BROADCAST NEWS

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CAMDEN, NEW JERSEY
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A Radio Corporation of America Subsidiary

Camden, N. J.

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BROADCAST NEWS

REG. U. S. PAT. OFF.

E. T. JONES
Editor

PAUL V. LUTZ
Associate Editor

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RCA MANUFACTURING COMPANY, INC.
CAMDEN, NEW JERSEY, U. S. A.

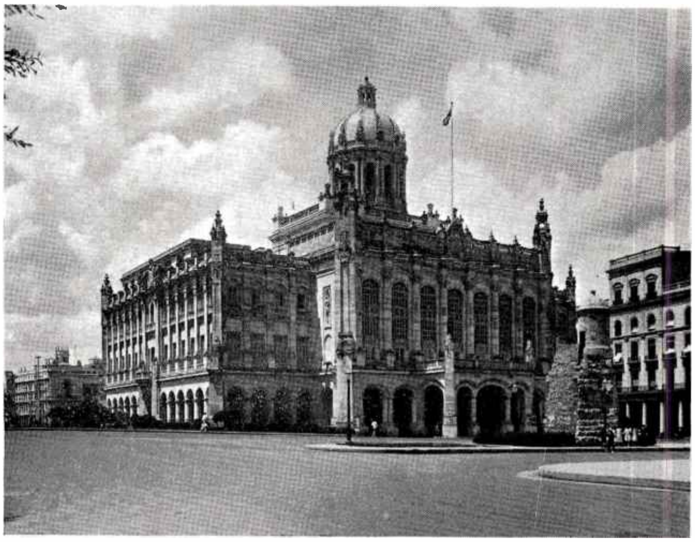
HAVANA GREETS THE INTERNATIONAL RADIO CLUB

Interesting Program for I. R. C. Members in Cuban Capital.

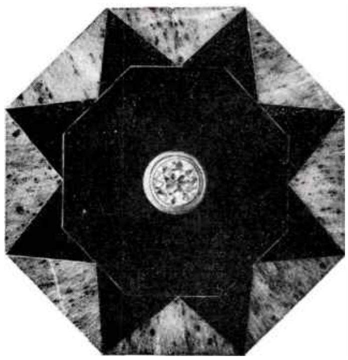
THE sixth annual convention of the International Radio Club held December 9th, 10th and 11th in the Cuban Capitol was a get-to-gether for the radio world that mingled business with pleasure—emphasis on the pleasure. Host to the gathering was the Cuban Tourist Commission and their elaborate arrangements, down to the last detail, marked a new high in the effort to be perfect hosts.

Officially, the initial interest centered in Miami where a general round-up of members took place on December 5th, with luncheon, sight-seeing tours of the southern playground and dinner. On the sixth the cruise was made to Havana where the guests were entertained until the convention opened on Monday, the 9th.

Not to be outdone by their northern neighbors, and perhaps to make the radio enthusiasts feel perfectly acclimated, the tourist commission staged a beauty contest in which twenty-four lovely blondes from the "States" participated. To invade a land noted for its beautiful women may seem like carrying coals to Newcastle, but it is only indicative of that inborn sense of Cuban courtesy which unfailingly makes the correct gesture.



Above: The White House of Havana. One of the many fine structures in the Island Republic.



(Right): The Twenty-four carat diamond in the great hall. All distances radiating from the city are measured from this "zero kilometer."

(Below): Aerial view of the beautiful capital.

Every moment of the time was jammed full of fascinating en-jammed full of fascinating entertainment. Music which was typinessed here—shall we say it softly—cocktails which were guaranteed to bring a sense of complete contentment.

Seriously, however, the convention was a definite step in the direction of international good will and the exchange of radio ideas which will prove of mutual benefit. Radio, being essentially international in scope, cannot be restrained by political borders, and such conventions as that held in Havana hold forth infinite possibilities not only from the point of view of technical advancement, but for the future peace of the world.

THE VOICE OF LABOR ON THE AIR

WCFL Provides for Expansion While Installing Country's First 5-C Transmitter

By MAYNARD MARQUARDT, Technical Supervisor

WCFL is justly proud of its position — the first station to place in operation one of the new Type 5-C 5KW RCA transmitters. Twenty miles southwest of the loop in Chicago, and twelve miles from the population center, WCFL has located its "Voice of Labor" transmitter near the town of Downer's Grove, Illinois.

Situated in the center of a twenty acre tract of land acquired by the Chicago Federation of Labor eight years ago, it allows ample space for the assured expansion of this station in the future. Moreover, with the broad policy of enlargement now contemplated, it will permit the additional installation of short-wave directional arrays such as the "Short Wave Voice of Labor," W9XAA (6080,11830 and 17780 KC), plans to use.

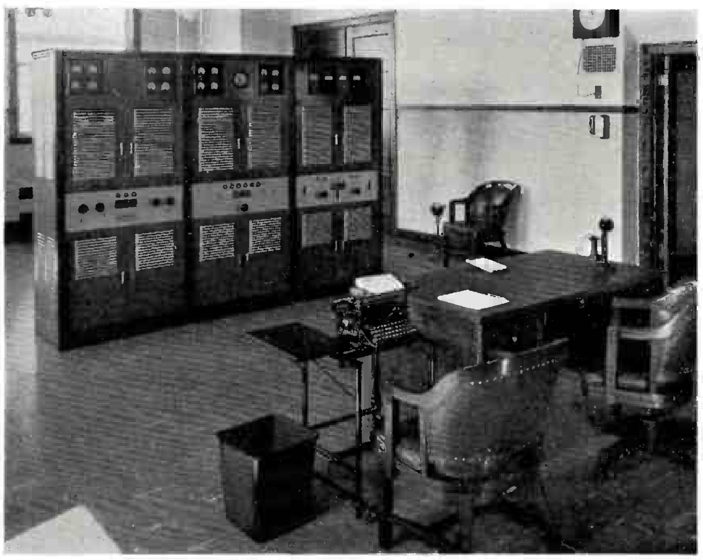
The vertical radiator built by the Blaw-Knox Company in accordance with WCFL specifications, is 490 feet high and insulated at the base. Eight great arms extend outward at the top much in the manner of umbrella ribs, attached to a common center. These arms support eight vertical wires dropped to a point just above the base. In this manner the radiator achieves the highly desirable effect of being a conductor wire of uniform cross section. Thus the distribution of current is more nearly sinusoidal than in radiators of varying cross section with a consequent lowering of the angle of radiation and likewise a diminishing of sky wave radiation.

One of the interesting phases of the radiator construction was the limitation placed upon its height. The optimum height for the tower at 970 kilocycles would be 530 feet. However the Bureau of Air Navigation, Department of Commerce, objected to this because of a ruling which permits planes to come into Chicago at a level of 500 feet. Consequently, the whole problem was reconsidered, and the figure of 490 feet was finally arrived at as a satisfactory compromise.

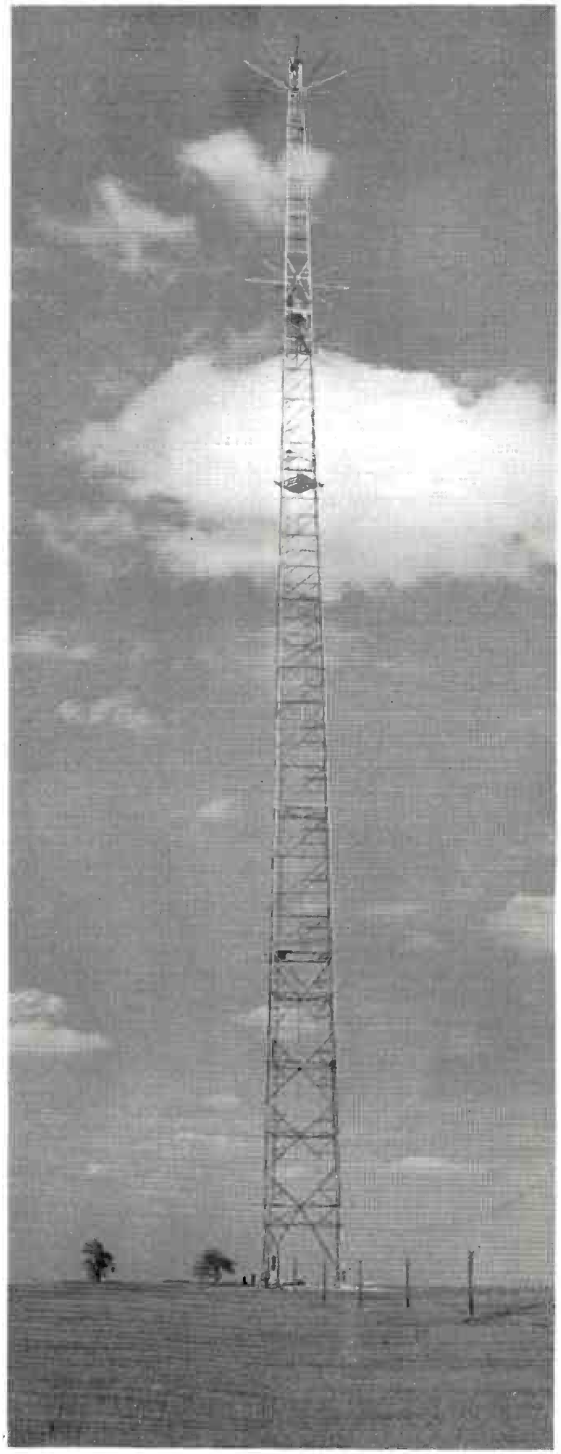
In order to circumvent the disadvantage of having the tower reduced 40 feet from its optimum height, insulators were included in each leg at 390 feet and a load-

(Continued on Page 32)

The New RCA Type 5-C Transmitter ready for operation.



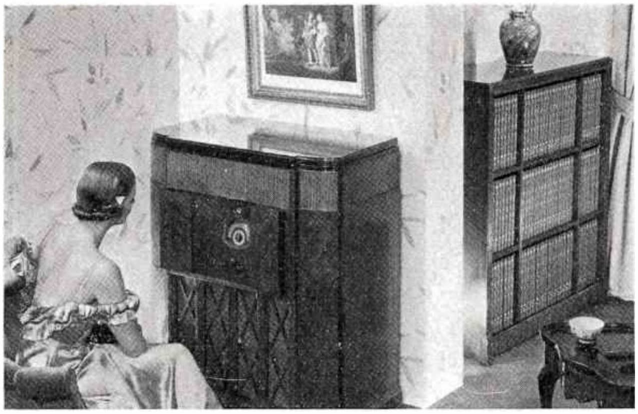
Below: The Tower Antenna.



A Brief Discussion of the DYNAMIC AMPLIFIER

Pertinent Facts About Its Operation

By CHESTER M. SINNETT



The RCA Victor De Luxe 22-Tube Magic Brain Automatic Radio-Phonograph, D22-1 which employs the Dynamic Amplifier. At the right the new Victor Record Library.

THE reproduction of music in the home, whether by radio or phonograph, has always lacked one very important element for complete satisfaction. Large changes in volume cannot be handled by either the radio transmitting equipment or the phonograph record. In the case of radio, over modulation is one limit and line noises, hum, etc., the other. A few of the better stations are capable of handling a total range of about 50 db, but it is doubtful whether many are capable of taking care of much over a 45 db range. In the case of phonograph records the limitations are similar; cutting over from groove to groove on loud passages unless the volume is reduced and being buried in surface noise if the volume is not raised on weak or pianissimo passages. This volume range on some of the new Victor records is about 45 db. The full range of a symphony orchestra has been estimated at from 70-75 db. From these figures an idea may be obtained of the amount of loss in volume range to which present-day receivers and phonographs are restricted.

Model D-22 for the first time in this country makes available to the public a phonograph having volume range capabilities of 65-70 db. This is accomplished by means of the volume expander, shown in Fig. 1.

A variable gain amplifier VT_1 employing a 6L7 is used as the first audio tube in the phonograph circuit. The signal grid, No. 1, is connected in the usual manner to the sliding arm of the input volume control. This grid is operated at a fixed bias of about 10 volts. The No. 3 grid, changes in the bias of which causes correspondingly large changes in the amount of tube amplification, is connected through the time delay and filter circuit R_2C_2, to the rectifier resistor R_9. The rectifier receives its voltage from VT_2 which in turn serves to amplify voltages appearing across resistor R_8 from the input system. The opposite end of the rectifier resistor R_9 is connected to a potentiometer R_{10} which provides an adjustable bias for grid No. 3 This adjustment permits setting the initial starting point for expansion at the desired level for different tubes some of which do not have exactly the same characteristics due to production variations. This initial adjustment fixes the static plate current in the 6L7 at about .12 MA. Other parts of the circuit and their functions are readily apparent from the diagram.

In operation, a signal is impressed across the secondary of the transformer T_1 by the magnetic pickup. This signal then appears across the phonograph volume control and the expander control R_6. VT_2 serves to amplify this signal the desired amount whereupon VT_3 rectifies it. The

(Continued on page 32)

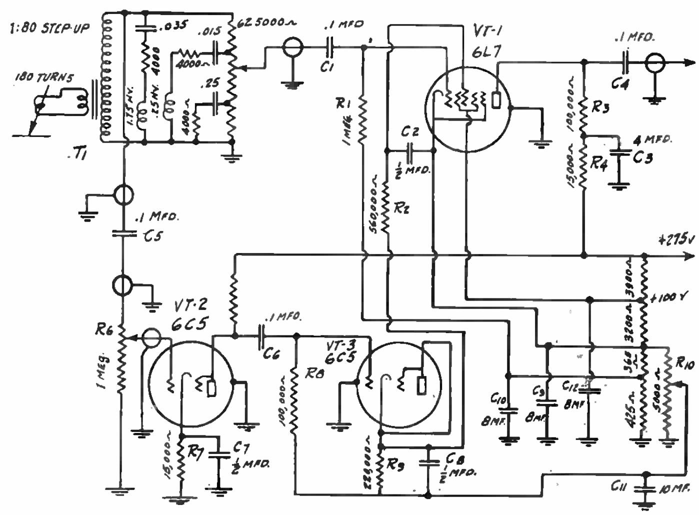


FIGURE 1.

PERSONAL APPEAL IS "TOPS" AT "SKY TOP"

Local Events of First Importance at WDAS

THE two words "Sky Top" epitomize the growth of WDAS, the only full time independent station in Philadelphia. In a short span of two years the station has advanced from the onerous status of a "one lunger" to an enviable position as one of Philadelphia's foremost outlets. This rapid progress was not effected by an increase in power or great ballyhoo but by the installation of the latest in broadcast equipment, the construction of modern studios—and an idea. Alexander W. Dannebaum and W. Maurice Steppacher, the president and secretary-treasurer respectively of WDAS sensed the need in the Philadelphia area for a station which would be characteristic of Philadelphia—which would broadcast events and programs of local interest, where civic leaders could broadcast at the most convenient times unencumbered by network affiliations—in short, reflect the spirit of Philadelphia. For these reasons WDAS and its owners set out to make Philadelphia "WDAS conscious." It broadcast programs of popular appeal. It, frankly, catered to the masses.

Speech input equipment at WDAS.

The idea caught on—but not until an RCA transmitter was installed and not until new high fidelity RCA speech input equipment was functioning in its control room. With these features and with the addition of a Blaw-Knox quarter-wave radiator 220 feet tall which was erected at its transmitter site at Woodside Park—then was WDAS in a position to attract the millions of Philadelphia listeners. To further this thought WDAS decided to make its studios one of the show places of Philadelphia. New studios were constructed atop the building at 1211 Chestnut Street.

Back of all this planning and construction was an idea—that a radio station, even in a large metropolis, could be an intimate medium — that a radio station need not be a cold impersonal medium of entertainment and education. WDAS discovered that urban and rural listeners are akin in many ways. WDAS therefore decided that its advertising copy would be delivered in an intimate, almost personal manner. It did that very thing, and also presented wherever possible all its programs in an informal manner. Not that WDAS has discarded its ideas on radio showmanship, but that this was the type of showmanship most needed in radio. As a result the studios were soon besieged with visitors. Since there are no staff announcers on WDAS —each being a distinct personality with his own following, their cohorts still swarm the studios.

The studios are the latest conception of streamlining, indirect lighting and comfort. Decorated in cheerful shades of crimson, chrome yellow, and black, they are, on first visit, both inspiring and inviting. Comfortable lounge chairs of chromium and red and yellow leather combine to make the reception rooms and studios an aesthetic spectacle. The studios themselves which flank the reception room are decorated in the modernistic manner, utilizing a black, silver and blue color motif. The dimensions, which are 35x25 feet for one and 33x20 feet for the other are sufficiently ample to accommodate soloists and the average size orchestra. The studios are soundproof, utilizing double layers of macite with blown wool interspersed. Double sheets of glass and acoustic tile make the studios the latest in soundproofing, yet they enable spectators seated in the audition gallery adjacent to each studio to view the entire proceedings. An ingenious arrangement of monitoring situated in the false ceiling of the studios allows the visitor to hear all programs without grouping around any particular monitor, since the program can be heard with equal clarity in all parts of the station.

A Studio in the modern manner.

The control room, centrally located, is elevated about five feet

(Continued on Page 22)

THERE'S GOLD IN THE AIR!

By E. T. JONES

"Volume of advertising tends generally to move with general business activity."

—Daniel Starch.

A CASUAL glance at the figures herewith on radio as well as other advertising media, will prove conclusively to anyone interested in this subject that advertising in general, and consequently business conditions are on the up grade. The figures given in this disclosure are those for the first half of 1934 business, as compared with the first half of the year 1935.

During the first half of 1934, gross receipts for broadcast advertising mounted to $38,221,480. For the same period this year the gross receipts amounted to $45,075,972. This represents an increase of 17.9%.

For the first half of 1934, National Networks (NBC and CBS) accounted for 57.56% of the gross, Local 21.7%, National Non-Network (Spot) 19.9%, and Regional Networks .8%. While the total gross for the first half of 1935 was 17.9 % above the 1934 first half gross, the distribution of the business as a whole shows very little change. For instance, during the first half of 1935, National Networks (NBC and CBS) accounted for 57.94% of the gross, Local 21.96%, National Non-Network (Spot) 1906%, and Regional Networks 1.03%. National Non-Networks (Spot) shows a very slight decrease in the total percentage of business obtained during 1935 as compared with the percentage obtained during the first half of 1934. On the other hand, Regional Networks experienced a slight increase in business.

NETWORK* EXPENDITURES BY SPONSOR GROUP

(First Half)

	Sponsor Group	1935	1934
1.	Drugs and Toilet Goods	$8,761,839	$6,823,031
2.	Food and Food Beverages	6,951,162	5,896,535
3.	Automotive Industry	2,116,514	1,958,611
4.	Cigars, Cigarettes, etc.	1,820,452	2,068,181
5.	Lubricants, Fuels, etc.	1,615,299	1,456,530
6.	Soaps and Housekeepers' Supplies	1,273,826	1,058,404
7.	Confectionery and Soft Drinks	774,386	703,544
8.	Radio, Phonographs, etc.	540,163	244,307
9.	House Furniture, etc.	367,012	289,544
10.	Financial and Insurance	229,992	344,364
11.	Stationery and Publishers	213,824	158,550
12.	Clothing and Dry Goods	181,565	176,110
13.	Wines, Beers, and Liquors	157,868	270,026
14.	Miscellaneous	145,099	90,545
15.	Building Materials	138,878	83,187
16.	Paints and Hardware	128,821	119,124
17.	Office Equipment	52,719	133,856
18.	Shoes and Leather Goods	47,449	....
19.	Travel and Hotels	46,150	80,473
20.	Jewelry and Silverware	25,886	11,773
21.	Schools and Correspondence Courses	22,993	....
22.	Garden	21,200	28,481
23.	Machinery, Farm Equipment, etc.	8,494	15,040
24.	Sporting Goods	....	....
	Totals (first 6 months)	$25,641,591	$22,010,216

*From National Advertising Records—does not include spot or local business.

