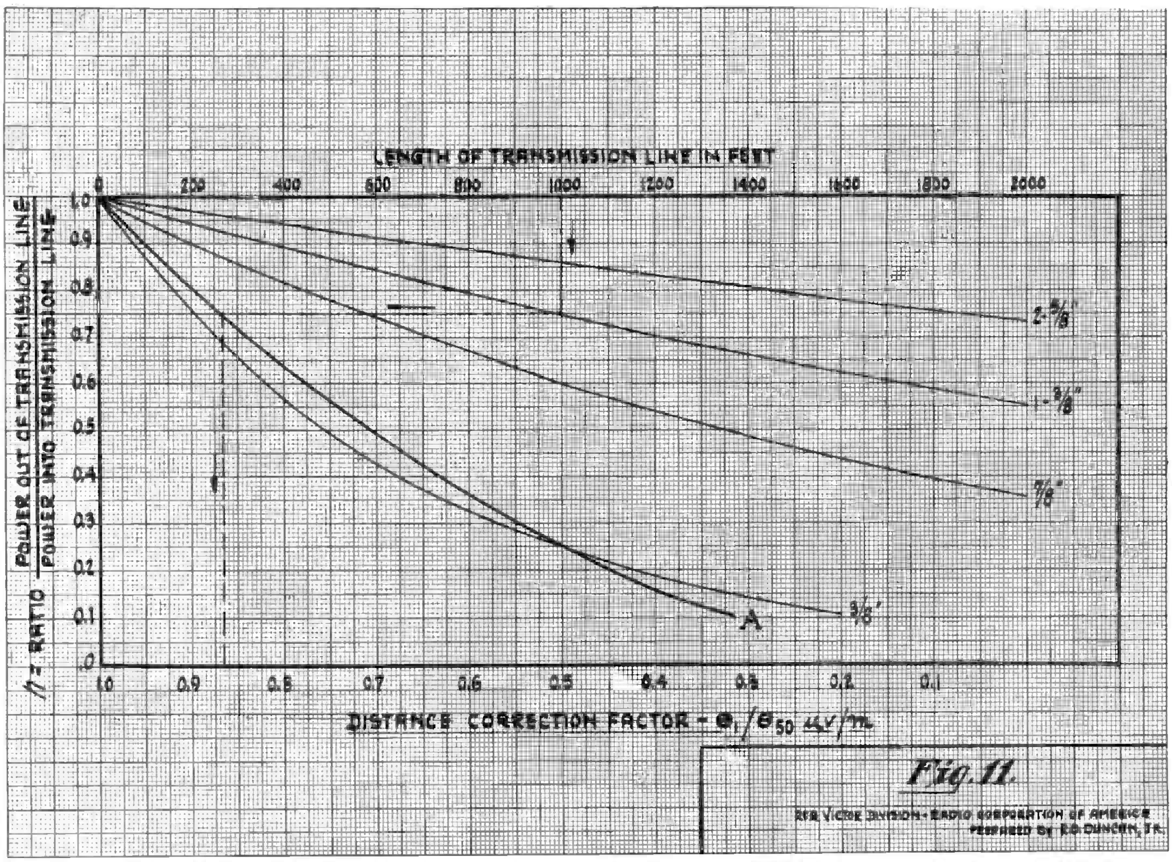

ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
Fig. 2.
FM COVERAGE WITH TURNSTILE ANTENNA
ANTENNA POWER-250 WATTS
50-MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED-ESR-Θ

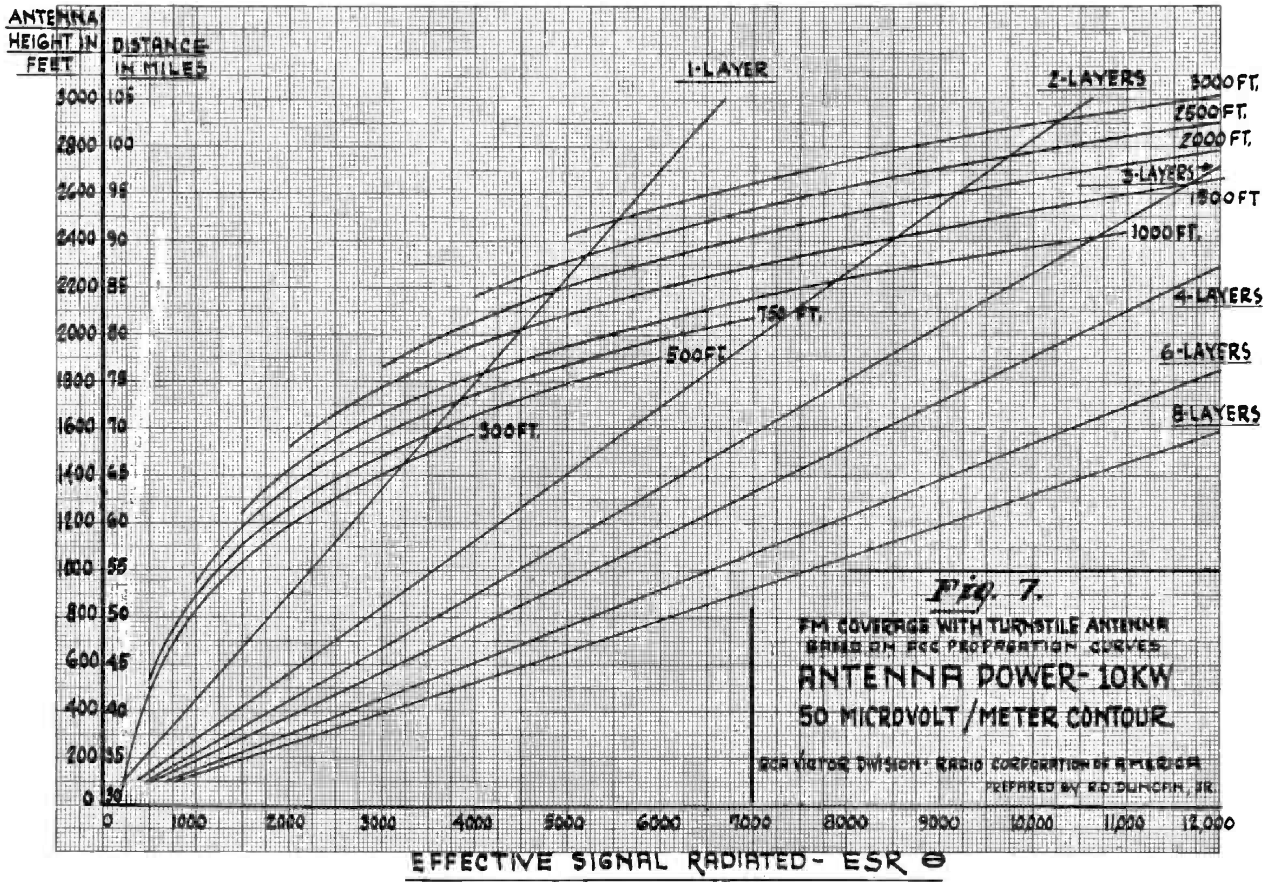

ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
Fig. 3.
FM COVERAGE WITH TURNSTILE ANTENNA
ANTENNA POWER-250 WATTS.
50 MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED-ESR-Θ

