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A Six Band, 20 Through 6 Meter Log Periodic Dipole Array

Introducing an extended range directional antenna to match the capabilities of the modern HF through 6 meter transceiver.

Ralph J. Crumrine, NØKC

All the major suppliers of Amateur Radio equipment now offer "HF" transceivers that extend into the VHF region with 6 meters. This venerable log periodic dipole array (LPDA) has been updated in such a way that it can match up with at least the upper reaches of frequency coverage of these new transceivers. Call it magic if you will, but it is actually due to a new type of phasing line being used to connect the dipole elements. With an exponentially increasing impedance phasing line, the old LPDA is transformed into a new beast that will operate in both the fundamental and harmonic modes of the dipoles in the array.

Mechanical and electrical details of LPDAs are well documented in recent editions of *The ARRL Antenna Book*.[1] The antenna described here, however, will not be found in those pages and adds a new dimension to the lore of LPDA design.

[1]Notes appear on page 43.

Why an LPDA?

Why visit the LPDA antenna type with a redesign? Here are some reasons for choosing the LPDA, and in particular this LPDA.

- Matches the capability of modern transceivers.
- Only nine elements to achieve what would probably require 12 to 15 elements in a multi element Yagi array and 17 elements in a conventional LPDA.[2]
- No installation adjustments are required.
- Single transmission line up the tower.
- Mechanical design choice does not require the strength of bridge girder construction.
- All elements can be tied to the tower to be at dc ground potential.
- Normal operation can take place under a load of snow and ice.
- Good value in the number of bands covered with a single antenna.

The Exponential Phasing Line

The idea of feeding an LPDA with an increasing tapered impedance phasing line was first used by Kuo in miniaturized microwave antenna arrays.[3] The antenna described here applies this idea to a full sized HF LPDA, with the impedance increasing exponentially along the phasing line. The concept of exponential matching networks goes way back to the wind up phonograph and the morning glory horn used to match the weak sound at the needle point pickup to the listener's ears.

