The Terrible T and Gamma, too!

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From Start to Finish—The Complete Story on How the T and Gamma Matching Networks were Developed and How They May be Used by Every Reader to Greatest Advantage

The various Handbooks and Manuals that deal with the subject of antennas and antenna matching systems invariably mention certain coupling devices called *T matches* or *Gamma matches*. After the Handbook gives a glowing description of how these wonderful coupling devices are supposed to work, the subject is summed up to the effect that, "the *T match* and the *Gamma match* are best adjusted by the cut-and-try method."

This article is respectfully dedicated to anyone who has spent hours or days juggling a *T match* at the top of a tower. It took me two years of spare time "cut-and-try" to conquer the *T match* to the point where I was the boss, rather than the *T match!* The discussion below is a summary of the results of the most successful "cut-and-try" method of adjusting these perplexing affairs.

Development of the T Match

The *T match* and the *Gamma match* are closely related to each other and to the single-wire fed antenna. Refer to *Fig. 1* for a moment. A simple dipole antenna is shown, with the voltage and current curves superimposed upon it. At the center of the antenna is a point of maximum current and minimum voltage. In practical cases, the center of the dipole may be connected to ground, or attached directly to the supporting structure that holds the dipole in the air. The structure may or may not be grounded.

As one moves toward the ends of the antenna, the current in the antenna gradually decreases in value, and the voltage slowly increases. At the ends of the dipole the current is practically nonexistent, but the voltage is extremely high. The high ratio of *e* to *i* at the tips of the dipole indicates that the impedance of the dipole to ground (*z*) is very high at these points. The impedance to ground gradually decreases as one moves back along the antenna towards the center, and when the center point is reached the impedance to ground is zero. As mentioned above, the dipole may be grounded at this point with no effect upon its performance.

Note that we are not talking about the *radiation resistance* of the dipole. If the dipole is split in the center *(Fig. 2)* and the impedance measured between the two halves, it would be found to be in the vicinity of 72 ohms. We can, in fact, break the antenna at the center and feed energy to it with a balanced 72-ohm line. If we do this, two rather unpleasant things happen:

1. Since the antenna is fed with a balanced line, both halves of the dipole are "hot" at the feed point, and the dipole cannot be grounded to the supporting structure. Insulated mountings must be used to clamp the dipole to the supporting framework.

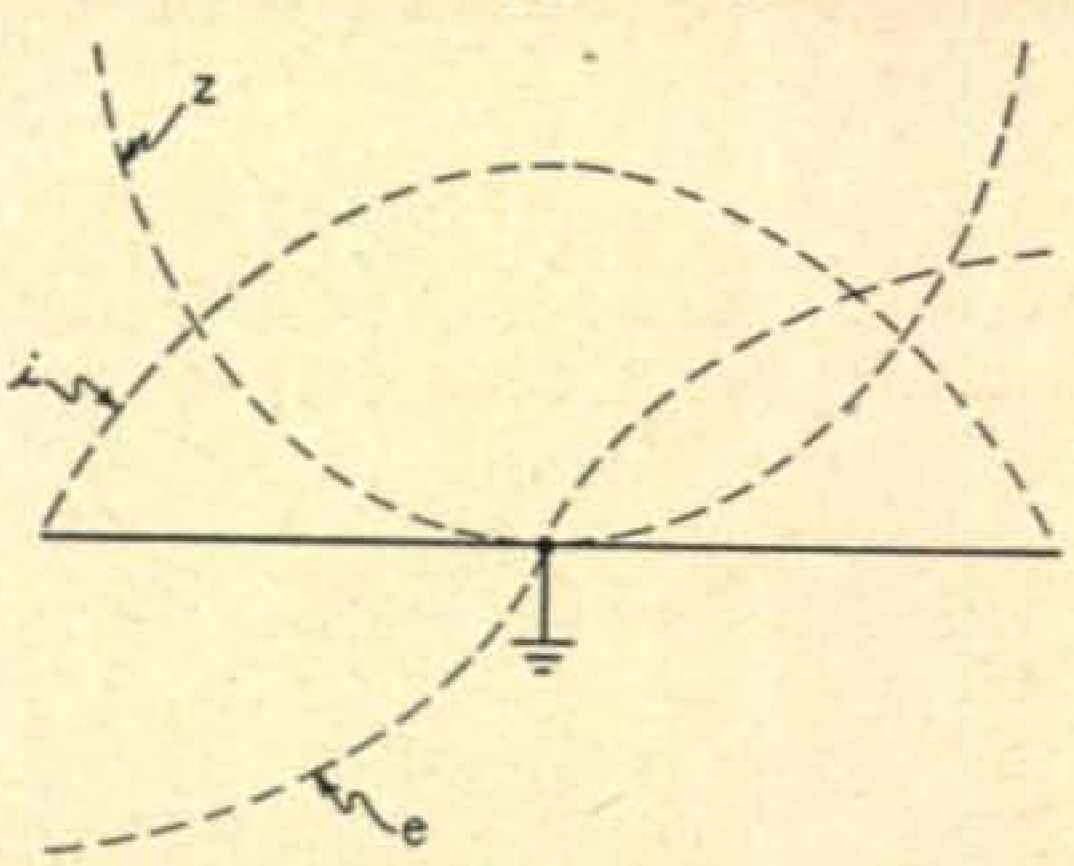

Fig. 1. This illustration shows the classic half-wave dipole with current (i), voltage (e) and impedance to ground (z) superimposed upon it. The center of the dipole may be assumed to be grounded.