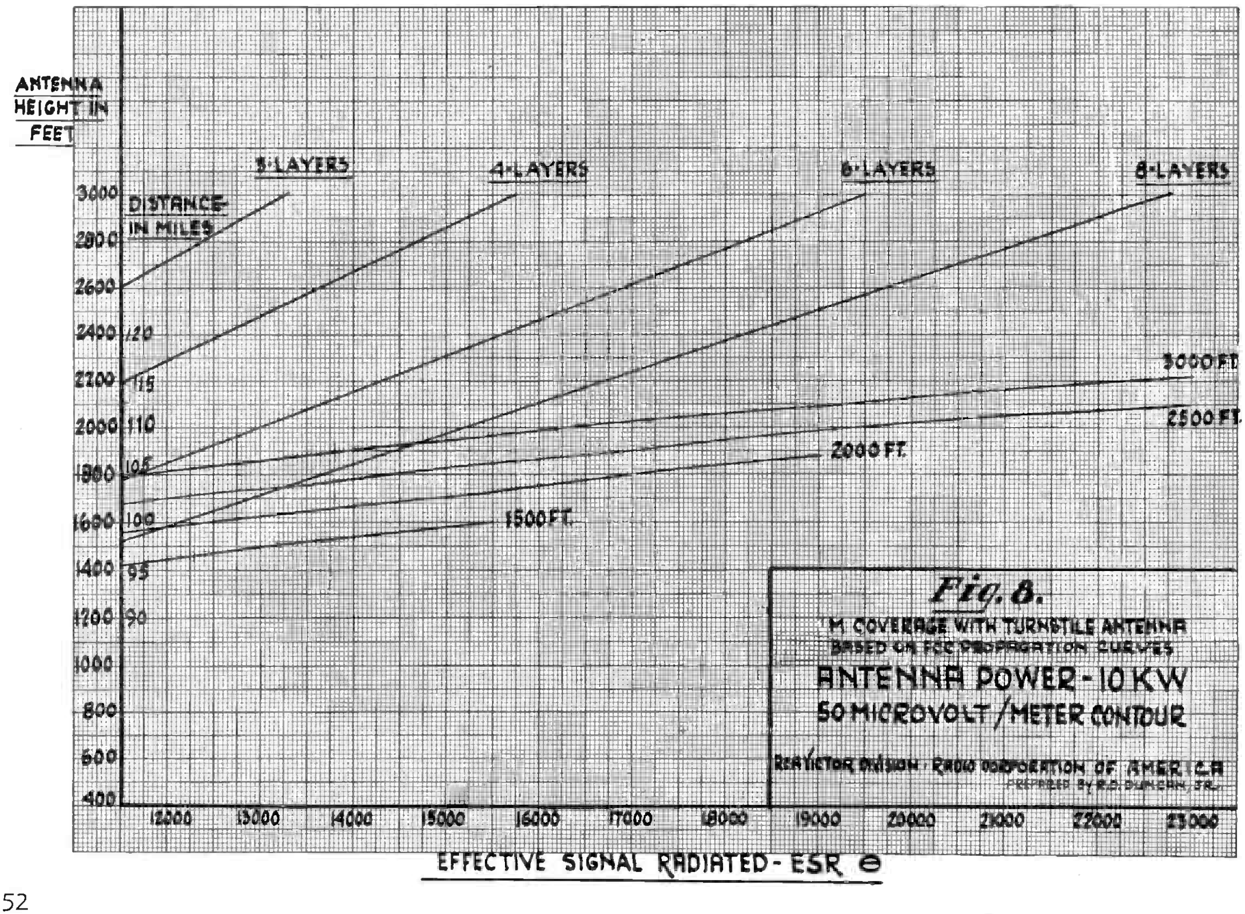

ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
300 FT.
Fig. 4.
FM COVERAGE WITH TURNSTILE ANTENNA
ANTENNA POWER - 1KW
50 MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED - ESR - Θ


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
Fig. 5.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 1KW
50 MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED - ESR Θ


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
300 FT.
Fig. 6.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON F.C.C. PROPAGATION CURVES
ANTENNA POWER-3 KW
50 MICROVOLT / METER CONTOUR
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY R.D. DUNCAN, JR.
EFFECTIVE SIGNAL RADIATED-ESR


LENGTH OF TRANSMISSION LINE IN FEET
η = RATIO POWER OUT OF TRANSMISSION LINE / POWER INTO TRANSMISSION LINE
2-5/8"
1-5/8"
7/8"
3/8"
A
DISTANCE CORRECTION FACTOR - e1/e50 μV/m
Fig. 11.
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY R.D. DUNCAN, JR.


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3000 FT.
2500 FT.
2000 FT.
3-LAYERS
1500 FT
1000 FT.
4-LAYERS
6-LAYERS
8-LAYERS
750 FT.
500 FT.
300 FT.
3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400 200 0
105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10,000 11,000 12,000
Fig. 7.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER- 10KW
50 MICROVOLT/METER CONTOUR
RCA VICTOR DIVISION · RADIO CORPORATION OF AMERICA
PREPARED BY R.D. DUNCAN, JR.
EFFECTIVE SIGNAL RADIATED - ESR θ


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400
120 115 110 105 100 95 90
12000 13000 14000 15000 16000 17000 18000 19000 20000 21000 22000 23000
Fig. 8.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 10 KW
50 MICROVOLT/METER CONTOUR
RCA VICTOR DIVISION · RADIO CORPORATION OF AMERICA
PREPARED BY R.D. DUNCAN, JR.
EFFECTIVE SIGNAL RADIATED - ESR θ

