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Raising the RASER to New Heights

A two-element beam for 80 meters.

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Because of the unique effectiveness of this antenna system, a number of the hams I have talked with have asked me to put the construction details into an article. This article, therefore, is directed to those who wish to duplicate the system without complicated formulas or computations. This is offered as a fun project which teaches some advanced understanding of antenna theory as well as some practical assembly experience.

In the past, I have successfully used conventional two-element phased-array beams on the 80-meter band. These were composed of two parallel resonant dipoles, spaced one quarter-wavelength apart, horizontally, and fed at their centers by coaxial cable. The pattern direction was reversed by throwing a switch. This changed the length of the feedlines, initially equal, so that one feedline was one quarter-wavelength longer than the other. The phase shift introduced by this "quadrature" delay results in reinforcement of the radiated signal in this direction with a corresponding cancellation or null in the opposite direction. Thus, we have a beam antenna with the ability to switch directivity, for example, from east to west! The phased array featured in this article has still greater gain, accomplished by replacing the dipoles in the former design with longer dipoles called RASERs.

I first wrote "The RASER," published in *73*, September 1992, and "The RASER Revisited," *73*, October 1993 (both of those articles can be viewed on the Internet at [http://home.att.net/~JETAYL/w2ozh.html], along with additional comments). As I described in those previous articles, the development of the RASER gain dipole was derived from prior work by Harry Mills W4FD.

(Note: I have chosen the term "RASER" for the novel structure, due to its remote similarity to the LASER—both use coherent radiation to obtain gain. Also, in the past, the acronym CCD for Controlled Current Distribution has been used. Because that term is now almost universally accepted by engineers to mean Charge Coupled Device, I will be using what I hope is a less confusing term, DCR—for Divided Current Radiator.)

The RASER approach

Let's go back to general principles: If we consider a short length of wire carrying RF current, it has an inductance which can be readily calculated; see **Table 1**. If the current is to be essentially constant along the wire in each DCR, its length must be a small fraction of a wavelength—for example, 1/50th.

RASER Parameters	
Assumed Frequency	3.953 MHz
Initial Terminator Length	59 feet, 2-1/4 inches
Wavelength	249 feet
1/50th Wavelength	~5 feet
Calculated Self-Inductance of DCRs	2.15 µH
Capacitance for Resonance	~750 µF
Empirically Determined Optimum Values	
DCR Length	57 inches per section
Reduction of Terminator per DCR Section	~2.21 feet

Table 1. RASER parameters—calculated and empirical.