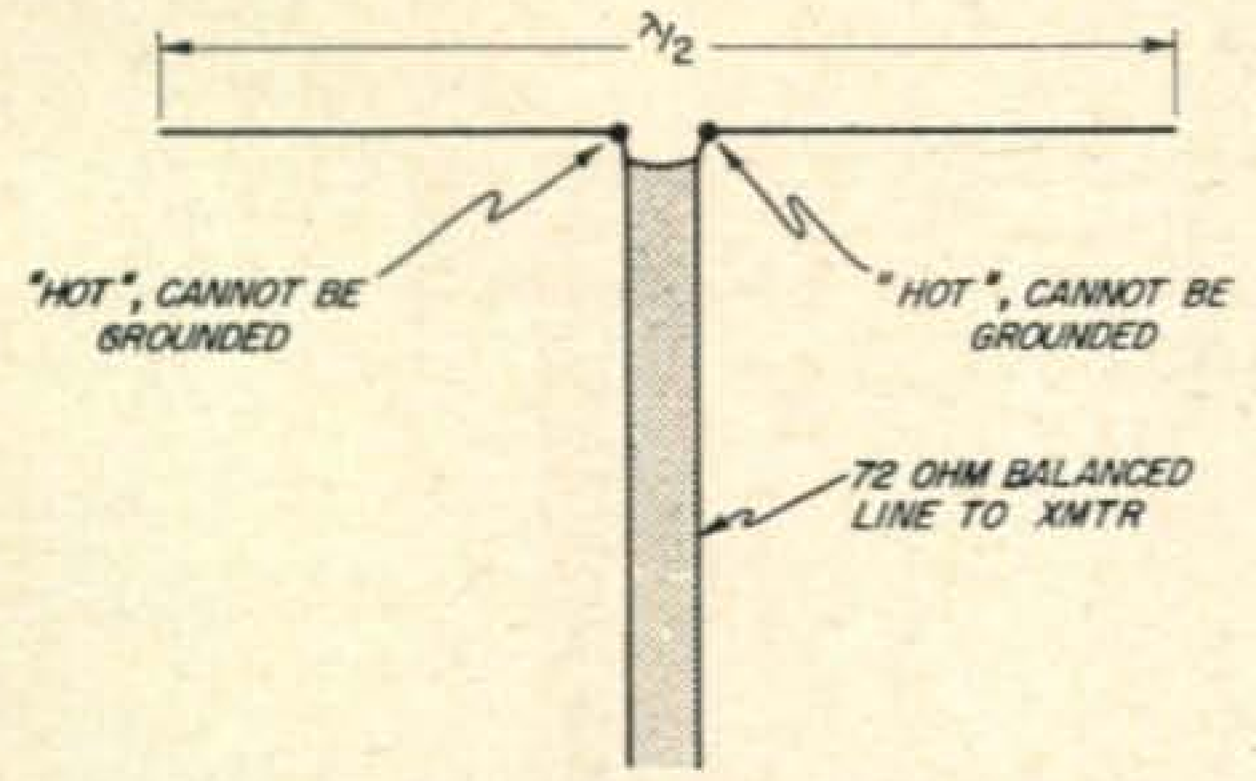

Fig. 2. Splitting a dipole into two quarter-wave sections will permit it to be fed from 72-ohm balanced feedlines.

The splitting of the dipole also introduces mechanical problems of mounting and preserving the rigidity and strength of the dipole.

2. The impedance of the dipole is a function of the antenna array in which it is used. The center feed point may drop to a value around 10 to 20 ohms. A matching network of some kind is needed to match this low impedance feedpoint to a 50 or 300-ohm feed system. If a *Q section* of quarter-wave transformer is used, only certain transformation ratios can be obtained, but there is no assurance that the center impedance of the beam will be kind enough to match the transformation ratio that is readily available.

It would seem, therefore, from both a mechanical and an electrical point of view that it would be best to leave the driven element in one whole piece. If the driven element is not split, but considered as a dipole, it may be fed in a number of ways that take advantage of the varying impedance to ground (or to the center of the dipole) that exists along the length of the dipole.

Early Relations of the T Match

The first antenna to utilize this method of feed was the single-wire fed antenna. *(Fig. 3)* A single-wire feeder was tapped on the dipole at a specific point representing about 500 ohms impedance to ground. A single wire has a surge impedance of about 500 ohms, depending upon the diameter of the wire and the proximity to nearby objects. If the placement of the tap was correct, the current in the feeder was uniform along its length, and the radiation from the feeder was at a minimum. This feed system utilized the mirror image of the antenna for a ground return, and was therefore subject to considerable ground losses which were dependent upon the conductivity of the soil above which the antenna was located.

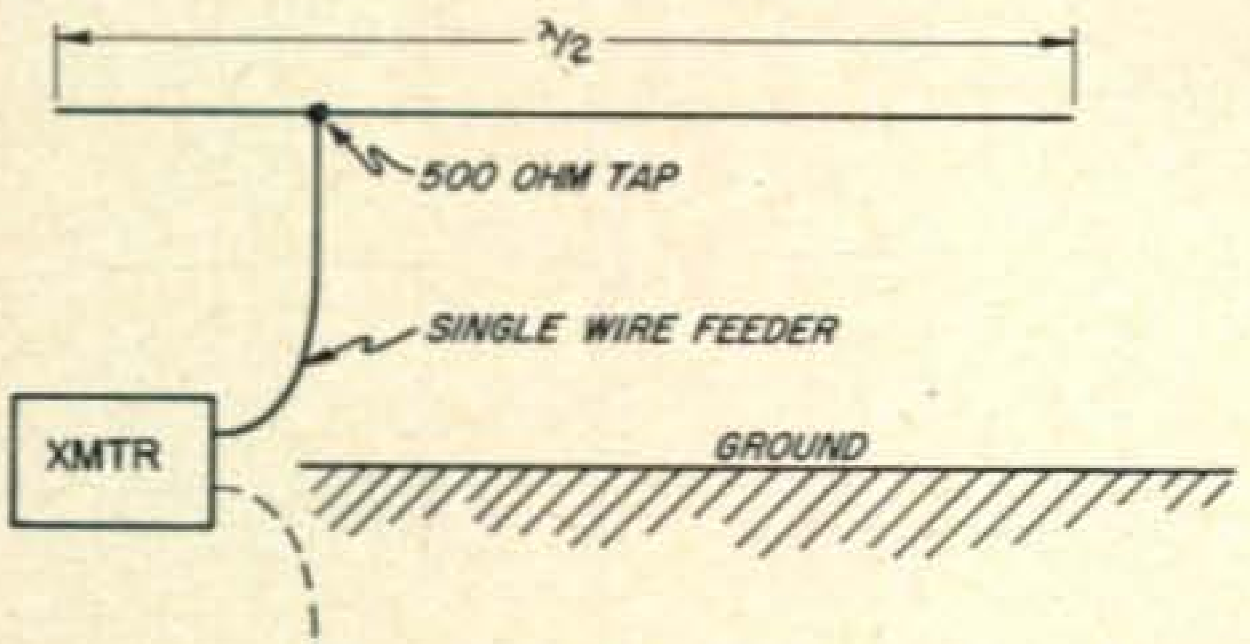

Fig. 3. The single-wire fed antenna is a distant relative of the gamma and T-match type of antenna feeding.

The single-wire fed antenna worked well in most cases, but the feeder did radiate, and distorted the pattern of the antenna.

To overcome the problem of feeder radiation, the grandfather of the *T match* was devised—the *Delta match*. The *Delta match* employed a balanced feedline, which was tapped out equidistant on each side of the dipole. *(Fig. 4)* It may be considered as two single wire feeders "back-to-back." The sides and length of the delta were varied to effect an impedance match between the impedance to ground points on the dipole, and the surge impedance of the two wire transmission line. The *Delta match* never became really popular because of the mechanical difficulties of varying the delta dimensions to obtain the proper match.

