Chapter 10

Log Periodic Arrays

This chapter was contributed by L. B. Cebik, W4RNL. The *Log Periodic Dipole Array* (*LPDA*) is one of a family of frequency-independent antennas. Alone, an LPDA forms a directional antenna with relatively constant characteristics across a wide frequency range. It may also be used with parasitic elements to achieve specific characteristic within a narrow frequency range. Common names for such hybrid arrays are the *log-cell Yagi* or the *Log-Yag*. We shall look at the essential characteristics of both types of arrays in this chapter.

The LPDA is the most popular form of log-periodic systems, which also include zig-zag, planar, trapezoidal, slot, and V forms. The appeal of the LPDA version of the log periodic antenna owes much to its structural similarity to the Yagi-Uda parasitic array. This permits the construction of directional LPDAs that can be rotated—at least within the upper HF and higher frequency ranges. Nevertheless, the LPDA has special structural as well as design considerations that distinguish it from the Yagi. A number of different construction techniques for both wire and tubular elements are illustrated later in this chapter.

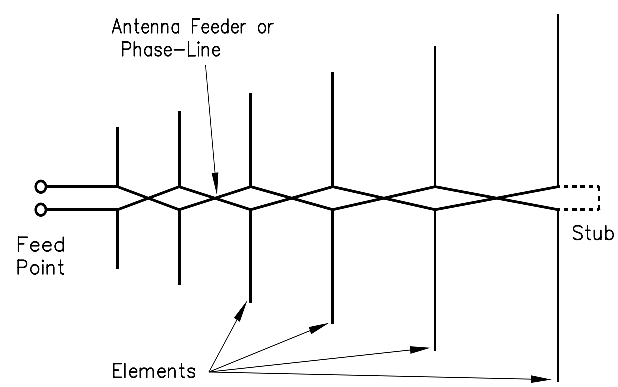

Fig 1—The basic components of a log periodic dipole array (LPDA). The forward direction is to the left in this sketch. Many variations of the basic design are possible.

The LPDA in its present form derives from the pioneering work of D. E. Isbell at the University of Illinois in the late 1950s. Although you may design LPDAs for large frequency ranges—for example, from 3 to 30 MHz or a little over 3 octaves—the most common LPDA designs that radio amateurs use are limited to a one-octave range, usually from 14 to 30 MHz. Amateur designs for this range tend to consist of linear elements. However, experimental designs for lower frequencies have used elements shaped like inverted Vs, and some versions use vertically oriented $^1/_4$ λ elements over a ground system.

Fig 1 shows the parts of a typical LPDA. The structure consists of a number of linear elements, the longest of which is approximately $^1/_2$ λ long at the lowest design frequency. The shortest element is usually about $^1/_2$ λ long at a frequency well above the highest operating frequency. The antenna feeder, also informally called the *phase-line*, connects the center points of each element in the series, with a phase reversal or *cross-over* between each element. A stub consisting of a shorted length of parallel feed line is often added at the back of an LPDA.

The arrangement of elements and the method of feed yield an array with relatively constant gain and front-to-back ratio across the designed operating range. In addition, the LPDA exhibits a relatively constant feed-point impedance, simplifying matching to a transmission line.

BASIC DESIGN CONSIDERATIONS

For the amateur designer, the most fundamental facets of the LPDA revolve around three interrelated design variables: α (alpha), τ (tau), and σ (sigma). Any one of the three variables may be defined by reference to the other two.

Fig 2 shows the basic components of an LPDA. The angle α defines the outline of an LPDA and permits every dimension to be treated as a radius or the consequence of a radius (R) of a circle. The most basic structural dimensions are the element lengths (L), the distance (R) of each element from the apex of angle α, and the distance between elements (D). A single design constant, τ, defines all of these relationships in the following manner:

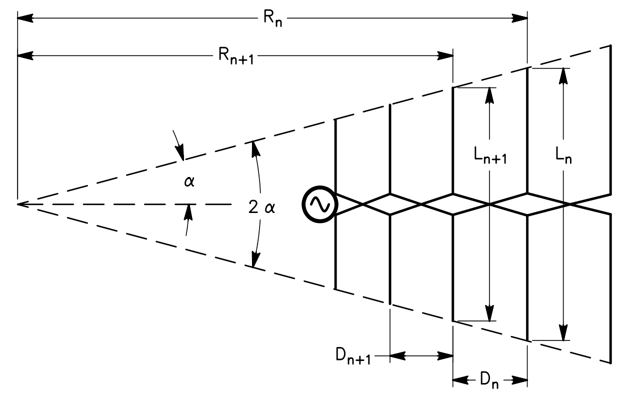

Fig 2—Some fundamental relationships that define an array as an LPDA. See the text for the defining equations.

$$\tau = \frac{R_{n+1}}{R_n} = \frac{D_{n+1}}{D_n} = \frac{L_{n+1}}{L_n} \quad \text{(Eq 1)}$$

where element n and n+1 are successive elements in the array working toward the apex of angle α. The value of τ is always less than 1.0, although effective LPDA design requires values as close to 1.0 as may be feasible.

The variable τ defines the relationship between successive element spacings but it does not itself determine the initial spacing between the longest and next longest elements upon which to apply τ successively. The initial spacing also defines the angle α for the array. Hence, we have two ways to determine the value of σ, the relative spacing constant:

$$\sigma = \frac{1-\tau}{4 \tan \alpha} = \frac{D_n}{2L_n} \quad \text{(Eq 2)}$$

where D_n is the distance between any two elements of the array and L_n is the length of the longer of the two elements. From the first of the two methods of determining the value of σ, we may also find a means of determining α when we know both τ and σ.

For any value of τ, we may determine the optimal value of σ:

$$\sigma_{opt} = 0.243\tau - 0.051 \quad \text{(Eq 3)}$$

The combination of a value for τ and its corresponding optimal value of σ yields the highest performance of which an LPDA is capable. For values of τ from 0.80 through 0.98, the value of optimal σ varies from 0.143 to 0.187, in increments of 0.00243 for each 0.01 change in τ. However, using the optimal value of σ usually yields a total array length that is beyond ham construction or tower/mast support capabilities. Consequently, amateur LPDAs usually employ compromise values of τ and σ that yield lesser but acceptable performance.

For a given frequency range, increasing the value of τ increases both the gain and the number of required elements. Increasing the value of σ increases both the gain and the overall boom length. A τ of 0.96—which approaches the upper maximum recommended value for τ—yields an optimal σ of about 0.18, and the resulting array grows to over 100 feet long for the 14 to 30 MHz range. The maximum free space gain is about 11 dBi, with a front-to-back ratio that approaches 40 dB. Normal amateur practice, however, uses values of τ from about 0.88 to 0.95 and values of σ from about 0.03 to 0.06.

Standard design procedures usually set the length of the rear element for a frequency about 7% lower than the lowest design frequency and use the common dipole formula ($L_{feet} = 468/f_{MHz}$) to determine its length (5% lower than a free-space half wavelength, where $L_{feet} = 493.56/f_{MHz}$). The upper frequency limit of the design is ordinarily set at about 1.3 times the highest design frequency. Since τ and σ set the increment between successive element lengths, the number of elements becomes a function of when the shortest element reaches the dipole length for the adjusted upper frequency.

The adjusted upper frequency limit results from the behavior of LPDAs with respect to the number of active elements. See **Fig 3**, which shows an edge view of a 10-element LPDA for 20 through 10 meters. The vertical lines represent the peak relative current magnitude for each element at the specified frequency. At 14 MHz, virtually every element of the array shows a significant cur-

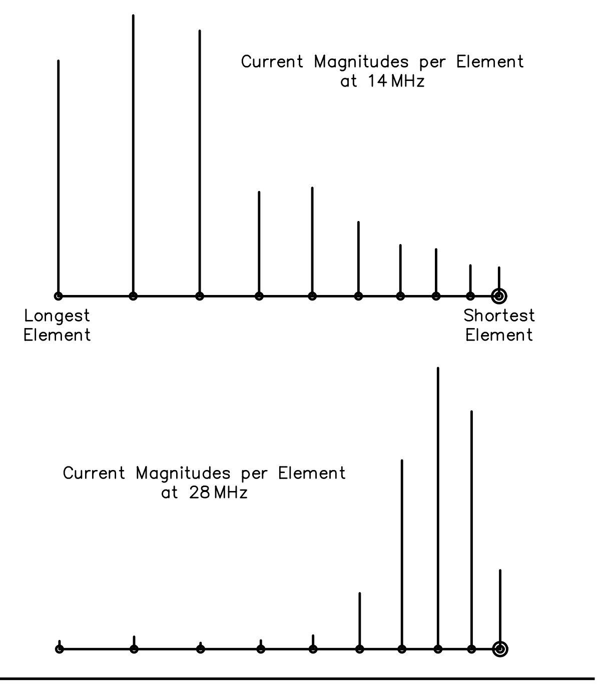

Fig 3—The relative current magnitude on the elements of an LPDA at the lowest and highest operating frequencies for a given design. Compare the number of "active" elements, that is, those with current levels at least 1/10 of the highest level.

rent magnitude. However, at 28 MHz, only the forward 5 elements carry significant current. Without the extended design range to nearly 40 MHz, the number of elements with significant current levels would be severely reduced, along with upper frequency performance.

The need to extend the design equations below the lowest proposed operating frequency varies with the value of τ. In **Fig 4**, we can compare the current on the rear elements of two LPDAs, both with a σ value of 0.04. The upper design uses a τ of 0.89, while the lower design uses a value of 0.93. The most significant current-bearing element moves forward with increases in τ, reducing (but not wholly eliminating) the need for elements whose lengths are longer than a dipole for the lowest operating frequency.

LPDA Design and Computers

Originally, LPDA design proceeded through a series of design equations intended to yield the complete specifications for an array. More recent techniques available to radio amateurs include basic LPDA design software and antenna modeling software. One good example of LPDA design software is *LPCAD28* by Roger Cox, WBØDGF. A copy of this freeware program is on the CD-ROM that accompanies this volume. The user begins by specifying the lowest and highest frequencies in the design. He then enters either his selected values for τ and σ or his choices for the number of elements and the total length of the array. With this and other input data, the program provides a table of element lengths and spacings, using the adjusted upper and lower frequency limits described earlier.

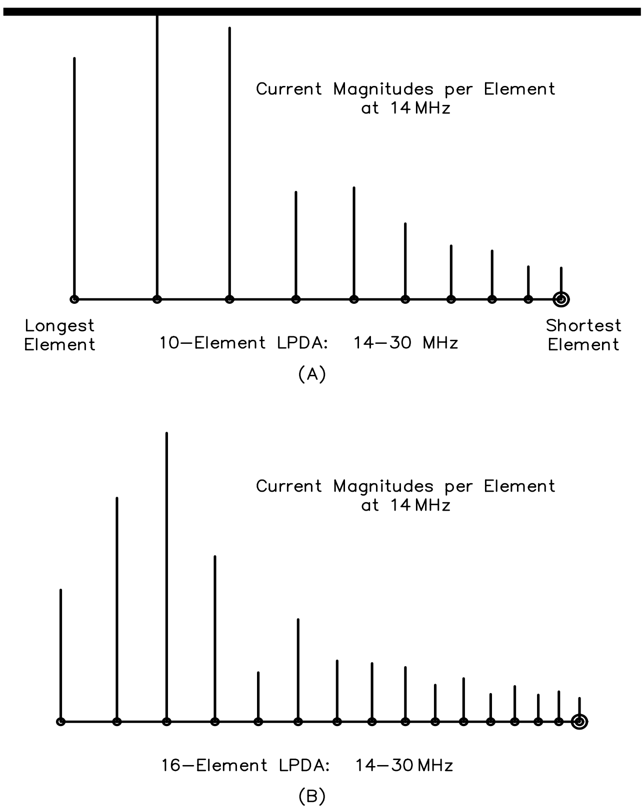

Fig 4—Patterns of current magnitude at the lowest operating frequency of two different LPDA designs: a 10-element low-τ design and a 16-element higher-τ design.

The program also requests the diameters of the longest and shortest elements in the array, as well as the diameter of average element. From this data, the program calculates a recommended value for the phase-line connecting the elements and the approximate resistive value of the input impedance. Among the additional data that *LPCAD28* makes available is the spacing of conductors to achieve the desired characteristic impedance of the phase-line. These conductors may be round—as we would use for a wire phase-line—or square—as we might use for double-boom construction.

An additional vital output from *LPCAD28* is the conversion of the design into antenna modeling input files of several formats, including versions for *AO* and *NEC4WIN* (both *MININEC*-based programs), and a version in the standard *.NEC format usable by many implementations of *NEC-2* and *NEC-4*, including *NECWin Plus*, *GNEC*, and *EZNEC Pro*. Every proposed LPDA design should be verified and optimized by means of antenna modeling, since basic design calculations rarely provide arrays that require no further work before construction. A one-octave LPDA represents a segment of an arc defined by α that is cut off at both the upper and the lower frequency limits. Moreover, some of the design equations are based upon approximations and do not completely predict LPDA behavior. Despite these limitations, most of the sample LPDA designs shown later in this chapter are based directly upon the fundamental calculations. Therefore, the procedure will be outlined in detail before turning to hybrid log-cell Yagi concepts.

