By L. B. Cebik, W4RNL

An LPDA for 2 Meters Plus

Here's a high-performance 2-meter antenna with a nice bonus—it also covers 130-170 MHz, for your monitoring pleasure!

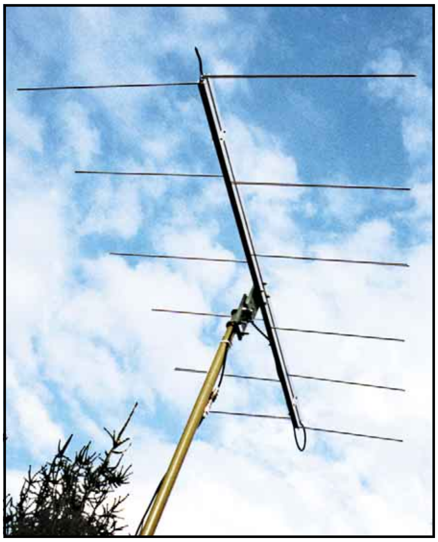
Building a log-periodic dipole array (LPDA) to cover all of 2 meters with good gain and a low 50-Ω SWR from 144 to 148 MHz requires about 6 elements and a 54-inch boom. The project would not make much sense (apart from satisfying raw curiosity), however, since that same number of elements on the same length boom can be arranged as a wideband Yagi with at least a dB more gain and an even lower SWR across the band.[1]

LPDAs find their niche wherever we need a wide operational passband with a relatively constant feed-point impedance. In the HF region, we typically build LPDAs for a 2:1 frequency range—for example, 14 to 28 MHz. Antennas with wider (10 to 30 MHz) and narrower (18 to 30 MHz) ranges are common. At VHF people have built wide-ranging LPDAs but most suffer from inadequate performance, except perhaps for general-utility purposes.

You can construct a fairly narrowband LPDA centered on 2 meters and built to high performance standards. It will also offer something beyond the range of Yagi performance—the ability to monitor frequencies from 130 to 170 MHz with a 2:1 or better 50-Ω SWR. However, the lowest SWR values and the best performance (in terms of gain and front-to-back ratio) occur within the transmitting region, namely the 144-148 MHz amateur band.

Such an antenna also serves other needs for sundry emergency and service functions, including coverage of CAP and other frequencies close to the amateur band. The region below 2 meters is largely devoted to aeronautical mobile services, while the region above

[1]Notes appear on page 46.



The LPDA with elements oriented horizontally.