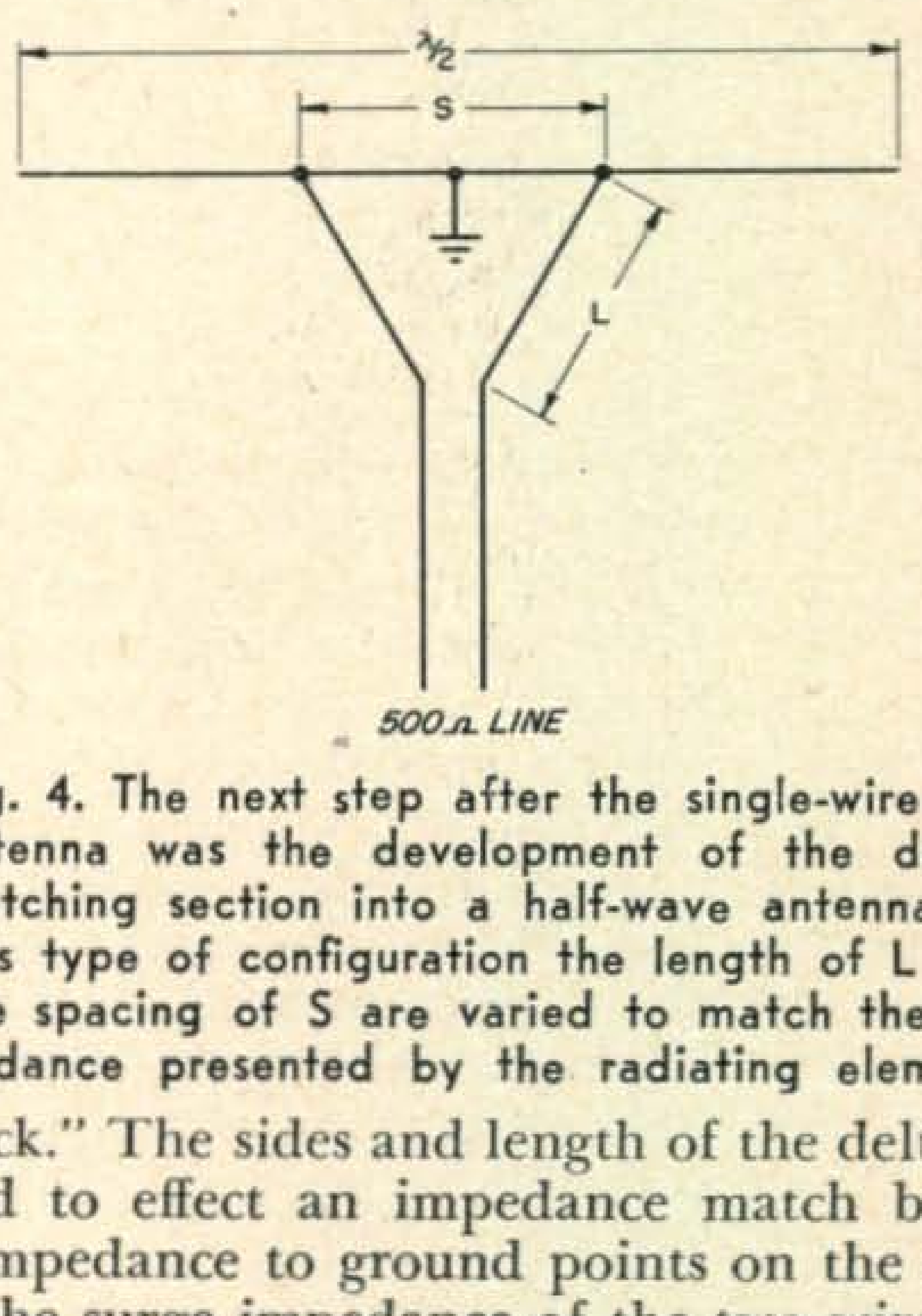

Fig. 4. The next step after the single-wire fed antenna was the development of the delta-matching section into a half-wave antenna. In this type of configuration the length of L and the spacing of S are varied to match the impedance presented by the radiating element.

The *T match* is the first cousin to the *Delta match*. It makes use of the varying impedance to ground characteristics of the dipole. The balanced feed line is used, and is fanned out to run parallel to the antenna, a short distance away from it. At the correct impedance point, the feeders are tapped on the dipole. The impedance between these two points (or between each point and the center of the antenna) is chosen to match the particular impedance of the transmission line. The transformation is accomplished by changing the length or spacing of the *T*-section with respect to the antenna. *(Fig. 5)*

Since a dipole antenna is a balanced device, it may be fed by an unbalanced feed system by merely applying the feed to one-half the dipole. This is done with the *Gamma match. (Fig. 6)*

The *Gamma match* is merely half of a *T match*, and is intended to be used with an unbalanced coaxial line. The shield of the coaxial line is grounded to the mid-point of the dipole, and the inner conductor is attached to the dipole at the correct impedance to ground point. One half the dipole is excited, and it is very difficult for the other half of the dipole not to follow suit!

The matching systems of *Fig. 5* and *Fig. 6* have been in general use since 1946 by many amateurs with good to indifferent results. In many cases the use of these matching systems resulted in a high SWR on the transmission line, and severe detuning of the dipole, regardless of the setting of the matching rod. With the advent of instruments such as the *Antennascope*[1] and the *Micro-match*,[2] many such installations that did perform in a satisfactory manner were nevertheless found to have an unsatisfactory SWR, and were reflecting considerable reactance back into the transmitter output circuit. Even though coaxial feed systems were known to be superior to others from a TVI standpoint, many amateurs shied away from the use of coaxial line because of the difficulty of arriving at a low enough SWR to permit the line to function properly. A truly sad state of affairs!

Preliminary Tests with the Gamma Match

When the 14-Mc. beam at W6SAI was overhauled, it was decided to change over from an open wire feedline to RG-8/U coaxial line as an anti-TVI measure. A series of tests were run to determine just what the correct adjustments for a *Gamma match* would be. The following results apply equally well to a balanced *T match*, since both are operating on the same principle.

The 2-element 14 Mc. beam was mounted on a short tower atop the garage roof in such a position that all elements could be easily reached from the roof of the garage. Before the tests were started, the driven element of the beam was grid-dipped to 14,150 kc., and the director was cut 5% shorter in length than the driven element. A short distance away, a 21-Mc. 3-element beam was set up, to serve as a cross check on the measurements made on the 14 Mc. array. The three test instruments used were a grid-dip oscillator,[3] an *Antennascope* and a coaxial standing wave indicator.[4]

Results of the Tests

Antenna Resonance. As soon as either the *Gamma match* or the *T match* was attached to the driven element, the resonant frequency of the driven element changed several hundred kilocycles. No adjustment of the matching system could be made that would provide a resistive 52-ohm load at the terminating end of the matching device. A SWR of about 2:1 could be reached by adjusting the matching rod length, but the terminating impedance always exhibited a large amount of reactance. This reactance could only be eliminated by retuning the driven element of the array. Different settings of the *Gamma match* necessitated changing the driven element length by as much as one foot. Since the *Gamma match* unbalances only one side of the driven element, the length correction was only applied to that side of the dipole. This produced a lop-sided looking beam, and resulted in a definite mental hazard, to say the least. Of course, the corrections would apply to both sides of the driven element if a *T match* had been used.