Modeling LPDA designs is most easily done on a version of *NEC*. The transmission line (TL) facility built into *NEC-2* and *NEC-4* alleviates the problem of modeling the phase-line as a set of physical wires, each section of which has a set of constraints in *MININEC* at the right-angle junctions with the elements. Although the *NEC* TL facility does not account for losses in the lines, the losses are ordinarily low enough to neglect.

NEC models do require some careful construction to obtain the most accurate results. Foremost among the cautions is the need for careful segmentation, since each element has a different length. The shortest element should have about 9 or 11 segments, so that it has sufficient segments at the highest modeling frequency for the design. Each element behind the shortest one should have a greater number of segments than the preceding element by the inverse of the value of τ. However, there is a further limitation. Since the transmission line is at the center of each element, *NEC* elements should have an odd number of segments to hold the phase-line centered. Hence, each segmentation value calculated from the inverse of τ must be rounded up to the nearest odd integer.

Initial modeling of LPDAs in *NEC-2* should be done with uniform-diameter elements, with any provision for stepped-diameter element correction turned off. Since these correction factors apply only to elements within about 15% of dipole resonance at the test frequency, models with stepped-diameter elements will correct for only a few elements at any test frequency. The resulting combination of corrected and uncorrected elements will not yield a model with assured reliability.

Once one has achieved a satisfactory model with uniform-diameter elements, the modeling program can be used to calculate stepped-diameter substitutes. Each uniform-diameter element, when extracted from the larger array, will have a resonant frequency. Once this frequency is determined, the stepped-diameter element to be used in final construction can be resonated to the same frequency. Although *NEC-4* handles stepped diameter elements with much greater accuracy than *NEC-2*, the process just described is also applicable to *NEC-4* models for the greatest precision.

LPDA Behavior

Although LPDA behavior is remarkably uniform over a wide frequency range compared to narrow-band designs, such as the Yagi-Uda array, it nevertheless exhibits very significant variations within the design range. **Fig 5** shows several facets of these behaviors. Fig 5 shows the free-space gain for three LPDA designs using 0.5-inch diameter aluminum elements. The designations for each model list the values of τ (0.93, 0.89, and 0.85) and of σ (0.02, 0.04, and 0.06) used to design each array. The resultant array lengths are listed with each designator. The total number of elements varies from 16 for "9302" to 10 for "8904" to 7 for "8504."

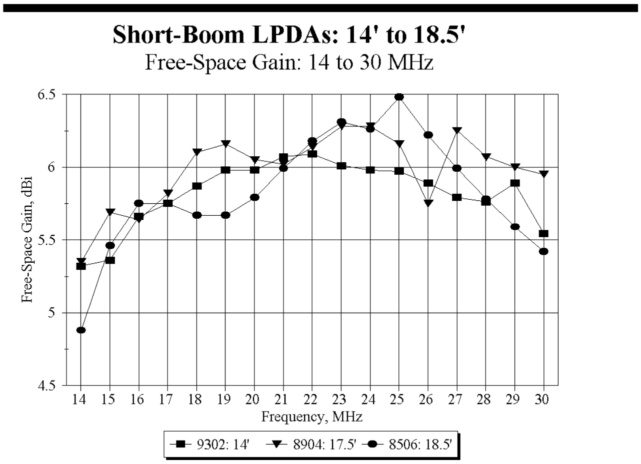

Fig 5—The modeled free-space gain of 3 relatively small LPDAs of different design. Note the relationship of the values of τ and of σ for these arrays with quite similar performance across the 14-30 MHz span.

First, the gain is never uniform across the entire frequency span. The gain tapers off at both the low and high ends of the design spectrum. Moreover, the amount of gain undulates across the spectrum, with the number of peaks dependent upon the selected value of τ and the resultant number of elements. The front-to-back ratio tends to follow the gain level. In general, it ranges from less than 10 dB when the free-space gain is below 5 dBi to over 20 dB as the gain approaches 7 dBi. The front-to-back ratio may reach the high 30s when the free-space array gain exceeds 8.5 dBi. Well-designed arrays, especially those with high values of τ and σ, tended to have well-controlled rear patterns that result in only small differences between the 180° front-to-back ratio and the averaged front-to-rear ratio.

Since array gain is a mutual function of both τ and σ, average gain becomes a function of array length for any given frequency range. Although the gain curves in Fig 5 interweave, there is little to choose among them in terms of average gain for the 14 to 18-foot range of array lengths. Well-designed 20- to 10-meter arrays in the 30-foot array length region are capable of about 7 dBi free-space gain, while 40-foot arrays for the same frequency range can achieve about 8 dBi free-space gain.

Exceeding an average gain of 8.5 dBi requires at least a 50-foot array length for this frequency range. Long arrays with high values of τ and σ also tend to show smaller excursions of gain and of front-to-back ratio in the overall curves. In addition, high-τ designs tend to show higher gain at the low frequency end of the design spectrum.

The frequency sweeps shown in Fig 5 are widely spaced at 1 MHz intervals. The evaluation of a specific design for the 14 to 30-MHz range should decrease the interval between check points to no greater than 0.25 MHz in order to detect frequencies at which the array may show a *performance weakness*. Weaknesses are frequency regions in the overall design spectrum at which the array shows unexpectedly lower values of gain and front-to-back ratio. In Fig 5 note the unexpected decrease in gain of model "8904" at 26 MHz. The other designs also have weak points, but they fall between the frequencies sampled.

In large arrays, these regions may be quite small and may occur in more than one frequency region. The weakness results from the harmonic operation of longer elements to the rear of those expected to have high current levels. Consider a 7-element LPDA about 12.25-foot long for 14 to 30 MHz using 0.5-inch aluminum elements. At 28 MHz, the rear elements operate in a harmonic mode, as shown by the high relative current magnitude curves in **Fig 6**. The result is a radical decrease in gain, as shown in the "No Stub" curve of **Fig 7**. The front-to-back ratio also drops as a result of strong radiation from the long

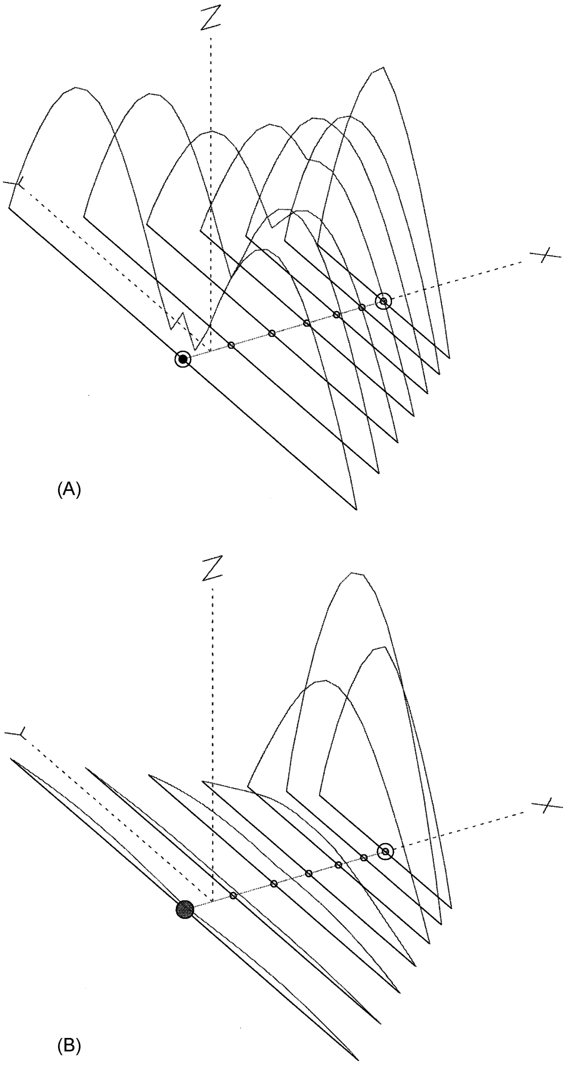

Fig 6—The relative current magnitude on the elements of model "8504" at 28 MHz without and with a stub. Note the harmonic operation of the rear elements before a stub is added to suppress such operation.

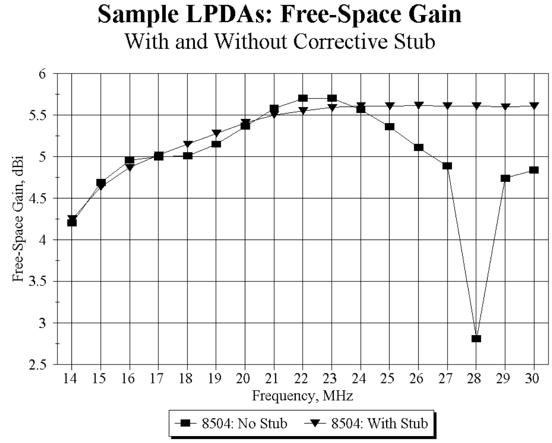

Fig 7—A graph of the gain of model "8504" showing the frequency region in which a "weakness" occurs and its absence once a suitable stub is added to the array.

elements to the rear of the array.

Early designs of LPDAs called for terminating transmission-line stubs as standard practice to help eliminate such weak spots in frequency coverage. In contemporary designs, their use tends to be more specific for eliminating or moving frequencies that show gain and front-to-back weakness. (Stubs have the added function of keeping both sides of each element at the same level of static charge or discharge.) The model dubbed "8504" was fitted (by trial and error) with an 18-inch shorted stub of 600-Ω transmission line. As Fig 6B shows, the harmonic operation of the rear elements is attenuated. The "stub" curve of Fig 7 shows the smoothing of the gain curve for the array throughout the upper half of its design spectrum. In some arrays showing multiple weaknesses, a single stub may not eliminate all of them. However, it may move the weaknesses to unused frequency regions. Where full-spectrum operation of an LPDA is necessary, additional stubs located at specific elements may be needed.

Most LPDA designs benefit (with respect to gain and front-to-back ratio) from the use of larger-diameter elements. Elements with an average diameter of at least 0.5-inch are desirable in the 14 to 30 MHz range. However, standard designs usually presume a constant element length-to-diameter ratio. In the case of *LPCAD28*, this ratio is about 125:1, which assumes an even larger diameter. To achieve a relatively constant length-to-diameter ratio in the computer models, you can set the diameter of the shortest element in a given array design and then increase the element diameter by the inverse of τ for each succeeding longer element. This procedure is often likely to result in unreasonably large element diameters for the longest elements, relative to standard amateur construction practices.

Since most amateur designs using aluminum tubing for elements employ stepped-diameter (tapered) elements, roughly uniform element diameters will result unless the LPDA mechanical design tries to lighten the elements at the forward end of the array. This practice may not be advisable, however. Larger elements at the high end of the design spectrum often counteract (at least partially) the natural decrease in high-frequency gain and show improved performance compared to smaller diameter elements.

An alternative construction method for LPDAs uses wire throughout. At every frequency, single-wire elements reduce gain relative to larger-diameter tubular elements. An alternative to tubular elements appears in **Fig 8**. For each element of a tubular design, there is a roughly equivalent 2-wire element that may be substituted. The

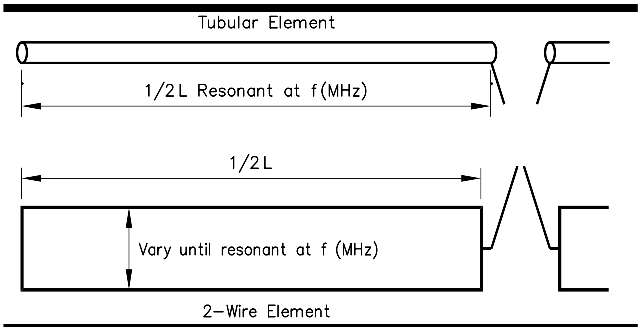

Fig 8—A substitute for a large-diameter tubular element composed of two wires shorted at both the outer ends and at the center junction with the phase-line.

spacing between the wire is determined by taking one of the modeled tubular elements and finding its resonant frequency. A two-wire element of the same length is then constructed with shorts at the far ends and at the junctions with the phase-line. The separation of the two wires is adjusted until the wire element is resonant at the same frequency as the original tubular element. The required separation will vary with the wire chosen for the element. Models used to develop these substitutes must pay close attention to segmentation rules for *NEC* due to the short length of segments in the end and center shorts, and to the need to keep segment junctions as exactly parallel as possible with close-spaced wires.

Feeding and Constructing the LPDA

Original design procedures for LPDAs used a single, ordinarily fairly high, characteristic impedance for the phase-line (antenna feeder). Over time, designers realized that other values of impedance for the phase line offered both mechanical and performance advantages for LPDA performance. Consequently, for the contemporary designer, phase-line choice and construction techniques are almost inseparable considerations.

