The "Clemens Match'

Balanced Feed with Coaxial Line

BY JOHN F. CLEMENS,* W9ERN

ABOUT a year ago a new 3-element 10-meter A rotary beam was under construction at W9ERN. A previous model, fed with 300-ohm Twin-Lead and a T-match, had just been taken down due to the unsatisfactory performance of the feed system, which exhibited a high s.w.r. and considerable unbalance of the feed-line currents. An experimental project was undertaken to devise a method of feeding the beam with coaxial cable to take advantage of the general availability and good weather characteristics of RG-8/U. The experimental work on the antenna was done on a scaled version at 300 Mc., fed with the smaller-sized RG-58/U.

A feed system finally evolved from these investigations which appeared promising. The system was then applied to the full-sized 10-meter beam and the entire antenna was installed and evaluated over an 8-month period. The results of operation over this length of time on ten meters confirmed the results with the 300-Mc. antenna. A description of the antenna feed system with the design data appeared in *Electronics in* October, 1950.[1]

A number of inquiries followed publication of this article, mostly from amateurs who wished to apply the system to amateur antennas. The original thought in the first article was the probability that the antenna feed system might be attractive for use on television receiving beams. *QST* requested information on the system since it apparently had greatest interest for amateurs and many amateurs would be reached only through *QST*.

Unlike several previous antenna feed systems, this one bears no resemblance to an alphabetical letter, either English or Greek; and therefore, for want of a descriptive name the system is called the "Clemens Match."

Fig. 1 is a drawing showing the method of assembling the feed system. All dimensions in Fig. 1 refer to the 29-Mc. 3-element "plumber's delight" beam and are inversely proportional to frequency. Thus, to use the system on half the frequency, all dimensions would be doubled. Theoretically, of course, to be exactly similar to the original even the diameter of the elements should be scaled to the new frequency: practically, only the lengths of the elements and longitudinal dimensions need be scaled. The effect of a different element diameter should be negligible.

An advantage of this method of feed is the simplicity of installation. The entire feed system can be prepared on the ground, rolled up, carried onto the roof, and fastened to the antenna. This is because the matching system itself is made of RG-8/U, without any additional tubing or clamps being required.

The simplicity of the system is evident from the drawing. The odd feature of the "Clemens Match" is that the center conductor of the coaxial cable is not connected directly to the antenna. Also, a decided advantage is the fact that it is not necessary to split the driven element and plumber's delight construction is therefore practical.

Principles and Construction

The general theory and development of the system may be explained thus: The impedance between two symmetrically located points on an antenna rises from zero, when the points are adjacent, to a very high value, when the points are at the ends of the antenna. By suitably locating two such points, we may have an impedance whose resistive component is equal to the characteristic impedance of the transmission line. The equivalent impedance between the two points may be represented as a resistance and reactance in series or in parallel. Suppose that these two points have been chosen so that the resistance component of the equivalent series impedance is the characteristic impedance of RG-8/U, or 50 ohms. These two points were obtained by experiment and are 20 inches each side of center in the antenna shown.

A coax cable may now be fed to the antenna, up along (or inside) the mast and along the boom to the center of the antenna. The shield of the cable may be connected to the center of the antenna, if desired, with negligible effect since the voltage at the center of the antenna is very low. The cable may then be fed along the antenna element out toward one of the driving points, and again, if desired, the shield may be bonded to the antenna element along their mutual length since such a connection will in effect only increase the diameter of the antenna element.

When the cable reaches one of the driving points, the shield must be well bonded to the antenna element. Current from one conductor of the transmission line, the coax shield, reaches one of the driving points by this connection.

The center conductor of the coax is extended, without shielding, and makes a "U" turn, passing back past the center of the antenna and so on to the other driving point. The center conductor enters a shield at this second driving point and the resultant coax cable continues along the antenna toward the boom and mast. The shield of this section of coax is bonded to the second

* % Electronics Research, Inc., Evansville. Ind.

[1] Clemens, "A Coaxial Feed System for Antennas," *Electronics*, October, 1950, p. 154.

driving point. This second section of cable is eventually short-circuited to form an equivalent capacitive reactance. In the antenna of Fig. 1 a 72-inch length of coax provides the proper value of capacitive reactance. The shield of the shorted coax section may also be bonded electrically to the antenna, mast, and boom, if desired, but it is essential that the shield be well connected to the antenna at the second driving point.