For the sake of immediate comparison, these figures are conveniently presented below.

Conclusive proof that radio advertising pays handsomely is brought out by the large sums of money consistently spent for this purpose by sponsors who have fully tested and proved the profit angle of radio broadcast advertising.

Some interesting facts concerning these expenditures will not prove amiss. Drugs and toilet goods continue to hold the top position with an increase of almost $2,000,000 allocated for the first half of 1935. Food and food beverages continue to hold second place; these sponsors having appropriated $1,000,000 additional for the first half of 1935. The automotive industry displayed a tendency to materially increase their appropriation and now hold third place as compared with fourth position in 1934. Cigar and cigarette sponsors decreased their radio advertising appropriation, having spent approximately one quarter of a million dollars less during the first half of this year. Lubricants and fuels, soaps and housekeepers' supplies, as well as confectionery and soft drinks held their respective positions, i. e., fifth, sixth and seventh. An interesting point is that each of these sponsors have increased their appropriation for this year.

Of even greater interest to us in the radio business is the fact that sponsors represented by the radio and phonograph industries have appropriated more than twice the amount they spent during the first half of 1934, ascending from eleventh to eighth position this year.

Very little change has taken place in the standing of the various sponsors who follow those already mentioned and which are shown in the list above.

While there has been very little change in the relative proportion of various types of rendition used in Non-Network Broadcast Adver-

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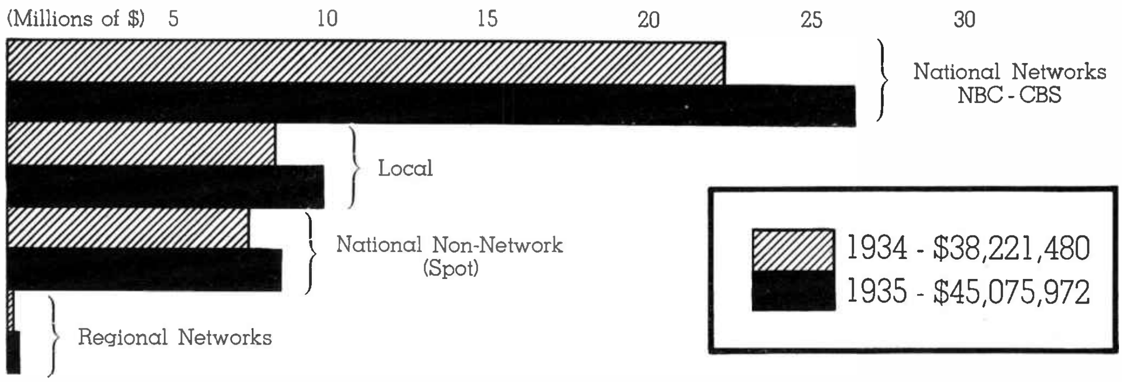
TOTAL BROADCAST ADVERTISING

(First Half)

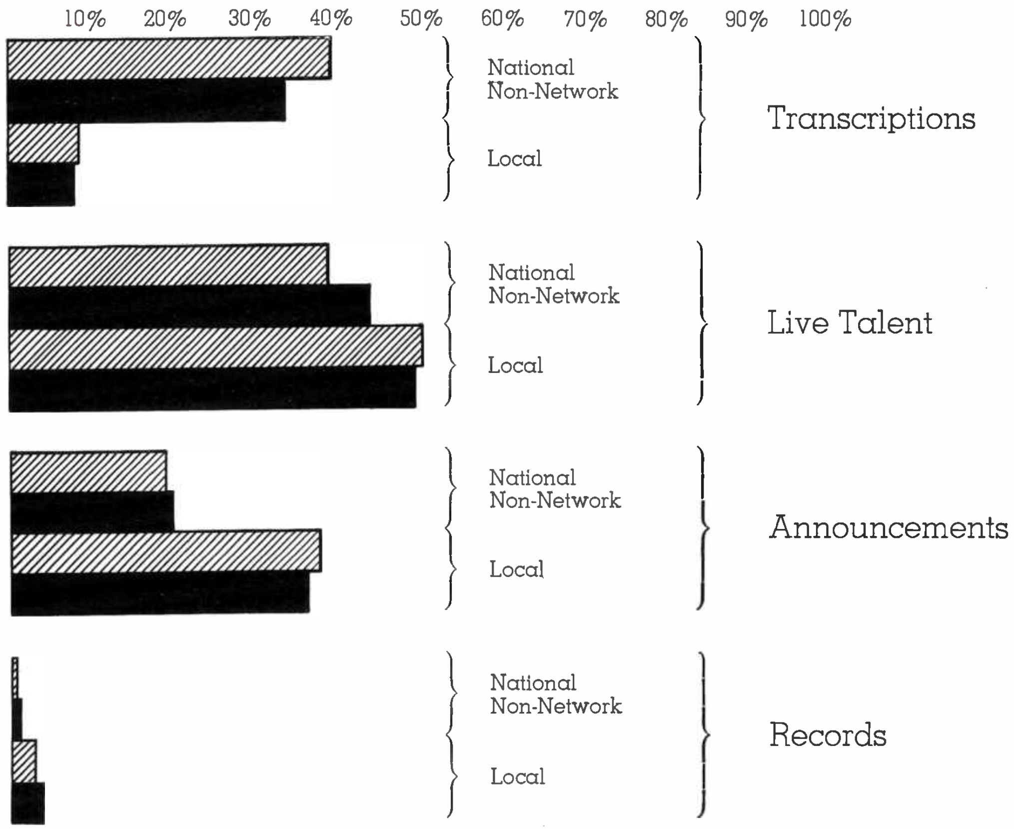
Class of Business	Gross Time Sales 1934	Percent of Total	1935	Percent of Total
National Networks (NBC & CBS)	$21,998,866	57.56	$26,120,410	57.94
Local	8,294,499	21.70	9,898,610	21.96
National Non-Network (Spot)	7,610,864	19.90	8,591,053	19.06
Regional Networks	317,251	.830	465,899	1.03
	$38,221,480		$45,075,972	

TOTAL BROADCAST ADVERTISING

(FIRST HALF)



Relative Proportion of Various Types of Rendition Used In Non-Network Broadcast Advertising



The Complete Story at a Glance!

Some Further Thoughts on Modulation

A Discussion Which Provides Additional Facts on an Important Subject

By LOY E. BARTON

THE first discussion on modulation systems which appeared in the June, 1935 edition of Broadcast News, stressed in particular the efficiency and necessary adjustments of the various systems mentioned. The efficiency of the output amplifier determines to a large extent the total power input required for the transmitter, although the data given for the 1000 watt high level Class B modulated transmitter indicated that the auxiliary equipment consumed a large portion of the total power input. Therefore, in considering the power input required for a transmitter, only the essentials of the transmitter should be considered in order to obtain a common basis for comparison. Such items as power to the driver systems and filament power in any system for modulation, are essential parts of a transmitter and should be included in the power input requirements for any particular type of modulation.

Increase in Efficiency

The degenerative feed-back amplifier has been developed to such a point that—so far as distortion is concerned—it can be succeessfully applied to transmitters with a feed-back sufficient to appreciably reduce harmonics, generated in an otherwise comparatively poor system, for modulation. The efficiency of low level modulation systems may be increased appreciably in transmitters with relatively poor driver systems, if a degenerative means is used to reduce distortion, although a degenerative system may introduce complications in adjustments and maintenance, that might offset any saving in power input effect.

The controlled plate efficiency system of modulation, as discussed in the June issue of Broadcast News, probably would be sufficiently complicated to inherently introduce distortion (necessitating more or less elaborate means of reducing or preventing distortion.) However, as indicated, the controlled plate efficiency system for modulation may be made quite efficient so far as input power is concerned.

Phase Controlled Modulation

Another interesting system of modulation which might be called phase controlled modulation, in order to distinguish the system from phase modulation, is perhaps the most efficient system devised. Briefly, the system consists of two separate Class C amplifiers which are inherently very efficient. The outputs of these two amplifiers are connected in such a manner that the phase of one with respect to the other is properly adjusted so that the vector sum of the antenna currents from the two Class C amplifiers will be equal to the normal antenna current. If the phase of each amplifier is by some means shifted from the carrier condition, to such a point that their output would exactly oppose the other, the antenna current will be zero, a condition for 100% downward modulation. It the phase is changed to the point at which the currents from the amplifiers will add, the antenna current wil lbe doubled, which is the condition for 100% upward modulation.

Overcoming Distortion Difficulties

This system of modulation, although efficient so far as input power to the transmitter is concerned, has certain inherent difficulties to overcome in order to reduce distortion. One of the most important requirements of a modulation system, previously discussed in the June issue of Broadcast News, is that the instantaneous peak power output at 100% modulation is four times the carrier power. Therefore the power output capacity of each of the amplifiers in this system of phase controlled modulation, must be double the demand at carrier output. It is also evident that the instantaneous load on each amplifier will be proportional to the instantaneous value of modulation. That is, at 100% downward modulation the antenna load on the amplifier is infinite and at 100% upward modulation the load is one-half the load at carrier conditions. Hence, the voltage regulation of the amplifiers, working into a variable load, will introduce non-linearity in the output. If a linear phase shift is used, non-linearity will also be inherent over the audio cycle, thereby requiring the use of elaborate distortion-correction means for transmitting a modulated signal with low distortion. The actual plate efficiency of the output amplifiers should approach the efficiency of a Class C amplifier, but the complications necessary to keep distortion to a minimum, the power output required for the driver systems, and the fact that more than carrier power in tube capacity is needed, offsets to a large measure the high plate efficiency of the output system.

An article on this type of modulation entitled "High Power Outphase Modulation," written by Mr. H. Chireix, appears in the November, 1935 issue of the Proceedings of the IRE.

Side Band Transmission

Another system for modulation that has been considered as a possibility for several years, consists of side band transmission with the carrier supplied by separate means. An ideal transmitter of this type is one in which both side bands are transmitted by one of several systems discussed in the IRE Proceedings and elsewhere, and the carrier supplied by some means at the receiver. In such a transmitter only power for sidebands is required which would probably amount to less than 5 or 10% of the power required by an equivalent normal transmitter—so far as received signals are concerned. A small

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AN IDEA ON THE AIR

The Intimate Touch Makes KROC Popular

CITY and state officials assisted at the opening ceremonies when KROC recently went on the air. It was a great occasion for Rochester, Minn., a small city with an internationally famous reputation. For, not only was the station broadcasting its first program, but it was also putting an idea on the air.

That idea can be stated in a few words. KROC, owned and operated by the Southern Minnesota Broadcasting Company, believes that a definite place exists in the radio world for the small station serving its local and bordering communities. It is able to touch the everyday life of its inhabitants much closer than the larger stations located in cities far removed from them. And that intimate touch is as welcome as the newsy columns of a home town paper to the ex-patriate dwelling in a metropolitan center.

Picking as its sphere of influence the territory within a radius of sixty miles, KROC is able to give intensive coverage. That area includes rich farming lands, numerous small cities, scores of villages and a potential audience of two hundred fifty thousand inhabitants. This represents a market of no mean proportions and with its modern facilities, KROC is able to serve its population efficiently and economically.

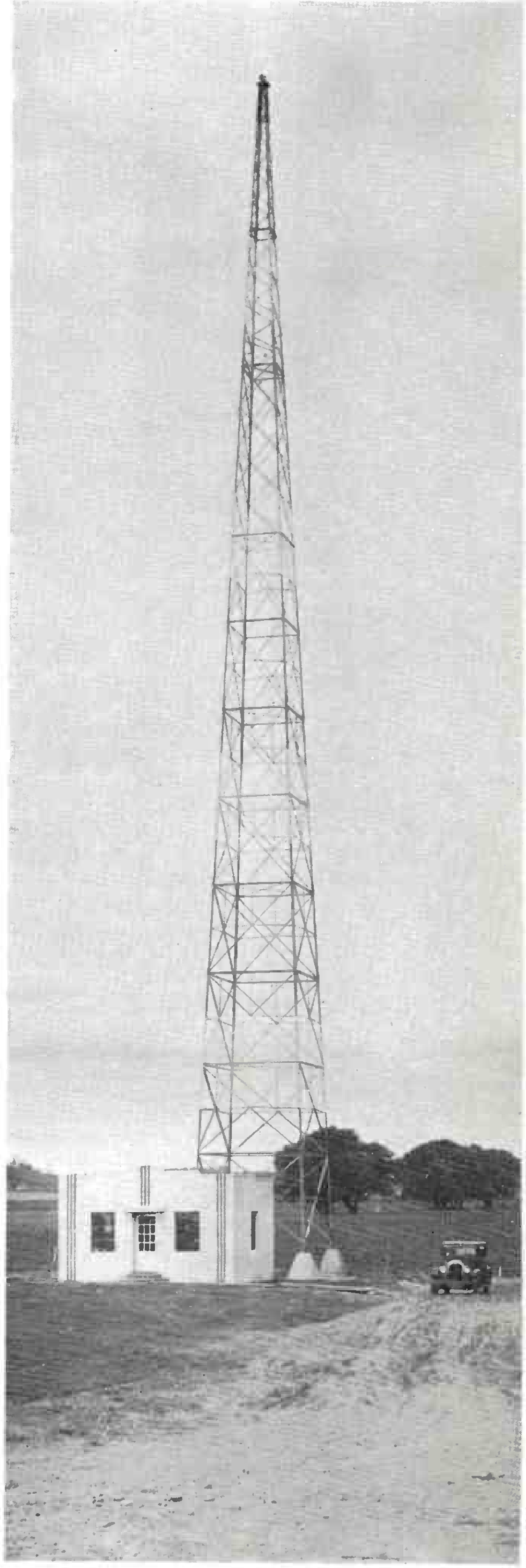
The station itself, located on a main highway, is convenient, and at night, brilliantly illuminated, it dominates the landscape. The vertical antenna rising nearly two hundred feet above the comparatively level surrounding terrain is an outstanding landmark.

The installation includes one of the new RCA 100-E High Fidelity transmitters which embraces the whole idea of efficient and economical operation. To complement this equipment, a complete NBC transcription library has been added.

From its studios in the Martin Hotel, KROC is on the air from 7 A. M. until midnight, and is connected by direct wire with KSTP, Minneapolis. One of the unique features in connection with the operation of KROC is the fact that all station announcements, other than studio programs, are handled by members of the operating staff.

(Below) The new 100-E transmitter in position at KROC.

(Right) A view of the antenna.



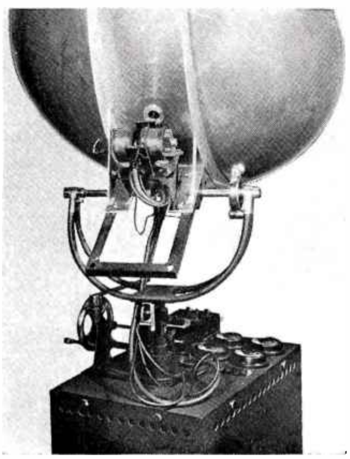
TRANSMISSION OF 9 CM. ELECTRO-MAGNETIC WAVES

A Study of Their Attenuation in the Atmosphere and the Effects of Weather Conditions on Their Transmission.

By IRVING WOLFF and E. G. LINDER

A NUMBER of tests have been carried out in different laboratories on the generation and reception of waves 10 cm. in length and shorter. However, for their practical application it is not only necessary to know that they can be generated and received, but we must also have data regarding the extent to which they are attenuated in the atmosphere, and the effect of weather conditions such as rain, snow and fog on their transmission. A series of tests to determine the attenuation of normal atmosphere were undertaken during the summer of 1934 at Atlantic Highlands, New Jersey, in cooperation with the U. S. Signal Corps, at Fort Monmouth and during the Spring of 1935, a system was placed in continuous operation between the laboratory at Camden and one of the tall buildings in Philadelphia, for the purpose of determining the effect of rain on the transmission.

The apparatus which was used in both of these tests was similar to that described in an article published in the Proceedings of the Institute of Radio Engineers in the January 1935 issue. A photograph of the transmitting apparatus is shown in Figure 1, below.



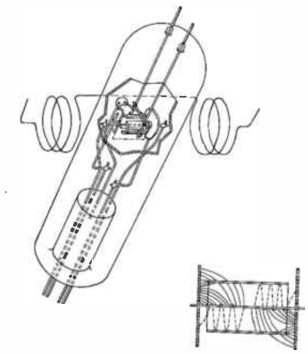
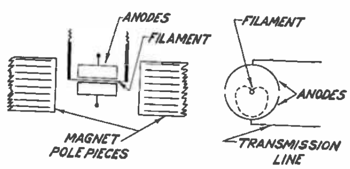


Figure 2

The transmitter consisted of a specially constructed magnetron connected to a half-wave antenna in the focus of a 4 ft. parabolic reflector, with appropriate voltage regulation of the supply circuits so that the output of the transmitter would remain reasonably constant without adjustment. Only a brief description of the tube and accompanying circuits will be given here. For more details, reference can be made to the article which appeared in the Proceedings of the Institute and an additional article which will appear shortly. A diagram of the tube is shown in Figure 2. This tube has for its basis the split anode magnetron which is shown diagrammatically in Figure 3. The split anode magnetron consists of two separated halves of a cylinder, whose axis is concentric with the filament, which are individually attached to the two halves of a two-wire balanced transmission line. The other end of the transmission line is terminated by a one-half wave antenna. This differs from the magnetron which is used at lower frequencies in having the anode in two parts, whereas, in the usual magnetron the anode is a continuous cylinder about the cathode and the oscillations are taken off between the cathode and the anode. The high frequency split anode magnetron differs also in its mode of operation from the ordinary magnetron in the adjustment of the magnetic field.

