The Wide Spread Twin Five

E. MILES BROWN, W2PAU*

A high-gain 144-mc array suitable for "flip-flop" mounting.

IT HAS BEEN STATED that a simple dipole is a pretty unsatisfactory v.h.f. and u.h.f. antenna.[1] While this might be contested on some grounds, the fact remains that any type of antenna that affords some power gain over a dipole will greatly enhance the over-all station performance. The power gain of an antenna is reciprocal and is effective in both transmission and reception. This is amply demonstrated by the fact that most, if not all, of the outstanding work which has been done to date on our higher frequencies has been done with the aid of multi-element high-gain antennas. Beams with sixteen elements are commonplace, while many stations active on two meters are using thirty-two or more elements.

Yours truly has viewed the rapid progress in 144-mc antenna development with considerable consternation. There had been a time when our little six-element beam could hold its own. Lately, the ambitious operators on this band had been running rings around us with their monstrous signal squirters, and something had to be done.

Located in a fairly settled suburban neighborhood, complete with TV antennas on almost every house, we were naturally somewhat reluctant to go *all out* on a 144-mc beam. The size of even a sixteen-element affair similar to the W3HWN design[2] would stand out sufficiently to provoke an almost steady stream of TVI reports —deserved or otherwise. We had previously

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The antenna being "flopped" from vertical to horizontal polarization. The assembly is mounted on a "mobile" support—on the door hinges of ye ol' faithful Plymouth. The feedline matching section and the "flip-flop" ropes are clearly visible.

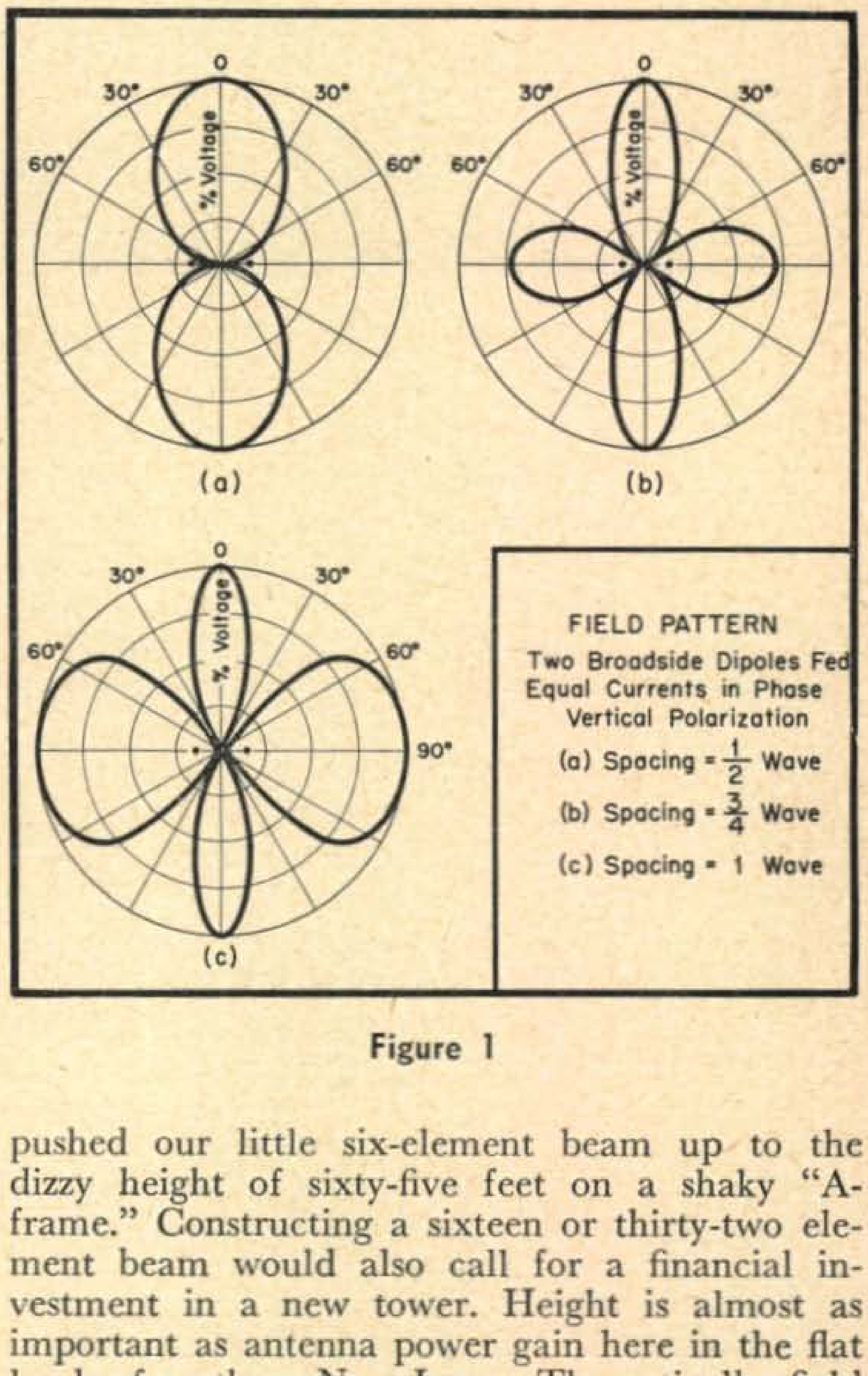
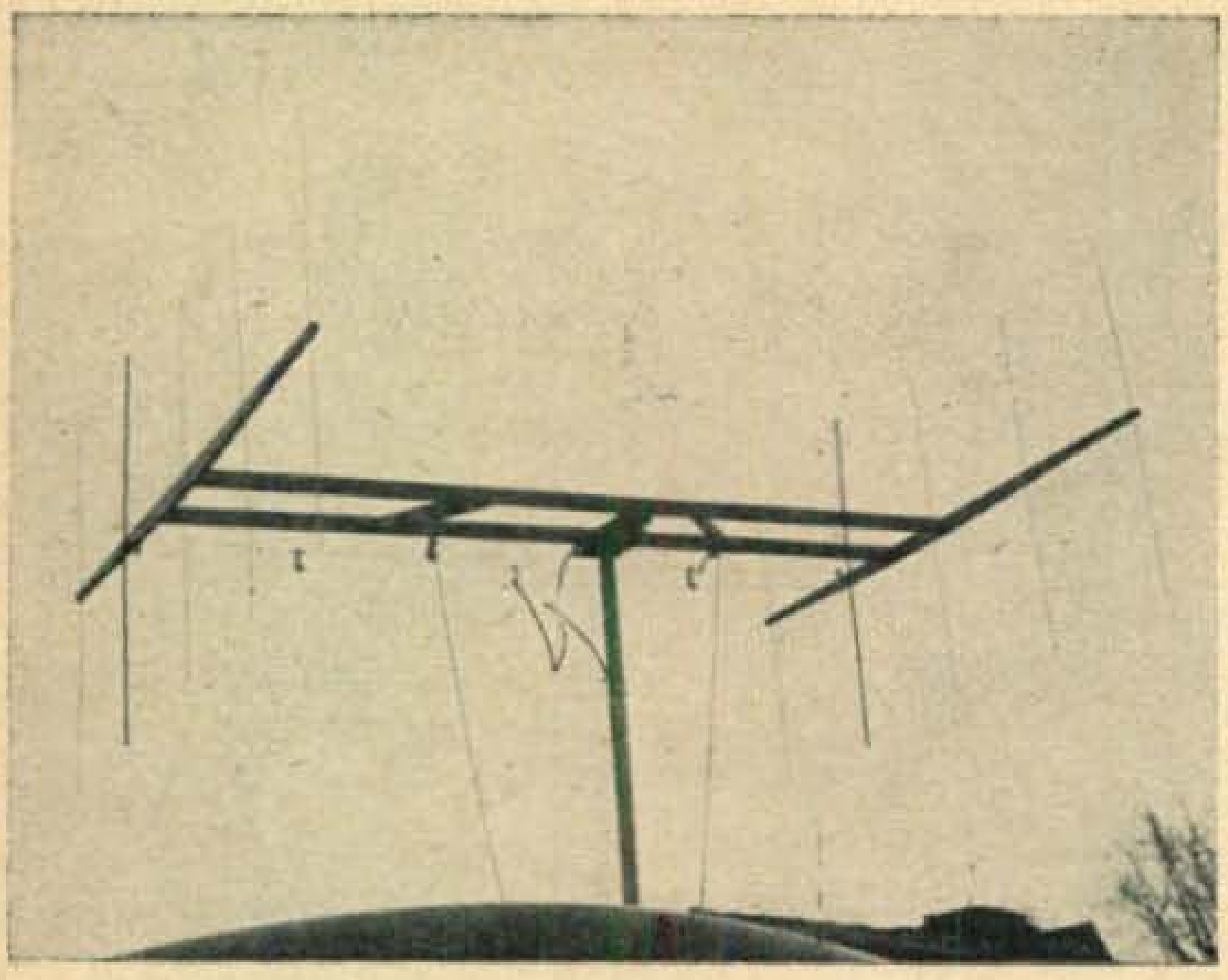