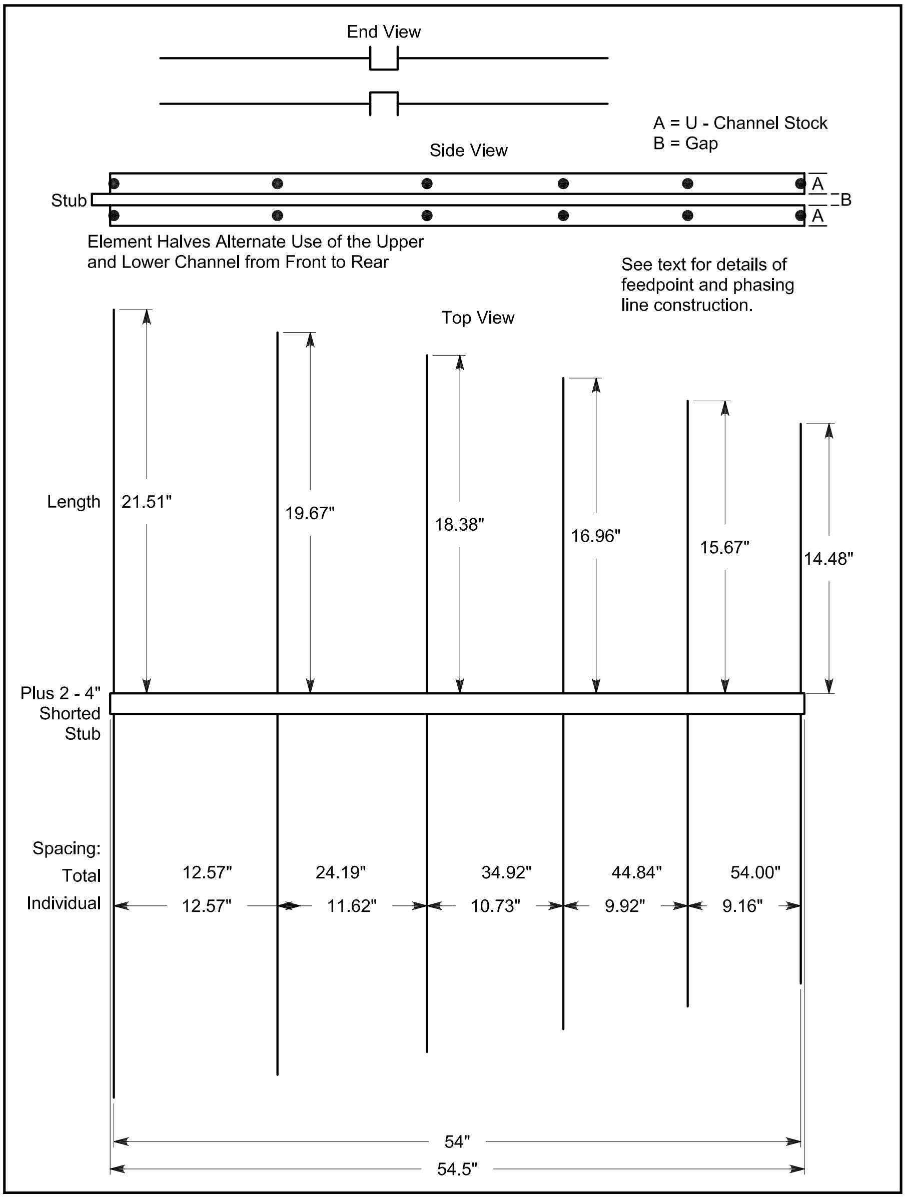


Figure 1—Outline sketch and dimensions of the 2-meter-plus LPDA.

2 meters is split between land and maritime mobile services. Let's see what an LPDA array to cover this wide frequency range looks like.

The Basic Design

Amateur-band LPDA design typically suffers from the attempt to use as few elements as possible on the shortest possible boom. LPDA design revolves around two mathematical variables: τ (*tau*), which defines the relationship between successive element spacings, and σ (*sigma*), the relative spacing constant. For every LPDA that uses less than the highest value of τ and the corresponding optimal value of σ, there will be only a few combinations that yield relatively high performance. For the present project, the design was restricted to 6 elements on a 54-inch boom, with a τ of 0.9238 and a σ of 0.1461. These values are short of the highest possible performance, but increasing τ would have required more elements and increasing σ would have lengthened the boom.[2]

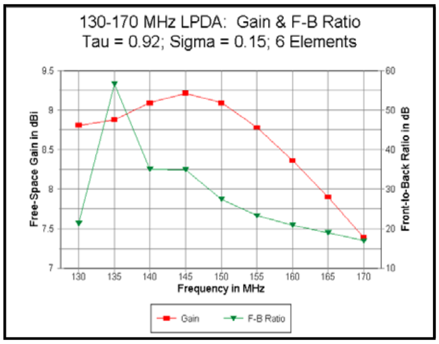


Figure 2—Modeled free-space gain and 180° front-to-back of the 2-meter-plus LPDA from 130 to 170 MHz.

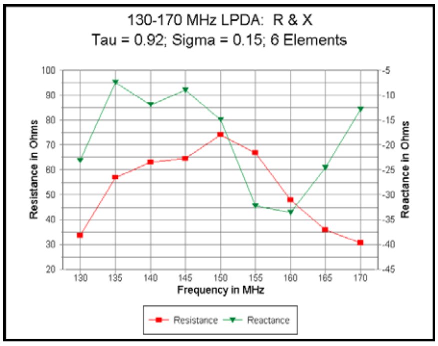


Figure 3—Modeled feed-point resistance and reactance of the 2-meter-plus LPDA from 130 to 170 MHz.

