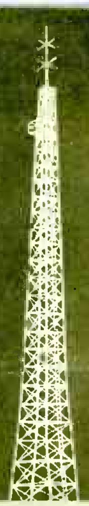
The RADIO ENGINEERS' DIGEST



JANUARY 1945 Vol. 1, No. 6

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Announcing Our New Policy

In order to render a better service by being in a position to reach *all* our friends in the radio and electronics fields, we take pleasure in announcing the formation of a new policy whereby *THE RADIO ENGINEER'S DIGEST* will from now on be distributed entirely without charge. In furtherance of this policy we have already refunded the full subscription price to all our paid subscribers.

In all other respects our magazine will continue as in the past, reprinting from the leading trade and professional magazines the outstanding technical articles of the month.

We look forward with pleasure to serving our readers in the future and trust that they, in turn, will derive continued enjoyment from reading our magazines.

THE RADIO ENGINEERS' DIGEST

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COAXIAL AND RADIO LINKS

Reprinted from Television

By T. R. Kennedy, Jr.

NEW light has recently been thrown on current and planned postwar relaying systems from which undoubtedly, will come the network facilities for nationwide television. One is coaxial cable; the other, a series of towers—about 30 miles apart — between which very high frequencies or microwaves will be transmitted and received.

Coaxial cable, as an efficient means of transmitting many telephone conversations simultaneously —480 over the New York-Philadelphia link—is well established. So is its use as a medium for television. But development work, begun before the war, is expected to be successful soon after the end of hostilities in providing a coaxial-channel frequency *width* of about 7,000,000 cycles (7 megacycles), compared with the current frequency of only about 2,700,000 cycles.

FULL FREQUENCY

WITH such a system installed in the thousands of miles of cable throughout the country it would be possible to transmit the full video frequency of 4,000,000 cycles. Capacity would thus be one complete television picture, plus 480 telephone conversations, simultaneously, or the transmission of a much broader television band if video standards are raised to permit an image of greater detail than the standard of 525 lines currently afford.

Discussing such possibilities, Harold S. Osborne, chief engineer of the American Telephone and Telegraph Company, disclosed at a recent meeting of the Society of Motion Picture Engineers: "Whether the coaxial cable will in the future be used with still broader bands of frequencies will be a question of economics rather than any inherent limitation of the cable."

He said *top* frequency to be sent over the coaxial cable is largely a matter of the spacing of repeater stations along the cable at intervals to build up the *level* of the signal being transmitted. Present cable repeater spacing of about 5.3 miles, he stated, will be about 3.5 miles with the 7-mc. cable.

"The whole development," Osborne went on, "is still young, and we do not want to say whether 7 mc. will be the final step, or whether further developments will lead us to the use of still broader frequency bands over this type of cable."

PIPE CIRCUIT

ALL this talk about television *pipe* now being capable of transmitting about 2,700,000 cycles—with possibilities in the future pointing to its extension to 7,000,000 cycles—means what can take place in just one coaxial cable; in short, in one pipe circuit. Cable installations today, however, are not being limited to

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(*Television, December* 1944)

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one or two pipes, each one a metallic tube with a single wire suspended by insulators at the tubes exact center. In other words, the wire is suspended coaxially within the outer tube.

As they are being plowed in today or contemplated for future installation, the coaxials comprise as many as eight pipes and many telephone *wire* channels packed around the pipes proper. All of which—pipes, wires and everything—are rolled into a big bundle and securely bound with armor and moisture-proof material. The resultant cable is sometimes two-and-onehalf inches in diameter.

Think of the telephone conversations and television programs such a cable would conduct over great distances. Actually, such an eight-pipe cable would carry 1,440 phone messages simultaneously, with two pipes held as spares in case of trouble in the circuit. Or, it would conduct three television programs each way, with two pipes held for stand-bys. Remember that telephone conversations require not only a going but a coming circuit in a coaxial pipe — going in one pipe, returning in another. This way of doing it minimizes cross-talk interference.

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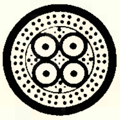
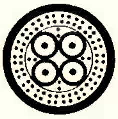
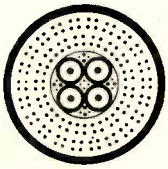


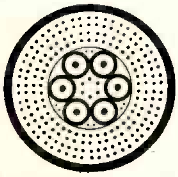
STEVENS POINT-MINNEAPOLIS



ATLANTA-MACON



BALTIMORE-WASHINGTON



PHILADELPHIA-BALTIMORE

Cross-sections of various types of cable are seen with coaxial pipes inside.

Cross-sections of the various cables are illustrated herewith, except the eight-pipe cable, a cross-section of which is not available.

Radio-relay links for all sorts of inter-city services of the future, including television, are regarded by many not as a threat to the coaxial cable's future but as a system likely to be employed with it to set up the most efficient nationwide

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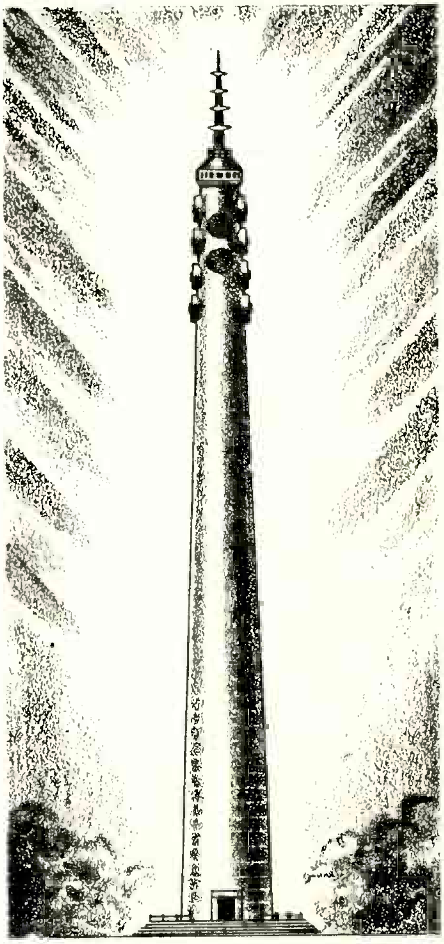
relay routes. The Radio Corporation of America and the AT&T are lookng forward to the use of such relay links between Eastern cities. That part of the AT&T link, planned between New York and Boston, will cost about $2,000,000. It will be operated experimentally, on frequencies of about 2,000, 4,000 and 12,000 mc. Bands up to about 10 mc. are to be transmitted between tall towers spaced some 30 miles apart.

Purpose will be to determine by practical operation in commercial service the relative advantages and disadvantages for the transmission of messages and television programs by radio relay, compared with similar transmission of such programs over wires and coaxials. Relative operating costs, it is said, will be one of the factors to be determined. Others will be quality of transmission, flexibility under operating conditions and dependability. Using very short radio waves, the telephone company already has established permanent phone links over various bodies of inland and coastal waters.



RCA tower may be equipped in future with observation platform to pay cost.

Extensive planning work along this line by RCA contemplates inter-city 20-mc, links between towers some 200 feet high, spotted every 30 miles or so cross-country. Such stations would be of the unattended type, visited by a serviceman

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only when a signal flashed to a central service depot *anticipates* trouble. RCA has made many estimates on the costs involved. They vary widely—$2,000 to $4,000 per mile, irrespective of the total distances to be covered.

It has been estimated that a 300-foot tower, for instance, might cost up to $45,000; 200-foot towers, somewhat less. The necessary tower, transmitter-receiver apparatus and auxiliaries such as power etc., would cost between $25,000 and $50,000 each.

A radio-relay television system planned by the Philco Corporation contemplates a series of towers between Philadelphia and Washington, D.C., with towers at Honey Brook, Pa.; Sappington, Md., and Havre de Grace, Md. The Honey Brook relay will utilize relay channels 11 and 12, or 204-216 mc.—one for receiving and the other for transmitting; Sappington, channels 13 and 14, or 230-242 mc. Havre de Grace is to have equipment for all four channels, and the terminal equipment in Philadelphia and Washington will utilize channels 11 and 12. Tower heights have not yet been determined. Experiments are under way on this part of the problem. Each relay transmitter will have a peak video power of 15 watts, and audio, the same or a little less. Experimental licenses have been granted for this work by the Federal Communications Commission.

Postwar look-and-listen relays are also contemplated by the General Electric Company and the International Business Machines Corporation, as previously reported in TELEVISION. Both are collaborating in the development of a system to be set up and operated experimentally between New York, Schenectady and Washington. Eventually, this system is expected to be expanded throughout the nation and possibly the hemisphere. In November the FFC approved GE-IBM applications for five experimental wide-band relay stations of multiple transmission in the above named points and New Scotland, N. Y. Allocation was granted for six 60-mc. continuous bands from 1,900 to 23,00 mc.

Radio-relay links have strong possibilities when it comes to the power required to send the waves at various frequencies. For instance, with 282-foot towers spaced 30 miles apart, the towered repeater-station transmitter would require 116 watts when a frequency of 500 mc. is employed. But look at the picture when 1000 mc. beams are used. Only 29 watts are needed and the tower height may be reduced to 234 feet. Similarly, by engineering formulae, it has been estimated that at 2,000 mc. only 7.25 watts would be required at a tower height of 200 feet.

Would this almost fantastic mathematical picture of tomorrow's ethereal roadways go on and on in favor of less and less power if the frequencies are made still higher, say to 10,000 megacycles? It looks that way, engineers declare. This would, it seems, bring big economies of equipment for tower-top installation, but not much less, perhaps, in the cost of the towers. Only time will tell where the biggest economies and the most efficient operation will result.

IT'S 1969—ELECTRICALLY

We're living in 1969, electrically. Electrical manufacturers report that the war has advanced technical knowledge by at least a quarter-century.

Significant Radiation from Directional Antennas of Broadcast Stations for Determining Sky-Wave Interference at Short Distances*

Reprinted from Proceedings of the I.R.E.

By J. H. DeWitt, Jr.† *Senior Member, I.R.E.*

and

A. D. Ring,§ *Associate, I.R.E.*

Summary—The present practice in the design of directional antennas for broadcast stations to prevent sky-wave interference to another station on the channel at short distances does not necessarily accomplish the purpose. The interference signal has been computed from the radiation along one path at a fixed vertical angle. This practice has been generally followed by consulting engineers and has been acceptable to the Federal Communications Commission. Measurements indicating the length of the path of sky-wave signals received at short distances show that signals take various paths and are not confined to a single path. Measurements were made by pulse transmissions of the relative time required for sky-wave signals to arrive at a receiving point some 230 miles from the transmitter. Control was had of the vertical radiation pattern. The records made of the received signal indicate varying heights and conditions of the reflection layer. To assure that no interference is caused by sky-wave signals, in accordance with the Commission's Standards of Good Engineering Practice, the Standards must be modified to require proper consideration of the radiation at all angles which constitute the "appropriate vertical vector."

THE DEMAND for additional standard broadcast stations to serve centers of population which have insufficient broadcast service has resulted in every effort being made toward maximum possible use of all duplicated channels. It has been found that by proper use of directional antennas the number of stations on a regonal channel may be doubled or even tripled and yet have each station serve adequately the desired center of population. The number of broadcast channels is definitely limited and it is only through the utilization of technical developments that it has been possible to improve and increase the service to many centers of population by the maximum utilization of regional and local stations.

Directional antennas are not used for stations on local channels which are limited in power to 250 watts and allocated without regard to sky-wave interference. Regional stations, however, use a power up to 5 kilowatts, and mutual interference from sky-wave signals at night must be taken into account to prevent serious curtailment of the service area of stations on the channel. The directional antenna permits control of radiation in the various directions so that additional stations or power may be employed on a channel without the creation of objectionable interference.

The design of directional antennas has become increasingly complex, both on account of the great number of directions in which protection must be provided

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(*Proceedings of the I.R.E., November* 1944)

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and the small mileage separation between stations. This short mileage means that the signal causing interference is not necessarily determined by the horizontal-plane radiation pattern. The radiation from the antenna as established by the vertical pattern becomes the determining factor when the distance is reduced to a few hundred miles.

Experience with directional antennas indicates that the present design practice of reducing the radiation at one angle in the vertical plane corresponding to one reflection from the E layer of the ionosphere does not necessarily control the interference signal. As a matter of fact, under some circumstances, it has been found that such directional antennas actually increase the interference, even through the method commonly used to determine the antenna characteristics and interference indicated there should have been no objectionable interference. It was evident that the signal arriving at the distant point had not traversed one fixed path but several widely different paths. This apparent condition gave rise to a study of length of the path of propagation of sky-wave signals arriving at points 175 to 250 miles distant from the transmitter.

