The RASER

A novel wire antenna system.

by James E. Taylor W2OZH

The length of a high-gain antenna for the 75 meter band is often limited by the available space. For example, my lot measures somewhat over 200 feet in the north-south direction and I would like to improve signal strength (gain) in the east-west direction. Conventional wisdom would dictate that I'm stuck with a half-wave dipole (length ~120 feet) because there isn't sufficient space available for a collinear two half-waves in phase (~240 feet). I would like to add length in the center of the dipole (where the radiation is greatest) in increments much less than 120 feet and still have the currents remain in-phase so as to increase the gain in the east-west direction.

Design details will be shown for two such enhanced dipoles. Both are fed with coaxial cable without the need for a separate tuner. One is end-fed and its development is described in some detail. The other is center-fed and it is covered at the end of this article. In each of the antennas the power gain relative to a dipole is a factor of two, with a length of less than 210 feet.

The Franklin/CCD Antenna Concept

Those who are familiar with the history of radio may know of the Franklin antenna, named after its inventor. This concept involves the modification of current distribution in the elements of an antenna by the introduction of series capacitors. General descriptions of early applications of the concept may be found in H. Jasick's *Antenna Engineering Handbook*, First Edition, pp. 4-35 and 4-36, McGraw-Hill publisher; or F. Terman's *Radio Engineers' Handbook*, First Edition, pp. 773 and 774, McGraw-Hill. Harry Mills W4FD and others have adapted the concept to the ham bands in the form of resonant dipoles or loops fed with high impedance line. Mills developed a resonant radiating system which, for 80 meters, was made up of 48 self-resonant sections, each 70 inches long—a total length of 280 feet. See H. Mills & G. Brizendine, "Antenna Design: Something New!," *73 Magazine*, Oct. 1978, pp. 282-289. Kaplan & Bauer developed calculations for "stretched" resonant radiators made up of multiple tuned sections where the series tuning capacitance is half that needed to resonate the wire in each section, the other half being used to resonate the