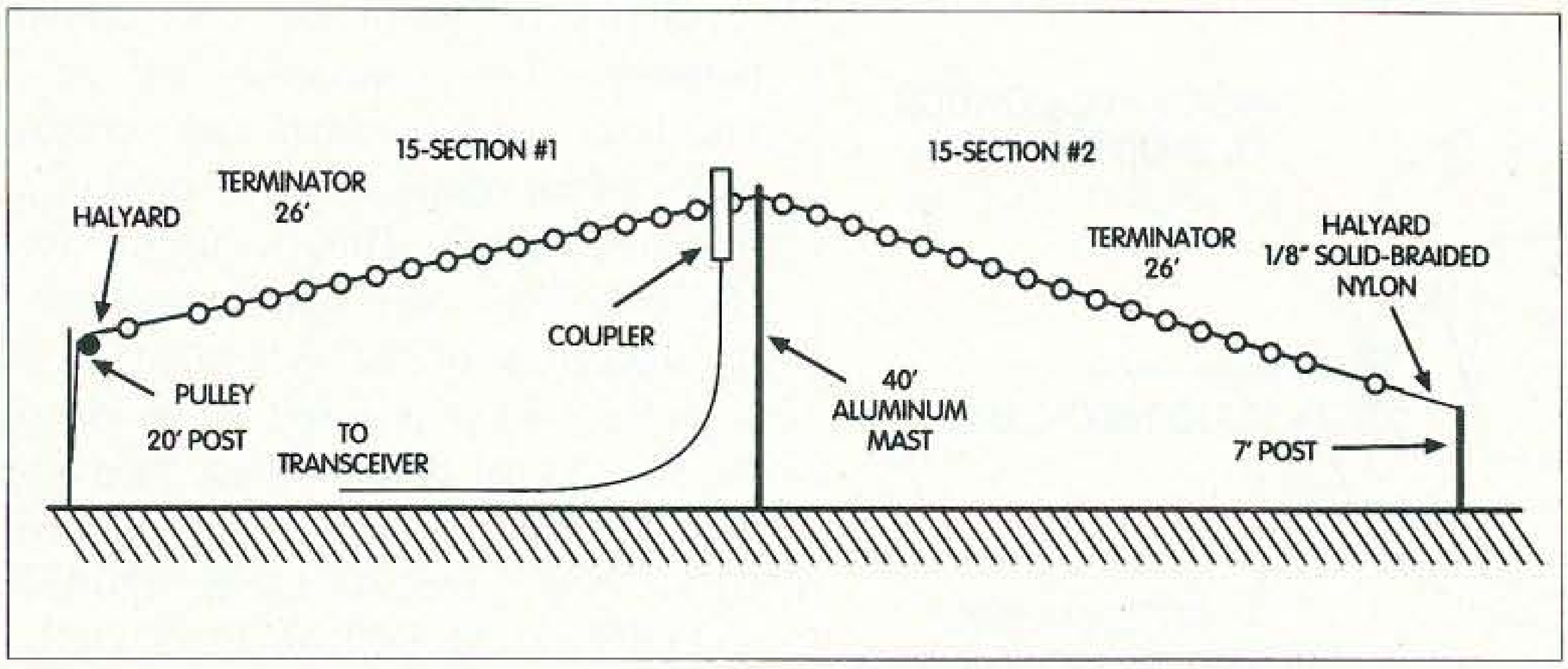

Fig. 1. Balanced 30-section RASER (centerfed).

This length could be increased with a corresponding decrease in the number of DCRs required. 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, nonreactive; that is, it acts like an element of radiation resistance with only the mutual inductance between DCRs remaining. If we place several of these tuned DCR sections in series, as in **Fig. 1**, their currents will be in phase and the resulting radiation will be coherent, i.e., mutually reinforcing. The result is a *stretched* resonant radiator. Let us now place a number of these DCR elements at either side of the center of a dipole, and trim the structure of resonance by adjusting the lengths of the capacitive terminating wires at its ends. This RASER concept offers gain over a half-wave dipole antenna due to the increased aperture and the coherent radiation from the resonant DCRs.

Construction

Let me review, briefly, the construction of RASER gain-dipoles for the 80-meter band, and also the extension of the idea to a two-element phased array with switchable directivity. A tabulation of values for other amateur bands is included. Also, please note that the quarter-wave delay line has been replaced by a simple pi-section phase-shifting circuit. The centerfed configuration will be emphasized here, although the endfed RFD arrangement has proven to be equally effective (see "RFD: Resonant Feedline Dipoles," *QST*, August 1991).

The RASER dipoles

The installation at my QTH has a single RASER dipole as shown in **Fig. 1**. Each RASER is composed of 30 DCR sections (see **Fig. 2**), with 26-foot wire terminating stubs at each end. Each RASER is fed with 52-ohm coaxial cable through a coupler unit placed at its center (see **Fig. 3**). The coupler unit is a bifilar-wound, toroidal impedance-matching transformer tapped at 26 turns and enclosed in a plastic box.

The RASERs are tuned to resonance at the desired frequency by pruning the lengths of the terminators symmetrically. The desired 1:1 SWR was obtained by changing the tap position on the transformer. An antenna impedance bridge is useful in this adjustment—I used a Palomar noise bridge. The overall length of each RASER radiator, some 200 feet, was determined solely by my site restrictions, as was the height above ground. The geometry can be changed to match other site dimensions by changing the number of DCRs, the lengths of the terminators, and the position of the tap on the matching transformer. Greater lengths of the RASER will increase gain up to the point where cumulative phasing errors diminish coherence of the radiation from the DCR sections. The height should be as great as possible for best efficiency of radiation.

