Feeding Vertical Antennas

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BY ARTHUR LYNCH,* W2DKJ

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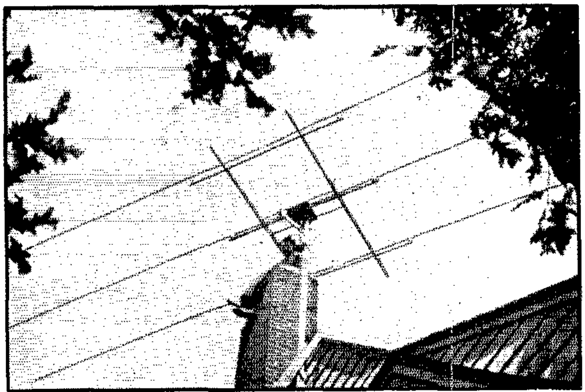

Photo by Ed. Ruth, W2GYL

The author and this chimney have been associated in a good many antenna experiments, which probably accounts for their obvious palishness. This photograph has nothing to do with the subject matter of the article, but shows a new six-element rotary beam which has been giving an excellent account of itself.

Methods of Using Vertical Elements Singly, and in Combination to Form Simple Directive Systems

It seems strange that there should be any problem regarding the proper method of feeding a vertical radiator, yet that such a problem exists is most certainly true. After all, except for a few comparatively unimportant details, there should be nothing more to feeding a vertical than feeding the more familiar horizontal types.

In giving consideration to the method for feeding any particular antenna, we must give some thought to its physical characteristics. It is well-known that the physical dimensions, for an antenna which is to be used on a certain frequency, will vary somewhat as a result of the proximity and the character of other bodies which may be in the active field of the antenna. The height above ground and the character of the ground have marked effects. The current literature is so full of information covering these important subjects that we will skip it entirely. It is mentioned only to indicate that it has not been given attention in the following text and that the dimensions given here cannot be set down for rule-of-thumb guidance, but are intended only as guide posts for determining the starting point for the particular antenna and feed system which will best fit into a particular group of conditions.

It is not to be assumed that any of the information given here is especially new; in its fundamental form, most of it is to be found in the *A.R.R.L. Handbook.* Those novel kinks, such as are illustrated in some of the last figures, are but conveniences which make for better operating conditions where it is necessary to make compromises, forced upon us by lack of space or local restrictions of one form or another.

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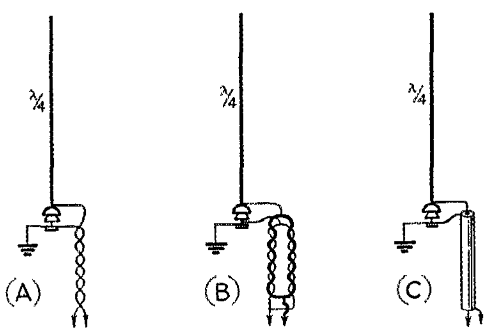

Fig. 1 — Various methods of feed to quarter-wave vertical "Marconi" antennas.

The Quarter-Wave "Marconi"

Several years of operating ultra-high-frequency equipment in airplanes and cars, to say nothing

For some mysterious reason the business of supplying power to a vertical antenna assumes the aspect of a Problem to a good many hams. If W2DKJ did nothing more than dispel the fog which seems to surround that region between the transmitter and the vertical radiator, this article would be well worth while. But he goes farther than that, bringing out some points which are decidedly worthy of consideration by the antenna-minded chap who has to worry about space. Good practical dope, tested at many different stations and locations.

of yachts and high buildings, has brought us to the conclusion that too little attention is given to the quarter-wave "Marconi" antenna. For most mobile purposes we have found it to be ideal, and certainly much less trouble to install and use than

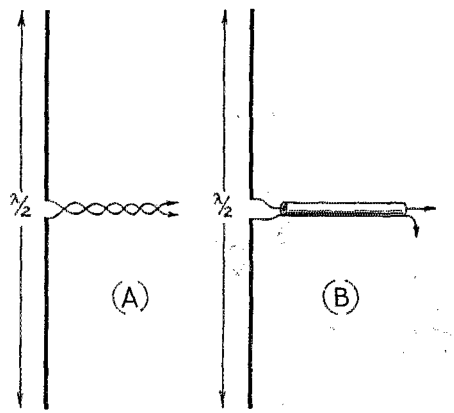

Fig. 2 — Center feed through twisted and concentric lines.

any of the more elaborate types. Then, too, we have never found any of the others, except beams, to perform better. A telescopic type of broadcast antenna, extended to approximately 4 feet, was hastily attached to a wooden cross-member of an airplane and the point was pushed up through the skin. It was installed with a view to making a single flight. It stuck with the ship, through all kinds of weather, for more than a hundred thousand miles. Actual tests made later with other types showed no superiority in performance electrically, and all of them were a headache mechanically. Very much the same story can be told of the job on our car.

