THE TROMBONE T

HENRY M. BACH, Jr. W2GWE*

A thorough analysis of the engineering behind the Trombone T is covered in Part 1. The second half of the article will give the practical application of this data. The antenna in field tests has given W2GWE an outstanding DX signal, attested by over 140 countries worked on 14 mc since the reopening of the band

In amateur circles, there is probably no more controversial subject than that of antenna systems. By an antenna system, we include all equipment used to transmit the radio-frequency power generated in the final tank circuit. This equipment includes a means for coupling the final tank circuit to the radiator, and a radiator capable of transmitting the power itself. That the antenna system be as efficient as possible is, of course, the goal.

In the one-band amateur antenna system, when we speak of maximum efficiency, we not only include the transmission of power from the tank circuit at a single frequency, but also over a band of frequencies with a minimum of effort on the part of the amateur operator. We include in the phrase "minimum of effort" the time and energy necessary to construct, erect, and initially adjust the antenna system, as well as to maintain proper operation over the operating frequency band. The initial cost of the antenna system is likewise a prime consideration, for we have yet to meet the amateur who has used the same antenna for the past ten or fifteen years.

The Trombone T

With the above considerations in mind, we have developed an antenna system which we have called the "Trombone T." If an exceptionally efficient one-band antenna system is desired, we feel that one will have difficulty in exceeding that of the "Trombone T." We devised this antenna system with the following specific requirements in mind:

a) The system shall be wide band. The transmitter final tank circuit shall look into a resistive impedance from the highest to the lowest frequency in a single band. The physical dimensions shall be non-critical, no "in the field" adjustment shall be required, duplicating calculated dimensions shall suffice and small errors in construction shall not affect the operation. This means that the band width shall substantially exceed the band width of the amateur band.

b) The operation shall be independent of weather conditions. Rain or shine, high humidity or dry, the loading shall not change and the final d-c plate current meter reading shall not vary.

c) The feed system shall not radiate; it shall not be a hazard to humans or animals and shall be capable of being run almost anywhere. The length of the feed line shall not affect the loading; i. e., the feed line shall be "flat."

d) The radiation pattern shall not be markedly directional, for we want to work all directions.

e) The antenna system shall be protected from lightning at all times (even during transmission).

f) The same antenna system shall be equally effective for receiving and transmitting—we want only *one* antenna, and if you can't hear them, you can't work them. The system, when used for receiving, shall not only be effective with respect to signal pickup, but also with respect to noise-reduction qualities. The feed line shall be incapable of pickup.

g) Last, but most important, the finished job shall not be objectionable to the wife (or landlord, if you are unfortunate enough to have one). We have found the wife is fussier than the neighbors, so if it meets with her approval, the neighbors won't squawk—(Except for BCI).

The antenna system may be broken up into three parts, the radiator, or antenna itself, the feed system, and the coupling between the tank circuit and the feed system. We shall consider them in the order named.

The first question that arises when considering the radiator is shall it be vertical or horizontal. Each has advantages and disadvantages. We know that the vertical antenna is non-directional in the horizontal plane, and the horizontal antenna is broadly directional in the horizontal plane. *Figure 1* shows how the input resistance at the center of a half-wave radiator (actually the length of the radiator is decreased approximately 5% in order to cause the reactive term of the impedance to vanish) varies with height above ground, for the horizontal and vertical radiator. The solid lines are for the case of a theoretically

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perfect ground, the dotted line is for a horizontal antenna above typical east coast ground.* A theoretically perfect conducting ground is found only in the case of an antenna over salt water and is closely approximated in the case of salt marshy ground. These are rarely possible in amateur installations. If the radiator were in free space and the cross-sectional area of the wire used were vanishingly thin, the resistance would be 73 ohms. We all know that when we have a second antenna in proximity to our transmitting antenna, the second antenna picks up some of the energy from the transmitting antenna and re-radiates it.

Self-Impedance

A radiator has a self-impedance which in the case of a half-wave (shortened 5%), whose cross section is negligibly small with respect to the antenna length, in free space, we have said is 73 ohms. The second wire couples to the radiator; there is a mutual impedance between the radiator and the second wire. This mutual impedance may be positive or negative, and it will either increase or decrease the impedance of the radiator. The magnitude of the mutual impedance will be a function of the spacing between the radiator and the second wire.

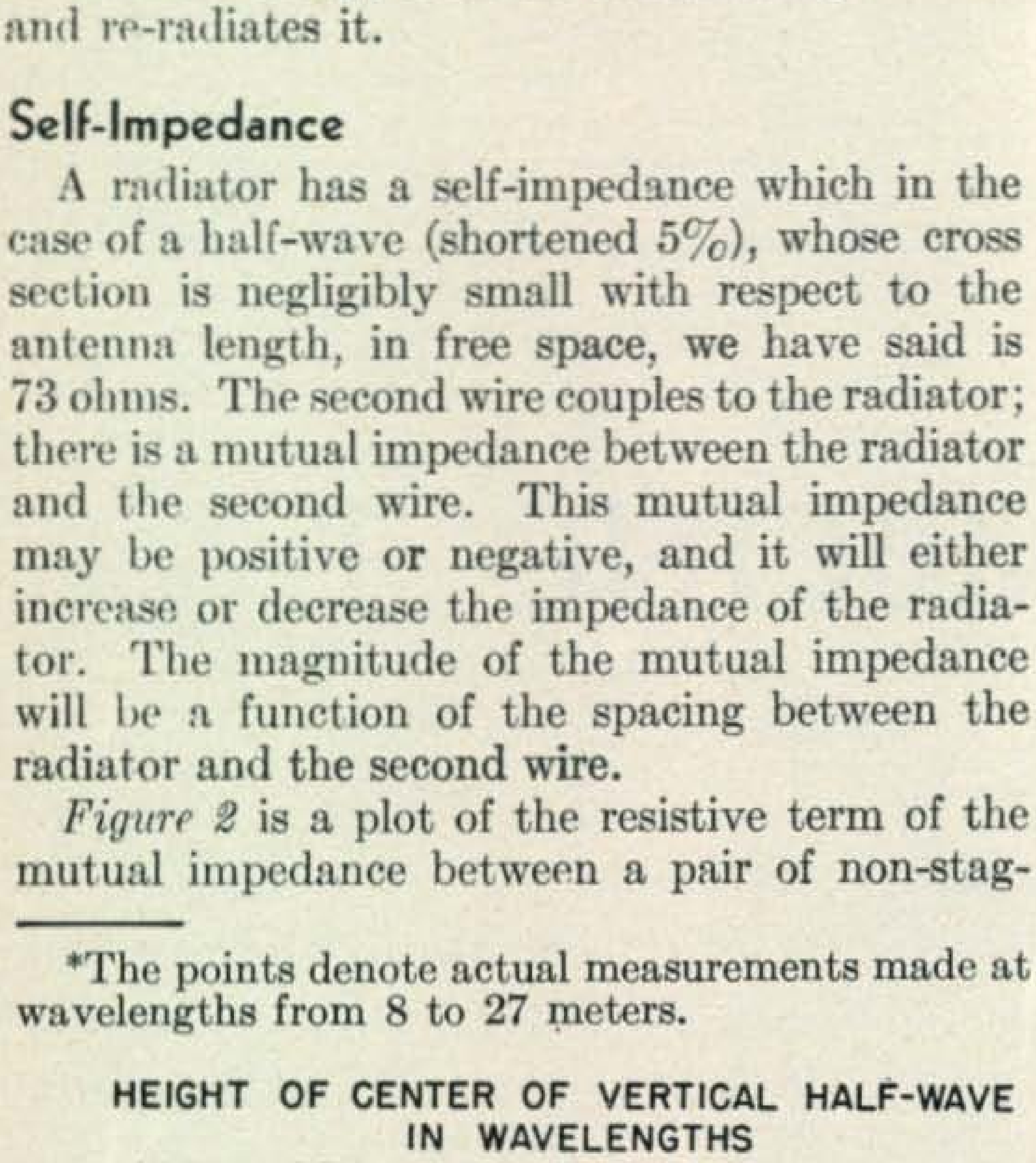

Fig. 1. Radiation resistance versus height. The solid curves are calculated for perfectly conducting ground. The points denote measurements made at wavelengths from 8 to 27 meters.

[From *Proceedings of the I.R.E.* Jan. 1934]

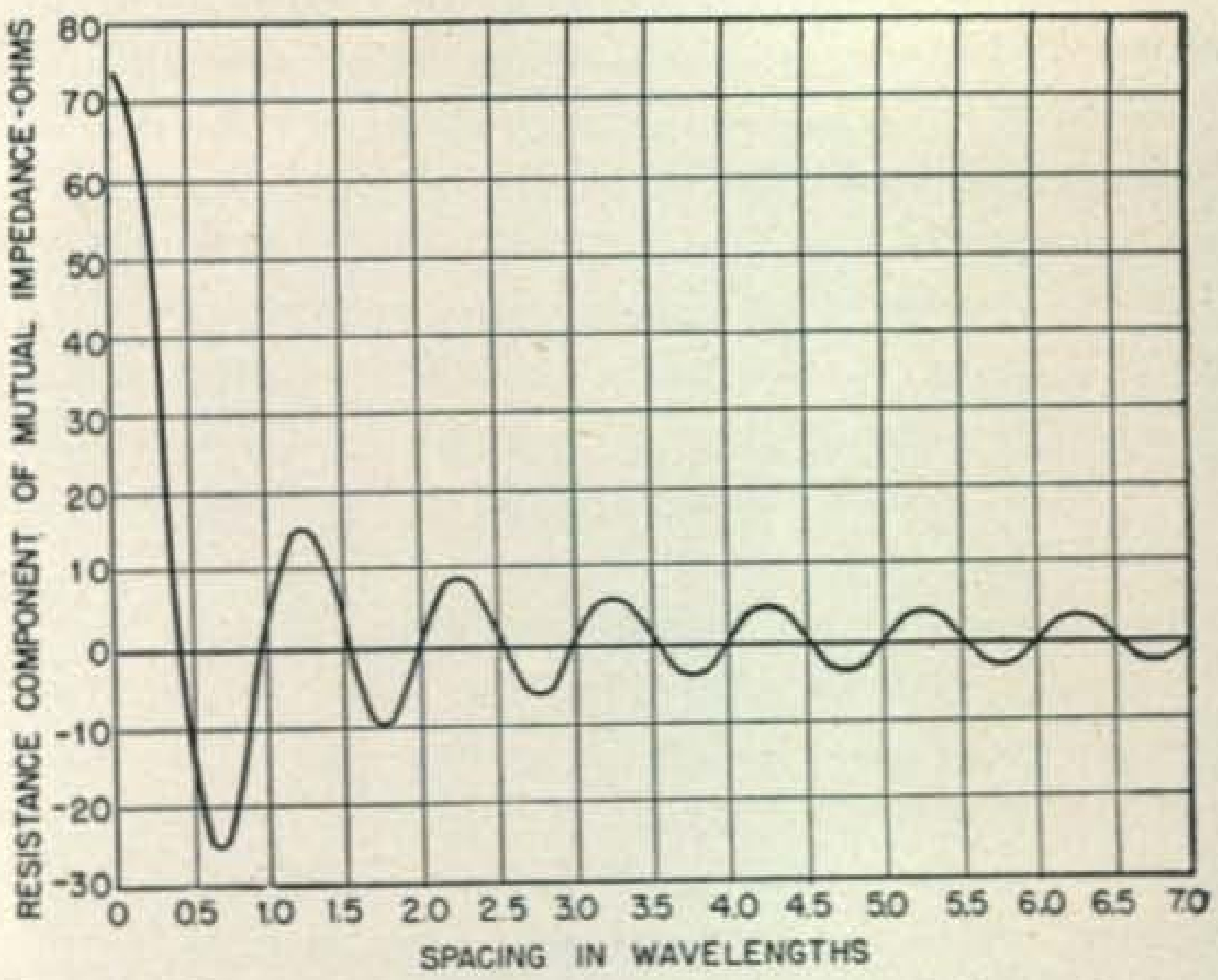

Fig. 2. Resistance component of mutual impedance between two parallel nonstaggered half-wavelength antennas.