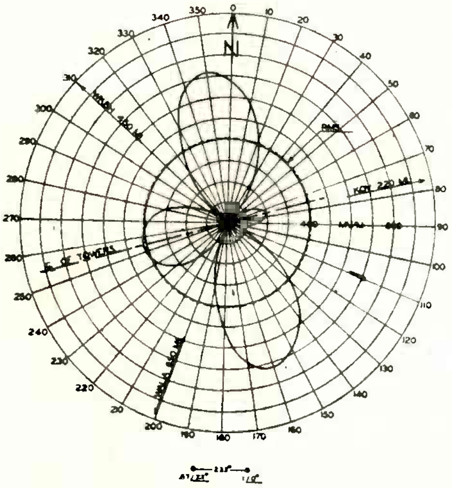

Fig. 1—Horizontal-plane radiation pattern.

In 1939, the Federal Communications Commission published certain standards of allocation for stations in the broadcast band. The method set out for determining nighttime interference between stations is based on a large number of sky-wave measurements which were made in the spring of 1935. The average of all the antennas measured corresponded to one having a height of 0.311 wavelength. In designing directional antennas, the engineer is required to consider all of the "appropriate vertical vectors," but consulting engineers in general have apparently thought it necessary to consider only the radiation at one angle above the earth, corresponding to that of a single reflection from the E layer of the ionosphere. The height of the ionosphere is generally taken as 110 kilometers or 68.4 miles.

In designing a directional antenna for a given situation, it is not always possible to control the radiation in both the horizontal and vertical planes. Certain vertical high-angle lobes must sometimes be tolerated when the signal along the ground is reduced to a low value. In several cases an attempt has been made to protect another station on a channel through the use of an antenna with a vertical pattern in which there is a minimum at the angle corresponding to a single reflection from the E layer. The authors recently undertook the investigation of the action of such an antenna, after serious complaints of the interference had been registered by the station which was supposedly protected. A description of the method employed and the results obtained are given as it is believed that the method may have some usefulness in other cases and also because the results have shown that much greater attention must be paid to the shape of the vertical pattern in the direction of the station to be protected.

The station in question is WING, located at Dayton, Ohio, which operates on a carrier frequency of 1410 kilocycles, with a power of 5000 watts, day and night. The directional antenna of this station must afford protection to stations at Mobile, Alabama; LaCrosse, Wisconsin; and Pittsburgh, Pennsylvania. The calculated horizontal and vertical radiation patterns for the antenna are shown in Figs. 1 and 2. The distance from Dayton to Pittsburgh is 230 miles. The vertical angle at Dayton, corresponding to a single reflection from the E layer, at a height of 68.4 miles, is 30 degrees. It will be noted from Fig. 2 that the designer

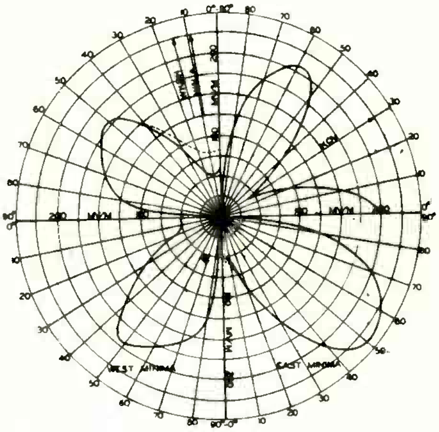

Fig 2—Vertical-plane radiation patterns.

has provided a minimum in the vertical pattern at this angle. Assuming that the ionosphere remains fixed in height and that only a single reflection takes place, this antenna should give adequate protection to the service area of KQV at Pittsburgh. It was found that such was not the case, as there were many nights during which interference to KQV was extremely serious, the station's coverage being limited to its 15-millivolt-per-meter contour.

In order to determine the paths over which the signals traveled, it was concluded that a pulse method of transmission, which is similar to the technique employed in measuring the height of the ionosphere, was most suitable. By transmitting sharp pulses of carrier at regular intervals and receiving them on an oscilloscope having a sweep circuit, it is possible to separate the various reflections because of the difference in time required for the transmitted energy to traverse paths of different lengths.

This method was first tried on WSM, operating wth a power of 50 kilowatts on 650 kilocycles. The pulse generator used in all of the tests to be described consisted of a 450-cycle sine-wave oscillator, which was fed into a cascade clipper amplifier and thence to a differentiator circuit. The circuit of this apparatus is shown in Fig. 3. Square waves from the clipper amplifier charge C_1 (a relatively small condenser) through a diode. On the reverse cycle the condenser is completely discharged by another diode connected in the opposite direction. A small resistance in series, with one of the diodes, provides a voltage which is a replica of the condenser-charging current. The width of this pulse is, of course, determined by the steepness of the square waves and the degree of charge which C_1 receives on each cycle. The circuit constants were adjusted so that the duration of each pulse was approximately 50 microseconds. The time between pulses is 2.22 milliseconds corresponding to the 450-cycle input signal. By adjusting the frequency of the audio oscillator, this interval may be varied at will. A frequency of 450 cycles was used in these tests as it permitted reception of two identical waves on the receiving oscilloscope during one sweep, and at the same time provided sufficient time interval between pulses so that all reflections could be spread on the cathode-ray-tube screen before the next succeeding group of pulses was received. Keying of the transmitter carrier was accomplished by removing the steady plate voltage from the modulated amplifier, and by exciting the modulator tubes to provide positive plate voltage. The excitation corresponded to the narrow vertical pulse. The output of the pulse generator was fed into the transmitter audio input terminals with the correct polarity and at the proper level. A schematic representation of the modulator is shown in Fig. 4.

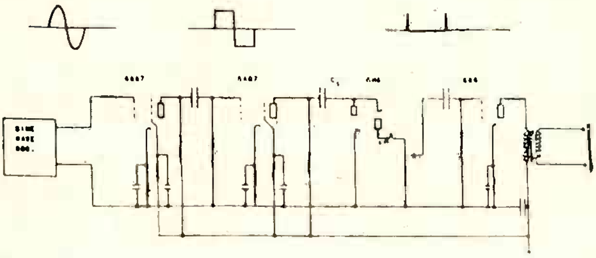

Fig. 3—Pulse-generating circuit.

In adjusting the transmitter, an oscilloscope was connected across the transmission line to the antenna and the deflection was noted for normal power output with a steady carrier. After this the pulse generator was applied and the peak pulse power was adjusted through the audio input so as to equal the normal carrier power. It was interesting to note that with the transmitter operating with 50 kilowatts of peak pulse power, the average antenna power is only about 1 kilowatt for the pulse used.

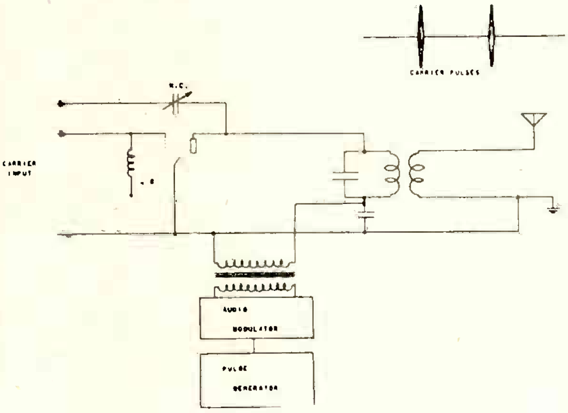

Fig. D—Transmitter connection for pulse transmission.

In order to preserve the shape of the pulse, it is essential that the transmitter have a bandwidth of about 10 kilocycles. It must also be free of any transient

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condition. Otherwise, the transmitted pulses will have the oscillatory character of a damped wave. The radio receiver used in the tests was of the superheterodyne type without automatic volume control, but having an adjustment for over-all radio-frequency gain. The total bandwidth of the receiver was adjusted for 10 kilocycles. A single-stage resistance-coupled audio amplifier was used between the diode-detector output and the vertical input circuit of an RCA 3-inch cathode-ray oscilloscope, type TMV-122B. The horizontal linear sweep circuit in the oscilloscope was used to spread out the received waves. The sweep oscillator was synchronized from the received impulses. This simple method of synchronization proved to be entirely reliable, but there was some trouble experienced from the movement of the image when the received pulses changed their relative magnitude.

The measurements on WSM were carried out on January 13, 1942, at Birmingham, Alabama, at an airline distance of 180 miles. A loop receiving antenna was used, which has a nondirectional vertical pattern. The next day, when all sky-wave transmission had disappeared, the ground wave at this point was measured and found to be 95 microvolts per meter. Some oscillograms of the received pulses are shown in Fig.5. The ground wave may be seen as the first small received pulse in all of the figures and this has been taken as zero time. Both the first and second reflections are visible in these photographs. The first reflection is present most of the time. At 2:05 a.m., it reached a peak value of approximately 1.25 millivolts per meter. The time interval between reception of the ground wave and the first reflection corresponds to a path difference of 37.5 miles, which would place the layer at an effective height of 70 miles. Regular fading of the reflections was the rule rather than the exception. When the first reflection began to fade, it was noticed that the crest of the pulse nearly always split in two sections, as may be seen in several of the oscillograms. This appears to be due to double refraction. The first part of the pulse is the ordinary ray and the second part is the extraordinary ray. The time interval between the two sections of this reflection corresponds to an apparent difference in layer height of about 20 miles. The second reflection was only evident occasionally. Its strength would not be expected to be great at such a short distance. The vertical

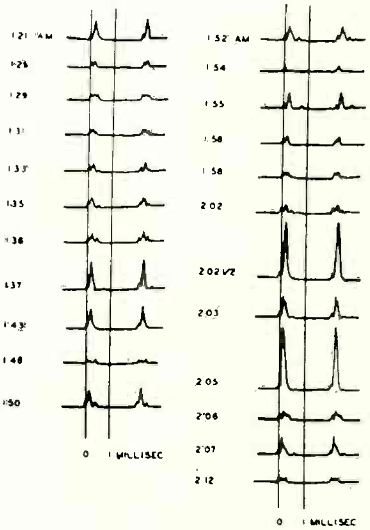

Fig. 5—WSM pulse transmission, 650 kilocycles, received near Birmingham, Alabama. Distance, 180 miles, January 13, 1942.

pattern of the WSM antenna, as measured in an airplane, is shown in Fig. 6. The arrows shown at angles of 50 degrees and 32 degrees correspond to the first and second reflections, for a distance of 180 miles.

On February 1, 1942, this technique was applied to the directional antenna at WING, Dayton, Ohio, the signal being received at Pittsburgh on a vertical quarter-wave antenna. When tests were begun at 1.00 a.m., with Dayton operating nondirectionally, the received signal at Pittsburgh was of a character similar to that found in the tests on WSM. No ground wave was visible because of the relatively high attenuation over this path. The first reflection was predominant, but the second reflection was present most of the time. The first reflection exhibited the same twinning when fading took place. At approximately 1:30 a.m., the pattern of transmission changed. A new strong reflection appeared at a point in time just after the second reflection. The strong first and second reflections which had been observed earlier disappeared almost completely. Subsequent measurements of these oscillograms have convinced the authors that the new reflection took place at the F layer of the ionosphere at a height of about 150 miles, assuming that the height of the E layer was 70 miles. The paths of the signal are illustrated in Fig. 7.

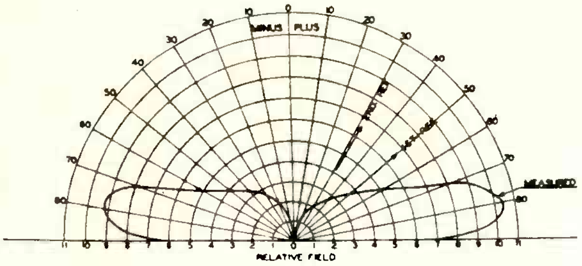

Fig. 6—WSM vertical radiator, measured December 5, 1940.

Before transmission conditions changed, the engineer at WING was asked to switch from nondirectional to directional operation. When this was done, there was a great decrease in strength of the first reflection and by changing the phasing between the two towers at WING, the first reflection could be substantially eliminated. A change in phase has the effect of moving the vertical minimum in the radiation pattern to a different angle with respect to the horizontal (see Fig. 2). Under these conditions, the first reflection could be eliminated for several minutes at a time, but it would always reappear, necessitating a change in phase between the towers, for its re-elimination. It was concluded from this result that the effective height of the E layer of the ionosphere was changing from minute to minute. This alone is sufficient to prove that such a vertical pattern cannot be relied upon to provide adequate protection.

Later, when the F-layer reflection was the controlling factor, less signal was received at Pittsburgh when the station was operating nondirectionally than when the directional antenna was used. The oscillograms shown in Fig. 8 were all taken after the onset of F-layer reflections. A large amount of scattered radiation may be seen just ahead (to the left) of the strong F-layer reflection.

The condition of the ionosphere at this time seems best explained by assuming that recombination of electrons in the E layer had progressed to such an extent that very little reflection took place. The waves upon arrival at the E layer were probably split into a number of rays, some of which were absorbed, some

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reflected wth greatly reduced intensity and others allowed to pass with some attenuation to the F layer, where they were refracted back to earth. Further measurements on WING were made at Nashville when this station operated nondirectionally. These oscillograms are shown in Fig. 9. Over the space of time in which they were made, there was no evidence of F-layer reflections, transmission conditions being entirely "normal". The first reflection from E layer was the predominating factor, but a second reflection was present most of the time.