Configuration of the RASER phased array

As shown in **Fig. 4**, I fabricated and installed two identical RASERs, horizontally spaced approximately one

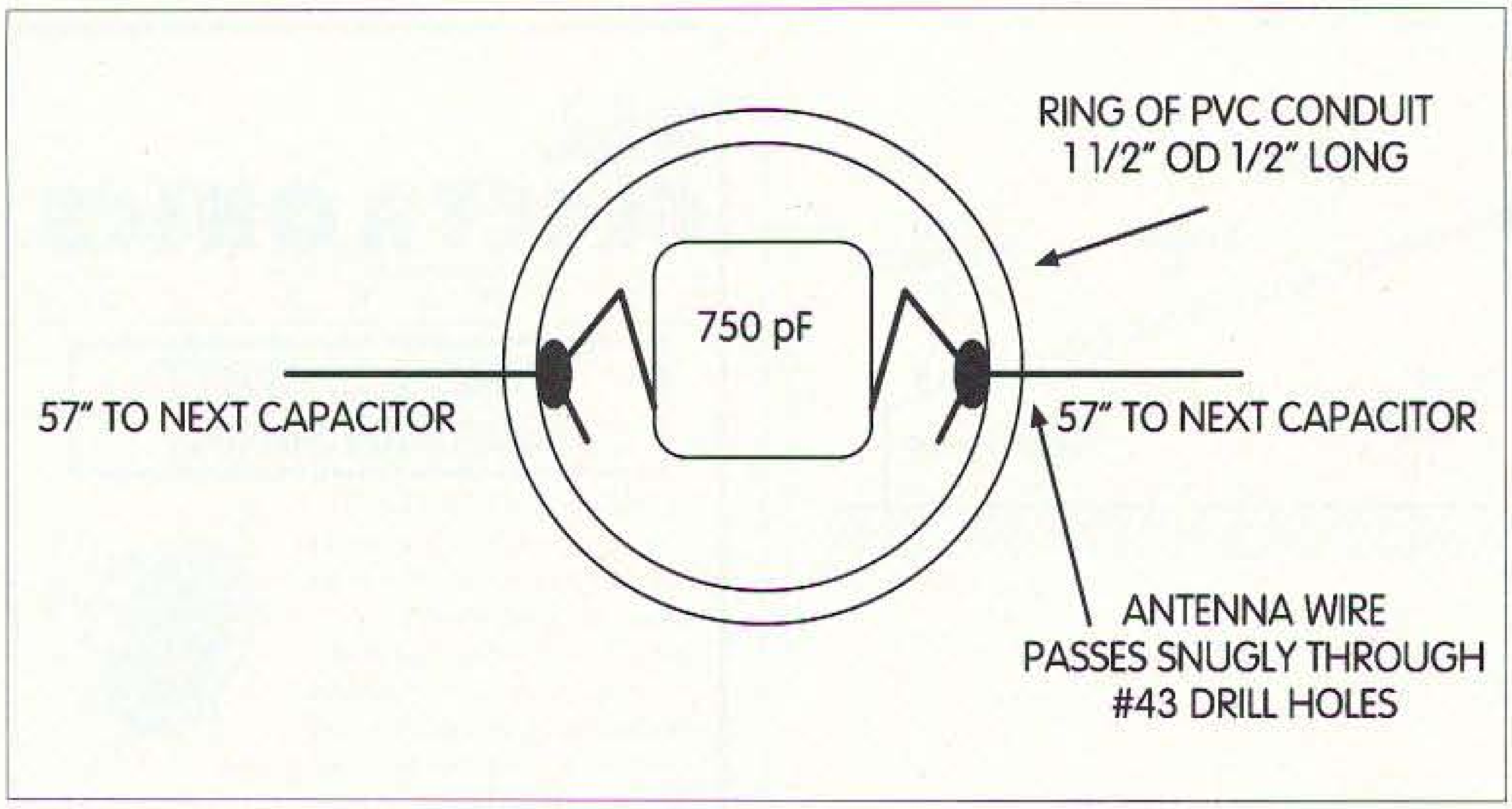

***Fig. 2.** Capacitor assemblies in the DCR.*

quarter-wavelength, or about 60 feet, along the perpendicular horizontal line through their centers. The initial feedline lengths are made equal. These lengths can be randomly chosen, although it is useful to use an integral multiple of a half-wave *(in the coax)* in each to minimize reactance effect. I found it convenient to use two lines, each of which is one wavelength long, or about 180 feet. The switching of direction of radiation is accomplished by the use of a multisection, wafer-type selector switch. An impedance matching transformer is required to correct for mismatch at the input to the feedlines. See **Fig. 5**, T1. As mentioned, instead of using the quarter-wavelength delay line to provide the required quadrature delay, I found it expedient to use a simple pi-section phase-shift network as shown in **Fig. 5** (L1, C1, and C2).

The operation of the system is more readily understood by referring to the schematic diagram, **Fig. 5**. If the selector switch is thrown to the dial position marked BEAM EAST, power from the transceiver is switched to the input of the impedance-matching transformer T1 through capacitor C3. This provides the small capacitive reactance necessary to compensate for the inductance of the transformer winding. The output from this transformer, at lowered impedance level, is fed into the pi-section phase-shift network, L1, C1, and C2. The unmodified signal at the input to the network is switched to the WEST RASER. The quadrature shifted output is switched to the EAST RASER. As mentioned earlier, this phase shift produces an antenna pattern with gain in the east direction and with cancellation in the west direction. Following the diagram, conversely, when the switch dial points to BEAM WEST, the pattern will be directed to the west.