Figure 1

pushed our little six-element beam up to the dizzy height of sixty-five feet on a shaky "A-frame." Constructing a sixteen or thirty-two element beam would also call for a financial investment in a new tower. Height is almost as important as antenna power gain here in the flat lands of southern New Jersey. Theoretically, field strength at a distant receiving location is directly proportional to the height of the transmitting antenna above the average elevation of the terrain over which the signal is propagated. Therefore, unless one lives on a hilltop, it is a pretty good assumption that doubling the antenna height above ground will approximately double the field strength at a distant point. This corresponds to a four-times power gain, or a full S-unit improvement. Rather than throw away the height-gain by lowering our antenna below its carefully rigged sixty-five feet, we aimed at developing a high-gain beam that would be reasonably small and fairly light in weight. Secondly, we also wanted to be able to flip this array from vertical to horizontal polarization, and that gets to be quite a problem with some stacked arrays.

[1] C. F. Hadlock, "Making the Higher Frequencies Pay Off," *QST*, page 25, January, 1949.
[2] P. Hertzler, "16-Element Array for the 144 Mc Band." *CQ*, page 7, October, 1946.



Here's how she looks in the vertical-polarization position.

A Ten-Element Beam is Born

After many tedious hours spent plotting field patterns, calculating the effect of directors, reflectors and screens at various spacings and considering the feedline losses and matching problems, we came up with a design which seems to solve our particular antenna problem quite nicely.

The specifications look something like this:

Gain	14 db, or a power gain of 25 over a dipole.
Feed Impedance	300 ohms, balanced line which is fed at the center of the array for ease in flipping over to change polarization.
Beam Width	Vertical Polarization—26° to half-power point. Horizontal Polarization—44° to half-power point.
Front-to-back Ratio	10 to 1 voltage, or about 20 db.
Minor Lobe Response	Less than 30% of the main lobe (voltage), or about 15 db below main lobe.
Weight	Less than 4 pounds.
Cost	Around $3.00, not including labor.
Mounting	Single mounting point, adaptable to mechanical flip-flop systems.

Design Theory

Just in case this begins to look like a something-for-nothing proposition, let us touch briefly on the theory involved in the design of this antenna. The field pattern of a dipole when viewed along the axis is a circle. If we mount a second dipole broadside to the first, space them one-half wave apart and feed them both in phase, the pattern becomes a figure eight. If the spacing between the two driven dipoles is increased, the lobes of the figure eight pattern will begin to sharpen up. Also, a pair of side lobes will be formed. As we reach the point of full-wave spacing, there is actually more power being radiated in the side lobes than in the main figure eight lobes. However, and this is the interesting point, the main lobes are very sharp—only about 28 degrees to the half power points. *Figure 1* shows the evolution of these patterns.

Now, for the time being, forget those two dipoles and consider the famous Yagi or parasitic array. Many articles have been published showing the possible field patterns which may be developed with a system of parasitic directors and reflectors.[3] Conservatively speaking, it takes the mathematics of Einstein and the patience of Job to calculate the field pattern and gain of one of these simple little gadgets. Rather than attempt to figure the performance out on paper, and being a lazy sort of fellow, we built up a little five-element Yagi using 0.2-wavelength spacing and "Handbook" dimensions. In spite of the three directors and one reflector, the feed impedance was not zero, or infinite, and, as a matter of fact, it was a cinch to match to a 300-ohm line. The field pattern looked like that shown in *Fig. 2*.

