ARRL Periodicals Archive – Search Results

A membership benefit of ARRL and the ARRL Technical Information Service

ARRL Members: You may print a copy for personal use. Any other use of the information requires permission (see Copyright/Reprint Notice below).

Need a higher quality reprint or scan? Some of the scans contained within the periodical archive were produced with older imaging technology. If you require a higher quality reprint or scan, please contact the ARRL Technical Information Service for assistance. Photocopies are $3 for ARRL members, $5 for nonmembers. For members, TIS can send the photocopies immediately and include an invoice. Nonmembers must prepay. Details are available at www.arrl.org/tis or email photocopy@arrl.org.

QST on CD-ROM: Annual CD-ROMs are available for recent publication years. For details and ordering information, visit www.arrl.org/qst.

Non-Members: Get access to the ARRL Periodicals Archive when you join ARRL today at www.arrl.org/join. For a complete list of membership benefits, visit www.arrl.org/benefits.

QST Issue: Sep 1982
Title: Half-Delta Loop: A Critical Analysis And Practical Deployment, The
Author: John Belrose, VE2CV

Click Here to Report a Problem with this File

The Half-Delta Loop: A Critical Analysis and Practical Deployment

A delta-shaped, grounded half-wavelength loop offers superior performance over the half- and full-sloper antennas. Low-band DXers should find this antenna effective for multiband operation.

By John S. Belrose,* VE2CV and Doug DeMaw,** W1FB

Is DXing one of your pursuits? Are you having inferior results with wire antennas for the 160-, 80- and 40-meter bands? Or, would a particularly good multiband antenna satisfy your needs for general communications in the mf and hf spectrum? If the answer to any of these questions is "yes," this paper will provide the information you may be looking for.

The Half-Delta Loop contains a sloping wire, approximately $\lambda/3$ in length, which is attached to the top of a grounded tower about $\lambda/6$ high. Feed to the antenna is applied between the lower end of the sloping wire and ground. Radial wires should be connected to the feed-point ground and the grounded end of the tower. This antenna is the grounded equivalent of a full-wavelength Delta Loop, apex down, apex-fed, that has been rotated through 90 degrees. The lower half is replaced by its image in the ground plane (see Fig. 1).

In a previous paper by author Belrose,[1] data obtained on an outdoor antenna-pattern range were presented to show the polar diagrams for the modeled antenna, measured at f_o, $2f_o$, $3f_o$ and $4f_o$, where f_o is the antenna fundamental frequency, or the frequency at which the half loop and its image equal one wavelength. Radiation is to some extent like that of a monopole-antenna array: The radiated field is dominantly vertically polarized, and the maximum in the vertical-plane pattern is directed at the horizon. However, the azimuthal pattern is complicated. At f_o it is elliptical, with maximum gain (5 dBi) in the directions that are broadside to the half loop. At $2f_o$, $3f_o$ and $4f_o$ the antenna is bidirectional, with maximum gain in opposite directions in the plane of the half loop. Nulls in the pattern are found in the broadside directions.

It was noticed that while the input impedance was low at f_o and at all harmonics, resonance did not occur at exact multiples of f_o. This paper (1) examines in detail the impedance-frequency variation; (2) describes experience in practical deployment of the antenna at full scale; and (3) discusses the practical situation where the supporting tower, which is part of the radiator, bears a triband Yagi, which is typical of most amateur situations.

Half-Delta Loop Modeled

A Half-Delta Loop was modeled at 200 MHz; i.e., the half loop and its image in the ground plane was a 1-wavelength loop with 200-MHz resonance. The mast was a copper rod that was 0.3175 cm in diameter and 28.25 cm high.[2] The sloping wire was twice this dimension — 56.5 cm long. Antenna mounting was done on a 1-1/2 meter square ground plane. A Hewlett-Packard 4191A rf impedance analyzer was used to measure the impedance. This microprocessor-controlled instrument provides, among other facilities, electrical-length compensation. This permits extension (up to 100 cm) of the test-port-to-measurement point, as needed to measure antennas. The machine-plotted impedance-value measurements are, therefore, the impedance of the Half-Delta Loop at its input. Measurements were made via a type-N chassis-feedthrough connector, fed through the ground plane to the measurement instrument located beneath.