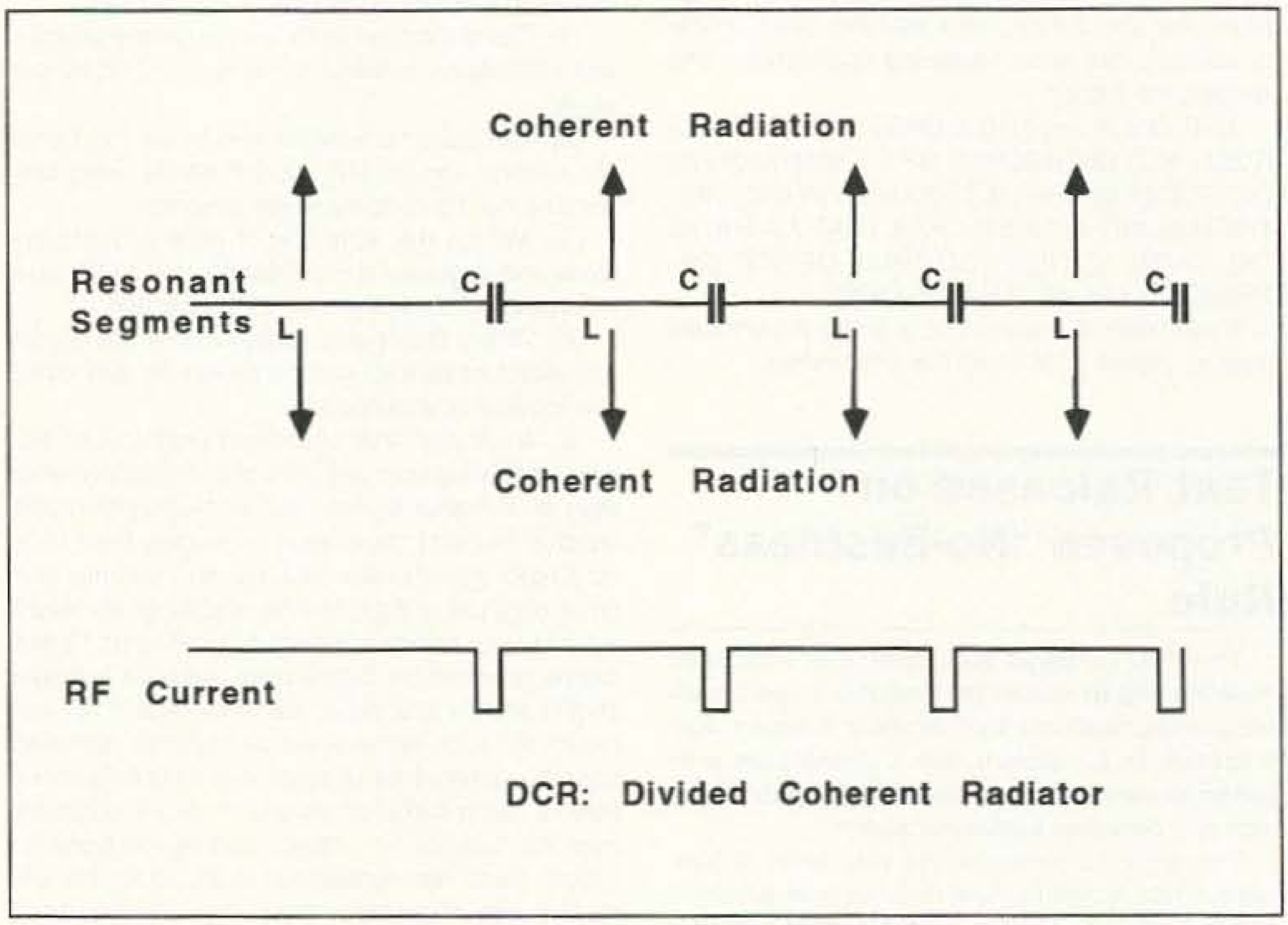

Figure 1. Divided coherent radiator

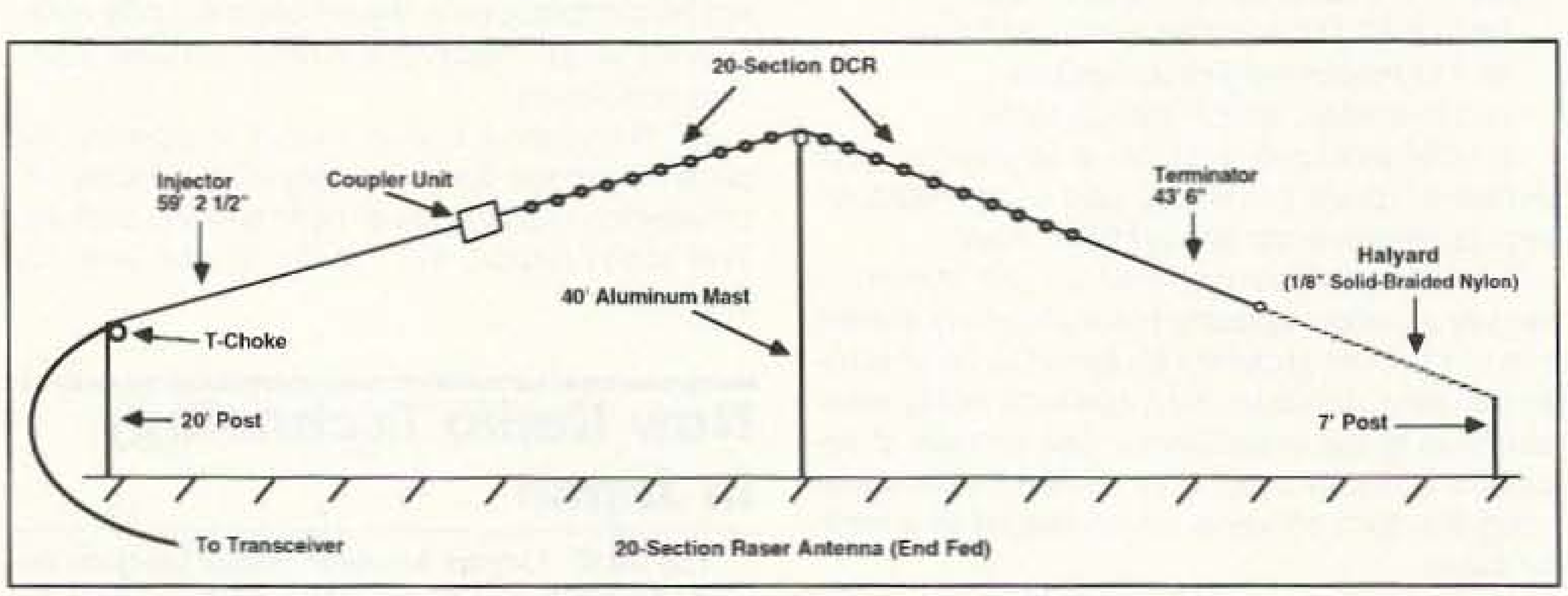

Figure 2. 20-section RASER antenna (end-fed).