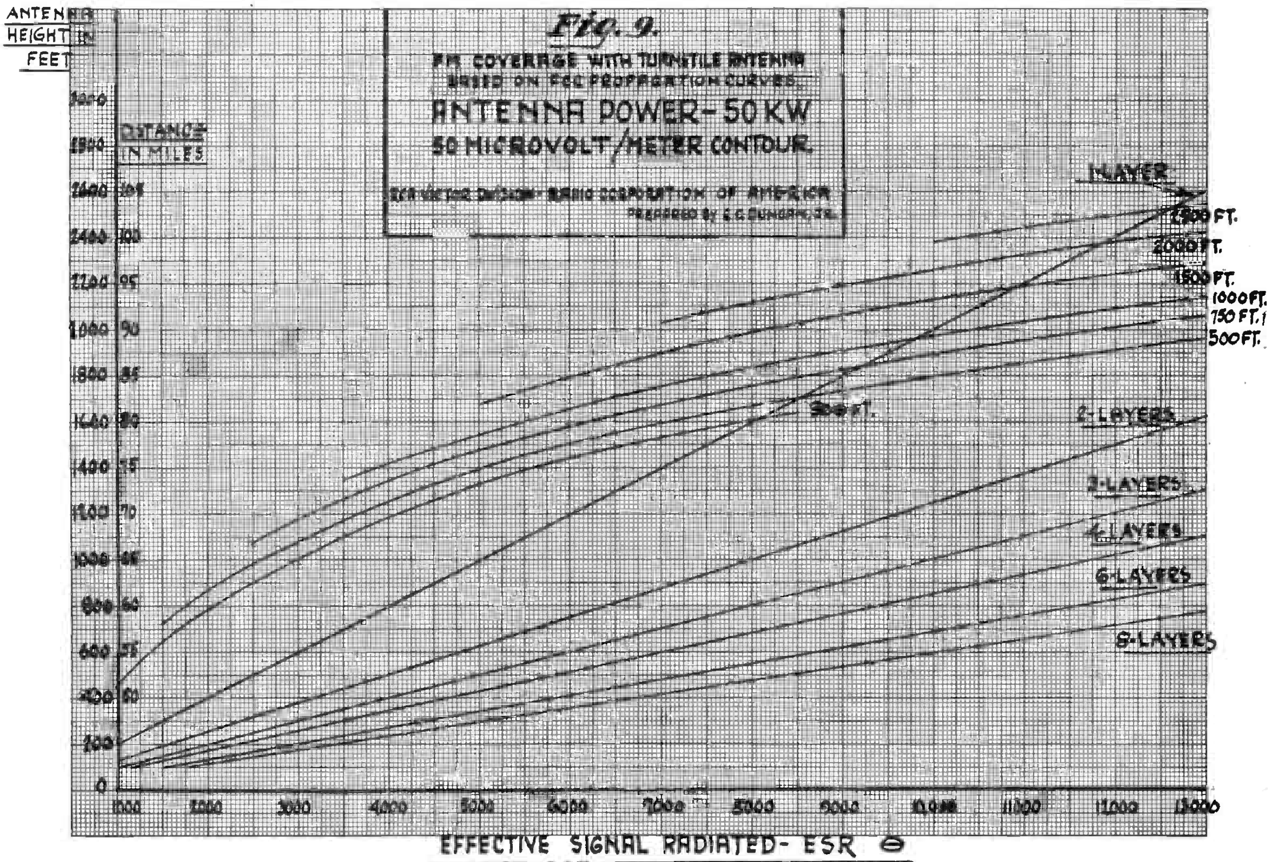


Fig. 9.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES.
ANTENNA POWER-50 KW
50 MICROVOLT/METER CONTOUR.
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY E.G. DUNGAN, JR.
ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2500 FT.
2000 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
EFFECTIVE SIGNAL RADIATED - ESR θ