The impedance |Z| and θ for the frequency range of 180 to 980 MHz are shown in Figs. 2 and 3. Notice the loop resonance (low Z and θ equal to zero) occurred at 203, 350, 545, 737 and 873 MHz. The Half-Delta Loop and its ground image was 1, 2, 3, 4 and 5 wavelength loop-resonant at these frequencies (Table 1).

If λ_n is the wavelength at a resonant frequency, f_n, where n is the integral number of electrical wavelengths around the loop and its image of length ℓ, then

$$\ell = k_n n \lambda_n \quad \text{and} \qquad \text{(Eq. 1)}$$

$$k_n = \frac{\ell}{n \lambda_n} \qquad \text{(Eq. 2)}$$

[1]Notes appear on page 32.

*ARRL TA, 3 Tadoussac Dr., Aylmer, PQ J9J 1G1, Canada
**ARRL Senior Technical Editor

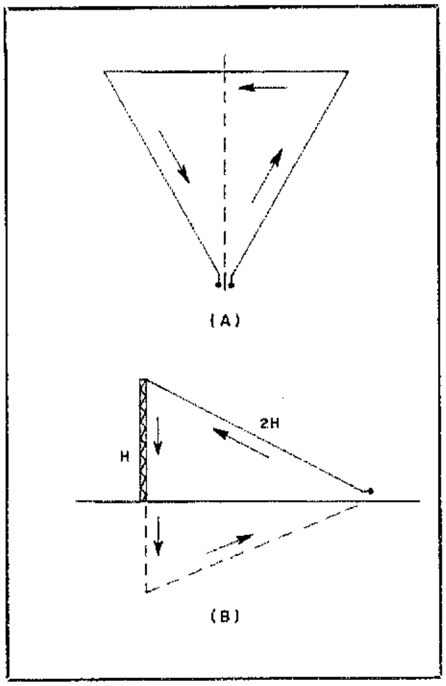

Fig. 1 — Illustration of (A) a conventional full-wave Delta Loop and (B) the grounded version with its image half in the ground plane.

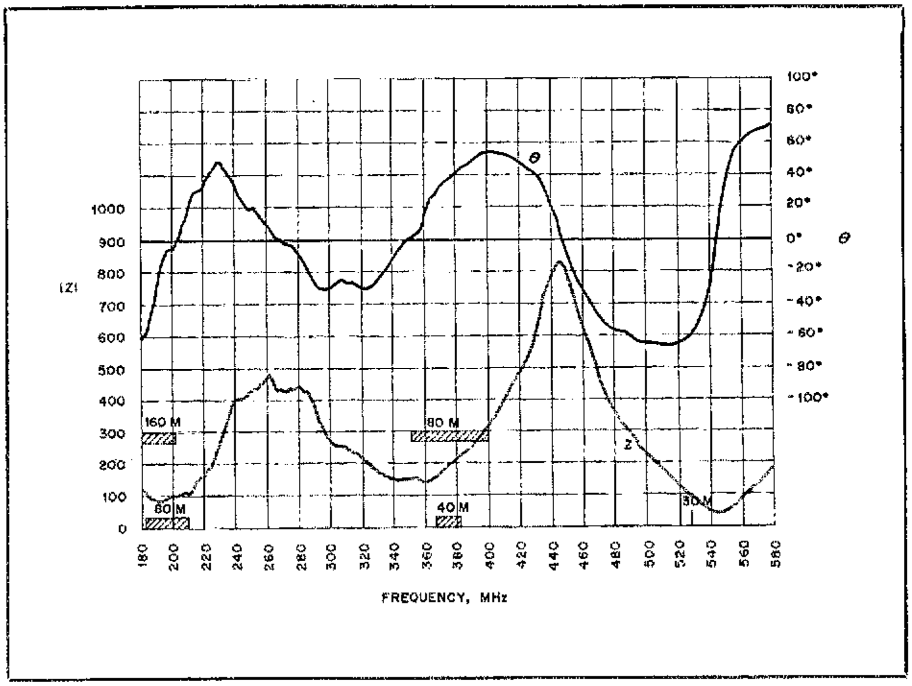

Fig. 2 — Curves that show the feed impedance of the Half-Delta Loop versus operating frequency for the scaled model. The upper curve relates to θ. Corresponding full-scale model frequencies are noted.

where k_n is a factor that relates the physical and electrical lengths. Values for k_n, deduced from the measured values for f_n, are also given in Table 1.

