Technical Correspondence

Conducted By
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CHOOSING WIRE SIZE FOR TOROIDAL INDUCTORS

☐ "What size wire should I use to wind the toroidal inductors with?" is a question frequently asked by people duplicating various circuits and rigs I've designed. The answer is that, in most cases, you can base your choice on availability and convenience, within certain limits. But what are those limits?

Speaking only of toroidal inductors that are found in typical amateur transmitters, receivers and the like, we can describe an inductor by noting its apparent inductance (its inductance modified by stray capacitance) and Q at the frequencies of interest. That is, we could substitute another inductor having the same apparent inductance and Q and get the same performance. There are, of course, some exceptions to this rule, such as VFO tank inductors and others that may be sensitive to very small changes in temperature or physical movement.

To show what effect wire size is likely to have on these two parameters, I wound 22 turns of various sizes of wire on several T-50-6 powdered-iron cores, and measured the inductance and Q of each one at 14 MHz. A home-built test fixture having an approximate accuracy of 5% was used for the experiment. No. 21 wire, which would fit precisely on a single layer, was the largest used, and the turns were evenly spaced around the cores wound with smaller wire. The results of my tests are shown in Table 1.

Within the accuracy of the test fixture, and expected core-to-core variation, the inductors wound with wire nos. 21 through 26 are the same. There is a definite drop in Q for inductors wound with no. 28 and smaller wire, but even this drop in Q won't be noticeable unless the inductor is used in a critical application, such as a VFO tank or a high-Q filter. Single-tuned circuits, transmitter interstage and output matching and filtering networks, etc., are generally of low enough loaded Q that the difference in inductor Q is completely inconsequential. Rf transformers, which are generally wound on ferrite instead of powdered-iron cores, are even less sensitive to wire sizes unless extreme bandwidths (e.g., two or three decades) are required.

A rule of thumb that will lead to the highest Q is to use the largest wire size that will fit on a single layer, but which isn't so large that the wire won't conform well to the core. As you can see from the results of this experiment, using wire as much as several sizes smaller than specified will deliver equally good performance. — *Roy Lewallen, W7EL, Beaverton, Oregon*

Table 1
Wire Size Vs. Inductor Value

Wire Size (AWG)	*Apparent L (µH)*	*Q*
21	2.10	252
22	2.17	237
24	2.17	250
26	2.07	248
28	2.15	220
30	2.13	196
32	2.28	182

OTHER BANDS FOR THE JF ARRAY

☐ I've had numerous inquiries concerning my article, "The JF Array" (Nov. 1982 *QST*). Readers wanted additional information about other bands of operation. Because of this response, I've shown applications of my array for other band combinations (Figs. 1, 2 and 3).

I also recommend that expansion of the JF or any other collinear array *not* continue beyond four elements. This is because current diminishes rapidly beyond four elements, and proper phase relationships become difficult to maintain. Also, note that higher gains are possible with the JF concept over conventional perpendicular phasing-stub arrangements because the outer elements are wide-spaced. The "clean" lines of the JF also provide improved multiband performance because little discontinuity is offered at frequencies other than what the antenna was designed for. — *Dick Schellenbach, W1JF, Reading, Massachusetts*

A HALF TWIN-DELTA LOOP ARRAY

☐ By utilizing the apex-driven Delta Loop, you can design a new, 2-element coplanar antenna array, called a Twin-Delta Loop (Fig. 4). This antenna element can be used for practical communication systems from vhf to uhf. In particular, Twin-Delta Loops can be used as

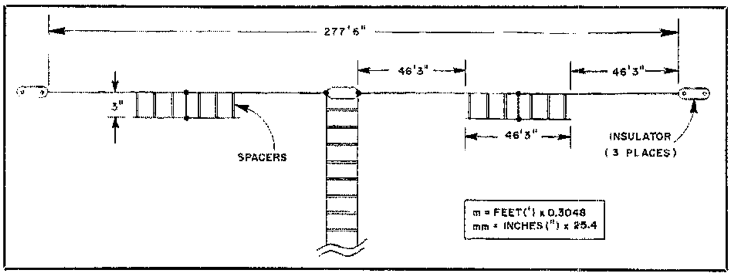

Fig. 1 — JF Array for the following bands and (theoretical gain) configurations: 30 meters — 4-element collinear (5.2 dBd); 80 meters — 2-element collinear (1.9 dBd); 160 meters — 1/2-wave dipole; 40, 20, 15 and 10 meters — extended dipole.