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Figure 2 is a plot of the resistive term of the mutual impedance between a pair of non-staggered half-wavelength wires in free space as a function of the spacing between the wires. *Figure 3* represents the resistive term of the mutual impedance between a pair of colinear half-wave radiators in free space as a function of the spacing between adjacent ends. Suppose we desire to know the resistive impedance at the drive point, *D*, of the array in free space shown in *Fig. 4*. The array is seen to be a half-wave radiator stacked above a half-wave radiator, with the radiators excited in phase, producing approximately 4 db gain in the vertical plane over a single half-wave horizontal antenna in free space. The self-impedance we have said is 73 ohms. The resistive term of the mutual impedance is given by *Fig. 2* as -14 ohms. Thus the center impedance of each radiator at the feed point is 59 ohms. The half-wave feed line provides a 1:1 impedance transfer; hence the resistive term of the impedance at the feed point is $\frac{59}{2}$ ohms = 29.5 ohms.

Coming back to the half-wave radiator, the presence of the earth alters the impedance of the radiator, and may be explained by postulating a second radiator the same distance under the ground as the radiator is above the ground. In the case of the vertical radiator, the image antenna is colinear with the vertical radiator, and its top end is spaced from the bottom end of the vertical radiator by twice the distance from the bottom of the radiator to the "ground." The "ground" may be actually of the order of one-tenth wavelength below the level of the earth, as in the case of Long Island soil.* In the case of the horizontal radiator, the radiator and its image may be visualized as a stacked, two-

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*The points denote actual measurements made at wavelengths from 8 to 27 meters.

*RCA Review, October, 1939, page 131, Fig. 21.

element horizontal array with the distance between the stacked elements equal to twice the distance from the radiator to the "ground." The mutual impedance between colinear radiators is less than the mutual impedance between parallel radiators for the same center-to-center distance, so we see why the input resistance of the horizontal radiator in the presence of the earth varies by a greater amount than the input resistance of the vertical radiator. At substantially great heights above the earth the magnitude of the mutual impedance is small and the resistance at the feed point varies much less.

From *Figs. 2* and *3* we can calculate the impedance of a half-wave radiator a given height above ground. Postulating a half-wave horizontal radiator with a center self-impedance of 73 ohms (in free space) 3/10ths wavelength above a perfect ground, we proceed as follows: The image will be spaced 6/10ths wavelength from the radiator. Hence, from *Fig. 2*, the resistive term of the mutual impedance then will be −25.5 ohms. However, in the case of the horizontal antenna, the current in the image flows in the opposite direction at any instant from that in the radiator. Thus the resistive term of the impedance will be 73 ohms−(−25.5 ohms) = 98.5 ohms. For vertical radiators, *add* the mutual impedance obtained from *Fig. 3* when the radiator is an odd number of half-wavelengths long and *subtract* when the radiator is an even number of half-wavelengths long. We will find later in this paper that the self-impedance of radiators is a function of the ratio of length to diameter of the radiator. Combining the data presented above with the subsequent data on the self-impedance will provide a rather accurate figure on the impedance at the feed point of a half-wave radiator. You will see that the familiar 73-ohm value is quite a bit off!

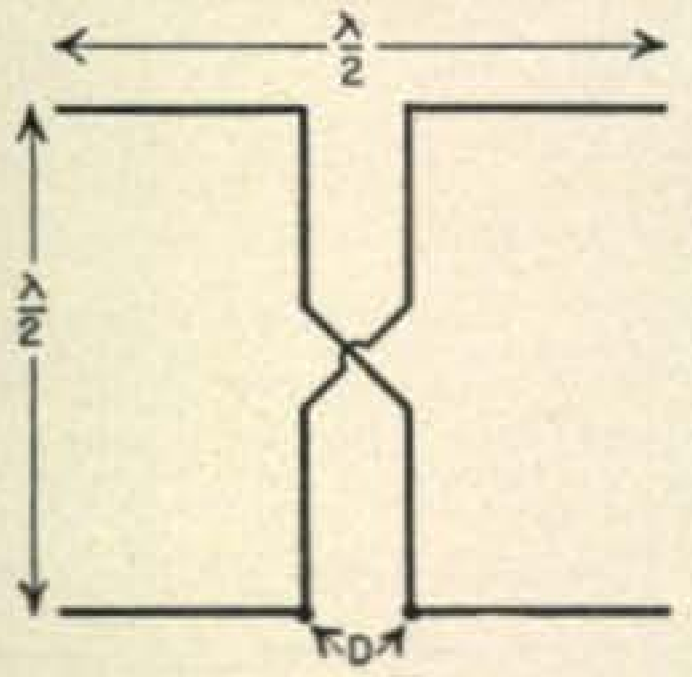

Fig. 4. Half-wave radiator stacked above a half-wave radiator, with the radiators excited in phase, producing approximately 4 db gain in the vertical plane over a single half-wave horizontal antenna in free space.

For 14-mc operation, the maximum usable vertical angles for DX communication are below 20° and probably lie between 10° and 20°. For 28-mc operation, the most effective angles are probably below 12°. For 7-mc communication, angles up to 30° are utilized, however, the low angles (below 20°) are the ones with which the DX is worked.

Figs. 5 A,B,C,D and E and *6* show the vertical plane directional characteristics of horizontal and vertical half-wave radiators for the case of perfectly conducting and typical grounds.

Provided we can get the half-wave horizontal at least a half wave above the ground, note that the horizontal is better than the vertical for typical ground conditions. In fact, we would prefer the one wave high, half-wave horizontal to the half-wave vertical even for perfectly conducting ground.

Concerning vertical directivity, the optimum height for the vertical half-wave antenna is seen to be with the center one quarter wave above ground— with the one end just at ground level, and for the case of the horizontal, enhanced results will be obtained at heights of approximately one wavelength.

The above considerations are for the case of the vertical directivity broadside to the half-wave horizontal antenna, and it should be realized that the low angle radiation off the ends will be substantially down.

The shape of the horizontal pattern of the half-wave horizontal (i.e., the pattern seen by an observer looking down at the antenna) is not affected by height above ground. The intensity of the horizontal pattern at a specific vertical angle is, however, determined by height above ground.

Horizontal Antenna Preferred

We conclude that even if one has a location with few surrounding objects (trees, houses, etc.), with an extremely good conducting soil, and is unable to get the horizontal antenna up to a

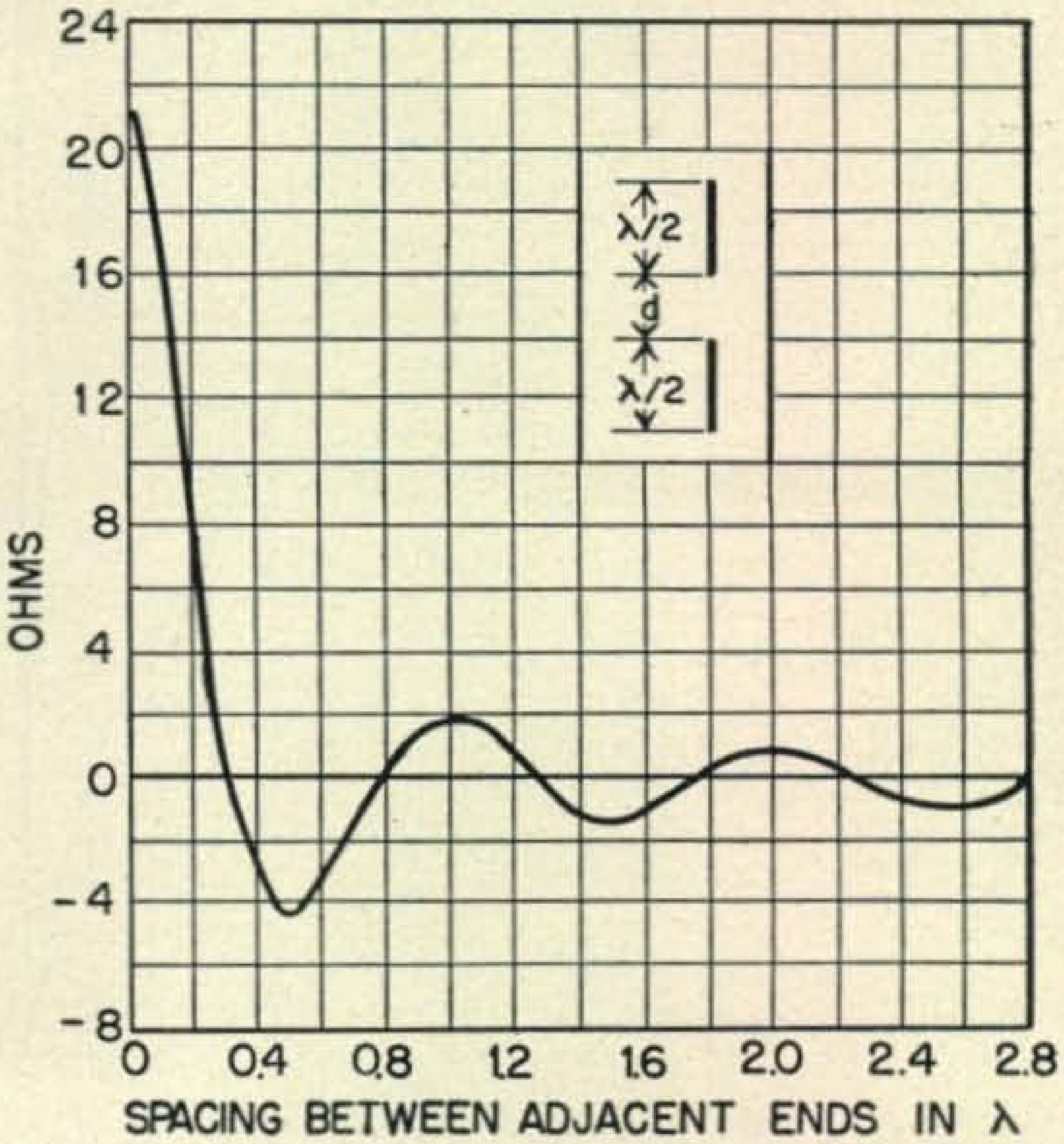

Fig. 3. Resistance component of mutual impedance between two colinear half-wave antennas.

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height of the order of one wavelength, nevertheless the horizontal antenna is to be preferred.

Now that we have decided to use a half-wave horizontal radiator placed as high as possible, we shall next consider the radiator itself.

The radiator shall be center-fed, since only in a symmetrical antenna system will the entire system be balanced with respect to ground, and the radiation pattern be symmetrical.

Table 1 shows how the input impedance at the center of the "shortened" half-wave 14.1-mc antenna varies with the ratio of length to thickness, how the end impedance varies and how the percentage that the length of the antenna must be decreased in order to present a resistive impedance increases as the thickness of the antenna is increased.