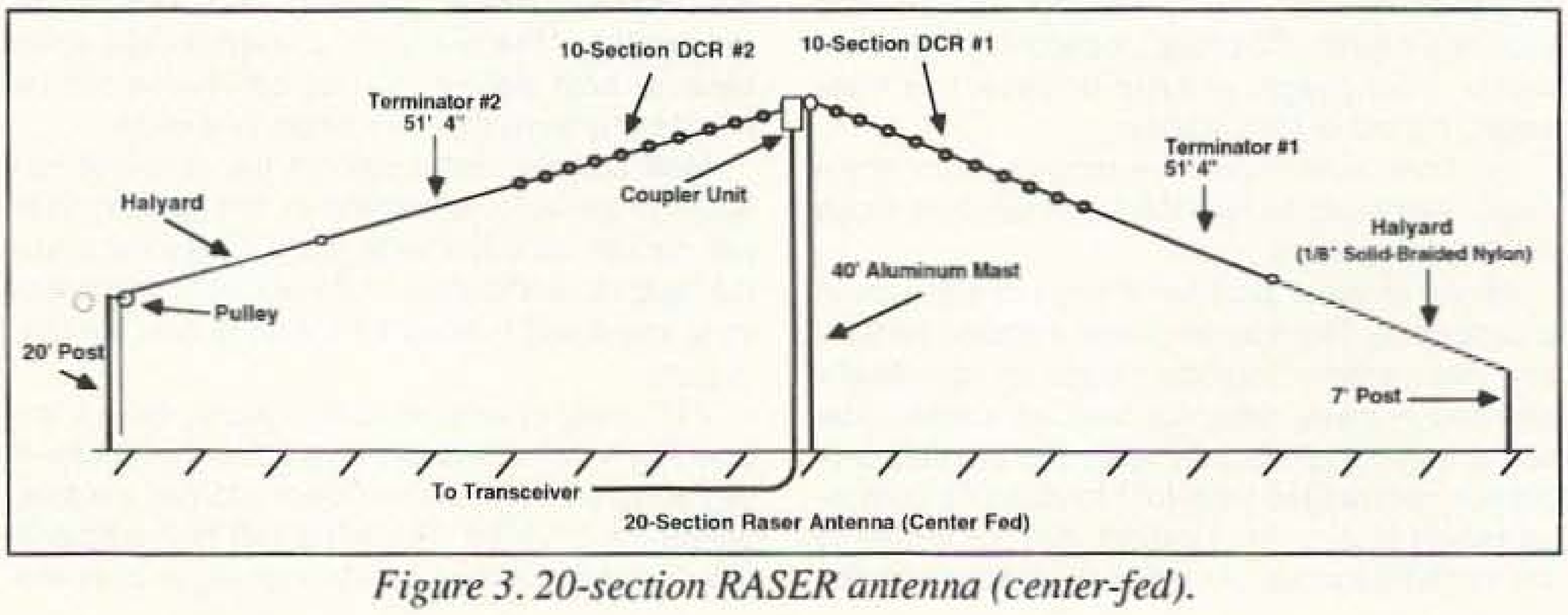

Figure 3. 20-section RASER antenna (center-fed).

system. In this case, care must be exercised to avoid compromising the phase and, therefore, the coherence of the radiation from the separate sections (see S. Kaplan & E. Bauer, "The Controlled Current Distribution Antenna," *ARRL Antenna Compendium*, Vol. 2, pp. 132-135).

This project uses a different approach. Here we insert series self-resonant sections into a resonant dipole antenna. This results in a coherent (in-phase) radiator for 75 meters, having extended length with a corresponding increase of gain and aperture. A simple empirical method is given to accomplish this without complicated computations. In the past such an arrangement has been referred to by the acronym CCD: Controlled Current Distribution. However, that acronym is now almost universally accepted to mean Charge-Coupled Device. Thus, I prefer to use the less confusing term "DCR": Divided Coherent Radiator.

The Divided Coherent Radiator Concept

If we consider a short length of wire carrying RF current, it has an inductance which can be readily calculated. If the current is to be essentially constant along the wire, its length must be a small fraction of a wavelength—for example, a fiftieth of a wavelength. For a chosen frequency the value of series capacitance required for resonance can then be calculated. At this frequency the tuned circuit is, of course, non-reactive; that is, essentially, it acts like an element of pure radiation resistance. If we place several of these tuned sections in series, as in Figure 1, their currents will be in-phase and the resulting radiation will be coherent, i.e. mutually reinforcing. Note that we are placing the DCR elements of pure radiation resistance in the center of a dipole which is then trimmed for resonance, rather than demanding that the entire multi-tuned structure be self-resonant.

The RASER Configurations—End-Fed and Center-Fed

This antenna is called a RASER because of its broad functional commonality with the LASER—both utilize multiple coherent radiating elements to achieve gain. Two RASER configurations were developed in response to needs generated by different site restrictions. The first, for end-feed, is derived from the RFD design ("RFD-1 and RFD-2: Resonant Feed-Line Dipoles," by J. Taylor, *QST*, August 1991, pp. 24-27). A second configuration, for center-feed, is reviewed briefly. Both use coaxial feedline. Neither design requires an antenna tuner and each provides an excellent impedance match with adequate bandwidth for normal amateur use. Figure 2 shows the final dimensions of the end-fed RASER and Figure 3 shows the center-fed arrangement. Of course, the heights above ground may vary for other locations.

Increasing the Aperture

Figure 4 is a diagram of the basic RFD-1 antenna system (shown in *QST*, August 1991, pp. 24-27, ref. above). Here I have labeled the input branch of the dipole radiator the "Injector" and the output branch the "Terminator." To develop this antenna, I first resonated the RFD-1 in the normal fashion, then introduced as many DCR sections as desired between the injector and the terminator. Since the RFD-1 is a resonant dipole antenna it continues to function as such even after the essentially non-reactive DCR sections are inserted, but with increased aperture and gain. *[Ed. Note: Due to the sinusoidal distribution of current in the dipole, the principal radiation will be from near its center. For example, the distance between the 6 dB power points (current 1/2 the maximum value) will be λ/3 for 75 meters, about 80 feet. This is a measure of the aperture over which the radiated wavefront is approximately plane. Thus, if we can add a DCR effectively equal to this length we will have doubled the aperture of the antenna.]* Residual mutual inductive and capacitive effects within the radiating system are compensated for by shortening both the DCR sections and the terminator. Simple coupler units (see Figures 5 & 10) assures accurate impedance matching at the desired resonant frequency.