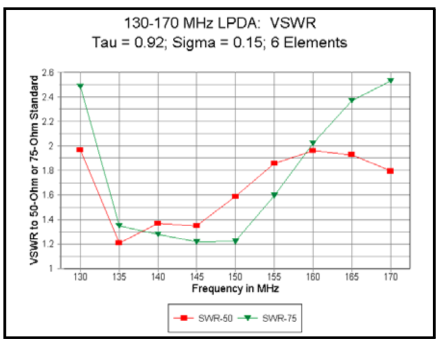


Figure 4—Modeled 50-Ω and 75-Ω VSWR of the 2-meter-plus LPDA from 130 to 170 MHz.

For an LPDA, decreasing the characteristic impedance of the phasing line connecting the elements tends to increase array gain and to decrease the feed-point impedance. A 75-Ω phasing line yields acceptable 50-Ω performance from the array, with an average free-space gain across 2 meters of about 9.2 dBi. Since the front-to-back ratio of an LPDA tends to vary with the gain, it is uniformly high; that is, better than 30 dB across the band, with no strong rearward side lobes to decrease the overall front-to-rear ratio.

Figure 1 shows the general layout and basic dimensions of the LPDA that achieves this level of 2-meter performance. We shall examine a number of the construction details later in this article.

Of equal importance with the performance in the 2-meter band is how the array works across the entire operating passband. Figure 2 is a graph of the modeled free-space gain and front-to-back ratio of the LPDA from 130 to 170 MHz. The gain peak in the 2-meter band is readily apparent, with less but still useful gain above and below the desired design range. The front-to-back ratio only decreases below 20 dB above 160 MHz. The peak in the front-to-back curve is a normal LPDA phenomenon, since it peaks—often very sharply—at a frequency a bit lower than the peak frequency for gain.

For monitoring frequencies well outside the amateur band, these performance characteristics are quite serviceable. This LPDA was modeled with a 4-inch shorted transmission-line stub at the rear element. A stub between 2 and 4 inches long is necessary to avoid a pattern reversal at about 160 MHz, and it improves the overall performance of the array within the 2-meter band too. A stub length shorter than 4 inches will increase the 2-meter front-to-back ratio by about 2 dB, while reducing the operating range to a lower limit of about 132 MHz.

Figure 3 provides a look at the excursions of feed-point resistance and reactance. The curves are quite normal for an LPDA. These arrays tend to show maximum and minimum values of resistance and reactance—as referenced to a median value for each—in a relatively *out-of-phase* pattern. The result is a broadbanded SWR curve when plotted against the median feed-point resistance value, in this case, about 60 Ω.

The 50-Ω and 75-Ω SWR curves appear in Figure 4. Within the 2-meter band, 75-Ω cable would be a slightly better choice of feed line—if you are looking for the lowest possible SWR. However, for the widest operating passband at an SWR of less than 2:1, 50-Ω cable is the better choice, since the resistive component of the feed-point impedance shows values well under 50 Ω at the high end of the operating passband.

Mounting the LPDA

You can orient an LPDA either vertically or horizontally. However, at conventional mounting heights, which are often (but not always) below 5 λ above ground, antenna far-field gain will vary according to orientation. Figure 5 shows the modeled far-field performance of the array at a height of 25 feet (300 inches or