When put on the air, the Yagi seemed to work o.k. over the whole two-meter band without noticeable degradation of performance on the high end of the band, despite the fact that it had been cut for 144.5 mc. In short, there was no doubt that the five-element pre-cut parasitic array was a thoroughly practical antenna.*

It was apparent that the nearly ideal antenna would combine the sharp main lobe features of

[3] D. C. Cleckner, "Parasitic Beam Patterns," *CQ*, page 25, July, 1948.

* Much to our surprise it proved to be equal in performance to the old reliable six-element beam, notwithstanding the difference in heights that favored the six-element by about fifteen feet.

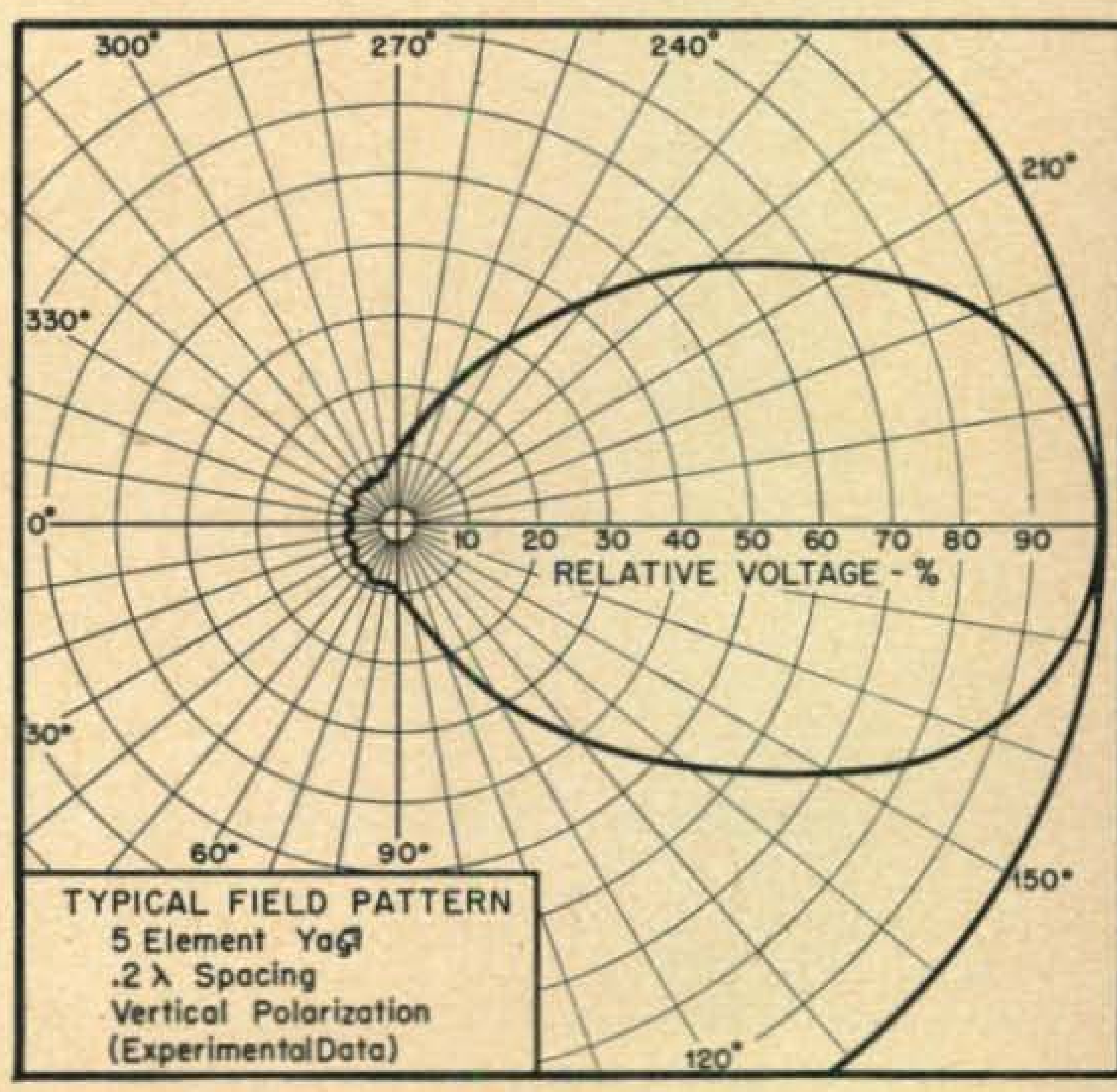


Figure 2

Fig. 1c and the smooth uni-directional single lobe pattern of the Yagi (*Fig. 2*). Thus, the idea of using two five-element Yagi antennas at a spacing of a full wavelength was born. The resultant pattern is shown in *Fig. 3*. This pattern is for vertical polarization. When the array is operated to obtain horizontal polarization, the broadside stacking of the two Yagi antennas seems to have a negligible effect on the sharpness of the forward lobe, and the field pattern is that of a single five-element Yagi. This pattern is shown in *Fig. 3* as the dashed line. All of these patterns have been verified by measurements, using a 1/3-scale model (420 mc) in the laboratory and using the full-scale array after it was erected in many on-the-air tests with stations at various distances in several directions.

What Makes a Beam Beam?

Before someone asks why we are talking so much about field patterns and so little about "power gain," it should be emphasized that these two factors go hand-in-hand. A highly-directional antenna is a high-gain antenna, if we neglect considerations of the "power efficiency" in the array itself. An analogy which illustrates the effect of high directivity is the old garden hose parable. If you want to fill a can on the other side of the yard with the garden hose, you would use the sharpest "beam" that the hose can produce. Antennas work much the same way—you can pour more power into the other fellow's receiving antenna with a sharply directed beam than you can with a fine spray, or a broad coverage pattern. As for the power efficiency of the Twin-Five beam, tests have shown that the losses in the elements themselves are practically negligible when compared to the radiated power.