Determination of DCR Design Parameters

The optimum lengths of the tuned sections of the DCR were determined by first calculating the inductance of a λ/50 length, then calculating the capacitance required for resonance (see F. Terman's, *Radio Engineer's Handbook*, First Edition, p. 48ff.). These simple calculations do not take into account mutual inductance and capacitance among the adjacent sections of the DCR. These effects were conveniently compensated for experimentally. The resulting parameters are shown in Table 1. Values for other frequencies can be scaled from these values.

These values are of key importance in the scaling of future RASER antennas for other frequencies. During the development of the design, I used, successively, DCRs having segments of several different numbers of sections which were mechanically separable by coaxial connectors. This was to derive and confirm the parameters of coupling and the optimum lengths of the sections and of the terminator as described above. However, now that the parameters have been determined, these tests need not be repeated in the future. I decided on a 20-section RASER because my lot is only about 220 feet from front to back. However, you can use more or fewer sections, depending on site dimensions—only the terminator dimensions and the coupler constants need be appropriately readjusted (see Table 1) to compensate. Alternatively, the RASER can be bent around the site, but with a less predictable pattern. Nevertheless, the increased aperture will still be beneficial, as will the other advantages cited by Kaplan and Bauer, including: improved directivity, reduced end effects and attendant losses, improved flexibility of

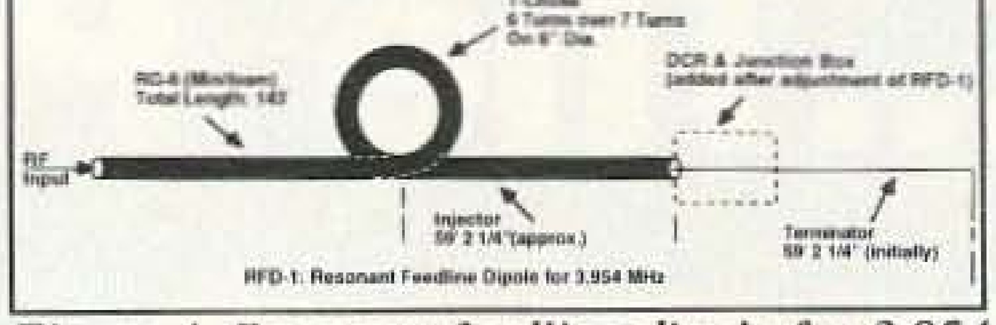

Figure 4. Resonant feedline dipole for 3.954 MHz

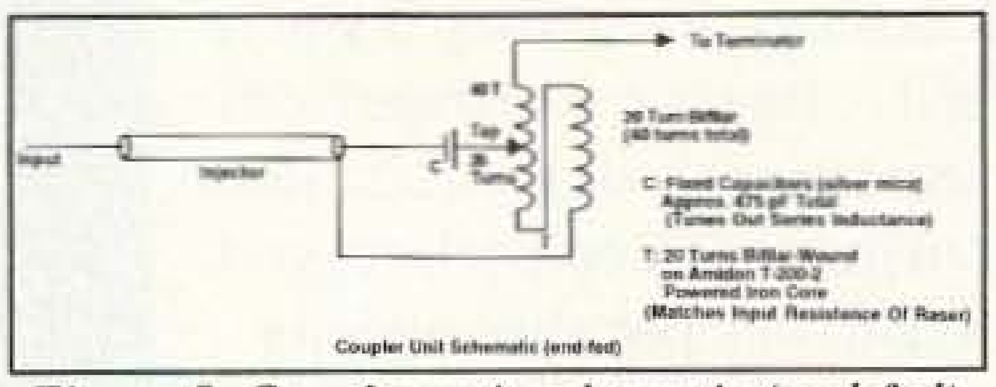

Figure 5. Coupler unit schematic (end-fed).