In view of the possibility of F-layer reflections and also the great probability of scattered E-layer reflections, it would seem that the designing engineer must, in the future, give closer attention to the vertical pattern in the direction of the stations to be protected,

What is needed for guidance in future designs is a fund of knowledge on the action of the ionosphere at broadcast frequencies. A tremendous amount of work has already been done on measurement of ionosphere heights and critical frequencies, but this work has apparently been directed toward the end of providing more information on the subject of long distance communication in the short-wave bands. From published papers it is possible to obtain a tremendous amount of general information on the ionized regions of the atmosphere. Nearly all of the measurements have been carried out with the receiver at approximately the same location as the transmitter, so that the results correspond to a wave reflected at vertical incidence. Under these conditions, the critical frequency for the E layer is very much lower than would be the case for waves reflected at other angles. It has been established that the critical frequency is a function of the secant of the angle of incidence.

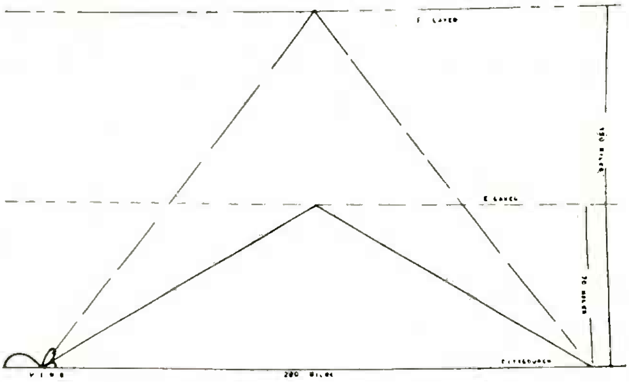

Fig. 7—Signal paths from WING to Pittsburgh

Nearly all of the measurements which have been reported on the E layer show its critical frequency only for daytime conditions. During daytime the E layer apparently has just below it a layer of intense ionization, which absorbs waves in the broadcast band. Its critical frequency must be very much higher in the daytime than at night, owing to the intense ionizing effect of the ultraviolet light from the sun. At sunset, recombination of the ions begins and continues throughout the night. One would think, therefore, that the E layer would have its lowest critical frequency in the early hours of the morning just before sunrise. It has been pointed[3] out that the normal E critical frequencies varied fairly regularly, both diurnally and seasonally. The E-layer critical frequency *rose rapidly at sunrise out of the broadcast band* and came to a broad maximum about noon, both in summer and winter. From this it appears that penetration of the E layer by

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broadcast waves at night may be a rather common occurrence. This would especially be true at the high-frequency end of the broadcast band and at small angles of incidence.

It would be highly desirable for someone to undertake a complete study of the characteristics of the ionosphere in a broadcast band. We need to know the critical frequency for the E layer at night in order that the designer of a directional antenna may know at what frequency in the broadcast-band penetration of this layer is likely to be encountered. The laws governing penetration and reflection at varying angles of incidence seem to be very well established. It is apparent that penetration of the E layer is much less likely when the waves arrive at large angles of incidence which would correspond to a wide mileage separation between the stations in question. More information on this subject, however, would be highly desirable.

For the present it seems that the design engineer must regard the space between the earth and the upper atmosphere as a vast hall with no walls, a rough floor, and a cloudy ceiling, which may vary in height from 60 to over 150 miles. Since the ceiling is composed of clouds of electrons, which are constantly shifting in much the same way that the water-vapor clouds shift in the troposphere, we cannot think of single rays of energy being reflected from an object similar to a plane mirror, yocated at a point halfway between the transmitter and receiver. The probable paths of the sky-wave signal are illustrated in Fig. 10. Such paths would explain the results obtained from the tests.

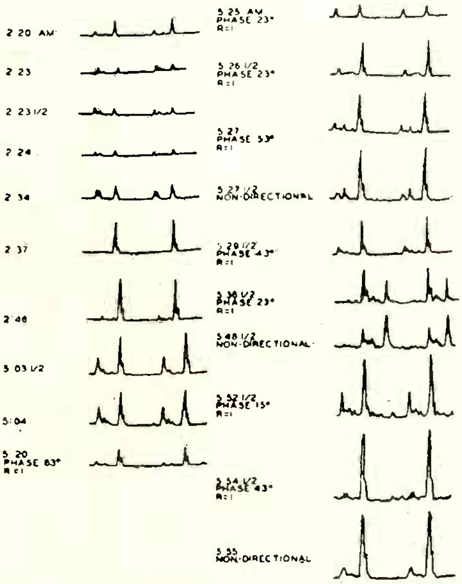

Fig. 8—WING, Dayton, Ohio, 1410 *kilocycles, as received on non-directional antenna at KQV, Pittsburgh, Pennsylvania, February* 1, 1942. *Time between two identical successive waves*—2.22 *milliseconds. Scale of all oscillograms not exactly the same.*

There are certain types of directional antennas which suppress radiation at all vertical angles in certain azimuth directions. These are usually linear arrays, so phased that the field normal to the line of the array is near zero. A simple example of this type of antenna is a two-tower array with any degree of spacing, but with the two elements operated in phase opposition. It would be interesting to select a few such antennas in the country and to make a study of the degree of protection they afford other stations on the channel, in comparison with the protection afforded by antennas such as that in use at WING.

Recent measurements of the current distribution on each element of a three-element directional antenna indicated that there is a substantial variation in the electrical height or current distribution due to the mutual. In this design the physical height of each element was 146 degrees, assuming propagation at the speed of light. The electrical heights were established from the measured current distribution fitted to a sine wave as 149, 183, and 160 degrees, respectively. This design had several minima in the vertical-plane pattern as computed for an electrical height of 146 degrees for all elements. These minima would not occur as computed for the measured electrical height and, in fact, actual sky-wave measurements indicated that the sky-wave signal was actually increased at these angles over that from a quarter-wave antenna having the same field in the horizontal plane.

It is believed that the pulse method of transmission and measurement may be a very useful tool for anyone who must adjust a directional antenna for specific suppression in the vertical plane pattern. It is not possible, through its use, to determine the vertical pattern of an antenna directly because the conditions of reflection at the ionosphere are not known with certainty at any given time. It is possible, however, to eliminate this variable through the common practice of comparing the results with an antenna having a known pattern. Most directional arrays are arranged for nondirectional operation in the daytime, and relays are usually provided so that the antenna may be shifted very quickly between the two conditons. It is only necessary then to set up the pulse-receiving equipment at a point within the service area of the station to be protected and then to shift rapidly between the directional and nondirectional conditions. Photographs of the received image may be taken and measurements made later, which will show the relative amount of energy radiated when operating directionally and nondirectionally. The vertical radiation pattern of a simple quarter-wave antenna is fairly well established. This may be used as a reference, both for measurement of directional antennas and also for the measurement of the vertical patterns of top-loaded or other forms of antennas, which are designed to surpress high-angle radiation.

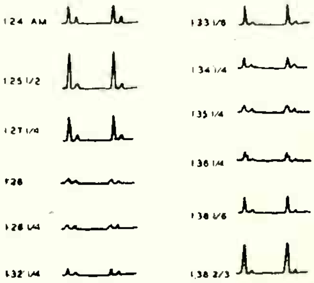

Fig. 9—WING, Dayton, Ohio, received Nashville, Tennessee on nondirectional antenna, February 10, 1942, WING operating nondirectionally. Time between two successive identical waves in 2.22 milliseconds.

CONCLUSIONS

The measurements disclosed clearly that there is no one sharp beam at a fixed angle which determines the sky-wave signal received from standard broadcast antennas at short distances. To assure protection from interference, as would be afforded from an antenna with the vertical distribution of a 0.311 antenna, the signal must not greatly exceed the value in the vertical plane for a comparable antenna in the horizontal plane. Whether the signal arrives by substantially different bearing routes has not been established, but there are definite indications that the signal computed for one bearing toward another station on the channel does not establish the interfering signal on that bearing. The percentage of time which the stray paths of propagation account for a substantial part of the total received signal has not been established. To establish this, in point of time and percentage, would be an extremely long and tedious job. The Commission's Standards might well be expanded with regard to the requirements with respect to the "appropriate vertical vector" by specifying the significant signal as all angles in a vertical pattern.

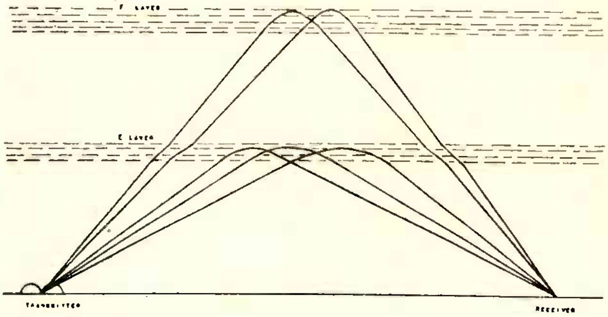

Fig. 10—Possible paths of sky waves.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of Mr. Paul F. Braden of Station WING and Mr. Walter W. McCoy of Station KQV in making the pulse measurements.

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AMPLIFIERS FOR R-F

Reprinted from Service

By Arnold D. Peters

R-F amplifiers are generally tuned amplifiers in which the plate load of the amplifier tube consists of a parallel-resonant circuit. In this type of circuit the tube capacity and stray circuit capacity act as parts of the tuned circuit and do not appreciably affect the gain. But since these capacities build up the minimum value of the tuning condenser, they reduce the tuning range. It should be recalled that, in untuned amplifiers, the tube and stray capacities act as a shunt, causing a loss in the transmission of the higher frequencies. We are better off than the past generation, however, because pentodes have less input capacity than triodes.

R-f amplifiers are important for increasing sensitvity, increasing selectivity and raising the signal/noise ratio, particularly in superhets where the converter tube requires a good signal for optimum performance. Early in the art there was another very important advantage, the isolating of a critical regenerative detector from the antenna circuit. This made regeneration practically independent of antenna tuning.

Originally r-f amplifiers had untuned input circuits, Fig.1, where the tube was of the 201 or 201A battery-type triode. The input potentiometer acted as an antenna attenuator and as a series-grid resistor for dual-volume control action. The next step in the development was the tuning of input and output circuits, Fig. 2. Oscillation then became the problem. Shielding was not generally used in these early amplifiers, but magnetic coupling between input and output transformers was minimized by mounting the coils at a critical angle of 55° to the base, parallel to each other. No attempt was made to minimize electrostatic coupling.

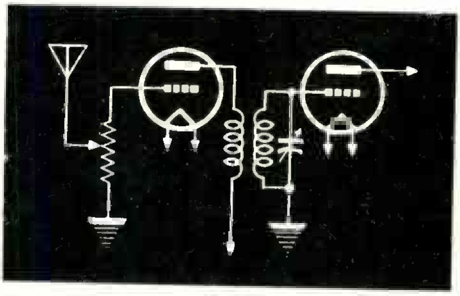

Fig. 1 (above). — An untuned input system where the input circuit potentiometer acts as a grid resistance. The potentiometer also attenuates antenna voltage.

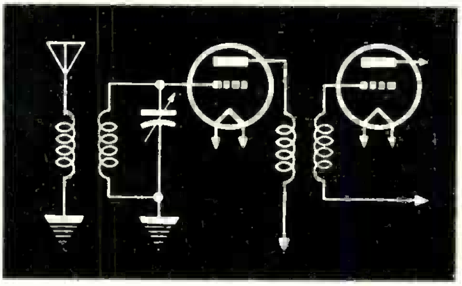

Fig. 2 (above) — An early tuned input amplifier. Generally the primary of the second transformer was also tuned with a variable capacitor.

One of the earlier methods used to curtail oscillation involved suppressor resistors, placed as close to the tubes' grids as possible, right at the socket. Since these amplifiers had lower losses at the higher frequencies they would tend to oscillate at these frequencies, but it was found that suppressors were more effective there also; hence, the application. Fig. 3 shows the position of the suppressors.

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Before considering the other methods of preventing oscillation, let us review some of the theory concerning oscillation.

The early triodes had a substantial grid-plate capacity. Thus when the plate potential changed, the grid potential followed suit due to the coupling by this capacity. If the grid potential were not allowed to change when the plate potential changed, regeneration could not occur. This happy state of affairs could be accomplished by placing an internal electrostatic shield within the tube which, if grounded, would effectively eliminate the grid-plate capacity. Thus came the shielded grid tube. But, before this momentous development, triodes had to be made to work efficiently. This was done by neutralizing the grid-plate capacity by opposing it with an external capacity of equal magnitude but connected in opposite phase. Thus, the feedback voltage due to the internal grid-plate capacity, was cancelled by an equal and opposite voltage passed by the neutralizing condenser.