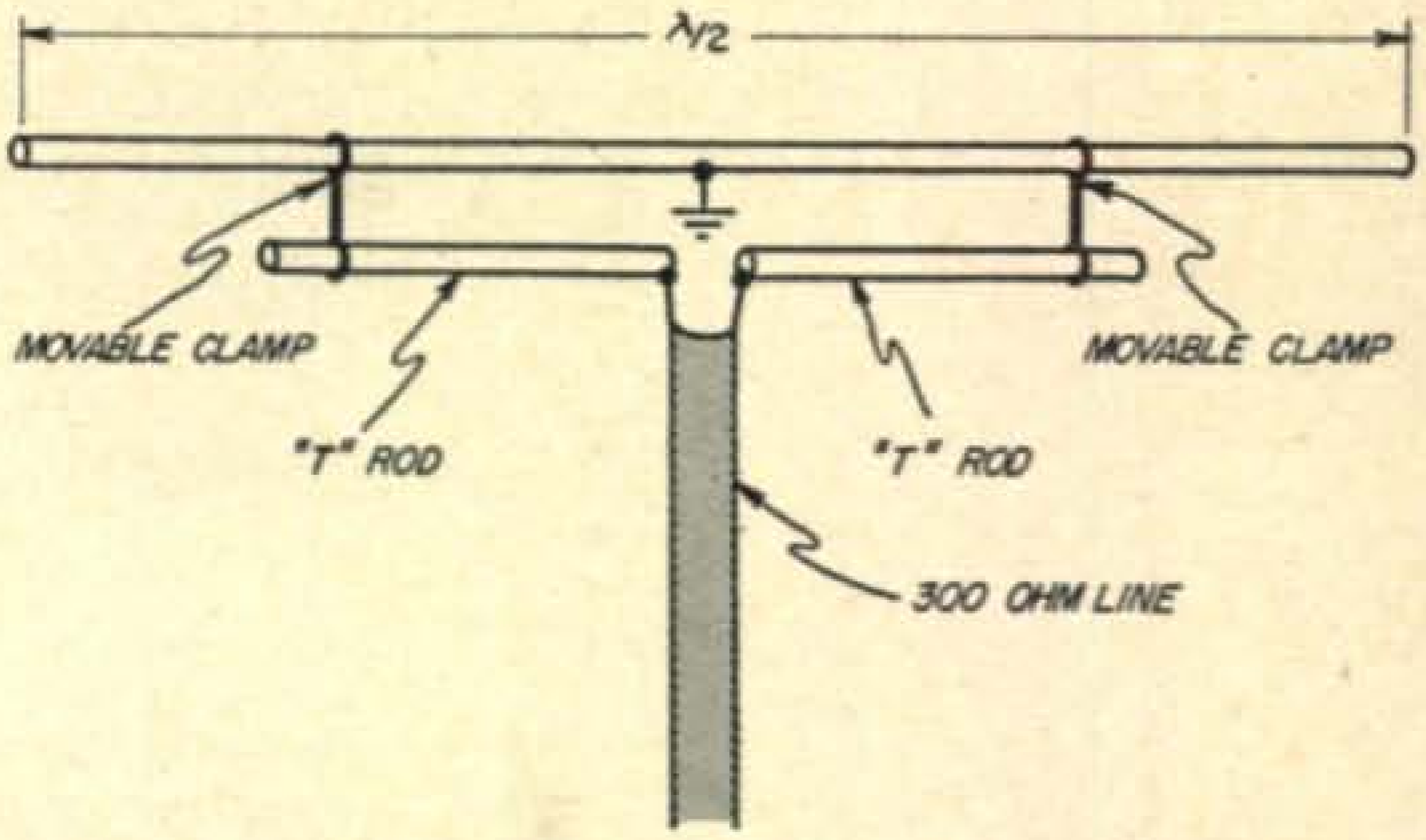

Fig. 5. In the T-match device the movable clamps are adjusted to provide a match between the dipole radiating element and the feed line.

This system is effective, but poor to use in actual practice, since the reference point for all adjustments is the initial resonant length of the driven element. If we continually "readjust our zero setting," the resonant frequency of the antenna is liable to wind up on top of WWV!

A much better method of eliminating the reactance of the *Gamma match* is to include a compensating condenser in series with the gamma rod. By properly adjusting the capacity of this condenser, the reactance of the *Gamma match* may be eliminated. A resistive load will be presented to the coaxial feedline, and the beam will not be detuned by the presence of the matching device.