Two advantages have been obtained by

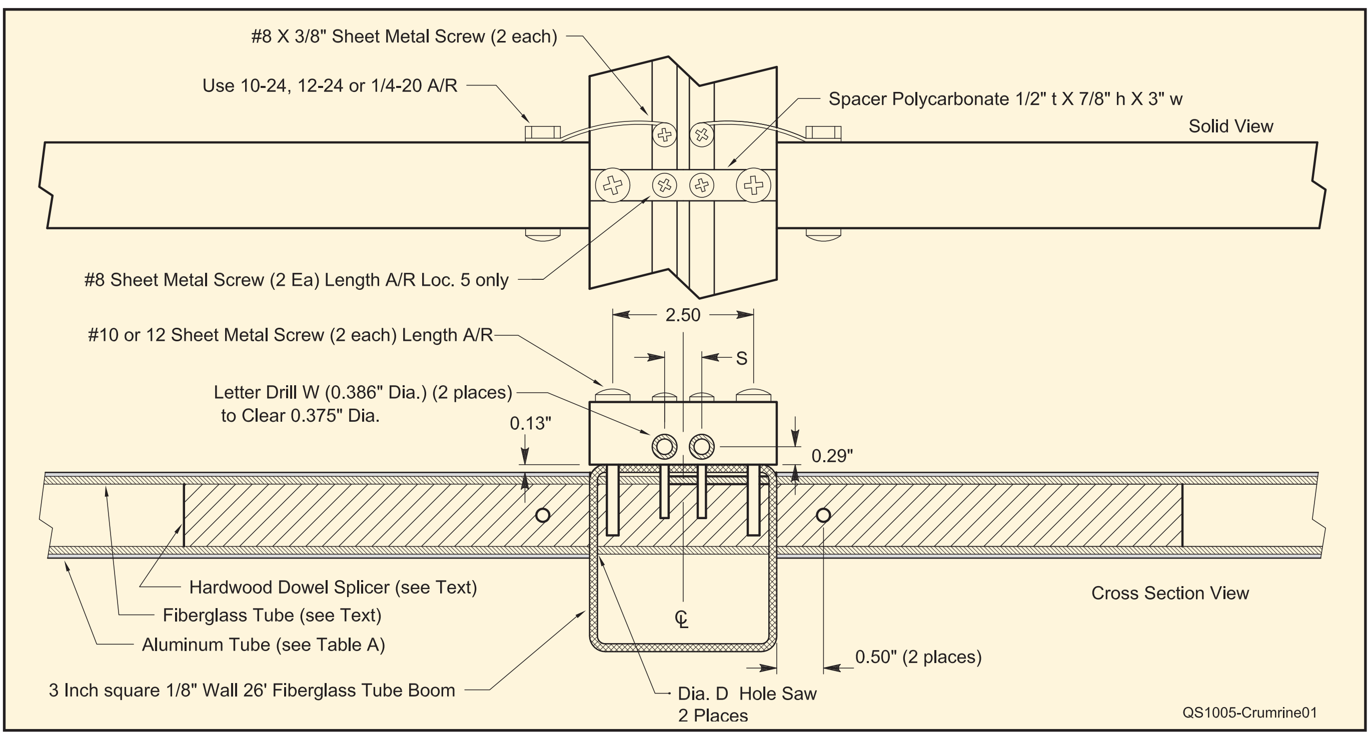

Figure 1 — Assembly drawing of boom, splicer and phasing line connections. See Table B on the Qst-In-Depth Web site for dimensions L, D and S.

such an application. First, the input impedance is now nominally 50 Ω across the full design range of the array. No matching transformer is required at the antenna input. Second, the exponential phasing line permits useful harmonic operation with the happy result that the 6 meter band also has a nominal 50 Ω input impedance.


Figure 2 — Assembled boom and splicers.

Mechanical Design

Many LPDAs use a boom made of two parallel sub booms with the sub booms also serving as a constant impedance phasing line for the dipole elements. Each sub boom holds a half length of every dipole in the antenna. Several arrangements to do this are shown in Chapter 10, Figures 9 B, C and D of *The ARRL Antenna Book*. This is a satisfactory method for lightweight VHF and UHF dipole half elements, but is not suitable for larger HF arrays because of the high cantilever force (torque) exerted on the boom at the mounting point of each half dipole. Figure 9A shows a single boom. But the method of construction shown there has the same cantilever disadvantage at each half dipole attachment point.

The most desirable arrangement is similar to that of a tightrope walker, carrying his balance pole, in this case a dipole, in the middle at the balance point. This analogy suggests using a single piece boom. The splicers, or insulators, for the dipole half elements carry the cantilever forces through the boom with the result that there is no cantilever force on the boom itself; the boom is only required as a support for the dipole weight.

The choice of fiberglass for the boom and dipole element splicers adds to the electrical simplicity of the complete antenna, avoiding any effects of the boom on the antenna design. A further advantage of the fiberglass boom is that the phasing line can be made of uninsulated conductors carried along and in contact with the boom, without any electrical problems.

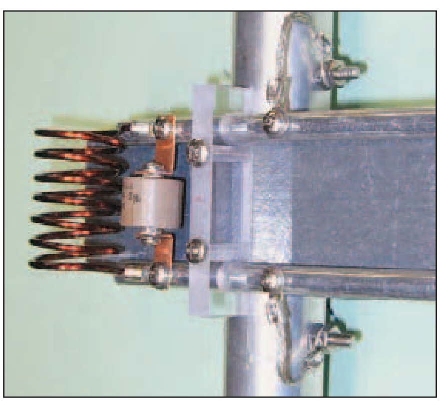
Figure 3 — Direct connections including end termination.

All parts of the antenna were designed with sufficient mechanical strength for a 1 inch ice load or 90 mph winds with a safety margin.

Electrical Design

As a starting point, information on LPDA design was taken from *The ARRL Antenna Book*. Practical numbers of dipole elements ranging from 7 to 11 were modeled using several boom lengths. Out of all of this came an optimum design, considering forward gain, front to back ratio and VSWR. The entire antenna was modeled in detail, including the exponential taper of the phasing line, using the *EZNEC* implementation of *NEC-2*.[4] The end dipoles were adjusted in length and spacing for best performance.