If we were going to erect a half-wave antenna for 14 mc using No. 12 wire and the antenna were going to be 40 feet high, we would calculate the center impedance in the following manner:

From the table we see that the resistive term of the self-impedance will be 67.85 ohm (neglecting ohmic resistance of the No. 12 copper wire, since it is only of the order of .05 ohms). One wavelength at 14 mc is roughly 70 feet. The actual ground will be approximately one-tenth wavelength below the ground for the case of Long Island soil so the spacing between the radiator and its image will be $\frac{47}{70}$ x 2—1.34 wavelengths which, from *Figure 2*, means the resistive term of the mutual impedance will be +11 ohms. The

14.1 MC Half-Wave* Dipoles in Free Space

Diameter of radiator in inches	Resistive value of center impedance* in ohms	Resistive value of end impedance* in ohms	% shortened from Half-wave
.064 (#14)	68	4050	2.83
.081 (#12)	67.85	3850	2.87
.102 (#10)	67.75	3700	2.95
.129 (#8)	67.52	3600	3.05
.250	66.95	2850	3.35
.375	66.47	2450	3.55
.500	66.1	2220	3.75
.750	65.5	1875	4.00
1.00	65.15	1725	4.2
1.125	64.9	1625	4.3
1.250	64.75	1560	4.4
1.375	64.6	1500	4.45
1.5	64.4	1440	4.55
1.75	64.1	1340	4.6
2.00	63.85	1260	4.85
2.50	63.35	1140	5.1
3.00	62.9	1045	5.35

*Length of antenna shortened from half-wave value $\left[L_{ft} = \frac{492}{\text{freq. (mc)}} \right]$ to cause reactive term impedance to vanish.

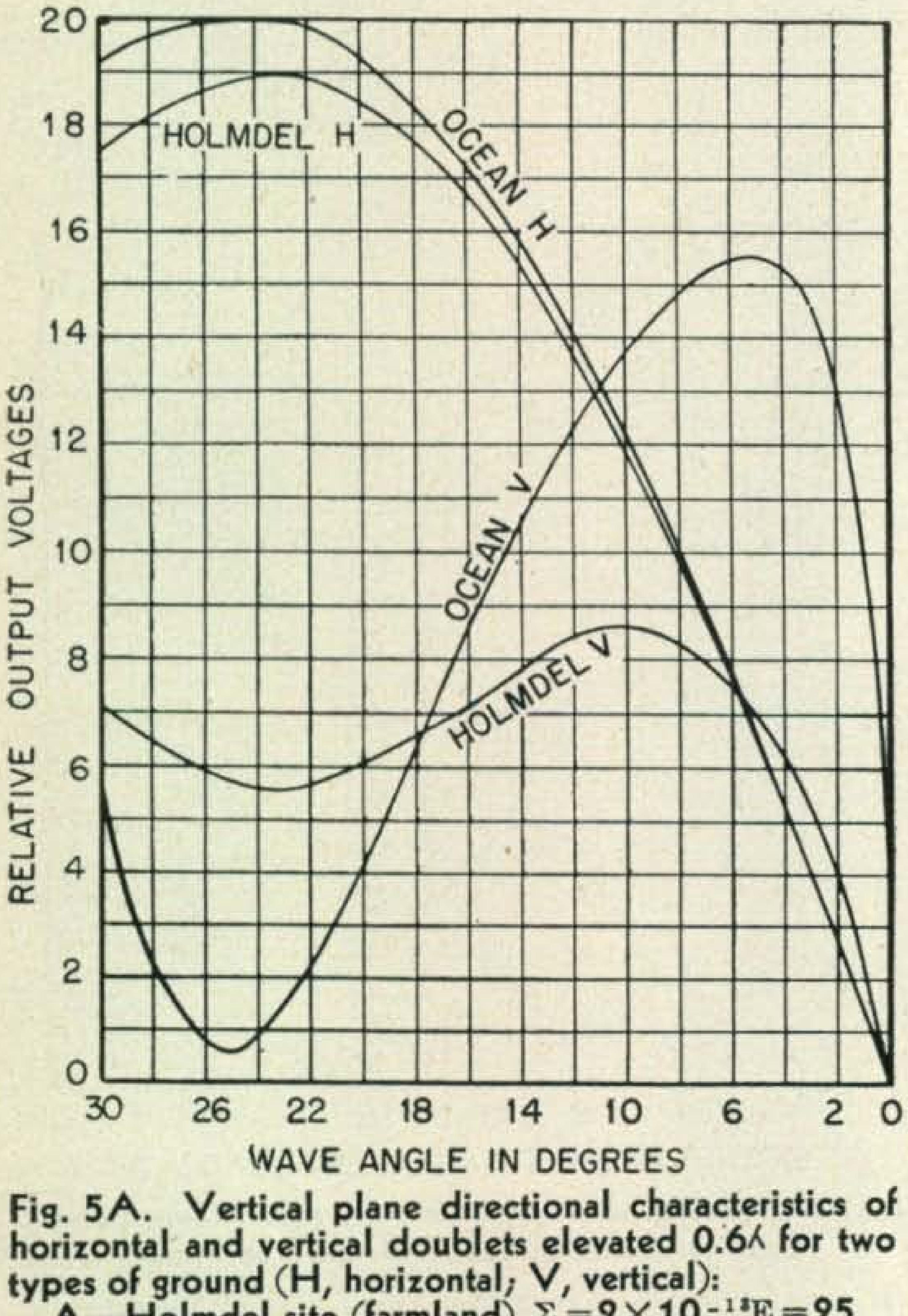

Fig. 5A. Vertical plane directional characteristics of horizontal and vertical doublets elevated 0.6λ for two types of ground (H, horizontal; V, vertical):
A—Holmdel site (farmland) $\Sigma = 2 \times 10^{-13}E = 25$.
B—Ocean site (salt marsh) $\Sigma = 3.3 \times 10^{-11}E = 80$.
[From *Proceedings of the I.R.E.*, April, 1932]

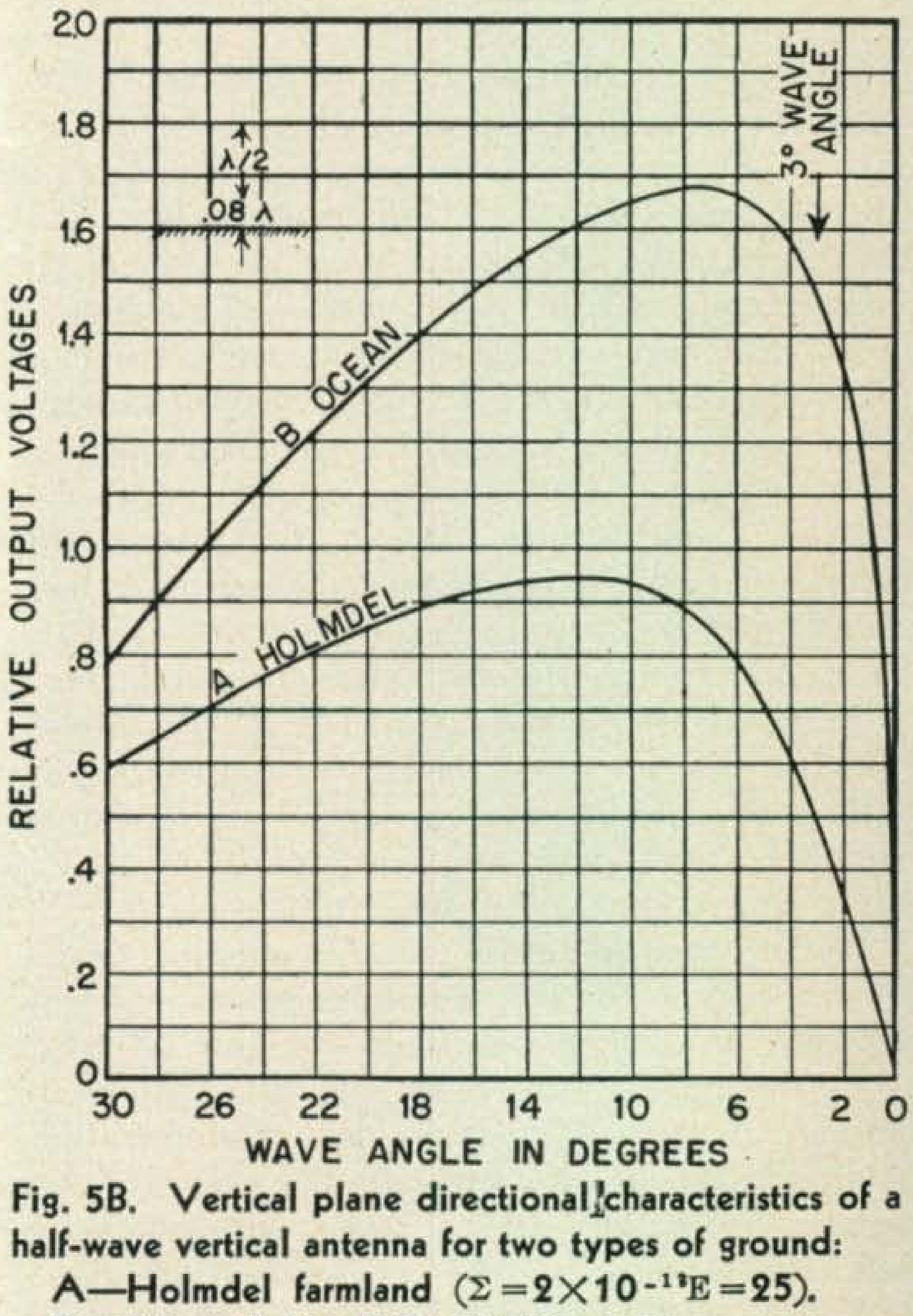

Fig. 5B. Vertical plane directional characteristics of a half-wave vertical antenna for two types of ground:
A—Holmdel farmland ($\Sigma = 2 \times 10^{-13}E = 25$).
B—Salt marsh ($\Sigma = 3.3 \times 10^{-11}E = 80$).
[From *Proceedings of the I.R.E.*, April, 1932]