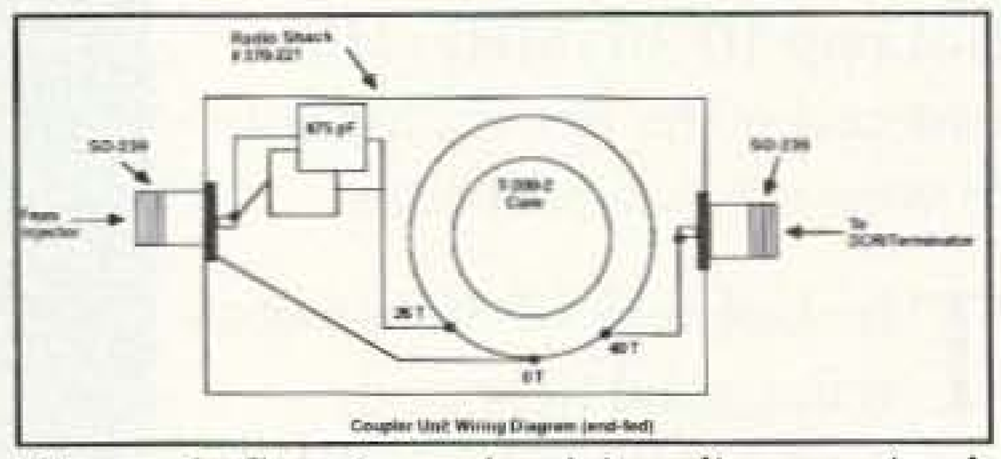

Figure 6. Coupler unit wiring diagram (end-fed).

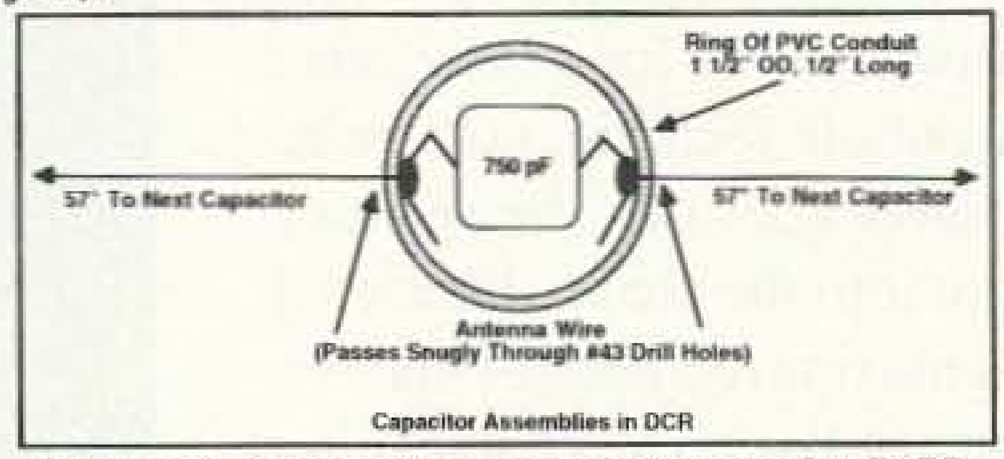

Figure 7. Capacitor assemblies in the DCR.

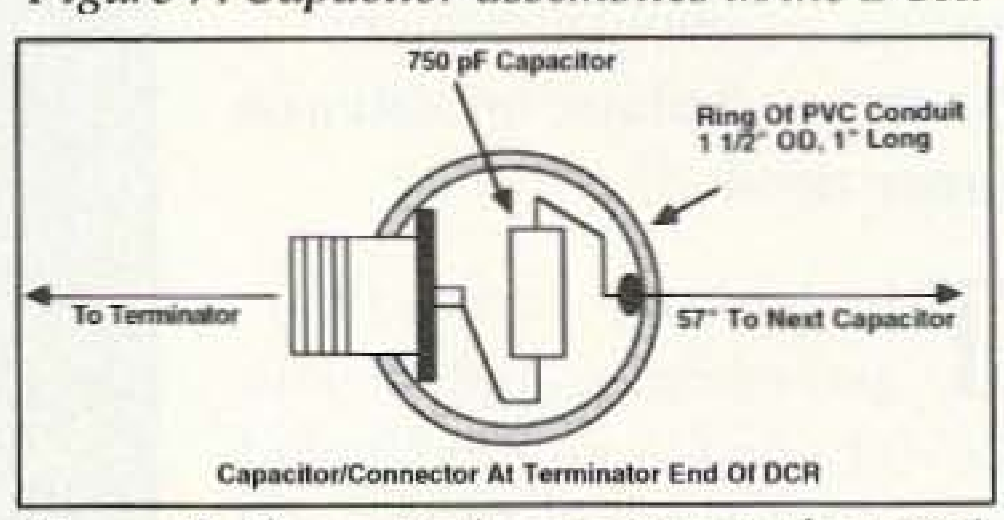

Figure 8. Capacitor/connector at the terminator end of the DCR.

scaling its length, broadband characteristics, and better operation close to the earth.

Coupling to the RASER

The addition of the DCR to the RFD-1 antenna increases the input impedance from the 50 ohm resistive value. This is because of the added radiation resistance and also because of any residual mutual reactance introduced. Several approaches were considered but the simplest and most satisfactory involved the use of a powdered iron toroidal autotransformer with a selected, fixed, series capacitor at its input, as shown in Figure 5. The bifilar transformer serves, primarily, to match the impedance to that of the line; the capacitor tunes out residual series inductance. This simple, compact coupler circuit, housed in a convenient plastic housing, (see the Parts List) enables a precise 1:1 SWR.