High-impedance phase lines (roughly 200 Ω and higher) are amenable to wire construction similar to that used with ordinary parallel-wire transmission lines. They require careful placement relative to a metal boom used to support individual elements (which themselves must be insulated from the support boom). Connections also require care. If the phase-line is given a half-twist between each element, the construction of the line must ensure constant spacing and relative isolation from metal supports to maintain a constant impedance and to prevent shorts.

Along with the standard parallel-wire line, shown in **Fig 9A**, there are a number of possible LPDA structures using booms. The booms serve both to support the elements and to create relatively low-impedance (under 200 Ω) phase-lines. Fig 9B shows the basics of a twin circular tubing boom with the elements cross-supported by insulated rods. Fig 9C shows the use of square tubing with the elements attached directly to each tube by through-bolts. Fig 9D illustrates the use of L-stock, which may be practical at VHF frequencies. Each of these sketches is incomplete, however, since it omits the necessary stress analyses that determine the mechanical feasibility of a structure for a given LPDA project.

The use of square boom material requires some adjustment when calculating the characteristic impedance of the phase-line. For conductors with a circular cross-section,

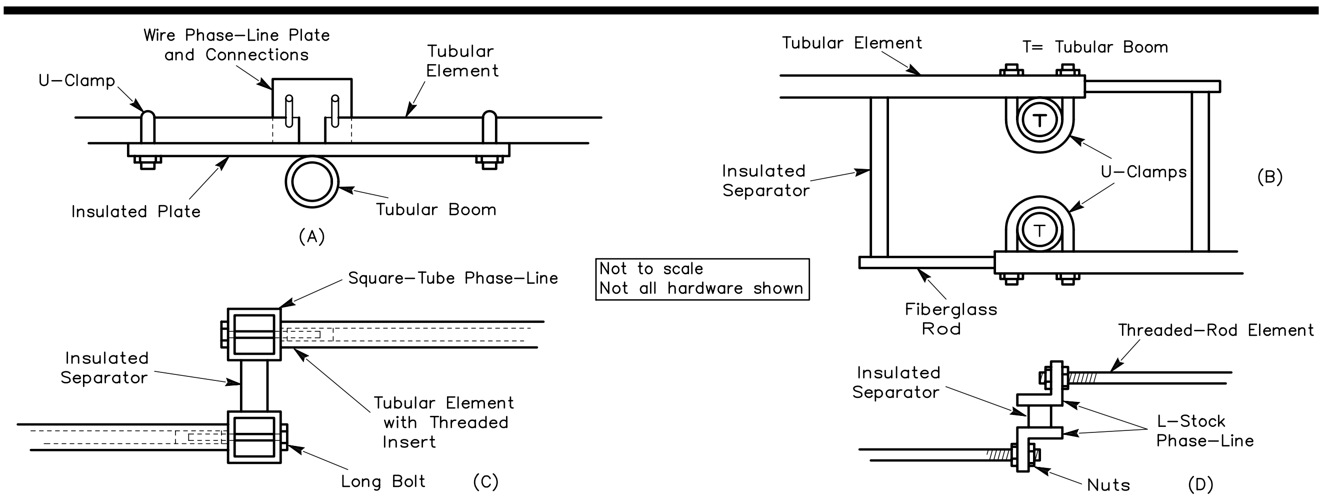

Fig 9—Four (of many) possible construction techniques, shown from the array end. In A, an insulated plate supports and separates the wires of the phase-line, suitable with wire or tubular elements. A dual circular boom phase-line also supports the elements, which are cross-supported for boom stability. Square tubing is used in C, with the elements joined to the boom/phase-line with through-bolts and an insert in each half element. The L-stock shown in D is useful for lighter VHF and UHF arrays.

$$Z_0 = 120 \cosh^{-1} \frac{D}{d} \qquad \text{(Eq 4)}$$

where D is the center-to-center spacing of the conductors and d is the outside diameter of each conductor, both expressed in the same units of measurement. Since we are dealing with closely spaced conductors, relative to their diameters, the use of this version of the equation for calculating the characteristic impedance (Z_0) is recommended. For a square conductor,

$$d \approx 1.18\ w \qquad \text{(Eq 5)}$$

where d is the approximate equivalent diameter of the square tubing and w is the width of the tubing across one side. Thus, for a given spacing, a square tube permits you to achieve a lower characteristic impedance than round conductors. However, square tubing requires special attention to matters of strength, relative to comparable round tubing.

Electrically, the characteristic impedance of the LPDA phase-line tends to influence other performance parameters of the array. Decreasing the phase-line Z_0 also decreases the feed-point impedance of the array. For small designs with few elements, the decrease is not fully matched by a decrease in the excursions of reactance. Consequently, using a low impedance phase-line may make it more difficult to achieve a 2:1 or less SWR for the entire frequency range. However, higher-impedance phase-lines may result in a feed-point impedance that requires the use of an impedance-matching balun.

Decreasing the phase-line Z_0 also tends to increase LPDA gain and front-to-back ratio. There is a price to be paid for this performance improvement—weaknesses at specific frequency regions become much more pronounced with reductions in the phase-line Z_0. For a specific array you must weigh carefully the gains and losses, while employing one or more transmission line stubs to get around performance weaknesses at specific frequencies.

Depending upon the specific values of τ and σ selected for a design, you can sometimes select a phase-line Z_0 that provides either a 50-Ω or a 75-Ω feed-point impedance, holding the SWR under 2:1 for the entire design range of the LPDA. The higher the values of τ and σ for the design, the lower the reactance and resistance excursions around a central value. Designs using optimal values of σ with high values of τ show a very slight capacitive reactance throughout the frequency range. Lower design values obscure this phenomenon due to the wide range of values taken by both resistance and reactance as the frequency is changed.

At the upper end of the frequency range, the source resistance value decreases more rapidly than elsewhere in the design spectrum. In larger arrays, this can be overcome by using a variable Z_0 phase-line for approximately the first 20% of the array length. This technique is, however, difficult to implement with anything other than wire phase-lines. Begin with a line impedance about half of the final value and increase the wire spacing evenly until it reaches its final and fixed spacing. This technique can sometimes produce smoother impedance performance across the entire frequency span and improved high-frequency SWR performance.

Designing an LPDA requires as much attention to designing the phase-line as to element design. It is always useful to run models of the proposed design through several iterations of possible phase-line Z_0 values before freezing the structure for construction.

Special Design Corrections

The curve for the sample 8504 LPDA in Fig 7 revealed several deficiencies in standard LPDA designs. The weakness in the overall curve was corrected by the use of a stub to eliminate or move the frequency at which rearward elements operated in a harmonic mode. In the course of describing the characteristics of the array, we have noted several other means to improve performance. Fattening elements (either uniformly or by increasing their diameter in step with τ) and reducing the characteristic impedance of the phase-line are capable of small improvements in performance. However, they cannot wholly correct the tendency of the array gain and front-to-back ratio to fall off at the upper and lower limits of the LPDA frequency range.

One technique sometimes used to improve performances near the frequency limits is to design the LPDA for upper and lower frequency limits much higher and lower than the frequencies of use. This technique unnecessarily increases the overall size of the array and does not eliminate the downward performance curves. Increasing the values of τ and σ will usually improve perfor-

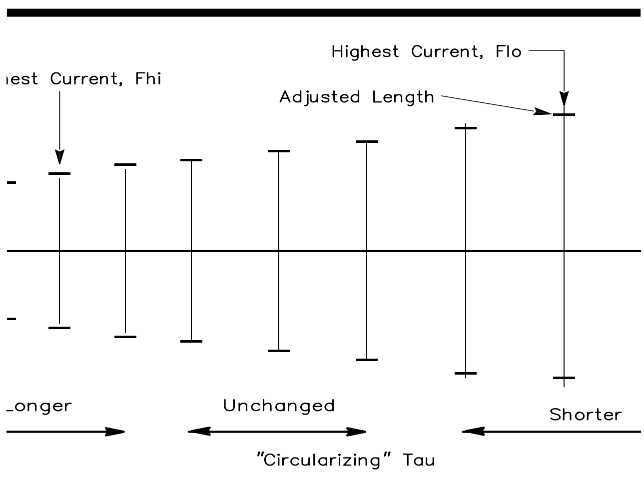

Fig 10—A before and after sketch of an LPDA, showing the original lengths of the elements and their adjustments from diminishing the value of τ at both ends of the array. See the text for the amount of change applicable to each element.

mance at no greater cost in size than extending the frequency range. Increasing the value of τ is especially effective in improving the low frequency performance of an LPDA.

Working within the overall size limits of a standard design, one may employ a technique of *circularizing* the value of τ for the rear-most and forward-most elements. See **Fig 10**, which is not to-scale relative to overall array length and width. Locate (using an antenna-modeling program) the element with the highest current at the lowest operating frequency, and the element with the highest current at the highest operating frequency. The adjustments to element lengths may begin with these elements or—at most—one element further toward the array center. For the first element (counting from the center) to be modified, reduce the value of τ by about 0.5%. For a rearward element, use the inverse of the adjusted value of τ to calculate the new length of the element relative to the unchanged element just forward of the change. For a forward element, use the new value of τ to calculate the new length of the element relative to the unchanged element immediately to the rear of it.

For succeeding elements outward, calculate new values of τ from the adjusted values, increasing the increment of decrease with each step. Second adjusted elements may use values of τ about 0.75% to 1.0% lower than the values just calculated. Third adjusted elements may use an increment of 1.0% to 1.5% relative to the preceding value.

Not all designs require extensive treatment. As the values of τ and σ increase, fewer elements may require adjustment to obtain the highest possible gain at the frequency limits, and these will always be the most outward elements in the array. A second caution is to check the feed-point impedance of the array after each change to ensure that it remains within design limits.

Fig 11 shows the free-space gain curves from 14 to 30 MHz for a 10-element LPDA with an initial τ of 0.89 and a σ of 0.04. The design uses a 200-Ω phase-line, 0.5-inch aluminum elements, and a 3-inch 600-Ω stub. The lowest curve shows the modeled performance across the design frequency range with only the stub. Performance at the frequency limits is visibly lower than within the peak performance region. The middle curve shows the effects of circularizing τ. Average performance levels have improved noticeably at both ends of the spectrum.

In lieu of, or in addition to, the adjustment of element lengths, you may also add a parasitic director to an LPDA, as shown in **Fig 12**. The director is cut roughly for the highest operating frequency. It may be spaced between 0.1 λ and 0.15 λ from the forward-most element of the LPDA. The exact length and spacing should be determined experimentally (or from models) with two factors in mind. First, the element should not adversely effect the feed-point impedance at the highest operating frequencies. Close spacing of the director has the greatest effect on this impedance. Second, the exact spacing and element length should be set to have the most desired effect on the overall performance curve of the array. The mechanical impact of adding a director is to increase overall array length by the spacing selected for the element.

The upper curve in Fig 11 shows the effect of adding a director to the circularized array already equipped with a stub. The effect of the director is cumulative, increasing the upper range gain still further. Note that the added parasitic director is not just effective at the highest

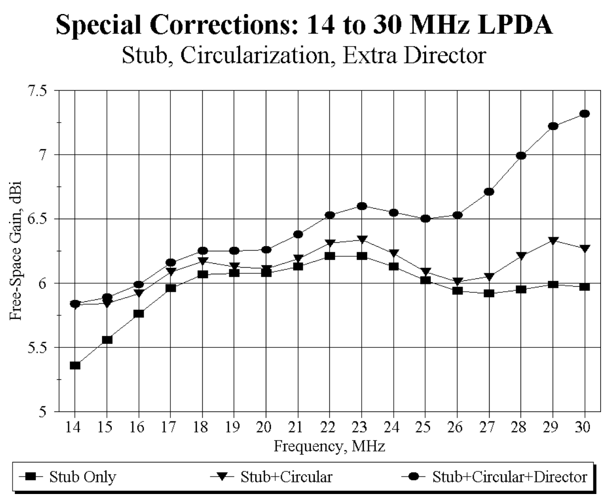

Fig 11—The modeled free space gain from 14 to 30 MHz of an LPDA with τ of 0.89 and σ of 0.04. Squares: just a stub to eliminate a weakness; Triangles: with a stub and circularized elements, and Circles: with a stub, circularized elements and a parasitic director.