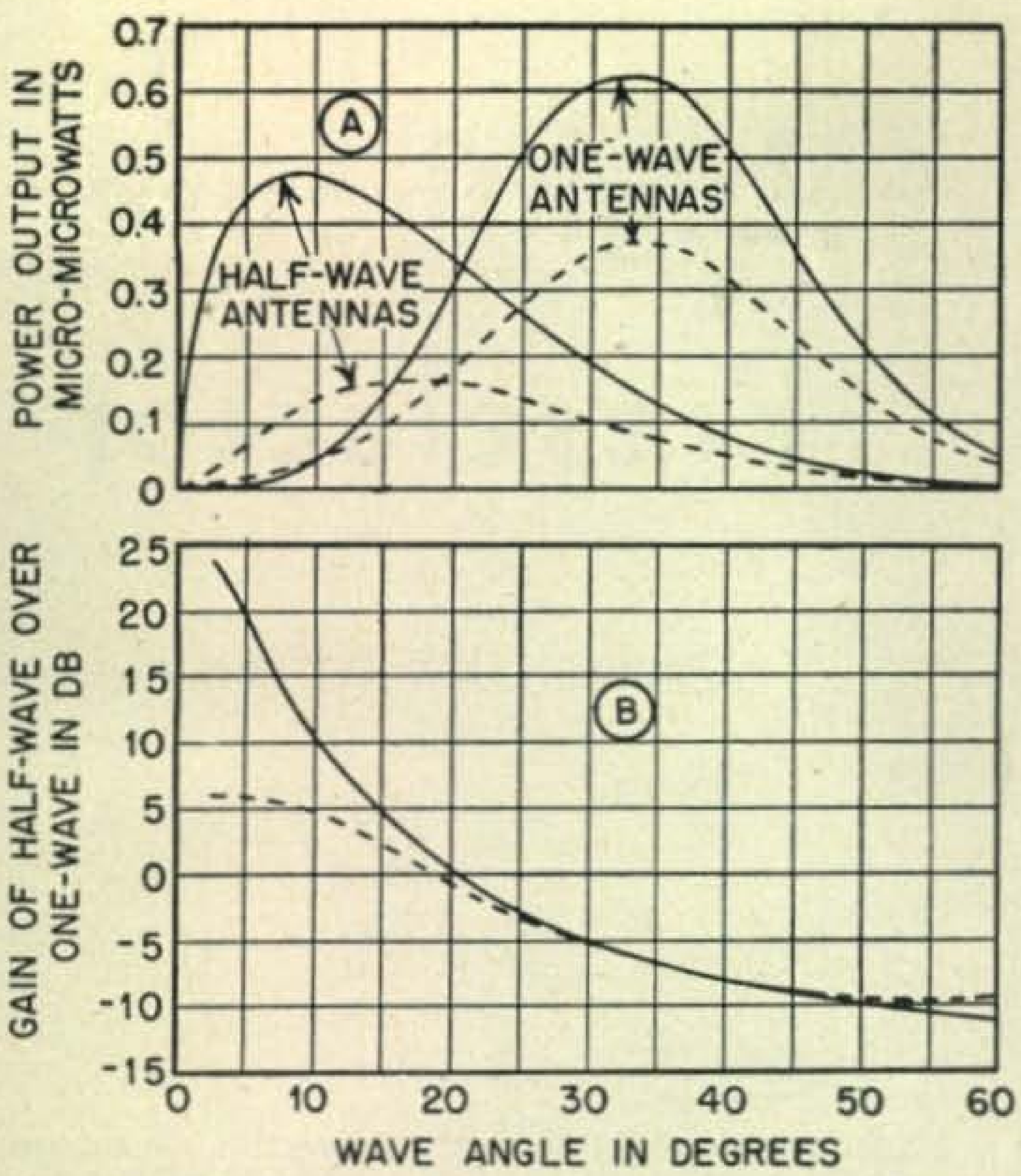

Fig. 5C. A shows vertical directional patterns of half-wave and one-wave vertical antennas. The solid curves are for ocean water (dielectric constant = 80, conductivity = 4×10^{-11} e.m.u.). The broken curves are for Holmdel ground (dielectric constant = 25, conductivity = 1.3×10^{-13} e.m.u.). The wavelength is assumed to be 25 meters and the incident field intensity one microvolt per meter. In B the ratio of power expressed as a gain is plotted for the two types of ground. The angle Δ is measured from the horizontal. The lower ends of the antennas are assumed to be in close proximity to the ground.

[From *Proceedings of the I.R.E.*, Jan., 1934]

impedance at the feed point then will be 67.85-11 = 56.85 ohms. We will obtain an almost perfect match with 52-ohm cable—RG 8/U, and we will have a mismatch with 73-ohm cable—1.3:1 standing wave ratio.

The "Q" or sharpness of a radiator is a function of the ratio of length to thickness—the thicker the radiator, the blunter the resonance becomes (and the lower the input impedance at the center). A worthwhile improvement at the higher frequencies can be obtained by using 1″ elements over the more generally used No. 12 or No. 14 wire.

However, the half-wave antenna is not sufficiently broad at 14 mc with a 1″ diameter conductor to present a purely resistive impedance to the feed system over the entire band.

The Folded Dipole

The folded dipole type of radiator, however, has a much lower "Q" and the resonance is sufficiently blunted to present a resistive impedance over the entire 14–mc band. The principle of the folded dipole is quite simple, and a short discussion of it will dispel some of the mysteries that seem to surround it.

Consider first an antenna of length $\frac{2k+1}{2}$ wavelength where k is zero or any positive integer. This antenna will have a current maximum at the center and for the special case of $k = 0$, the input resistance R_{in} will equal 73 ohms when the antenna is a multiple of a quarter-wavelength high, is shortened slightly to eliminate the reactive term, and the cross-section is vanishingly thin with respect to the length. The power radiated, P_r, by the antenna will equal the square of the current, I, times this resistance R_{in}:

$$P_r = I^2 R_{in}$$

(Neglecting the heating loss in the antenna wire itself, which is negligible.) Now if we parallel two half-wave antennas, split and feed one at the center and space them sufficiently close together so as not to alter their coupling to the universe from that of the single antenna, we will make an important change in the input resistance. The current in the parallel elements is in phase, and the radiated power is unchanged from that of the single dipole. Each parallel element carries but half the current of the single dipole—the current in each of the parallel elements is $I/2$. The input resistance at the feed point may be obtained by equating the equal powers:

$$P_r = I^2 R_{in} = \left[\frac{I}{2}\right]^2 R'_{in} = \frac{I^2}{4} R'_{in}$$

[*Continued on page 70*]

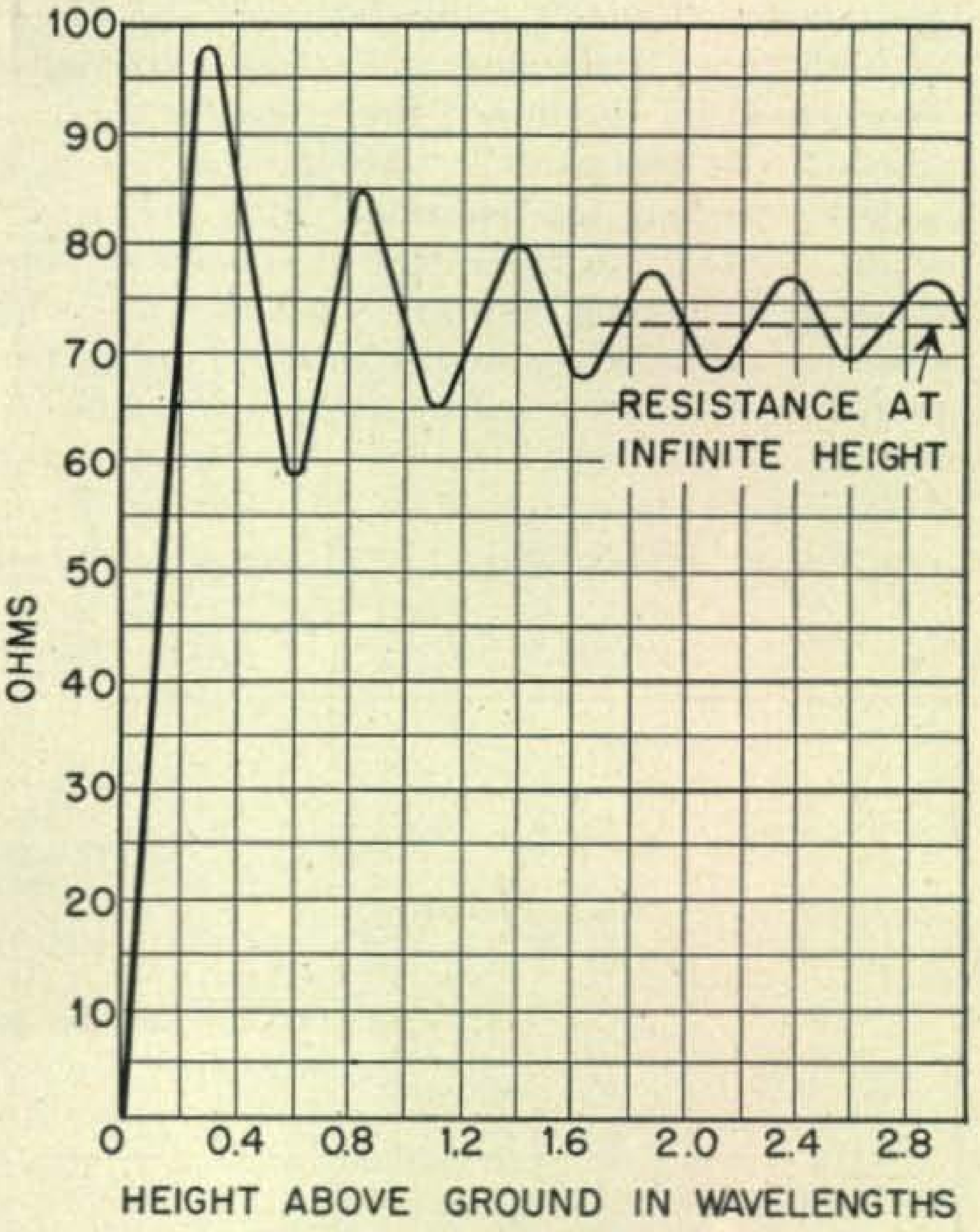

Fig. 5D. Half-wave dipole radiation resistance versus height (perfect ground assumed).

[From *Proceedings of the I.R.E.*, June, 1932]

of his pants. Then we watched W6BIP's toddler get a round of applause after he personally investigated that big key and tried it out. Now—there is an up and coming c-w man!

We talked to W6OJU who, on Aug. 25th, worked W6PZQon 2 for a near record of 270 miles!

Then we watched that old Texas Cow Poke, W6TCP, a v-h-f-minded character if you ever met one, win a BC-375 transmitter on a raffle. TCP wasn't quite sure what he had won—just wait until he opens that crate! Well, maybe he can salvage some of the parts, anyway!

The list of those present would look like a west coast's Who's Who in Hamdom and we were really pleased to have the opportunity to meet so many of the W6 gang. Now we know what they look like. Honest, gang, they don't speak with that characteristic W6 note at all.

There was one feller there with a fine 22, complete with 'scope. We never did figure out what he was aiming to do with that firearm at a peaceful hamfest. Maybe he had some gripe we didn't know about!

When the prize was awarded for the ham who came the farthest distance, I was busily engaged in bending somebody's ear and did not hear the announcement. When W6OIN of San Diego was called to the platform and offered the prize, Ray stated that W2OEN/1 from Connecticut was in the audience. Evidently the master of ceremonies thought that Connecticut was just another of those inland California counties and he pressed the prize on W6OIN, who, by the way is another Sub Sig alumnus and a very good friend of the writer.

Anyhow—after holding a raffle ticket ending in the number 13 which didn't pay off, and after coming clear across the entire USA to attend their hamfest, I get left out on an 815 by an MC who doesn't know his geography. Nevertheless a really good time was had by all, including Mr. and Mrs. W1CA from Connecticut. That's a *state*, Son!

TROMBONE T

[*from page 31*]

where R'_{in} is the input resistance of the folded dipole.

The squares of the currents cancel and we see that R'_{in} is four times R_{in}. For the case of $R_{in} = 73$ ohms, $R'_{in} = 292$ ohms. For the case of $R_{in} = 52$ ohms, $R'_{in} = 208$ ohms.

Thus we see that the input impedance of the folded dipole when fed at the center approximates 300 ohms for an antenna height of a quarter-wave or multiples thereof and a thickness that is vanishingly thin with respect to the antenna length. For other heights it is equal to four times the resistance of a half-wave antenna at the same height.

Incidentally, the use of *N* wires, each of equal diameter, opening one at the center for feeding, will increase the resistance at the feed point over that of a single wire by the factor n^2. (This is derived in *Appendix A.*) This of course holds true only when the spacing between the wires is very, very close with respect to a half wave in order that the coupling to the universe not be altered from that of the single dipole.

Following the same analyses, using two (or more) wires of different diameter, the currents in the two wires will be dissimilar (but will be of the same phase), and by opening the smaller of the two at the center, resistance values greater than four times may be obtained, the values being a function of the ratio of the currents. By opening the larger of the two conductors the resistance will be less than four times, lying between one and four times the value of the single half-wave dipole, as a function of the ratio of the currents in the two conductors.