Notice that except for the 1-wavelength loop resonance, the electrical and physical lengths are approximately equal; i.e., $k_n \approx 1$, within an uncertainty that is probably experimental error (±3 percent). While this is an interesting fact, since the electrical and physical lengths at f_o are significantly different (15 percent), the higher-order resonant frequencies are not integral multiples of f_o. If the Half-Delta Loop is employed for amateur communications, therefore, the physical size and resonant conditions must be a compromise. Table 2 contains dimensions (estimated) for a Half-Delta Loop for use on 80, 40, 30 and 20 meters. The average scale factor is, therefore, 52.26, and for this scale factor the band edges can be marked on Figs. 2 and 3. The mast height at full scale would be 14.76 m (48.4 feet), the length of the sloping wire 29.53 m (96.8 feet) and the diameter of the mast would be 166 mm (6.5 inches).

A similar analysis for a Half-Delta Loop designed for use on 160, 80 and 40 meters yields a scale factor of 100.44. This corresponds to a tower height of 28.37 m (93 feet). The length of the slope wire would be 56.76 m (186.2 feet).

Half-Delta Loop, Tower and 20-M Yagi

The curves in Fig. 4 show impedance-frequency plots for a Half-Delta Loop alone, and connected to a tower that supports a 3-element, 20-M, wide-spaced Yagi. For these measurements, since a

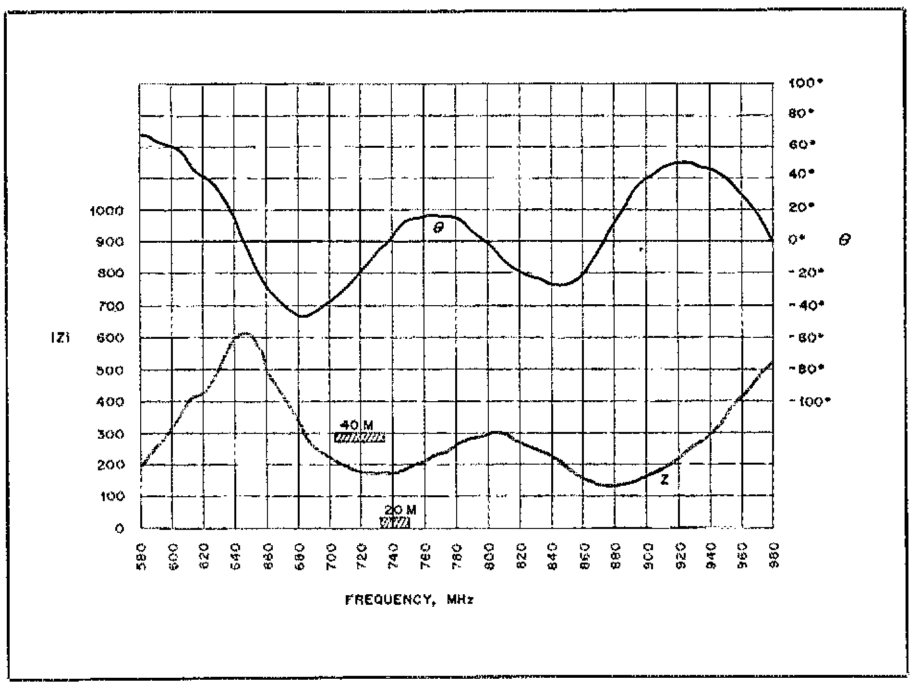

Fig. 3 — Impedance and θ curves that show the corresponding full-scale performance at 40 and 20 meters.

Table 1
Scale-Model Characteristics

N	*F (MHz)*	*R_a (ohms)*	*k_n*
1	203	100	1.15
2	350	150	0.99
3	545	40	1.03
4	737	170	1.04
5	873	133	0.98

Table 2
Harmonic Resonances

Band (m)	*Midband f (MHz)*	*Model Resonant f (MHz)*	*Scale Factor*
80	3.75	203	54.13
40	7.15	350	48.95
30	10.10	545	53.96
20	14.17	737	52.00