When a magnetron is used at the lower frequencies the magnetic field should be just strong enough to prevent the electrons from reaching the anode to put the tube in an oscillating condition. As the potential applied to the anodes is increased a stronger magnetic field is required to do this. However, oscillations at a particular frequency can be obtained with a wide variety of electric and corresponding magnetic fields, the frequency being determined by the external circuit. As we attempt to continuously raise the frequency, we find that oscillations no longer take place for all adjustments of the plate potential and magnetic field in which the electrons just fail to reach the plate, even though an external circuit is provided which could oscillate at the correct frequency. A further study shows the reason for this. The time taken for the electrons to go from the filament to the plate becomes an appreciable part of the cycle so that the phase relations, between current and voltage, which are required to deliver energy to the oscillating circuit no longer hold. Under such conditions it is necessary to time the arrival of the electron at or close to the anode in such a way that the correct phase between current and voltage will continue to be provided. This requires that the speed of travel of the electron

Figure 3



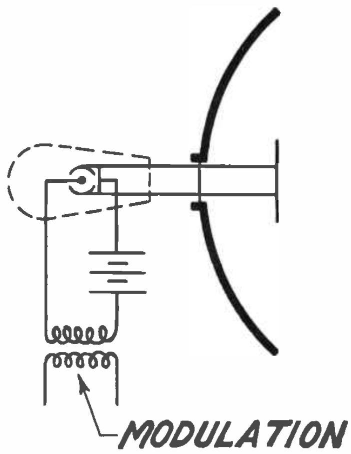


Figure 4

across the tube be taken into account, a factor which is almost negligible in a consideration of oscillation, even in the so-called ultra short wave band between 3 and 10 meters. It has been found that the tube will oscillate at high frequency if the time it takes the electrons to make a complete circuit in the tube from cathode in the direction of the anode and back to cathode again, is equal to the period of the wave it is desired to produce. This adjustment is quite critical. The oscillations which depend on adjusting the electron speed to the period of the wave have been called "electronic oscillations." The time that it takes the electron to go from cathode to anode has been called the "transit time."

The tube which was used for the transmission tests was an improved type of split anode magnetron in which an electric field in the direction of the magnetic field was added in addition to the transverse electric field between cathode and anode. This electric field was obtained by placing two metallic discs at the open end of the cylindrical anodes and supporting them so that they are insulated from the cathode. They were both operated at a potential approximately three-quarters that of the anode potential. Their function was to draw electrons from the inside of the cylinder. A theoretical and experimental consideration had shown that a tilting of the tube without end plates was required to allow electrons to spiral out from the region inside the anodes, so as to obtain proper space charge conditions for maximum oscillation. In the case of the ordinary split anode magnetron, the relative adjustment of angle of tilt and plate voltage is very critical and if either one is changed the other must be changed to some new value, in order to continue oscillation. In a tube using the end plates, stability of operation is much better. This is due to the fact that the anode and end plate potentials may be taken from the same voltage supply and therefore will vary proportionately. It has been found that when the anode potential is varied the end plate potential, which is required in order to maintain oscillation at the maximum value, is very nearly that which keeps this proportionality constant.

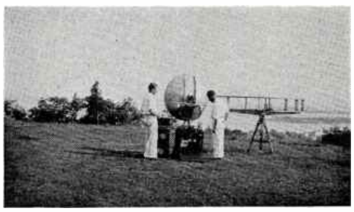


Figure 5

Since the output of the tube depends on the ratio between end plate and anode potential, modulation can be easily obtained by varying either one of these independently of the other. In order to modulate the transmitter, we therefore place the secondary of the modulation transformer in series with the anode supply, and adjust the anode potential so that oscillation amplitude for no modulation is approximately one-half the maximum. This allows the output of the tube to swing from close to zero to maximum for full modulation. A diagram showing the modulation system, the antenna, and the reflector used with the transmitter is shown in Figure 4. It will be noted on this diagram that the anode supply is brought in across a line which appears to be shorted directly across the transmission line. This bar has two purposes. In the first place, it acts as a short circuit for long wave parasitic oscillations which the tube would like to generate, if it were not prevented from doing so. In the second place, its position is adjusted so that the capacity between the halves of the anodes and the inductance of the small loop circuit is correct to tune to the frequency of oscillation.

The receiver consisted of an iron pyrites crystal attached to a small loop, which was placed in the focus of a 4-foot reflector and does not require further explanation. The output of the crystal was attached to an audio amplifier which in turn was fed into a tube detector and microammeter for the first tests, and into an Esterline recording meter for the tests which were made to determine the transmission through rain.

In the tests that were made at Atlantic Highlands, the transmitter was placed close to Navesink Light House which is on a hill about 200 feet above sea level.

The transmitter as set up for the tests is shown in Fig. 5. The receiver, mounted on the stern of the test ship is shown in Fig. 6.

The apparatus to the right of the transmitter in Fig. 5. has no connection with these tests. These pictures are supplied through the courtesy of the Signal Corps Lab-

Figure 6

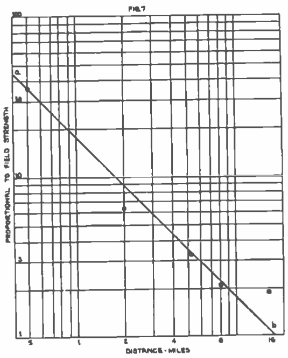


Figure 7

oratories at Fort Monmouth. The line of sight range to the horizon from this point was approximately 17½ miles. A number of readings were taken at different distances from the transmitter. The transmission distances were from one-half to five and one-quarter miles over land, and eight to sixteen miles over water. The signal which was received at the 16 mile distance was sufficiently strong so that it would have been possible to move the receiver out to 40 miles before the signal intensity became equal to the amplifier noise. Some previous measurements had shown that the output of the crystal detector was proportional to the square of the signal strength. This fact, along with the amplifier gain control setting, made it easy to calculate the relative field strength at each one of the points where the receiver was set up. In Fig. 7 the relative field strengths are plotted against the distance on log-log coordinate system. If attenuation in the atmosphere is negligible the signal strength should decrease inversely as the distance from the transmitter, since the radiation is in the form of a cone starting at a relatively short distance from the transmitter. The points should lie along a straight line of slope —1. The line a-b has been drawn through the half-mile point with this slope. There is no indication that there is any attenuation other than that due to the spreading of the energy. There was considerable uncertainty in the readings since the crystal had to be readjusted at each point, and the transmitter output may have shifted somewhat. Nevertheless, we can safely say, that attenuation in the clear atmosphere for 3000 megacycle electromagnetic waves is negligible up to distances of 16 miles, and probably more.

The measurements which were made at Atlantic Highlands were all conducted when the weather was clear, although at the time of the 16-mile test there was sufficient haze so that the transmitting point could not be seen from the receiving point. In the next series of tests, an attempt was made to determine whether the water in the atmosphere during heavy rain or fog would be sufficient to attenuate the 3000 megacycle signal. Although the amount of water present in a heavy rain storm over a distance of 20 miles, if concentrated into a single sheet, would definitely be sufficient to affect the transmission, we should expect a smaller effect to be caused by the rain because of the relatively small size of the rain drops compared to the wavelength.

In Table 1, various data on fog and rain are given. Columns 1, 2, 3, 5, and 6 were taken from Humphreys' "Physics of the Air." Columns 4, 7, 8, 9 and 10 have been computed from Humphreys' data. The data on snow are our own estimates.

Since the effect of water in the atmosphere may be considered as an attenuation phenomenon, and therefore exponential with respect to distance, the measurements had to be made over as large a distance as possible, in order to obtain sufficient accuracy. In view of the fact, that any surfaces when wet might have reflected the waves differently than when dry, it was also desirable that not only the test location be line-of-sight from the transmitter, but that there be a minimum of buildings or other objects on the side of the beam, particularly near the line joining the receiver and transmitter. This meant approximately that there should be as few objects as possible in the circular cone of vertex angle 10 degrees, whose vertex was on the transmitter, and whose axis was the line joining the receiver and transmitter.

An inspection of the available locations in the neighborhood of Camden showed that these conditions could be most effectively and conveniently met by installing the transmitter on one of the upper floors of the engineering building, and the receiver in one of the tall buildings in Philadelphia, as far from the transmitter as possible. A location on the 34th floor of 12 S. 12th St., Philadelphia, was found suitable for the receiver. This was two miles from the transmitter.

The transmitter-receiver system was first maintained in operation during several clear days, so that an idea of the constancy of output to be expected could be measured. Having obtained these data,

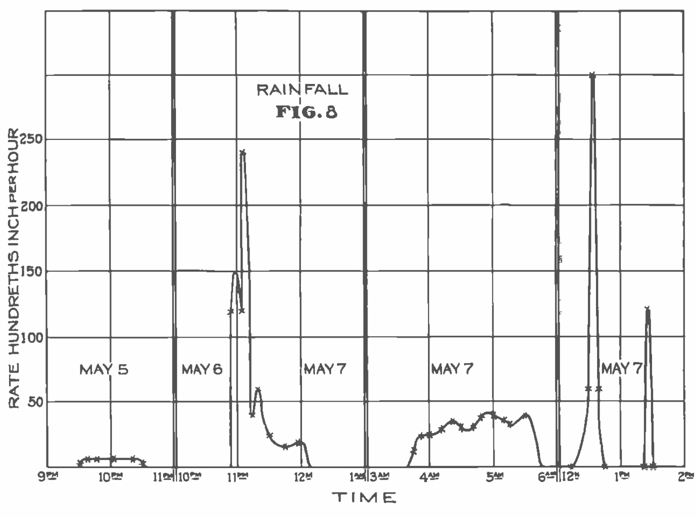
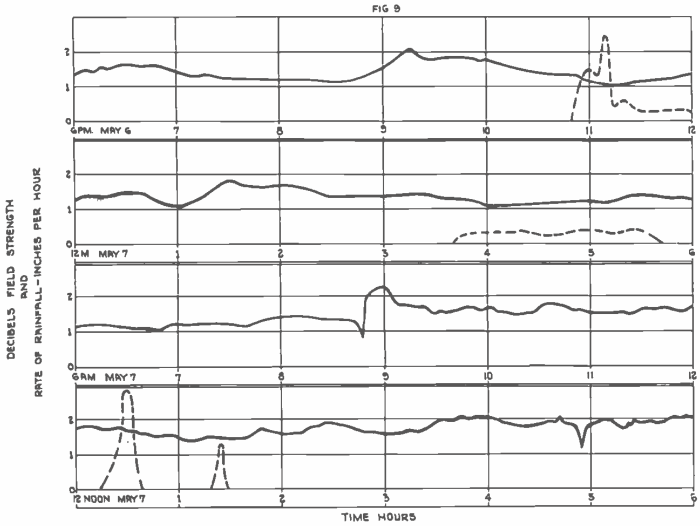


FIG 9



we hoped that several rainy periods would occur and permit a determination of the difference in transmission, after which an additional calibraion could be made in clear weather to determine whether any change had taken place in the equipment.

On May 6 and 7, 1935, conditions were very favorable for determining the effect of rainfall on the transmission. Some very heavy short showers took place, followed by periods of no rainfall. The chart of rainfall for these days taken from the tipping bucket chart of the U. S. Weather Bureau at Philadelphia through the courtesy of Mr. Bliss is shown in Fig. 8. The place where the rainfall was recorded was very nearly on the straight line joining the transmitter and receiver points, and about one-half way between them. It was also fortunate that the transmitter and receiver had been in continuous operation for several days previous to these dates.

The meter record from 6 P. M., May 6 to 6 P. M., May 7, is shown on Fig. 9. The heavy line represents the field strength, the dotted line the rainfall. The maximum fluctuation in output was 1 db. This, however, was not connected with rainfall and also was recorded on clear days. The sharp rise at 8:45 A. M. was caused by a change which was made in the transmitter magnetic field. The first rainfall took place at about 11 P. M., reaching a maximum intensity of 2.4 inches an hour, which is what Humphreys calls an excessive rain. There were other showers from 3:45 to 5:30 A. M., and shortly after noon. The one at 12:30 reached almost cloudburst intensity. With the exception of the early morning shower the short duration of the rainfall makes it improbable that the whole region between the transmitter and receiver was filled with rainfall of maximum intensity at any one time. Comparison of the curves for field intensity and rainfall show that the maximum amplitude attenuation, if any, is less than .1 db. per mile.

On the basis of the data which were obtained, and Table I we are able to decide whether the lighter forms of rain and fog, mist, or snow should affect the transmission. To do this we will consider the amount and distribution of water in the air separately. Table 1 shows that the mass of water per unit volume was greater for the rains which were tested than for any other form of precipitation and therefore on this basis alone should have caused the greatest effect. As the rain becomes lighter the mass of water decreases and the drop size becomes smaller, but the spacing decreases also. Conditions approach closer to that of water vapor. It is, therefore, interesting to compare the mass of water vapor per cubic meter in saturated air with the water in the air due to the rainfall. (It seems fair to assume that the air is near saturation during all forms of rainfall.) The Smithsonian tables give the water vapor as 22 gms. per cu. meter at 20 degrees C. and 760 mm. mercury pressure. It is rather surprising that this is four times the amount of water due to a heavy rain, and almost 4000 times that of the droplets in a fog. It therefore appears as if the effect of the water vapor should be greater than that of the free water when it is very finely divided and closely spaced and that, therefore, by making the measurement in a heavy rain, the most severe conditions have been encountered.

The comparatively large amount of water in a saturated atmos-

(Continued on Page 33)

TABLE I. DROP SIZE AND SPACING FOR DIFFERENT TYPES OF RAINFALL, MIST AND FOG.

(1)	(2) Precipitation mm/hr.	(3) Diam. of drop mm.	(4) Mass of drop grams	(5) Velocity of fall m per sec.	(6) Water mg. per m^3 air	(7) No. of drops per m^3	(8) Drop spacing (cm)	(9) Frac. of water by vol in air	(10) Thickness of water layer in cm. in 2 mi. path
Fog	....	.01	$5.2 \cdot 10^{-10}$	.003	6.	$1.2 \cdot 10^{7}$	.43	$6 \cdot 10^{-9}$	$1.9 \cdot 10^{-3}$
Mist	.05	.1	$5.2 \cdot 10^{-7}$	.25	55.5	$1.1 \cdot 10^{5}$	2.1	$5.5 \cdot 10^{-8}$	$1.8 \cdot 10^{-2}$
Drizzle	.25	.2	$4.2 \cdot 10^{-6}$	.75	92.6	$2.2 \cdot 10^{4}$	3.6	$9.3 \cdot 10^{-8}$	$3.0 \cdot 10^{-2}$
Light Rain	1.00	.45	$4.8 \cdot 10^{-5}$	2.00	138	$2.9 \cdot 10^{3}$	7.0	$1.4 \cdot 10^{-7}$	$4.4 \cdot 10^{-2}$
Moderate Rain	4.00	1.0	$5.2 \cdot 10^{-4}$	4.00	277	$5.3 \ 10^{2}$	12.3	$2.8 \cdot 10^{-7}$	$8.9 \cdot 10^{-2}$
Heavy Rain	15.00	1.5	$1.8 \cdot 10^{-3}$	5.00	833	$4.6 \cdot 10^{2}$	13.0	$8.3 \cdot 10^{-7}$	$2.7 \cdot 10^{-1}$
Excessive Rain	40.00	2.1	$4.9 \cdot 10^{-3}$	6.00	1850	$3.8 \cdot 10^{2}$	13.8	$1.8 \cdot 10^{-6}$	$5.9 \cdot 10^{-1}$
Cloudburst	100.00	3.0	$1.4 \cdot 10^{-2}$	7.00	5400	$3.9 \cdot 10^{2}$	13.7	$5.4 \cdot 10^{-6}$	1.7
Snow (Heavy) estimated melted	4.00			.25 to 1.00	1100 to 4500				

GENERAL CONSIDERATIONS OF TOWER ANTENNAS

By Dr. G. H. BROWN and H. E. GIHRING, RCA Engineers

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APPENDIX A

Method of Computing Field Intensity and Radiation Resistance of a Vertical Antenna Over a Perfect Earth, When the Antenna Current Distribution Is Nonsinusoidal

To determine the probable action of an antenna array, it is desirable to calculate the radiation pattern and the radiation resistance. Many authors have treated the case where the current distribution on the antenna is sinusoidal. We will outline a method of determining these quantities when the current distribution on the antenna is known but is not sinusoidal.

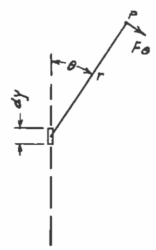


Figure 32

Let us consider the element of current shown in Fig. 32. The current in the element is assumed to be sinusoidally varying with time with a frequency of f cycles per second. The length of the element is an infinitesimal quantity, dy. Then it can be shown that, at a point P several wavelengths removed from the current element, the electric field intensity lies in the plane formed by the axis of the current element and the radius vector, r, and this intensity is normal to r (Fig. 32). Thus, if θ is the angle between the current axis and r, the electric intensity will point in the direction of increasing θ. This electric intensity is given by

$$dF_\theta = +j30k\frac{i_y}{r}\epsilon^{-jkr}dy\sin\theta \qquad (1)$$

where,

i_y = r-m-s current in the element (amperes)

dy = length of element (centimeters)

λ = wavelength of radiated wave (centimeters)

r = distance from current element to remote point, P (centimeters)

$k = 2\pi/\lambda$

$\epsilon^{-jkr} = \cos(kr) - j\sin(kr)$

$j = \sqrt{-1}$

θ = angle between dy and r

dF_θ = electric field intensity due to current element (volts/centimeter).

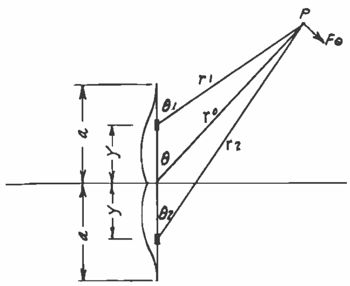


Figure 33

Let us now consider the situation when the current element is a part of the antenna shown in Fig. 33. The antenna is a vertical wire with its lower end adjacent to a perfectly conducting earth. The length of the antenna is designated by a. The current along the antenna is some known function of y, the distance from the ground.

From (1), the electric field at point P due to a current element y centimeters from the earth is

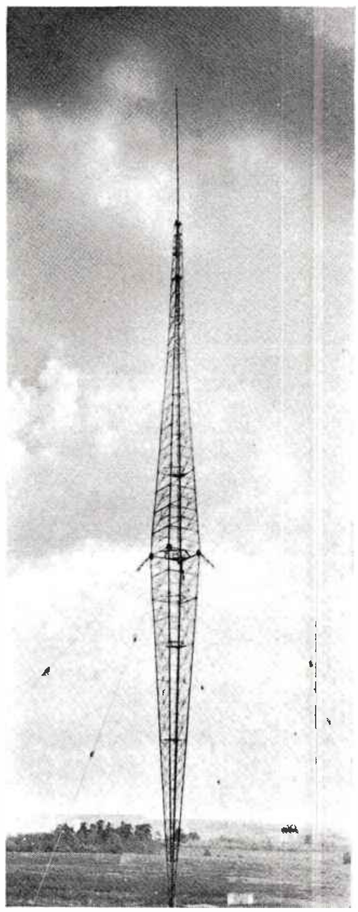
$$dF_{\theta,1} = +j30k\frac{i_y}{r_1}\epsilon^{-jkr_1}dy\sin\theta_1 \qquad (2)$$

and the contribution due to the image of this element is

$$dF_{\theta,2} = +j30k\frac{i_y}{r_2}\epsilon^{-jkr_2}dy\sin\theta_2. \qquad (3)$$

It is assumed that P is sufficiently remote that

$$\left.\begin{array}{l} \theta_1 \doteq \theta_2 \doteq \theta \\ \dfrac{1}{r_1} \doteq \dfrac{1}{r_2} \doteq \dfrac{1}{r_0} \\ r_1 \doteq r_0 - y\cos\theta \\ r_2 \doteq r_0 + y\cos\theta \end{array}\right\} \qquad (4)$$



Then the addition of (2) and (3) yields

$$dF_\theta = +j60\,\frac{ki_y}{r_0}\cos(ky\cos\theta)\,dy\,\sin\theta\,\epsilon^{-jkr_0}. \qquad (5)$$

The total field due to the entire antenna is obtained by integrating over the antenna.

$$F_\theta = +j60\,\frac{k\epsilon^{-jkr_0}}{r_0}\sin\theta \int_{y=0}^{y=a} i_y\cos(ky\cos\theta)\,dy. \qquad (6)$$

If the current distribution is an analytic function of y, the electric intensity is given by integrating (6). If the equation of the distribution is unknown but the distribution is given by a plotted curve (obtained by experiment in the case of the tower antennas) two procedures are possible. One is to try to find an analytic function which will fit the current distribution curve. This is generally not very fruitful. The other procedure is to plot the integrand and measure the included area. At best, the method is rather tedious.