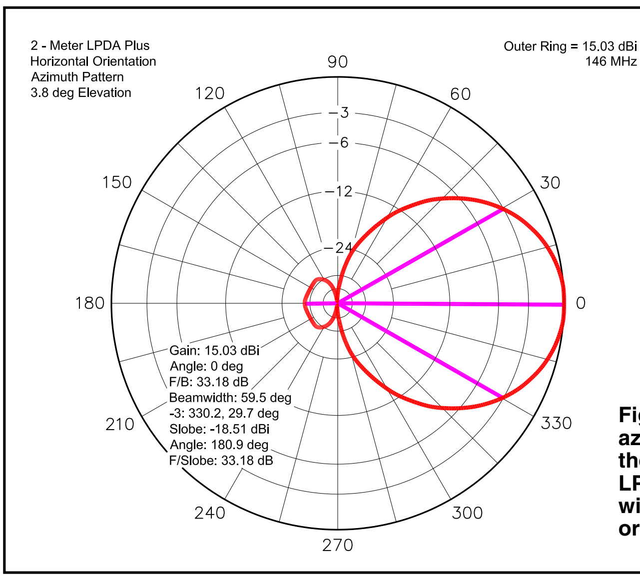


Figure 5—Free-space azimuth pattern of the 2-meter-plus LPDA at 146 MHz with elements oriented horizontally.

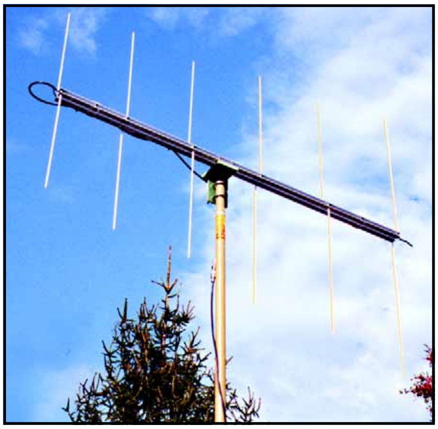
about 3.75 λ in the 2-meter band), with the antenna oriented horizontally. The operating frequency is 146 MHz. The 9.2 dBi free-space gain, when taking into account ground reflections, becomes just over 15 dBi at the elevation angle of maximum radiation (3.8°). Figure 5 also clearly shows the well-controlled rear pattern of an LPDA that uses high values for both τ and σ.

If we remodel the antenna to place the boom at the same height, but with the elements oriented vertically, we obtain the pattern in Figure 6. The –3 dB beamwidth has increased by about 25° for both the forward and rear patterns. The elevation angle of maximum radiation is 3.5°. The price of having a significantly wider beamwidth is forward gain, which is about 1.7 dB lower than the value shown in Figure 5 for the horizontal mounting configuration. An array must be well above 5 λ above ground before the gain figures for the two orientations begin to converge.

Questions arise from time to time about whether the far field patterns are good indicators of the antenna patterns in ground-wave point-to-point service. Figure 7 compares the relative patterns for the two orientations, using a receiving point 1 mile from the antenna at 25 feet above ground. It's clear that the antenna retains its pattern shape in point-to-point service. However, these patterns presume a clear field between the two antennas. Intervening objects and terrain variations can modify the actual performance of an antenna between any two stations.

Construction

Table 1 provides the basic dimensions of the LPDA array, in both inches and millimeters. The half-length values are



The LPDA with elements oriented vertically. Use this orientation only with a nonconductive mast.

important for construction, since each element is split at the center and connects to the phasing line.

The boom and phasing line for this design are one and the same. I chose 3/4×3/4×1/8-inch thick aluminum channel stock for the twin-boom. This stock can be obtained from some hardware outlets and can often be special ordered if not immediately available.[3] The choice of thick-wall stock (in contrast to the same material with a 1/16-inch wall thickness) arose from the element size and mounting detail I selected for the antenna.

U-channel has been used in a number of commercial antennas for VHF and UHF booms. Very often, commercial antennas will pressure-fit elements into the stock. For home shop construction, I use a different system. I picked 3/16-inch diameter elements because they remain strong when the ends are threaded for 10-24 nuts. If I had tried to use 1/8-inch diameter elements, they would be fragile when threaded. The selection of 10-24 threads required thick enough U-channel stock so that the threaded holes have enough threads to grab the element.

Figure 8 shows a cut-away end view of the scheme. I drilled 5/32-inch holes in the two sides of the channel stock for each half element and then threaded them for 10-24 bolts. About 3/4- to 7/8-inch of the end of each half element is also threaded. As I screwed the half element through the first side of the channel, I threaded two stainless steel 10-24 nuts onto it. I screwed the half-element end into the far channel wall until it just met the outer surface. Then I tightened the two nuts against the inner walls to lock the element.