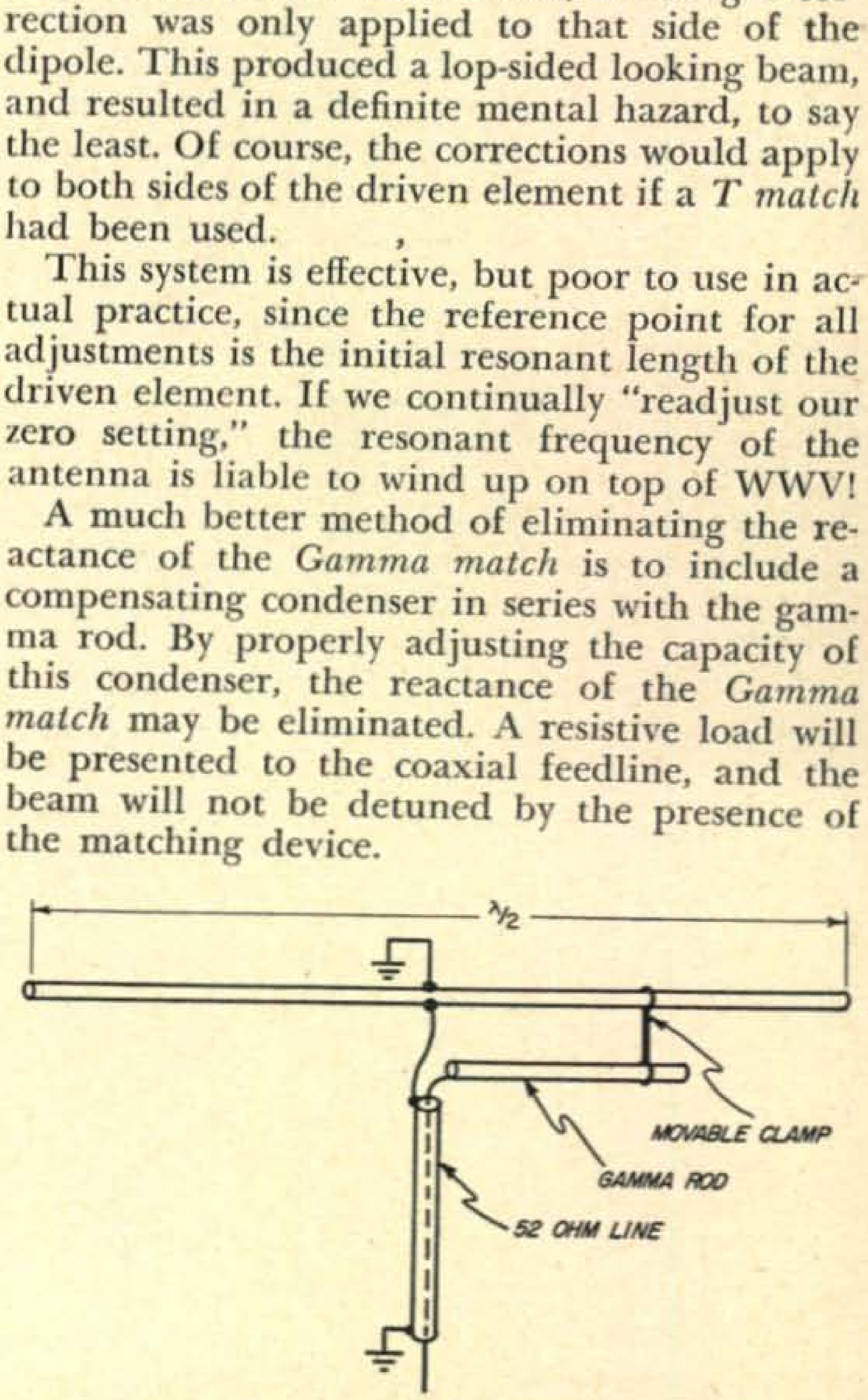

Fig. 6. The gamma match was developed to provide an easy method of feeding the radiating element with coaxial line. It is effectively one-half the T-match shown above.

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[1] Scherer, "Building and Using the Antennascope," **CQ**, Sept., 1950.

[2] Jones and Sontheimer, "The Micro-Match," **QST**, April, 1947.

[3] Brown and Scherer, "Subject: Grid Dippers," **CQ**, January, 1953.

[4] Scherer, "Balanced Feed Systems with Coax," **CQ** July, 1949.

Gamma Dimensions. The dimensions of the *Gamma match* determine the transformation ratio that is being performed.

1. The *longer* the gamma rod, the *higher* the impedance presented at the base of the rod.
2. The *longer* the gamma rod, the *smaller* the value of the resonating series capacity.
3. The *greater the spacing* between the gamma rod and the driven element, the *higher* the impedance presented at the base of the gamma rod.
4. The converse of these statements is also true.

A *Gamma match* or a *T match* may be made to perfectly match line impedances of 10 to 500 ohms. In general, a rod-to-driven-element spacing (measured center-to-center) of 5″ should be used for 28 Mc., 6″ for 21 Mc., and 7″ for 14 Mc. If spacings much less than this are used, the length of the gamma rod will be excessive. Gamma lengths of about 2 feet at 28 Mc., 3 feet at 21 Mc., and 4 feet at 14 Mc. may be expected when the above spacings are used. These lengths apply for 52-ohm feedlines. For 300-ohm lines, the *T match* rod will be about 50% longer on each side than the above figures.

The diameter of the gamma rod is of relatively little importance. It may be a piece of one-inch tubing for maximum rigidity, or it may be as small as No. 12 enamelled wire. The length of the gamma, and the setting of the compensating condenser will take care of these variations in the gamma diameter with ease. If a piece of wire is used, it need not run parallel to the driven element as the tubing would do, but may approach the driven element by the shortest direct path. A hose clamp or tubing clamp may be used to attach the wire to the element. *(Fig. 7)*

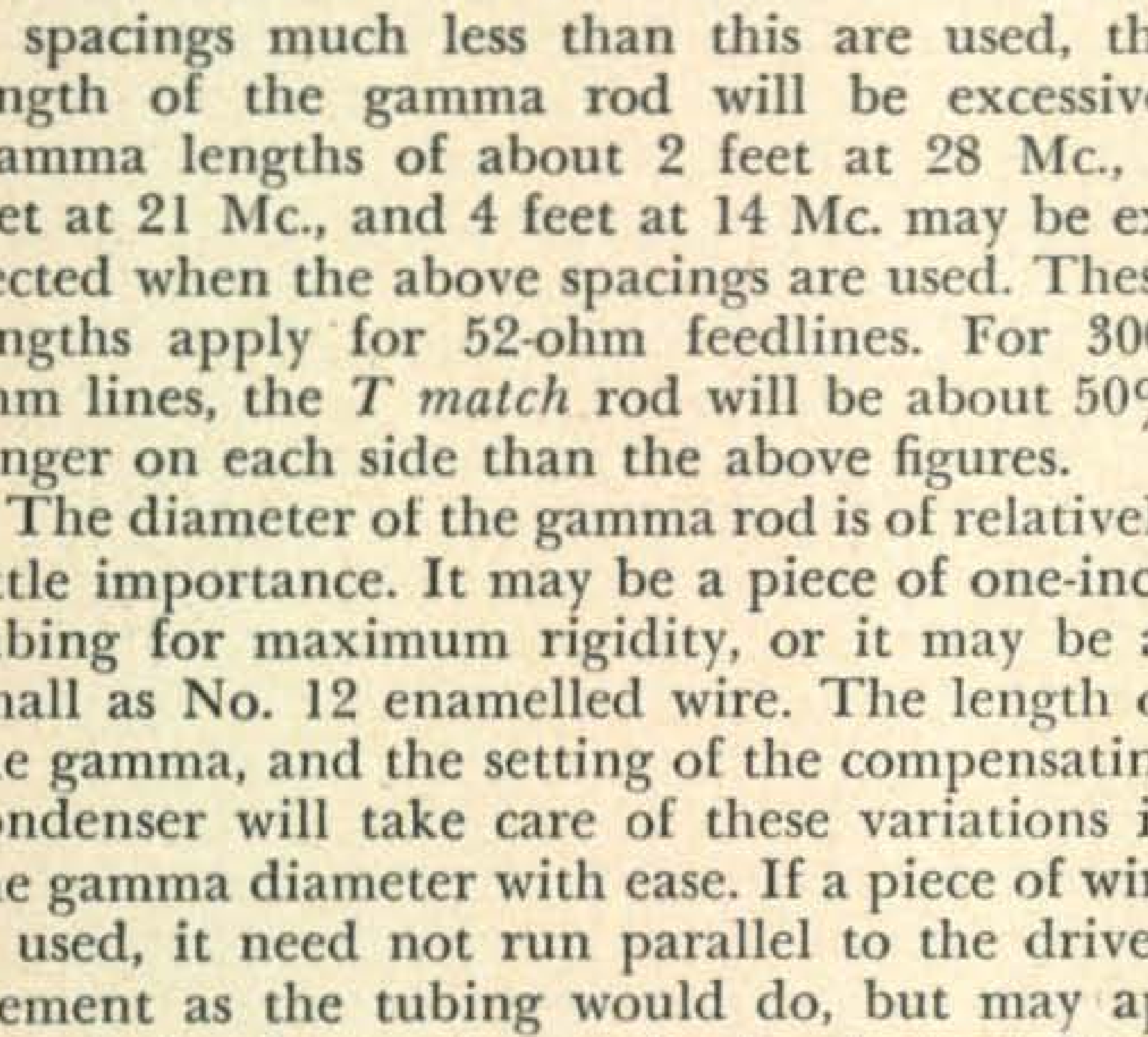

Fig. 7. Illustrating the use of a wire in place of the rod or tubing in the gamma match.