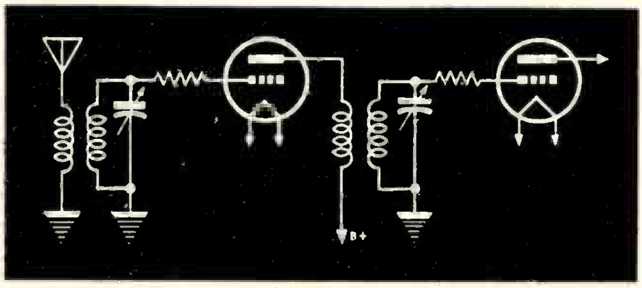

Fig. 3 — Here we have one method of controlling oscillation by using grid suppressors.

Fig. 4 shows two typical methods of neutralization; (a) the most popular grid neutralization, and (b) plate neutralization. In both cases, the center of the coil which develops the out-of-phase voltage is effectively grounded at a tap. As in a push-pull circuit, the two ends of the coil are 180° out of phase.

The neutralizing condenser, C_n, is adjusted as follows: The tube's filament

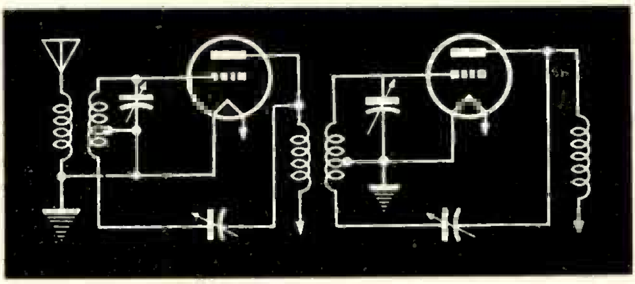

Fig. 4a—A triode radio-frequency amplifier with grid neutralization is illustrated here. This is the most popular form of neutralization.

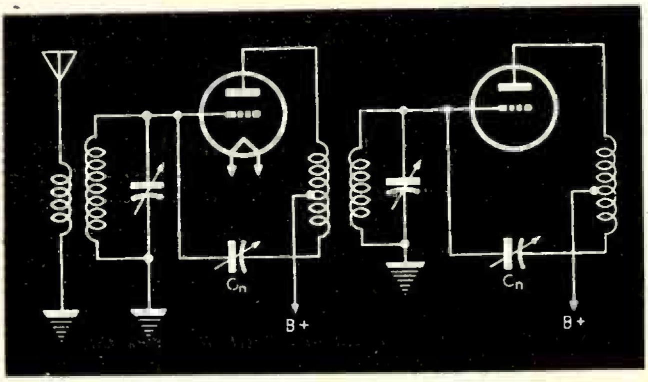

Fig. 4b—Plate neutralization in a triode radio-frequency amplifier.

is opened and a strong signal applied. C_n is then tuned until a null is obtained, exactly like an a-c bridge being balanced . In fact, the act of neutralizing is just that.

Since the triodes in use had a mu of around 9, quite a few stages were necessary to obtain a reasonable gain. Thus a good r-f amplifier was an expensive item. The '22 was the first screen-grid amplifier to replace triodes. Although designed as a d-c tube it was used with a-c on the filament in a number of receivers . The '24 soon replaced the '22 and r-f amplifiers became popular. The '24 had one serious defect; it was a sharp cut-off tube and couldn't take a wide range of signal voltages. This led to the *local-distance* switch which could be called an attenuator for strong stations, preventing overloading of the first r-f amplifier tube. If necessity is the mother of invention, this certainly led to the invention of the variable-mu, or remote cut-off tube. This was exemplified by the '35, later the '35-51, which were very popular as r-f and i-f amplifiers in all types of sets, both t-r-f and superhets.

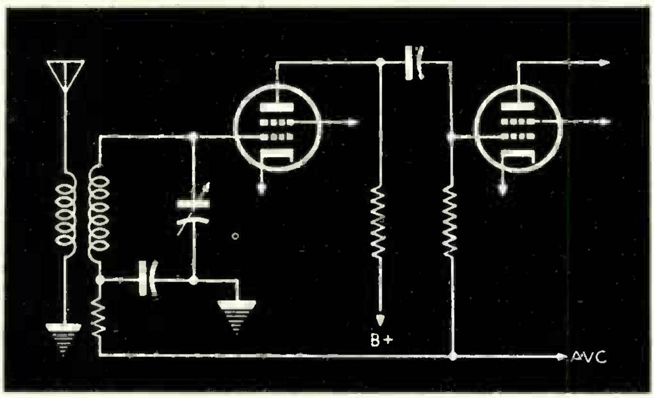

Fig. 5 — Resistance coupled r-f amplifier popular in portables, midgets, and loop receivers.

Not all r-f amplifiers are tuned. Fig. 5 shows a resistance-coupled amplifier which gained considerable popularity in portables and small loop receivers where the addition of a tuning condenser section (3-gang) was undesirable because of size, weight, or cost. The gain of this type amplifier is from 5 to 11 in the broadcast band, which is considerably less than a modern pentode-type tuned amplifier, but still useful. Of course, there is no gain in selectivity with such an untuned

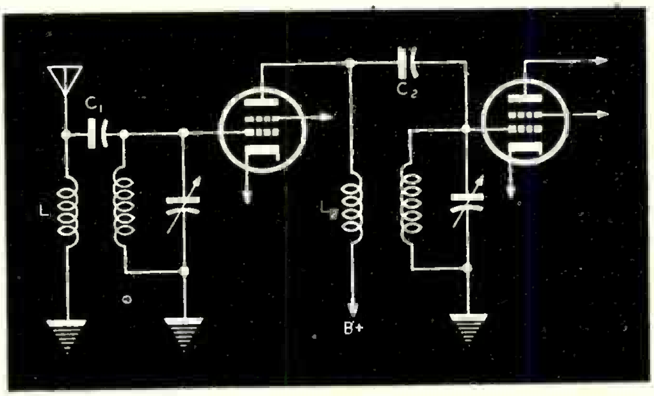

Fig. 6 — A combination of inductive and capacitive coupling are used here for constant gain/frequency characteristics.

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stage. Frequently, an i-f wave trap is inserted to prevent i-f direct pickup. This is important when using a large external antenna.

We have already considered some of the defects of r-f amplifiers, particularly their instability (when using triodes), and the overloading of sharp cut-off amplifiers. These are now of no consequence but there are other difficulties. One of these is the change of gain with change in frequency. One method of obtaining a constant gain/frequency characteristic involves the use of a complex coupling circuit, where one element favors high frequencies, and the other lows. In Fig. 6, for instance, both inductive and capacitive coupling are used in the first and second r-f stages. The antenna inductor, L_1, peaks at a frequency slightly lower than the low end of the band; the capacitor, C_1, is very small, favoring the high frequencies. Similarly, L_2 and C_2 are designed to favor the lows and highs, respectively. The magnetic coupling between the pairs of coils shown is usually quite loose, but varies in individual designs. The main point is that the gain is substantially constant throughout the band.

Continuing with defects in r-f amplification, we have the problem of distortion. Included here are such complications as the modulating of the desired carrier by the modulation of a second, unwanted station, known as cross modulation; hum modulation or tunable hum due to some stray 60-cycle voltage in one of the r-f amplifier tube grid circuits or heater-cathode leakage; intermodulation of sideband frequencies sometimes producing undesired signals within the tuning range; change of modulation factor. All these defects are caused by non-linearity or curvature of the grid voltage—plate current tube characteristic.

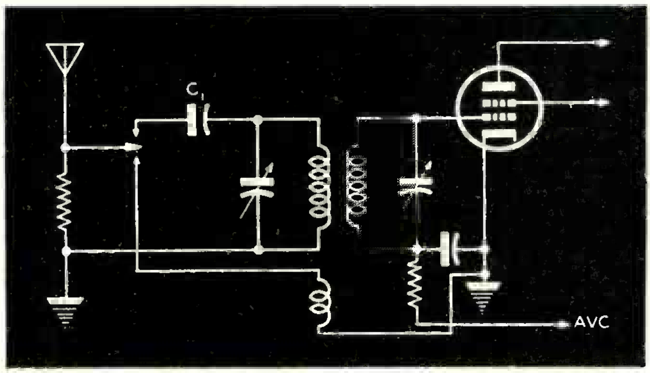

Fig. 1—A double hump band-pass wide-band amplifier.

Tracking is another problem in r-f amplifiers of the tuned type. With a little plate bending and the valuable assistance of a trimmer we get by in most cases. At one time copper slugs were inserted in broadcast-band coils for tuning the low frequency end.

No discussion of r-f amplifiers could afford to omit the double-tuned band-pass type of amplifier which is so popular in fixed-tune i-f amplifiers. Fig. 7 shows a double-tuned antenna input circuit with two types of antenna coupling. With close coupling, double tuning can be made to give a double hump resonance curve approximating a flat topped band-pass characteristic, valuable for high fidelity reception and even more valuable for wide-band amplification as in television. In all-wave receivers where a single antenna goes through all kinds of resonance points the 2-method antenna coupling will prove valuable.

On short waves r-f amplification is very difficult. Special tubes with very high mutual conductance and low capacities are necessary to realize a high gain. Since the war, many of these type tubes have been designed. These will benefit short-wave reception of the future, involving v-h-f (television and f-m) and, perhaps, also u-h-f.

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TUBE OF THE FUTURE

Reprinted from Radio-Craft

By Capt. Eugene E. Skinner
Hq. A.A.F. Training Aids Division

THE new fields of radio that have been developed in recent years have so changed some radio components that it is now impossible for the amateur to wind a coil, change the number and size of the plates on a condenser, and follow the latest developments. Instead, as frequencies become higher, special, critical components are required. Examples of these are found in th resonant circuits and tubes.

For the ordinary range of frequencies with which radio technicians and amateurs were concerned a few years ago, a resonant circuit could be designed to fit any frequency or band of frequencies by changing the number of turns on a coil and the size of the condensers, or by changing crystals. With an increase in frequency, fewer turns in the coils and fewer condenser plates are used. As a very high range of frequencies is reached, a single small turn of wire connecting two condenser plates must be used and crystals become so thin as to be useless. Any further variation along conventional lines is very difficult. New methods must be adopted.

In addition to the problems offered by the *lumped circuit* constants, as inductance of turns of coils and capacitance of plates of condensers are called, the problems of the vacuum tubes themselves become evident. These problems, caused by characteristics which were not bothersome in ordinary tubes at lower frequencies, became of major importance in the ultra-high frequencies. In these ranges, such small quantities of capacitance and inductance are needed that the capacitance between the electrodes of the tubes and the inductance of the loops formed by the electrical circuits through which the electrons flow in the tubes are of relatively large value. In addition to this, the electrodes are of such size, distance apart, and relative position, that the time required for the electrons to travel through the tube becomes an appreciable part of a cycle. Finally a frequency is reached for each type of tube at which the starting and maintenance of steady oscillations becomes impossible. This feature is compensated for by the construction of smaller tubes of the "acorn" and other types, but the difficulties still exist above the ultra-high frequencies, for eventually the point is reached at which the tubes are necessarily so small and possess such little power capacity as to be impractical.

One method of solving both these problems at the same time was devised by Russell and Sigurd Varian and W. W. Hansen at Stanford University in 1937, by the invention of "Klystron"* tubes. This type of tube embodies the principle of modulating the *velocity* of the electrons as they flow through it and which has at least a portion and possibly all of the oscillating circuit components included as integral parts of the tube.

The most important component of the Klystron is the *resonant cavity*. It is an outgrowth of the application of the lumped circuit constants in resonant circuits. When the point is reached at which a single small loop and a pair of condenser plates will no longer serve for the extremely high frequency desired, a method must be devised to apply the same principles in a different form. To decrease the inductance beyond that of a single loop, the principle that loops in parallel have less inductance than one loop is applied. Therefore, coil loops are placed between

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the same pair of condenser plates, until an infinite number of them have been added. See Fig. 1. The result is a doughnut-shaped ring slotted within the hole at the shortest diameter, with two plates placed parallel to the axis of the doughnut, one at each edge of the slot, so that it appears to a casual observer to be only a solid doughnut shaped object with a short plug in the center. If laid flat and cut as one would cut a pie, the cut edge would be like the outline of a dumbbell.

As the frequency is increased, this doughnut becomes smaller. In most Klystron tubes two of these resonant cavities are used, one as the "buncher" and one as the "catcher." It is obvious that an electron stream cannot pass through the solid plates in the centers of these cavities. These plates are therefore replaced by meshes or grids. In actual applications, the cavities are not always tubular doughnut in shape, but more often have distorted variations.

The action of the tube may be understood by referring to Fig. 2. A stream of electrons is beamed by a cathode through focusing electrodes and an accelerator grid toward the pair of buncher grids through which the stream must pass. The cathode and focusing electrodes have applied to them a high negative voltage with respect to the rest of the tube, which is grounded on the positive side. Voltage must necessarily be well regulated as fluctuations will affect the frequency of the tube. The buncher grids and their associated resonant cavity are excited by a radio frequency source in such a manner that as one is positively charged, the other is negatively charged as in coil-and-condenser action. These grids have between them, therefore, an electrostatic field which is parallel to the flow of electrons. The strength of this field is such that it appreciably changes the velocity of the electrons, but does not do so to the point that it will stop the flow completely at any time. As an electron comes into the field, assume that it enters such a portion of the cycle as to cause it to speed up. As the radio frequency excitation passes through the zero point of the cycle, the speed of the electron is not affected. Then, as the second half of the cycle is applied, or the charges are reversed, the electrostatic field opposes the flow of the electron, slowing it down. Now it can be seen that as the excitation passes through several cycles, those electrons which have been slowed down during a cycle are overtaken by those whose speeds were not affected, and both groups are overtaken by those electrons which were sped up, causing a bunching of the electrons at a point past the "buncher" grids.