Note that using this system requires that you add 3/8 inch to each half-element length in Figure 1 and Table 1. The U-channel centerline is the reference point for all half-element lengths.

For my prototype, I used three nuts on the front half-elements, with a solder lug sandwiched between nuts on the element sides. I later soldered the coax cable to the feed-line lugs. The extra nuts on the rear element halves also do double duty when I added the shorted stub to the assembly.

The separation between U-channel faces is not at all arbitrary. The flat stock faces form a parallel transmission line. The use of flat-faced stock for the boom requires some adjustment when calculating the characteristic impedance of the phase-line. For conductors with a circular cross-section,

$$Z_0 = 120 \cosh^{-1} \frac{D}{d} \approx 276 \log_{10} \frac{2D}{d} \quad \text{(Eq 1)}$$

where D is the center-to-center spacing of the conductors and d is the outside diameter of each conductor, and D and d

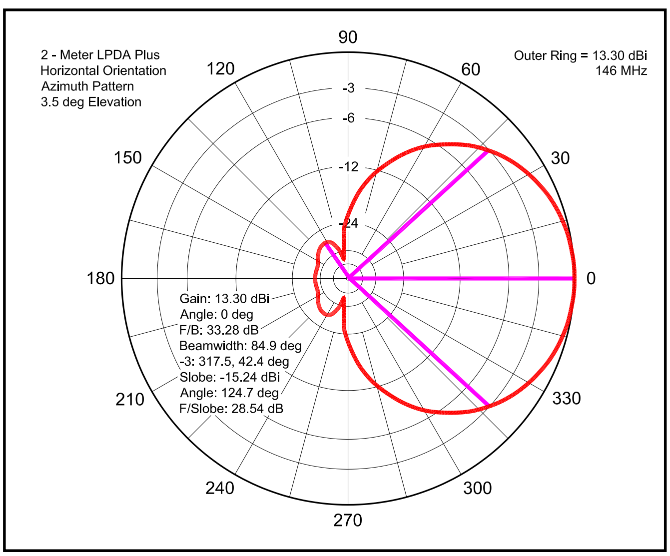


Figure 6—Free-space azimuth pattern of the 2-meter-plus LPDA at 146 MHz with elements oriented vertically.

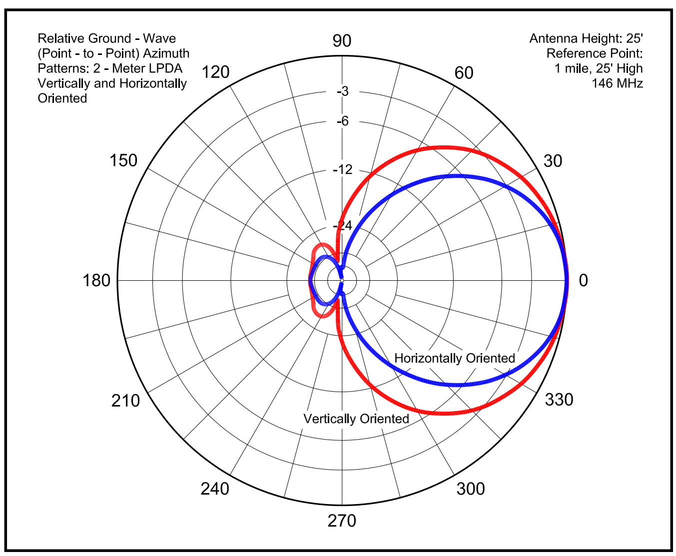


Figure 7—Relative ground-wave azimuth patterns with the elements oriented horizontally and vertically.