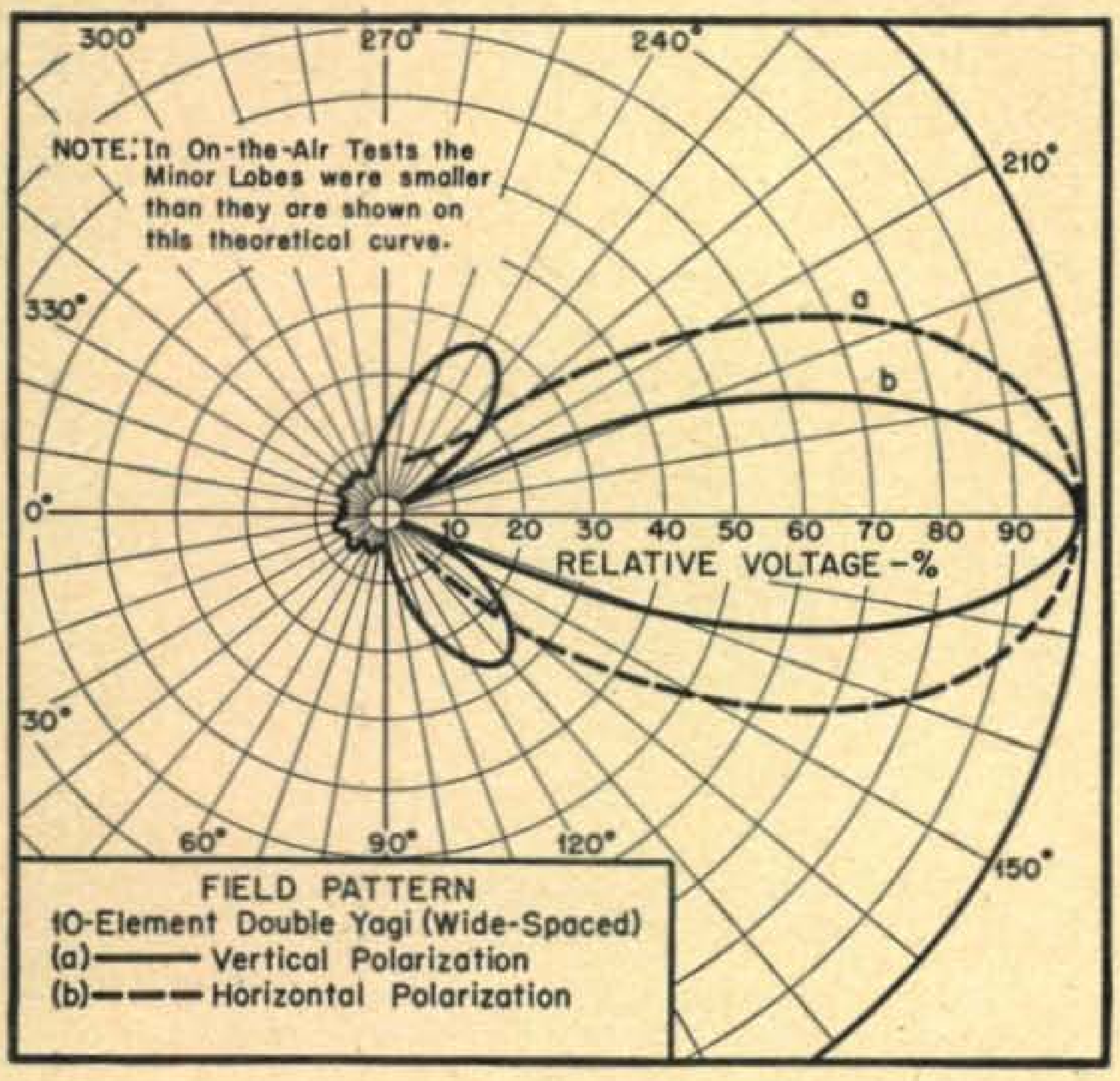


Figure 3

We have both calculated and measured the field pattern of the 10-element dual Yagi with the full-wavelength spacing, and we have done the same with many popular type arrays. Both theoretically and experimentally, the pattern of the double Yagi is sharper than most 144-mc beams. As a matter of fact, it may be laid inside the pattern of the familiar 16-element beam.[2] The obvious conclusion from the foregoing is that the double-Yagi has more gain than the 16-element job. We have calculated the gain to be 14 db, or a power gain of 25 over a dipole.