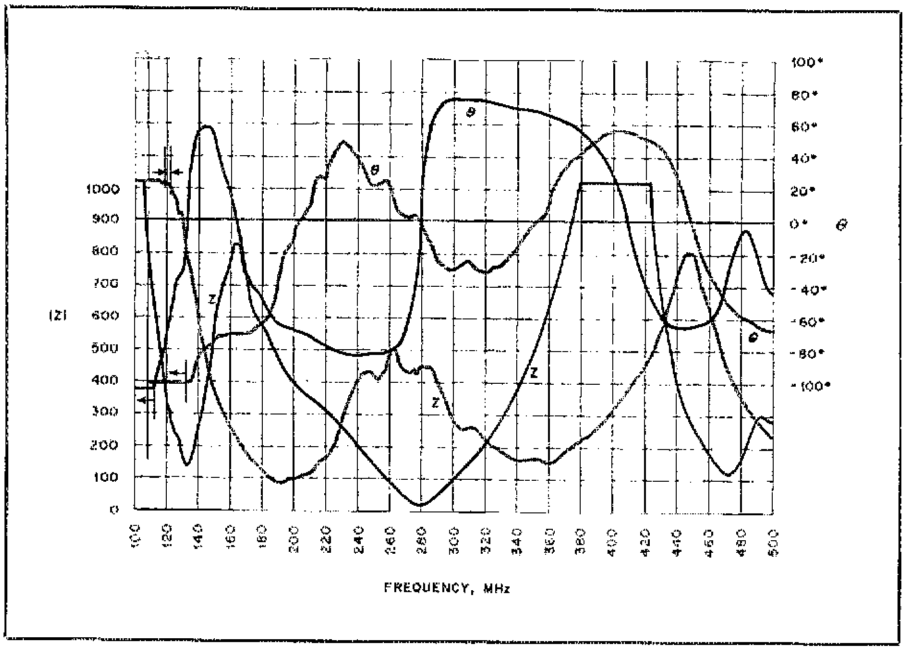

Fig. 4 — Impedance-frequency plots for a Half-Delta Loop alone, and plots for the same system with a 20-meter Yagi atop the tower. (See text.)

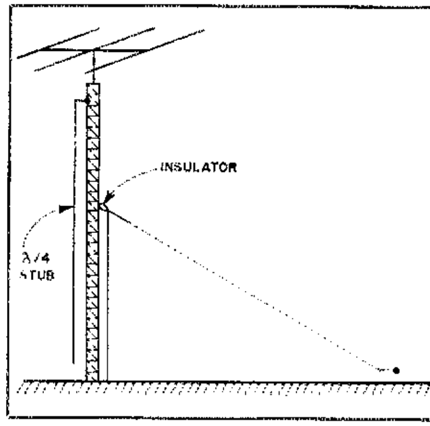

Fig. 5 — Suggested arrangement for stub-tuning the tower when the loop is insulated from the tower and a 20-meter or other beam antenna is affixed to the tower. (See text.)

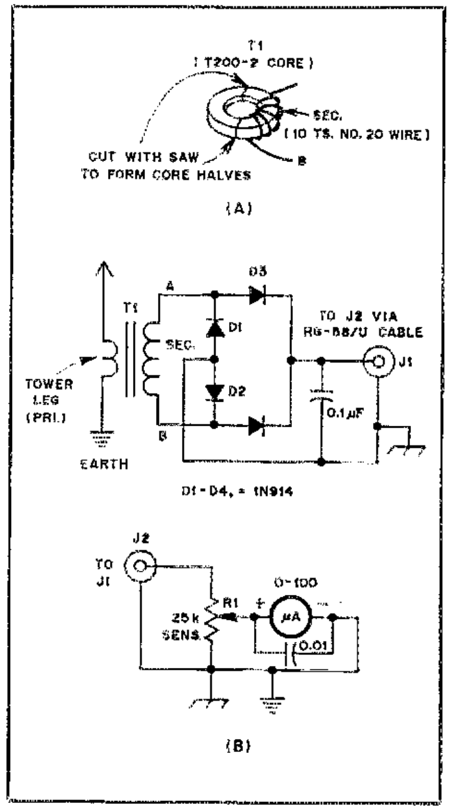

Fig. 6 — Current-probe arrangement that can be applied when adjusting the tuning stub of Fig. 5. Illustration A shows the sampling transformer, which is cut in half and installed on a tower leg (see text). The bridge rectifier and metering circuit is shown at B.