Table 1
2-Meter Plus LPDA Dimensions, in inches and mm

	inches				*mm*			
Ele #	*Length inches*	*Half Length*	*Space from Ele n–1*	*Space from Rear Ele*	*Length mm*	*Half Length*	*Space from Ele n–1*	*Space from Rear Ele*
1	43.02	21.51	—	—	546.3	273.2	—	—
2	39.74	19.87	12.57	12.57	504.7	252.4	319.4	319.4
3	36.72	18.36	11.62	24.19	466.3	233.2	295.1	614.5
4	33.92	16.96	10.73	34.92	430.8	215.4	272.6	887.1
5	31.34	15.67	9.92	44.84	398.0	199.0	251.9	1138.9
6	28.95	14.48	9.16	54.00	367.7	183.9	232.7	1371.6

are in the same units of measurement. Since we are dealing with closely spaced conductors, relative to their diameters, the following adjustment to the equation for calculating the characteristic impedance (Z_0) yields more accurate results. For a square or flat-face conductor,

$$d \approx 1.18\ w \quad \text{(Eq 2)}$$

where d is the approximate equivalent diameter of the square tubing or flat-faced stock and w is the width of the stock across the facing side.

For a given spacing, a square or flat-face stock permits you to achieve a lower characteristic impedance than with a round conductor. The approximation is useful but not precise, especially for stock that is not perfectly square. However, it is only necessary that the phasing-line impedance be close to 75 Ω to achieve the desired results with the present array. For 3/4-inch U-channel, a spacing of about 0.32 inches (8.1 mm) is close enough for all practical purposes. The spacing can be adjusted during testing, with a closer spacing yielding—up to a point—a lower phasing-line impedance and feed-point impedance, with a potentially better 50-Ω SWR curve. However, too close a spacing (less than 0.25 inch or 6.3 mm) may be self-defeating, by altering array performance at one or the other ends of the operating passband.

Since the characteristic-impedance calculation presumes an air dielectric between conductors, I employed insulating spacers attached to the sides of the U-channel stock. Between the most forward element and the next one—and likewise between the rearmost element and the next one—I attached scrap Plexiglas strips on both sides of the twin boom. This is shown in the photo showing a side view of the array. At the boom center, I used a mounting plate with through bolts to support and separate the U-channel pieces.

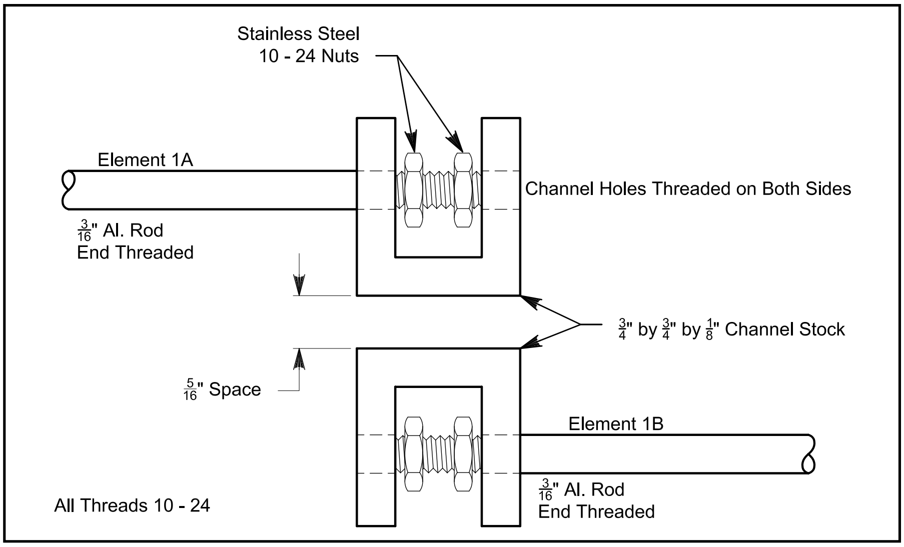
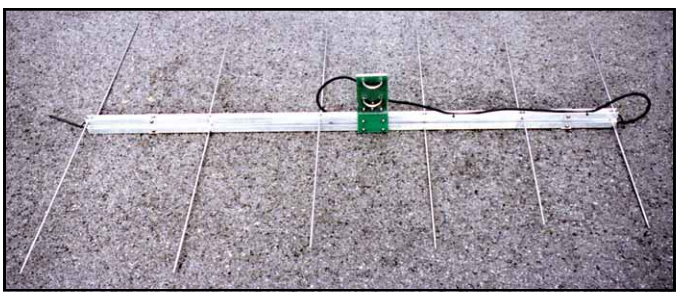


Figure 8—Cutaway end view of the twin-boom U-channel element mounting system.