So, when there is not much room and you want to put up an aerial which is the least conspicuous, give some consideration to one of the arrangements shown in Figs. 1. They are the shortest units possible for good performance on a particular band and, since they are to be current fed, the insulation problem is not a serious one.

Also, the impedance between the base of such an antenna and ground is in the vicinity of 35 ohms.[1] Some of the better twisted-pair transmission lines have an impedance in the vicinity of 75 ohms. If the line is to be short and the power not too high, the mismatch of impedance, when the arrangement shown in Fig. 1-A is used, doesn't really cut much ice. Theoretically, yes; practically, no! If you want to run a longer line or want to run more power, or if you're just fussy about efficiency, the arrangement shown in Fig. 1-B will fill the bill nicely for you. Here two twisted-pair lines are run in multiple, making certain that they are of the same polarity,[2] and you have cut the surge impedance in half and doubled the power-carrying ability of the line. You have not, however, cut down the dielectric loss per foot in the line itself,[3] although the temperature rise will be less if the line is being overloaded.

In Fig. 1-B we have indicated the method for feeding a vertical quarter-wave "Marconi" with a concentric or coaxial line. If a line of 30 or 35 ohms is available it will do the trick very nicely, but the mechanical difficulties which are generally encountered in making such a line are seldom justified by the improvement in performance, if any.

In all three of these cases we have shown one side of the transmission line grounded adjacent to the base of the antenna. It doesn't seem to make much difference if this part of the line is permitted to hang in thin air. The line may, of course, be random length.

For most practical purposes, a quarter-wave radiator on 5 meters is 4 feet, 10 meters is 8 feet, 20 meters is 16 feet, 40 meters is 33 feet, 80 meters is 66 feet, and 160 meters is 133 feet.

Half-Wave Dipoles

Where two quarter-waves are used, as in Fig. 2, we have the typical half-wave dipole. In free space, where the antenna is not influenced by the ground or surrounding objects, the impedance at the center is approximately 72 ohms. This is,

[1] W. C. Tinus, "Ultra-high Frequency Antenna Terminations," *Electronics*, August, 1935.

[2] I.e., each wire in one feeder connected to the corresponding wire in the other. The wires usually are coded in a two-conductor cable. — EDITOR.

[3] S. W. Seeley, "Match and Mismatch," *QST*, November, 1937.

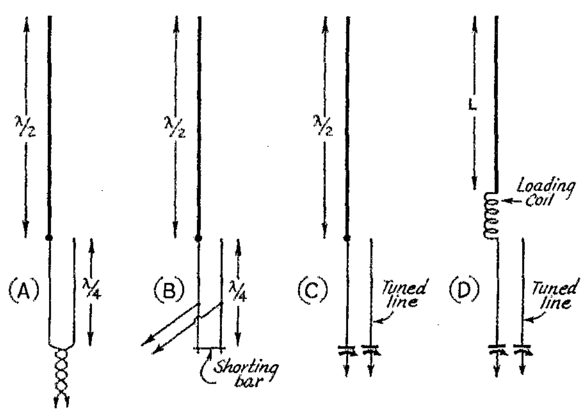

Fig. 3 — Representative end-feeding methods. In "D" the inductance of the loading coil should be adjustable.