The entire assembly is almost perfectly symmetrical and as a result may be expected to be free of electrical unbalance effects.

The purpose of the shorted coax section is to provide a capacitance to resonate with the inductance of the exposed center conductor of the cable, which is the cross lead (42 inches long in Fig. 1) plus the small additional equivalent series inductance of the antenna element itself between the two driving points. All of these various capacitive and inductive components can be calculated once the two driving points have been

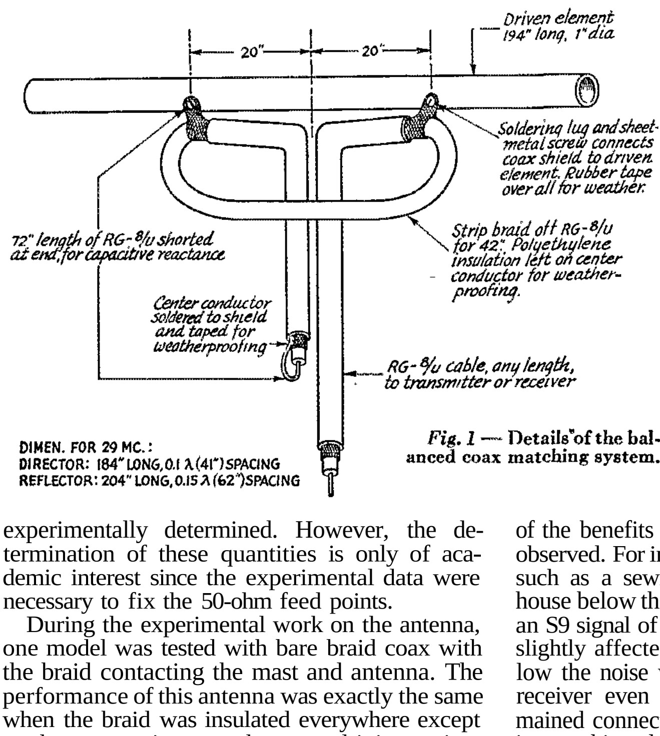

Fig. 1 — Details of the balanced coax matching system.

experimentally determined. However, the determination of these quantities is only of academic interest since the experimental data were necessary to fix the 50-ohm feed points.

During the experimental work on the antenna, one model was tested with bare braid coax with the braid contacting the mast and antenna. The performance of this antenna was exactly the same when the braid was insulated everywhere except at the connections to the two driving points. Since the weatherproof feature of coax was a prime aim, the final installation was made with RG-8/U with the vinyl jacket intact, except for an inch or so at each connecting point where a heavy soldering lug was soldered to the braid and fastened to the antenna element with a self-tapping screw. The entire region of the connection was then taped with Scotch electrical tape to prevent the entry of water under the vinyl jacket. The cross lead was formed of 42 inches of coax center conductor from which the vinyl jacket and shield braid had been removed. The heavy polyethylene insulation was left on the center conductor for weatherproofing. After 8 months, which, included a winter, the feed system was still in perfect condition. The 42-inch length of center conductor sags about 3 inches below the antenna element and from a distance the feed system looks like a T-match.

Both the feed line and the shorted capacitive section were wound in a slow spiral a turn or two around the antenna element for mechanical support and likewise spiraled around the mast and then taped in position.

Transmission-Line Pick-Up

Standing-wave measurements on the transmission line showed a perfect 1/1 match at 29 Mc., rising to approximately 1.5/1 at 28.5 and 30.0 Mc. Experiment then continued to determine the balance of the feed-line currents. Balance of the feed-line currents is essential to achieve maximum signal-to-noise ratio, since the beam and not the feed line does the receiving. One test for balance is the alignment between the direction of maximum radiation and the elements of the antenna, maximum radiation occurring perpendicular to the antenna element in a balanced antenna. This desirable condition was found to exist by tests with a field-strength meter and local receiver S-meters. The voltages at the two tips of the antenna were compared and found to be the same by dangling flashlight bulbs at each tip. The center conductor of the coax was then broken at the antenna where it emerged from the shield and the receiver in the shack went completely dead, demonstrating the lack of signal pick-up on the shield.