For convenience, let us write

$$F_\theta = +j\frac{60}{r_0}Kf(\theta)I_0\epsilon^{-jkr_0}. \qquad (7)$$

where I_0 = current at the base of the antenna. We will call K the form factor of the antenna and $f(\theta)$ the vertical radiation characteristic.

$$K = \left[k\sin\theta\int_{y=0}^{y=a}\frac{i_y}{I_0}\cos(ky\cos\theta)\,dy\right]_{\theta=90} = \left[k\int_{y=0}^{y=a} i_y\frac{dy}{I_0}\right] \qquad (8)$$

and,

$$f(\theta) = \left[k\sin\theta\int_{y=0}^{y=a}\frac{i_y}{I_0}\cos(ky\cos\theta)\,dy\right]/K. \qquad (9)$$

It should be noted that $f(\theta)$ is unity when θ is 90 degrees.

It is of interest to show the form taken by K and $f(\theta)$ when the current distribution is sinusoidal. Suppose that the antenna has a nonradiating capacity area at the top so that the current distribution is shown in Fig. 34. Then b is the length of the portion of sine wave suppressed by the capacity area. Then we define the quantities

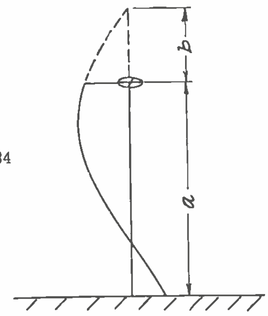


Figure 34

$$B = 360b/\lambda \text{ (degrees)}$$
$$A = 360a/\lambda \text{ (degrees)}$$
$$G = A + B.$$

The current distribution is

$$i_y = \frac{I_0\sin(G - ky)}{\sin G}. \qquad (10)$$

Then,

$$K = \frac{\cos B - \cos G}{\text{Sin } G} \qquad (11)$$

and,

$$f(\theta) = \frac{\cos B\cos(A\cos\theta) - \cos\theta\sin B\sin(A\cos\theta) - \cos G}{\sin\theta\,[\cos B - \cos G]}. \qquad (12)$$

When there is no capacity at the top of the antenna, the current at the top is zero and $B = 0$, $G = A$, so

$$K = \frac{1 - \cos G}{\sin G} \qquad (13)$$

and,

$$f(\theta) = \frac{\cos(G\cos\theta) - \cos G}{\sin\theta\,(1 - \cos G)}. \qquad (14)$$

At the point on the earth (θ = 90 degrees) a distance r from the antenna

$$|F_{90^\circ}| = \frac{60I_0}{r}\,\frac{(\cos B - \cos G)}{\text{Sin } G} \text{ (volts/centimeter)}. \qquad (15)$$

In (15), when I_0 is measured in amperes and r in centimeters, the electric intensity is given in volts per centimeter. These units are not particularly convenient. A more suitable expression is

$$|F_{90^\circ}| = \frac{37.25I_0}{r}\,\frac{(\cos B - \cos G)}{\sin G} \text{ (millivolts/meter)} \qquad (16)$$

where now r is expressed in miles and the electric intensity is given in millivolts per meter.

The current at the base of the antenna depends on the input power and the antenna resistance thus

$$I_0 = \sqrt{\frac{P}{R_a}}. \qquad (17)$$

The antenna resistance is made up of the loss resistance and the radiation resistance. In a well-designed antenna, the radiation resistance predominates.

The calculation of radiation resistance is a fairly simple matter when the current distribution is sinusoidal and the results are well known. When the current is sinusoidally distributed as shown in Fig. 34, the radiation resistance is*

$$R_r\text{(ohms)} = \frac{30}{\sin^2 G}\Big[\sin^2 B\left\{\frac{\sin(2A)}{2A} - 1\right\} - \frac{\cos(2G)}{2}\{C + \log(4A) - Ci(4A)\} + \{1 + \cos(2G)\}\{C + \log(2A) - Ci(2A)\} + \sin(2G)\left\{\frac{Si(4A)}{2} - Si(2A)\right\}\Big] \qquad (18)$$

where A, B, and G are the quantities defined previously and expressed in radians. $C = 0.57721+$ is Euler's constant and $Ci(x)$ and $Si(x)$ are respectively the integral-cosine and the integral sine as defined on page 19 of the Jahnke-Emde "Funktionentafeln."

When the current distribution is nonsinusoidal, one must resort to other tactics. A simple graphical method will be outlined. It can be shown that the total power radiated through the surface of a hemisphere of radius, r_0, and

* Balth. Van der Pol, Jr., Jahrbuch d. drahtl. Telegr., Vol. 13, p. 217, (1918).

whose center is at the base of the antenna is

$$P_r\,(\text{watts}) = \int_{\theta=0}^{\theta=\pi/2} \frac{F_\theta^2 r_0^2 \sin\theta}{60}\,d\theta. \qquad (19)$$

Substituting (7) in (19)

$$P_r = \int_{\theta=0}^{\theta=\pi/2} 60K^2 f^2(\theta) I_0^2 \sin\theta d\theta$$

$$= 60K^2 I_0^2 \int_{\theta=0}^{\theta=\pi/2} f^2(\theta) \sin\theta d\theta$$

$$= I_0^2 R_r. \qquad (20)$$

The integral of (20) may be integrated by plotting $f^2(\theta)\cdot\sin\theta$ against θ in rectangular coordinates and determining the included area. This operation requires squaring the quantity $f(\theta)$ and multiplying by $\sin\theta$. We have used a slight variation from this procedure. It first requires the preparation of a new type of graph paper (Fig. 35). The angular coordinates are still radial lines. The magnitude coordinates are no longer circles, but are circles multiplied by $\sqrt{\sin\theta}$. We merely plot $f(\theta)$ for any antenna on this paper. The area lying under the resultant diagram is then proportional to the integral

$$\int_{\theta=0}^{\theta=\pi/2} f^2(\theta) \sin\theta d\theta.$$

For reference, we also plot an $f(\theta)$ curve for a quarter-wave antenna. We will use the quarter-wave antenna as a standard. Then

$$f(\theta)_s = \frac{\cos(90^0 \cos\theta)}{\sin\theta}. \qquad (21)$$

This curve is shown on Fig. 35 and its included area is designated as A_s. A_0 is the area of the antenna in question. Then the power radiated from this particular antenna is

$$I_0^2 R_r = 60K^2 I_0^2 A_0 \qquad (22)$$

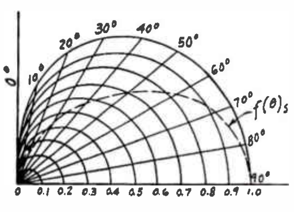


Figure 35

and the power radiated by the standard quarter-wave antenna is

$$I_s^2 R_s^2 = 60 I_s^2 A_s. \qquad (23)$$

Dividing (22) by (23),

$$R_r = K^2 \frac{A_0}{A_s} R_s \qquad (24)$$

where R_s = 36.6 ohms. Thus to determine the radiation resistance of any given antenna whose form and vertical radiation pattern we know, merely plot the vertical radiation pattern on the graph paper of Fig. 35, planimeter the area of this diagram and the standard area and substitute in (24).

The ratio of the intensity at the horizon to the intensity due to a quarter-wave antenna radiating the same power is given by

$$F_0/F_s = \sqrt{\frac{A_s}{A_0}}. \qquad (25)$$

APPENDIX B

Magnetic Flux Density Measurements with a Loop Antenna

The ordinary field intensity measuring set makes use of a loop antenna. This device inherently measures the magnetic flux density of a radiated field, and really yields the electric intensity by virtue of the fact that at remote points from the source of radiation the magnitudes of the electric vector and the magnetic flux density vector are related in a constant ratio. This simple relation no longer holds when the measurement is made close to the source of radiation. In the usual calibration of a loop antenna, the induced voltage is taken as

$$e_i = Fh \qquad (1)$$

where F is the vertical electric intensity, and h is the effective height of the antenna in centimeters, given by the equation

$$h = \frac{2\pi fNA}{c}\ (\text{centimeters}) \qquad (2)$$

f = frequency in cycles per second

N = number of turns on the loop

A = area of loop (square centimeters)

$c = 3 \times 10^{10}$ centimeters per second = velocity of propagation in free space.

Actually, the induced voltage is given by

$$e_i = 2\pi fNAB = chB \qquad (3)$$

where B is the magnetic flux density measured in webers per square centimeter. At a point remote from the transmitting antenna,

$$|\bar{F}| = c \cdot |\bar{B}|\ (\text{volts/centimeters}) \qquad (4)$$

and (1) may be used to measure the magnitude of the electric intensity F. At any point where (4) does not hold, we can only measure the magnetic flux density as given by (3), and obtain a false value of F by using (1).

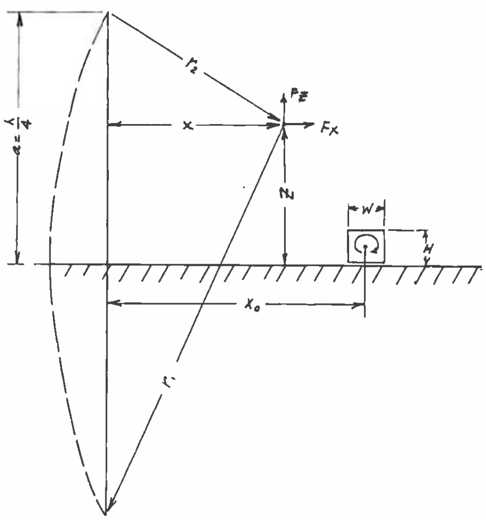


Figure 36

To illustrate the point, let us examine the case of a small loop antenna placed in the vicinity of a quarter-wave transmitting antenna. (Fig. 36). The loop is placed at the surface of the earth, which is assumed to be perfectly conducting. The plane of the loop is placed in the plane determined by the axis of the transmitting antenna and the center of the loop. H is the actual height of the loop, while W is its width. We will find the voltage induced in the loop.

At any point, P, in space (Fig. 36) the components of electric intensity are

$$F_z = -j30I_0\left[\frac{\epsilon^{-jkr_2}}{r_2} + \frac{\epsilon^{-jkr_1}}{r_1}\right] \qquad (5)$$

and,

$$F_x = +j30I_0\left[\frac{\epsilon^{-jkr_2}}{r_2}\,\frac{(z-a)}{x} + \frac{(a+z)}{x}\,\frac{\epsilon^{-jkr_1}}{r_1}\right] \qquad (6)$$

where,

$a = \lambda/4$, the height of the transmitting antenna,

$r_2 = \sqrt{(a-z)^2+x^2}$

$r_1 = \sqrt{(a+z)^2+x^2}$

I_0 = current at the base of the transmitting antenna

$k = 2\pi/\lambda$.

Then the voltage induced in the vertical side of the loop nearest the transmitting antenna is

$$e_1 = -j60I_0NH\left[\frac{\epsilon^{-jkr_0+j(kWx_0/2r_0)}}{r_0 - \frac{Wx_0}{2r_0}}\right] \qquad (7)$$

where $r_0 = \sqrt{a^2+x_0^2}$

and, if the dimensions of the loop are small compared to a, the following approximation holds true,

$$r_2 = r_1 = \sqrt{a^2 + \left(x_0 - \frac{W}{2}\right)^2} = \sqrt{a^2 + x_0^2 - x_0W + \frac{W^2}{4}}$$

$$\doteq r_0\sqrt{1 - \frac{Wx_0}{r_0^2}} \doteq r_0 - \frac{Wx_0}{2r_0}.$$

Under a similar approximation, the voltage induced in the opposite vertical side is

$$e_2 = +j60I_0NH\left[\frac{\epsilon^{-jkr_0-j(kWx_0/2r_0)}}{r_0 + \frac{Wx_0}{2r_0}}\right] \qquad (8)$$

In (8), the sign has been reversed so that e has the same direction around the loop as e_1. Adding (7) and (8), we find

$$e_1 + e_2 = -j60I_0\frac{HWN}{r_0^2}\epsilon^{-jkr_0}\left[\frac{x_0}{r_0} + jkx_0\right] \qquad (9)$$

where it has been observed that

$$\cos\left(\frac{kWx_0}{2r_0}\right) \doteq 1$$

and,

$$\sin\left(\frac{kWx_0}{2r_0}\right) \doteq \frac{kWx_0}{2r_0}.$$

The voltage induced in the horizontal section of the loop most remote from the ground is found from (6) by placing $z = H$, and noting that

$$r_2 = \sqrt{(a-H)^2 + x_0^2} \doteq r_0 - \frac{aH}{r_0}$$

and,

$$r_1 = \sqrt{(a+H)^2 + x_0^2} \doteq r_0 + \frac{aH}{r_0}.$$

This voltage is

$$e_3 = +j30I_0WN\left[\frac{(H-a)}{x_0}\,\frac{\epsilon^{-jkr_0+j(kaH/r_0)}}{\left(r_0 - \frac{aH}{r_0}\right)} + \frac{(a+H)}{x_0}\,\frac{\epsilon^{-jkr_0-j(kaH/r_0)}}{\left(r_0 + \frac{aH}{r_0}\right)}\right] \qquad (10)$$

If,

$$\cos\left(\frac{kaH}{r_0}\right) \doteq 1$$

and,

$$\sin\left(\frac{kaH}{r_0}\right) \doteq \frac{kaH}{r_0},$$

(10) becomes

$$e = +j60I_0WHN\frac{\epsilon^{-jkr_0}}{r_0^2}\left[\frac{x_0}{r_0} - j\frac{ka^2}{x_0}\right] \qquad (11)$$

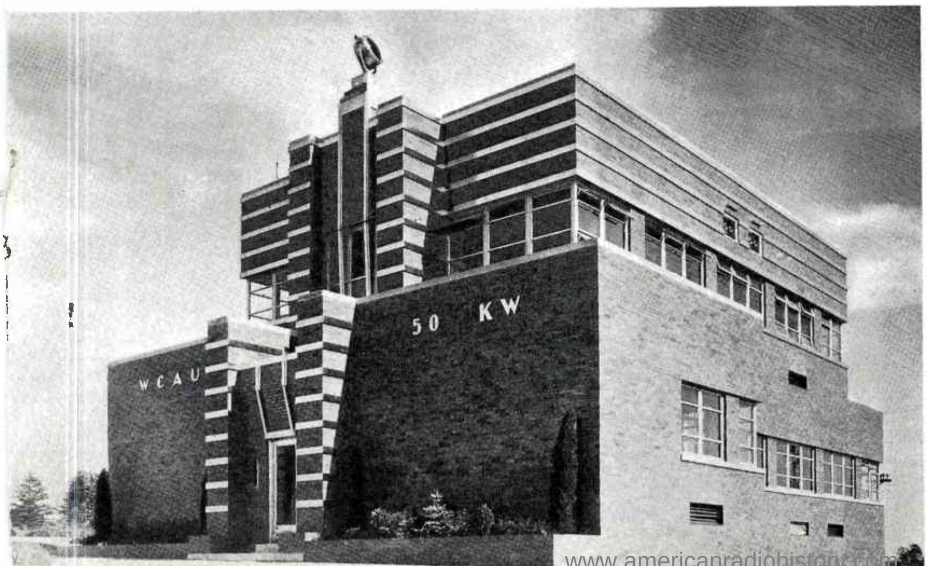
Since the bottom horizontal section of the loop is at the surface of the earth, the voltage induced in the section is zero. This may be seen by setting $z = 0$ in (6).

Then the total induced voltage is obtained by adding (9) and (11),

$$e_i = +60I_0HWN\frac{\epsilon^{-jkr_0}}{r_0^2}\left[kx_0 + \frac{ka^2}{x_0}\right] = +\frac{60I_0}{x_0}\epsilon^{-jkr_0}kHWN = +\frac{60I_0}{x_0}h\epsilon^{-jkr_0}. \qquad (12)$$

It is seen from (5) that the actual vertical electric intensity vector at this point is

(Continued on Page 20)



HIGH FIDELITY FOR WREN

With New Studios and Equipment Kansas Station Ranks High in Mid-West

By FREDERICK WHEELER, Chief Engineer

WITH the installation of a new RCA Type 5-C transmitter, station WREN steps into the powerful High Fidelity broadcasting field to match the largest and finest studios in that part of the country. From a 1KW setup in 1927 to the present 5KW equipment of today is an interesting story of radio progress and expansion.

Covering the rich territory of Kansas City and its environs WREN has consistently maintained very high standards in its programs and the means for putting those programs on the air. The management headed by Mr. Vernon H. Smith, after careful study decided that the 5-C transmitter met their rigid standards most exactly and with the installation completed early in July the first programs were aired.

The changes in the standard 5-C installation include the use of two of the new "V" cut crystal oscillators.[1] Two complete crystal controlled oscillators are enclosed in a single unit and quick change-over may be made by means of a switch located on top of the unit. The change in power from 5KW to 1KW is accomplished by reducing the plate and excitation voltages on the final amplifier. The plate voltage change is made directly with a 20,000 volt relay while the excitation change is obtained by dropping the plate voltage on the modulated amplifier. For the latter, a 2000 volt relay is used. Additional contacts on this relay connect to a loading resistor, thus providing a constant load on the modulator. Grid bias voltage on the final amplifier is automatically reduced because it is obtained by means of resistors in the cathode connection to the power amplifier tubes.

Specially Designed Units

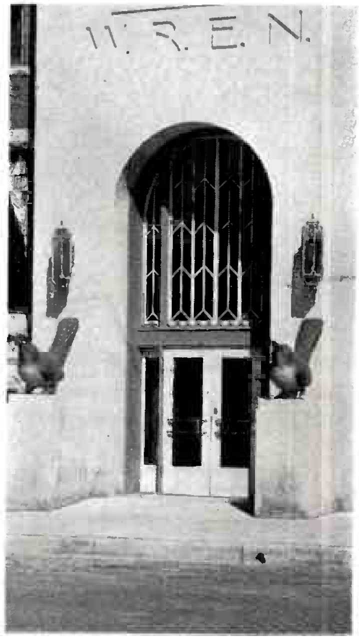
Inasmuch as the antenna at WREN is placed directly over the transmitter building, no transmission line or associated coupling equipment was needed. The standard outdoor antenna coupling unit was therefore replaced with a specifically designed antenna tuning unit for indoor mounting, which was furnished by the RCA Manufacturing Company. This unit includes loading coils, series condensers, a harmonic suppression tank, and the antenna monitoring rectifier.