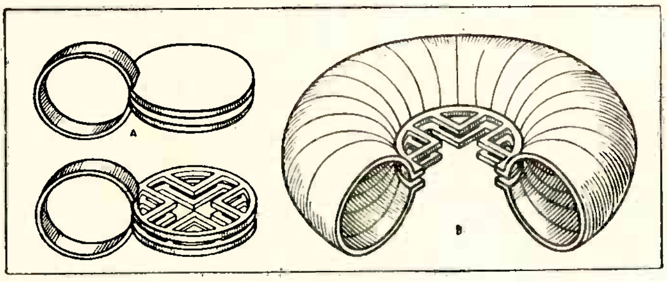

Fig. 1, left—evolution of a resonant-cavity circuit from the coil-condenser combination may be traced with the help of this diagram.

A second pair of grids, known as the "catcher" grids, is placed in such a position that the bunched electrons pass through them at the rate of one bunch per cycle. It is assumed that the first of the grids is in the negative half cycle of an oscillation. As the electrons approach the first of these two grids, which are part of a tuned circuit, the negative charges in the electrons induce a positive charge on the first grid in a condenser-like action, then pass on toward the second

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grid. The original negative charge on the first grid has a slowing-down effect on the electrons, and as the energy of motion cannot be lost by the electrons without being gained elsewhere, this loss of electrons induces energy in the tuned circuit. The change of charge supports the oscillation in the tuned circuit, and by the time the bunch of electrons has reached the second catcher grid, the oscillations have changed the charge on it so that it is then negative. This negative charge, again in opposition to the charge of the electrons still further decreases the velocity of the electrons, and. as before, this loss of energy by the electrons induces energy in this tuned circuit. After the electrons have passed the catcher grids, they are picked up on a collector plate.

It can be readily be seen that the energy considerations are very important. It has been shown how energy is taken from the catcher grids while none is supplied from sources other than the electron stream. In the buncher, it is necessary to supply a source of energy to provide for the bunching, but as some of the electrons are speeded up, taking up energy from the buncher, so are some of them slowed down, giving up an almost equal amount of energy to the buncher. The overall result is that there is a very little additional energy needed. A short coaxial cable feedback from the catcher to the buncher provides the necessary source of radio frequency oscillations and energy. The excess energy from the catcher is the output of the tube and is also taken from the resonant cavity by means of a coaxial cable. Output and the feedback is accomplished by means

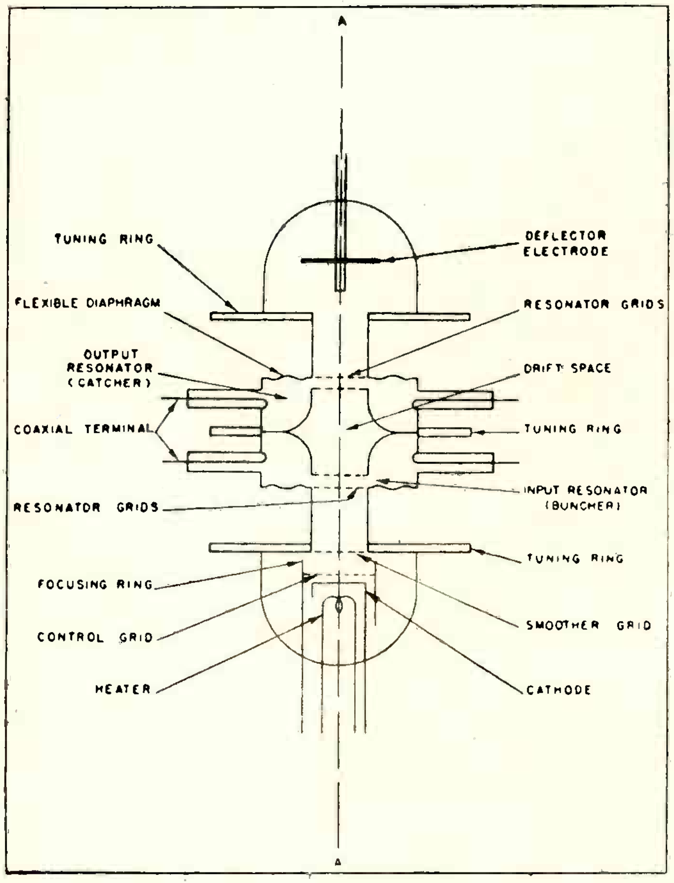

Fig. 2—Schematic view of the Klystron

of one-turn loops which are formed by the central conductor of the coaxial cables, which enter the hollow "doughnut," form a loop, and are grounded at the end. A part of the magnetic flux of the resonant cavities which exists within the hollow doughnut cavities, also passes through this loop, giving an inductive coupling which is equivalent of an air-cored transformer.

The Klystron tubes are very versatile and have many applications. In addition to their electrical capabilities, they are reasonably rugged, lending great value under far-from-ideal combat conditions. As the frequencies increase, the tubes become smaller, the wave lengths being the controlling factor of practically all the physical dimensions. The general design is such as to provide satisfactorily for the necessary dissipation of heat.

Tuning the Klystrons may be accomplished by several different methods, depending upon their physical construction. If a tube is so constructed that the cavity is sealed within it, provision may be made whereby tuning can be accomplished by changing the spacing between the grids. Most Sperry Klystrons utilize a screw-type arrangement by which the spacing between the grids can be varied, made possible by having the grids mounted on a diaphragm which can be flexed by the screw control. See Fig. 3. This spacing is the most critical dimension as far as frequency is concerned.

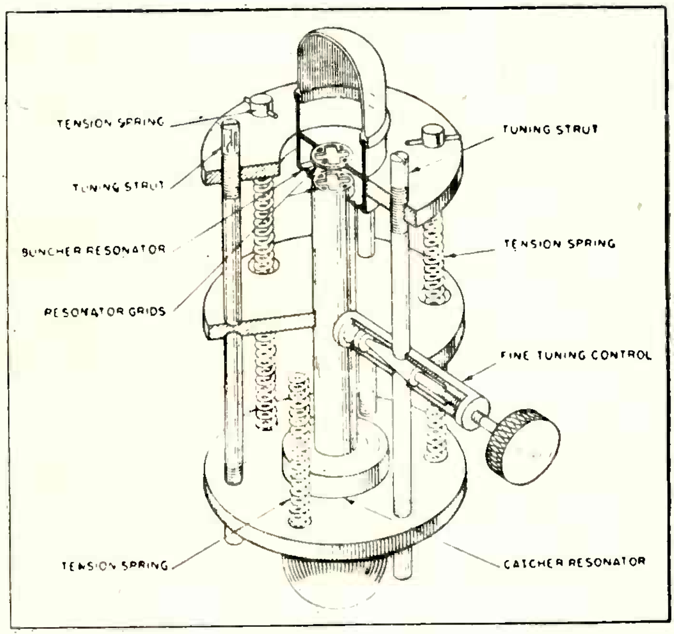

Fig. 3—How the tube is tuned. Coarse adjustments are made with the three large struts, fine tuning by varying one against the other two.

If the cavity is outside the tube, tuning may be accomplished by screwing plugs into the cavity, effectively changing its volume. Several other methods of varying the dimensions of the resonant cavity or the flux inside it may be used. as well as variation of the applied voltage.

When no method of feedback is used with the Klystron tube, but a separate oscillation is used in the buncher, the tube is being applied in its simplest form

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as an amplifier. Since the beam of electrans gives off a great deal more energy than it absorbs it is therefore a power amplifier (equivalent of a Class C type) and may also be used as a voltage amplifier for small radio-frequency voltages.

All that is necessary to convert such an amplifier into an oscillator is a method of feedback so as to sustain oscillations, and this is accomplished by means of the coaxial feed-back coupling previously described. The Klystron is generally as efficient as any other type of ultra-high-frequency oscillator. While theory indicated that efficiencies of 58% are possible, in actual practice they are considerably less.

It is very improbable that electrons would be bunched in such a manner ts to produce a pure sine wave. The wave produced is actually composed of a large number of harmonics. This being the case, it is only natural that the Klystron tube should find application as a frequency multiplier. In order to accomplish this, it is necessary that the relative phase of the two resonant cavities be such that bunches of electrons hit the catcher at a time which will cause the oscillations to build up, and the catcher cavity must be designed for the desired harmonic frequency,

Unfortunately a great many of the most important applications of the Klystron tubes cannot be discussed. In the meantime, more and more applications are becoming apparent daily in the fields opened by the discovery of this important electronic device.

FIBER GLASS IN SURGICAL SPONGES

Strands of radio-opaque fiber glass yarn now are incorporated in surgical sponges. If a sponge is left inadvertently in a wound, it may be detected by X-ray.

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A PROPOSAL FOR A GLOBAL SHORTWAVE BROADCASTING SYSTEM

Reprinted from Electrical Communication, Vol. 22, No. 2, 1944

Compiled by F. J. Mann

Editorial Staff, Electrical Communication

The following article, in non-technical form, originally was published by the Federal Telephone and Radio Corporation to aid in the materialization of adequate international broadcasting facilities on the part of the U. S. A,

—Editor, *Electrical Communication*

LEADING nations of the world long have recognized powerful shortwave broadcasting as essential to international relations. The United States, less pressed by its neighbors, has not in the past stressed international broadcasting, but World War II and its repercussions obviously necessitate presenting American events and ideas to the rest of the world in the most rapid, direct, and effective manner possible. For this purpose, global broadcasting clearly ranks as the foremost of the available media. Thus, a basic problem now confronting the nation is how best to provide completely effective world radio coverage.

The utilization of numerous broadcasting stations powered at 50 or 100 kilowatts represents an approach that is demonstrably inadequate from the viewpoint of efficiency, clarity and reliability of reception, and reasonable freedom from "jamming" by unfriendly stations. Studies by the Federal Telephone and Radio Corporation in collaboration with International Telephone and Telegraph Corporation engineers, on the other hand, show that a superpower broadcasting system, comprising 12 stations individually powered at 200 kilowatts and grouped in an east coast area and in a west coast area, would effectively meet the requirements for world coverage.

The basic idea of a plan for such a superbroadcasting system was originally presented to United States Government authorities in September, 1941, by the Federal Telephone and Radio Corporation, an affiliate of the International Telephone and Telegraph Corporation. The present description, it is felt, will aid in visualizing this sizable and necessarilly complex proposal and thus contribute towards the realization of an American international broadcasting system commensurate with the position of the United States in world affairs.

HIGH POWER, DIRECTIONAL BEAMS FOR GLOBAL RANGE

While the power of each of the twelve 200-kilowatt transmitters in the proposed superpower broadcasting system would be about double that of any transmitter now known to be in operation, efficient radiation of this energy would be imperative for world-wide coverage. The signals moreover, would be radiated from highly directive antennas, thus concentrating the energy into sharply focused beams in order to cover given world areas or zones with signals of maximum intensity. The signal strength on the path of any zone, in fact, would be the same as that produced by a five million-watt broadcaster with a conventional non-directive antenna. Since twelve simultaneous transmissions of equal power to separate zones would be possible — all on frequencies most suitable

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for reaching a particular area at a specific time of day and year†—the effective output of the entire system would be greater than sixty million watts broadcast from a single transmitter with non-directional radiation such as is generally used with broadcasting stations operating in the intermediate frequency broadcast bands.

Signals of this magnitude would make possible regular reception of programs in the most distant areas despite ocassional jamming by unfriendly stations. Jamming, it should be explained, is accomplished by transmitting noises or tones to prevent normal broadcasts from being heard. It can be overcome either by broadcasting signals powerful enough to override the jamming signal or by shifting frequency. The proposed system would provide transmitters so powerful and capable of operating on so many different frequencies that radio broadcasts from these American stations would be largely free from any interference of this type likely to be encountered.

Not only would a broadcasting system of the size proposed permit direct reception of clear, steady signals capable of overriding all types of interference, but it would also provide programs ideally suited for rebroadcasting by foreign networks. Rebroadcasts of this character are made after the programs are picked up with a special high quality radio receiver and distributed over telephone lines to the various local network stations. Since the rebroadcasting transmitters operate on the local intermediate frequency, persons in distant countries not equipped with sensitive shortwave receivers may also listen to the programs on their present intermediate frequency radios.

I. T. & T. PIONEER BUILDER OF HIGH-POWER BROADCASTERS

For more than ten years, International Telephone and Telegraph System companies have acquired valuable and extensive experience in the design, construction, and operation of large broadcasting centers similar to the one proposed. Due to the continuous demand from many European sources for increasingly greater power, these companies carried high-power radio research and development well ahead of what was deemed necessary in America in past years, so that they are now well equipped to produce large transmitters.