Additional switch positions have been provided so that we can select either of the two RASERs separately. This capability is useful for comparison purposes. Two connectors are provided for the horizontal and vertical plates of an oscilloscope to present a lissajous figure. This is useful for checking phase shift and for monitoring operation of the system. Also, a separate switch position is provided for an external dummy load. Two coaxial connectors are provided (marked OPTIONAL DELAY-LINE INPUT and OPTIONAL DELAY-LINE OUTPUT) for use if an external quarter-wave delay line is desired instead of the internal phase-shift circuitry. To achieve this, the circuit is broken at the three points marked X, effectively eliminating the components L1, C1, and C2.

Please refer to the schematic diagram, **Fig. 5**, and to its notes, **Table 2**. The switch, the toroidal matching transformer, the phase-shift circuitry, and the sockets required for all of the coaxial cable connections are housed in a metal chassis box. I used a three- by five- by seven-inch aluminum box, although any one sufficiently large to accommodate the parts will be satisfactory. As any experimenter will agree, you are wise to install extra coaxial connectors for possible future experiments. **Table 3** is a simplified parts list for the system.

Adjustment of the system

The two RASER gain-dipoles in the beam are separately adjusted for resonance using the noise bridge. For these resonance adjustments, the selector switch is alternately in the EAST RASER position, then the WEST RASER position. During these measurements, the feedline of the unused RASER is disconnected at the switchbox and terminated at its input with a noninductive 52-ohm carbon resistor. This is used to simulate the cross-coupling between the two RASERs during operation. After the separate radiators have been adjusted to resonance by trimming the lengths of the terminator wires, and the match has been set by adjusting each coupling unit, the beam is ready for on-the-air use. If the option of using a quarter-wavelength of coax is chosen, no further adjustment is needed.