If tubing is used for the gamma rod, a suitable clamp should be bent out of soft dural or brass that can be easily slid along the driven element and the rod, to facilitate changes in the length of the match. Once the gamma is positioned the extra length of rod that is free of the clamp may be cut off, if desired. There will be no noticeable difference in the action of the match if this is done. Be sure that all bolts, nuts and parts of the *Gamma match* are made of plated or non-corrosive material! If you forget this important step, you may need an acetylene torch the next time you want to make changes in the feed system!

The resonating condenser for the gamma rod may be a small receiving type 200 uufd. condenser for the tests. The coaxial line should attach to the beam framework (if metal) by a *SO-239* coaxial receptacle, bolted to the boom directly next to the center of the driven element. It should be bonded firmly to the center of the element. The center pin of the receptacle connects to one side of the variable compensating condenser. The opposite side of the condenser connects to the gamma rod. *(Fig. 8)*

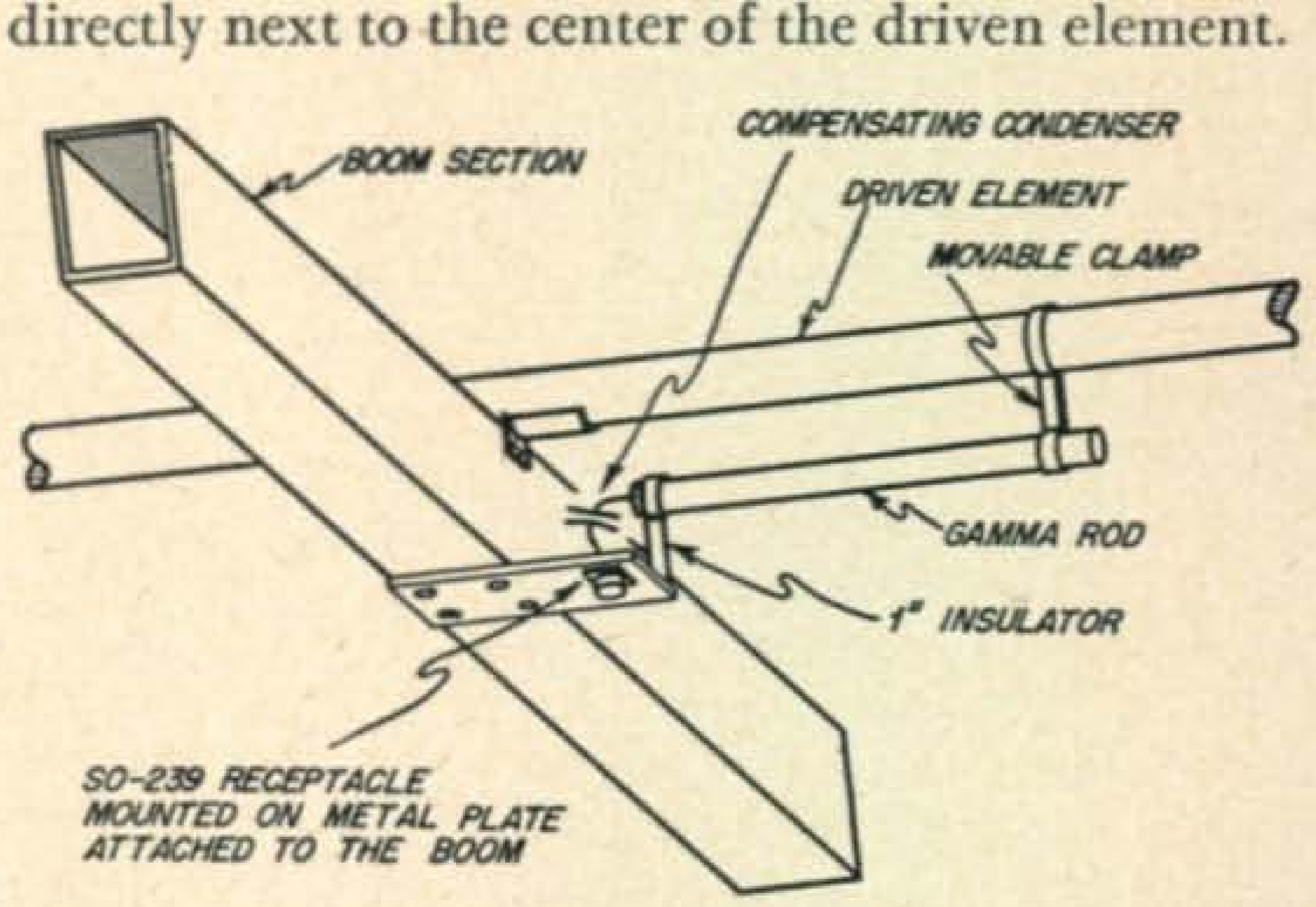

Fig. 8. Suggested method of mounting the compensating condenser and gamma rod.

Metal vs. Wood for the Structure. Either metal or wood will work well for the beam framework and tower. If a wood boom is used, the elements of the beam should be left "floating." If a metal boom is used, best results will be obtained if the elements are grounded at their centers to the metal boom. This point was brought to my attention during the tests on the beam when it was found that the SWR would fluctuate violently when the extremities of the boom were touched, indicating that the boom was not at ground potential. All the elements were attached to the boom by short insulators, and when the centers of the elements were grounded to the boom this hand capacity effect disappeared. The SWR measurements were now independent of the positioning of the boom, or the placing of hands thereon.

If the width of the boom is small, the elements may be clamped directly to it by means of metal straps. If the boom is a lattice structure of a foot or so in width, it is better to insulate the elements from the boom by means of thin strips of micarta or other flexible insulating material, and then ground the elements to the boom by means of a short, flexible strap. This will tend to keep circulating currents at a minimum.

If both a metal tower and a metal boom are used for the array, the entire assembly should be bonded together, so that the center of the elements, the boom, and the tower are all at the same potential.

The Choice of Feedline. The easiest and most practical feedline for a *Gamma match* is coaxial cable, such as RG-8/U. If a metal tower is used, the outer conductor of the coaxial line should be bonded to the tower at the base. The coaxial line may be run underground to the transmitter, is desired.

When a *T match* is used, either open line of the 75-ohm or 300-ohm variety, or balanced diaxial line (RG-57/U or RG-22/U) may be used. The latter type of line is best, since the shield may be grounded and the line will remain balanced to ground regardless of how it is conducted about the yard, or the proximity of the line to other objects. The open wire TV-type lines, on the other hand, may become easily unbalanced to ground during the run from antenna to transmitter. Also, the open line is exposed to the field of the antenna and may distort the beam pattern, or may pick up undesirable fields from the antenna that will tend to cause a greater unbalance in the system. Since the *Gamma match* and coaxial line performs as well as the *T match* and the diaxial line, it would seem to be the proper answer to the feed problem for any parasitic array. Then, too, modern transmitters, such as the *Viking*, the *Collins 32V* and the *KW-1* all have unbalanced coaxial feed systems and are designed for 50 or 70-ohm output lines.