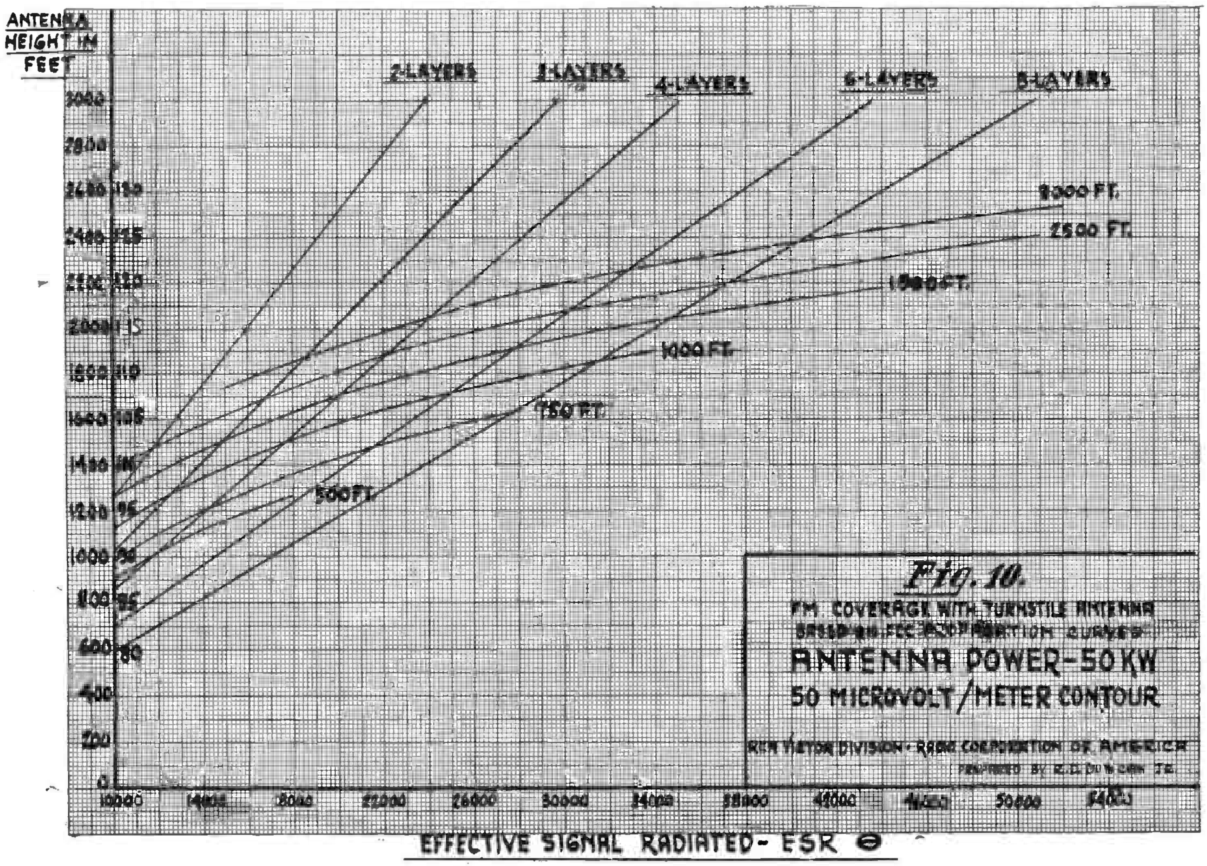
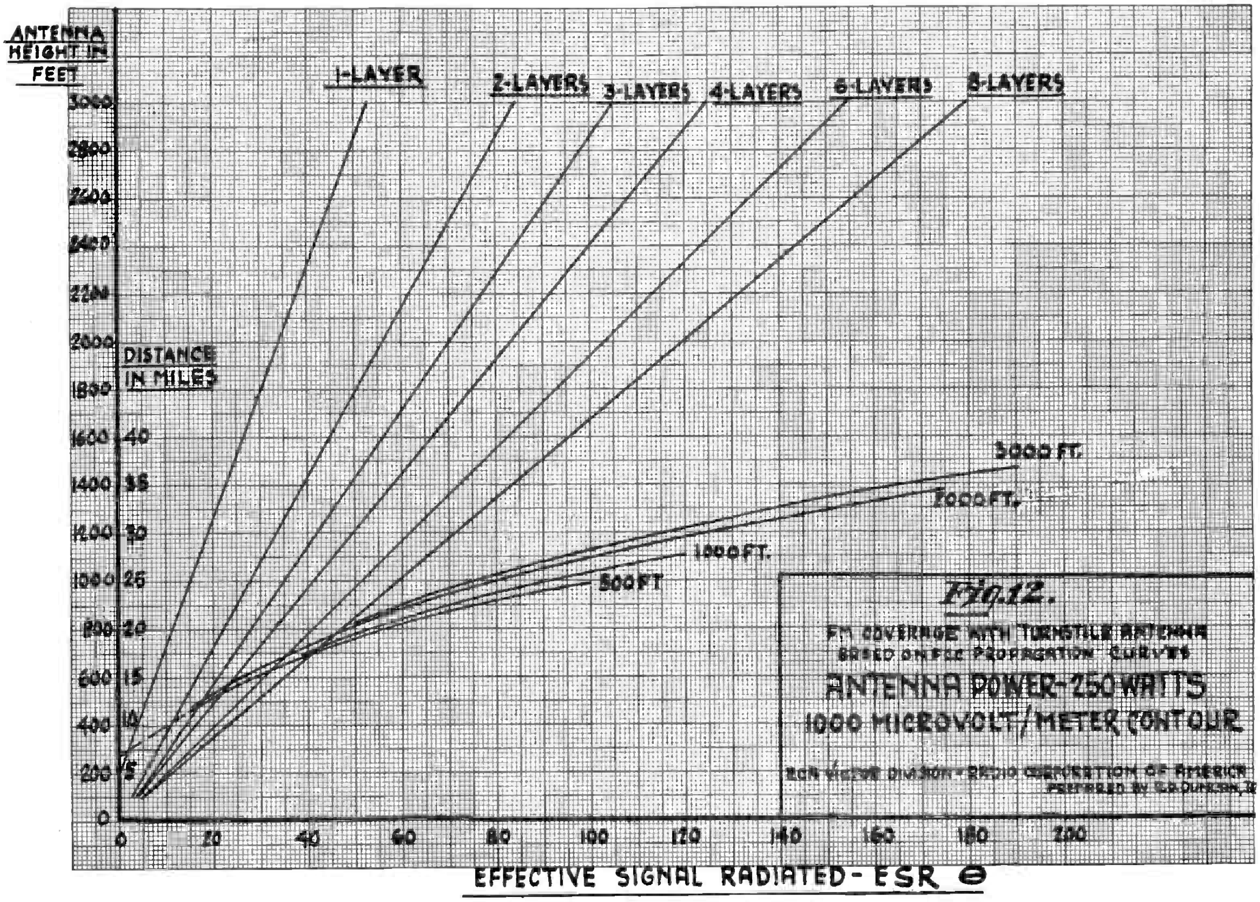
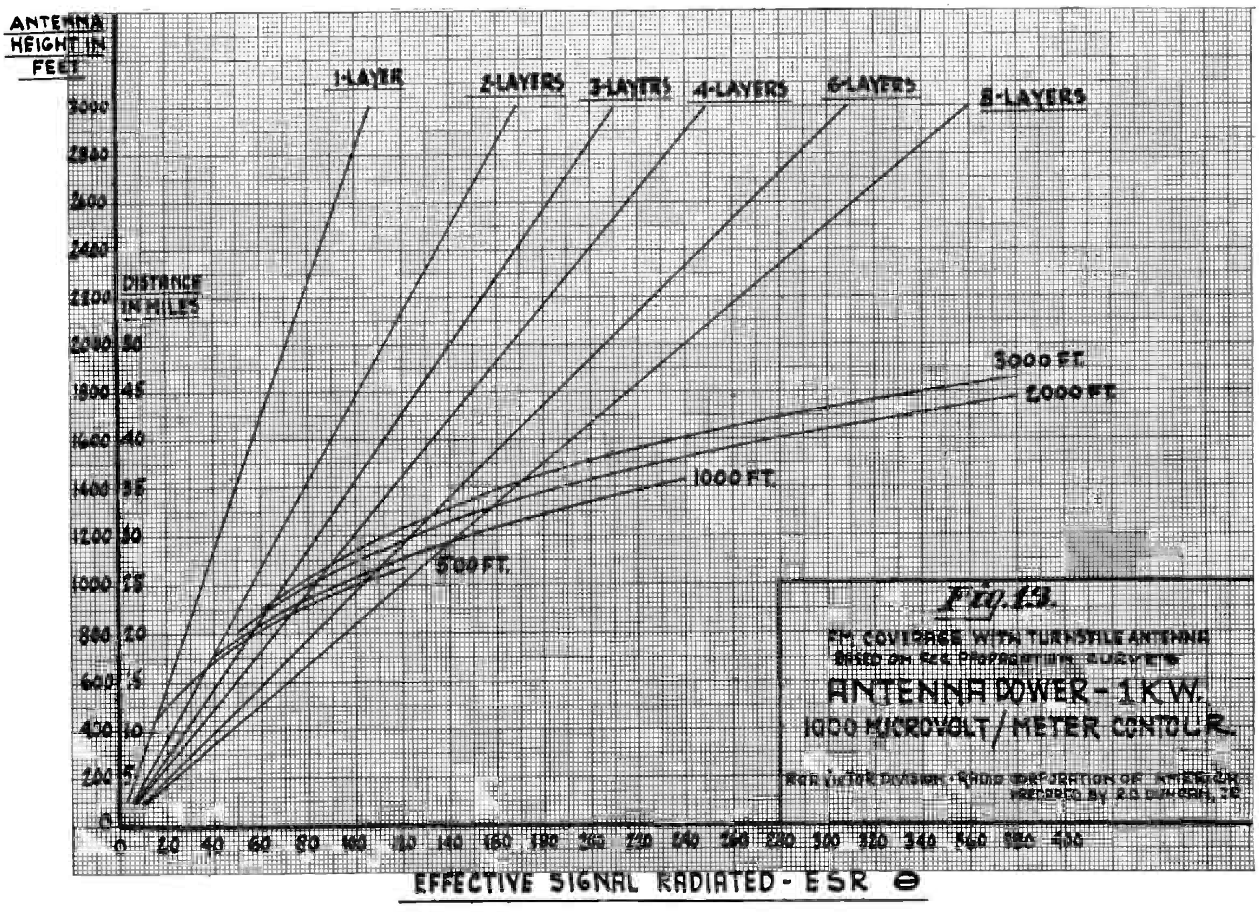