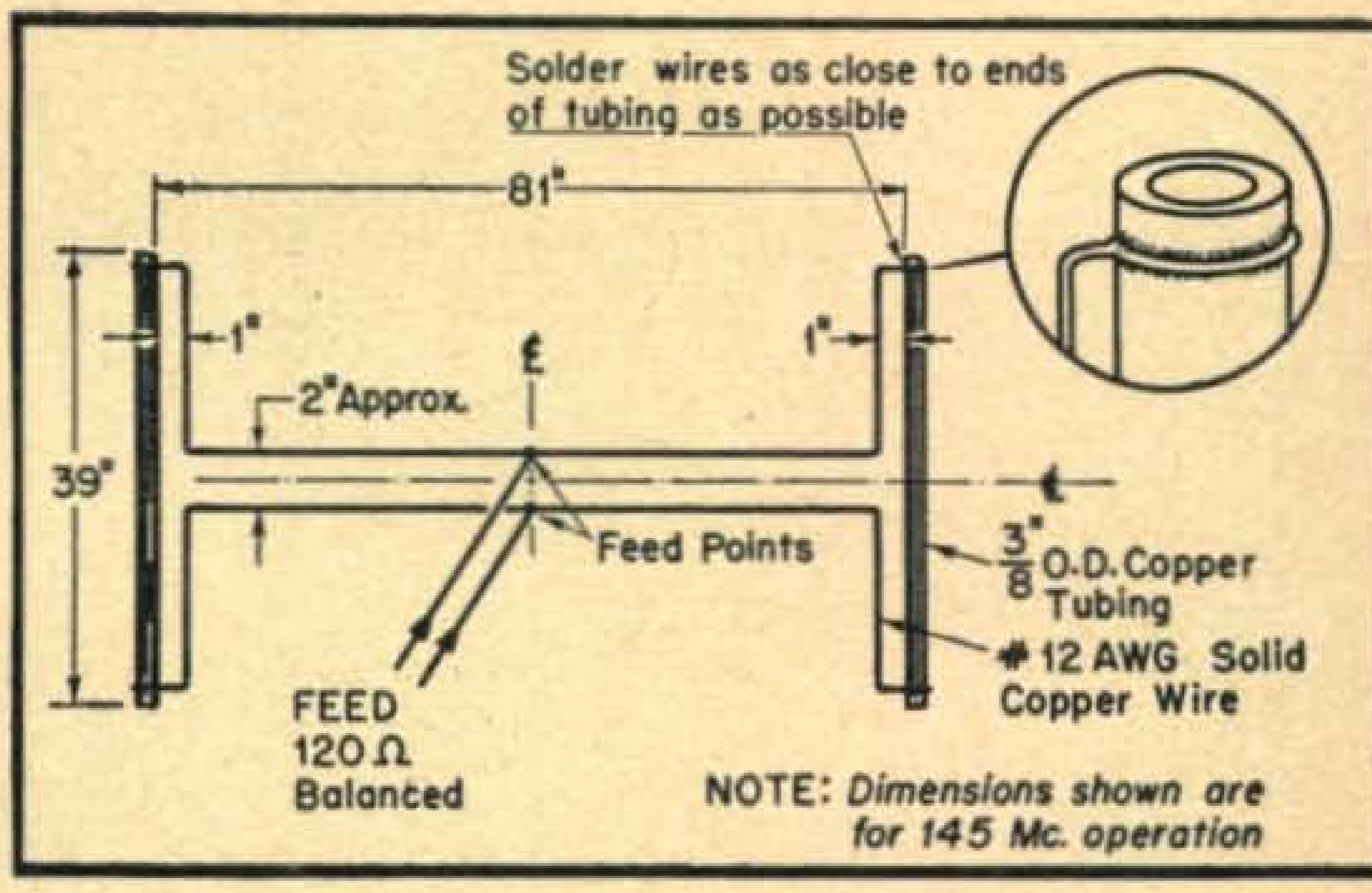
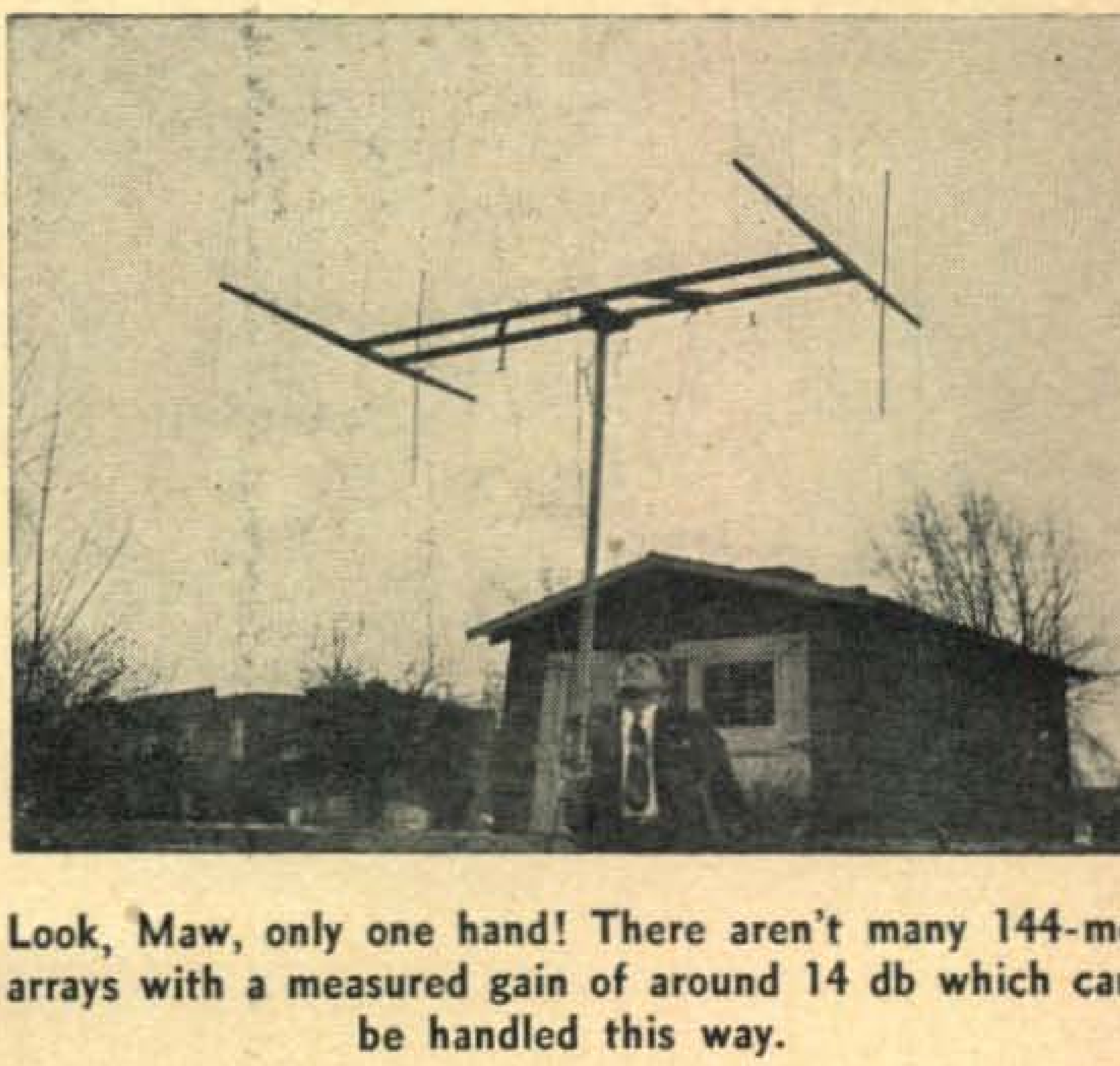


Fig. 4. The radiators and the feed wires.

It is quite easy to obtain very "optimistic" results from on-the-air tests. As an example, using a Twin-Five at the QTH of W2EH, Collingswood, N. J., a series of tests were made with W3KBA, Dover, Pa., at a distance of about 100 miles. Using the W2PAU signal on the same frequency as a reference level, the double-Yagi showed the surprising gain of two full S-units over the standard 6-element beam formerly used by W2EH. Since this 6-element affair reputedly has a gain of 8 db over a dipole, it should follow that the double-Yagi has a gain of 20 db over the same dipole! In more practical terms, the new antenna made it possible for W2EH to override the signal from W2PAU at the Dover, Pa., receiving location, whereas with the former antenna, the two signals were approximately equal in strength. Such an improvement is most obvious in the presence of heavy QRM!



Look, Maw, only one hand! There aren't many 144-mc arrays with a measured gain of around 14 db which can be handled this way.