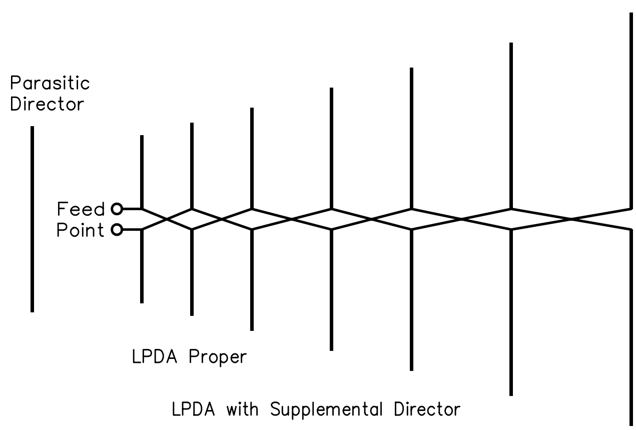

Fig 12—A generalized sketch of an LPDA with the addition of a parasitic director to improve performance at the higher frequencies within the design range.

frequencies within the LPDA design range. It has a perceptible effect almost all the way across the frequency span of the array, although the effect is smallest at the low-frequency end of the range.

The addition of a director can be used to enhance upper frequency performance of an LPDA, as in the illustration, or simply to equalize upper frequency performance with mid-range performance. High-τ designs, with good low-frequency performance, may need only a director to compensate for high-frequency gain decrease. One potential challenge to adding a director to an LPDA is sustaining a high front-to-back ratio at the upper frequency range.

Throughout the discussion of LPDAs, the performance curves of sample designs have been treated at all frequencies alike, seeking maximum performance across the entire design frequency span. Special compensations are also possible for ham-band-only LPDA designs. They include the insertion of parasitic elements within the array as well as outside the initial design boundaries. In addition, stubs may be employed not so much to eliminate weaknesses, but only to move them to frequencies outside the range of amateur interests.

A DESIGN PROCEDURE FOR AN LPDA

The following presents a systematic step-by-step design procedure for an LPDA with any desired bandwidth. The procedure requires some mathematical calculations, but a common calculator with square-root, logarithmic, and trigonometric functions is completely adequate. The notation used in this section may vary slightly from that used earlier in this chapter.

1) Decide on an operating bandwidth B between f_1, lowest frequency and f_n, highest frequency:

$$B = \frac{f_n}{f_1} \qquad \text{(Eq 6)}$$

2) Choose τ and σ to give the desired estimated average gain.

$$0.8 \le \tau \le 0.98 \text{ and } 0.03 \le \sigma \le \sigma_{opt} \qquad \text{(Eq 7)}$$

where σ_{opt} is calculated as noted earlier in this chapter.

3)Determine the value for the cotangent of the apex half-angle α from

$$\cot\alpha = \frac{4\sigma}{1-\tau} \qquad \text{(Eq 8)}$$

Although α is not directly used in the calculations, cot α is used extensively.

4) Determine the bandwidth of the active region B_{ar} from

$$B_{ar} = 1.1 + 7.7(1-\tau)^2 \cot\alpha \qquad \text{(Eq 9)}$$

5) Determine the structure (array) bandwidth B_s from

$$B_S = B \times B_{ar} \qquad \text{(Eq 10)}$$

6) Determine the boom length L, number of elements N, and longest element length ℓ_1.

$$L_n = \left(1 - \frac{1}{B_S}\right) \cot\alpha \times \frac{\lambda_{max}}{4} \qquad \text{(Eq 11)}$$

$$\lambda_{max} = \frac{984}{f_1} \qquad \text{(Eq 12)}$$

$$N = 1 + \frac{\log B_s}{\log \frac{1}{\tau}} = 1 + \frac{\ln B_S}{\ln \frac{1}{\tau}} \qquad \text{(Eq 13)}$$

$$\lambda_{1ft} = \frac{492}{f_1} \qquad \text{(Eq 14)}$$

Usually the calculated value for N will not be an integral number of elements. If the fractional value is more than about 0.3, increase the value of N to the next higher integer. Increasing the value of N will also increase the actual value of L over that obtained from the sequence of calculations just performed.

Examine L, N and l_1 to determine whether or not the array size is acceptable for your needs. If the array is too large, increase f_1 or decrease σ or τ and repeat steps 2 through 6. Increasing f_1 will decrease all dimensions. Decreasing σ will decrease the boom length. Decreasing τ will decrease both the boom length and the number of elements.

7) Determine the terminating stub Z_t. (Note: For many HF arrays, you may omit the stub, short out the longest element with a 6-inch jumper, or design a stub to overcome a specific performance weakness.) For VHF and UHF arrays calculate the stub length from

$$Z_t = \frac{\lambda_{max}}{8} \qquad \text{(Eq 15)}$$

8) Solve for the remaining element lengths from

$$\ell_n = \tau \ell_{n-1} \qquad \text{(Eq 16)}$$

9) Determine the element spacing $d_{1\text{-}2}$ from

$$d_{1-2} = \frac{(\ell_1 - \ell_2)\cot\alpha}{2} \qquad \text{(Eq 17)}$$

where ℓ_1 and ℓ_2 are the lengths of the rearmost elements, and d_{1-2} is the distance between the elements with the lengths ℓ_1 and ℓ_2. Determine the remaining element-to-element spacings from

$$d_{(n-1)-n} = \tau d_{(n-2)-(n-1)} \qquad \text{(Eq 18)}$$

10) Choose R_0, the desired feed-point resistance, to give the lowest SWR for the intended balun ratio and feed-line impedance. R_0, the mean radiation resistance level of the LPDA input impedance, is approximated by:

$$R_0 = \frac{Z_0}{\sqrt{1 + \frac{Z_0}{4\sigma' Z_{AV}}}} \quad \text{(Eq 19)}$$

where the component terms are defined and/or calculated in the following way.

From the following equations, determine the necessary antenna feeder (phase-line) impedance, Z_0:

$$Z_0 = \frac{R_0^{\ 2}}{8\sigma' Z_{AV}} + R_0 \sqrt{\left(\frac{R_0}{8\sigma' Z_{AV}}\right)^2 + 1} \quad \text{(Eq 20)}$$

σ' is the mean spacing factor and is given by

$$\sigma' = \frac{\sigma}{\sqrt{\tau}} \quad \text{(Eq 21)}$$

Z_{AV} is the average characteristic impedance of a dipole and is given by

$$Z_{AV} = 120\left[\ln\left(\frac{\ell_n}{\text{diam}_n}\right) - 2.25\right] \quad \text{(Eq 22)}$$

The ratio, l_n/diam_n is the length-to-diameter ratio of the element n.

11) Once Z_0 has been determined, select a combination of conductor size and spacing to achieve that impedance, using the appropriate equation for the shape of the conductors. If an impractical spacing results for the antenna feeder, select a different conductor diameter and repeat step 11. In severe cases it may be necessary to select a different R_0 and repeat steps 10 and 11. Once a satisfactory feeder arrangement is found, the LPDA design is complete.

A number of the LPDA design examples at the end of this chapter make use of this calculation method. However, the resultant design should be subjected to extensive modeling tests to determine whether there are performance deficiencies or weaknesses that require modification of the design before actual construction.

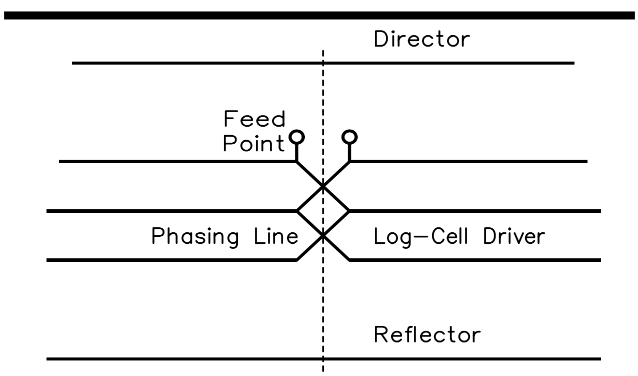

Fig 13—A sketch of a typical monoband log-cell Yagi. The reflector is, in principle, optional. The log-cell may have from 2 to 5 (or more elements). There may be one or more directors.

Log-Cell Yagis

Fig 12 showed an LPDA with an added parasitic director. Technically, this converts the original design into a hybrid Log-Yag. However, the term *Log-Yag* (or more generally the *log-cell Yagi*) is normally reserved for monoband designs that employ two or more elements in a single-band LPDA arrangement, together with (usually) a reflector and one or more directors. The aim is to produce a monoband directive array with superior directional qualities over a wider bandwidth than can be obtained from many Yagi-Uda designs. Log-cells have also been successfully used as wide-band driver sections for multiband Yagi beams.

Fig 13 illustrates the general outline of a typical log-cell Yagi. The driver section consists of a log periodic array designed for the confines of a single amateur band or other narrow range of frequencies. The parasitic reflector is usually spaced about 0.085 λ behind the rear element of the log cell, while the parasitic director is normally placed between 0.13 and 0.15 λ ahead of the log cell.

Early log-cell Yagis tended to be casually designed. Most of these designs have inferior performance compared with present-day computer-optimized Yagis of the same boom length. Some were designed by adding one or more parasitic directors to simple phased pairs of elements. Although good performance is possible, the operating bandwidth of these designs is small, suitable only for the so-called WARC bands. However, when the log-cell is designed as a narrowly spaced monoband log periodic array, the operating bandwidth increases dramatically. Operating bandwidth here refers not just to the SWR bandwidth, but also to the gain and front-to-back bandwidth.

The widest operating bandwidths require log cells of 3 to 4 elements for HF bands like 20 meters, and 4 to 5 elements for bands as wide as 10 meters. (The bandwidth of the 20-meter band is approximately 2.4% of the center frequency, while the bandwidth of the 10-meter band approaches 9.4% of the center frequency.) A practical limit to σ for log cells used within parasitic arrays is about 0.05. Slightly higher gain may be obtained from higher values of σ, but at the cost of a much longer log cell. The limiting figure for σ results in a practical value for τ between 0.94 and 0.95 to achieve a cell with the desired bandwidth characteristics.

An array designed according to these principles has an overall length that varies with the size of the log cell. A typical array with a 4-element log-cell and single parasitic elements fore and aft is a bit over 0.35 λ long, while a 5-element log-cell Yagi will be between 0.4 and 0.45 λ long. Spacing the reflector more widely (for example, up

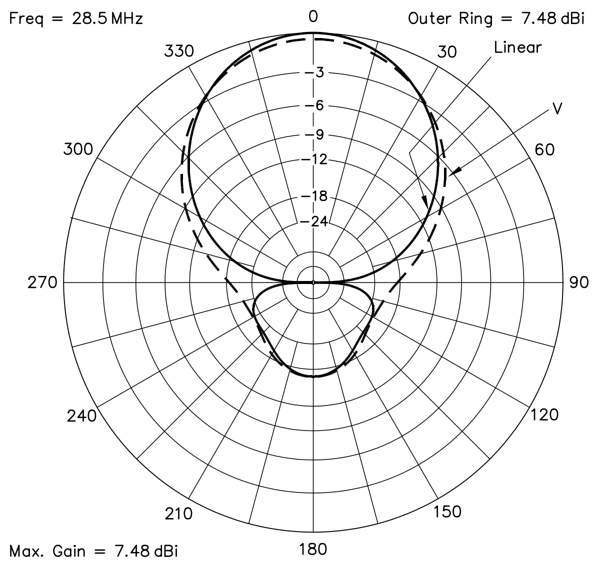

Fig 14—Overlaid free-space azimuth patterns for virtually identical 5-element log-cell Yagis (with 3-element log-cells), one having the elements V'd forward at 40° from linear (dashed), the other with linear elements (solid).

to 0.25 λ) has little effect on either gain or front-to-back ratio. Wider spacing of the director will also have only a small effect on gain, since the arrangement is already close to the boom-length limit recommended for director-driver-reflector arrays. Further lengthening of the boom should be accompanied by the addition of one or more directors to the array, if additional gain is desired from the design.

Compared to a modern-day Yagi of the same boom length, the log-cell Yagi is considerably heavier and exhibits a higher wind load due to the requirements of the log-cell driver. Yagis with 3- and 4-elements within the boom lengths just given are capable of peak free-space gain values of 8.2 to 8.5 dBi, while sustaining a high front-to-back ratio. Peak front-to-back ratios are typically in the vicinity of 25 dB. However, Yagi gain tends to decrease below the design frequency (and increase above it), while the front-to-back ratio tends to taper off as one moves away from the design frequency. For the largest log-cell sizes, log-cell Yagis of the indicated boom lengths are capable of sustaining at least 8.2 dBi free-space gain over the entire band, with front-to-back ratios of over 30 dB across the operating bandwidth.

The feed-point impedance of a log-cell Yagi is a function of both the cell design and the influence of the parasitic elements. However, for most cell designs and common phase-line designs, you can achieve a very low variation of resistance and reactance across a desired band. In many cases, the feed impedance will form a direct match for the standard 50-Ω coaxial cable used by most amateur installations. (In contrast, the high-gain, high-front-to-back Yagis used for comparison here have feed-point impedances ranging from 20 to 25 Ω.)

A common design technique used in some LPDA and log-cell Yagi designs is to bend the elements forward to form a series of Vs. A forward angle on each side of the array centerline of about 40° relative to a linear element has been popular. In some instances, the mechanical design of the array may dictate this element formation. However, this arrangement has no special benefits and possibly may degrade performance.