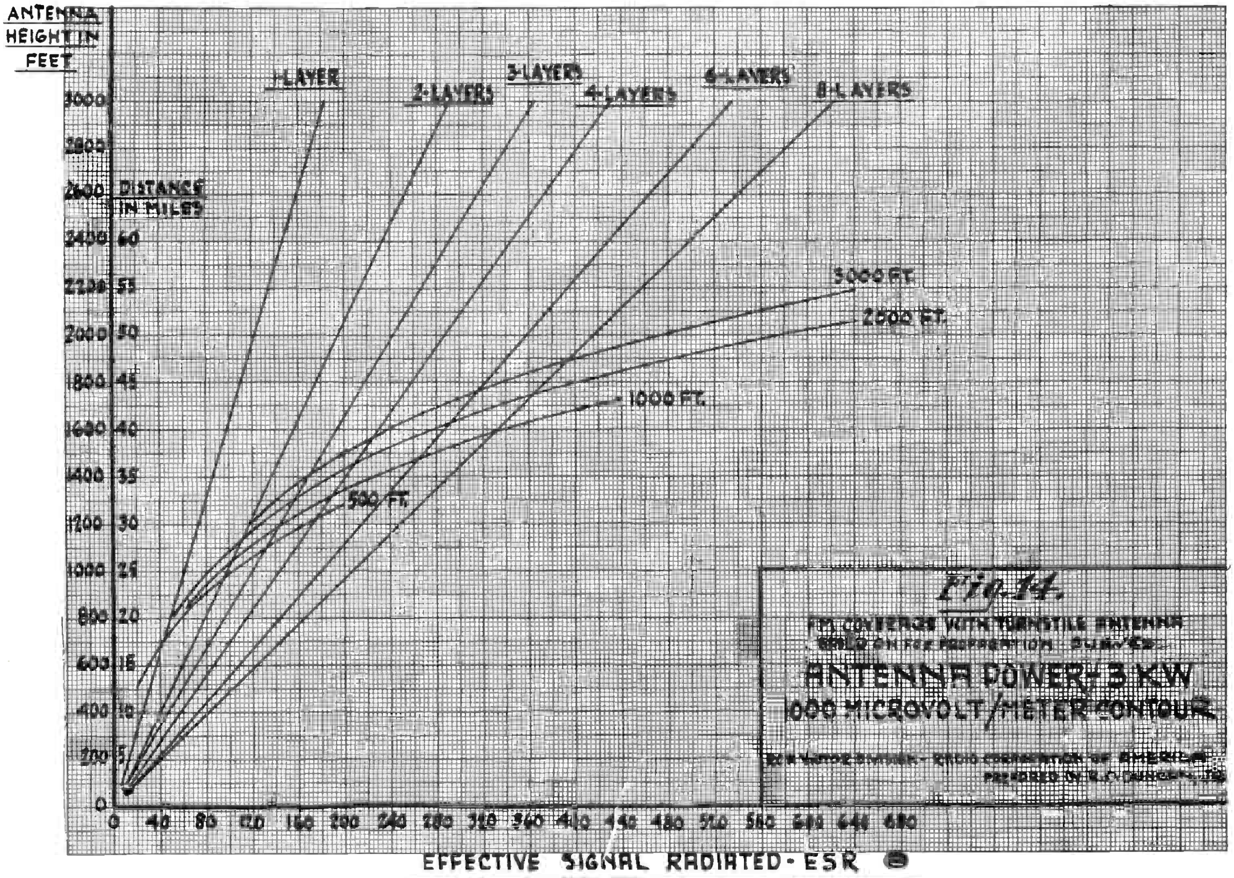
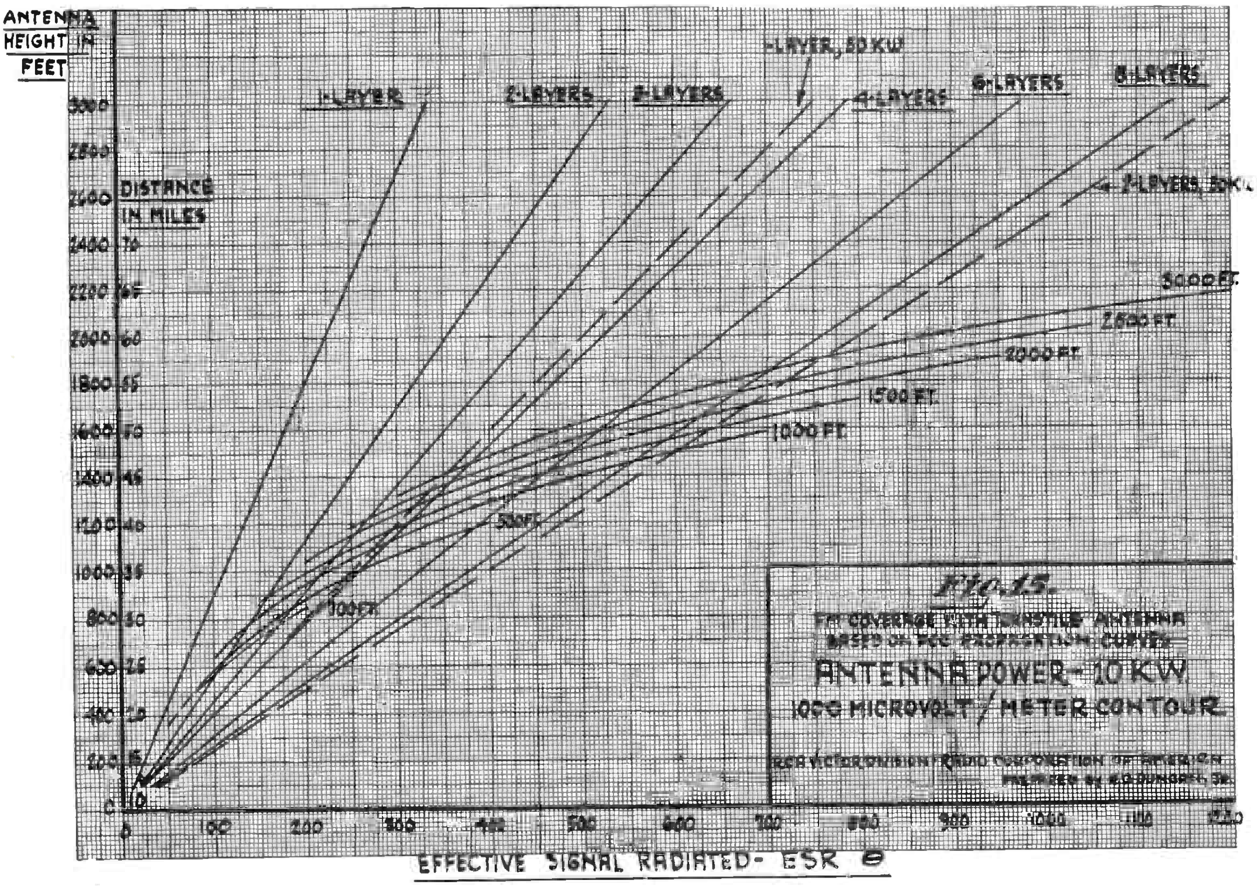