Further improvement of gain and pattern performance, particularly at the low frequency end of the range, was accomplished by adding an inductive termination at the far end of the phasing line. The termination is modeled in the antenna design file as a circuit in parallel at the end of the phasing line.

While the design range for this array was 14 to 30 MHz, it was discovered that there was a bonus and that was that at the 6 meter band the LPDA performed equally well. For more information on this see the test results section.

Construction

The boom is fabricated from 26 feet of 3 inch square, 1/8 inch wall fiberglass tube. At this length it will be necessary to splice two pieces. The splicer is a 3 foot length of CCA treated lumber. This antenna was first assembled using a 2 inch square, 1/8 inch wall fiberglass tube, but it was thought to be a little too flexible, considering the bending forces along the length of the boom caused by the trusses.

The dipole elements are numbered #1 through #9 from the input end of the antenna with lengths and diameters of nesting aluminum tubing listed in Table A on the QST-In-Depth Web site.[5] The location of each dipole along the length of the boom is also given. Splicers and reducers are also listed to complete the makeup of each dipole.

The center splicers are cut from round fiberglass tube having a wall thickness of 1/8 inch. Three 32 inch splicers can be cut from an 8 foot length of tubing. The fiberglass tube is reinforced with a 16 inch length of hardwood dowel rod. This piece is totally protected from the weather, but none-the-less, it is treated with a preservative. See Figure 1 and Table B on QST-In-Depth for assembly details of each element station. Figure 2 shows the boom and element splicers assembled.

The phasing line is made from two 3/8 inch diameter round aluminum tubes, each one 25 feet 10 inches long, that run under the boom. They extend 1 1/2 inches beyond the end elements for connection to the transmission line at element #1 and the end termination at element #9. At each dipole element location a spacer made from 1/2 inch thick sheet polycarbonate is attached to the boom and holds the phasing line in place. Table B gives the center to center line spacings for the phasing line for each of the nine parts.

The phasing line tubes slide freely through the spacers at all but one location. At loca-


Figure 4 — Crossover connections.

Table 1

Computed and Measured VSWR at Two Heights

Data measured through 74 feet of RG-8X and corrected to the input of the antenna

Band	Computed Frequency		Measured 30 Feet	Measured 50 Feet
20M	14.000	1.42:1		
	14.200	1.13:1	1.22:1	1.43:1
	14.350	1.12:1		
17M	18.068	1.24:1		
	18.100	1.24:1	1.35:1	1.22:1
	18.168	1.22:1		
15M	21.000	1.34:1		
	21.200	1.25:1	1.34:1	1.34:1
	21.450	1.14:1		

Band	Computed Frequency		Measured 30 Feet	Measured 50 Feet
12M	24.890	1.27:1		
	24.930	1.29:1		
	24.990	1.37:1	1.10:1	1.10:1
10M	28.000	1.40:1	1.23:1	1.35:1
	28.500	1.29:1		
	29.000	1.24:1	1.10:1	1.10:1
	29.700	1.40:1		
6M	50.000	1.69:1	1.65:1	1.65:1
	52.000	1.35:1	1.65:1	1.65:1
	54.000	1.37:1	1.50:1	1.50:1

Figure 5 — Complete assembled antenna.

Figure 6 — Antenna test site.

tion 5, the phasing line is held fixed to the spacer and boom with screws. In that way the phasing line is held in position at this point, but can slip freely elsewhere and will not experience distortion as the boom flexes from handling in assembly and hoisting or the wind once the antenna is on the tower. Locate the screw holes in the phasing line for connections to the elements about a ½ inch away from the spacer to allow for this motion of the phasing line through the spacer.

The phasing line is connected to the dipole half elements by connecting directly the odd numbered elements and crossing over the connections for the even numbered elements. See Figures 1, 3 and 4. Use 8 × ⅜ inch stainless steel sheet metal screws to connect to the phasing line. Heat shrinkable Teflon tubing is used to insulate the crossover connections.

At the far end of the phasing line a coil, L1, and a capacitor, C1, are installed in parallel. See Figure 3 and Table A. Note that this circuit provides grounding of all the dipole elements when the transmission line cable outer braid is connected to the tower. A 50 Ω coaxial transmission line is attached at the end of the phasing line at element #1. It should be looped in a U turn at the end of the boom and fished back through the inside of the boom to a hole in one side of the boom near the location of the mast attachment point.