We have stressed that the currents in the two branches of the folded dipole are in phase. Thus even if the folded dipole is constructed from the

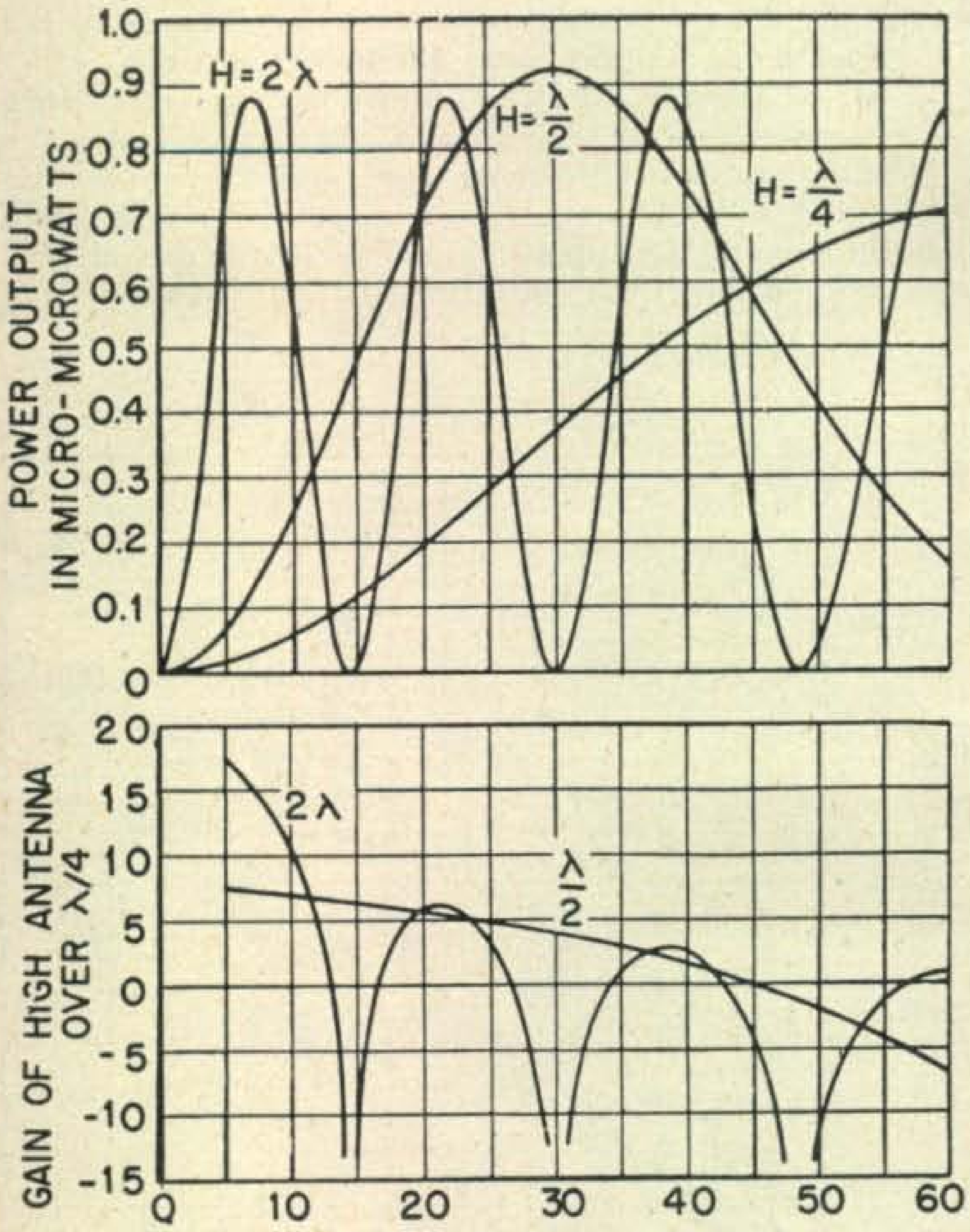

Fig. 5E. Vertical directional patterns of horizontal antennas calculated for perfectly conducting ground. The wavelength is assumed to be 25 meters and the incident field intensity one microvolt per meter.

[From *Proceedings of the I.R.E.*, Jan. 1934]

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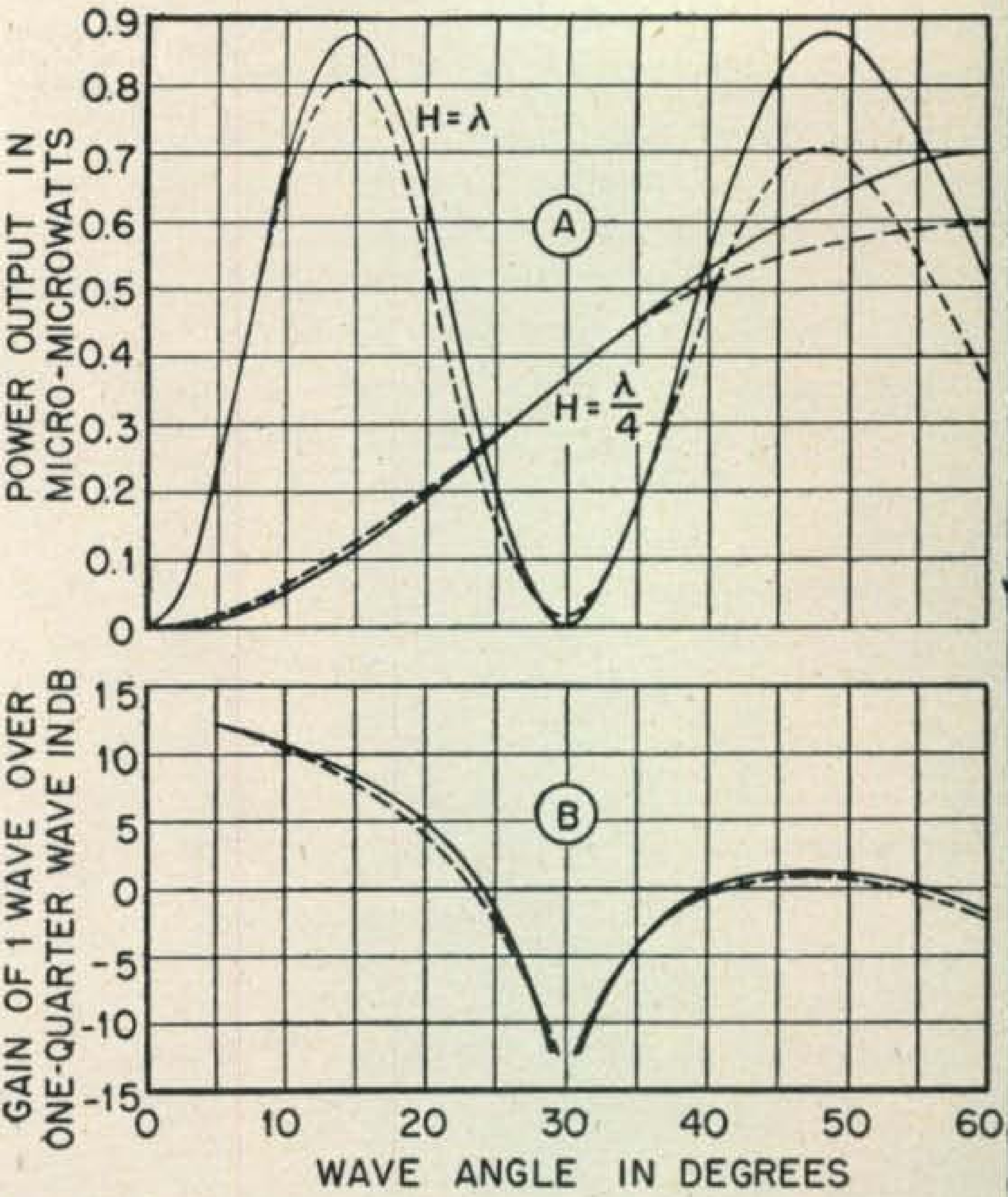


Fig. 5E. A shows vertical directional patterns in the median plane of horizontal antennas. *H* denotes the height above ground. The solid curves are calculated for perfectly conducting ground, the broken curves for Homldel ground (dielectric constant = 25, conductivity = 1.3×10^{-13} e.m.u., wavelength 25 meters, and the incident field intensity one microvolt per meter). *B* shows the corresponding gain curves.

[From *Proceedings of the I.R.E.* Jan. 1934]

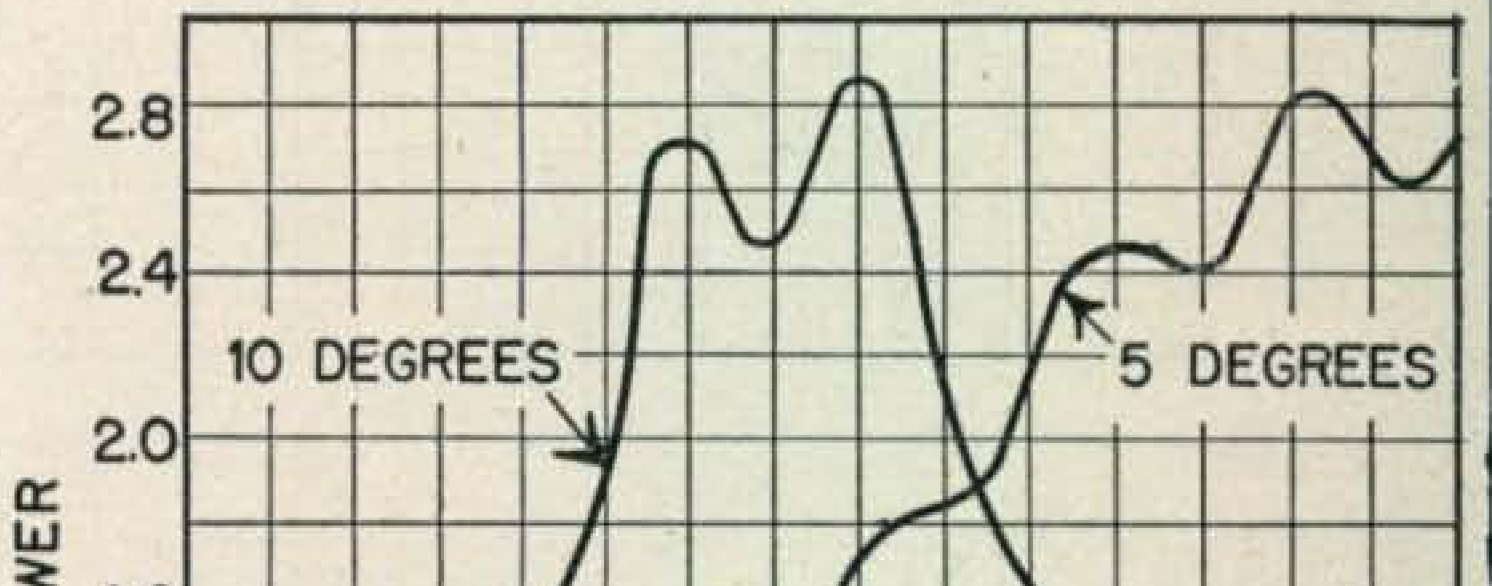


Fig. 6. Half-wave horizontal dipole relative radiation at elevation angles of five and ten degrees vs. height above ground. (Perfect ground assumed).