Fig 14 shows the free-space azimuth patterns of a single 5-element log-cell Yagi in two versions: with the elements linear and with the elements bent forward 40°. The V-array loses about 1/2 dB gain, but more significantly, it loses considerable signal rejection from the sides. Similar comparisons can be obtained from pure LPDA designs and from Yagi-Uda designs when using elements in the vicinity of 1/2 λ. Unless mechanical considerations call for arranging the elements in a V, the technique is not recommended.

Ultimately, the decision to build and use a log-cell Yagi involves balancing the additional weight and wind-load requirements of this design against the improvements in operating bandwidth for all of the major operating parameters, especially with respect to the front-to-back ratio and the feed-point impedance.

Wire Log-Periodic Dipole Arrays for 3.5 or 7 MHz

These wire log-periodic dipole arrays for the lower HF bands are simple in design and easy to build. They are designed to have reasonable gain, be inexpensive and lightweight, and may be assembled with stock items found in large hardware stores. They are also strong—they can withstand a hurricane! These antennas were first described by John J. Uhl, KV5E, in *QST* for August, 1986. **Fig 15** shows one method of installation. You can use the information here as a guide and point of reference for building similar LPDAs.

If space is available, the antennas can be rotated or repositioned in azimuth after they are completed. A 75-foot tower and a clear turning radius of 120 feet around the base of the tower are needed. The task is simplified

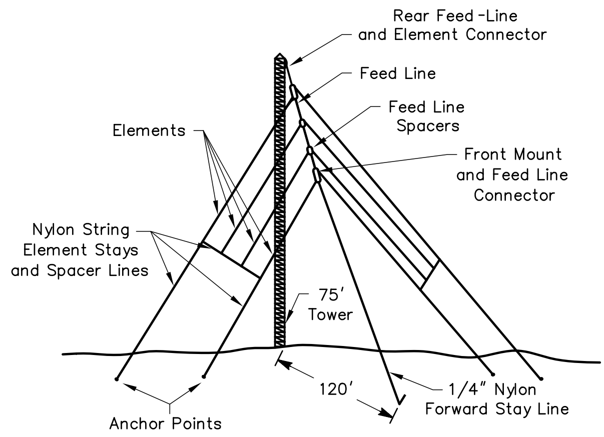

Fig 15—Typical lower-HF wire 4-element log periodic dipole array erected on a tower.

if you use only three anchor points, instead of the five shown in Fig 15. Omit the two anchor points on the forward element, and extend the two nylon strings used for element stays all the way to the forward stay line.

DESIGN OF THE LOG-PERIODIC DIPOLE ARRAYS

Design constants for the two arrays are listed in **Tables 1** and **2**. The preceding sections of this chapter contain the design procedure for arriving at the dimensions and other parameters of these arrays. The primary differences between these designs and one-octave upper HF arrays are the narrower frequency ranges and the use of wire, rather than tubing, for the elements. As design examples for the LPDA, you may wish to work through the step-by-step procedure and check your results against the values in Tables 1 and 2. You may also wish to compare these results with the output of an LPDA design software package such as *LPCAD28*.

From the design procedure, the feeder wire spacings for the two arrays are slightly different, 0.58 inch for the 3.5-MHz array and 0.66 inch for the 7-MHz version. As a compromise toward the use of common spacers for both bands, a spacing of $^5/_8$ inch is quite satisfactory. Surprisingly, the feeder spacing is not at all critical here from a matching standpoint, as may be verified from $Z_0 = 276 \log (2S/\text{diam})$ and from Eq 4. Increasing the spacing to as much as $^3/_4$ inch results in an R_0 SWR of less than 1.1:1 on both bands.

Constructing the Arrays

Construction techniques are the same for both the 3.5 and the 7-MHz versions of the array. Once the designs are completed, the next step is to fabricate the fittings; see **Fig 16** for details. Cut the wire elements and feed lines to the proper sizes and mark them for identification. After the wires are cut and placed aside, it will be difficult to remember which is which unless they are marked. When you have finished fabricating the connectors and cutting all of the wires, the antenna can be assembled. Use your ingenuity when building one of these antennas; it isn't necessary to duplicate these LPDAs precisely.

The elements are made of standard #14 stranded cop-

Table 1

Design Parameters for the 3.5-MHz Single-Band LPDA

f1 = 3.3 MHz	Element lengths:
f_n = 4.1 MHz	ℓ1 = 149.091 feet
B = 1.2424	ℓ2 = 125.982 feet
τ = 0.845	ℓ3 = 106.455 feet
σ = 0.06	ℓ4 = 89.954 feet
Gain = 5.9 dBi = 3.8 dBd	Element spacings:
cot α = 1.5484	d_{12}=17.891 feet
B_{ar} = 1.3864	d_{23} = 15.118 feet
B_s = 1.7225	d_{34} = 12.775 feet
L = 48.42 feet	Element diameters
N = 4.23 elements (decrease to 4)	All = 0.0641 inches
Zt = 6-inch short jumper	ℓ/diameter ratios:
R_0 = 208 Ω	ℓ/diam_4 = 16840
Z_{AV} = 897.8 Ω	ℓ/diam_3 = 19929
σ' = 0.06527	ℓ/diam_2 = 23585
Z_0 = 319.8 Ω	ℓ/diam_1 = 27911
Antenna feeder:	
#12 wire spaced 0.58 inches	
Balun: 4:1	
Feed line: 52-Ω coax	

Table 2

Design Parameters for the 7-MHz Single-Band LPDA

f1 = 6.9 MHz	Element lengths:
f_n = 7.5 MHz	ℓ1 = 71.304 feet
B = 1.0870	ℓ2 = 60.252 feet
τ = 0.845	ℓ3 = 50.913 feet
σ = 0.06	ℓ4 = 43.022 feet
Gain = 5.9 dBi = 3.8 dBd	Element spacings:
cot α = 1.5484	d_{12} = 8.557 feet
B_{ar} = 1.3864	d_{23} = 7.230 feet
B_s = 1.5070	d_{34} = 6.110 feet
L = 18.57 feet	Element diameters:
N = 3.44 elements (increase to 4)	All = 0.0641 inches
Z_t = 6-inch short jumper	ℓ/diameter ratios:
R_0 = 208 Ω	$\ell4/\text{diam}_4$ = 8054
Z_{AV} = 809.3 Ω	$\ell3/\text{diam}_3$ = 9531
σ' = 0.06527	$\ell2/\text{diam}_2$ = 11280
Z_0 = 334.2 Ω	$\ell1/\text{diam}_1$ = 13349
Antenna feeder:	
#12 wire spaced 0.66 inches	
Balun: 4:1	
Feed line: 52-Ω coax	

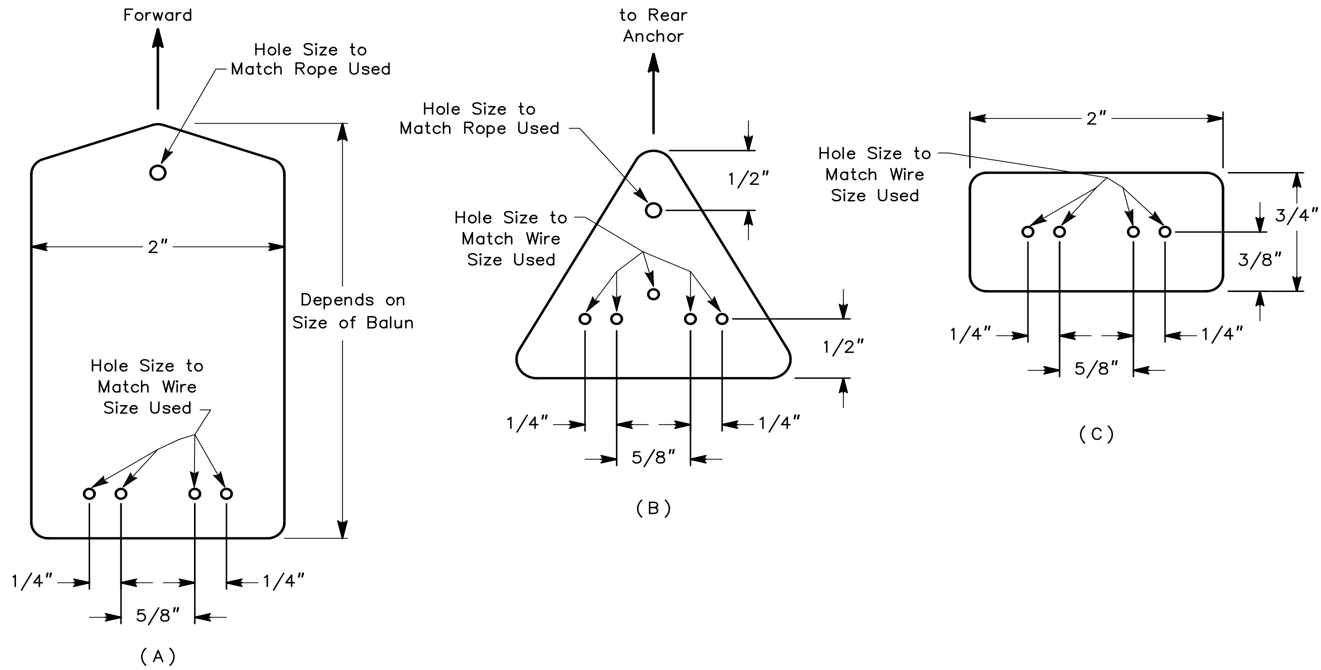

Fig 16—Pieces for the LPDA that require fabrication. At A is the forward connector, made from 1/2-inch Lexan (polycarbonate). At B is the rear connector, also made from 1/2-inch Lexan. At C is the pattern for the phase-line spacers, made from 1/4-inch Plexiglas. Two spacers are required for the array.

per wire. The two parallel feed lines are made of #12 solid copper-coated steel wire, such as Copperweld. Copperweld will not stretch when placed under tension. The front and rear connectors are cut from 1/2-inch thick Lexan sheeting, and the feed-line spacers from 1/4-inch Plexiglas sheeting.

Study the drawings carefully and be familiar with the way the wire elements are connected to the two feed lines, through the front, rear and spacer connectors. Details are sketched in **Figs 17** and **18**. Connections made in the way shown in the drawings prevent the wire from breaking. All of the rope, string, and connectors must be made of materials that can withstand the effects of tension and weathering. Use nylon rope and strings, the type that yachtsmen use. Fig 15 shows the front stay rope coming down to ground level at a point 120 feet from the base of a 75-foot tower. Space may not be available for this arrangement in all cases. An alternative installation technique is to put a pulley 40 feet up in a tree and run the front stay rope through the pulley and down to ground level at the base of the tree. The front stay rope will have to be tightened with a block and tackle at ground level.

Putting an LPDA together is not difficult if it is assembled in an orderly manner. It is easier to connect the elements to the feeder lines when the feed-line

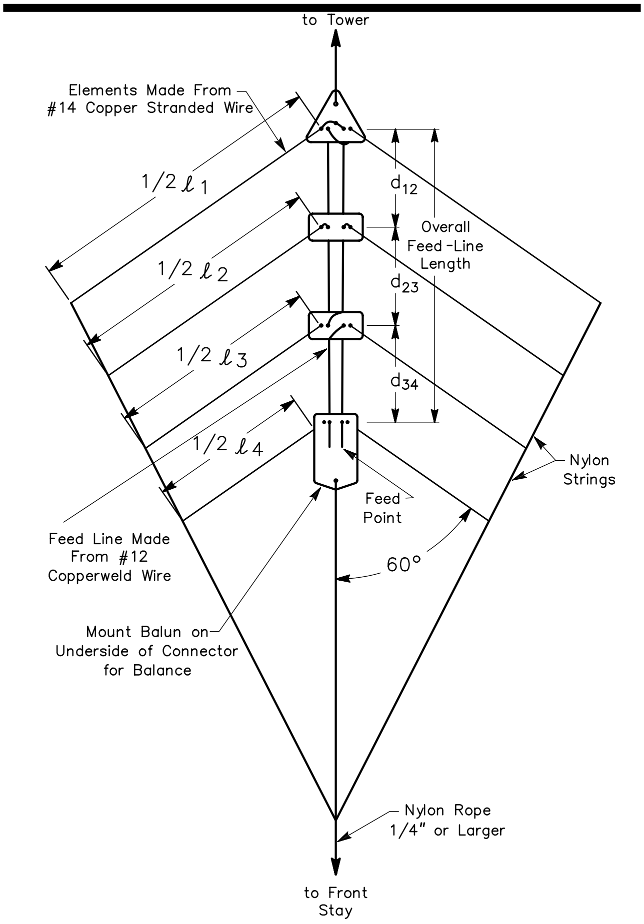

Fig 17—The generic layout for the lower HF wire LPDA. Use a 4:1 balun on the forward connector. See Tables 1 and 2 for dimensions.