Out of more than 100 powerful transmitters supplied by I. T. & T. associate companies, the following are of interest as establishing the record of progress during the past decade or more, here and in Europe.

Prague, Czechoslovakia: medium wave—1 transmitter of 120 kilowatts—1930
Daventry, England: short wave—2 transmitters of 80 kilowatts—1937
Rome, Italy: short wave—2 transmitters of 100 kilowatts—1939
Issoudun, France: short wave—4 transmitters of 120 kilowatts—not completed
Brentwood, New York: short wave—3 transmitters of 50 kilowatts—1942

Further, for more than ten years, I. T. & T. associate companies have manufactured or developed vacuum tubes capable of 100-kilowatt output and, more recently, vacuum tubes capable of 250-kilowatt continuous output on short waves and others for continuous 500-kilowatt operation on medium waves.

OPERATING FLEXIBILITY

Not only does this proposed design follow sound experience and principles developed by the I. T. & T. System in the past, but it provides for flexibility of operation of each center that should meet new demands likely to arise in the next few years. This flexibility, ample for all requirements, would be provided as follows:

1. One or more programs could be transmitted on several frequencies in any zone or any desired combination of zones.

2. Transmitters would be designed so that they could operate on the same

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† See appendix.

frequency into separate halves of an antenna to give the equivalent of a 400-kilowatt transmitter in a given zone.

3. Antennas would be constructed to serve in any desired zone and on all frequencies suitable for a given zone or area.

If, after completion of the proposed broadcasting system, we should fly over the east coast center, the imposing number of antennas arranged in a semicircle—thirty-two antennas in all—would first attract our attention. They would cover, with the transmitter buildings and power input substations, an area of flat land approximately two miles long and one mile wide—the area to be unsettled and free of nearby hills and mountains.

Some of the antennas would be supported from wooden poles and some from steel masts, depending on the lengths of the wires and their heights from the ground. There would be a great variety of sizes of antennas, but only two shapes or patterns would be noted. The rectangular-shaped antennas would be the multi-element arrays for use on specific frequencies in the short-wave broadcast band. These would be the antennas normally used. The diamond-shaped, or rhombic, antennas would provide for operation on any frequency in the shortwave broadcast band. Thus, efficient operation would be achieved with the multi-element arrays on the specific assigned frequencies of the station, while the rhombic antennas would ensure frequency flexibility necessary to avoid jamming from other stations, or provide for special broadcasts on frequencies not regularly assigned.

Array-type antennas have been chosen as the principal radiators for this short-wave broadcasting system since they are the most efficient type of antenna structure for high - power, short - wave, directional transmission. This type of antenna has been perfected to a high degree by International Telephone and Telegraph System engineers who have engaged in extensive research and development of antenna equipment for the many radio telephone and telegraph installations of the I. T. & T. System throughout the world. Research has made it possible to formulate design data required to control the specific direction as well as the angle of radiation. within extremely close limits.

Arrays are usually designed for operation on a specific frequency. Each array antenna also would operate in a particular direction. This accounts for the large number of antennas that would be needed for regular multiple-frequency operation in the various zones. It should be pointed out that a small group of complicated and expensive rotatable antennas would not provide the required flexibility and multi-frequency operation necessary for a successful system. Moreover, they would be expensive and require more maintenance that the proposed antennas.

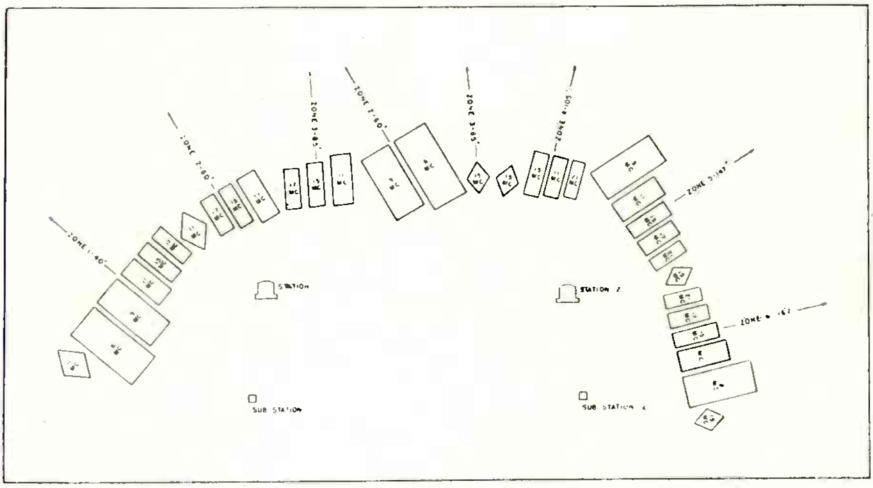
Ability to operate two transmitters tuned to the same frequency into a single array is an important feature of the proposed antenna system. This would result in 400,000 watts equivalent carrier output concentrated into the zone served by the antenna thus connected—an effective power output eight times greater than most broadcasting transmitters now operating in this country and about four times greater than any operating in this country or elsewhere. Such operation would make increased hours of service possible when conditions are adverse.

Rhombic antennas, while not so efficient as the arrays, are simple to construct and may easily be adjusted to any frequency within the shortwave broadcast band. They would be included only for use under emergency conditions or when it might become desireable to operate a transmitter on a frequency for which no array is provided.

TRANSMITTER BUILDINGS

INSTEAD of the usual single transmitter building, there would be two modern concrete and glass buildings, identical in size and appearance at each site, making a total of four buildings for the system. They would be located within the area of the semicircle and spaced a good distance apart. By dividing the equipment between two separate buildings, shorter leads to the antennas would be practicable. Then too, the arrangement would provide a safety factor not possible with a single building since damage to one building would affect only half the equipment. The undamaged building could still continue operation of half the station. A decorative pool with spray fountains (providing water to cool the equipment) would be located in front of each building.

Entering one of the transmitter buildings, we should find ourselves in an attractive foyer. A short distance to the left of the foyer would be a door labeled "Frequency Control Room." This room, containing all the radio frequency control equipment, would be a unique feature of the proposed transmitting stations.



Antenna disposition.

Here the high or radio frequencies for all the transmitters in the building would be generated by accurate, temperature-controlled, piezoelectric crystal oscillators. The regular fixed frequencies assigned to the stations would originate from these piezoelectric crystal oscillators. Continuously variable master oscillators would be provided also to permit operation on frequencies between the fixed, crystal-controlled frequencies officially assigned to the transmitters.

Included in the frequency control room would be an accurate frequency standard to assure that the transmitters would be kept exactly on their correct frequencies. This would be the "Bureau of Standards" of the station, where close supervision would be maintained over the steadiness of these initial frequencies, which later would be amplified many times and radiated from the antenna system as powerful radio signals. In fact, with the special attention which would be given to the accuracy of frequency control and the ease of picking up their steady signals on any part of the earth, these stations could serve another useful purpose, quite aside from broadcasting, by enabling the signals to be utilized for setting world-wide standards of frequency measurement.

To the rear of the foyer, doors would lead to the main transmitter room. Passing through these doors, we would come into the brightly lighted area housing the more powerful transmitter equipment. (See illustration on page 161.)

Panels for the transmitters would almost cover the surfaces of three walls. Directly facing us would be a console closely resembling a console of a huge theatre organ. On it we should see neat rows of switches, plugs, knobs, meters, and colored lights. Seated at the console would be an operator who, by means of the many controls, would coordinate the functions of the entire station. At his fingertips would be the means of starting up power supplies, turning on transmitters, changing to different frequencies, switching in various programs coming from studios in nearby or distant cities—and, as each operation was performed, a different light would go on or off to indicate the status of a transmitter or power supply. At the same time other colored lights in other parts of the building would go on and off to indicate that some remote operation had been completed. The illusion would be complete—the operator would truly seem like a musician playing a giant color organ — only this instrument, while silent in the room itself, would have a radio voice loud enough to be heard around the world.

HOW RADIO SIGNALS ARE BROADCAST

WHILE the scene before us would be impressive to those of us who were not radio engineers the array of panels, colored lights, switches, and meters could easily become a confusing jumble. The plan of the building indicates specific names and locations of the major pieces of equipment, but without basic knowledge of the functions of the varous apparatus, this information might not be specifically helpful. However, the purpose of the apparatus may be understood from the following description of how radio signals are broadcast. First we must note that a large radio broadcasting station is in reality a huge amplifier of two types of feeble electric currents.

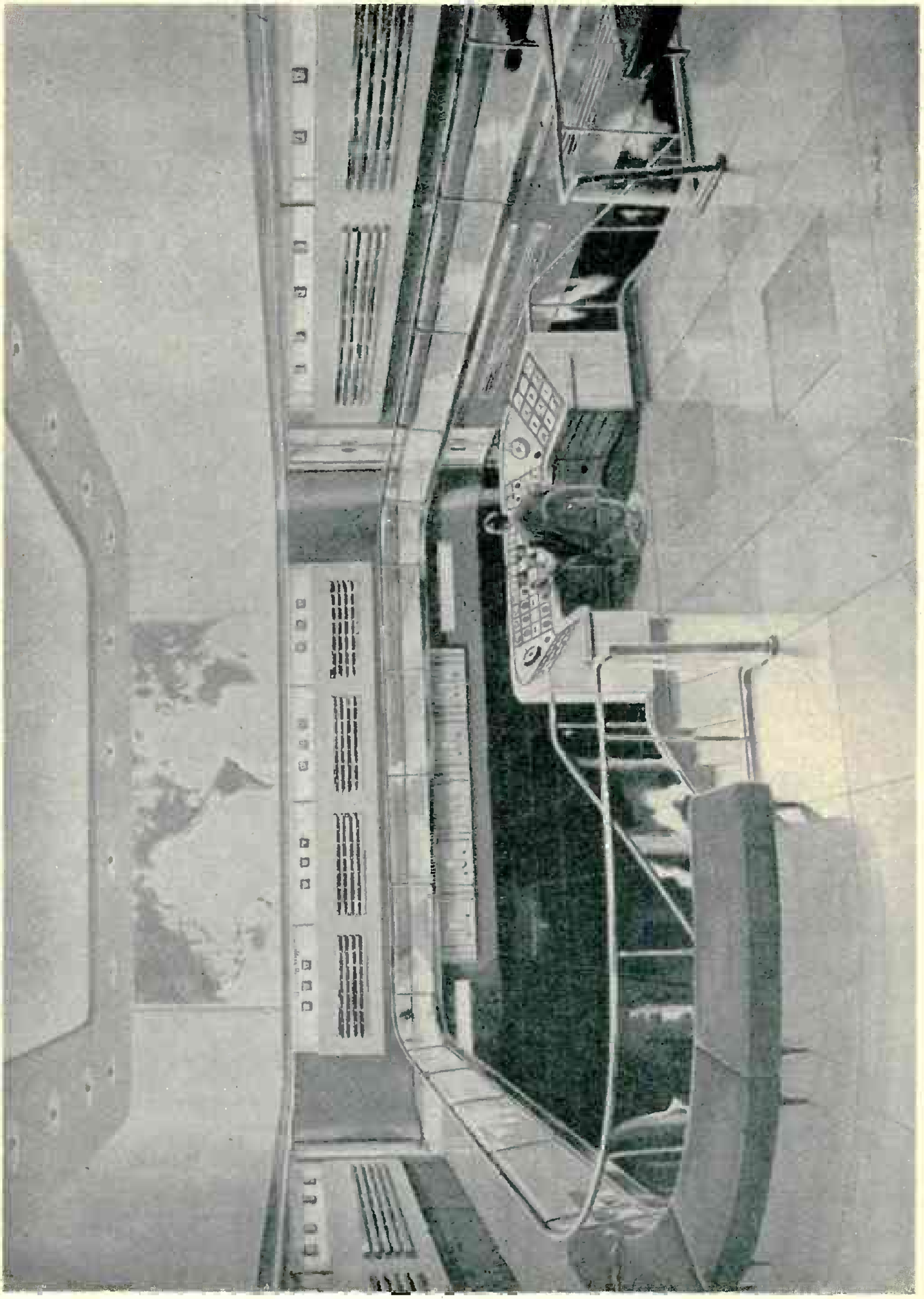
One type is a steady alternating current whose alternations change millions of times a second, i.e., at radio frequency. We have already seen how these radio frequency currents would be generated at the proposed station by oscillators in the frequency control room. From there they would be conducted to the RF (radio frequency) drivers.

An RF driver in a transmitter amplifies the feeble radio frequency currents several times. After amplification, they pass to the much larger final power amplifiers where the RF energy is again boosted many times until it reaches its full output and can be connected to an antenna to be radiated into space.

Amplification between the oscillator and the antenna is of the order of millions. At each stage of amplification, the apparatus for handling the greater power must be increasingly larger, provided with higher voltages, and equipped with more and more intricate apparatus to control the greater powers generated.