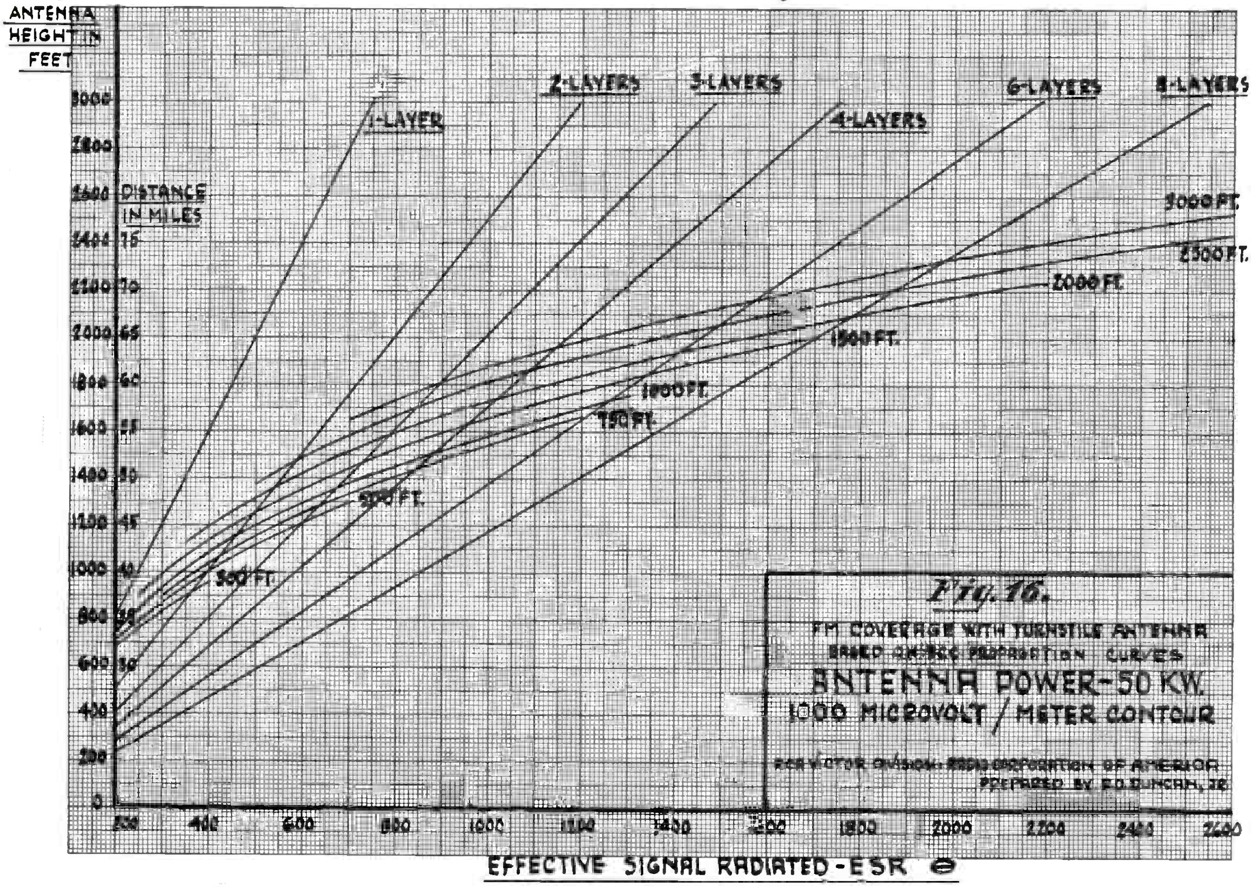
Fig. 10.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER-50 KW
50 MICROVOLT/METER CONTOUR
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY E.G. DUNGAN JR.
ANTENNA HEIGHT IN FEET
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
2000 FT.
2500 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
EFFECTIVE SIGNAL RADIATED - ESR θ