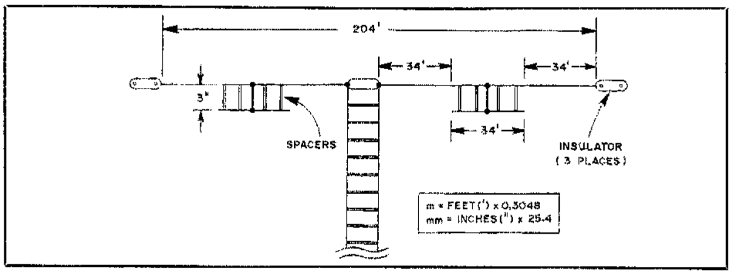

Fig. 2 — JF Array for the following bands and (theoretical gain) configurations: 20 meters — 4-element collinear (5.2 dBd); 80, 40, 30, 15 and 10 meters — extended dipole.

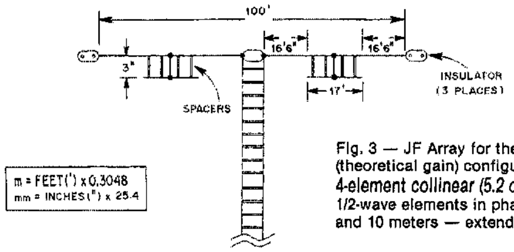

Fig. 3 — JF Array for the following bands and (theoretical gain) configurations: 10 meters — 4-element collinear (5.2 dBd); 30 meters — two 1/2-wave elements in phase (1.9 dBd); 40, 20, 15 and 10 meters — extended dipole.

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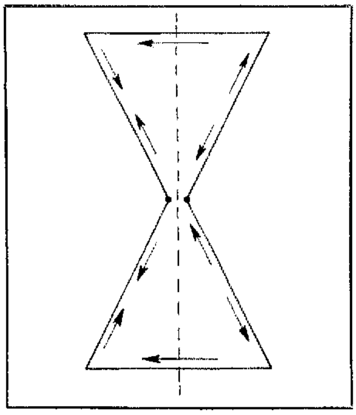

Fig. 4 — Illustration of a Twin-Delta Loop. The total length of the twin loops is approximately 2 wavelengths. Arrows indicate direction of the instantaneous currents on the antenna.

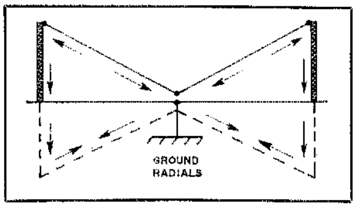

Fig. 5 — The grounded version of the Twin-Delta Loop, with the image in the ground plane.

Table 2
Half Twin-Delta Loop Dimensions

Band	*Tower Height (ft)*	*Length of Sloping Wires (ft)*
160 m†	102.03	204.06
80 m	49.86	99.72
40 m	25.92	51.84

†Optimized for 1.825 MHz.

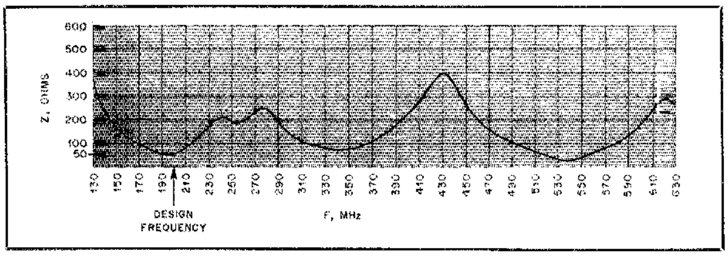

Fig. 6 — Feedpoint impedance of the (grounded) Half Twin-Delta Loop versus operating frequency for the scaled model.

elements of a Yagi-Uda array, providing superior gain and bandwidth characteristics compared to conventional full-wave loop and dipole arrays.[1] If (as with the Half-Delta Loop) this antenna element is rotated 90°, and the lower half is replaced by an image in the ground plane, we now have an M-shaped antenna (Fig. 5) that can be constructed for the hf bands. This antenna offers outstanding performance — even better than the Half-Delta Loop, which in itself is a good hf antenna.[2,3] The new antenna provides a better match to 50-ohm coaxial cable, with greater bandwidth and gain than the Half-Delta Loop.

A Half Twin-Delta Loop was modeled at 200 MHz. That is, *each* Half-Delta Loop and image in the ground plane is 1-wavelength long at 200 MHz. The masts were copper rods of 1/8-in. diameter and 11.12 in. high.[4] The sloping wires (no. 22) were 22.24 in. long. The antenna was mounted on a 98.4-ft-diameter ground screen, which was elevated so that impedance-measuring instruments could be located directly beneath it. A Hewlett-Packard 4191A rf impedance analyzer was used to measure the impedance. Measurements were made through a type-N chassis connector, fed through the ground plane to the measurement instrument located beneath. The electrical length of the feeder cable including the type-N connector was subtracted, so that the measured impedances are referenced to the feed point of the antenna.