Referring to the Parts List, the recommended feedline is RG-8/M (Minifoam) having a total length of 143': (~59' Injector + ~22' T-Choke + ~62' λ/4 Lead-in). The minifoam is chosen for its light weight and the 62' (~λ/4) lead-in provides a measure of added isolation. For convenience, I have used coaxial connectors at strategic spots. Two SO-239s are mounted in the two ends of the coupler box which contains the autotransformer and the fixed capacitor(s), C, as shown in Figures 5 and 6. Final adjustments are described below. The T-choke is wound on a plastic spool. The spools which I used were the red plastic items which wire suppliers have. The winding channel is 6" diameter x 2-1/4" wide. The T-choke comprises seven turns close-wound with six turns wound back in a second layer so that turn #13 is adjacent to turn #1. This coil is adjusted using a noise bridge or an SWR bridge. A supporting rope is tied around the spool and the T-choke is raised for final adjustment of the RFD-1.

Fabrication of the DCR Sections

The DCR sections were designed for strength, lightness of weight and low wind resistance. Cut 20 lengths of the antenna wire to 57" each. The 750 pF capacitors are each contained in 1/2" long rings cut from the PVC tubular conduit. The rings can be neatly cut using a rotary copper tubing cutter. I did it best by supporting the conduit internally using a plastic fitting (available at the plumbing distributor) slipped inside. The cutter was clamped in a bench vice and the tubing was rotated to produce a clean cut. (The DCRs should be tested in the system before the potting compound is applied.) The capacitor assemblies are shown in Figures 7 and 8. The leads of the capacitor and the stranded wire are bent for stress relief. An excess of solder is used here to reinforce these joints as there can be considerable torsion during high winds. The terminator was initially measured to be 59' 2-1/4" long after allowance for the end insulator which is, conveniently, one of the 1/2" long rings of conduit. This terminator length was used for initial adjustments of the T-choke in the RFD-1. After these adjustments, the terminator length was reduced to the final value of 43-1/2' (for the 20-section RASER).

Construction of the Supporting Mast

As with any low frequency antenna system, all parts of the RASER should be mounted as high as possible above ground. At W2OZH I have, for a number of years, used a 2-element phased array (see J. Taylor, "An 80m Phased Array," *73 Magazine*, March 1975, pp. 52-54, 56) with the manifest advantages of switchable directivity. I now use two 20-section RASERs in such an array. The arrangement shown in Figure 9 has proved to be quite practical for the two masts supporting the RASER elements. The 4" diameter aluminum pipe is light, easily erected, and it is sufficiently rigid to permit minimal guying. The pivoted cord-reel at the top acts like a huge pulley so that rope, knots, clamps, insulators, etc. can be easily pulled over the top with no trouble—a great advantage both for installation and experimentation.