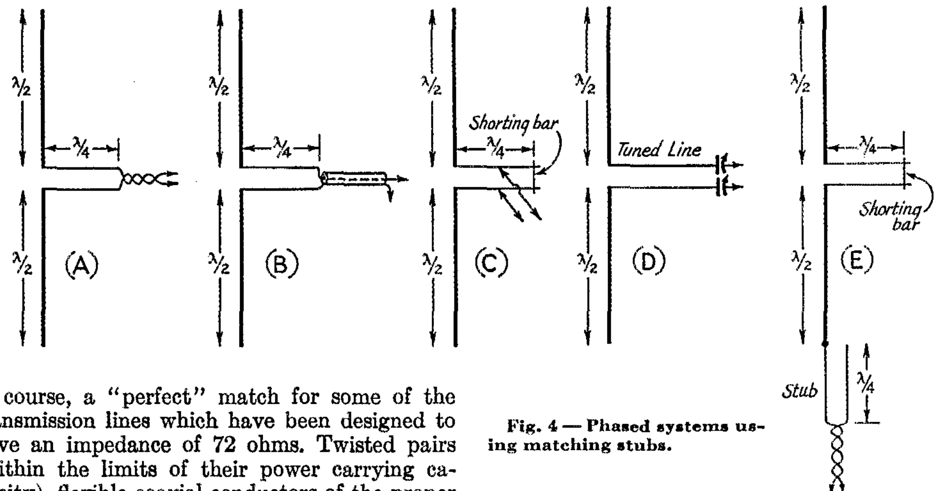

Fig. 4 — Phased systems using matching stubs.

of course, a "perfect" match for some of the transmission lines which have been designed to have an impedance of 72 ohms. Twisted pairs (within the limits of their power carrying capacity), flexible coaxial conductors of the proper impedance, or solid coaxial lines may be used to feed this very simple type of antenna.

It should be remembered that all coaxial lines are not of the same impedance and that the proper line for a given type of antenna feed system should be used. This is equally true of twisted-pair feeders. They will be found to vary from about 65 to 170 ohms. This variation is not very important if the line is not to be too long and is not made to carry a power overload.

The Half-Wave "J"

Because, no doubt, of the popularity of the "J" type of antenna for police high-frequency installations, many amateurs are using this aerial in one form or another. We have played some nasty tricks on this type of antenna, and it seems to have taken the abuse very nicely. A unit of the type shown in Fig. 3-A was made up of rather heavy wire. A rope was fastened to an insulator attached to the top, and the whole business was run up to the top of a yacht's mast, among steel shrouds, etc. The lower end was held in place by winding the twisted-pair transmission line up and down over a belaying pin, which was brass and grounded. The line was run some 20 feet along the deck and into a cabin window. Using only a few watts, we were able to contact other installations of the same character, on 5 meters, up to about 35 miles. On the lower-frequency bands, the results to be obtained are very satisfactory.

The simplest way to get such an antenna started is to make the length 0.97 × a half-wave (492,000/*f* in kc.) and the matching section can generally be cut a quarter-wave long.[4] If it is possible to shock-excite the whole system the point of highest current may be found on the matching stub, and will be the point where a low-impedance transmission line should be attached.

There is little difference between such a simple system and the one shown in Fig. 3-B other than the use of the shorting bar and the open-wire higher-impedance transmission-line. The shorting bar is placed in the stub, at the point of highest current, as indicated by a current-squared galvanometer, and the transmission-line is slid up and down above the shorting bar, with the power on, until a point is found where the standing waves on the line are minimum or disappear altogether.

For a permanent installation, where objection will not be raised to the unsightly appearance of the open wire line, particularly where power above 200 watts is to be used, this arrangement is to be preferred to the simpler system at 3-A.

Of course it is always possible to use "Zepp" feeders with almost any kind of vertical antenna, and the arrangement shown in Fig. 3-C is suggested as a typical case. For full details on the use of this kind of line reference should be made to the *A.R.R.L. Handbook*.

Where operation is desired on more than one band, it is possible to do a fair job by taking advantage of the system shown in Fig. 3-D. A loading coil is inserted between the base of the vertical radiator and one end of the "Zepp" feeders. If the loading coil is of the flat spiral type, the positions for the tuning clips can be marked on the copper strip, for the various frequencies desired, so that the adjustment may be made with the least loss of time.

A new setting of the variable condensers in the feeders will need to be made and they may be marked in a similar fashion. The condensers may be adjacent to the final amplifier or in any other convenient part of the line, depending on the

[4] More commonly, the factor is taken as 0.95 for the half-wave antenna and 0.97 for a two-wire open feeder. In any event, if exactly the right length is wanted the system had best be adjusted experimentally. — EDITOR.

length and type of tuning (series or parallel) used. A good arrangement for this type of antenna is to place the loading coil in a weather-proof housing which is set right at the base of the vertical radiator.