Yagi was modeled, the measurements refer to a particular scale factor — 53.33. It was assumed that the tower height was 15.06 m (49.4 feet), and that the beam antenna was attached to a mast that extended 1.6 m (5.25 feet) above the top of the tower. Notice that, as expected, the beam antenna had a marked effect on the resonant frequency of the loop antenna. The loop alone was resonant at 202 MHz (3.787 MHz at full scale), whereas the loop-mast-Yagi system was resonant at 132 MHz (2.475 MHz at full scale) and at 280 MHz (5.25 MHz). Clearly, the radiation pattern (not measured) would also be different from that of the Half-Delta Loop alone. Therefore, a Half-Delta Loop can't be deployed on a tower that supports a beam antenna. Although an antenna-matching circuit could be employed (needed even for the Half-Delta Loop alone), the resultant antenna configuration is more like a shunt-fed tower with top loading (the Yagi) than a Half-Delta Loop.

Minimizing the Beam-Antenna Effect

It is possible to stub-tune the tower to minimize reradiation from it. More than one stub can be used to "detune" a tower at more than one frequency. A possible arrangement is seen in Fig. 5. The Half-Delta Loop would be made completely from wire and insulated from the tower, and the tower would be stub-tuned to minimize reradiation from it. The optimum stub length is critical. While it should be "field tuned," a nominal length (total length plus the length of the shorting element) is about 5 percent less than a quarter wavelength. This should provide satisfactory results.

Ideally, *each* leg of the tower should be stub-tuned, since this arrangement reduces the reradiation best and provides the greatest bandwidth. If the tower is less than a quarter wavelength, it will be necessary to tune the stub by connecting a capacitor across the open end of it. But, this will reduce the bandwidth of the system. It will also complicate the mechanical/electrical construction. Optimum tuning will be tricky without instrumentation. The simplest adjustment method is to tune for minimum current in the portion of the tower below the stub. A current probe will be required if this is done. A suggested technique is shown in Fig. 6. It has been used successfully by author DeMaw for probing shunt-fed towers. A T200-2 Amidon or a Micrometals powdered-iron toroid core (μ_i = 120) is sawed in half, then taped together with the tower leg inside the center hole.

Practical Deployment at Full Scale

The VE2CV professional test-range results were confirmed generally during practical analysis of the Half-Delta Loop at full scale (Fig. 7). The differences in test conditions were the two ground systems (an ideal ground plane at VE2CV and a mediocre buried-radial system at W1FB) and a disparity in the cross-sectional area of the slant wire at W1FB with respect to that of the scaled version at VE2CV. The latter would have required no. 40 wire to represent approximate scaling of the no. 16 wire used in the full-scale example, which would have been impractical. No. 22 wire was used for the 200-MHz scaled model. Therefore, at full scale the impedances at the anti-resonant frequencies should be greater than those of the modeled version, but the impedances at resonance should not be much different. A cage-type or parallel-pair slope wire could be used to lower the Q of the loop, and the impedances would be reduced. Several months of testing took place at W1FB in Newington, Connecticut, during 1981 and 1982. Evaluation was carried out at 3.5, 7.0 and 14.0 MHz, with short-term tests at 21.0 and 28.0 MHz.

Initial tests involved the use of a 50-foot[3] Rohn-25 tower (unguyed). No antennas other than the Half-Delta Loop slant wire were attached to the tower. A system of 16 buried radials extended out from the tower. These wires varied in length from 60 to 110 feet. They were complemented by a 6-foot ground rod driven into the earth at the base of the tower. Four more ground rods (4 feet each) were used at the loop feed point, plus four on-ground 40-meter radials and two on-ground 80-meter radials. The composite ground system was obviously less effective than that at the VE2CV professional test range, but the results were good. It is important to recognize the need for an effective ground system when using this and other ground-dependent antennas, such as grounded quarter-wavelength verticals. The integrity of the tower-section continuity is vital also: A quality electrical joint must prevail at the junction of each tower section. A copper bonding strap across the tower-leg joints will help ensure proper electrical integrity. Crank-up towers will require special attention in this regard. This rule is applicable also in the case of Half-Sloper antennas, since the tower is an integral part of the antenna.