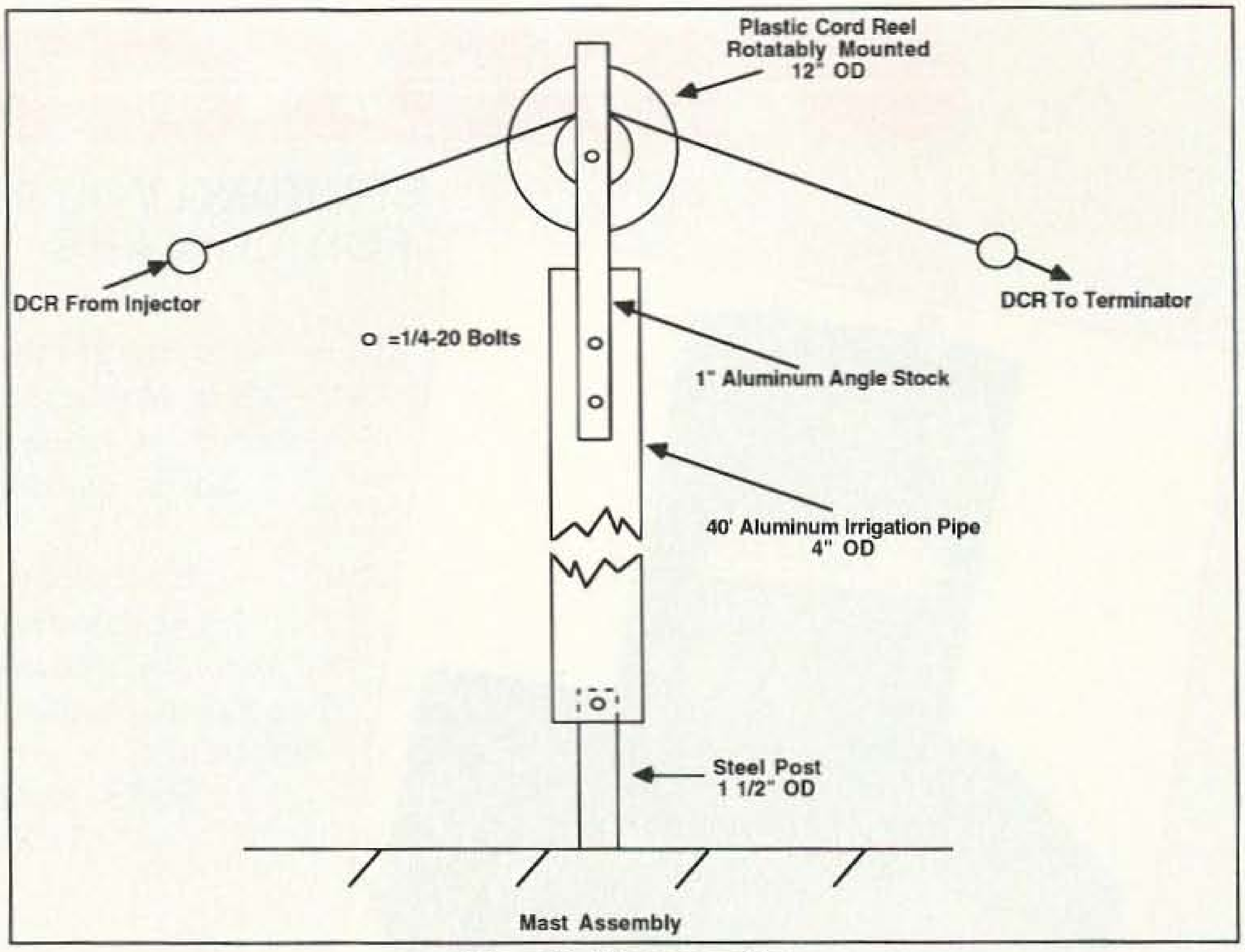

Figure 9. Mast assembly.

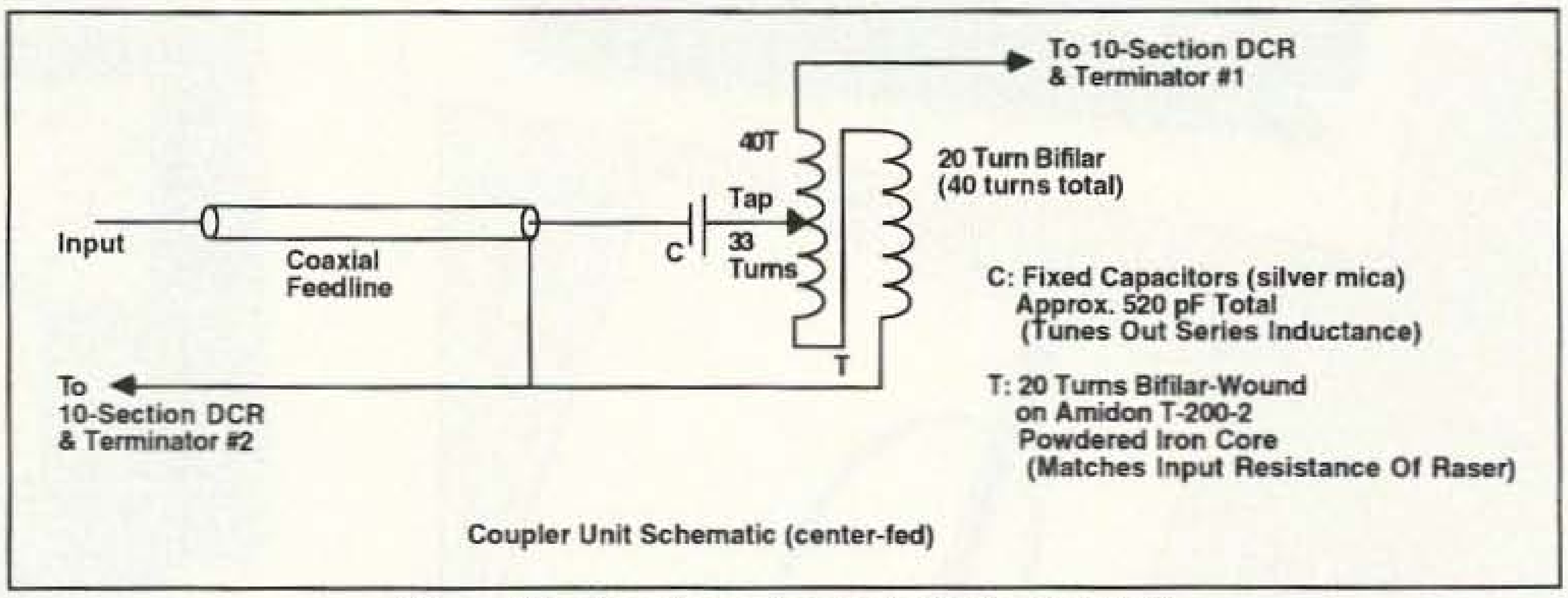

Figure 10. Coupler unit schematic (center-fed).

Resonating the RFD-1

The RFD-1 was assembled as in Figure 4 and adjusted for 50 ohms input resistance as mentioned above (without the DCR and coupler). After the T-choke has been adjusted, the coil is taped in place so that the windings won't shift. We are now ready to adjust the complete RASER.