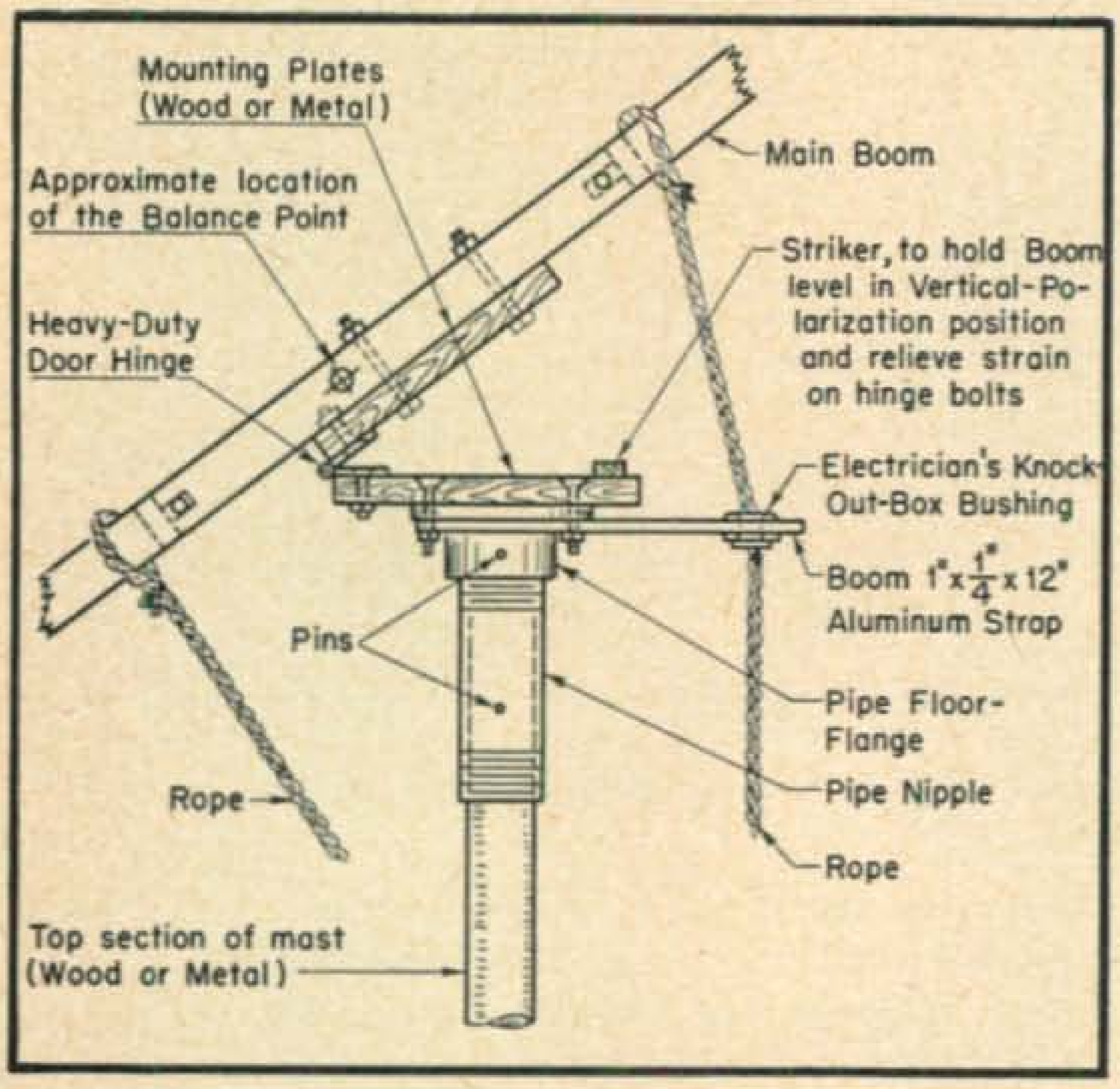


Fig. 5. Suggested hinged mounting for "flip-flop" operation.

The actual mechanical design of this beam will probably depend largely on the tastes of the builder. Of the several models which have been built since we unveiled the basic design, no two are mechanically alike, although the performance of all the models is uniformly excellent. We personally are partial to the use of a wooden element-support frame, since it avoids the possibility of noise caused by intermittent metal-to-metal contacts in the antenna assembly. It also simplifies the problem of weatherproofing, since there are no joints required between dissimilar metals.

For the parasitic elements, we used solid aluminum wire, 0.143 inches in diameter, sold in the local hardware store under the name of "clothesline wire." Some conservative mechanical engineers might criticize this choice of material on the basis of inadequate strength, but we have had antennas constructed of this material up on our mast for over three years with no signs of damage due to wind, ice, or roosting birds! The material is cheap, readily available, has low wind resistance, and, because of its small diameter, collects very little ice. Its weight is practically negligible.

The driven elements are folded dipoles, one section of which is made of 3/8″-o.d. copper tubing; the fed section is formed of #12 AWG copper wire, actually an extension of the open-wire phasing line which connects the two Yagi sections. Copper was chosen as the element material in this case mainly because it is easy to solder. The problem of establishing and maintaining a permanent, low-resistance contact between the copper feeder wires and aluminum elements was one which we would rather avoid.

The general layout of the beam is shown by the photographs. *Figure 4a* shows the radiators and their feedlines schematically. The spacing of the wires which form the dipole feeder section is not critical, as a half-wave section of line does not act as an impedance transformer, and the distance from the main feed point to either dipole is one-half wave. This system of feeding the beam produces an impedance at the central feed point which is one-half the feed impedance of the individual Yagi sections.

The critical dimensions of the array are summarized below:

Reflector length	40½ inches
Radiator length	39 inches
Director lengths:	
#1	36¼ inches
#2	36 inches
#3	35¾ inches
Spacing between adjacent elements	16 inches
Spacing between Yagis	81 inches

These dimensions were chosen for optimum performance near 145 megacycles. It is strongly recommended that the element sizes and dimensions be held fairly close to the values shown, unless one is willing to experiment with tuning and matching adjustments. However, a few general suggestions might be offered as a guide to those who would prefer to alter certain features of the design. If optimum performance is desired for a frequency other than 145 megacycles, all dimensions should be multiplied by a factor equal to the ratio between 145 megacycles and the desired frequency. If larger element diameters are to be used, the lengths of the elements should be reduced approximately 2% for each 50% increase in element diameter. If a tubular