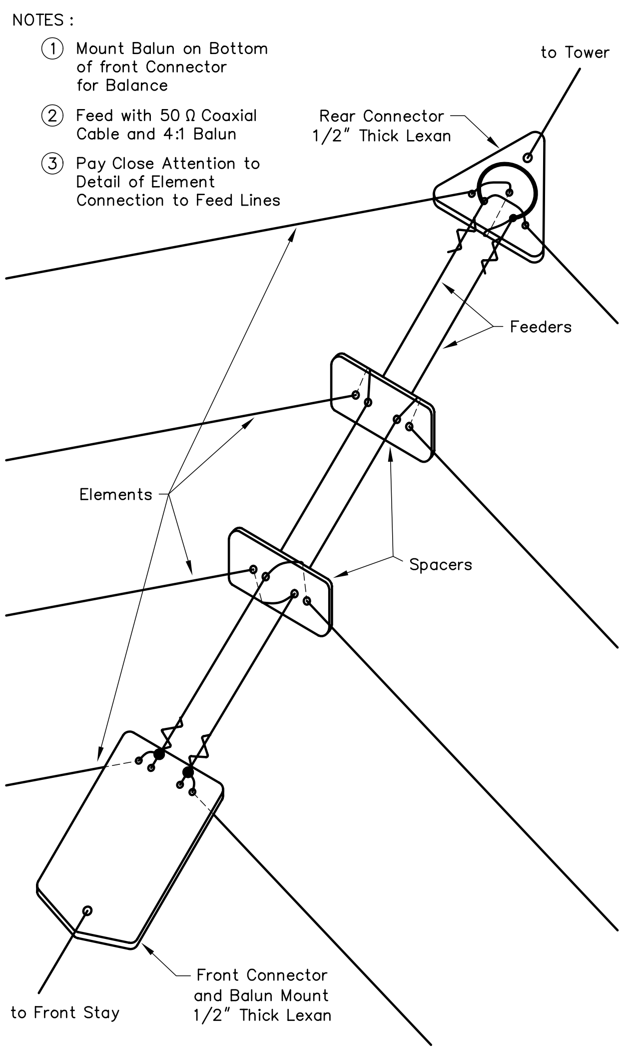

Fig 18—Details of the electrical and mechanical connections of the elements to the phase-line. Knots in the nylon rope stay line are not shown.

assembly is stretched between two points. Use the tower and a block and tackle. Attaching the rear connector to the tower and assembling the LPDA at the base of the tower makes raising the antenna into place a much simpler task. Tie the rear connector securely to the base of the tower and attach the two feeder lines to it. Then thread the two feed-line spacers onto the feed line. The spacers will be loose at this time, but will be positioned properly when the elements are connected. Now connect the front connector to the feed lines. A word of caution: Measure accurately and carefully! Double-check all measurements before you make permanent connections.

Connect the elements to the feeder lines through their respective plastic connectors, beginning with element 1, then element 2, and so on. Keep all of the element wires securely coiled. If they unravel, you will have a tangled mess of kinked wire. Recheck the element-to-feeder connections to ensure proper and secure junctions. (See Figs 17 and 18.) Once you have completed all of the element connections, attach the 4:1 balun to the underside of the front connector. Connect the feeder lines and the coaxial cable to the balun.

You will need a separate piece of rope and a pulley to raise the completed LPDA into position. First secure the eight element ends with nylon string, referring to Figs 15 and 17. The string must be long enough to reach the tie-down points. Connect the front stay rope to the front connector, and the completed LPDA is now ready to be raised into position. While raising the antenna, uncoil the element wires to prevent their getting away and tangling up into a mess. Use care! Raise the rear connector to the proper height and attach it securely to the tower, then pull the front stay rope tight and secure it. Move the elements so they form a 60° angle with the feed lines, in the direction of the front, and space them properly relative to one another. By adjusting the end positions of the elements as you walk back and forth, you will be able to align all the elements properly. Now it is time to hook your rig to the system and make some contacts.

Performance

The reports received from these LPDAs were compared with an inverted-V dipole. All of the antennas are fixed; the LPDAs radiate to the northeast, and the dipole to the northeast and southwest. The apex of the dipole is at 70 feet, and the 40- and 80-meter LPDAs are at 60 and 50 feet, respectively. Basic array gain was apparent from many of the reports received. During pileups, it was possible to break in with a few tries on the LPDAs, yet it was impossible to break in the same pileups using the dipole. The gain of the LPDAs is several dB over the dipole. For additional gain, experimenters may wish to try a parasitic director about $^{1}/_{8}$ λ ahead of the array. Director length and spacing from the forward LPDA element should be field-adjusted for maximum performance while maintaining the impedance match across each of the bands.

Wire LPDA systems offer many possibilities. They are easy to design and to construct: real advantages in countries where commercially built antennas and parts are not available at reasonable cost. The wire needed can be obtained in all parts of the world, and cost of construction is low. If damaged, the LPDAs can be repaired easily with pliers and solder. For those who travel on DXpeditions where space and weight are large considerations, LPDAs are lightweight but sturdy, and they perform well.

5-Band Log Periodic Dipole Array

A rotatable log periodic array designed to cover the frequency range from 13 to 30 MHz is pictured in **Fig 19**. This is a large array having a free-space gain that varies from 6.6 to over 6.9 dBi, depending upon the operating portion of the design spectrum. This antenna system was originally described by Peter D. Rhodes, WA4JVE, in Nov 1973 *QST*. A measured radiation pattern for the array appears in **Fig 20**.

The characteristics of this array are:

1) Half-power beamwidth, 43° (14 MHz)
2) Design parameter $\tau = 0.9$
3) Relative element spacing constant $\sigma = 0.05$
4) Boom length, L = 26 feet
5) Longest element $\lambda 1$ = 37 feet 10 inches. (A tabulation

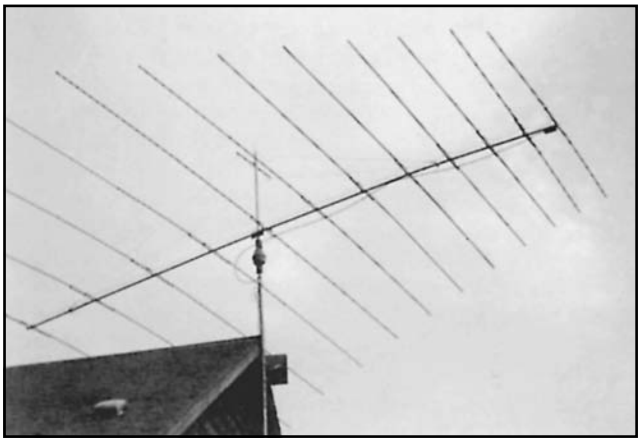

Fig 19—The 13-30 MHz log periodic dipole array.

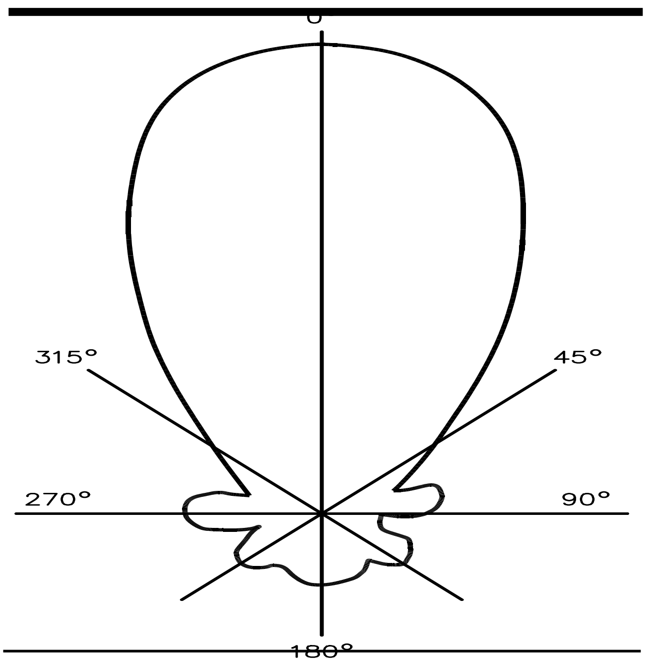

Fig 20—Measured radiation pattern of the 13-30 MHz LPDA. The front-to-back ratio is about 14 dB at 14 MHz and increases to 21 dB at 28 MHz.

Table 3
13-30 MHz LPDA Dimensions, feet

Ele. No.	*Length*	$d_{n-1,n}$ *(spacing)*	*Nearest Resonant*
1	37′ 10.2″	—	
2	34′ 0.7″	3′ 9.4″ = d_{12}	14 MHz
3	30′ 7.9″	3′ 4.9″ = d_{23}	
4	27′ 7.1″	3′ 0.8″ = d_{34}	
5	24′ 10.0″	2′ 9.1″ = d_{45}	18 MHz
6	22′ 4.2″	2′ 5.8″ = d_{56}	21 MHz
7	20′ 1.4″	2′ 2.8″ = d_{67}	
8	18′ 1.2″	2′ 0.1″ = d_{78}	24.9 MHz
9	16′ 3.5″	1′ 9.7″ = d_{89}	28 MHz
10	14′ 7.9″	1′ 7.5″ = $d_{9,10}$	
11	13′ 2.4″	1′ 5.6″ = $d_{10,11}$	
12	11′ 10.5″	1′ 3.8″ = $d_{11,12}$	

Table 4
Materials list: 13-30 MHz LPDA

Material Description	*Quantity*
1) Aluminum tubing—0.047″ wall thickness	
1″—12′ or 6′ lengths	126 lineal feet
7/8″—12′ lengths	96 lineal feet
7/8″—6′ or 12′ lengths	66 lineal feet
3/4″—8′ lengths	16 lineal feet
2) Stainless-steel hose clamps—2″ max	48 ea
3) Stainless-steel hose clamps—1 1/4″ max	26 ea
4) TV type U bolts	14 ea
5) U bolts, galv. type	
5/16″ × 1 1/2″	4 ea
1/4″ × 1″	2 ea
6) 1″ ID polyethylene water-service pipe 160 lb/in.^{2} test, approx. 1 1/4″ OD	20 lineal feet
A) 1 1/4″ × 1 1/4 × 1/8″ aluminum Angle—6' lengths	30 lineal feet
B) 1″ × 1/4″ aluminum bar—6′ lengths	12 lineal feet
7) 1 1/4″ top rail of chain-link fence	26 lineal feet
8) 1:1 toroid balun	1 ea
9) 6-32 × 1″ stainless steel screws	24 ea
6-32 stainless steel nuts	48 ea
#6 solder lugs	24 ea
10) #12 copper feeder wire	60 lineal feet
11A) 12″ × 8″ × 1/4″ aluminum plate	1 ea
B) 6″ × 4″ × 1/4″ aluminum plate	1 ea
12A) 3/4″ galv. Pipe	3 lineal feet
B) 1″ galv. pipe-mast	5 lineal feet
13) Galv. guy wire	50 lineal feet
14) 1/4″ × 2″ turnbuckles	4 ea
15) 1/4″ × 1 1/2″ eye bolts	2 ea
16) TV guy clamps and eye bolts	2 ea