Several remarkable instances of the benefits of a balanced coax feed have been observed. For instance, when an electric appliance such as a sewing machine was operated in the house below the operating room, it was found that an S9 signal of perfect readability which was only slightly affected by the noise disappeared far below the noise when the shield was broken at the receiver even though the center conductor remained connected. The noise signal from the sewing machine also rose from S4 or so to S9+ when the shield connection was broken at the receiver.

The directional characteristic of the beam was just as pronounced on reception as on transmission, a further indication of balanced feed.

The same matching system should be applicable to other types of antennas, such as a 4-element beam or simple half-wave single element. It is possible that 50-ohm cable can be matched even to a half-wave dipole having a center impedance of 73 ohms, because the antenna is not broken but allowed to shunt the resistance component which can produce a 50-ohm equivalent series_ resistance by suitable selection of the driving points. Lack of time has prevented work on applying the system to other antennas. There is reason to believe, however, that the same dimensions could be used on a 4-element close-spaced or even a wide-spaced beam with a negligible mismatch, say, less than 1.5/1. The reasoning behind this belief is that although the center impedance of the driven element varies appreciably as the number or spacing of parasitic elements is changed, the impedance between the tips of the antenna varies in the opposite direction. Therefore, there must be a region on the antenna where the impedance varies only slightly or actually remains constant and the two feed points, 40 inches apart, *may* be in this region.

Adjustment

Should anyone wish to determine exactly the correct feed points for any type of beam, a description of the test procedure will be helpful. A Micromatch is used to determine the s.w.r. on the transmission line. Instead of the shorted length of coax cable a small variable condenser may be temporarily used in series with the cross lead. Two feed points are arbitrarily selected and the coax shield is clamped to one, and one terminal of the variable condenser is clamped to the other. The center conductor is then connected to the other terminal of the variable condenser, power is applied, and the condenser is tuned for a minimum s.w.r. If this minimum value is not 1/1, the feed points should be relocated and the test repeated. In this way the proper points of feed may be rapidly located. The capacity setting of the condenser should then be determined and a length of shorted coax should be cut to provide the same value of capacitive reactance and this shorted stub is then used to replace the condenser.

The necessary length of cable for a closed stub is determined, once one knows the necessary capacitive reactance, by

$$X_c = Z_k \tan \theta = -\frac{Y}{Z_0},$$

solving for 6. The electrical angle *0* will always be between 90 and 180 degrees and may then be converted to inches of coax by the formula

$$D = \frac{32.8\ V_P}{f}\theta$$

where D is the length in inches, *0* is expressed in degrees, / in megacycles, and V_P, the propagation velocity, as a fraction. (V_p for RG-8/U is 0.66.)

The series-resonant circuit formed by the shorted coax capacitor, the antenna and cross-lead inductance and the antenna radiation resistance is a low-Q circuit and therefore has a negligible effect on the over-all bandwidth. In other words, since a parasitic beam is a relatively high-Q narrow-band device, the matching circuit will not affect the bandwidth of the system to an appreciable degree.

A standing wave will always exist in the shorted capacitive stub but the values of voltage reached are well within the ratings of RG-8/U for oven a kilowatt of r.f. The currents in the shorted section will exceed the rating of RG-8/U with transmitter powers of over 100 watts or so. The obvious remedy is to use an open-circuited coax capacitor section, which will suffice for over a kilowatt of r.f. This change will require subtracting a quarter-wave-long section from the capacitive section and then leaving the coax open-circuited. The number of Inches of coax equivalent to 90 degrees at the operating frequency may be computed and subtracted from the length originally determined. In Fig. 1 the shorted coax section may bo shortened by 67 inches, leaving an open stub 5 inches long (f = 29 Mc.). The open end should be well taped for weatherproofing.

The benefits of coaxial cable will be greatly appreciated by anyone who has attempted to use Twin-Lead under adverse weather conditions. The loading of the coax-fed antenna is unaffected by rain or ice and the feed line may be wrapped around the mast without harm.