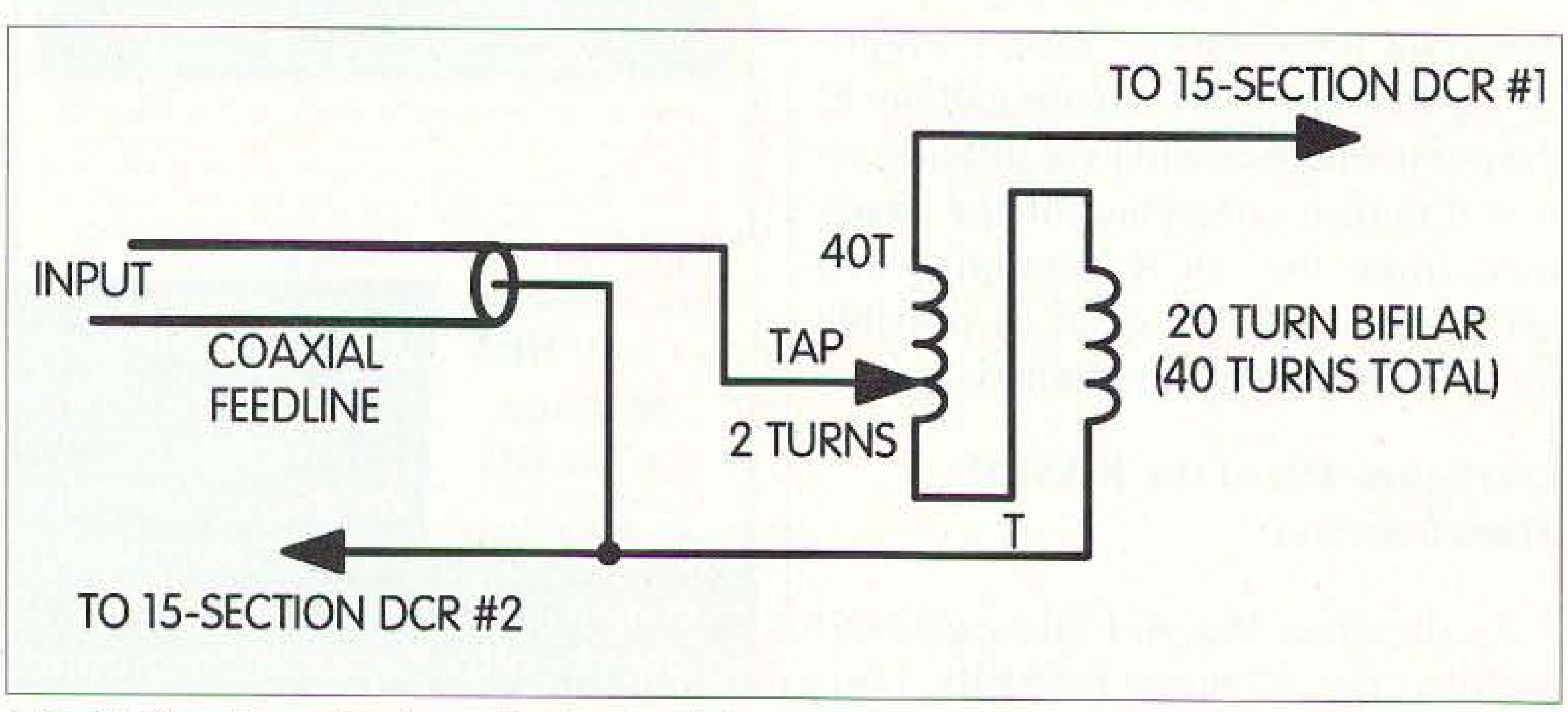

***Fig. 3.** Coupler unit schematic (centerfed).*

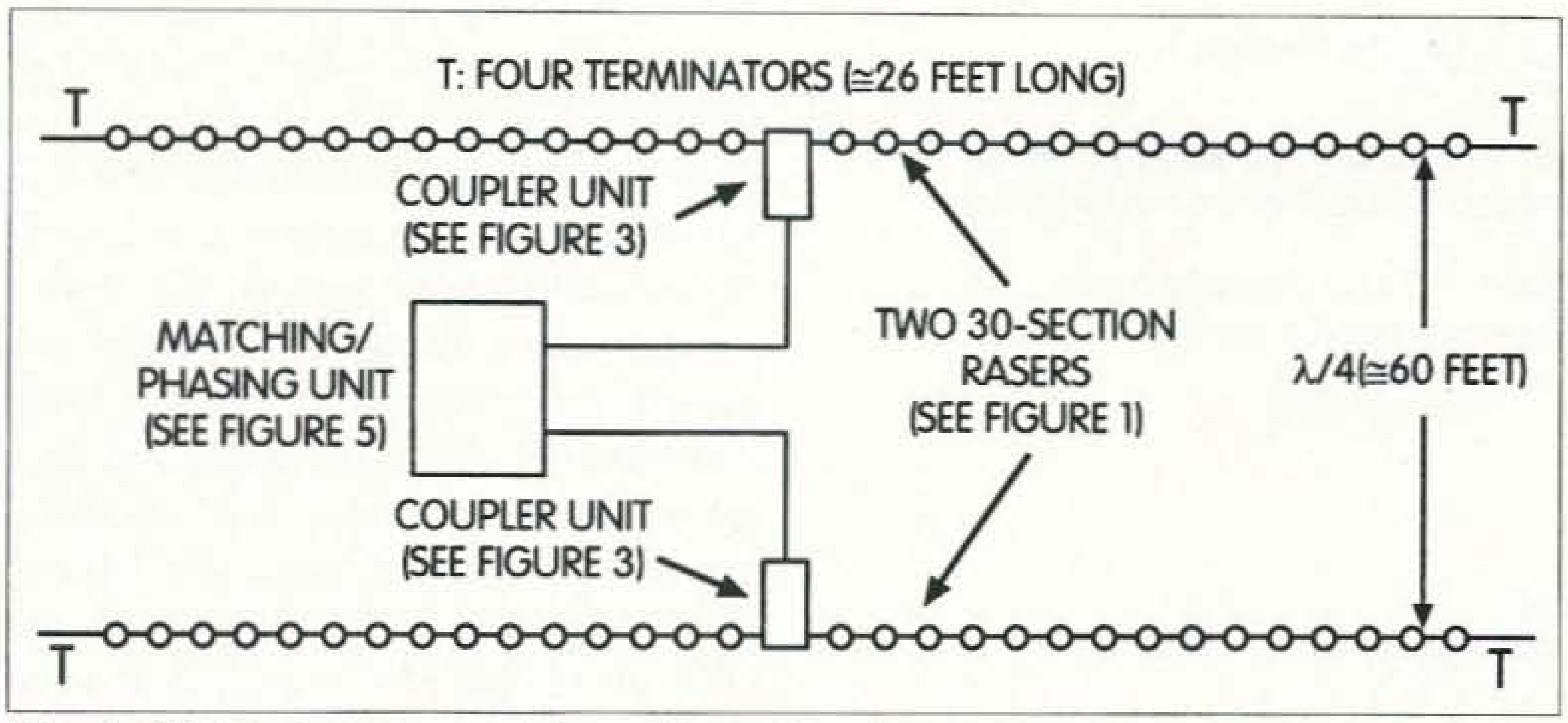

Fig. 4. RASER phased array (viewed from above).

However, if the pi-section phase-shift network has been chosen instead of the coaxial delay line, it will be necessary to optimize the values of the inductor L1 and the capacitors C1 and C2 for optimum phase-shift between the two RASER radiators. If the inductor has been fabricated as described, probably no readjustment of this component will be required. The values of C1 and C2 can be readily adjusted by use of a split-stator air capacitor, since these are nominally equal capacitors. The adjustment is made by viewing the lissajous pattern, or by measuring received signal strengths. The capacitors are then adjusted for the most symmetrical elliptical scope pattern or for optimum signal strength and front-to-back ratio when the direction of the antenna pattern is switched from EAST to WEST. Ideally the patterns would be perfect circles, but actually this is seldom achieved because of cumulative differences in the parameters of the antennas. These may be due, in part, to site variations and differences of component values. Bill Shanney W6QR has modeled the RASER beam using the EZMEC 1.0 program. The resulting charts strongly reinforce my experimental results. Contact Bill by E-mail at [wshanney@earthlink.com] for more information.