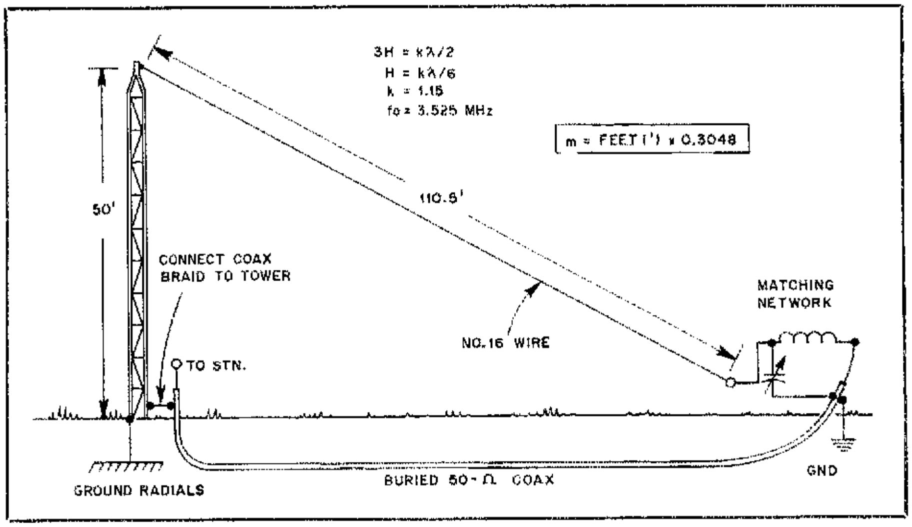

Fig. 7 — Diagram of the Half-Delta Loop deployed at full-scale for practical analysis. The matching network was controlled remotely, and was switchable for 80, 40 and 20 meters. It was housed in a weatherproof box on a short pole at the antenna feed point. The network control cable and the RG-8/U feed line were buried 3 inches in the ground and routed back to the tower (note shield braid connections to ground at each end of the antenna). See text for details of the earth- and radial-ground system.

Early Results

The first practical model of the Half-Delta Loop was based on the VE2CV k-factor for overall length. It did not follow exactly the H-2H rule of Fig. 1, but it was close. Indeed, the harmonic relationship was not precise as performance was checked from 80 through 10 meters. In fact, the feed impedances, as measured with a General Radio 1606-A rf bridge, were substantially higher than those obtained by VE2CV on the 200-MHz model. Fortunately, the impedances were greater than 50 ohms, but not greatly so (see Table 3). The notable exception was at 7 MHz, where the value was about 1000 ohms. The advantage of having a terminal impedance greater than 50 ohms on all of the bands is that an L network can be used to provide a step-up transformation. Therefore, there is no need to reverse the network for one or more bands to shift to a step-down condition. Fig. 8 shows the network used at W1FB during practical analysis of the system.[4]

It is probable that a more effective ground system would have had some effect on the impedances measured for the full-scale model. A Kenwood TS-820S transceiver was used during the tests to provide a signal source. The resistive-resonance condition was noted for the bands of interest, as were band-edge impedances.

Some peculiar results were obtained during the first set of tests. The impedance values made little sense on certain frequencies, and suddenly the cause was found: The tower still contained a 30-foot shunt arm (feed line disconnected from the lower end of it) that was used to feed the tower as an 80-meter vertical. Removal of the feed arm resolved the problem. This illustrates clearly the effect of a tuned stub, as discussed earlier, on the loop system. In this example the "stub" was not desirable, since there was no beam antenna atop the tower.

Performance Characteristics

Owing to the small city lot (5/8 acre) at W1FB, it was not practical to deploy a reference dipole for performance com-

Table 3

Full-scale Characteristics

F (MHz)	*R_a (ohms)*	*Reactance*
3.5	228	+j43
3.7	620	+j14
4.0	140	−j306
7.0	1000	−j571
14.0	251	+j18
14.3	345	+j70
21.0	100	−j238
1.8	290	−j1775

Measurement results obtained at the feed point of a full-scale Half-Delta Loop. The rf impedance bridge was connected directly to the loop feed terminals. The loop was dimensioned as indicated in Fig. 7.