[From *Proceedings of the I.R.E.* June 1932] containing a dielectric is shortened by the V. P. of the dielectric only when the lines of force are *through* the dielectric. In the case of a twin parallel conductor or coax containing *out-of-phase currents*, the electrical length is reduced by the V. P. of the cable. When the conductors are carrying in-phase currents the lines of force are not through the dielectric, and the velocity of propagation is as with air dielectric. The electrical length of a half wave is 95% of the physical length. This has been experimentally verified at a frequency of 100 mc by Marvin Kronenberg, W2IJU. He verified that half-wave antennas of No. 14 wire and twin parallel conductor (known as Twin 300) shortened to provide a resistive impedance, were of the same length.

[*To be continued next month*]

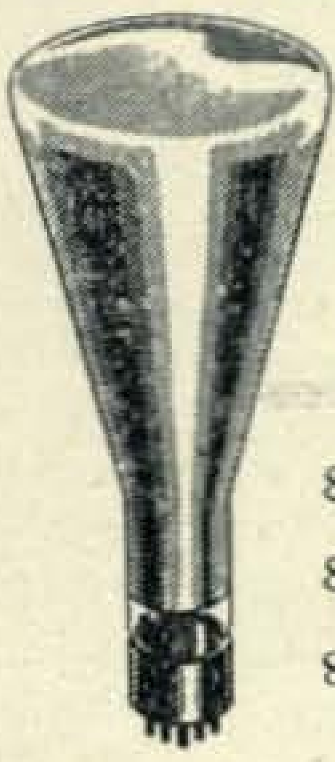
DX PREDICTIONS

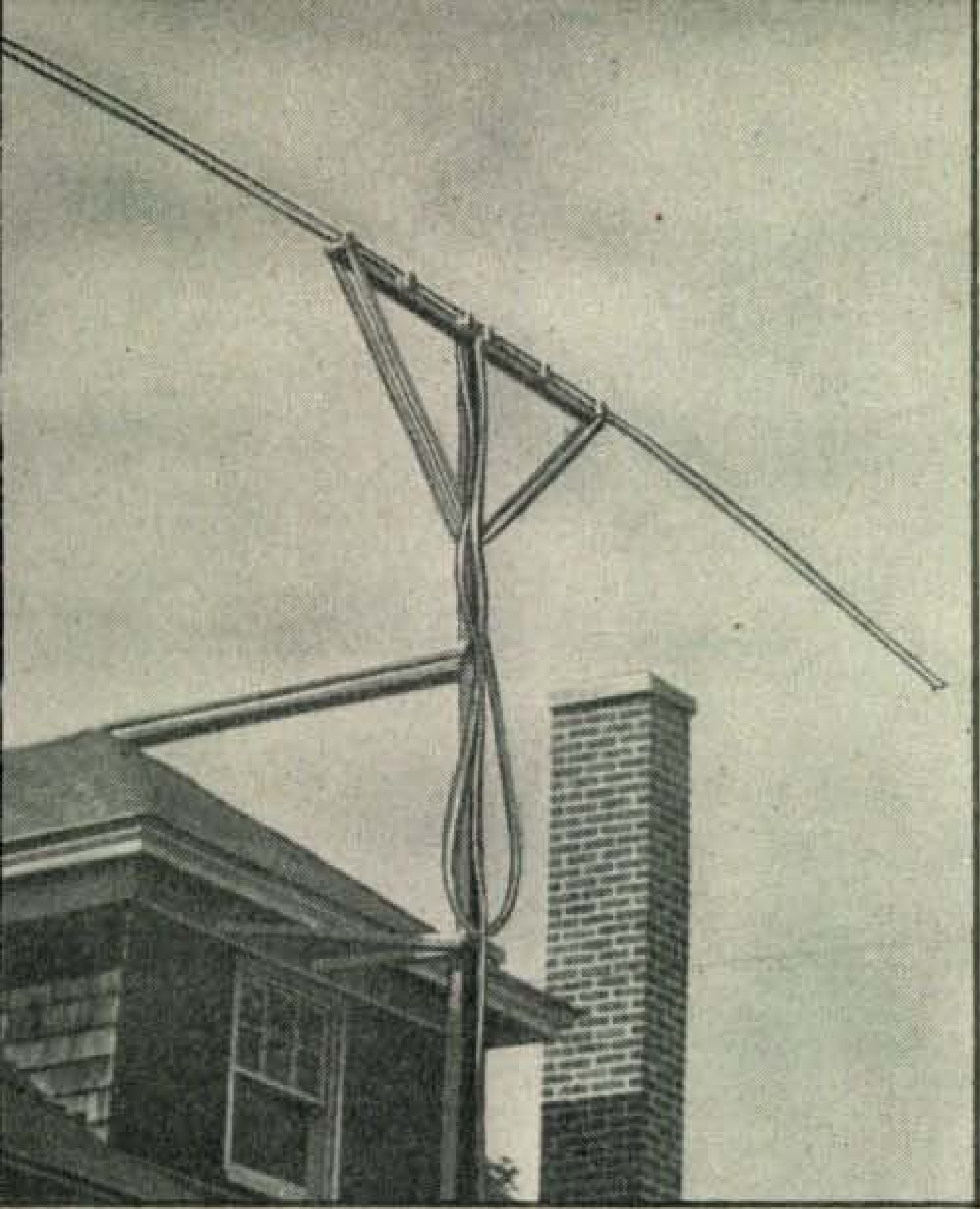
[*from page 35*]

twenty-four hour clock scale on the abscissa and the frequency in megacycles on the ordinate scale. The upper or outer trend outline is the MUF while the inner trend line is the OWF. Entering the graph at the left hand border we find that the MUF trend crosses the 20-meter band at about 0350 hours EST. This means that conditions of ionization in the upper atmosphere are such that they will support 14-mc communication. However the optimum working frequency (OWF) when 20 meters will definitely be open on this particular path does not occur until shortly after 0500 hours EST. Neglecting sub-solar signal absorption around midday, 20 meters will then be open, equal to the span of the OWF, or closing down after 1800 hours EST. Although this path may not actually close after 1800 hours and since daily variations in the length of the opening do occur, it is necessary to include the margin of safety afforded by the frequency separation of the MUF and OWF scales. Therefore, the graph indicates that 10 meters over this path may open with scattered signals as early as 0645 hours EST and will close at about 1300 hours EST. On 10 meters the peak conditions are relative to the noticeable peak in the MUF outline, or in other words, conditions should be excellent between 1000 and 1100 hours EST.

The path from the eastern section of the United States to the general London-Paris area, which is not illustrated this month, is expected to reach a peak MUF of approximately 39.0 to 40.0 mc, although by the first week in April this will have dropped to about 32.0 mc. During the first few weeks of March, 10 meters will open on this path at about 0645 hours EST and should not close down till after 1500 hours EST.

The South Americans make the most notable improvement during March and April. This is illustrated in *Fig. 2*. A peak MUF of about 44.0 mc is expected around 1500 hours EST, or if you are in the middle west around 1530 hours CST and 1400 hours PST, if you are on the west coast. Good 10-meter conditions are expected from 0730 to 1830 hours EST. It will be noted that during this particular season of the year, the 20-meter band may stay open nearly twenty-four hours with only the likelihood of a slight dropout around 0445 hours





The Trombone T

HENRY M. BACH, Jr. W2GWE*

The engineering design behind the simple, but very effective Trombone T was covered in March CQ. Completing the series, the author discusses several other design features and gives details of actual antenna construction

Clearly visible in the photograph of the complete Trombone T, is the folded dipole constructed of Premax antenna elements and also the quarter-wave trombone matching section.

THE LENGTH OF THE BAZOOKA or quarter-wave transformers should *not* be shortened by the V.P. of the cable, since the out-of-phase currents are carried by the *outer* conductors of the transmission line and the bazooka. The dielectric comprises the two thicknesses of vinylite outer coverings, and the air between the bazooka and the transmission line. Since the spacing between the quarter-wave transformer and the feed line will be much greater than the thickness of the vinylite and thus the dielectric is mainly air, the transformer length should be a quarter-wave times .95. A preferred method of installation would be to remove the vinylite sheath (vinylite is a rather poor electrical insulation), and to space the line approximately 1″. In fact for this type of quarter-wave transformer, coax is no better than standard tubing having the same O. D. as the outside diameter of the outer conductor of the coax used for the transmission line.

While on the subject of the quarter-wave transformer, much better results will be obtained if it is made of tubing larger than the coax, with the coax placed inside the tubing, used as a sheath. The vinylite should be removed from the coax for a distance of a quarterwave and annular rings of insulation used as spacers to center the coax concentrically within the tubing. No connection need be made between the tubing and the coax at the antenna, and at the other end of the quarter-wave tubing, the tubing is connected to the outer conductor of the coax. (See *Fig. 7*). If the diameter of the quarter-wave shield is much larger than the diameter of the coax, the vinylite may be left on the coax.

It is important to point out that coax is actually a *three-wire line*. The transmission or feed-line currents flow on the outside of the inner conductor and the inside of the outer conductor. Antenna currents flow on the outside of the outer conductor. The above shorted quarter-wave stub prevents the antenna currents from developing on the outside of the outer conductor of the coax.

In the case of the twin-conductor cable used as a folded dipole radiator, the out-of-phase currents are between the two quarter-wave sections, and the amount of polyethylene dielectric is manifestly negligible with respect to the air dielectric between corresponding portions of the sections. The polyethylene dielectric between the two *conductors* of each section is of no effect save that it acts as an insulator, since the currents in the two conductors of each section are in phase.

Our digression on coax was intentional, since as will be seen, we are going to feed our folded dipole with coax. Properly matched, coax is capable of transmitting efficiently the power from the final tank circuit to the antenna. The loss in present-day coax is negligible, it may be run anywhere, it will not radiate (provided the coax is detuned so the outside conductor cannot carry antenna currents; it will not radiate feeder current), it presents no hazard since the outside is "cold," and it is not affected by humidity.

However, a coax feeder is unbalanced with respect to ground since the outer conductor has a larger capacity to ground. This unbalance is not important when feeding a quarter-wave vertical or other types where it is desirable to have the generator appear between the base or feed point and ground as shown in (*a*) of *Fig. 8*. However, in a half-wave horizontal, *Fig. 8* (*b*), the capacity to ground of both sections is equal, and the feed line should be balanced with respect to ground to preserve the symmetry. *Fig. 8* (*c*) shows the de-