Adjusting the Coupler

The capacitance and the position of the tap in the coupler are determined after the length of the terminator has been reduced, from Table 1, as appropriate for the number of sections chosen for the DCR. First, the tap and the silver-mica capacitors can be clipped in place and the antenna raised to its normal height before measuring the input impedance, for example, using a noise bridge. From my experience, it should not be necessary to compromise on these values—a precise 1:1 SWR should be attainable. For the two 20-section end-fed RASERS constructed the taps turned out to be at 24 turns and 28 turns and the capacitance 465 pF and 487 pF respectively. Thus, the mean values of 26 turns and about 476 pF should be a good starting point for a specific installation of a 20-section RASER. For another number of sections in the DCR the terminator will be changed appropriately from the initial value from Table 1. The proper tap and capacitor are then determined experimentally. I found a variable capacitor or decade box to be quite valuable for such preliminary measurements, which were first made with the coupler box at stepladder height.

Results

One question which occurs for any antenna is: What is the SWR as a function of frequency? I measured the SWR for two 20-element RASER systems using a Heath SWR bridge at the input to the two-wavelength-long feedline used. For each, the measured value was 1:1 from 3.900 to 4.000 MHz. The value was less than 1.1:1 from 3.850 to 4.050 and under 1.5:1 from 3.750 to 4.200 MHz. Thus, the system has a relatively broad passband. One other experiment was done to confirm the proper operation of the DCR. A 10-section RASER was erected at stepladder height and the RF current in the DCR sections and in the adjacent injector and the terminator were checked, using an

Table 1. Raser Parameters—Calculated and Empirical

Assumed frequency: 3.954 MHz
Initial lengths of RFD-1 injector and terminator: 59' 2 1/4"
Wavelength: 249'
1/50 wavelength: ~5'
Capacitance for resonance: ~750 pF
Calculated self-inductance: 2.15 μH
Empirically determined optimum values:
DCR Length: 57" per section
Reduction of terminator per DCR section added: 9.425"
Calculated terminator length for 20-section RASER: 43-1/2'

RASER Parts List (For convenience, optional suppliers are indicated)

#200'	Antenna wire	7 x #22, stranded, copper-clad (W1JC)	
143'	Coaxial cable	RG-8 (minifoam) (Radio Shack)	
1	Plastic box	4" x 2-7/16" x 1-1/16" (Radio Shack)	
Assorted	Silver-mica capacitors	50 pF to 500 pF	(Fertik's Electronics, 5400 Ella St., Philadelphia PA 19120)
20	Silver mica capacitors	750 pF	(Fertik's)
#5'	Thin-walled PVC conduit	1-1/2" o.d.	(MPT db4PVC1120 at plumbing distributor)
Foam epoxy potting compound for electronic assemblies			(Spray-can insulating foam for plumbing sealing should work.)
#1	Type T-200-2 powdered iron core		(Amidon Associates, 12033 Otsego St., N. Hollywood CA 91607)
10'	Parallel bell wire	2 x #20 in plastic sheath	(Servistar Hardware Store)
4	Type SO-239 coaxial sockets	(Radio Shack)	

MFJ H-Field probe. The meter measured essentially the same reading throughout, indicating the desired constant-current operation of the DCR sections.

The RASER system produces a readily discernible gain over a non-enhanced dipole. Two RASERs used in a switchable phased-array (see J. Taylor, "An 80m Phased Array," referenced above) gave front-to-back ratios as high as 35 decibels. The directivity of each RASER is quite pronounced. Reported signal strengths are outstanding with output power of 100 watts or less. Stations in the preferred E-W direction are worked with uniform superiority, whereas those in the N-S direction are seldom worked—there is no free lunch! The RASER phased array has been in operation at W2OZH for a year now and it has shown clear improvement over the dipole-based array previously used.

Addendum: The Center-Fed RASER (A Double-Edged RASER)

The RASER described, shown in Figure 2, is most suitable for sites which favor an end-fed antenna. For sites which favor **center-feed**, the version shown in Figure 3 was constructed using the principles already developed. Briefly, it was only necessary to split the 20-section DCR into two equal parts and connect a coaxial feedline into a coupler unit at this point. The injector of the RASER was replaced by a second terminator. Each of the two terminators is 51' 4". The diagrams, Figures 3 and 10, indicate the changes in geometry and coupler constants. The center-fed RASER is currently in daily use in the phased-array at W2OZH, with results which are essentially the same as those experienced for the end-fed RASER.

Conclusion

This development project was initiated to satisfy the need for an end-fed dipole antenna system having enhanced gain while retaining the efficiency and simplicity of feed which is characteristic of the RFD approach. The RASER system described above provides the desired enhancement. It offers an excellent match to the transceiver, without a separate antenna tuner, and without a dangling feedline to contend with. The concept is applicable to other bands and, because of its broadband characteristics, all-band operation, using an external tuner, should be possible. For locations where center feed is desired, suitable changes in design values were developed and tested.

Acknowledgments

I wish to acknowledge encouraging telephone conversations with Harry Mills W4FD, and with Gene Brizendine W4ATE, whose joint paper originally triggered my interest. Thanks are also due the numerous 75 meter hams who showed interest and who gave me comparative signal strength reports.