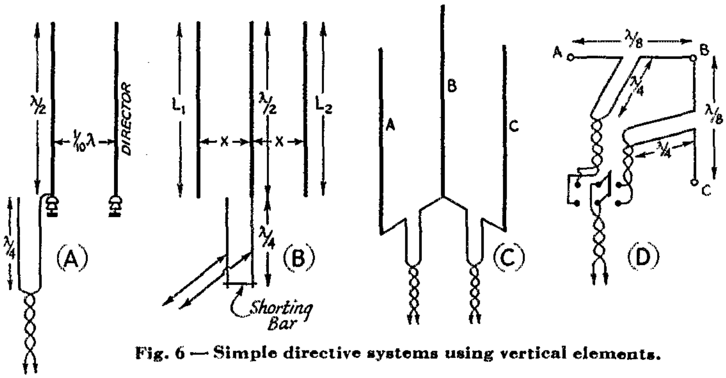

Fig. 6 — Simple directive systems using vertical elements.

Two or More Half-Waves in Phase

A lot of the energy which is shot up at too high an angle to be useful, when one of the foregoing vertical antennas is used, is pulled down and shot out in more desirable directions when half-wave antennas are operated in phase and stacked one above the other. Everything else being equal, the radiation from one of the systems shown in Fig. 4 should be just about 150 per cent that which could be had from any of the other aerials we have considered.

Any former remarks concerning matching stubs and transmission lines may be considered as applying directly to these aerials, in just the same manner. The method of feeding from the end, as shown in Fig. 4-E, may be a mechanical convenience, but it is likely to produce a system which is not as symmetrical as the center-fed methods. Various types of transmission-lines may be used in connection with the matching stub (Fig. 4-E) as outlined previously.[5] However, it is desirable to leave off the stub and the transmission-line and find the correct position of the shorting bar on the phasing section, by shock-exciting the antenna and locating the point of highest current in the phasing section with a current squared galvanometer. Then the stub may be attached and fed in the same manner as with any other form of aerial.

Additional half waves may be added, if additional phasing sections are used, but they are not very useful if the entire system is not more than a half wave above ground at its lowest point.

[5] Where a twisted pair or coaxial line is series-fed into the low-impedance point on the stub, the exactness of the match will depend upon the surge impedance of the matching stub. The mismatch with a 600-ohm stub should not be greater than 2:1, which is not serious, under ordinary circumstances. Closer match can be secured by adjusting the conductor spacing of the matching stub to minimize standing waves on the transmission line. — EDITOR.

"Pitch-fork" Bi-directional Half-wave Beams

In locations where space is limited, and where a bi-directional antenna may be a convenience, we should not lose sight of the possible gain to be had from the "pitchfork" (Fig. 5) over the ordinary type of vertical antenna. In many cases, it will be an improvement over two half-waves in phase, for the reason that it tends to put the signal where we want it. For receiving, it tends to cut out interference from stations in undesired directions as well as increasing signal strength from those stations in desired directions.

Since the spacing between the two vertical sections is only an eighth wavelength and the matching stub is only a quarter-wave long, it is possible to set such an array above an apartment-house roof, using self-supporting vertical rods. The entire assembly does not become too cumbersome, even though it is used on the 20-meter band, when the vertical elements become about 29 feet high, with a separation of about 8 feet. Some of the more ingenious fellows have made beams of this nature rotary, but where rotation is possible, we prefer the arrangements shown in Figs. 6-A and 6-B, for reasons outlined later.

In locations where rotation is not possible and a single aerial is all that can be used, the pitchfork has its advantages if we choose the two directions with care. If two such beams can be set up a reasonable distance apart, we can cover all directions with a great deal more efficiency than would be

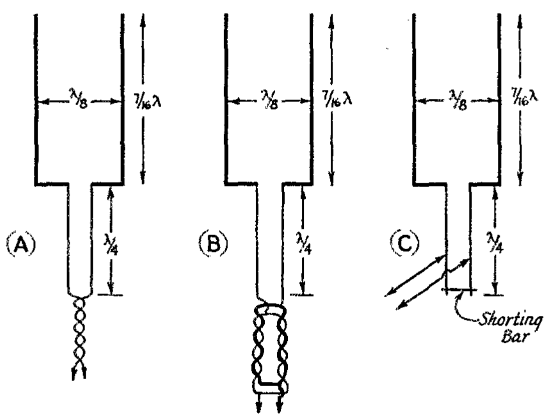

Fig. 5 — "Pitchfork" antennas with stub feed.

The vertical two-section "W8JK" rotatable beam installed at W2AZ. Self-supporting 20-meter half-wave elements are used. The beam is bi-directional and the antenna need be rotated only 180 degrees for complete horizontal coverage.