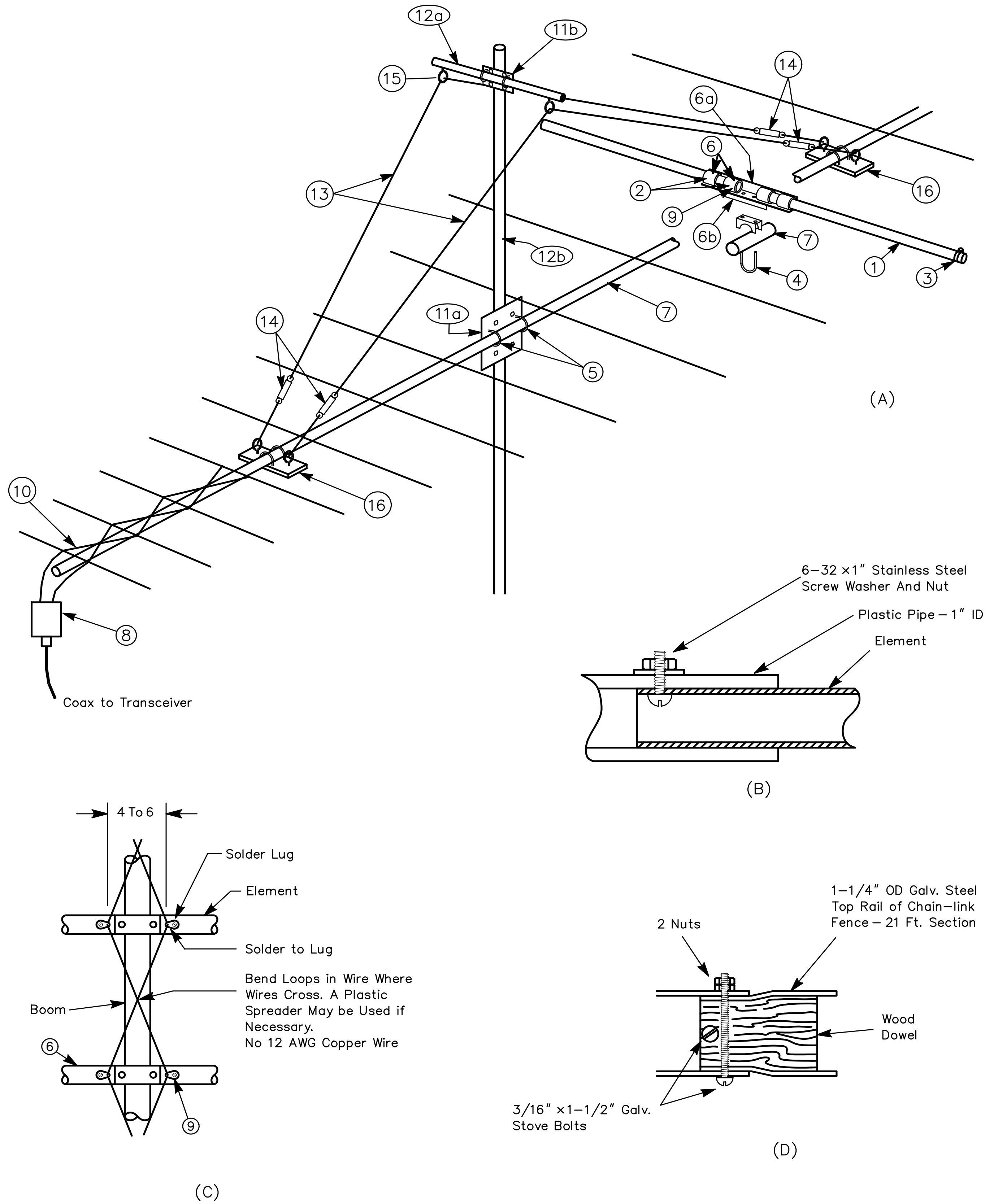

Fig 21—Construction diagrams of the 13-30 MHz LPDA. B and C show the method of making electrical connection between the phase-line and each half-element. D shows how the boom sections are joined.

Table 5
Element Material Requirements: 13-30 MHz LPDA

Ele. No.	*1″ Tubing Len.*	*1″ Tubing Qty*	*7/8″ Tubing Len.*	*7/8″ Tubing Qty*	*3/4″ Tubing Len.*	*3/4″ Tubing Qty*	*1 1/4″ Angle Len.*	*1″ Bar Len.*
1	6′	2	6′	2	8′	2	3′	1′
2	6′	2	12′	2	—	—	3′	1′
3	6′	2	12′	2	—	—	3′	1′
4	6′	2	8.5′	2	—	—	3′	1′
5	6′	2	7′	2	—	—	3′	1′
6	6′	2	6′	2	—	—	3′	1′
7	6′	2	5′	2	—	—	2′	1′
8	6′	2	3.5′	2	—	—	2′	1′
9	6′	2	2.5′	2	—	—	2′	1′
10	3′	2	5′	2	—	—	2′	1′
11	3′	2	4′	2	—	—	2′	1′
12	3′	2	4′	2	—	—	2′	1′

of element lengths and spacings appears in **Table 3**.)
6) Total weight, 116 pounds
7) Wind-load area, 10.7 square feet
8) Required input impedance (mean resistance), R_0 = 72 Ω, Z_t = 6-inch jumper #18 wire
9) Average characteristic dipole impedance, Z_{AV}: 337.8 Ω
10) Impedance of the feeder, Z_0: 117.1 Ω
11) Feeder: #12 wire, close spaced
12) With a 1:1 toroid balun at the input terminals and a 72-Ω coax feed line, the maximum SWR is 1.4:1.

The mechanical assembly uses materials readily available from most local hardware stores or aluminum supply houses. The materials needed are given in **Table 4**. In the construction diagram, **Fig 21**, the materials are referenced by their respective material list numbers. The photograph shows the overall construction, and the drawings show the details. **Table 5** gives the required tubing lengths to construct the elements.

Experimenters may wish to improve the performance of the array at both the upper and lower frequency ends of the design spectrum so that it more closely approaches the performance in the middle of the design frequency range. The most apt general technique for raising both the gain and the front-to-back ratio at the frequency extremes would be to circularize τ as described earlier in this chapter. However, other techniques may also be applied.

The Telerana

The Telerana (Spanish for *spider web*) is a rotatable log periodic antenna that is lightweight, easy to construct and relatively inexpensive to build. Designed to cover 12.1 to 30 MHz, it was co-designed by George Smith, W4AEO, and Ansyl Eckols, YV5DLT, and first described by Eckols in *QST* for Jul 1981. Some of the design parameters are as follow.

1) $\tau = 0.9$
2) $\sigma = 0.05$
3) Gain = 4.5 to 5.5 dBi (free-space) depending upon frequency
4) Feed arrangement: 400-Ω feeder line with 4:1 balun, fed with 52-Ω coax. The SWR is 1.5:1 or less in all amateur bands.

The array consists of 13 dipole elements, properly spaced and transposed, along an open wire feeder having an impedance of approximately 400 Ω. See **Figs 22** and **23**. The array is fed at the forward (smallest) end with a 4:1 balun and RG-8 cable placed inside the front arm and leading to the transmitter. An alternative feed method is to use open wire or ordinary TV ribbon and a tuner, eliminating the balun.

The frame that supports the array (**Fig 24**) consists of four 15-foot fiberglass vaulting poles slipped over short nipples at the hub, appearing like wheel spokes (**Fig 25**). Instead of being mounted directly into the fiberglass, the hub mounts into short metal tubing sleeves that are inserted into the ends of each arm to prevent crushing and splitting the fiberglass. The necessary holes are drilled to receive the wires and nylon.

A shopping list is provided in **Table 6**. The center hub is made from a 1 1/4-inch galvanized four-outlet cross or X and four 8-inch nipples (Fig 25). A 1-inch diameter X may be used alternatively, depending on the diameter of the fiberglass. A hole is drilled in the bottom of the hub to allow the cable to be passed through after welding the hub to the rotator mounting stub.

All four arms of the array must be 15 feet long. They should be strong and springy to maintain the tautness of the array. If vaulting poles are used, try to obtain all of them with identical strength ratings.

The forward spreader should be approximately 14.8 feet long. It can be much lighter than the four main arms, but must be strong enough to keep the lines rigid.

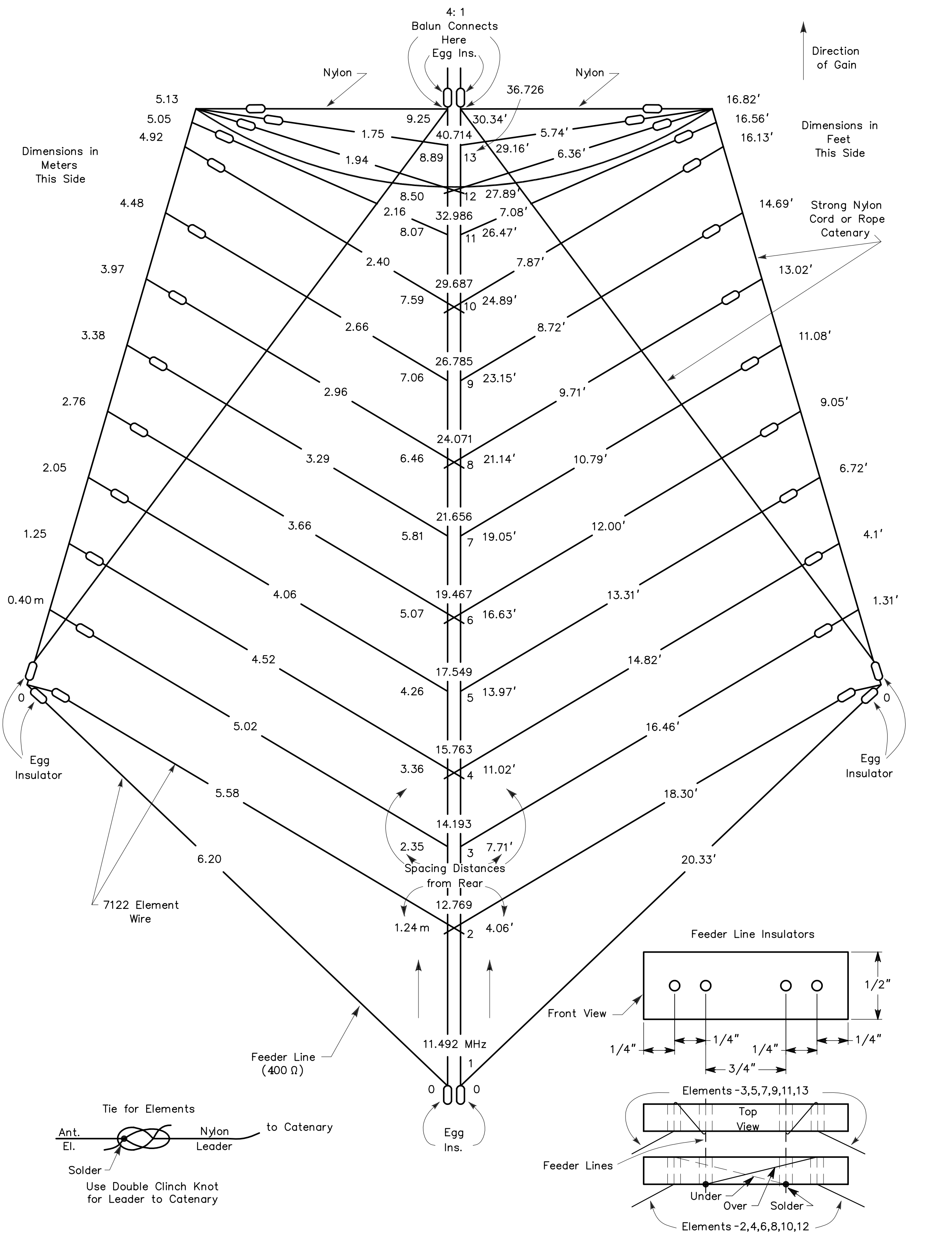

Fig 22—The overall configuration of the spider web antenna. Nylon monofilament line is used from the ends of the elements to the nylon cords. Use nylon line to tie every point where lines cross. The forward fiberglass feeder lies on the feeder line and is tied to it. Both metric and English measurements are shown, except for the illustration of the feed-line insulator. Use soft-drawn copper or stranded wire for elements 2 through 12. Element 1 should use 7/22 flexible wire or #14 AWG Copperweld.

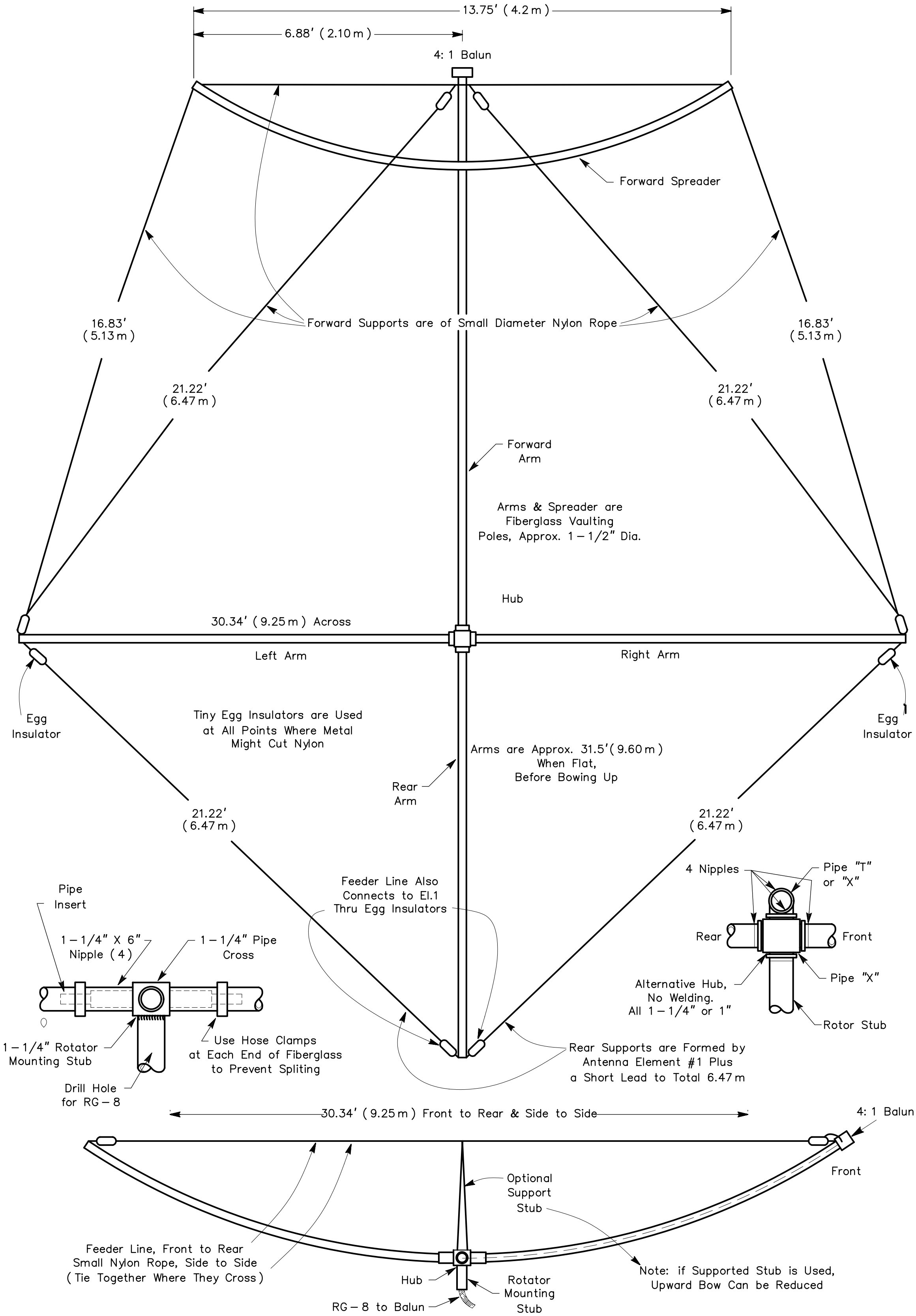

Fig 23—The frame construction of the spider web antenna. Two different hub arrangements are illustrated.