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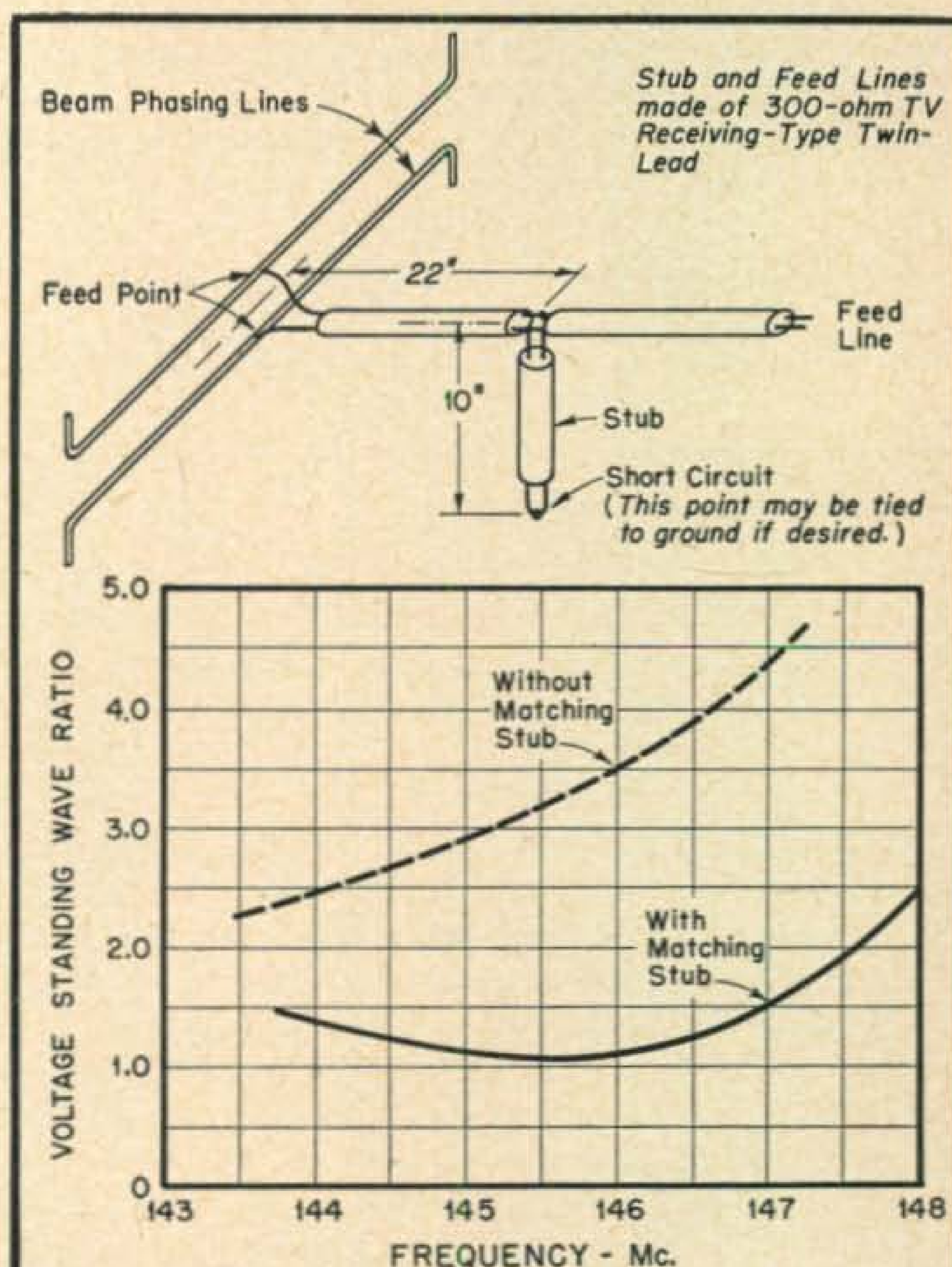

Fig. 6. The details of the matching system and a plot of the voltage-standing-wave-ratio on 300-ohm twin-line with and without the matching stub.

When the internal resistance of the meter is unknown, about the only way to arrive at a correct value of shunt resistance is to make a wild guess at what the meter is and then place almost any length of No. 30 wire across its terminals, using the set-up shown in *Fig. 1*. For instance, assume a meter of unknown internal resistance is in a circuit (*Fig. 1*) with a random length of wire across the terminals for a shunt. With the standard meter reading full scale, say 100 ma, the unknown meter might read 6/10ths of full scale. This would indicate that the unknown meter is not carrying enough current (the shunt is passing too much current, in other words). Obviously, the better way to arrive at the correct value desired is to have too high a resistance to start with so that the length of wire may be pruned until the correct value is obtained.

It would be beyond the scope of this article to cover specifically even the most representative cases of surplus meters and their modification for amateur use. A little common sense, a considerable amount of care, and perhaps some reading in the handbooks would enable the average amateur to put these meters to good use. By using the principles outlined herein, you should be able to have better meters on your transmitter and at the same time save a dollar for the purchase of some other needed part.

THE TWIN FIVE

(from page 14)

metal element-support boom is employed, the element lengths should be increased by about ¾ of the diameter of the metal mounting tube.[4] In order to achieve even approximately the same feed impedance as was realized in the original design, the ratio of conductor diameters of the folded dipoles should be preserved.

Our wooden frame was made of 1″ × 2″ selected red cedar, and the two Yagi "booms" were made of the same material, tapered to 1″ × 1″ at the ends to cut down weight and wind resistance. The clothes-wire elements were force-fit into holes drilled into the wooden booms, and were secured by the use of wood screws as set screws. The tips of these screws biting into the aluminum wire insure that the wire cannot slip out of place. The large-diameter conductors of the folded radiators were attached to the outside edges of the wooden boom by small metal cable clamps, which were screwed to the booms with wood screws. The small amount of mis-alignment caused by mounting the dipole section on the side of the boom apparently produces no deleterious effects. A few coats of spar varnish over the wooden frame will protect it against the ravages of weather.

The main mounting plate (*Fig. 5*) may be

[4] R. M. Fishenden and E. R. Wiblin "Design of Yagi Aerials" *Proc. I. E. E.* (London), January, 1949, Part III Vol. 96, pp. 5–12.

constructed of wood or metal. It can serve as a mounting point for a bearing or flange. If "flip-flop" operation is desired, a sturdy hinge may be attached to this plate to provide a tilt-top mounting at the mast head. It is possible to locate the balance point of the beam assembly so that very little force is required to tilt the entire array through ninety degrees, and it can be made to rest stably in either position without the use of springs or counter-weights. The details of the polarization-changing mechanism will be left to the individual choice of the builder. We have seen everything from spring-return screen-door hinges to elaborate motor-driven systems employed for this purpose. At W2PAU we use two ropes which run all the way up to the masthead from the first-floor operating position, and, despite the fact that these ropes wind around the mast guy system as the beam turns, we have not experienced any trouble due to fouling, mainly because the force required to tilt the beam is so small.