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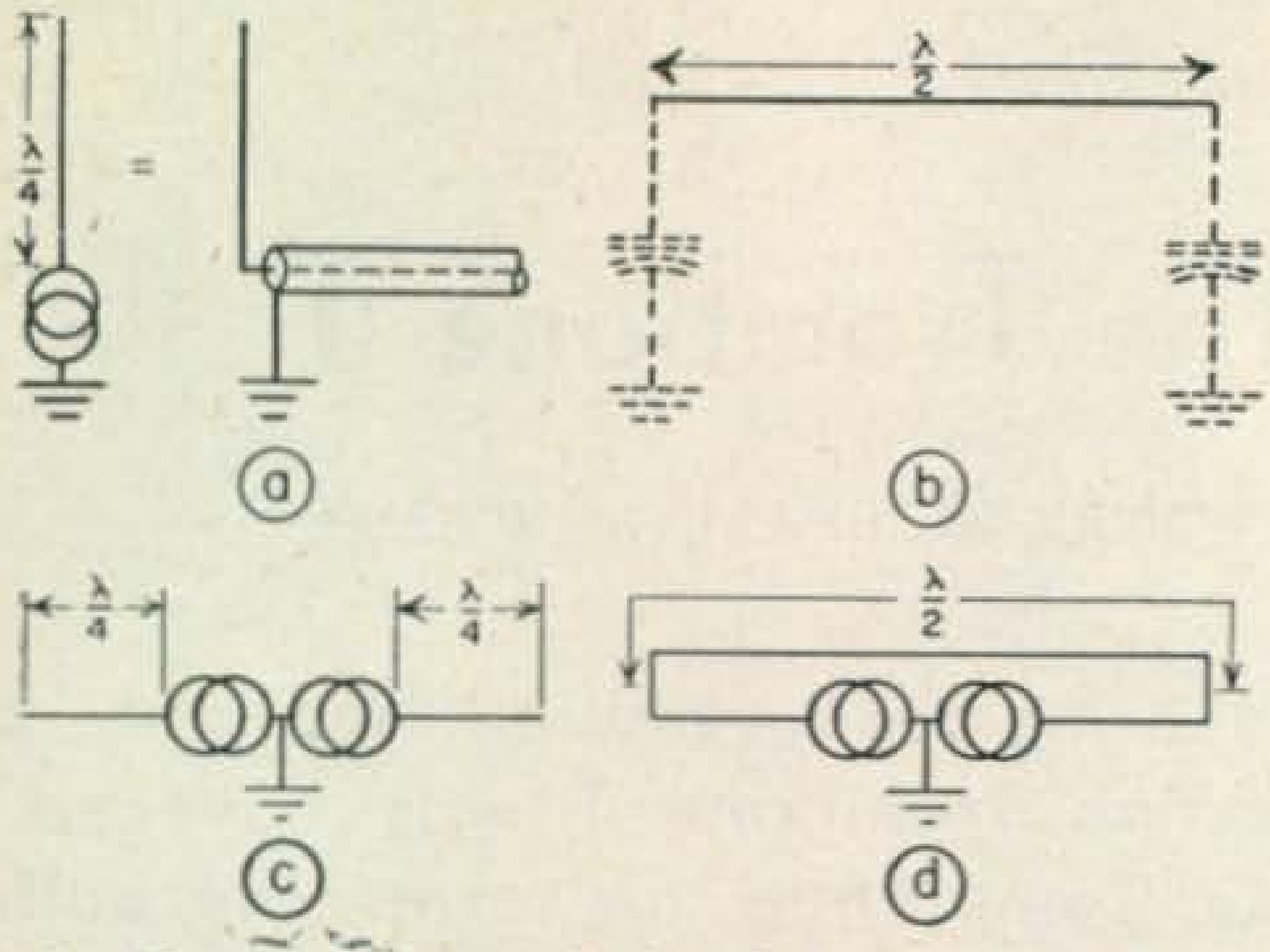


Fig. 8. Development of the balanced feed system required for any folded dipole (see text).

sirable symmetrical feed for the center-fed antenna. The folded dipole requires the same balanced feed system as shown in *Fig. 8* (*d*). The input into which the feed line looks, in the case of the center-fed, half-wave dipole, is shown in *Fig. 9* (*a*), and for the folded dipole, in *Fig. 9* (*b*), In *Figs. 9* (*c*) and (*d*), the symmetrical resistances with respect to ground are shown, and the points *A* and *B* must be excited 180° out of phase.

Coax cable is supplied in surge impedances of approximately 52 ohms and 73 ohms. Whereas impedances as high as 125 ohms may be obtained, the coax cable is expensive and the attenuation is higher due to the substantial departure from the optimum ratio between conductor diameters. Further, for a given O. D., the power-handling capacity is reduced because the center conductor diameter is less for a given O. D. in higher impedance coax, and can dissipate less heat.

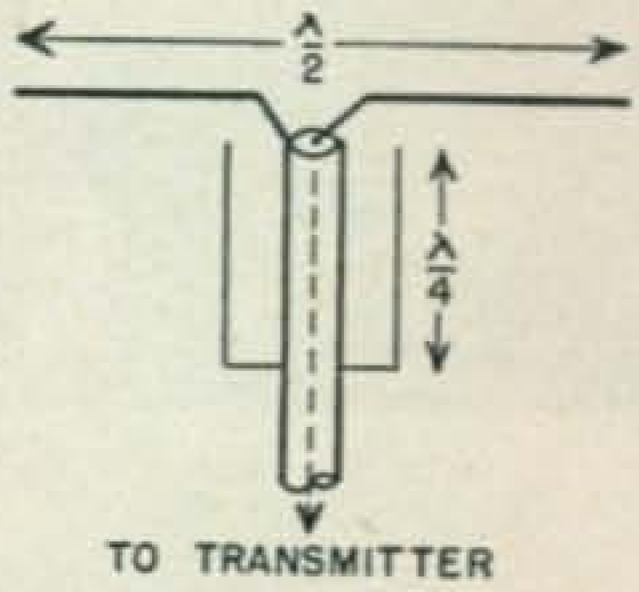
If we were to feed our folded dipole with standard 73-ohm cable we see that a bad mismatch would occur, and further, the balanced feed between *A* and *B* and the ground or datum point would not be realized.

The writer was confronted with the following problem: A folded dipole radiator was desired to provide entire band operation and a coax feeder was wanted for the reasons outlined above. Yet the feed impedance of the folded dipole was 292 ohms symmetrical with respect to ground and the impedance of the coax feeder was 73 ohms, nonsymmetrical with respect to ground. We have named our solution to the problem, "The Trombone T."

Referring to *Fig. 9* (*b*), it will be noted that the impedance between *A* and *B* is equal to 292 ohms which in *Fig. 9* (*d*) is shown to be equal to an impedance of 146 ohms between *A* and ground and an impedance of 146 ohms between *B* and ground. Points *A* and *B* must be fed 180° out of phase. If we were able to parallel points *A* and *B* we would have an impedance of 73 ohms between the junction of *A* and *B* and ground, one side of this impedance being grounded. This would be perfect for the coax feeder. However, *A* and *B* cannot be directly paralleled, since it would be impossible to effect the phase reversal between *A* and *B*.

Consider now a half-wave transmission line used as a transformer. The half-wave transmission line effects the transformation $Z_{in} = Z_{out}$ and the phase is shifted 180°. Hence, if we were to connect the points *A* and *B* together through a half-wave transmission line, we would effectively parallel the points *A* and *B*, yet would feed *A* and *B* 180° out of phase. Refer to *Fig. 10*, in which we show this junction. Now we can feed the antenna between *A* and ground, or between *B* and ground, and the impedance looking in at the feed point will be 73 ohms. Just as in *Fig. 9* (*d*) it was shown that the ground was the electrical midpoint between *A* and *B*, the same applies to the other antenna element of the folded dipole. *Fig. 11* shows the entire arrangement of the "Trombone T." The center of the unbroken element is connected to the outer conductor of all three concentric terminations, and by grounding the outer conductor of the feed line at a convenient point the entire system is grounded and protected from lightning at all times.

Fig. 7. Recommended method of constructing quarter-wave detuning sleeve.



From our previous discussion, the electrical length of the half-wave coax transformer is the physical length times the V. P. of the cable. From measurements made by the author, a value of V.P. = .66 for the polyethylene concentric cable, made by Federal Tel. and Radio Co., has been found to be correct. In the case of any coax, the V.P. may be calculated from the relationship $\text{V. P.} = \frac{1}{\sqrt{k}}$, where k is the dielectric constant of the dielectric. ($k = 2.3$ for polyethylene made by F. T. and R.) Cutting the half-wave coax transformer according to the following formula

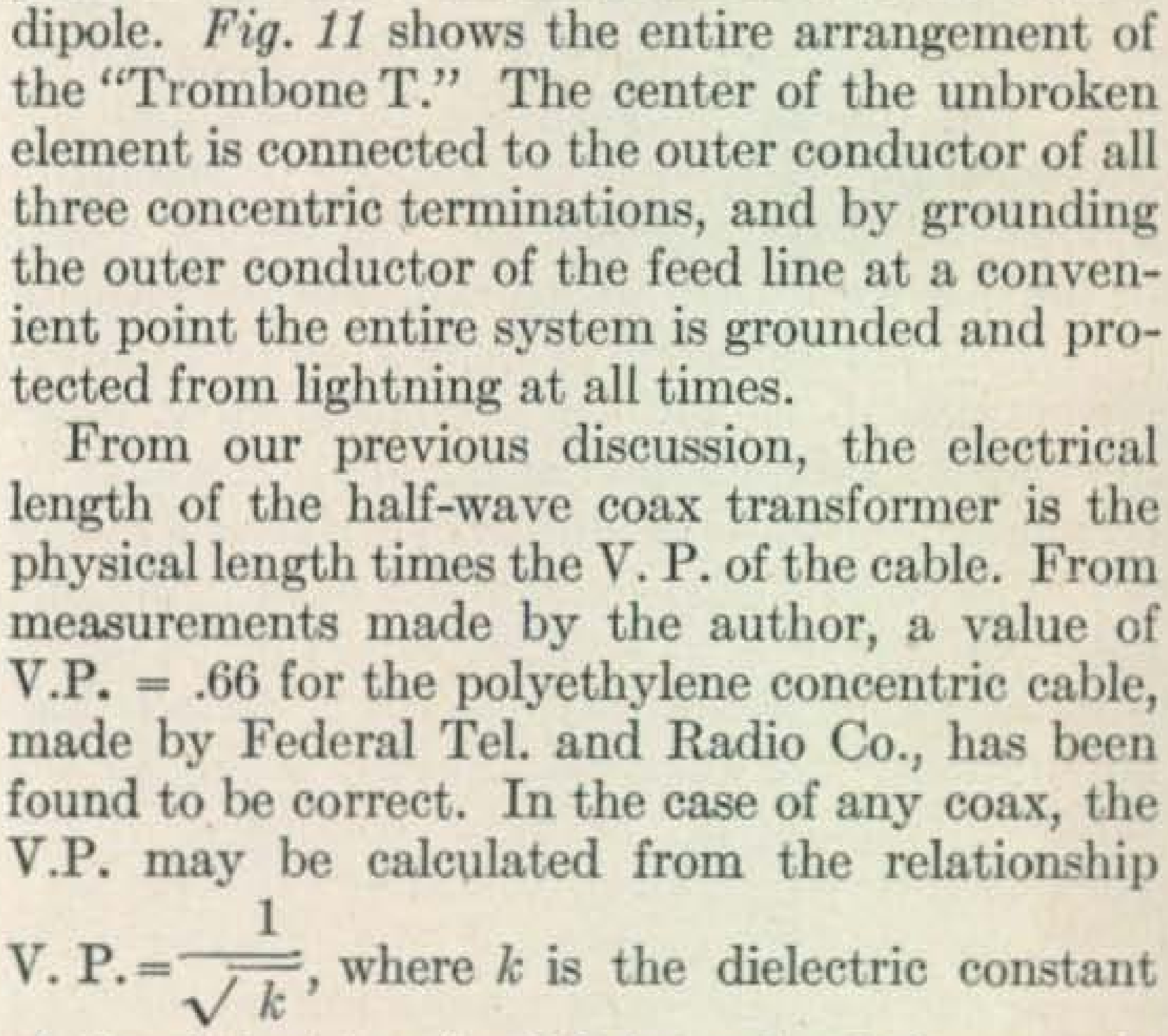


Fig 9. Impedance into which the feed line looks in the case of (a) center-fed half-wave dipole, (b) folded dipole. Symmetrical resistance with respect to ground are shown in c and d. End points must be excited 180° out of phase.

will be found entirely accurate: Length of half-wave transformer $= \frac{492}{f\ (\text{mc})}[.66] = \frac{324.7}{f\ (\text{mc})}$

If you wish to check your results resonate a stage in your transmitter to the desired operating frequency by tuning for minimum plate current. Connect the inner conductor of the half-wave transformer to the hot side of the tank coil, the outer conductor to ground. Leave the other end of the transformer open (*be careful*—this open end will be "hot"). Then check that the addition of the half-wave transformer has not changed the tuning. If you have to close or open the tank condenser to effect resonance (minimum plate current), the half-wave transformer is too short or too long and it can be pruned to the correct length by altering the length of the open end. However, the use of the equation Length half-wave transformer $= \frac{492}{\text{freq. (mc)}}$ (V.P.), provided the V.P. is known, will be found to be accurate, and the above procedure is necessary only when one wants to use a cable of questionable dielectric.