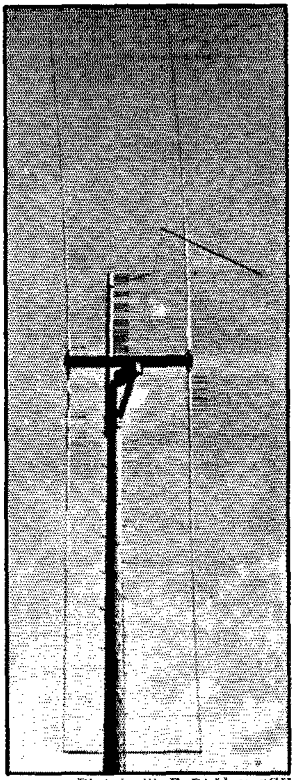

Photo by W. F. Diehl, ex-2CY

possible with any of the single units previously considered.

The use of three vertical elements for making a fixed beam which covers four directions, with fair results, is shown in Figs. 6-C and 6-D. It will be seen that the center unit is used with both systems and we have, in effect, two distinct beams at right angles to each other and having two distinct feed systems. The results which have been produced by this layout have been most encouraging. While they are not so good as those to be had from two similar beams a reasonable distance apart, and while it is possible to find current in the vertical element which is not in use, the performance is distinctly better than we thought it would be. This holds true for both transmitting and receiving.

The double-pole double-throw switch used to make the experiments on the 10- and 20-meter bands was located near the transmitter. It is thought that a suitable switch located at the base of the antenna, and remotely controlled, would bring about even better results.

One marked advantage of this double pitchfork beam was its gain over a single half-wave radiator for use in covering all directions simultaneously. To accomplish that result it was only necessary to feed the two transmission lines in multiple. The advantage of such an arrangement for general calling purposes is obvious.

As outlined before, any desirable transmission-line may be run to the quarter-wave stub, if the conditions for using those lines are met.

Vertical Rotary Beams

It is a bit difficult to know just where to give credit for the various ideas which have been conceived and worked out by so many investigators, and it is likely that much credit is given to some who have not been the first to use various arrangements because those who have actually been first have not made their findings known. In outlining the next two types of arrays, we wish to thank Lawrence M. Cockaday, W2JCY, and Frank Lester, W2AMJ, for much of the electrical and mechanical work which they have done and for the information this work brought to light.

Many investigators have had the impression that Brown's paper before the I.R.E. which so ably covered the subject of half-wave radiators and close-spacing,[6] was intended to convey the idea that his findings would apply only to the use of a single radiator and a single director or reflector. It has been generally thought that the use of both director and reflector would not be an advantage. We think that what he intended to convey was the thought that the actual results which he described were found to be true under a given set of circumstances and that other sets of circumstances had not been investigated. In any event, there is no doubt now that both the director and the reflector, used with close-spacing and a half-wave radiator, provide better performance than either of them alone.

The mechanical difficulties usually encountered with nearly every type of rotary beam are reduced to a minimum when the arrangements shown in Fig. 6-A and 6-B are employed. In the former, we have shown a half-wave radiator with a director and no reflector, while in the latter we have shown the manner in which both may be used. Again, all the information regarding transmission-lines and matching stubs applies to this case, and two of the simpler methods have been illustrated.

It will be seen that changing the direction of radiation with this type of beam depends entirely upon the location of the director and/or reflector and that the radiator, matching stub and transmission-line remain fixed. The mechanical details for bringing this condition about are obviously simple, even where it is desired to use the three-element array on 20 meters.

Single-Wire Feed

One of the least used and one of the simplest methods of getting energy from a final tank circuit to an antenna is

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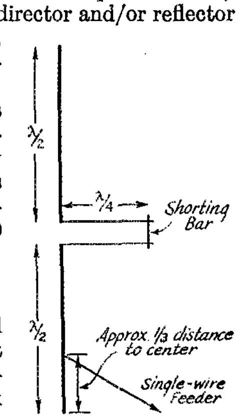

Fig. 7 — Half waves in phase with single-wire feed and phasing stub.

[6] G. H. Brown, Proc. I.R.E., January, 1937.

Vertical Antennas

(Continued from page 17)

the old single-wire feed method. The information covering this form of feed which is given in the *A.R.R.L. Handbook* may be applied to almost any of the foregoing antenna systems and will bring about a certain amount of simplification of the mechanical details. It would be hard to think of a simpler way of feeding almost any of the vertical systems which are made up of single or stacked half-wave units. More or less as an added starter and just to show how easy it is, we have added Fig. 7, which will be recognized as a simplification of Fig. 4-E. As a rule, single-wire feed is not suitable for rotary systems, for reasons which are strictly mechanical, so we have omitted previous mention of it.