Extensions to other bands

As pointed out, the lengths and other parameters mentioned above were

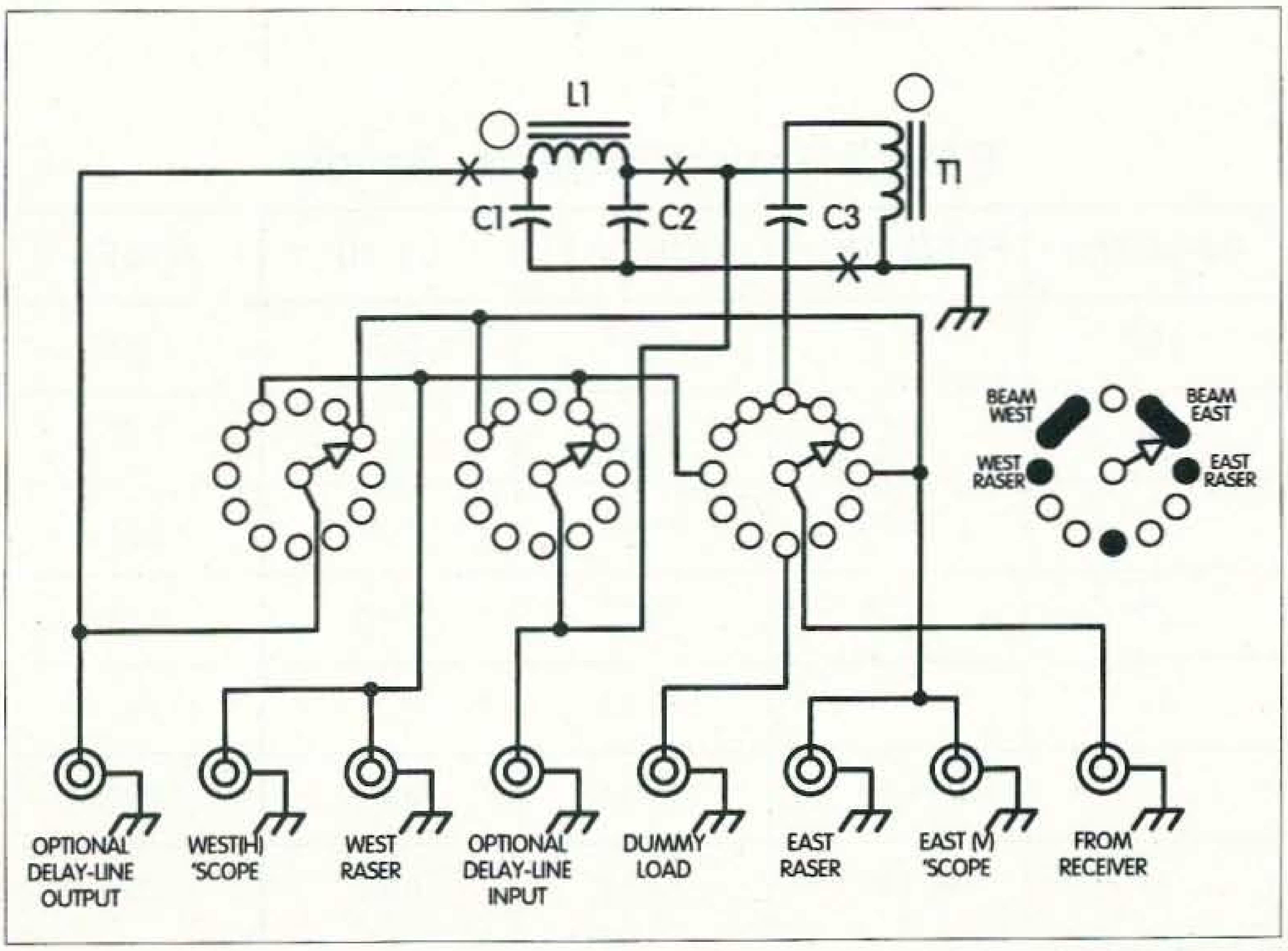

Fig. 5. Two-RASER phased array switching/phasing unit.