Selecting Cable Impedance

To determine whether to use 52 ohm or 73 ohm cable to feed the "Trombone T," calculate the resistive term of the self-impedance of the radiator as a function of the wire size or tubing diameter from the table.* Calculate the resistive term of the mutual impedance from *Fig. 2.** Combine the resistive terms of the self and mutual resistive impedances to obtain the drive impedance. If the drive impedance is closer to 52 ohm than 73 ohm, use 52-ohm cable; if it is closer to 73 ohm than 52 ohm use 73-ohm cable. The half-wave transformer should preferably be made from 73-ohm cable although the effect of using 52-ohm cable will not be detectable.

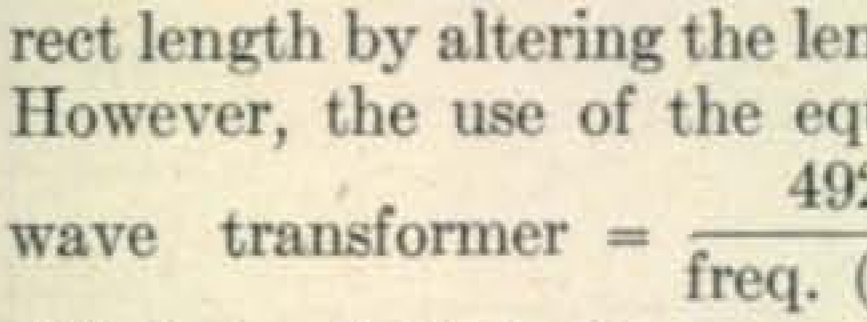


Fig. 10. Transformer used to effect the phase reversal necessary for proper operation of antenna.

Coupling to Final Tank Circuit

To couple the coax feeder to the final tank coil, use a link at the low-potential portion of the tank coil. In the case of a split stator final tank condenser, the rotor of which is at r-f ground potential, the link should be at the center of the tank coil. For a non-split stator final tank condenser whose rotor is grounded, the link should be positioned at the tank-coil end which is connected to the condenser rotor. That portion of the link winding nearest the end of the coil that goes to the rotor of the condenser should connect to the shield of the coax. The link should be wound around the final tank coil on the end which is at ground potential.

We recommend the "swinging link" arrangement, since the coefficient of coupling necessary to reduce the Q of the final tank coil to the value required to draw the desired plate current may be readily secured.

One word of warning. Be sure you have adequate insulation between the link and the final tank coil when the final tank coil is carrying the d.c. And we strongly recommend, as mentioned previously, grounding the outer conductor of the coax feeder of the "Trombone T." Then if the insulation between the link and the tank coil becomes faulty (and the mechanical design of the link does allow this to happen quite frequently) all that can happen is a blown fuse. If the outside of the coax is not grounded, and the insulation between the link and the tank coil becomes faulty a real hazard exists and will escape notice until someone comes in contact with the outside conductor of the coax, perhaps with a fatal result! Of course, grounding the outer conductor also acts as lightning protection since even during transmission, the *entire* antenna system is grounded.

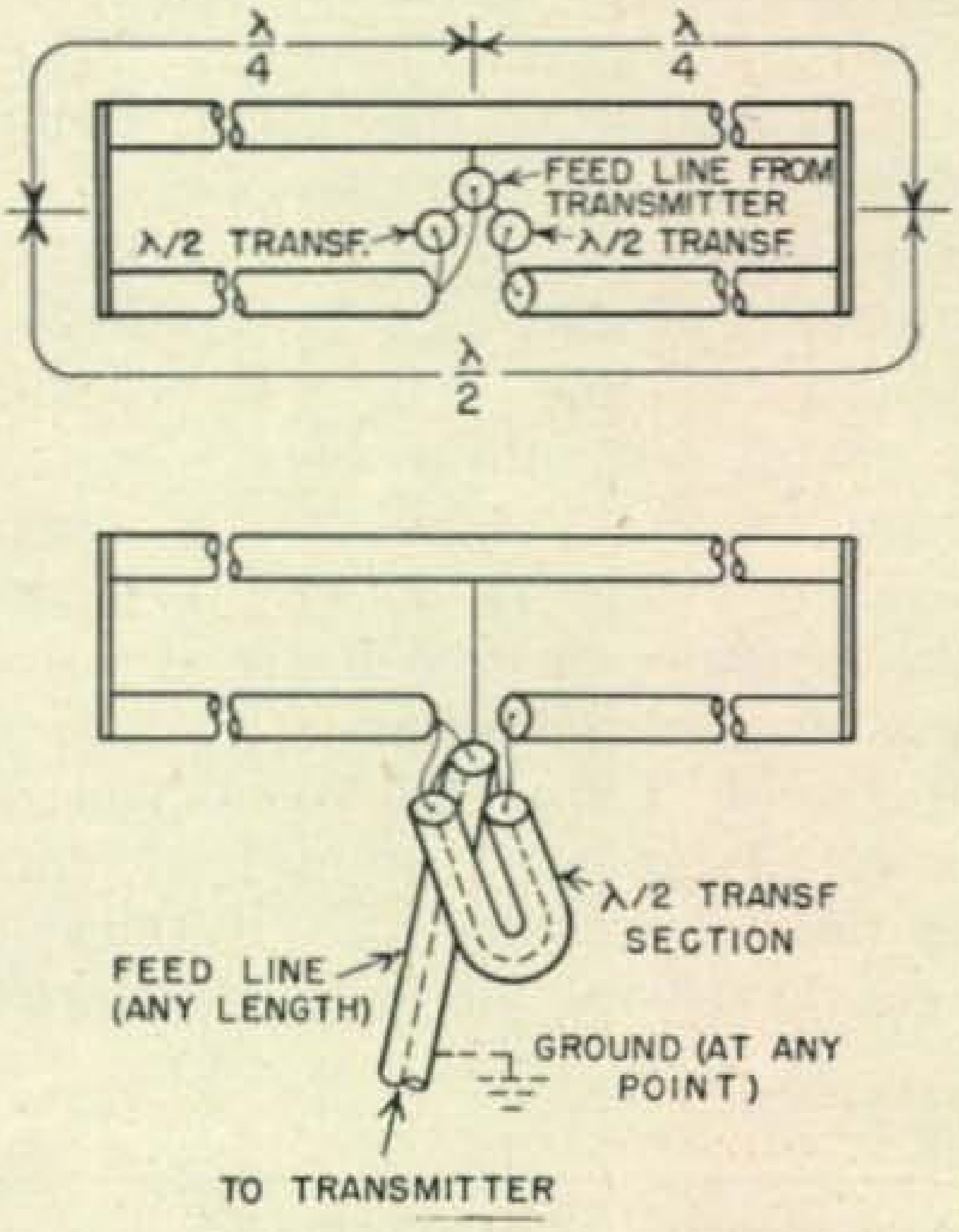


Fig. 11. Construction details of Trombone T.

Installation

A description of the installation of the "Trombone T" at the writer's station, W2GWE, will be of interest to those desirous of duplicating the system. Practically any convenient mounting can be employed so long as the antenna itself follows carefully the original dimensions.

The writer had hammered together the 27-foot mast comprised of 15 foot long 2 x 3s as shown in

[*Continued on page 77*]

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TROMBONE T

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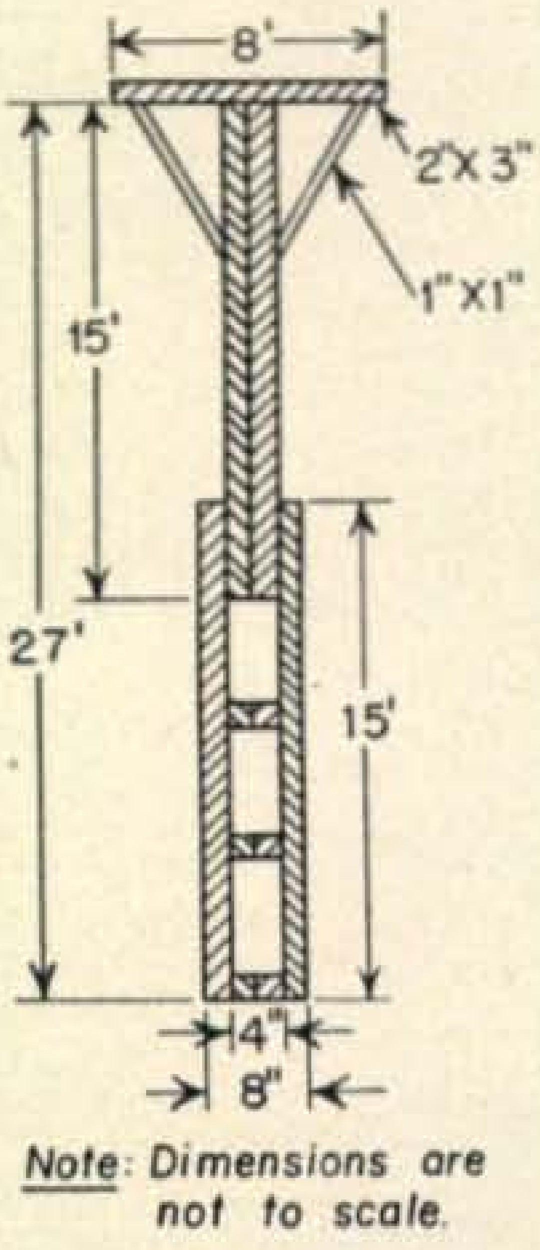
Fig. 12. A 3-foot overlap was used between the sections, and a fifth 2 x 3 was sawed up and used as a spacer between the bottom 2 x 3's. Six-inch spikes were used to hold the sections together.

With the help of W2AST, we mounted an 8-foot 2 x 3 in the form of a T on what was to be the top of the mast, nailed on the four 1 x 1 45° supports, mounted the Premax elements by use of Premax No. 492 insulators on the eight-foot 2 x 3, and adjusted the length of the four half elements from the formula:

$$\text{Length of elements (ft.)} = \frac{233.7}{14.1}$$



Note: Dimensions are not to scale.

Fig. 12. Construction details of mast for supporting Trombone T.

The center of the elements comprising the unbroken dipole were butted together, and the centers of the broken dipole (points *A* and *B*) were spaced approximately one inch. The two dipoles were spaced approximately four inches (not critical) and copper straps were soldered to the far ends in such a manner as to maintain the four-inch spacing as at the center. With the additional help of W2IOP and W2RPZ we dragged the mast up to the flat roof (height approximately 18 feet above ground) and with W2RPZ (the fearless one) on the peak of the third floor roof, acting as a human guy wire, the entire structure was walked into place, resting on two 2 x 8s, 36 in. long, which had been placed on the flat roof. While the writer secured the mast to the base, W2IOP climbed a ladder and hammered home the center supports, and W2RPZ then put in the top supports—(all 2 x 3s).

A few words as to its performance. On July 1st, when 14 mc first opened we worked several dozen VKs and ZLs, a few Europeans and VS4JH for his first 14-mc W QSO. Returning from work in the evening we worked Europeans and South Americans by the dozen, ZD8A for WAC postwar, and EP1C for his first W contact on 14 mc.