The resulting electromagnetic waves so generated then carry the radio signal to distant points. When tuned in, it can cause an electric eye tuning indicator to operate on a radio receiver thousands of miles away, but, alone, it produces no audible response in the receiver's loudspeaker. The name "carrier frequency" given to this signal describes its important function of acting as a means of carrying the voice or music of the broadcast program through space. The carrier, therefore, may be compared to an invisible telephone wire connected between transmitter and receiver over which sound currents can be transmitted.

The proposed main transmitter room on the opposite page shows the two-level arrangement of transmitters and power supply panels.



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The other type of electric current which must be amplified by the transmitter originates at the microphone in the studio. This current varies in frequency with the vibrations of the speech or music reaching the microphone as sound; it also varies proportionately to the loudness or softness of the sound. When these audio frequencies, as they have been named—generated by the microphone from the sound waves—reach the transmitter, they possess only the strength of a whisper in a telephone receiver. But in the audio frequency section of the transmitter, the final stage of which is called the modulator, they also must be amplified millions of times before they can be made to modulate the carrier fequency—amplification that must be effected without distortion of the signal frequencies.

While the audio frequency currents are unchanged in form as they are amplified, they are enormously increased in power. When they have received their final boost through the modulator, it would be possible to connect them directly to a loudspeaker. A loudspeaker large enough to operate on the full power of a broadcast transmitter modulator would have a voice louder than the sound emitted from a large squadron of four-motored bombers and would be many thousand times as powerful as an average large home loudspeaker.

Even with such great power, the sound produced would be heard only a few miles away while, if equivalent energy is utilized to modulate a powerful radio frequency carrier, the distance sound may be heard through a radio receiver capable of being tuned to the carrier frequency is practically unlimited.

For complete modulation, the audio power from the modulator actually must match the power of the radio frequency amplifier so that a single 200-kilowatt radio transmitter would require two 200-kilowatt amplifiers—one for audio frequencies and one for radio frequencies. Each would be very different in function, but the vacuum tubes used in both would be much alike and power supplied to each would be similar.

We see therefore that, while the high frequency or radio carrier itself cannot be heard in the ordinary radio receiver, the variations imposed upon it through modulation are at audible frequencies which enable the loudspeaker of the distant receiver to reproduce the sound. We see also that the problem of constructing a large radio transmitter is the problem of producing equipment capable of amplifying infinitesimally feeble currents millions of times.

The radio frequency, while being amplified, must be kept steady, free from interference, and must not be allowed to radiate before it is connected to the antenna. The audio frequencies also must be kept free from interference and confined to their respective channels, and they must be amplified faithfully, that is, without distortion.

Both tasks become increasingly greater as the power of a transmitter is increased. The first amplifier stages of a 200-kilowatt transmitter might be very similar to the first stages of any other transmitter. But the final stages, the 200-kilowatt power amplifiers and modulators, would be quite unlike those of a 50-kilowatt transmitter, not only in size but also in the specialized design and construction necessary to handle this greater power.

LAYOUT OF A 200-KILOWATT BROADCASTING STATION

Returning now to the station plan, we note that the various amplifiers are segregated in relation to function and to power. At the left of the console are the audio racks containing amplifiers to give an initial boost to the program material coming in on the telephone lines from the studios. These racks would be provided with patchboards to permit any program to be connected, by means of lines running from the racks to suitable switches on the console. Operation of these switches would permit connecting separate programs to each of the four modulators located toward the rear of the building; or a single program might be connected to all four.

Three RF drivers are shown located in cabinets on either side of the building, making a total of six drivers to connect to the six penultimate and final power amplifiers located in rows behind them. These drivers and amplifiers would step up the radio frequency currents generated in the frequency control room, previously described, to the power necessary for reliable long-distance broadcasting, that is, to the full 200 kilowatts output.

It should be noted that fifty per cent more radio than audio frequency equipment would be provided. This ratio would exist in all the transmitter buildings. Four programs could actually be transmitted simultaneously from the single transmitter building shown since there would be four modulators. The additional radio frequency equipment would enable the operators to preset the frequencies of the two radio frequency sections not in service while the other four sections are in operation. Two of the program channels could then be switched by means of controls on the console to the two idle radio frequency sections, thereby permitting instantaneous change of frequency. Thus, all switching and control operations necessary to change an RF power amplifier and its pre-amplifier stages from one frequency to another could be performed with the power off and without taking a transmitter off the air.

Ready access to all heavy power transformers, rectifiers, power control equipment, and air conditioning and water cooling machinery in the basement would be provided by stairs on either side of the console. This power equipment would have panels fronting on an open area arranged so that meters, controls, tubes and warning lights would be visible to the control operator at the console above—another unique feature of station design.

The monitoring booths would be equipped with special insensitive radio receivers which would pick up the programs from the air and make them audible to the monitor operators. Complete, permanent recordings of all programs broadcast as received by the monitor radios would be made in these booths. Each booth also would include a microphone and a transcription turntable, both connected to the audio racks, so that, when necessary during an emergency or when adjustments were being made, programs could be originated at the station itself.

The high frequency distribution board at the rear of each building would carry the total power output of the transmitters to the antennas at radio frequency. The purpose of such a board is to permit instant connection of the output of any transmitter to any antenna. Since there would be sixteen antennas for each transmitter building to operate with six radio frequency power amplifiers, a total of 96 switching functions must be possible on the switchboard, not counting switches to permit operating two amplifiers on the same antenna. The design of this switchboard would be especially complex since the board must handle high voltages at extremely high frequencies—a difficult problem of insulation and design of components, not only to prevent breakdown, but also to assure minimum power loss. Power reaching such a switchboard would necessarily be in its most expensive and usable form so that waste at this point would be particularly undesirable and relatively very costly.

After lengthy study and many experiments with dielectrics and switch designs, I. T. & T. System engineers have perfected a design for a high frequency distribution board that is ideally suited to the task[1]. Such a board was installed

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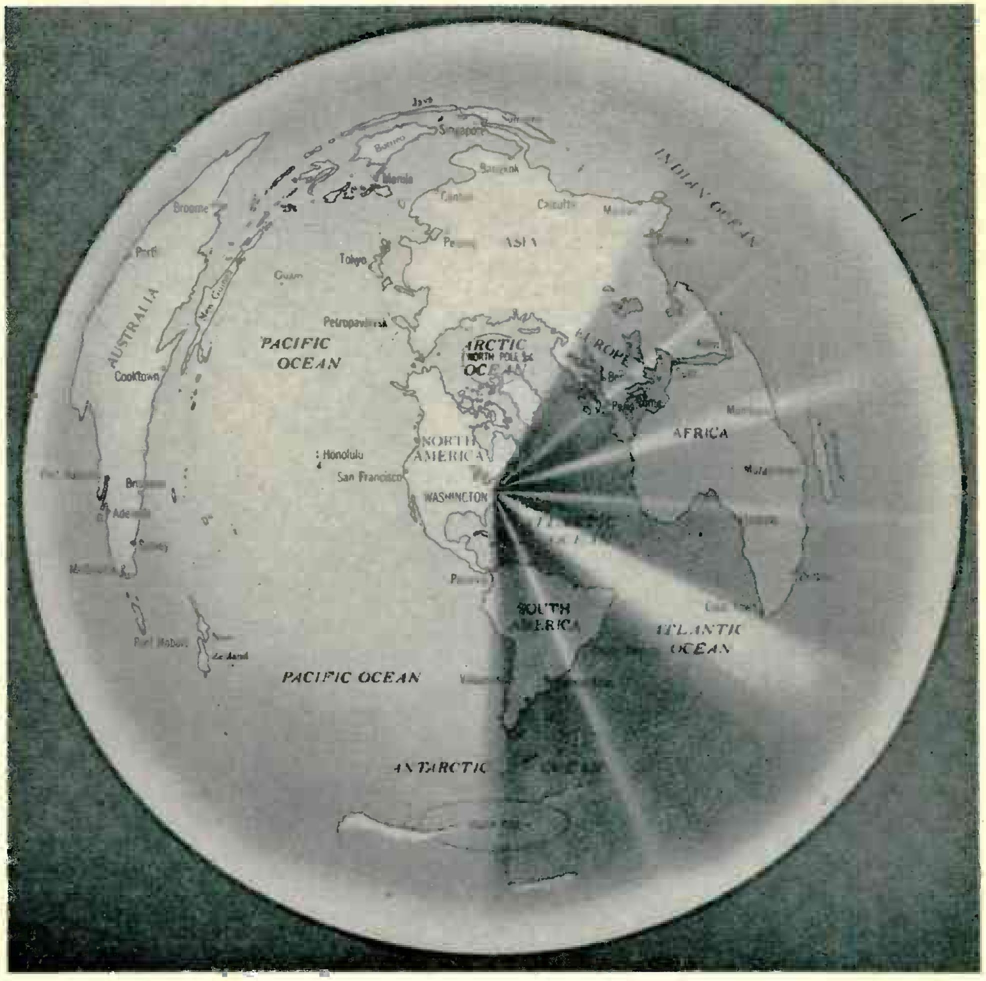
[1] "Radio Frequency High Voltage Phenomena," by Andrew Alford and Sidney Pickles, *Electrical Communication*, Vol. 18, N. 2, 1939; *Electrical Engineering*, Vol. 59, March 1940.



World-embracing zones—Radio programs would cover world population centers in twelve zones, assuring maximum reception in these areas. But even in adjacent areas satisfactory reception would be possible, since zone edges merely mark portions where signal strength would be less than full intensity. Zones shown on the maps are by no means fixed. They might easily be shifted or broadened to compensate for changes in population or center of interest.

at the CBS International Broadcasting Station on Long Island, where it is now in operation, and has completely solved the difficulty of providing means for instantaneous interchange of radio frequency amplifiers among the various antennas.[2] In practice, this switchboard not only provides an efficient and fast means of switching from one antenna to another, but it also makes the operation foolproof. Switches are equipped with warning lights and interlocks to guard against the possibility of connecting transmitters to antennas already in use or of disconnecting an antenna while power is being fed to it. The antennas of the world broadcasting system would be similar to those used at the CBS station and the same type of board would be employed.

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[2] "New 50-Kilowatt CBS International Broadcasters," by H. Romander, *Electrical Communication*, Vol. 21, No. 2, 1943.

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GIANT-SIZED VACUUM TUBES

In the final power amplifiers and modulators, giant-sized vacuum tubes would be used. On shortwaves it is not practical to parallel a large number of medium-powered tubes to obtain high power as has been the practice on intermediate and longwave transmitters. Hence, the power tubes in a 200-kilowatt shortwave trasmitter must be capable of carrying the full output of the station under normal conditions of continuous operation.

Design of tube structures of the size proposed is in itself a major problem. The larger elements employed not only create new mechanical difficulties but, as their size increases, the problems of design for high frequency operation mount in even greater proportion. As previously mentioned, I. T. & T. associate companies have been building high-powered vacuum tubes for many years so that the chief obstacles to the production of vacuum tubes of the highest power have been overcome. Tubes suited to the purpose, in fact, have been manufactured; they were of the sealed-off type and were over four feet long. They are the largest tubes of

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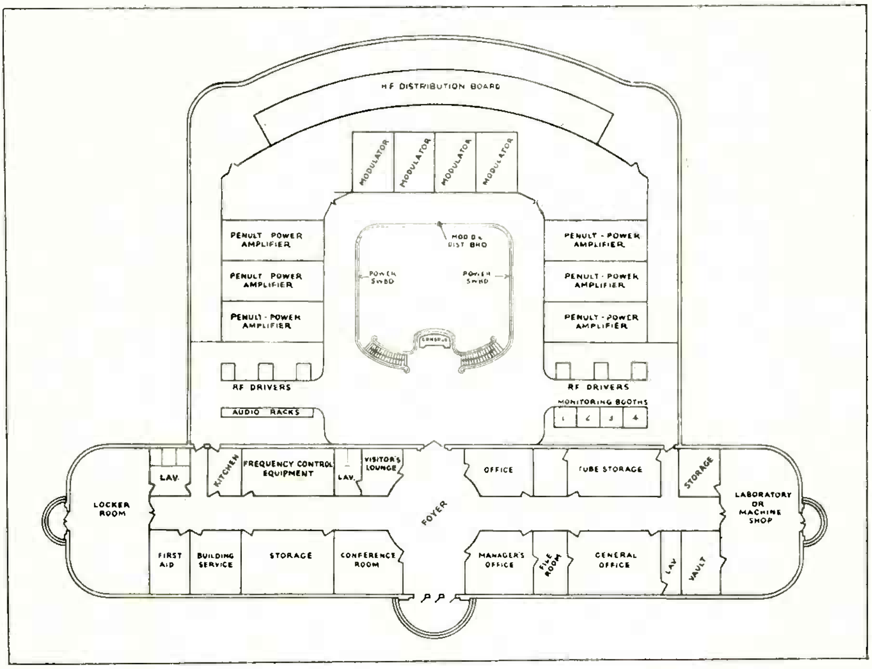
their kind ever manufactured.[3] A new design permits smaller elements and a slightly smaller overall size, resulting in improved efficiency without loss of power. This newer tube design would be employed in the proposed transmitters.