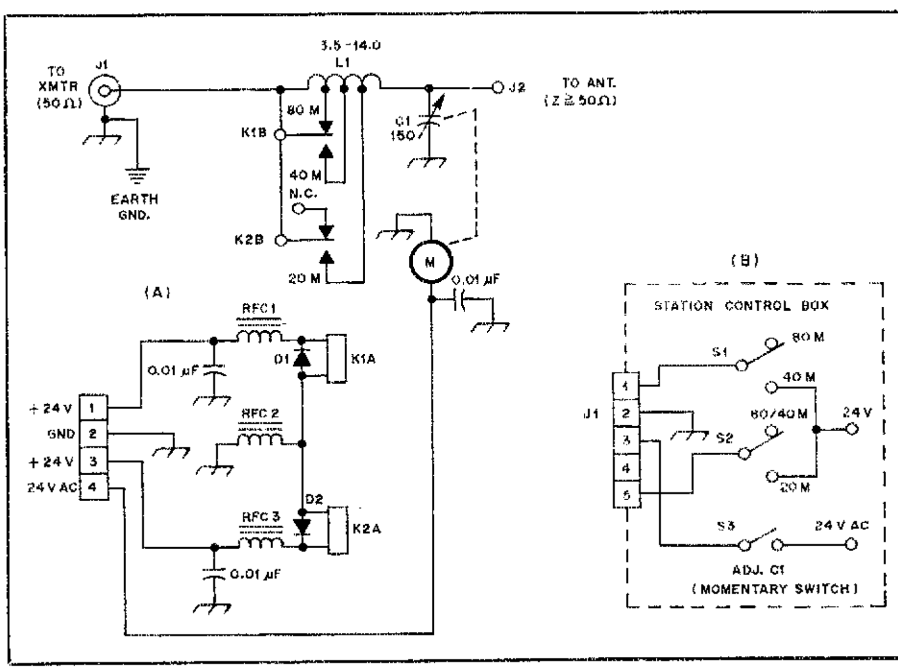

Fig. 8 — Schematic diagram of the three-band L network used to provide a match to 50-ohm cable. Specific circuit data are available from *QST* (see ref. 4). K1 and K2 are rf-isolated from ground to prevent arcing at high rf-power levels. L1 is a large piece of Miniductor® stock.

parisons. Furthermore, the dipole would necessarily have been in the immediate field of the Half-Delta Loop. This would have affected the accuracy of the performance comparisons. However, the loop proved to be very effective for DX work, and is perhaps the best wire antenna that W1FB has used for that purpose at 3.5 and 7.0 MHz. Previous 80- and 40-meter antennas included full slopers, half slopers, inverted Vs and shunt-fed towers.

Many reports of RST 599 were received from European, South American and Australian stations. Some DX stations reported, "OM, you have the loudest signal from the U.S." Such reports were consistent over several months. Calls were received via "long path" from JA stations on 40 meters as early in the day as 2100 UTC. This did not happen with previous 40-meter antennas at W1FB. It was a nice experience!

Reception with the loop was somewhat superior to that while using the shunt-fed tower and half-sloper antennas. There was less man-made noise heard in the receiver, owing to the closed-loop characteristics of the new antenna. Initial receiving tests implied that something was amiss — a short or open circuit somewhere in the system: The S meter registered no noise, as opposed to the more normal noise reading of S1 to S3 on 80 and 40 meters. But, upon tuning the bands, it was learned that all was well: Signals popped up to S9 and higher, despite the otherwise quiet reception! In some locations, depending on non-ionospheric noise levels, this feature could be an asset for weak-signal reception.

Performance out to approximately 1000 miles on 40 meters seemed to be on par with that of the sloper and half-sloper antennas. This was based on a three-year weekly schedule with W8PLC and W8EEF (ARRL TA) in Michigan. At greater distances, the Half-Delta Loop appeared to outperform the slopers greatly, based on historical observations.

Indications are that the loop is rather omnidirectional at f_0, but that it becomes increasingly directive (with gain) at the harmonic frequencies. Directivity appears bidirectional in the plane of the slant wire (north-south at W1FB), confirming the test-range findings of VE2CV. Excellent coverage was had over relatively short north-south distances on 20 meters, with S9-plus reports from as far away as Nova Scotia and southern New Jersey (in-plane); this was never the case when using the triband Yagi at 50 feet. This demonstrated the gain and directivity of the loop at the higher harmonics.