The purist would probably prefer to use a wooden mast, or at least a wooden top section, if vertical polarization is to be extensively employed. Unless the feeders are supported out in back of the beam structure and brought down away from the mast until they are well below the ends of the elements, there is nothing to be gained through such a refinement. We have checked the performance of one of these beams mounted on a metal mast, and the effect of the mast seems to be negligible. The wide spacing between the Yagi sections pays a dividend in this case because the elements are at least a one-half wave from the vertical run of feeders and from the supporting mast; thus, the mutual coupling between these members is less than in the conventional close-spaced configuration.

Matching the Array

The antenna was designed to be fed with 300-ohm twin line. The model described above was checked experimentally, and the standing wave ratio was found to be approximately 2 to 1 at the low-frequency end of the two-meter band. The beam feed impedance was lower than desired and measured about 120 ohms, essentially resistive. Here we were faced with a problem. Should we re-design the entire array in the hopes that the next attempt would yield a feed impedance closer to the desired goal, or should we simply provide a matching system to transform the measured impedance up to the correct value? It was finally decided that the basic design was almost satisfactory for many applications without change. For example, if 75-ohm coaxial cable were used with a "bazooka" type of balancing device, the beam impedance was only a little too high. If 50-ohm coaxial cable were used with a "trombone" type of balancing transformer, the beam impedance should be 200 ohms.[5] In

[5] W. M. Scherer, "Balanced Feed Systems with Coax," *CQ*, July, 1949, page 29.

short, any effort expended to make the design specifically suitable for the 300-ohm twin line would only serve to make it worse for the other types of feeders.

Any of the common methods of matching a beam could have been used, but we decided to use the single-stub matching system. By using a stub of adjustable length, tapped across the feedline at an adjustable distance from the load, practically any type of line can be matched to any impedance load. Our stub was constructed of the same type of 300-ohm twin line as was used for the feeders. The adjustment which produced optimum results consisted of a 10″ shorted stub connected across the feedline 22″ from the antenna feed point. The shorted end of this stub may be grounded if desired, it can be tied to the mast, or attached to the beam structure at any convenient point; thus, it does not represent a very formidable mechanical problem. This matching system produced practically a perfect match over the major part of the two-meter band.

Bandwidth Considerations

Parasitic arrays have generally had the bad reputation of being acutely frequency-conscious. We were quite surprised to discover that this antenna, with the simple matching system described above, showed very little change in feed impedance over the entire lower three megacycles of the two-meter band. As is shown by *Fig. 6*, the v.s.w.r. was better than 1.5 to 1 over this range. The obvious implication is that the antenna will accept full power and presumably radiate essentially all of same at any frequency within this band. The only other consideration which might affect the utility of the array over a wide frequency band would be a degradation of the field pattern as the frequency is shifted. In practice, very little change of the major features of the field pattern can be noted, even at the extremes of the band. Although the front-to-back ratio may change slightly as the frequency is shifted, the percentage of the total radiated *power* that leaks out in undesired directions is still very small. In short, the specification performance of this array should be maintained over the lower three megacycles of the band, and only the most precise measuring techniques would detect the dropping-off of performance in the remaining megacycle.

The Field Pattern

A few words of explanation about the directivity pattern of this array might be in order, as we have heard several questions from users of the design who wonder why the beam seems to respond better to signals coming in from undesired directions than their old beams did. This complaint is probably justified. A re-examination of the pattern of *Fig. 3* will disclose the fact that the minor lobes are only about ¼ as large as the main lobe on the basis of relative field strength. When expressed in terms of power ratio, this is equivalent to 16 to 1, so the actual amount of power radiated in the minor lobes is small, in the order of 10 or 15 percent of the total power. However, expressed in terms of db, which is the scale usually used on receiver "S" meters, each minor lobe is only down about 12 db or two S-units. The rear and sides of the beam are not entirely "dead," but may have minor responses up to about 20 db below the main lobe. The presence of such appreciable pickup in undesired directions might make this beam appear, at first glance, to be inferior to other popular arrays, but, in every respect except ability to suppress QRM, it can out-perform any other simple antenna of comparable size which we have checked. It has filled a real need for us and for many other of the 144-mc operators who have investigated its possibilities.

SCRATCHI

(from page 4)

ceiver is turned on. Also, the louder I have the receiver volume, the better the car runs.

Things are going fine after I discover the key to the mystery, except that as I got farther and farther from town on my way to the ranch, the noise level on the receiver is getting lower and lower, and the car is getting to run no better faster and faster. About one mile from home, the car is sputtering to a stop and this time I can not get it started again.

Scratchi is now in 1/c predicament. The old sun is making the car hot, Scratchi hot, and the pavement hotter. I are not relishing idea of walking home, so I are putting Hon. Brain in high gear. If the car runs when the receiver is turned on with high volume, and receiver not not putting out high volume because there is no ignition noise around, why not make ignition noise in the car? Sounding like peechy idea, so I quick-like take off the spark plug suppressors, jump in the car, and step on the starter. Hot Diggedity, everything working FB.

With motor running the spark plugs are making noise like fury in the receiver, which are making loud volume outputs so motor are running. Scratchi is now getting home in jigs time and soon explaining master stroke of genius to Brother Itchi. He is quite impressed with my ability, but he is wondering how come the car not working in the first place. So, he is taking look at what might be wrong.

First thing Itchi is finding is a short in regular ignition circuit. Next he find that the speaker leads from the ten meter receiver are mixed up with the spark coil. It seems that when the receiver is on the output voltage going to the speaker is also into the spark coil, which are energizing spark plugs and motor is running. Scratchi like this system so much that I ask Brother Itchi to leave it that way, but he say that he went to fix the car properly.

After getting leads straightened out the car is still non compis mentis, and I are about to give Itchi big horsey laugh when he going to the gas tank. Yes, Hon. Ed., you are guessing it. No gas. Your for bigger and better quarter-wave vertical 75 meter mobile antennas.

Respectively yours,
Hashafisti Scratchi