Preliminary Beam Adjustments. To properly adjust the *Gamma match,* three pieces of equipment are needed: A grid-dip oscillator, an *Antennascope* and a midget 200 μμfd. variable condenser. A small dial and marker plate should be attached to the condenser, and the condenser should be calibrated on a capacity bridge. If a semi-circular plate condenser such as a *BUD MC-1858* is used, the capacity settings between minimum 9 μμfd.) and maximum (190 μμfd.) may be easily estimated.

The beam should be placed atop a tall step ladder, or on the roof of a wooden structure, such as a garage. It should clear the ground by about ten feet, and be in a reasonably clear area. If the beam must be near some objects, such as telephone wires, it is best that the reflector be nearer the object, as it is much less susceptible to outside influences than the director. The following steps are now taken:

1. The driven element should be set to frequency. A very close approximation is: Length in feet of the element equal to

$$\frac{470}{f_{(Mc)}}$$

2. The director should be set 5% shorter than the driven element for director driven-element spacings of 0.15 to 0.20 wavelengths. For spacings less than 0.15 wavelength, the director should be set 4% shorter than the driven element.
3. The reflector should be set 6% longer than the driven element if the reflector to driven element spacing is 0.16 wavelength or less. For spacings between 0.16 wavelength and 0.2 wavelength, the reflector should be set 5% longer than the driven element.

When the elements have been set to the above lengths, the next thing to do is to adjust the driven element length, adjust the gamma rod length, and resonate the gamma condenser. All the above can be done in one step.

Adjusting the Gamma Match. With the beam in the elevated position, the *Gamma match* is attached to the resonating condenser, and the g.d.o. is coupled to the *Antennascope,* as shown in *Fig. 9*. If RG-8/U line is to be used, the *Antennascope* is set for 52 ohms.

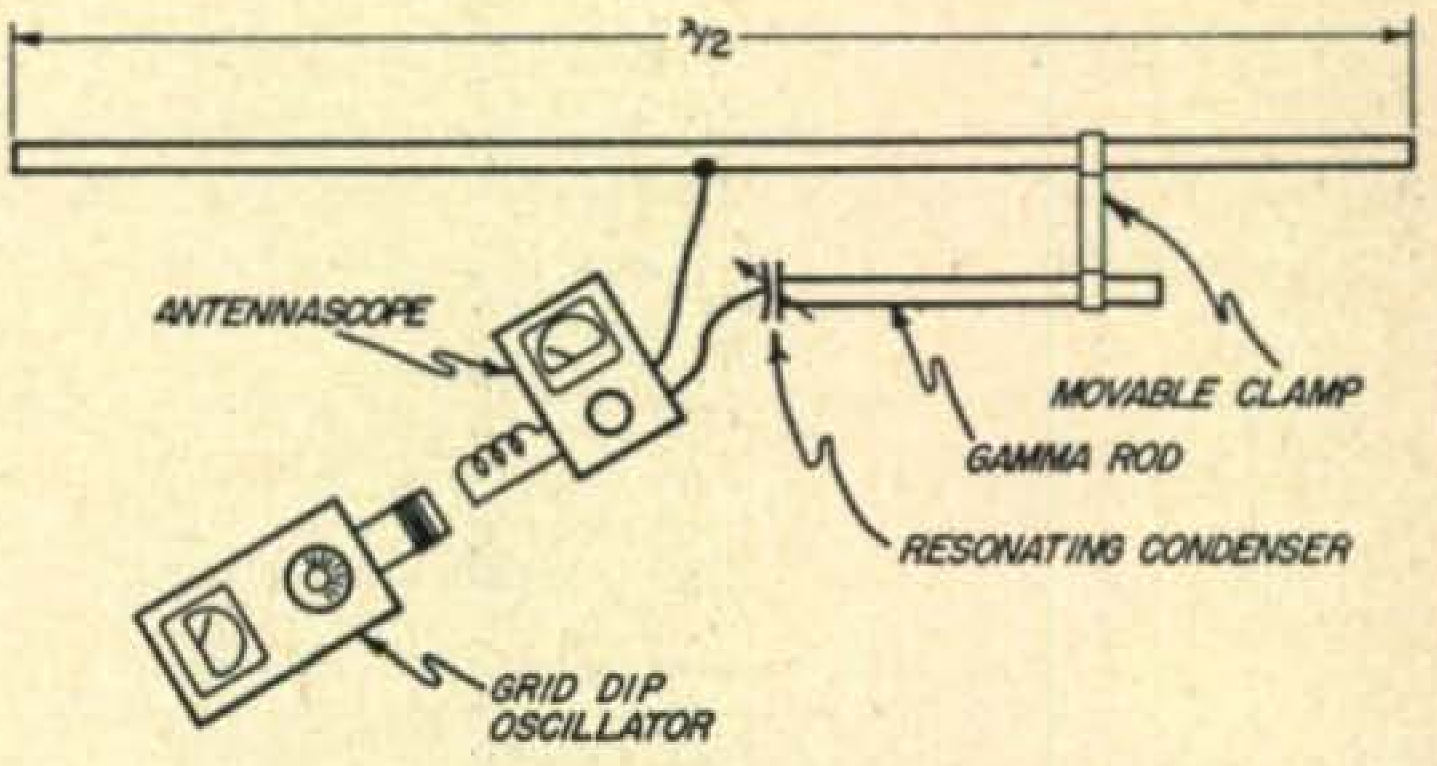

Fig. 9. Test setup for adjusting the gamma match.

The g.d.o. is tuned back and forth across the band, and the meter of the *Antennascope* is watched for a null, indicating the resonant frequency of the driven element. When the null is found, the resonating condenser of the gamma is tuned to enhance the null. The frequency of the g.d.o., the resonating condenser and the impedance dial of the *Antennascope* are all adjusted to complete the null, and bring the meter of the *Antennascope* to a zero reading. If a zero null cannot be obtained inside the band limits, the length of the driven element (both sides) must be altered slightly to bring the null to the correct point in the band. If the null occurs at some other impedance setting than 52 ohms, the length of the gamma rod must be changed, according to the rules set forth above. The frequency of the null should be checked with a calibrated receiver, as the calibration of the usual g.d.o. is none too good at high frequencies. Also, the calibration of the g.d.o. may shift slightly when it is coupled to the driven element of the beam.

During the course of these measurements it will be noted that there are two spurious nulls of weaker intensity, one on each side of the larger, center null. These represent the resonant frequencies of the reflector and director. As a cross-check on the tuning of an array, it should be noted that both these spurious nulls must fall outside the limits of the amateur band. If they do not, the lengths of the parasitic elements should be adjusted slightly until the nulls move out of the band. The low frequency null is caused by the reflector, and the high frequency null by the director.

When these adjustments have been completed, the capacity setting of the gamma resonating condenser should be measured. It is well to replace the variable condenser with a fixed condenser of the correct capacity, since the usual variable condenser will corrode badly, even when protected by a waterproof box. *Erie 850S and 853 series* Ceramic capacators may be paralleled to provide the correct value. Parallel connected 3000-volt transmitting mica condensers may also be used. Some surplus mica condensers have the exact capacity value stamped on the side of the case, and it might be possible to find a single unit in the junk box that is of the correct capacity. A slight deviation from the correct value will not be harmful. It will merely raise the minimum SWR from 1:1 at the resonant frequency of the array. As long as the overall SWR across the band is below 1.5:1, the beam is probably "on the nose."