The loaded Q of the matching network of Fig. 8, plus the loop bandwidth, has been entirely suitable for covering 50 kHz on 80 meters, 100 kHz on 40 meters and 200 kHz on 20 meters without readjusting the network. This provided operation well within the 1.5:1 VSWR points for each band. The network is remote-controlled from the shack, thereby negating a need to go to the rear of the property to change bands or tune the network.

Recent Tests

A Cushcraft A4 triband Yagi was placed atop the tower in early 1982. The results were devastating with respect to the loop performance. In order to reestablish resonance and obtain a matched condition, the slant wire had to be shortened by some 25 feet. Although performance remained good, it no longer equalled that of the correctly dimensioned loop. Resonance was checked with a calibrated dip meter before the slant wire was shortened. The readings changed from 3.5 and 7 MHz to 2.5 and 5 MHz, indicating the effect from the Yagi. This supports the findings of VE2CV, reported earlier in this paper. It appeared that the revised system performed as a shunt-fed tower with delta feed (or slant-wire feed).

Summary Comments

One need not have a tower to use the Half-Delta Loop antenna. A telescoping mast (joints bonded electrically) can be used as the vertical member of the loop. Similarly, a tree can serve as a vertical support. In this instance, it will be necessary to employ a drop wire from the top of the tree to ground, thereby providing the necessary conductor that would otherwise be formed by the tower. The drop wire should not touch the trunk, limbs or leaves of the tree.

A Half-Delta Loop should serve admirably for multiband use during Field Day operations. It offers an excellent alternative to complicated directive arrays on the lower bands. It should appeal also to those with small city lots.

Acknowledgments

Author DeMaw wishes to express his gratitude to Jack Belrose for providing early-on information concerning the scale-model tests. Thanks is given to Jerry Hall (K1TD) and George Collins (KC1V) of the ARRL staff for their help in making peformance measurements on the first model of the full-scale Half-Delta Loop.

Notes

1 J. Belrose, "The Half-Delta Loop: A Grounded, Vertically Polarized Antenna," *Ham Radio*, May 1982.

2 Ft = m × 3.281; in. = mm × 0.03937; in = cm × 0.3937. The diameter of a triangular lattice mast 8 in. on a side equals 0.84 b = 0.84 (8) = 6.7 in. See Belrose, "The Half-Wave Vertical," *Ham Radio*, Sept. 1981, pp. 36-39.

3 m = ft × 0.3048.

4 D. DeMaw, "Antenna Matching, Remotely — Some Thoughts," *QST*, July 1982.

5 The disparity between the impedances measured by VE2CV and by W1FB may be due in part to a difference in the conductor-size ratios of the scaled and full-scale models. Also, the slope angle of the full-size model at W1FB was different from that of the 200-MHz professional model, owing to the feed point being elevated some 3 feet above the ground plane (snow problems).

Strays

TA PROFILES

With our thanks for the expert advice we've received on rf power amplifiers and radio transmitters, we are pleased to introduce ARRL Technical Advisor Nathan O. Sokal, WA1HQC. He joined our TA family in 1979.

Nat has been a licensed radio amateur since 1967. He holds an Advanced class license. As a technical speaker, he has given several outstanding papers at radio clubs and at ARRL-organized IEEE seminars. He is the holder of a Bachelor's and a Master's degree in electronics from the Massachusetts Institute of Technology. While attending MIT, he was elected to the Eta Kappa Nu electrical engineering honor society and the Sigma Xi research honorary society. After graduating from MIT, Nat held engineering and supervisory positions with several companies. He was involved primarily with design, manufacture, field installation and operation of a wide variety of analog and digital equipment for instrumentation, control, communication, computation, and signal and data processing.

In 1965, Nat founded Design Automation, Inc., an electronics consulting company. Here he has been involved with the design (and design review) of a wide variety of electronic equipment. He is engaged also with computer simulation of electronic systems and circuits, and development of high-efficiency switching-mode power amplifiers (including rf power amplifiers) and power converters. He is a co-inventor of the Class E switching-mode rf power amplifier and of a high-efficiency, high-linearity rf power amplifier. Nat resides in Lexington, Massachusetts. He is a busy fellow, but when he has any time to spare he can be found in his ham shack and, we hope, reading *QST!* — *Marian Anderson, WB1FSB*

Meet TA Nat Sokal, WA1HQC.