Tubes of this size are water-cooled to permit efficient dissipation of the enormous heat developed in them. Distilled water conducts the heat from the tubes to large heat exchangers which are, in turn, cooled by water circulated through spray type fountains in front of each building. The water in these fountain ponds cannot be applied to the tubes directly, since even sight impurities would cause a current leakage.

POWER REQUIREMENTS

Enough power to supply a city of about 20,000 persons would be the total power input requirements of the two sites. Substations on the east and west coast sites would have a capacity of 3500 kilowatts and 2000 kilowatts respectively —a total of 11,000 kilowatts. Both sites would be provided with two substations supplied from standard commercial power lines. Each substation would be connected to a different source of power so that failure of one source of supply would not cause shutdown of the station.

Despite this enormous power capacity ,the overall efficiency of the stations undoubtedly would exceed that of smaller stations; for, as station size increases, the efficiency tends to improve. The proposal actually makes possible a tremendous saving in power cost compared with a large number of stations of lower power— inadequate for world coverage. Other costs also would be appreciably lower since



Building plan showing the arrangement of station components. Each building would be equipped to provide for the comfort of operating personnel as well as for administration of the station.

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[3] "Tubes for High Power Shortwave Broadcasting Stations—Their Characteristics and Use," by G. Chevigny, *Electrical Communication*, Vol. 21, No. 3, 1943; *Proceedings of the I R E* , Vol. 31, No. 7, July, 1943.

personnel, buildings, land, and control equipment could all be utilized more effectively with the higher-powered, centralized system.

High power and high efficiency would be attained in the proposed transmitters without lowering standards of performance. Quality of modulation, frequency response, and noise suppression would be equal or superior to any shortwave broadcast station now in operation. Realizing too, that it is more important to keep the frequency stability of such enormous powers within closer limits—just as it is more important, say, to keep a large ocean liner on its appointed course than a small fishing boat—the designers have provided for a carrier frequency deviation even less than permitted by international law for broadcasting stations operating in the high frequency broadcast range. In all respects, the system would meet or exceed the most advanced design practices.

APPENDIX—HOW SHORT WAVES ARE BROADCAST

Shortwave radio signals travel in a straight line much like the beam of a searchlight. We know that the most powerful searchlight in the world would never reach the earth's surface beyond the horizon because the curvature of the earth forms an impenetrable opaque "bump." But radio waves can skip beyond the horizon and be heard at a great distance, even around the world under favorable condition.

To understand this skipping, we might visualize an attempt to flash a light around the corner of a building. It cannot be done, because light will not bend that way. But light can be reflected and if we set up a mirror tilted to the correct angle, the light will be reflected around the corner, still traveling in straight lines.

Nature has provided such a mirror for radio waves, high in the sky. It is made up of the particles of the ionosphere, a region in the upper atmosphere where free ions and electrons exist in sufficient quantity to cause radio waves to be reflected. Like light against a mirror, radio waves strike this reflecting surface and bounce back to earth, the angle of reflection determining how far around the globe they will be heard.

Some of the energy of the radio signal is lost from the first reflection, but, if sufficient energy remains, the waves may still be reflected from the earth back to the ionosphere and thence back again to earth where they will be heard much further away from the transmitter. The distance between each area of reception are known as "skip" distances and ordinarily the signals are either not heard in these areas or are of unsatisfactory strength or quality for reliable reception with a minimum of fading or noise.

Reflection determining the skip distance areas is itself dependent on several factors. One is the actual height of the ionosphere, which varies from 50 to 250 miles. It is higher at night than during the day; higher in the winter than in the summer. A second is the frequency of the transmitter wave; a third the antenna design. These factors control the angle of reflection of the propagated waves which, in turn, influences the depth of the transmitted beam.

The longer wavelengths, such as those assigned to local broadcasting stations, have a very sharp angle of reflection so that they require numerous reflections for long range propagation. Thus, tremendous powers would be needed at these wave-lengths for reliable reception more than a few hundred miles away. It is true that under unusual or freak conditions, local radio stations on medium waves in New York have been heard in Australia or China, but this happens very rarely. Hence, these wavelengths are not suitable for great distances.

The shortest wavelengths, called ultra-short waves or ultra-high frequencies, have a very flat angle of reflection. The angles are so flat that when the waves hit the ionosphere, they are never reflected back to earth, but keep traveling over the surface of the ionosphere until their energy is dissipated. So the ultra-short waves are said to behave similar to light rays and to travel only in a straight line. And like a beam of light, their range is close to the horizon. The ultra-short waves are excellent for local transmission and are valuable for television and other special broadcast and communication facilities. Their range is ordinarily limited to less than 100 miles.

From actual experiment and operational data, it has been found that radio signals of frequencies from about 6 to 21 megacycles are best for long distance transmission. By changing frequencies in relation to the height of the ionosphere at the time of transmission, it is possible to reflect a radio signal to any part of the world.

Radio waves share another property with light—radio energy, like light energy, can be diffused over a wide area or concentrated into a sharp beam. If the lens and reflector are removed from an ordinary battery flashlight, the light is hardly strong enough to read by in a room with no other light source, but the same amount of light can be focused into a sharp beam that will penetrate with good strength hundreds of feet. In the same manner short radio waves can be concentrated into narrow beams with specially designed antennas and reflectors. Such antenna systems have the property of increasing the effective radiation to a particular segment of the earth's surface so that the signal reaches its destination hundreds and even thousands of times stronger than would be the case without such concentration. The reliable distance range with a given power is thus greatly increased.

Development has progressed to a point where a radio signal can be spotted on a particular area almost as accurately as checkers can be placed on a checker board. Further, it is possible to design antennas permitting the radio beam to broaden or expand so that, after the initial skip of several hundred miles, the signals from subsequent reflections would overlap enough to permit good reception without further skip distance.

Directing and locating a radio wave in this manner greatly increases the efficiency and precision of radio propagation. Without such technique, reliable transmission over great distances would be impossible. Nevertheless, wherever radio waves must travel long distances, they meet barriers over which the radio engineer at present has no control. These barriers may be likened to fog or smoke between a light and its objective, obscuring the light. A radio signal is obscured by unwanted sound or noise. Some of this noise, like fog, results from natural phenomena called static or atmospherics; some of the noise, like smoke, is man-made, the result of many present-day applications of electricity. *Whatever the cause, its only cure in long range broadcasting is higher power.* It is perfectly possible to send a radio signal to the other side of the world using very little power and, under favorable conditions, this signal will be heard by the far-distant radio listener. If the noise barrier is too great, the signal will still be transmitted as before, but it will be as unintelligible in the radio receiver as a whisper in a noisy room. The effective power of the transmitted signal must, therefore, be raised enough so that the received signal will be appreciably louder than any type of noise coming into the receiver simultaneously with the signal.

Providing a global broadcasting system thus resolves itself into a problem of building transmitters capable of radiating on specific frequencies between 6 and 21 megacycles, capable of concentrating or focusing these radiations for maximum world coverage in relation to population centers and possessing power sufficient to override existing noise and thus produce clear and steady signals at the remotest points.

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WHAT'S BEING READ THIS MONTH

In addition to the articles presented each month in our magazine we plan to give a complete listing of all the various articles which have appeared in the most recent issues of the leading radio and electronics magazines. Many of these articles we believe will be of wide-spread interest to our readers.

COMMUNICATIONS (Dec. 1944)

U-H-F TRANSMISSION DESIGN
Dielectrics in U-H-F Flexible Coaxial Cables........*A. J. Werner*

TELEVISION ENGINEERING
Signal Intensity Tests on a Mountain Top........*Donald Phillips*

ENGINEERING CONFERENCE REVIEW
A Report On The 1944 Rochester Fall Meeting........*Lewis Winner*
- Filament Design (H. J. Dailey)
- Video Amplifiers (Dr. M. J. Larsen)
- Resononators (W. R. MacLean)
- Pulse Time Modulation (E Labin)
- U-H-F Measurements (Dr. W. T. Dakin)
- Silicones (Dr. S. L. Bass)

AERONAUTICAL COMMUNICATIONS
Graphical Solution for CAA Course Allignment
(Part II, Charts)........*G. L. Brewer*

BROADCAST TRANSMITTER DESIGN
Bethany 200-kw H-F Transmitters
(Part II)........*R. J. Rockwell*

U-H-F LABORATORY RESEARCH
Power Supply for U-H-F Velocity-Modulated Tubes........*Iredell Eachus, Jr.*

TRANSMITTER DEVELOPMENT
Transmitter Design Yesterday and Today........*Donald McNicol*

ELECTRICAL COMMUNICATION (Volume 22 1944 Number 2)

PULSE TIME MODULATION........E. M. Deloraine and E. Labin

BRAZILIAN INTERIOR RADIOTELEPHONE........Leonard Jacob, II

THE WESTERN UNION VARIOPLEX TELEGRAPH SYSTEM........O. E. Pierson

TRANSIT TIME AND SPACE-CHARGE IN A PLANE DIODE........Leon Brillouin

COMPLEX TRANSMISSION LINE NETWORK ANALYSIS........N. Marchand

CATHODIC PROTECTION AND APPLICATIONS OF SELENIUM RECTIFIERS........W. F. Bonner

POWER TRANSMISSION SYSTEMS — A REVIEW OF PROGRESS DURING THE WAR WITH SPECIAL REFERENCE TO POSTWAR DEVELPOMENTS........T. R. Scott

DEVELOPMENTS IN THE FIELD OF CABLE AND RADIO TELEGRAPH COMMUNICATIONS........Haraden Pratt and John K. Roosevelt

A PROPOSAL FOR A GLOBAL SHORTWAVE BROADCASTING SYSTEM

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ELECTRONICS (Jan. 1945)

BROADCASTING'S POST-WAR EQUIPMENT PLANS
Standard a-m stations indicate what gear they will need to modernize

THE K-8 COMPUTING GUNSIGHT
New electronic servo application automatically provides correct deflection to insure hits on aircraft........*H. Erwin Hale*

PULSE TIME MODULATION
New modulation method for use at very high frequencies to improve signal-to-noise ratio........*E. M. Deloraine and E. Labin*

MEASUREMENT OF V-H-F BURSTS
Tests confirm theory that sudden rises in strength of f-m signals are due to meteors

MULTIPLE X-Y RECORDER FOR TESTING QUARTZ CRYSTALS
Plots frequency and activity curves of 71 crystals simultaneously in less than an hour........*George Keinath*

PRACTICAL STRAIN-GAGE APPLICATIONS
Electronic techniques speed material-testing by recording strains in test specimens........*R. O. Fehr*

BROADCASTING POLITICAL CONVENTIONS
Technical report on radio facilities at Chicago Stadium for future convention guidance........*George McElrath*

QUARTZ ETCHING TECHNIQUE
Equipment and procedures for reaching final frequency chemically........*L. A. Elbl*

QUALITY CONTROL IN TUBE MANUFACTURE
Statistical considerations required to keep production irregularities in hand........*Eugene Goddess*

AUDIBLE AUDIO DISTORTION
Technical justification for unfavorable listener reaction to so-called high-fidelity receivers........*H. H. Scott*

ELECTRONIC ENGINE-PRESSURE INDICATOR
Pressure-sensitive quartz unit feeds oscilloscope through amplifier having flat response from 1 to 20,000 cps........*J. W. Head*

RELAYS IN INDUSTRIAL TUBE CIRCUITS — PART II
Sensitivity and plate current wave shape of vacuum tubes in relay control circuits........*Ulrich R. Furst*

THE ENGINEER'S PLACE IN DISTRIBUTION
Answers on post-war sales questions from the buyers of electronic equipment

AMPLIFIER THEORY APPLIED TO REGULATORS
Solution of voltage-regulator problems with principles usually applied to negative-feedback amplifiers........*John M. Cage*

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Let these guys start it!

There's a day coming when the enemy will be licked, beaten, whipped to a fare-thee-well—every last vestige of fight knocked out of him.

And there's a day coming when every mother's son of us will want to stand up and yell, to cheer ourselves hoarse over the greatest victory in history.

But let's not start the cheering yet.

In fact, let's not start it at all—over here. Let's leave it to the fellows who are *doing* the job—the only fellows who will *know* when it's done—to begin the celebrating.

Our leaders have told us, over and over again, that the smashing of the Axis will be a slow job, a dangerous job, a bloody job.

And they've told us what our own common sense confirms: that, if we at home start throwing our hats in the air and easing up before the job's completely done, it will be slower, more dangerous, bloodier.

Right now, it's still up to us to buy War Bonds—and to *keep on* buying War Bonds until this war is completely won. That doesn't mean victory over the Nazis *alone*. It means bringing the Japs to their knees, too.

Let's keep bearing down till we get the news of final victory from the only place such news can come: the battle-line.

If we do that, we'll have the *right* to join the cheering when the time comes.

Keep backing 'em up with War Bonds

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