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BP-84 pack	7.2v	1200mAh	$34.95
BP-83xh pk.(NiMH)	7.2v	1500mAh	$39.95
BP-90	6-Cell AA case		$15.95
BC-79A	Rapid/Trickle Charger		$52.95
For **ICOM** *02AT etc &* ***Radio Shack*** *HTX-202 / 404:*			
BP-8h pack	8.4v	1400mAh	$32.95
BP-202s pk.	7.2v	1400mAh	$29.95
IC-8	8-Cell AA NiCd/Alkaline Case		$15.95
BC-350	Rapid Charger		$52.95
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For KENWOOD *TH-78 / 48 / 28 / 27:*			
PB-13 (original size!)	7.2v	700mAh	$26.95
PB-13xh pk.(NiMH)	7.2v	1500mAh	$39.95
BC-15A	Rapid/Trickle Charger		$54.95
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Notes for Schematic, Fig. 5 (parts details)	
L1	10 turns #12 enameled copper wire wound on approximately 1/4 of the circumference of an Amidon T-200-2 powdered iron core
T1	8 turns, bifilar, wound on Amidon T-200-2 powdered iron core, tapped 4 turns down from the ungrounded end (8 + 4 turns up from the grounded end)
C1, C2, C3	Silver Mica, or equivalent C1 = 857 pF C2 = 848 pF C3 = 953 pF (for resistor loads) C3 = 803 pF (for 30-section RASERs)
Switch	3-gang, multipole selector switch: I used a Centralab Type 2017 with contacts paralleled

Coaxial sockets shown are SO-239 (8)

***Table 2.** Notes for **Fig. 5**.*

chosen for the band of principal interest, 80 meters. However, in response to a number of requests, I have calculated approximate values of DCR lengths and capacitances for the HF bands as shown in **Table 4** (the lengths of terminators and tap position on the transformer are best determined through experimenting after a rough estimate by scaling to the frequency).

Parts List	
Qty.	Description
425 ft.	7X #22 stranded copper-clad antenna wire
400 ft.	RG/8 coaxial cable
2	4" x 2-7/16" x 1-1/16" plastic boxes
1	3" x 5" x 7" aluminum chassis box
1	2017 3-gang multipole switch
Assorted	Silver mica caps, 50 pF to 1000 pF
60	Silver mica caps, 750 pF, or equivalent
2	T-200-2 powdered iron toroid cores
8	SO-239 Coaxial sockets
10 ft.	2 x #20 Parallel bell wire
Foam epoxy potting compound	

***Table 3.** Parts list.*

The gain of each RASER is directly dependent upon the number of DCR sections used, so the more sections the better! The 30 elements in my two-element array work just fine!

Results

The two-element RASER phased array has been in operation at W2OZH for several years now with outstanding results. I have consistently received reports of superior signal strength from both east and west directions, as expected. I call many CQs using a single gain-dipole and have had almost no answers from the more distant northerly and southerly locations. This is to be expected if the pattern is mainly east and west as designed. As might be expected for the variations of propagation conditions encountered on 80 meters, the front-to-back ratios, measured on either received or transmitted signals, vary considerably with time of day and distance. However, a ratio of 25 decibels is commonly experienced and I have frequently measured a front-to-back ratio of 35 decibels—equivalent to a power ratio of some 3000 to one! This ratio is even more impressive when we realize that the signal strength of a station running the legal limit of power to the rear of the beam is reduced to sound like a half-watter!

One dramatic dividend from the use of a beam on the lower frequency bands is the obvious reduction of QRM, especially during the crowded evening hours. For example, if I have the pattern pointed to the east, I can readily work stations in that direction without either hearing or interfering with same-frequency stations to the west.

I wish to acknowledge the encouragement and assistance of many hams who have shown interest and who have patiently given signal strength comparisons for the numerous experimental arrangements which led to this final design.

RASER Scaled For Other Bands

BAND (m)	FREQ (MHz)	DCR (in.)	L (μ H)	C (pF)
160	1.9	118.6	5.33	1250
80	3.954	57	2.15	750
40	7.263	31.03	1.10	430
20	14.29	15.77	0.40	310
17	18.14	12.42	0.31	250
15	21.38	10.54	0.29	185
10	28.65	7.866	0.21	150

***Table 4.** RASER scaled for other bands.*