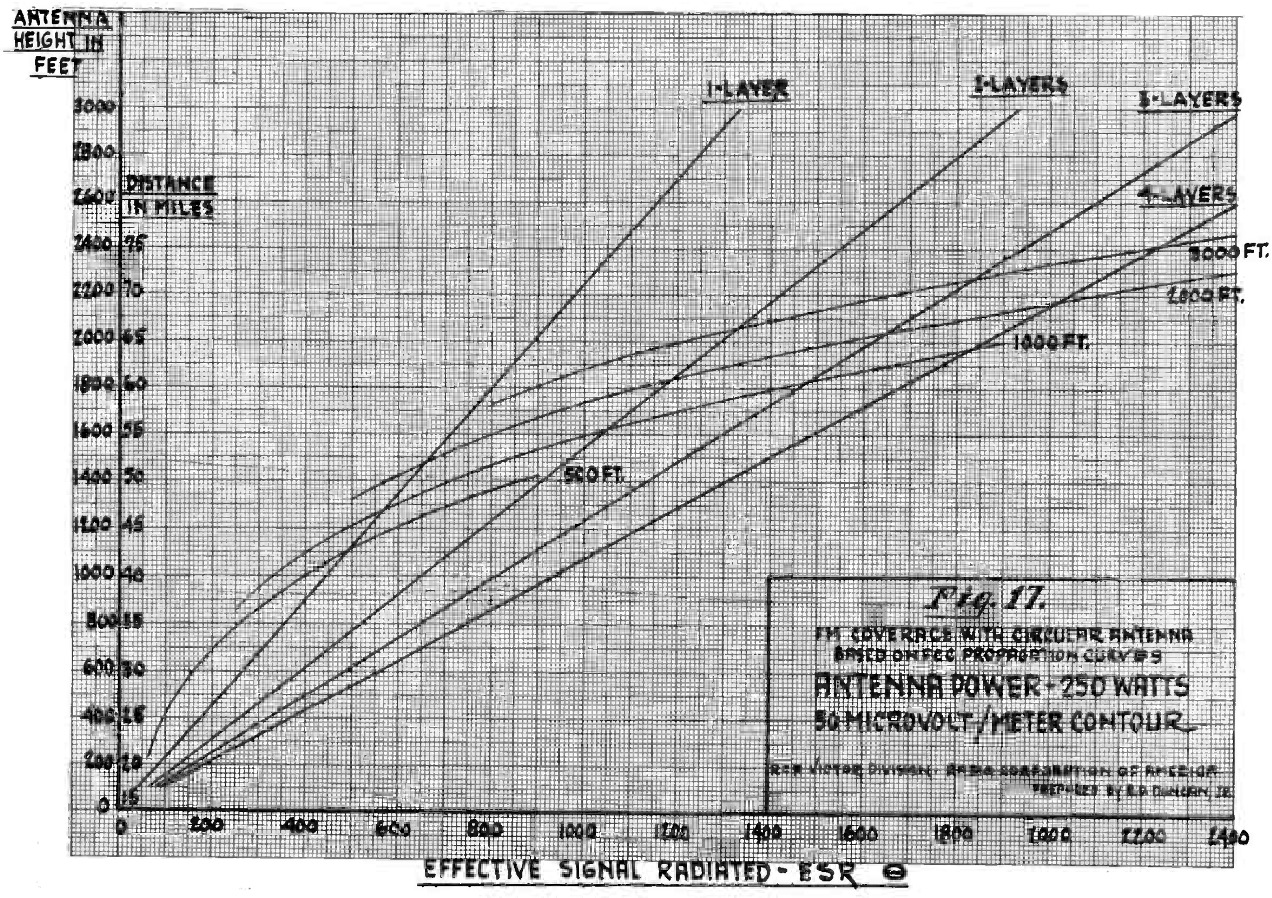

ANTENNA HEIGHT IN FEET
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
DISTANCE IN MILES
3000 FT.
2000 FT.
1000 FT.
500 FT
Fig. 12.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 250 WATTS
1000 MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED - ESR

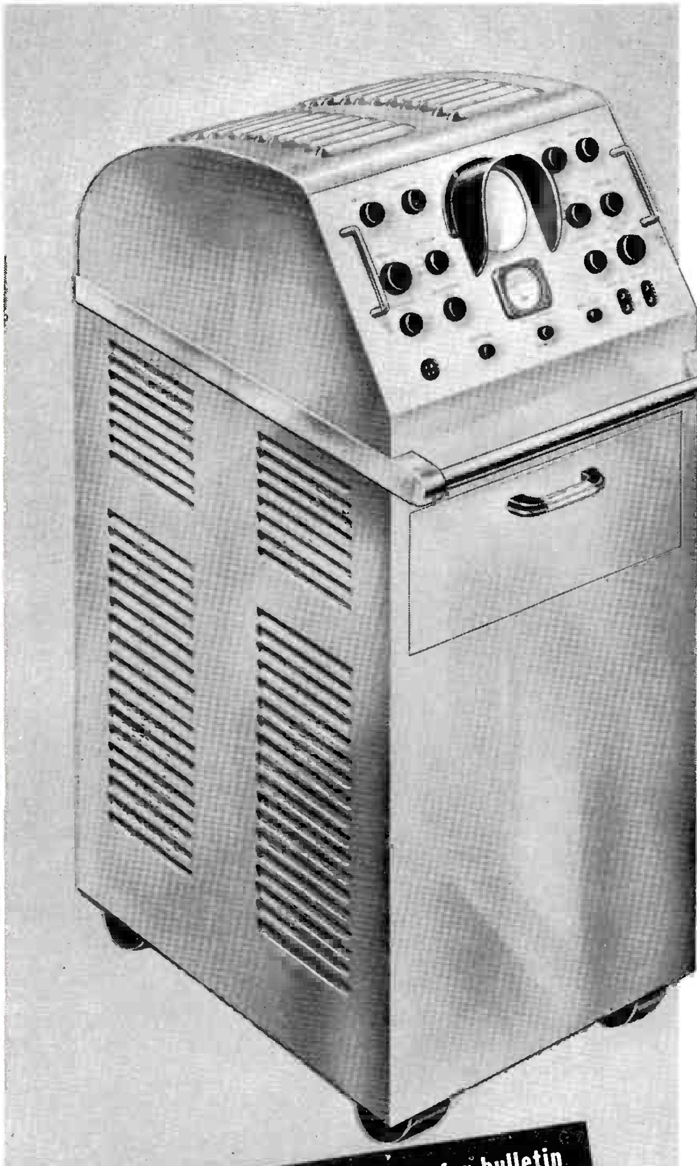

ANTENNA HEIGHT IN FEET
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
DISTANCE IN MILES
3000 FT.
2000 FT.
1000 FT.
500 FT.
Fig. 13.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 1 KW.
1000 MICROVOLT/METER CONTOUR
EFFECTIVE SIGNAL RADIATED - ESR


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
1000 FT.
500 FT.
EFFECTIVE SIGNAL RADIATED - ESR
Fig. 14.
ANTENNA POWER - 3 KW
1000 MICROVOLT/METER CONTOUR


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
1-LAYER, 50 KW
4-LAYERS
6-LAYERS
8-LAYERS
2-LAYERS, 50 KW
3000 FT.
2500 FT.
2000 FT.
1500 FT.
1000 FT.
500 FT.
100 FT.
EFFECTIVE SIGNAL RADIATED - ESR
Fig. 15.
FM COVERAGE WITH TURNSTILE ANTENNA BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 10 KW
1000 MICROVOLT / METER CONTOUR