Installation of the new transmitter was made entirely by the regular operating staff, and the actual working time requirerd somewhat less than three weeks.

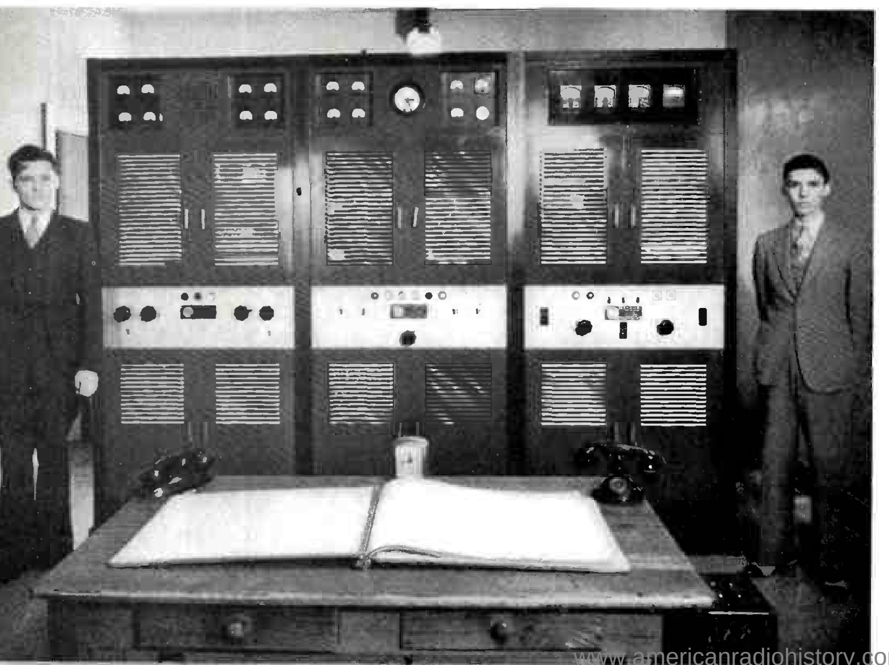
Since the new transmitter was to occupy the same position in the transmitter room as formerly used by the old set, it was necessary to move the old set across the room during the installation. This was accomplished by extending all the external wiring to the old set. Tube cooling water connections were temporarily made by means of flexible copper tubing. No program time was lost during the changeover or installation.

Work on the new transmitter proceeded rapidly and smoothly, and the first tests were made June 27. Four days later the transmitter was used on regular program schedule.

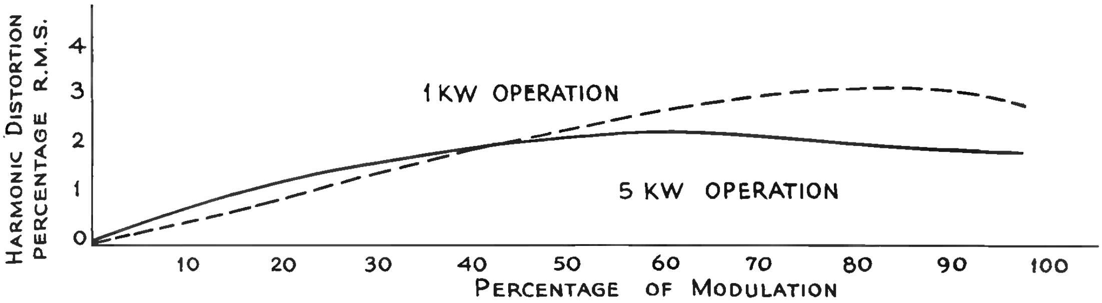
[1] Cf. Broadcast News, Aug. '34, Feb. '35.



The attractive entrance to the new studios.



(Left): Carl Bleisner, left and Carlton Marquardt, right, WREN engineers, standing beside the new transmitter.



HARMONIC DISTORTION CURVE TAKEN ON RCA 5-C BROADCAST TRANSMITTER AT WREN, LAWRENCE, KANSAS, JUNE 4, 1935.

An unusually intense heat wave was crossing the Mid-Western States during the installation, and afforded the engineers an excellent opportunity for checking the transmitter's operation in high ambient temperatures. Daytime temperatures in the transmitter room exceeded 120 degrees F and readings taken within the frame showed temperatures of 130 degrees F. In spite of the fact that mercury vapor rectifier tubes are not recommended for operation in ambient temperatures above 125 degrees F, no unusual number of arc-backs occurred in the RCA-872A tubes. Those arc-backs which did occur were quickly located by observing the arc-back indicators provided for each tube. No program time was lost from arc-backs since the automatic control system instantly returns the transmitter to the air with one-half normal plate voltage. Full plate voltage is applied seven seconds later. Listening tests showed the automatic control operation to be so fast as to be unnoticeable by the listener. The automatic control circuit is arranged so that plate voltage does not return after the third overload. In this way, circuit and tube protection is assured. An air blower system, designed to provide a blast of air against a spot on the tube envelope, is being installed by RCA to keep the operation of the rectifier tube within the manufacture ratings.

The plate transformer, voltage regulator, and power contactors were installed in the basement in a cage behind the switchboard used for power supply distribution. The water cooling system was also installed in the basement in a separate room provided for that purpose.

A bird in good hands at WREN.

Performance capable of meeting all present and proposed high fidelity requirements was desired in this transmitter, selected as it was during a period of rapidly changing engineering practice. That it meets these requirements is easily seen from the performance curves. The audio frequency response is within a 2.5 decibels variation from 30 to 12000 cycles. The use of small tubes throughout, except in the power amplifier, results in economy and also a simpler and more compact unit capable of improved performance.

With the equipment now installed, WREN is placed in an extremely advantageous position to give complete and intensive coverage over a wide area. With a large population to serve and one of the wealthiest markets in the country it looks into the future with opportunities that eclipse those of the past.

The Silver Studio—just one of the beautifully appointed studios in the new building.

TOWER ANTENNAS

(Continued from Page 17)

$$F = -j60\frac{I_0}{r_0}\epsilon^{-jkr_0} \quad (13)$$

so that, if (1) is applied, we would obtain an erroneous value for the electric intensity.

It can be shown that the flux density at the center of the loop is

$$\bar{B} = +j\frac{\mu}{2\pi}\frac{I_0}{x_0}\epsilon^{-jkr_0} \quad (14)$$

where $\mu = 4\pi \cdot 10^{-9}$ = permeability of free space. The total flux linking the loop is

$$\phi = BNWH. \quad (15)$$

The induced voltage is

$$e_i = -\frac{d\phi}{dt} = -j2\pi f\phi$$
$$= -j2\pi fNWHB = -jhcB$$
$$= +\frac{\mu c}{2\pi}\frac{I_0}{x_0}\epsilon^{-jkr_0}kNWH$$
$$= +\frac{60I_0}{x_0}h\epsilon^{-jkr_0} \quad (16)$$

which result checks with (12). Thus we see that while it is not valid to use (1) to determine F, it is true that (3) may be used to determine the electromagnetic flux density. This is the procedure that was followed in determining experimentally the distortion of earth currents in the neighborhood of the WCAU antenna.

It is interesting to observe the amount of error one makes in using equation (1) to measure the vertical electric intensity. If the transmitting antenna is a straight vertical wire of height, a, with a sinusoidal distribution of current, the true electric intensity to a point on the earth a distance x, from the base of the antenna is given by

$$|\bar{F}_{\text{actual}}| = \left|\frac{60I_0}{\sin G}\left(\frac{\epsilon^{-jkr_0}}{r_0} - \frac{\cos G}{x}\epsilon^{-jkx}\right)\right| \quad (17)$$

where $r_0 = \sqrt{a^2 + x^2}$ and $G = 2\pi a/\lambda$, and the apparent measured electric intensity as given by (1) is

$$|\bar{F}_{\text{meas.}}| = \left|\frac{60I_0}{\sin G}\left(\frac{-\epsilon^{jkr_0}}{x} - \frac{\cos G}{x}\epsilon^{-jkx}\right)\right| \quad (18)$$

Fig. 37 shows the ratio of $|F_{\text{actual}}|/|F_{\text{meas.}}|$ as a function of the distance from the base of the antenna for a number of transmitting antenna heights. We see that all the curves approach unity as we go to distances greater than one wavelength. It is also seen that for distances from the antenna less than one-half wavelength, the error in measuring the electric intensity becomes very large. Thus we see that a loop antenna may be employed to measure the magnetic flux density in the neighborhood of transmitting antennas; some other arrangement, such as two parallel disks, must be used as an antenna to measure the electric intensity in the same region.

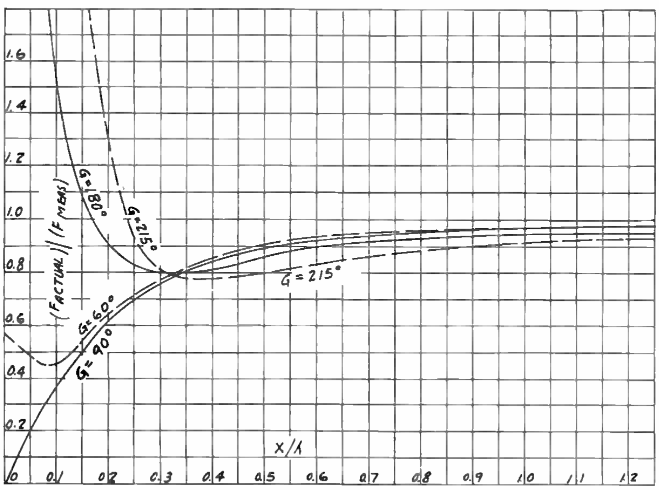
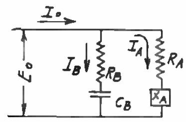


Figure 37

Figure 38



APPENDIX C

The Effect of the Base Insulator

Since the tower type antennas necessarily rest on one or more base insulators, the capacitance of these insulators is shunted across the antenna circuit itself, thus altering the effective impedance offered to the driving voltage. We will examine this effect quantitatively. The equivalent circuit is shown in Fig. 38. In this figure,

R_A = antenna resistance

X_A = antenna reactance (inductive or capacitive, depending on the antenna length)

C_B = capacitance of base insulators

R_B = equivalent series resistance of the base insulator capacitance. (This series resistance may be due to losses occurring in the base insulators or to losses occurring in the earth if the capacitance current flows through a layer of earth in returning to the ground connection.)

I_A = true antenna current

I_B = current flowing to earth through the base insulators

I_0 = total current applied to the antenna system (the vector sum of $\bar{I}_A$ and $\bar{I}_B$.)

$\bar{E}_0$ = driving voltage at the base of the antenna

$\bar{Z}_A = R_A + jX_A$

$Z_B = R_B + jX_B \; (X_B = -1/2\pi fC_B)$

$Z_0 = R_0 + jX_0$ = equivalent impedance of the combined circuits.

We may arrive at the equivalent impedance of the combined circuits by the relation,

$$Z_0 = R_0 + jX_0 = \frac{\bar{Z}_A\bar{Z}_B}{\bar{Z}_A + \bar{Z}_B}. \quad (1)$$

From the equation,

$$\bar{E}_0 = \bar{I}_0\bar{Z}_0 = \bar{I}_A\bar{Z}_A = \bar{I}_B\bar{Z}_B \quad (2)$$

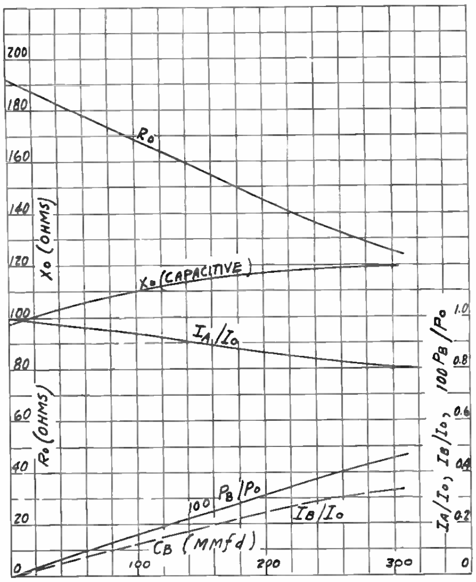


Figure 39

we find,

$$\bar{I}_A/\bar{I}_0 = \bar{Z}_0/\bar{Z}_A,$$

$$\bar{I}_B/\bar{I}_0 = \bar{Z}_0/\bar{Z}_B . \qquad (3)$$

The power lost in the base insulator circuit is,

$$P_B = I_B^2 R_B = I_0^2 R_B Z_0^2/Z_B^2 \qquad (4)$$

while the total power supplied to the combined circuits is

$$P_0 = I_0^2 R_0 . \qquad (5)$$

Thus, the power wasted in the base circuit in percent of the total input power is

$$100 P_B/P_0 = \frac{100 R_B}{R_0} \frac{Z_0^2}{Z_B}$$

$$= \frac{(\text{p.f.})_B Z_0^2 \times 100}{R_0 Z_B},$$

$$(\text{p.f.})_B = \frac{R_B}{Z_B} \qquad (6)$$

We thus have available enough expressions to tell us the complete story. We see from (6), if R_B is made zero, that the total input power is spent in the antenna itself. This is an obvious conclusion from inspecting Fig. 38. While it is impossible to make R_B precisely equal to zero, it will in general be small compared to the reactance of C_B. For instance, if the total displacement current flowed entirely through the porcelain, we would assign a power factor of approximately 0.7 of one per cent. Since some of the path is through the air the power factor will be lowered. This is of course on the assumption that due precautions have been taken to prevent these displacement currents from flowing through any high resistance layers of earth. The various quantities expressed by (1), (3) and (6) have been computed as a function of C_B for the following conditions:

Antenna height = 0.5975 wavelength = 215 degrees

Effective radius of antenna = 12.5 feet

R_A = 191.0 ohms

X_A = —97.0 ohms

Frequency = 10^6 cycles per second

$(p.f.)_B = R_B/Z_B = 0.01$.

The results are shown in Fig. 39. We see that the effective resistance decreases while the reactance increases with an increase in the base capacitance. The power loss in the base circuit increases, but has only attained a value of 0.6 of one per cent of the total input power when the base capacitance is 300.0 microfarads.

Fig. 40 shows similar results for the following conditions:

Antenna height = 0.4166 wavelength = 150 degrees

Radius of antenna = 12.5 feet

Frequency = 10^6 cycles per second

R_A = 400.0 ohms

X_A = 472.0 ohms

$(p.f.)_B = 0.01$.

In this case, we see that parallel resonance may be obtained for an antenna much less than a half wavelength long. We also see that the power wasted may be of the order of 1.5 per cent of the total input power. When it is observed that the field intensity is proportional to the square root of the power radiated, one sees that a loss of power of 1.5 per cent lowers the field intensity about 0.75 of one per cent.

A similar calculation for an antenna whose height is close to

(Coneinued on Page 34)

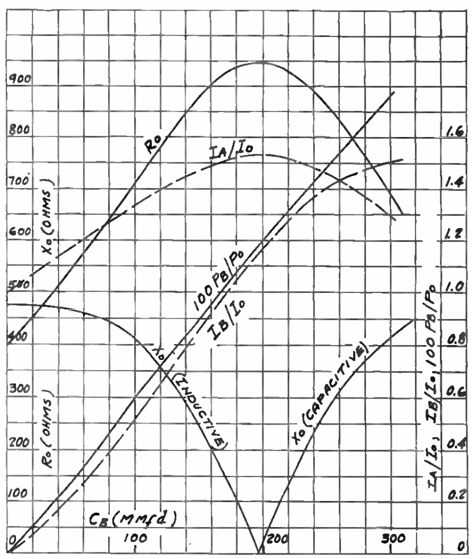


Figure 40

SOME FURTHER THOUGHTS ON MODULATION

(Continued from Page 8)

carrier could be transmitted with little increase in input power which would permit the receiver to keep in tune. However, to date, no normal broadcast receiver can receive such a signal without appreciable distortion so that such a system for modulation would require the full carrier with sidebands supplied at the transmitter. The carrier may be supplied with a Class C amplifier which may be combined with the sideband output amplifier.

In devising a system to prevent distortion, the most difficult part is in properly combining the output of the carrier amplifier and sideband amplifier. Voltage regulation difficulties in the output of the two amplifiers will result in non-linearity as for the phase controlled system of modulation. The carrier amplifier must also be capable of double carrier output for peaks of modulation, as indicated for the phase-controlled modulation system. The efficiency of the Class C or carrier amplifier may be normal, but if the sideband amplifier is of the Class B radio type, the overall plate efficiency of this system for modulation should be somewhat less for the phase-controlled modulation system. The sideband system of modulation was tried several years ago by one or more of the companies then associated with the RCA but no satisfactory means was devised to couple the carrier and sideband amplifiers to a common radiating system. Multiple antennas were also tried in an effort to keep the distortion at a low value, but met with little success.

Even though the above systems are inherently non-linear output systems and are comparatively complicated, it is quite possible that the proper application of the degerative amplifier system with other special means for reducing distortion, may result in a transmitter with a power input comparable to the Class B modulated high level system of modulation.

The Class B high level system of modulation was discussed more or less in detail in the previous discussion of modulation systems in Broadcast News and needs only be compared to the systems discussed above. Recent measurements on a comparatively high power modulator indicated a distortion of less than 3% arithmetic sum of harmonics and under conditions for lower output the above value of harmonics was reduced to half the above value. These measurements on the modulator included the entire audio system and did not have any means for harmonic reduction except straight forward Class A and Class B audio amplifier design. As is commonly known no inherent distortion is present in the plate-modulated Class C amplifier. Therefore, a Class B high level system of modulation is the least critical of all systems of modulation with which the writer is familiar.

As for plate efficiency of the high level modulated system the efficiency should be equal to or better than the efficiency of the above discussed systems of modulation and without critical adjustments and special means of reducing distortion. This characteristic of the high level modulated system with its inherent low distortion, much less critical adjustments, greater stability, and ease of maintenance, makes the system a very desirable one to use for broadcast transmitters.

PERSONAL APPEAL IS "TOPS"

(Continued from Page 5)

above the floor level of the studios and affords the control operator clear vision into any of the studios. In it have been installed the RCA high fidelity speech equipment (40C amplifiers, 46A mixers, 41B preamplifiers and 4194 monitor amplifiers). These, coupled with RCA velocity microphones in the studios afford listeners to the station the best possible reception.

Flanking the studios, on one side is an uncompleted studio which will house a grand organ to be installed shortly, and off the spectators' gallery is located the musicians' lounge, which is furnished in more conservative and subdued tones. All the executive offices are equipped with a three way monitoring system.

(Continued on Page 33)

Modern Broadcast Station Design

Additional Suggestions Will Follow in Later Issues.