The impedance of the Half Twin-Delta Loop was measured over the frequency range of 130-1000 MHz (Fig. 6). Loop resonance (low Z and θ equal to zero) occurred at 201, 346, 540, 755 and 869 MHz, which are close to the resonant frequencies measured for the single Half-Delta Loop over a much smaller ground plane.[5] Notice that at f_0 (201 MHz) the feed impedance is 50 ohms.

The gain in the plane of the ground screen was accurately measured, employing a Hewlett-Packard 8505A rf network analyzer. Gain was measured with respect to a carefully constructed and accurately matched (to 50 ohms) 1/4-wave monopole. The azimuthal gain was measured in two orthogonal directions — in the plane and perpendicular to the loops.

At f_0, a maximum gain of 10.2 dBi (5 dB over a 1/4-wave monopole) occurred in the directions perpendicular to the plane of the loops. The gain was 20 dB less in the plane of the loops. The gain and pattern are similar to that for two monopole antennas spaced $\lambda/2$ apart and fed in phase. At $2f_0$, the maximum gain was nearly the same (9.2 dBi), but it occurred in the plane of the loops. A deep null was not found in the perpendicular directions, for which the gain was 6.7 dBi.

The M-shaped, Half Twin-Delta Loop is bidirectional. Low-band DXers who decide to employ this antenna should therefore give consideration to installing two arrays perpendicular to each other, with a switching arrangement so that either antenna can be selected. The Half Twin-Delta Loop offers superior performance over other wire antennas, provides a good match to a 50-ohm coaxial cable and has a wide bandwidth. In a previous article, DeMaw and I stressed the multiband performance of the Half-Delta Loop, and the dimensions given were a compromise to allow this application.[6] The dedicated low-band DXer may wish to optimize this antenna for his or her favorite band. Table 2 provides dimensions for operation on the 160, 80 and 40-meter bands (based on our model antenna measurements). The bandwidth at f_0 is 12.8% for an SWR < 2:1; therefore, an 80-meter version would operate well over the entire band, without the need for an antenna-matching unit.

I would like to acknowledge the Communications Research Center and the National Research Center for use of their antenna ranges. Also, thanks to Len Bode, who constructed the antennas and made the measurements. — *John Belrose, VE2CV, ARRL TA, Aylmer, Quebec*

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[1] T. Tsuliji and S. Tou, "High-Gain, Broad-Band Yagi-Uda Array Composed of Twin-Delta Loops," IEEE Conference Publication No. 195, *Antennas and Propagation*, Part 1: Antennas, 1981, pp. 438-441.

[2] J. Belrose, "The Half-Delta Loop: A Grounded, Vertically Polarized Antenna," *Ham Radio*, May 1982, pp. 37-39.

[3] J. Belrose and D. DeMaw, "The Half-Delta Loop: A Critical Analysis and Practical Deployment," *QST*, Sept. 1982, pp. 28-32. Also see D. DeMaw and J. Belrose, "Design and Practical Deployment of the Multiband Half-Delta Loop," IEEE Southcon-83 *Preprint*, Session 9, Atlanta, Georgia.

[4] mm = in. × 25.4; m = ft × 0.3048.

[5] See note 3.

[6] See note 3.

Feedback

☐ The following additions and corrections to "The Reality of Reflected Power," Technical Correspondence, Feb. 1983 *QST*, should be made. The text should read: ". . . by a distance of 90°.[5] Line voltage measured across the line is the phasor sum of the forward and reflected voltages; line current measured in series with the line is the phasor sum of the forward and reflected currents. The distance between . . . ." Additionally: ". . . phase angle between the *line* voltage and current is exactly 0°. At points . . . "

The equation in the last sentence should read $E_{\pm x} \times H_{\mp y} = P_{x}$

Author Maxwell also suggests referring to the article by Kramer, "Reflected Waves and Mismatched Loads," June 1978 *CQ*, for more information on the subject.

☐ Readers who enjoyed the article by Webb, "Electrical Antenna Null Steering," Oct. 1982 *QST*, may be interested in a coincidental British approach to the same problem. The Oct. 1982 issue of *Radio Communication* (RSGB) contains an article by Page-Jones, G3JWI, entitled "An Experimental Adjustable Null Receiving Antenna for 14 and 21 MHz."