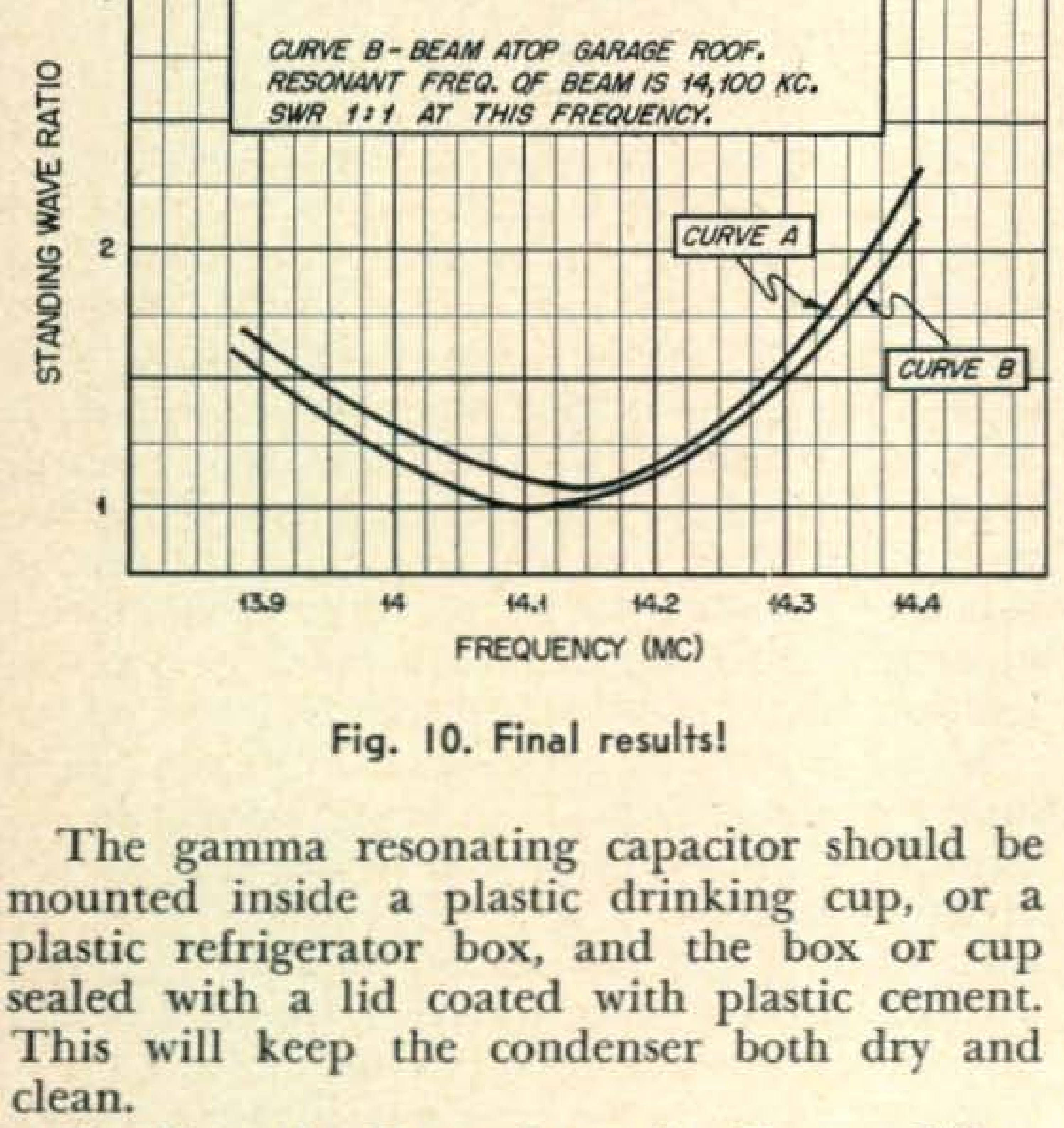

Fig. 10. Final results!

The gamma resonating capacitor should be mounted inside a plastic drinking cup, or a plastic refrigerator box, and the box or cup sealed with a lid coated with plastic cement. This will keep the condenser both dry and clean.

Checking the Beam Atop the Tower. When the beam has been placed atop the tower, a length of coaxial line should be attached to the beam, and the free end dropped to the ground. The SWR meter and the g.d.o. may be attached to the line and a final SWR curve should be run. If the beam was tuned up in a fairly clear spot, the resonant frequency of the beam should not have changed over 50 kilocycles, and the SWR at the resonant frequency should have not increased appreciably.

Curves A and *B* of *Fig. 10* illustrate the change in SWR and the frequency shift of a beam tuned up 12 feet above the ground, and then mounted atop a 45-foot tower. Close inspection of these curves will show that the SWR is not symmetrical about the resonant frequency, the slope of the curve being greatest on the high frequency side of resonance. This interesting deviation has been noticed on every beam antenna that has been checked, and is caused by the action of the director. The director is in the field of highest intensity, and exerts more influence on the driven element than does the reflector. In fact, changing the length of the director one inch changes the resonant frequency of the array a greater amount than does a one-inch change in the radiator length itself!

Loading the Beam Antenna

A frequent complaint of users of coaxial feed lines is that the array refuses to take a load from the transmitter. This is the result of a high SWR on the coaxial line reflecting an undesired reactance at the transmitting end of the line that the transmitter is unable to handle. This effect is caused by improper tuning of the beam, or reactance in the matching device, or both. Sometimes, however, even with a SWR as low as 1.2:1 a coaxial feed system will refuse to take a load from a transmitter. It is only necessary to add a few extra feet of line to the coaxial system to reflect a slightly different load to the transmitter and this trouble will clear up. The writer has four special pieces of RG-8/U cable, fitted with *PL-259* plugs at each end, and a *PL-258* splice at one end. The pieces are two feet, four feet, six feet and eight feet long. Through the use of these short pieces of line, the length of the main feed line can be changed by two-foot increments from two feet to twenty feet. This little stunt is not intended as a cure-all for cases of loading trouble where there is a high value of SWR on the coaxial feedline. There is no better way to blow up a coaxial fitting or to heat up a coaxial line than to have a high SWR on the feed system. In the cases where the SWR is reasonably low, the short splicing sections will save a lot of headaches.

Present and Prophetic

As soon as the September issue was on the presses we suddenly realized that the crossword puzzle on page 40 had not been properly credited. Our very sincere apologies to Mr. William E. Snow, W6UUC who submitted this very well received puzzle.

Have you found it difficult to decide between plate and screen modulation on the basis of which is the most efficient? Next month Contributing Editor, W3FQB reviews straight plate modulation, controlled-carrier and constant carrier screen grid methods analyzing the advantages and disadvantages of each.