Note that construction, so far, is done with the phasing line facing up. Rotate the boom so the phasing line is facing down to install the dipole elements. The antenna is meant to be installed with the phasing line under the boom, protected from the weather. Figure 5 shows the antenna assembled in an upside down position.

All the fiberglass and plastic parts are made from ultraviolet (UV) resistant material. Further UV protection with a coat of paint may be added if desired. If paint is applied to these parts, the surfaces should be properly prepared to hold the paint. All hardware should be stainless steel. Plated steel hardware will eventually rust. You can count on it.

That completes the assembly. The weight of the array is approximately 90 pounds. Mount the array at its balance point, 14 feet from the front end, to the mast with commercial hardware, or make your own from ¼ inch aluminum plate and U bolts appropriate to the boom and mast shapes and dimensions. Whatever hardware is used, make sure that it stays well clear of the phasing line running past the mast mounting point.

Regardless of choice of material for the boom, considering the cumulative weight of the elements and boom, it is a good idea to add trusses to support the ends of the boom. Rig the trusses with turnbuckles located at the mast ends for adjustment after the array is installed. The truss elevation at the mast should be no less than 4 feet above the antenna. The trusses should attach to the boom at 6 feet from the front end and 5 feet from the back end of the boom. Adjust the trusses so that the ends sag enough to drain any moisture that might gather in the boom. There are no other electrical or mechanical adjustments necessary before or after installation of this antenna.

Table 2

Electrical Components

C1 — Doorknob capacitor, 10 pF, type 850S 5 kV dc (RF Parts Company).

L1 — Air inductor, 7 turns, #10 AWG copper wire, 1 inch inside diameter, 2 inches long. Leave ⅜ inch leads and solder onto terminal lugs

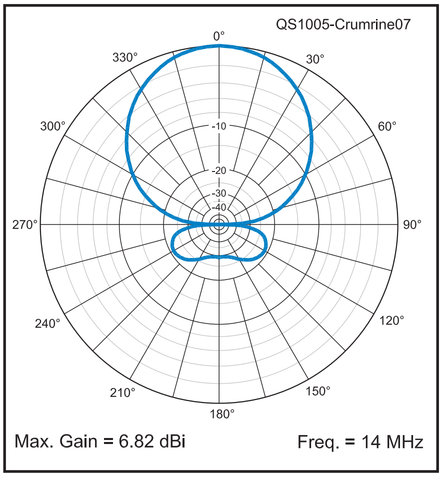

Figure 7 — Free space azimuth plot, 20 meters.

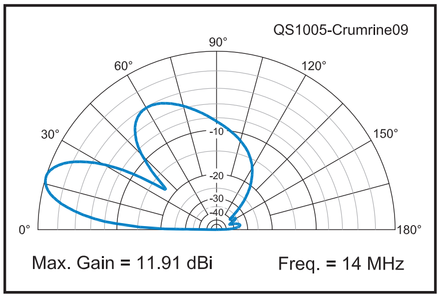

Figure 9 — Elevation plot, 20 meters at 55 feet above real ground.

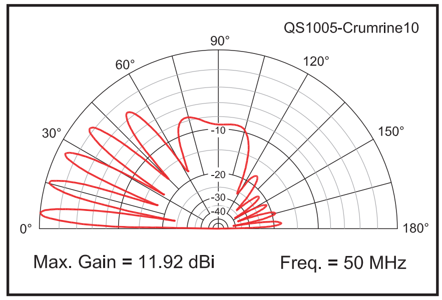

Figure 10 — Elevation plot, 6 meters at 55 feet above real ground.

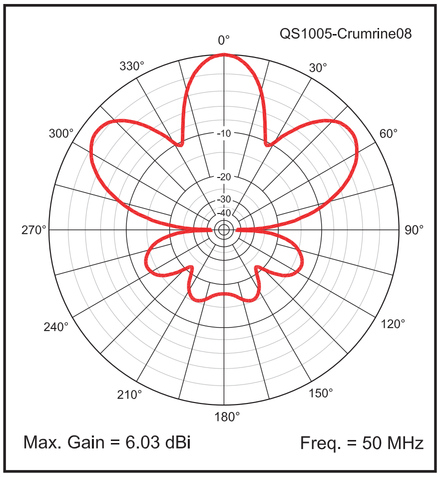

Figure 8 — Free space azimuth plot, 6 meters.