The mounting-plate system was designed to permit the antenna to be oriented horizontally or vertically for various tests. A simpler system is certainly possible using a single mounting plate. The basic requirements are that the mounting system establishes the boom separation and that it holds fasteners (normally U-bolts) for attachment to the mast.

Figure 9 shows the double-plate system that I used for the prototype. Plate 1 holds the antenna's double boom at the approximate center point between elements 3 and 4. Stainless steel #10 nuts and bolts secure the boom to the plate. Plate 2 secures the assembly to the mast and is drilled for 1.25-inch wide stainless steel U-bolts. The most interesting feature of the mounting is the 2.5-inch hinge—rated for outdoor use—connecting the two plates.

View of the front of the LPDA showing the elements, the feed-line mounting system and the front Plexiglas boom insulators.



Side view of the array, showing the main mounting plate.

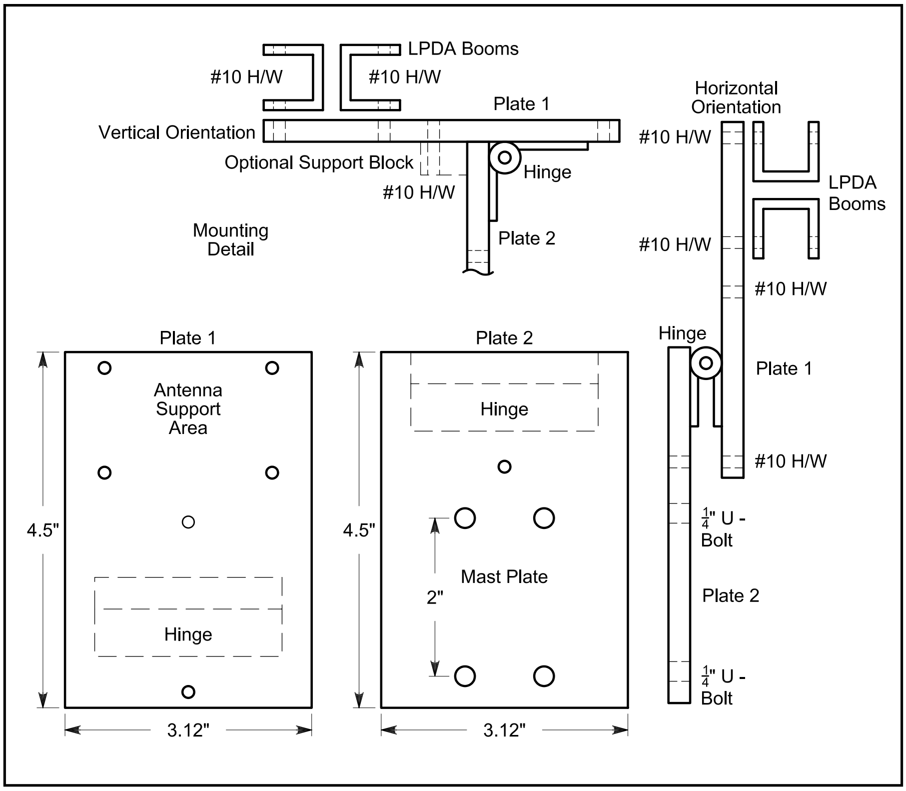


Figure 9—Details of the hinged boom-to-mast plate. Use a nonconductive mast if elements are oriented vertically.

The plate stock I used was 3/8-inch scrap fiberglass, which is structural overkill to some degree. Figure 9 shows the dimensions of the pieces that I used. When the antenna is vertically oriented, the top of antenna Plate 1 rests on the mast Plate 2 edge. For permanent use, I would add a further support epoxied and screwed to the mast plate. A stainless steel bolt would then lock down the antenna plate. When the antenna is horizontally oriented, the antenna plate is vertical and locked to the mast plate with a similar bolt.