Almost any of the quarter-wave Marconi aerials described in the first part of this text may be single-wire fed. Theoretically each of the quarter-wave units has for its other quarter-wave section either the building on which it has been erected or the ground. Many of those that we have used have been on high buildings, and possibly that is the reason for our having secured almost as good results with quarter-wave aerials as with center-fed half-wave units.

The quarter-wave antenna may be single-wire fed by considering the vertical portion as only half the antenna, and the feed line may be attached at a point approximately two-thirds the distance down from the top. It is sometimes thought that it is impossible to use single-wire feed without having standing waves on the transmission line. This need not be true because single-wire feed may be considered in exactly the same light as two-wire feed, the ground itself forming the other half of the line. Therefore the single-wire line may be used as a resonant feed system having standing waves[7] or a non-resonant system without standing waves. Where vertical aerials are to be used on apartment houses in localities where a great many broadcast receivers are in use, it is desirable to use the non-resonant line to avoid interference.

In the quarter-wave vertical, the point of highest current is at the base of the antenna. The point of lowest voltage is also at the base. This means that there is no need for an insulator at the base at all, and if care is taken in the selection of the feed system there is no reason why a vertical quarter-wave radiator cannot be mounted directly on the steel frame of a building without using insulation of any kind.

Combinations of Vertical Antennas

In all the antennas considered up to now, simplicity has been the keynote. It is perfectly possible to make combinations of vertical ele-

[7] Resonant operation is inadvisable in practically all cases because under such circumstances the line radiates practically as well as the antenna and is not, therefore, really a transmission line in the usual sense of the term. With non-resonant operation the radiation is low because the line current is low, but the cancellation effect of the two-conductor line is lacking.—EDITOR.

ments to provide some very interesting effects. An outstanding example of the use of two half-wave verticals which could be made to transmit end-fire or broadside by the simple expedient of altering the connection between the transmission line and the feeding stubs was described by Dana Griffin, W2AOE, in *QST* for October, 1935.[8] The spacing which Griffin used between the vertical elements was quite different from the close spacing which is now so popular, and the advantages of the close spacing will be immediately recognized. A more recent outline of what is essentially the same idea will be found in *QST* for May 1938, under the title "Simple Directional Arrays using Half-Wave Elements," by Nicholas C. Stavrou, W2DFN.

Some very interesting information on the application of three vertical elements for use on 10 meters, as shown diagrammatically in our Fig. 6-B, will be found in an article entitled "A Continuously Rotatable 28-Mc. Beam," by A. F. Neuenhaus, W2BSF, and M. E. Schreiner, W2AJF, which appeared in *QST* for March, 1938.

The most outstanding example that we have seen of the way in which verticals can be used in a rotary beam is now in operation at the station owned by Frank Carter, W2AZ, at East Rockaway, Long Island. On top of a 60-foot telephone pole, which is unguyed, he has set up a pivoted crossarm made of two 2 x 10 planks mounted edgewise. On the top side of this crossarm are mounted two of the new Premax self-supporting 36-foot vertical telescopic radiators. Two similar radiators extend downward from the bottom. The four units have been worked into a vertical two-section "8JK" beam. Since the beam is bi-directional it is only necessary to provide 180 degrees of rotation for 360-degree coverage.

Using about 900 watts input, W2AZ has worked 100 countries on 'phone, using a single frequency in the 20-meter band. Some indication of the superiority of his vertical beam over the three similar horizontal beams that he has been using may be gleaned from the fact that VU2CQ in Bombay, India, can be received S8 on the vertical, when he is just audible on the horizontal beam. On a recent weekend W2AZ made WAC on 20-meter 'phone, and he now reports PK6XX in Dutch New Guinea S7 on the vertical beam, when he could not be heard on the horizontal beams at all. VQ3HJP in Tanganyika and TF5C in Iceland have been workable with this new vertical, after they had faded out completely on the horizontal beams.[9]

[8] D. A. Griffin, "Shifting Antenna Directivity by Phase Switching," *QST*, October, 1935.

[9] These results are interesting in view of the fact that the only obvious explanation is that the signals were arriving with vertical polarization, since antenna systems having practically the same gain were used. Long-time observations on high-frequency waves have shown that on the average the polarization at the receiving point is horizontal although, of course, there are frequent exceptions. A possible alternative explanation is the difference in vertical characteristics of the systems; the vertical array is broader in the vertical plane than the horizontal array, so that the vertical might show large gain if the signals were arriving at relatively high angles.—EDITOR.