By JOHN VASSOS

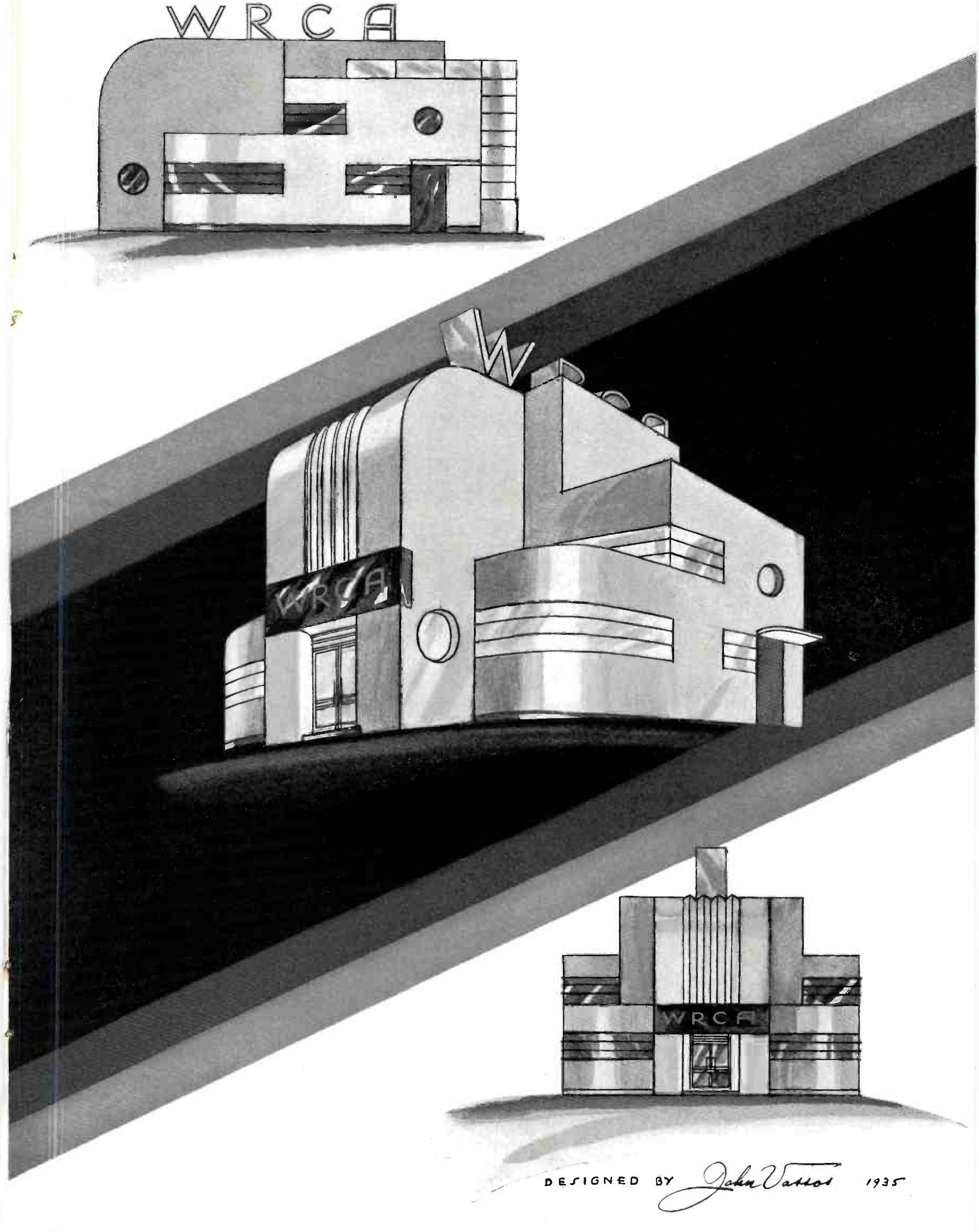
WITH the advent of modern construction and functions of interiors in broadcasting studios, a consciousness of design is now being manifested in transmitter houses. Just because these plants are usually situated beyond city limits, there is no reason why they should not be unique in design and beautiful in arrangement. With new equipment constantly being created and "dressed up" to the point where such devices cease to look like ordinary machinery, the buildings that house these new units can express the tempo and spirit of the most modern invention of the age—the radio.

With this in view, the adjoining plan and romantic sketch is created. The materials used in this building are steel, cement, glass, and aluminum. The arrangement of the building proper is a main hall entrance, two offices on either side, sleeping quarters above for emergencies, store room, and work shop.

The transmitter is placed toward the back of the building, its background being the new Pyrex glass brick. This grouping creates a desired electrical effect, particularly at night, the glass being non-transparent but luminous.

The principles of horizontalism have been adapted in this particular design, with the station's call letters placed directly on top of the station proper. Neon light effectively illuminates these letters from the inside on both sides. These letters are structural in width, and carry out the spirit of metal alloy. Structural glass is also used directly above the main entrance, facing the heavens, at night throwing a ray of light and in the daytime proving an adequate light shaft for the entrance and reception hall.

In the next issue, interior arrangements of this plan will be offered to our readers.


WRCA
WRCA
WRCA
DESIGNED BY John Vassos 1935

AVIATION HEADQUARTERS AT RADIO HEADQUARTERS

Airmen Find RCA Service Valuable

SPACIOUS hangar accommodations, radio installation and servicing facilities, office and resting spaces, as well as a working demonstration of all the newest types of aviation radio apparatus are placed at the disposal of itinerant pilots by the RCA Manufacturing Company, at its newly established aviation radio headquarters, located at Camden's Central Airport, according to David S. Little, in charge of RCA's aviation radio sales. All of the above facilities and equipment are housed in a modern hangar building 120 feet long by 80 feet wide.

Complete Line

Simultaneous with the opening of RCA's aviation radio headquarters building, Mr. Little announced the introduction of the most complete and advanced assortment of aircraft radio apparatus in the Company's history. Each unit is a product of that specialized type of engineering which modern aviation's special requirements make necessary. Outstanding among the new instruments is an extremely compact, light-weight and low-cost receiver which should prove especially attractive to sportsman pilots. It is available in a choice of two wave-band reception combinations, either to receive the beacon and entertainment bands (RCA Model AVR-7), or the beacon and communications bands (RCA Model AVR-7A). Each is a highly efficient superheterodyne receiver, equipped with four multi-function RCA tubes giving the equivalent of six-tube performance, with a resultant lower primary power drain. The receiver case, with built-in "B" and "C" power supply unit measures only 8¾" by 6¾" by 9⅛", and weighs only 16 lbs., 10 ozs. It is remotely controlled by mechanical cable from a unit which fits easily in the small, unused spaces on the instrument panel. It requires only standard aircraft dry cells or storage batteries for its low, economical drain. Ease of operation, ruggedness of construction and simplicity of installation are some of the many features to recommend the new receiver.

Light and Compact

Then there is a new aircraft transmitter (RCA AVT-3A), of 20 watts power output and weighing only thirty-eight pounds, which Mr. Little described as a "single package" equipment of exceptional capabilities. It is a small, single-unit transmitter especially designed and constructed to meet the severe requirements of aircraft communications. During flight, it offers the pilot a choice of three types of high-quality emission, including telephone, continuous-wave telegraph (CW), and tone modulated continuous wave telegraph, (MCW)—assuring reliable and efficient communication with ground and stations in all kinds of weather and under all operating conditions. The entire equipment including dynamotor supply, is housed in a single, durable metal case measuring only 10½" by 10" by 16⅜". Reception is provided in the frequency range of from 2000 to 6500 kilocycles and a simple switching arrangement permits rapid selection while in flight of any of three pre-determined frequency channels within this range. Power is supplied by a standard 12-volt storage battery or other direct-current source. Accessibility to the chassis is provided by an ingenious mechanical arrangement by which the entire chassis slides out for inspection.

Flexibility Featured

Included in the newly developed RCA aviation radio apparatus is a complete and impressive variety of airport communication instruments. Provision against rapid obsolescence is one of the many ingenious engineering features of the equipment. For instance, an airport starting with one of the transmitters can add additional lower powered communication power, and provide for speech amplification systems and radio-beacon service, by adding other apparatus especially engineered for adaption, and using the original transmitter as a foundation. In addition to the ruggedness, ease of operation and adaptability which the airport manager should expect from present-day advanced aircraft radio design and construction, the new RCA apparatus represents a marked improvement in appearance. Trim, smart lines and two-toned finish serve a decorative as well as utilitarian purpose.

BUSINESS IS GOOD AT WEMP

New Equipment Boosts Reputation of Milwaukee Station

WEMP, Milwaukee, steps up to prove that size is not an indispensable quality in making a broadcasting station successful. Limiting its field of action to a very definite and local territory and cultivating that field to the utmost is the secret which has placed it on top.

The compact arrangement of the new transmitter and associated equipment for service and efficiency.

Located on the seventh floor of the Empire Building in the heart of the city, WEMP, utilizes two sound proof studios, a combination control and transmitter room, reception room, private office and general offices. Situated as it is in the center of the city it is able to give excellent service to its clientele. This central location not only makes it convenient but also enables it to give intensive and uniform coverage over the metropolitan area and its environs.

Determined to give advertisers the benefit of the very latest equipment and at the same time to bring to its listeners the highest quality in radio WEMP has installed a new High Fidelity transmitter and new speech input equipment. The response was quite as striking to the station executives as to the audience. Letters, telegrams and telephone calls poured in to prove that the difference had been noted.

It proved moreover that the smaller local station did not have to retire before the larger metropolitan stations. A clear signal, interesting programs and the essentially local touch were all that were needed to place it in the front rank. For, after all, a local population is tremendously interested in its own problems, its own businesses and its own talent. That was the key which enabled WEMP to unlock the door to local success just as it has enabled many small stations to realize that the Broadway which really interests the inhabitant of any city is the Main Street of his home town.

Full vision into the studio.

The installation included an RCA 100-E transmitter, velocity microphones, 41-B pre-amplifiers and 40-C amplifiers. For monitoring, a 4194-B amplifier is used in conjunction with UZ-4209 loud speakers. In addition two 70-A transcription units, one using both lateral and vertical pickup, makes a complete and compact set-up. The transmitter operates into a concentric transmission line which feeds into the 179 foot vertical radiator located on top of the fourteen story building.

A FIELD INTENSITY SLIDE RULE

By H. E. GIHRING

A FIELD intensity slide rule that has been used by the RCA Manufacturing Company for the past four years in predicting field strengths, analyzing surveys, determining the location of transmitters, etc., has proved to be an extremely valuable instrument for the purpose. In order that its function and method of operation may be more clearly understood we are giving this detailed explanation based on actual field work.

First, consideration was given to the choice of the correct propagation formulae. There were many to choose from, including Austin-Cohen, Eckersley, Rolf, Van der Pol and others, each giving different results.

Prior to 1930, the Austin-Cohen formula was in general use. In that year, a survey was made of the police transmitter in Akron, approximately 40 miles from Cleveland and was compared to a previous RCA survey of WTAM in Cleveland. Since the surveys were conducted over the same territory, the attenuation factors should have been the same. Upon computation they were found to be about .01 to .02 for WTAM on 1070 KC and .06 for the police transmitter in the 2400 KC band. Obviously the Austin-Cohen attenuation constant did not remain constant with the frequency, indicating an error in this formula. Discrepancies of the same order and greater were noted by Kirby and Norton in their paper.[1]

A number of papers appeared on this subject at about this time, including "Graphs to Prof. Sommerfeld's Attenuation Formula for Radio Waves," by Bruno Rolf;[2] "The Calculation of the Service Area of Broadcast Stations" by P. P. Eckersley;[3] "The propagation of Electromagnetic Waves over a Flat Earth," by Van der Pol and K. F. Niessen[4] and "The Propagation of Electro-Magnetic Waves by B. Van der Pol.[5] Since Van der Pol's formula agreed most closely with the results and was simplest to use, it was chosen. P. P. Eckersley's curves agreed with those of Van der Pol for some distance and then Eckersley's curves dropped off more rapidly. This was explained in his article "Direct-Ray Broadcast Transmission."[6] To correct for the curvature of the earth, Eckersley used the same formula as Van der Pol up to a certain distance and then used Watson's formula. This formula did not agree with observed results.

Rolf's curves have been shown to be inaccurate. In "Nature" for June 8, 1935, K. H. Norton of the Federal Communications Commission states as follows:

> "The purpose of this letter is to point out an error in sign in Prof. A. Sommerfeld's original paper[7] on the attenuation of radio waves. The error in sign has recently been reflected in Bruno Rolph's graphs[2] of the Sommerfeld formula, predicting dips to zero in the field intensity at finite distances from a radio transmitter and other anomalous phenomena. The error in sign has been corrected in Prof. Sommerfeld's 1926 papers[8] and also does not occur in the derivation by B. Van der Pol and K. F. Niessen."[4]

The Van der Pol formula has been experimentally checked by us a number of times during the past few years. The best criterion is that the constants of the earth at any location measure the same for widely different frequencies.

Van der Pol Formula

The Van der Pol formula can be briefly stated as follows:

$$E_2 = \frac{E_1 r_1 S}{r_2} \quad \text{where}$$

E_1 is the field intensity in millivolts per meter at some distance r_1 close enough to the antenna so that attenuation has not set in.

E_2 is the field intensity at some distance r_2.

S is the reduction factor.

S is related to P, the numerical distance, by the following expressions. For values of P less than 20,

$$S = \frac{2 + .3P}{2 + P + .6P^2}$$

and for values of P greater than 20,

$$S = \frac{1}{2P}$$

P is determined as follows:

$$P = \frac{.842 r_2}{\lambda^2 \sigma \times 10^{15}}$$

where

P is the "numerical distance"

r_2 is the distance in miles from the antenna to the point where the field strength value is desired.

λ is the wavelength in kilometers

σ is the conductivity of the earth in electromagnetic units (emu).

The formula as given above neglects the dielectric constant of the earth. This renders the formula approximate with only a small error in the broadcast band, and a somewhat greater error in the police band from 1600 to 2500 KC. In view of the fact that a number of broad assumptions are necessary to predict field strength, such as assigning a value to E_1, determining the value of the conductivity, etc., the error is negligible in comparison. In spite of this, with a little experience predictions can be made with a surprising degree of accuracy.

Use of Formula

To use the formula to determine the field strength, E_2, the following quantities must be known:

E_1, the field strength close to the antenna.

r_1, the distance at which E_1 is measured.

r_2, the distance at which E_2 is to be determined.

λ, the wavelength in kilometers.

σ, the conductivity of the earth.

Of these quantities, all except E_1 and σ are readily available.

Determination of E_1

E_1 depends on the current distribution on the antenna or form factor, the current, and the per-

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[1] "Radio Field Intensity Measurements at Frequencies from 285 to 5400 KC per Second." Bureau of Standards Journal of Research Vol 18, Apr., 1932.
[2] Proc. IRE March, 1930, page 391.
[3] Proc. IRE July, 1930, page 1160.
[4] Annalen der Physik, 1930, Vol. 6, Series 5, No. 3, page 273.
[5] Zeit fur Hochfrequenz 37, Apr. 1931, pages 152-156.
[6] IRE Proc. Oct., 1932, page 1555.
[2] loc cit.
[7] Annalen der Physik 28, 665; 1909.
[8] Ann der Physik 81, 1135; 1926.
[4] loc cit.

centage of power radiated. It is beyond the scope of this article to give all of the necessary information to obtain the value of E_1. The value will be given, however, for the three most important types of antennas. The three types are as follows:

1. *Vertical antenna .16 to .2 wavelength high.* This antenna with a good ground system (100 radials ½ wave in length) will give high efficiency (180 to 190 millivolts per meter at one mile for I KW input) and a semicircular vertical pattern. It is best suited for general use where economy is a factor. Serious fading under average conditions begins at 50 to 60 miles.

2. *Vertical antenna .528 wavelength high with sinusoidal distribution or loaded to simulate such an antenna.* This antenna is of interest primarily to cleared channel stations and its aim is to reduce fading to a minimum.* It is the best antenna for fading reduction that can be built in a simple structure with heights of the order specified. Under average conditions, the fading free distance will be 70% greater than the first type. The field strength at one mile is 27% greater than the first type when using the same ground system, which means that the service radius will be increased 12% as compared to the first type.

To obtain sinusoidal distribution, it is necessary to make the cross section of the entire antenna uniform.

A smaller height .35 to .4 wavelengths can be used in conjunction with loading. Loading is accomplished either by placing a coil between the top of the tower and an outrigger, or by placing a coil between two insulated sections of the tower. The adjustment of a loaded tower for minimum fading is quite a task if the degree of fading is used to determine the adjustment. A more satisfactory means based on measurements made close to the antenna has been developed.

3. *Vertical antenna .64 wavelength high with sinusoidal distribution or loaded to simulate such an antenna.* This antenna will give the maximum field strength along the ground for a simple vertical antenna in the order of the height specified. Its only disadvantage is that its vertical pattern is such that it produces fading at about the same point as the first type. This may not be a detriment to a regional station where heterodyne interference limits the service radius or to a "day only" station. With the ground system mentioned above, this antenna will give 40% more field strength at one mile than the first type mentioned. This will increase the service radius 18%.

To obtain sinusoidal distribution it is necessary to have the cross section of the antenna uniform. A smaller height of .37 to .42 wavelengths high can be used with loading as described for the second type. For this case the loading coil is adjusted for maximum field strength along the ground.

TABLE I

UNATTENUATED FIELD STRENGTH IN MILLIVOLTS PER METER AT ONE MILE FOR 1 WATT INPUT TO THE ANTENNA.

Eff. in Pct.	Antenna height in wavelengths*		
	.167	.528	.64
100	6.05	7.80	8.60
90	5.75	7.40	8.16
80	5.41	6.98	7.69
70	5.07	6.52	7.20
60	4.69	6.03	6.68
50	4.28	5.51	6.11

* For antenna height in feet multiply height in wavelengths by wavelength in feet. (1 meter = 3.28 feet)

TABLE II

Power Watts	Multiplying Factor
1	1
100	10
250	15.8
500	22.4
1,000	31.6
2,500	50
5,000	70.7
10,000	100
25,000	158
50,000	224
500,000	707

Hence, for the three types of antennas mentioned, the unattenuated field strength in millivolts per meter at one mile for one watt of input is given in Table I.

To obtain the field strength for any other power, multiply the value in the table by the square root of the power in watts, as given in Table II. For a 1 KW station, for instance, the unattenuated field strength at one mile for an antenna .167 wavelengths high and 100% efficient is 192 millivolts per meter.

Since all of the power going into the antenna is not radiated, because of losses, some allowances must be made for this. An efficiency must be assumed which depends on the antenna installation, primarily on the ground system. When 100 to 120 copper wire radials are buried in the ground at least one-half wavelength long, efficiencies of 85% to 95% may be expected. If the radials are few and shorter than one-quarter wavelength, 70% to 80% efficiency may be anticipated, etc. For antennas on roofs of buildings where the ground system is necessarily limited, efficiencies as low as 50% to 60% or even less may result.

While the values given in Table I apply strictly to vertical antennas only, the value for the .167 wave antenna is very nearly correct for any height between .16 to .3 wavelengths, provided an adequate ground system is used. It is also very nearly correct for T and other top loaded antennas with an adequate ground system when the vertical portion is not less than .16 wavelengths in height. The value given for the .528 wavelength antenna is correct for any antenna not less than .35 wavelengths in height, loaded at the top by some efficient means to simulate a .528 wave antenna. The same applies for an antenna .64 wavelength in height.

Hence, we can now obtain a value for E_1. The value of E_1 is not too critical since, as will be shown later, a change of 10% in E_1 will cause a change of only 5% in distance at the edge of the service area at which a certain field strength is obtained. Any estimate within 5% is certainly good enough.