The coaxial feed line for my prototype is RG-8X. A series of small holes (1/8 inch diameter) in the lower U-channel permits the cable to ride inside cable tie loops within the channel until it reaches the mast area. At the forward or feed end of the array, the cable center conductor and braid connect to the previously mentioned solder lugs attached to each side of the front element. These connections need to be weatherproofed by a suitable *cap* structure or by applying standard weatherproofing techniques. For the prototype, the cable end was coated with a plastic dipping compound available at home centers. Since it returns under the lower U-channel, you should size the coax loop to avoid internal deformation as the weather changes from cold to hot and back and to avoid stress on the connection points.

The final step in the process is to add the shorted stub to the rear of the array. I used a length of 75-Ω cable (RG-59U) with foam insulation, with a velocity factor of about 0.78. Hence, my 4-inch stub is about 3.1 inches long physically to account for the approximate 0.78 velocity factor of the line. Like the feed line, the ends of the cable were dipped in a plastic compound to provide a weather-seal.

In the final version, you might simply extend the twin booms 4 inches to the rear of the last element and connect the boom ends. This system might require moving the mounting plate to the rear slightly to keep the weight reasonably balanced. The array is likely a bit too heavy for effective rear-end mounting.

The stub completes construction. Lighter construction is undoubtedly possible, since the weight of the stock used in the prototype more nearly approximates commercial service sizing. However, the antenna has stood up to rough use in testing.

Performance

The photographs show the finished product, which I tested at 6, 10 and 15 feet above ground. The view of the antenna showing the elements oriented vertically is for photographic purposes only. The use of a metal mast would actually detune the array. When I changed the upper 5 feet of mast to a length of PVC, everything returned to normal—that is, to the values obtained with the elements horizontally oriented.

Initial SWR curves were taken with 20 feet of RG-8X between the array and an MFJ 259B analyzer, frequency calibrated to a 2-meter receiver. Within the 2-meter band, measured SWR was 1.5:1 or better. The predicted 2:1 SWR curve for the model (Figure 4), which did not employ a feed line, ranged from 130 to 170 MHz. The measured SWR provided less than a 2:1 SWR from 124 to 172 MHz. Part of this frequency range expansion is due to cable losses. However, the greater low-end extension of the curve suggested that the stub might be a bit long relative to the 4-inch equivalence desired. A ruler confirmed the suspicion, since the stub lead lengths had not been fully accounted for during construction.

Although I have no antenna range on which to directly confirm gain and front-to-back values, the array gain equaled that of other antennas in my shop of similar capabilities. With the antenna vertically oriented, I was able to silence all but one local repeater for over 180° of array rotation, indicating that the front-to-back ratio was as modeled. With a borrowed scanner, I received numerous signals at full quieting throughout the design passband.

The LPDA described here is not a competitor to wide-band Yagis designed expressly for 2 meters. Instead, it is a complementary antenna, designed for good 2-meter performance, but with additional capabilities over the 130-170 MHz range. If the wider-band service of an antenna is among your needs, then this 2-meter-plus LPDA may find a niche in your gallery of antennas.

Notes

[1]See the article "In Pursuit of Better VHF Quad Beams: A Work in Progress" in the 2001 *Proceedings of the Southeast VHF Society* for details of a wide-band Yagi meeting the specifications noted in the text. An alternative but close set of dimensions is provided in an article at my Web site (**www.cebik.com**) in the item called "High-Gain, Wide-Band Yagis for 10, 6 and 2 Meters." This item first appeared in *AntenneX*, Aug 1999 (**www.antennex.com**).

[2]See Chapter 10 of *The ARRL Antenna Book*, 19th Edition, for a full explanation of LPDA design and the fundamental design factors, τ and σ.

[3]My thanks to Raul Pla, W4AWI, of Antenna World, who generously donated the U-channel stock for this project.

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