Test Results

The antenna was tested at elevations of 30 and 50 feet by suspension from a hoisting crane (see Figure 6). The VSWR at each band center was measured with the results shown in Table 1 along with modeled VSWR for comparison. It should be mentioned here that when the antenna was tested at ground level the results did not agree very well with *NEC-2* calculations. At elevation, however, the numbers fell, as the English say, spot on. The VSWR measurements were in agreement and location of VSWR minimum and maximum agreed very well, in the range of ½ to 2% for frequency accuracy. For such a broadband antenna, I consider these variations insignificant.

Modeled free space azimuth plots for 20 and 6 meters are shown in Figures 7 and 8. Note that because the antenna is operating harmonically at 6 meters, the forward lobe is actually three lobes, symmetrical about the antenna axis. At about 52 MHz, the three lobes become equivalent in gain and at 54 MHz the sidelobes become dominant and offer a ½ dB more gain than the central lobe at 50 MHz.

All the HF bands through 10 meters, with the exception of the 12 meter band, have performance virtually identical to the 20 meter plot, having similar forward gain and front to back ratios greater than 20 dB. At 12 meters, the forward gain is ½ dB less and the front to back ratio is 16.3 dB. Free space patterns are the gold standard of antenna comparison. But in reality we operate antennas above real earth. So, computed elevation plots with the antenna mounted at 55 feet elevation — the installation elevation at my location — are shown in Figures 9 and 10.

Summary

This antenna should serve the user very well and be especially useful for working DX, especially as the current sunspot cycle improves. There's a lot of bang for the buck in this design, considering the six band, single feed line design described here. If the readers have a desire to have this antenna, but are not inclined to build it from scratch, or are limited in facilities to do so, I suggest that they get in touch with me and see at what level of fabrication parts might be supplied to get the project done. I'll help anyone who is interested to see to it that they mate up this fine "HF + 6 meter" antenna to their "HF + 6 meter" transceiver.

Acknowledgments

I want to offer my thanks to Rod Richardson, WAØHHX, and Tony Ferraro, W3AJF, for their review and very helpful comments in putting together this article. With this antenna I can offer some friendly competition to Rod's multiband quad, and we will see which one keeps working in the next Kansas ice storm.

Notes

[1]R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop**; **pubsales@arrl.org**.

[2]Based on computations using the LPCAD28 log periodic design software supplied in *The ARRL Antenna Book*, 19th Edition, assuming 14 MHz and 54 MHz design end points, an equivalent boom length and performance specifications.

[3]S. Kuo, "Foreshortened Dipole Antenna with Triangular Radiating Elements and Tapered Coaxial Feedline," United States Patent 4,907,011, Mar 6, 1990.

[4]Design analysis was done with, first *EZNEC* v.3.0 and then later, *EZNEC* v.5.0. The later version was most helpful in several ways, with its additional features of virtual elements and the ability to use parallel loads directly without a workaround patch job. Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[5]See Tables A and B on **www.arrl.org/qst-in-depth** for dimensions, positioning information and suggested suppliers. If you are going to scrounge up pieces of tubing to make the dipoles, be aware that any changes in diameter and piece lengths may affect the required length.

Ralph J. Crumrine, NØKC, was first licensed as a Novice in 1953 with the call WN3WFZ. He upgraded to General class and then in 1978 to Amateur Extra class. His enlistment in the USAF put him to work in radio and navigation equipment repair. After military service he attended The Pennsylvania State University where he earned a BSEE degree, graduating with honors. A career followed in the design and development of avionics products, first with King Radio Corporation, then Wulfsberg Electronics. He then retired from Honeywell Avionics Division. Ralph is a member of ARRL and has been an active ham since retiring, earning the WAS and DXCC in 2002. Antenna design has been his greatest interest lately, including a design reported on in The ARRL Antenna Compendium, Vol 7.

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