Estimating Conductivity

Probably the most difficult term to estimate is the value of conductivity, σ, to use. The only accurate means of determining this is by actual measurement. A good clue to the value of the conductivity may be obtained, however, from a knowledge of the type of soil and terrain. The two are usually

* Proc. IRE April, 1935, "General Considerations of Broadcast Antennas" by Gihring and Brown.

TABLE III

DETERMINATION OF CONDUCTIVITY

Terrain	Difference in Elevation	Soil Type	Remarks	Conductivity e m u × 10^{15}
Sea water				10,000
Fresh water				5000-8000
Marsh		Loam and silt		1000
Flat or rolling gently	50 feet	Black loam		150-200
Rolling	50-100 feet	Loam and sandy loams, loam predominating		80-100
Rolling	100-500 feet	Sandy loam predominating		60-80
Hilly	500-800 feet	Gravelly, sandy loams and rocky loams		40-60
Suburbs and small towns				30-40
Hilly	600-1000 ft.	Gravelly, sandy loams and rocky loams		30-40
Flat or hilly		Sand and Shale		25-40
Very broken	300-1000 ft.	Gravelly, stony land	Ravined but not necessarily high	20-30
Residential sections			Does not apply to areas with high steel buildings	20-30
Mountainous	1000-1500 ft.	Stony land		10
Broken mountainous	1000-8000 ft.	Stony land		5-7

NOTE:

Three indexes are give:

1. The nature of the terrain—hilly, broken hilly, etc.
2. Differences in elevation.
3. Soil types.

The first two can be determined from countour maps.

The third, from soil maps prepared by the Department of Agriculture, usually available at County Seats, etc.

The third is the most reliable index since it is more or less responsible for the first two. The first two must be used jointly since the difference in elevation may be small, but if the terrain is rugged and broken, the conductivity is also low. Furthermore, Long Island, mostly flat, has a very low conductivity because it is composed mostly of sand. The third index should be used whenever possible. When not available, the first two may be used jointly. I stated that the third index is responsible for the first two since, in the erosion processes, the amount and nature of the erosion is determined by the material being eroded. This process determines the shape of the terrain and the differences in elevation. The conductivity of a soil is more or less determined by the moisture it is able to retain. Loam holds moisture very well, while sand barely retains any. Nearly all values given in the table have been determined from surveys.

mutually dependent. Flat country like that of our plains states usually has fertile soil of good conductivity, while mountainous country ordinarily has poor conductivity because the soil is sandy and rocky. A hill generally retains its elevation because it is composed of material which does not erode rapidly, namely rock. In the process of erosion the product is a sandy, rocky soil. Hence good conductivity and good soil are found in flat country while poor soil and poor conductivity are found in hilly or mountainous country. A notable exception to this is Long Island, which is comparatively flat but is composed for the most part of sand. Long Island is an exception because it was formed by glacial action and not by natural processes of erosion. Nearly all of the territory encountered which was effected by glacial action has shown low conductivity.

Table III may be helpful in determining conductivities. For the sake of convenience, the conductivities are expressed in electromagnetic units × 10^{15}. The values usually encountered on land range from 10 to 200 × 10^{-15} emu, which are expressed as merely 10 to 200. Hence, with this method, a conductivity of 10^{-13} would be 100 × 10^{-15} or 100.

Table IV gives the conductivity in every state where data was obtained. Practically all of these data were obtained from surveys made by the RCA Manufacturing Company. Anyone familiar with the territory mentioned, may compare it with the part of the country in which the conductivity is desired, and thus establish a reference point. When conductivities are given between certain definite points, it should not be concluded that the conductivity beyond those points is different, unless the terrain as shown by a contour map changes radically. Definite points are given since surveys were carried out to those places only. The conductivity given, unless definitely stated otherwise, applies to rural areas, not urban areas. The conductivity for the residential section of an average city generally is about 30. Brooklyn, Bronx and Queens are exceptions with conductivities of 20 to 25, because of the height and concentration of the buildings. The values do not apply to combinations of water and land, but to land only.

Hence, with the above information, it should be possible to assign a definite value to the conductivity, σ.

Typical Problem

Since all of the data is now at hand, let us work out a typical problem. Suppose it is desired to erect a station on the outskirts of Philadelphia with a power of 1 KW and a quarter-wave antenna with a large adequate ground system of 100 radials one-half wave in length.

The field strength towards the west at 10 miles is desired. The frequency is 1000 KC.

Then

E_1 from Table I assuming 90% efficiency is 184

r_1 is one mile

r_2 is 10 miles

λ is .3 kilometers

σ from table IV is 50

$$P = \frac{.842 \times 10}{4.5} = 1.87$$

TABLE IV

CONDUCTIVITIES OBTAINED FROM SURVEYS

California	City of Los Angeles	30
	Vicinity Los Angeles 20 miles	50
	Vicinity San Francisco 40 miles NE, E, SE	85
Delaware	Northern part	40-50
Illinois	Upper half average	70
	Lower half average	100
	Average for state	85
Indiana	Central portion average	120
Iowa	Within 30 miles of Des Moines	110-180
Kentucky	Southeast Cincinnati for 30 miles average	60
	Southwest Cincinnati for 30 miles average	100
Massachusetts	Between Worcester and Boston	23
Minnesota	60 miles southeast and southwest Minneapolis	55
Missouri	City of St. Louis	30
New Jersey	Average Bound Brook to Camden	55
	Ramapo and Watchung Mts.	20
	Vicinity Montclair, Clinton, Passaic	60
	New Brunswick to Trenton	120
New York	Vicinity Syracuse 15 miles	20-30
	Brooklyn and Bronx and Queens	20-25
North Carolina	Average conductivity within 30 miles of Charlotte	40
Ohio	Cleveland to Akron	60
	Cincinnati to Indianapolis	87
	Cincinnati to Columbus	90
	Cincinnati North to State Boundary	100
Oregon	South and West of Portland 15 miles	42
Pennsylvania	Area bounded by Philadelphia, Trenton, Quakerstown, Pottstown, Coatesville, Wilmington, outside city limits	40-50
	North Reading 15 miles	40
	East Reading 15 miles	15
	South Reading 15 miles	20
	West Reading 15 miles	40
	City of Pittsburgh and suburbs	30
South Carolina	Northern part immediately south of Charlotte, N. C.	40
Tennessee	Vicinity of Nashville, 30 miles	47
Texas	Between Dallas, Ft. Worth and Denton	150
	Northeast and southwest San Antonio, 20 miles	100
	Average San Antonio to Corpus Christi	50
Washington	Vicinity Tacoma and Seattle, land only	30-40
Wisconsin	Southern part	60-80
	Northern part	20-30
	Approximate average of all states listed	60

$$S = \frac{2 + .56}{2 + 1.87 + .6 \times 3.5} = .43$$

$$E_2 = \frac{184 \times 1 \times .43}{10} = 7.9$$

The Slide Rule for Predicting

While all of the necessary data could be computed in this manner, it is a rather long and tedious process. The field intensity slide rule was evolved to eliminate this work. Figure 1 shown on back fly leaf is a full size slide rule which can be used when properly mounted. As may be seen, the ordinates are in millivolts per meter and abscissa expressed in miles. The numbers on the various curves are numbers of $\lambda^2\sigma$. The curves are drawn on a basis of 1000 millivolts per meter at one mile. Suppose we work out the above problem. The curve sheet should be mounted as shown on Figure 2 with a celluloid slider. A piece of tracing or tissue paper will do temporarily. Mark a vertical line on the paper and have it coincide with the left edge of Figure 1. Place a horizontal mark at 1000 millivolts per meter, in the upper left hand corner. This mark will be referred to hereafter as the index mark. Since $\lambda^2\sigma$ in our problem was 4.5, trace in a curve half way between the 4 and 5 curve, with the index mark coinciding with 1000 MV/M. Then slide the paper down parallel to itself, so that the index mark coincides with 184 millivolts per meter. Then at 10 miles, the value should be 7.9 millivolts per meter. Now we have not only this value, but also the value at any distance up to 100 miles. It should be noted that the traced curve does not come up to 184 MV/M at one mile, but up to about 170. The value of 170 would actually be measured at one mile, the difference being due to attenuation in the first mile.

Variable Terrain

If the terrain has various conductivities, such as 10 miles of good soil, 5 miles of swamp land, 30 miles of sandy soil, etc., the values of $\lambda^2\sigma$ should be computed for each soil. Suppose they are 9, infinity, and 4.5. Proceed the same as before and trace the 9 curve to 10 miles. Then slide the point where the traced curve stopped at 10 miles to the infinity curve. This is the uppermost curve sloped at 45 degrees and represents inverse distance transmission or no attenuation. Trace this curve for 15 miles. Then slide the end of the traced curve to the 4.5 curve and trace this for 30 miles to 45 miles. The resulting curve then gives field strength versus miles for that particular condition.

Use of Slide Rule for Determining Conductivities

The slide rule can also be used in a reverse manner. If field strength data has been obtained on a line from a station to some point, the average conductivity of this soil may be obtained. It is absolutely necessary in doing this to know the value of field strength at one mile preferably every mile for about the first five. The slope of the curve tells little or nothing, since the average set of data varies possibly 15 to 20% or more above and below a smooth curve which rules out any possibility of fitting the slopes. The variation in slopes of Figure 1 is so slight under any conditions, that a considerable error will be obtained unless the field strength at one mile is accurately known. If it is not known, a reasonable figure of conductivity will be obtained if a value is assigned to the field strength at one mile from Table I.

The variations of 15 to 20% mentioned above are no reflection on the art. They invariably result, especially if the survey was made over rough terrain. A reading on top of a hill is optimistic, while a value at the bottom, especially at the higher frequencies, is pessimistic. Hence it is difficult to obtain average readings in hilly country. Even in flat country it is difficult to avoid local effects entirely which may be caused by power or telephone lines or other conductors. Furthermore, the readings may not all be in exactly the same direction, which becomes an important factor if the field intensity at one mile is different in various directions, and if the conductivity over the various paths is different. Under these conditions, especially if the signal is modulated which makes it more difficult to tune the field intensity meter, it is easy to obtain a reading which departs 20% from a smooth curve.

Suppose a set of readings is at hand with sufficient data for the first few miles. The slider is placed in any position, usually with the index mark coinciding with 1000 millivolts per meter. The data is plotted on the slider. The slider is then manipulated until the points fall equidistant on either side of one curve, particular attention being given to the value at one mile. The value marked on the curve divided by λ^2 then gives the conductivity.

If the above procedure is followed with the data given in Table V, an answer of 70 will be found for the conductivity for 1000 KC.

TABLE V

Miles	MV/M
1	150
2	80
5.3	20
10.1	9.3
15	5.5
20	3
21	2
40	.75

Unless the changes in the terrain are definitely known, it is better to obtain an average conductivity for the entire curve rather than divide it and determine that the conductivity for ten miles is 100, the next ten 40, etc. This is impossible unless a great number of points are available and also a knowledge of the terrain is obtained from soil maps.

If a city lies in the path of propogation under consideration, an abrupt change (if the conductivity outside of the city is higher) is noticeable and this can be taken into account.

Use of Slide Rule for Determining Unattenuated Field Strength at One Mile.

The customary and most accurate method of determining the unattenuated field strength at one mile is to measure the field strength every .1 mile from about .3 to 1.0 mile and every mile up to about 5. The product of field strength and distance is then plotted versus distance. If there is no attenuation this would be a horizontal line. With attenuation the points form a curve. This curve should be extrapolated to zero. The value so obtained is the unattenuated field strength at one mile.

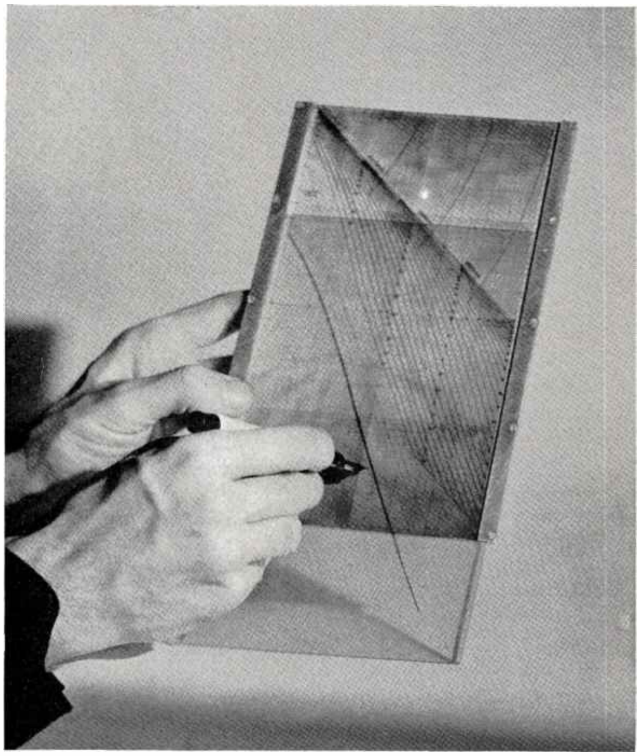


Fig. 2. The field intensity slide rule mounted ready for use.

The value of unattenuated field strength may also be determined from the curves of Figure 1. It should be noted that although the curves are drawn on a basis of 1000 MV/M at one mile, the value at one mile may be as low as 500. The difference is due to attenuation in the first mile. Suppose a set of data of field strength vs. distance is plotted on Figure 1 and that it coincides with the curve marked 1.25. The measured value at one mile will be 760 millivolts per meter. The unattenuated value, however, will be 1000.

In drawing this conclusion, it is assumed that the conductivity of the soil in the first mile is the same as that over which the survey was taken. This may not be true if a station is located a mile from a heavily populated residential section, since the value of $\lambda^2\sigma$ would be determined on the basis of the residential section and would not apply to the first mile. If the data was obtained on a station located in a rural section, the above method would be applicable since the conductivity is not likely to change rapidly under those conditions.

Drawing Field Intensity Contour Maps

The slide rule is also an aid in drawing field intensity contour maps. When drawing contour maps, the usual procedure is to place all the field strength readings on a map and then draw say a 10 MV/M contour. An attempt is made to split the distance proportionately, for instance, between an 8 and 13 MV/M reading. A more accurate method is to plot all readings in the same direction on the slide rule. With all the points plotted, it is easy to discern readings which are obviously in error. These can be disregarded and an average curve drawn through the balance. The conductivity, σ, may then be determined as previously described. The unattenuated value of field strength at one mile may also be obtained as described. By setting the index at the unattenuated value at one mile, the distance to the various contours may then immediately be determined in each direction and plotted on the map. This is a more accurate method of drawing contour maps and eliminates some of the obvious errors which are sometimes noted, caused by perhaps one false reading.

This method is especially valuable for preliminary surveys when a small test transmitter is set up at a proposed site. A set of readings in one direction is plotted with the slider in any position. The slider is then manipulated until the proper $\lambda^2\sigma$ curve is found. With the slider in this position, a mark is placed at 1000 MV/M on the left edge. The expected value of field strength from the final installation should then be estimated from Table I and II. The slider should then be moved so that the mark placed at 1000 MV/M coincides with the value of estimated field strength. The distance to any contour may then be obtained on the basis of the final power and antenna used. This obviates the necessity of multiplying every reading by the ratio of the final field strength to that obtained from the test transmitter which would otherwise be necessary. The conductivity of the earth over which the survey is made can also be obtained in the process of noting the value of $\lambda^2\sigma$. It should be noted that a preliminary field intensity survey is of no value for determining the output of the final antenna since a very small antenna and ground system are used which cannot compare with the final installation. A preliminary survey also does not "test" the soil at the site or in the immediate vicinity. The only satisfactory means of "testing" or determining the soil constants of the proposed site and the immediate vicinity is by means of wave tilt measurements. The only information which can be obtained from a preliminary survey is the rate of attenuation in various directions.

The Inverse Square Relation

It will be noted that the general slope of the lower end of all the curves of Figure 1 is about the same. This slope below the point marked by the dotted line is an inverse square curve. This is obvious from the formula. It will be remembered that when P is greater than 20 that

$$S = \frac{1}{2P}$$

then

$$P = \frac{1}{2S} = \frac{.842 r_2}{\lambda^2 \sigma\, 10^{15}}$$

then

$$S = \frac{\lambda^2 \sigma\, 10^{15}}{1.684\, r_2}$$

since

$$E_2 = \frac{S E_1 r_1}{r_2}$$

$$E_2 = \frac{\lambda^2 \sigma\, 10^{15} E_1 r_1}{1.684\, r_2^2}$$

From the last equation holding λ^2, σ, and r_1, constant

$$E_2 = \frac{K E_1}{r_2^2}$$

or

$$r_2 = K \sqrt{\frac{E_1}{E_2}}$$

Suppose the 2 millivolt/meter contour line occurs at 20 miles. Increasing E_1, the output of the antenna 22.5%, which is equivalent to going from a one-quarter to a one-half wave antenna, the new distance r_2 at which the 2 MV/M contour will be located is 22.2 miles, or an increase in distance of $\sqrt{1.225} = 1.11$ or 11%. If the frequency for the above case is 1000 KC, a quarter-wave tower would be 238 feet and a half-wave tower 476 feet or $6000. and 20,000. respectively.[11] This represents an additional tower cost of $14,000. to locate the 2 MV/M contour 2.2 miles further from the transmitter. In some very special instances it may be worth the investment but, in the majority of cases, it hardly seems justified. The above example is not given as an argument against high radiators but is given merely to show their limitations as a means of increasing the service area. The only real advantage of high radiators lies in their ability to control fading. Under average conditions of conductivity and wavelength a quarter-wave antenna will cause complete fading irrespective of power, at about 60 miles. Under the same conditions a .528 wave antenna with sinusoidal current distribution will not allow complete fading in the first 100 miles. In the range of heights specified the .528 wave antenna is optimum for fading reduction. This is a real gain for a 50 KW station on a cleared channel but is certainly of no value value for a low power station which cannot even be heard at 60 miles because of interference.

It may be argued that this inverse square relation holds only in rare cases. An examination of Fig. 1 will show that the slope of the curves above the dotted line is even steeper, which will render the results still more pessimistic in this respect. Excellent experimental verification of the inverse square relation has also been obtained.

Mounting the Slide Rule

Carefully cut along the border lines of Fig. 1 and mount on a piece of brass or aluminum 6 x 10¼ x 1/16 with "Artist's Frisket Cement." Do not use any paste which uses water as a solvent since this will wrinkle the paper. Any cement which uses carbon tetrachloride or benzol as a solvent is satisfactory. Before mounting drill and tap 10 holes for a No. 4 screw, 5 equally spaced, on each long edge. The center line for the screws should be 3/32" from the edge. Obtain two metal strips 10¼ x ⅜ x 1/16 and a sheet of transparent celluloid 5⅝ x 10¼ x 1/32. Mill the edges of the ⅜" strip for 3/16" or half way across with a 1/32" cut, the thickness of the celluloid. The strips should be drilled to clear a No. 4 screw to match the holes in the mounting plate. They should then

(Continued on Page 34)

[11] Figures taken from the "Broadcast Antenna" by A. B. Chamberlain and W. B. Lodge, Proc. Radio Club of America, November, 1934, page 58. Figures are for antennas ready for operation.