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
6-LAYERS
8-LAYERS
3000 FT.
2500 FT.
2000 FT.
1500 FT.
1000 FT.
750 FT.
500 FT.
300 FT.
Fig. 16.
FM COVERAGE WITH TURNSTILE ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER-50 KW.
1000 MICROVOLT / METER CONTOUR
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY E.D. DUNCAN, JR.
EFFECTIVE SIGNAL RADIATED - ESR


ANTENNA HEIGHT IN FEET
DISTANCE IN MILES
1-LAYER
2-LAYERS
3-LAYERS
4-LAYERS
3000 FT.
2000 FT.
1000 FT.
500 FT.
Fig. 17.
FM COVERAGE WITH CIRCULAR ANTENNA
BASED ON FCC PROPAGATION CURVES
ANTENNA POWER - 250 WATTS
50 MICROVOLT / METER CONTOUR
RCA VICTOR DIVISION - RADIO CORPORATION OF AMERICA
PREPARED BY E.D. DUNCAN, JR.
EFFECTIVE SIGNAL RADIATED - ESR



For complete details, send for bulletin

Deliveries of this instrument will be as scheduled by WPB approved Form 3243 under Scheduling Order M-293. Please address inquiries to Test and Measuring Equipment Section, RADIO CORPORATION OF AMERICA, Camden, New Jersey.

The NEW RCA Type 715-A

Laboratory-type
OSCILLOSCOPE
Triggered Sweep and Time-Base Marker

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10 Important Features

1. Triggered sweep—individually triggered by each signal.
2. Time-base marker; one microsecond intervals.
3. Sinusoidal horizontal spot deflection at power line frequency with adjustable phase control.
4. Extended frequency range — vertical amplifier flat to 10 megacycles.
5. High vertical deflection sensitivity (.66 volts/inch).
6. Precisely compensated attenuator for vertical amplifier.
7. Calibration meter to permit direct determination of amplitude of any voltage component in signal.
8. Low input capacity and high input resistance for vertical amplifier.
9. Complete absence of cross-coupling between horizontal and vertical deflection circuits.
10. Regulated power supply to insure steady pattern on screen independent of line voltage changes.

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RCA VICTOR DIVISION • CAMDEN, N. J.

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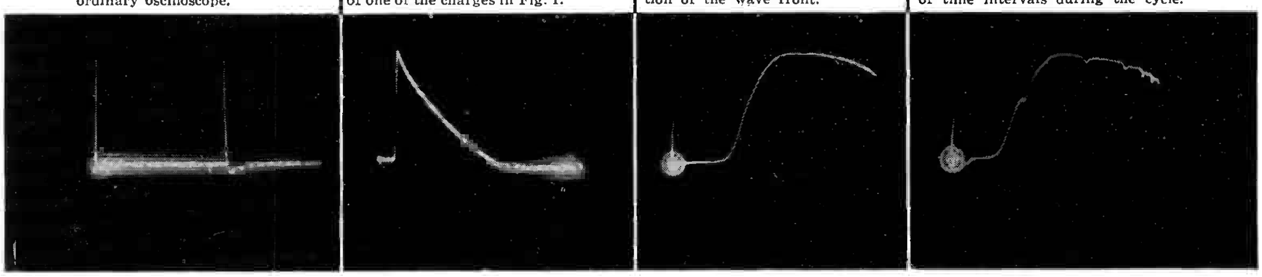
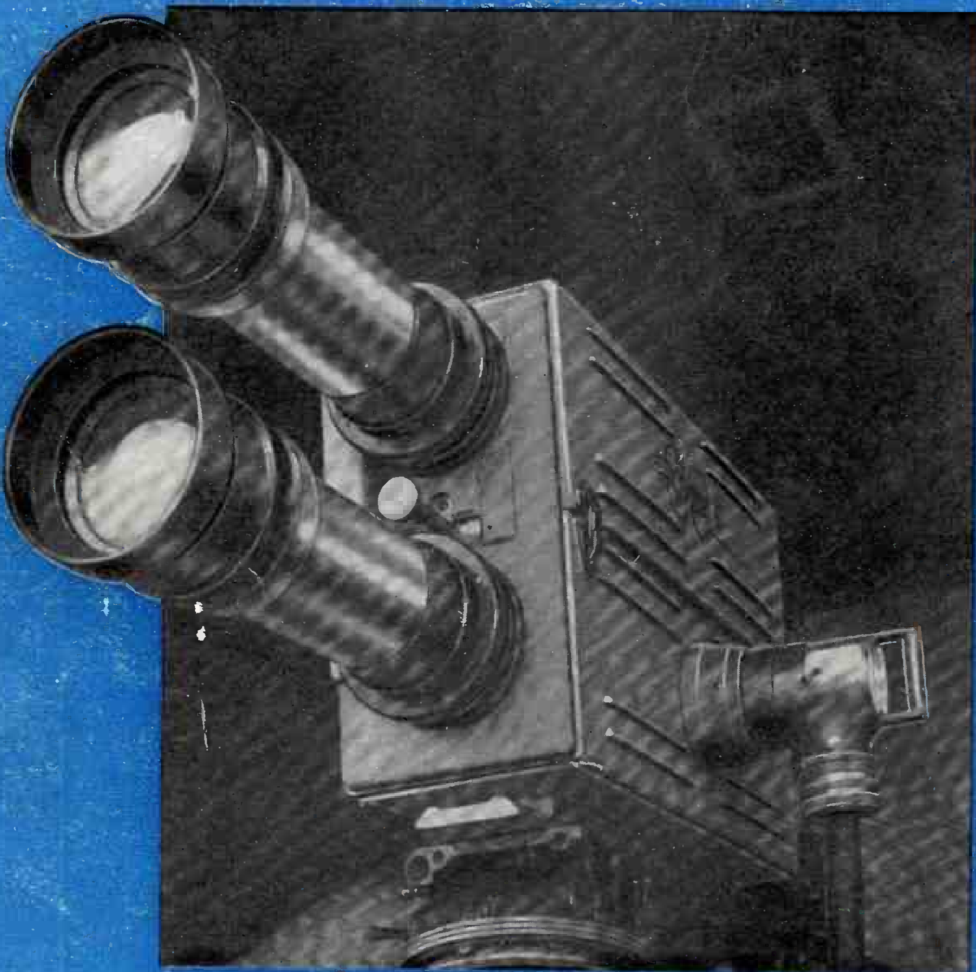
1 Sudden condenser charge and subsequent discharge as seen on ordinary oscilloscope.	2 Externally synchronized and expanded 50 times, revealing the true form of one of the charges in Fig. 1.	3 The same charge, expanded 1000 times, permits detailed observation of the wave front.	4 Applying a one-microsecond time-base marker allows determination of time intervals during the cycle.





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