DYNAMIC AMPLIFIER

(Continued from Page 4)

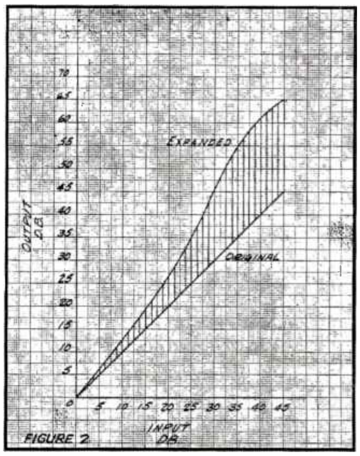


FIGURE 2

polarity of the rectified voltage is in opposition to the bias on No. 3 grid and serves to reduce this by the amount of the rectified voltage. Consequently loud signals from the record result in a higher rectified voltage and lower bias voltage in the No. 3 grid. Since a reduction in this bias voltage results in an increase in gain in VT_1, a much louder output signal from the loudspeaker results than as though the amplification of VT_1 were constant. At low levels very little voltage is rectified with the result that the bias of No. 3 grid is practically undisturbed and the gain for that value of bias is obtained.

The time delay circuit R_2C_2 is necessary to prevent erratic operation with sudden changes in volume. The present values were determined as the result of many listening tests and represent the best compromise in the opinion of those involved. Its time delay is approximately .3 second and is barely noticeable, to the musically trained ear, on staccato passages.

This 20 db extension in volume range may be used in either of two ways. With the same level on low or pianissimo passages the expander will provide a new sense of realism on the loud or fortissimo passages. Since the gain in VT_1 is variable depending entirely on the input voltage a certain amount of expansion takes place at all times and thus provides shadings in the music at average levels which are missed entirely without the expander. The other popular use of the expander involves setting the top volume on loud passages to the desired maximum. In this case the 20 db expansion is used to effectively reduce the pianissimo passages 20 db lower than they would be with constant amplification and the same top volume. This has the effect of reducing the record surface noise to a greater degree than the music. This produces a very desirable effect since surface noise on low volume passages has always been a source of annoyance.

The above figure shows the average amount of expansion obtained with different inputs when the plate current on VT_1 is adjusted as specified at about .12 MA. From this it can be seen that at all levels above zero some expansion takes place. Also if the expanded curve at maximum is made to coincide with the original curve the effect of reduction in signal on pianissimo passages is obtained.

In conclusion the full benefit of the expander will not be realized until automatic compression is employed during recording. A gain of at least 15 db in surface noise could be obtained with automatic compression without seriously impairing reproduction on standard phonographs. When played on an instrument employing expansion, surface noise would be practically eliminated on low passages and the full dynamic range of the orchestra could be restored.

The above system can be used on radio if desired provided signal inputs to No. 1 grid of VT_1 are kept below 1.5 volts. Several new problems are involved in the use of expansion on radio since a compromise in the degree of time delay is necessary between music and voice. With experimentation and study, however, this could be worked out and the result would entirely justify the labor.

WCFL

(Continued from Page 3)

ing coil was mounted in a weatherproof box and connected to the upper and lower portions of the tower.

At the top, the antenna has a beacon containing two 500-watt bulbs in a fresnel lens. At 330 feet and at 130 feet from the ground dual obstruction lights are located on diagonally opposite corners.

The transmitter itself fulfills all of the present and projected requirements for high fidelity operation. The only rotating machine retained in this equipment is the water pump which supplied the cooling system to the anodes of the vacuum tubes.

The equipment was designed for complete accessibility not alone for trouble shooting but also with routine maintenance uppermost in mind. Modern in construction, from the technical standpoint, it includes many features of design which appeal to the eye as definitely attractive and to the engineer as utilitarian.

Through the use of new methods of design and construction it has been possible to reduce greatly the space required for the transmitting equipment and at the same time to reduce the number of component parts. This has resulted directly in a corresponding reduction in installation costs, time and material. This saving has been reflected not only in the transmitter cost, but also in the cost of the building required to house it.

A two story brick and concrete structure fifty-six by forty-five feet is quite adequate, not only for the present setup, but also for the future expansion which will eventually be necessary. It is so designed that a room adjoins the present location of the 5KW transmitter, ready to accommodate a linear stage to raise the power to 50KW. The partition separating the two rooms contains no conduits or other obstructions which would prevent its removal. The additional space is now arranged as an emergency studio. The floor, inlaid with concealed ducts, will not require undue wreckage in accommodating future expansion.

THERE'S GOLD IN THE AIR!

(Continued from Page 6)

tising, the few changes recorded in the statistical chart shown below are interesting. Use of electrical transcriptions declined during the first half of this year. Live talent programs show a favorable increase. This may be attributed to the great number of talented youngsters amateur programs have brought to the attention of sponsors. It will be noted that very little change has developed in both records and announcements.

RELATIVE PROPORTION OF VARIOUS TYPES OF RENDITION USED IN NON-NETWORK BROADCAST ADVERTISING

(First Half)

Percentage Represented by Rendition Type

Type of Rendition	National Non-Network 1934	National Non-Network 1935	Local 1934	Local 1935
Elec. Transcriptions	40.0	34.6	8.7	8.5
Live Talent Prog'ms	39.7	44.7	50.7	50.4
Records	.5	.7	2.7	3.8
Announcements	19.8	20.0	37.9	37.3
Totals	100.0	100.0	100.0	100.0

Some very interesting facts are given below showing the amounts of money that were spent during the first half of 1934, as well as 1935, in major advertising media:

ADVERTISING BY MAJOR MEDIA

(First Half)

Gross Time & Space Sales

Adv. Medium	1934	1935
Radio B'dcasting	$38,221,480	$45,075,972
Nat'l Magazines	61,409,805	67,954,820
Nat'l Farm Papers	2,870,927	2,973,225
Newspapers*	242,535,000	254,551,000
Totals	$345,037,212	$370,555,017

*Estimated

While radio broadcasting accounted for only 11.08% of the total amount spent during the first half of 1934, an improvement was noted during the first half of 1935. Radio broadcast advertising accounted for 12.16% of the total. These figures prove conclusively that there is still considerable room for growth insofar as selling "time on the air" is concerned. The mere fact that appropriations for radio broadcasting are continually being increased is sufficient proof that a large volume of additional business is available.

CORRECTION

In the article entitled "Impedance Matching Attenuation Networks" by J. B. Epperson, appearing in the September issue, errors occurred in the equations which are corrected below.

$$R1 = \tfrac{1}{2}\left[\frac{Z1}{\operatorname{Tanh} X} - R2\right] \quad (4)$$

$$R3 = \tfrac{1}{2}\left[\frac{Z2}{\operatorname{Tanh} X} - R2\right] \quad (5)$$

$$\operatorname{Tanh} X = \frac{K}{\sqrt{1+K^2}}$$

where $K = \tfrac{1}{2}\text{anti-log}\ X(.4342)$

$$R1 = \tfrac{1}{2}\left[Z1\,\frac{\sqrt{1+K^2}}{K} - R2\right] \quad (10)$$

$$R3 = \tfrac{1}{2}\left[Z2\,\frac{\sqrt{1+K^2}}{K} - R2\right] \quad (11)$$

$$R1 = \tfrac{1}{2}\left[\frac{500}{.98} - 64\right]$$

$$R3 = \tfrac{1}{2}\left[\frac{200}{.98} - 64\right]$$

$$Z1 = .98(64 + 446.2)$$
$$= 499.9$$

$$R1 = \tfrac{1}{2}\left[500\,\frac{\sqrt{1+(4.94)^2}}{4.94} - 64\right] = 223 \text{ ohms}$$

$$R3 = \tfrac{1}{2}\left[200\,\frac{\sqrt{1+(4.94)^2}}{4.94} - 64\right] = 70 \text{ ohms}$$

PERSONAL APPEAL IS "TOPS"

(Continued from Page 22)

Situated on the 12th floor of the building (the top) at 1211 Chestnut Street the view from any of the studios or offices commands the entire sky line of Philadelphia and far into New Jersey—hence the call letter slogan "Sky Top Studios." But not only have all these improvements enhanced the reputation of WDAS and brought it to its enviable status, but the station has proved conclusively that high power is not essential in a large city—all that is necessary is a determined and set policy of operation, a cognizance of the trends in technical improvements, and a recognition of the intelligence of the listener and his will—these factors have brought WDAS to its "Skytop" position in Philadelphia.

9 CM. WAVES

(Continued from Page 13)

phere points to the possibility that more effect on transmission might be expected under conditions where the path traverses regions of variable vapor content, than during times of precipitation when humidity is relatively constant. A calculation of the relative index of refraction of moist and dry air, assuming that there is no anomalous change in the dielectric constant at 3000 megacycles, compared to lower frequencies, indicates that it should be of the order of 1.0001. The figure of 1.0001 requires either many transitions, or interfaces at very glancing angles to cause noticeable variations in transmission.

In conclusion we may say that the tests, both at Sandy Hook and at Camden, have shown for 3000 megacycle electromagnetic waves: (1) that the attenuation in a clear atmosphere is negligible up to a distance as great as 16 miles, and (2) that the attenuation of the field caused by heavy rain, is less than .1 db. per mile; (3) that an investigation of the water content and drop size of fog, mist and light rain show that their effect on the transmission should be less than that of heavy rain.

SLIDE RULE

(Continued from Page 31)

be mounted with the outer edge of the strips flush and the milled portion arranged so that the celluloid can be slid in. The strips may then be screwed down and the celluloid slider fitted. Ink, especially India ink, takes well on the celluloid and may readily be washed off.*

TOWER ANTENNAS

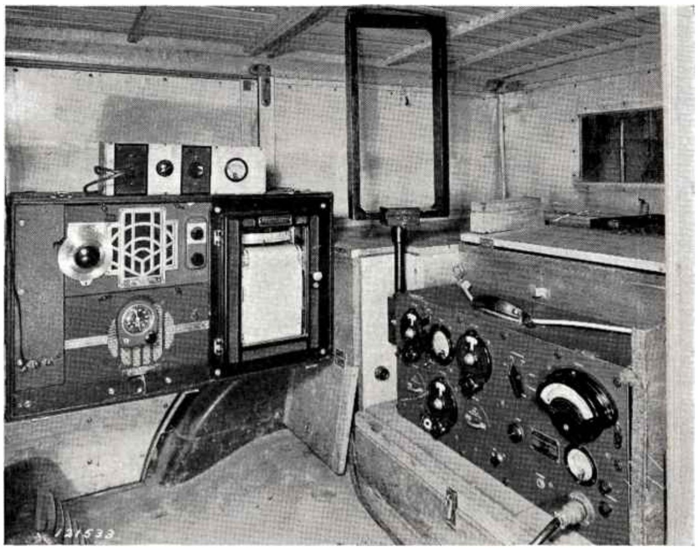
(Continued from Page 21)

one-quarter wavelength shows that the power wasted is less than 0.1 of one per cent.

These calculations show that a large amount of base capacitance is harmless as long as the equivalent resistance of this circuit is kept small. In fact, an added capacitance is often placed across the antenna to match the resultant circuit to the transmission line which feeds the antenna. It has been found very desirable to place metallic plates or mats beneath the base insulator to receive any displacement currents which might otherwise flow through a layer of earth to reach the ground system. These mats are of course bonded directly to the ground system. In one particular case, the use of such mats served to increase the field strength 11.0 per cent.

* See Page 35.

FIELD INTENSITY AND SIGNAL RECORDING EQUIPMENT IS USED EXTENSIVELY



Station wagon type car used by Edwards and Martin, consulting radio engineers, Detroit, Michigan.

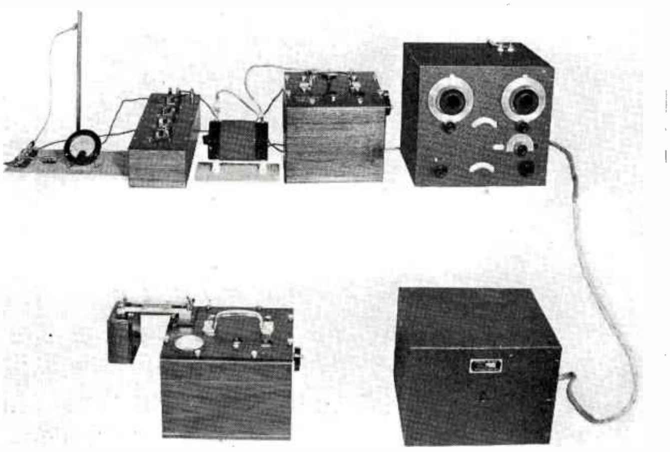
MANY stations, both foreign and domestic, have found the use of field intensity recording equipment extremely valuable in making surveys. The photographs give a very clear view of the equipment and the method of installation employed by Edwards and Martin.

It is permanently mounted on thick sponge rubber in a Ford Station Wagon type of automobile, the body of which is constructed entirely of wood.

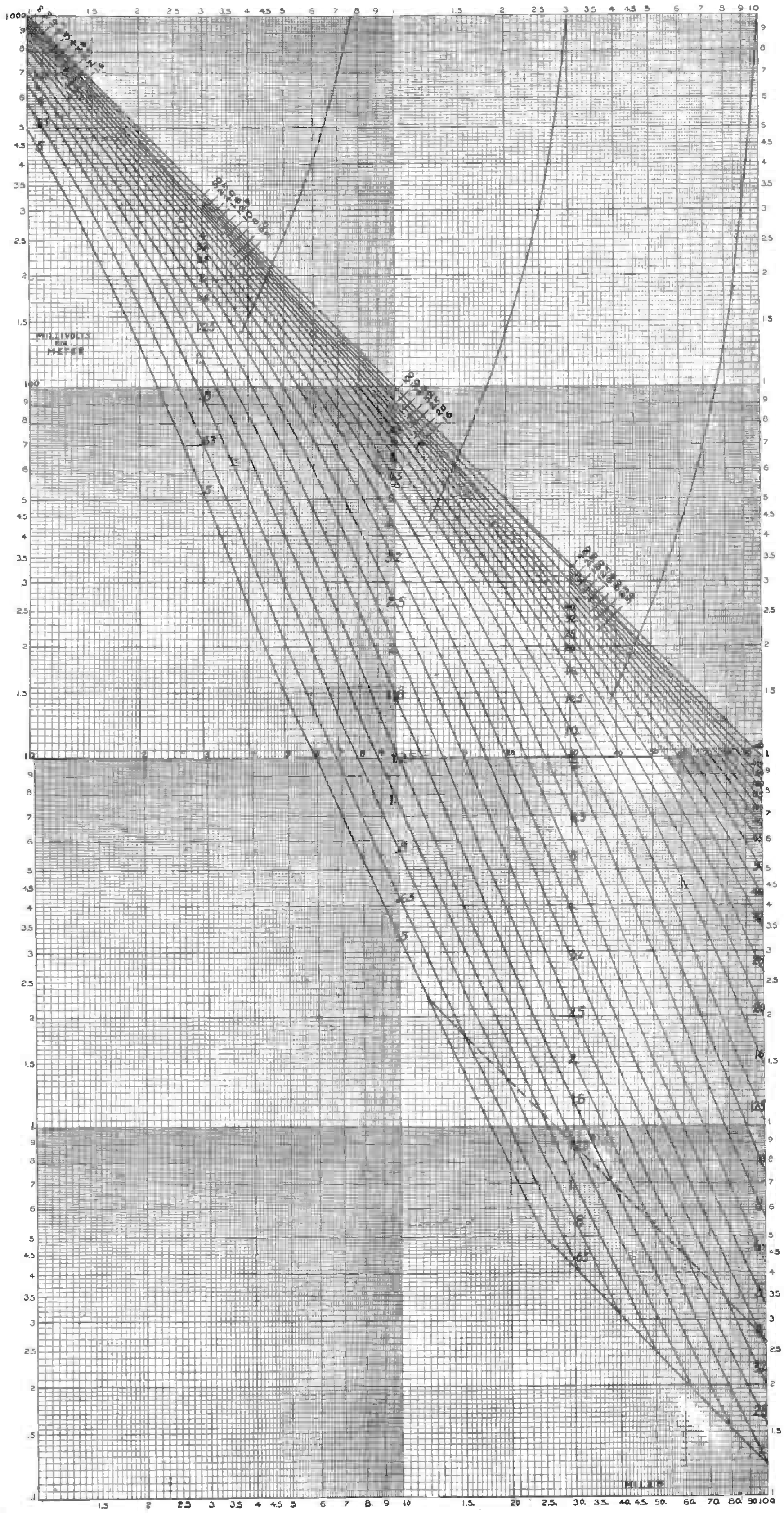
The signal recorder consists of an RCA Type M 123, Automobile Receiver with revised tuning control and calibrated RF gain control, a DC amplifier and an Esterline-Angus 0-5 recording milliammeter. The Field Intensity Meter used is an RCA type TMV 75-B, having a frequency range from 500 kc to 20,000 kc and capable of measuring, with a high degree of accuracy, signal voltages in the rance 20 microvolts per meter to 6 volts per meter.

The RCA Field Intensity Meter is not only used in all location survey and field intensity coverage survey work but is also used to calibrate the signal recorder. A jack is provided in the signal recorder to insert a 0-10 milliammeter in series with the Esterline-Angus Recording Milliammeter for the purpose of tuning and to insure an "in phase condition" when calibrating with the RCA Type TMV 75-B Field Intensity Meter.

The power supply for the Signal Recorder is furnished by an 8 volt battery and maintained constant across the power input to the recorder by means of a series resistor and volt meter.



(Left) Part of the equipment before installation.



(Cut Here)

THE FIELD INTENSITY SLIDE RULE READY FOR MOUNTING

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See instructions on Page 31

NOTES ABOUT OUR CONTRIBUTORS

LOY E. BARTON. Graduated from the University of Arkansas where he first began his investigation of Class B Modulation Systems. He is now recognized as an authority on the subject.

DR. G. H. BROWN. He began his investigations of antennas at the University of Wisconsin and his ideas and theories on wave propagation and radiation systems are now being adopted universally.

H. E. GIHRING. A graduate of Washington University, St. Louis, was a civilian employee of the U. S. Government in radio activities for several years and has been associated with RCA since 1929 on field intensity and antenna work.

E. G. LINDER, who collaborates with **DR. IRVING WOLFF** in the article on Transmission of 9 CM Waves in this issue, attended Cornell and specializes in research on short wave transmission.

MAYNARD MARQUARDT has been closely connected with the American Federation of Labor for many years, and is chief engineer at WCFL. Many of his ideas have been incorporated in the new station.

CHESTER M. SINNETT. Graduated from the University of Maine and has been in charge of phonograph development for the past several years.

JERRY STONE, who tells the interesting story about WDAS, is connected with the publicity department at that station.

FREDERICK WHEELER, a graduate of the University of Kansas, has been on the engineering staff at WREN for the past six years and at present is chief engineer.

DR. IRVING WOLFF received his training at Dartmouth and Cornell. During his affiliation with RCA he has carried on research work in acoustics and short waves.

JOHN VASSOS. Listed among the ten leading industrial designers in the United States. He is also widely known as an author, lecturer and critic.


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and it does a big job!
KOMO
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