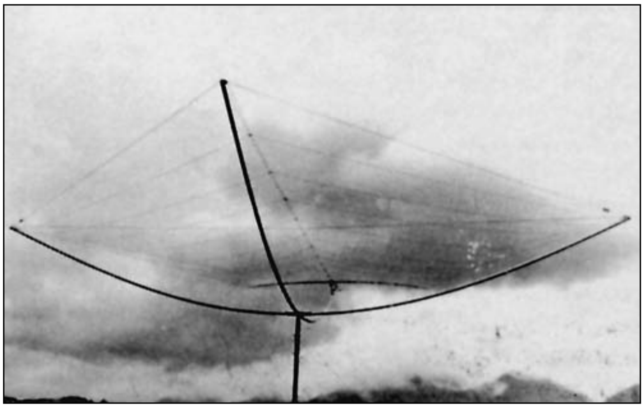

Fig 24—Although the spider web antenna resembles a rotatable clothes line, it is much larger, as indicated by Figs 22 and 23. However, the antenna can be lifted by hand.

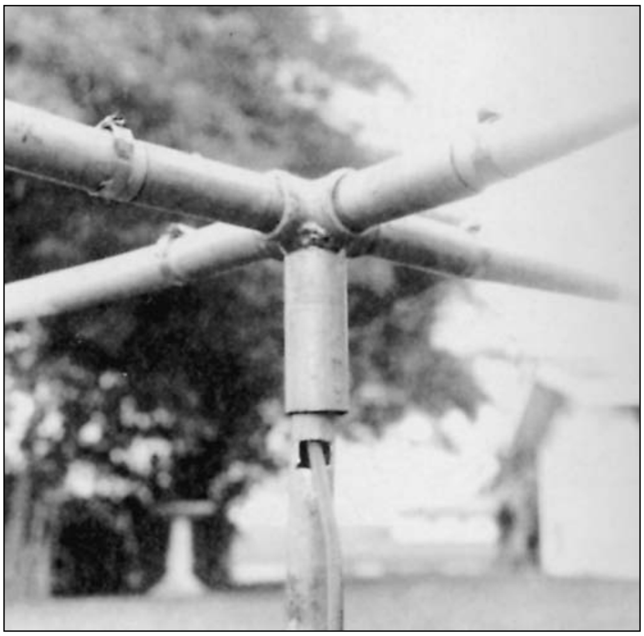

Fig 25—The simple arrangement of the spider web antenna hub. See Fig 23 and the text for details.

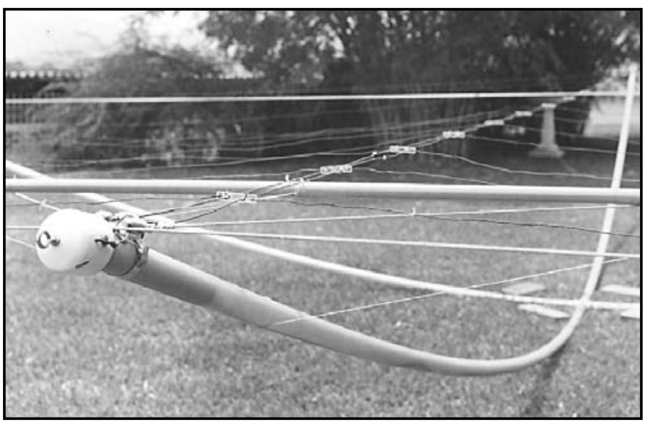

Fig 26—The elements, balun, transmission line and main bow of the spider web antenna.

Table 6
Shopping List for the Telerana

1—1 1/4-inch galvanized, 4-outlet cross or X.
4—8-inch nipples.
4—15-foot long arms. Vaulting poles suggested. These must be strong and all of the same strength (150 lb) or better.
1—Spreader, 14.8 foot long (must not be metal).
1—4:1 balun unless open-wire or TV cable is used.
12—Feed-line insulators made from Plexiglas or fiberglass.
36—Small egg insulators.
328 feet copper wire for elements; flexible 7/22 is suggested.
65.6 feet (20 m) #14 Copperweld wire for interelement feed line.
164 feet (50 m) strong 1/8-inch dia cord.
1—Roll of nylon monofilament fishing line, 50 lb test or better.
4—Metal tubing inserts go into the ends of the fiberglass arms.
2—Fiberglass fishing-rod blanks.
4—Hose clamps.

If tapered, the spreader should have the same measurements from the center to each end. *Do not use metal for this spreader*.

Building the frame for the array is the first construction step. Once the frame is prepared, then everything else can be built onto it. Begin by assembling the hub and the four arms, letting them lie flat on the ground with the rotator stub inserted in a hole in the ground. The tip-to-tip length should be about 31.5 feet each way. A hose clamp is used at each end of the arms to prevent splitting. Place the metal inserts in the outer ends of the arms, with 1 inch protruding. The mounting holes should have been drilled at this point. If the egg insulators and nylon cords are mounted to these tube inserts, the whole antenna can be disassembled simply by bending up the arms and pulling out the inserts with everything still attached.

Choose the arm to be at the front end. Mount two egg insulators at the front and rear to accommodate the inter-element feeder. These insulators should be as close as possible to the ends.

At each end of the cross-arm on top, install a small pulley and string nylon cord across and back. Tighten the cord until the upward bow reaches 3 feet above the hub. All cords will require retightening after the first few days because of stretching. The cross-arm can be laid on its side while preparing the feeder line. For the front-to-rear bowstring it is important to use a wire that will not stretch, such as #14 Copperweld. This bowstring is actually the inter-element transmission line. See **Fig 26**.

Secure the rear ends of the feeder to the two rear insulators, soldering the wrap. Before securing the fronts, slip the 12 insulators onto the two feed lines. A rope can be used temporarily to form the bow and to aid in mounting the feeder line. The end-to-end length of the feeder

Improving the Telerana

In *The ARRL Antenna Compendium, Vol 4*, Markus Hansen, VE7CA, described how he modified the Telerana to improve the front-to-back ratio on 20 and 15 meters. In addition, he added a trapped 30/40-meter dipole that functions as a top truss system to stabilize the modified Telerana in strong uprising winds that otherwise could turn the antenna into an "inside-out umbrella."

Fig A shows the layout for the modified Telerana, and Table A lists the lengths and spacings for the #14 wire elements. Note that VE7CA used tuning stubs to tweak the 15 and 20-meter reflector wires for best rearward pattern. The construction techniques used by VE7CA are the same as for the original Telerana. Fig B shows a side view of the additional 40/30-meter-dipole truss sytem.

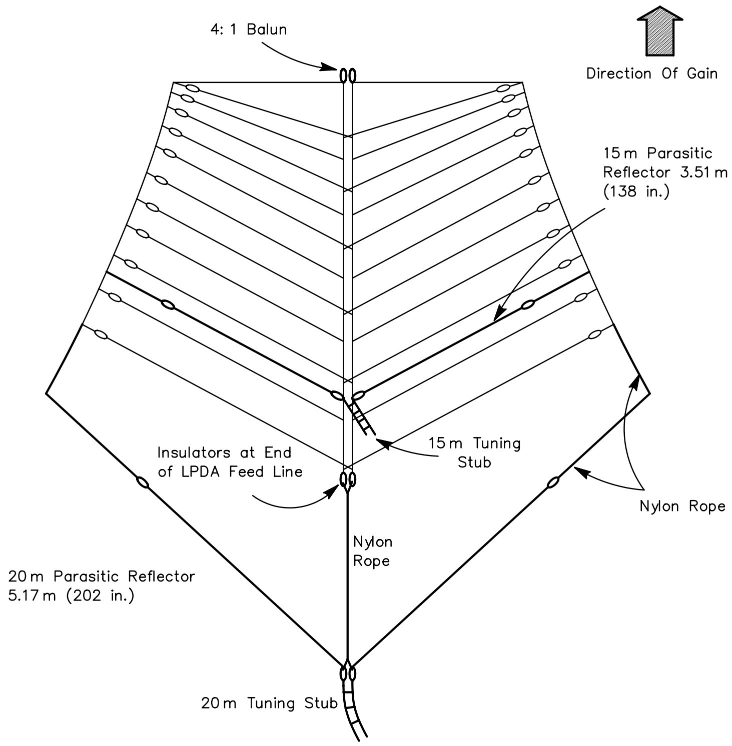

Table A

Element Lengths and Spacings, in Inches

Element Number	*1/2 Element Length (inches)*	*Total Distance (inches)*
R1	202.0	0.0
L1	210.1	102.0
L2	191.2	140.7
R2	138.0	158.3
L3	174.0	175.9
L4	158.3	207.9
L5	144.1	237.0
L6	131.1	261.5
L7	119.3	285.6
L8	108.6	307.6
L9	98.8	327.6
L10	89.9	345.8
L11	82.4	364.5

Note: the reflector lengths do not include the length of the tuning stubs.

Fig A—Physical layout of modified Telerana with 20 and 15-meter reflectors added (in place of first two elements in original Telerana). Note the tuning stubs for the added reflectors.

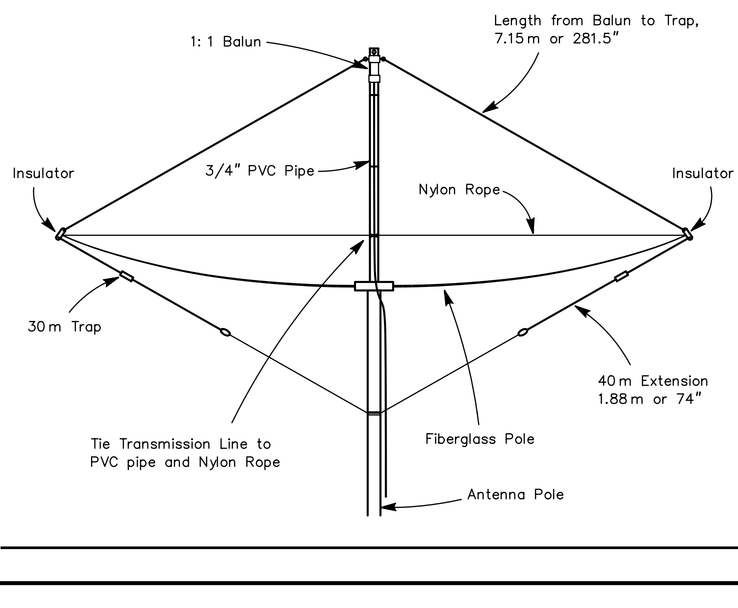

Fig B—Side view of 30/40-meter addition to the modified Telerana, using 3/4-inch PVC pipe as a vertical stabilizer and support for the 30/40-meter trapped dipole.

should be 30.24 feet.

Now lift both bows to their upright position and tie the feeder line and the cross-arm bowstring together where they cross, directly over and approximately 3 feet above the hub.

The next step is to install the number 1 rear element from the rear egg insulators to the right and left cross-arms using other egg insulators to provide the proper element length. Be sure to solder the element halves to the transmission line. Complete this portion of the construction by installing the nylon cord catenaries from the front arm to the cross-arm tips. Use egg insulators where needed to prevent cutting the nylon cords.

When preparing the fiberglass forward spreader, keep in mind that it should be 14.75 feet long before bowing and is approximately 13.75 feet across when bowed. Secure the center of the bowstring to the end of the front arm. Lay the spreader on top of the feed line, then tie the feeder to the spreader with nylon fish line. String the catenary from the spreader tips to the cross-arm tips.

At this point of assembly, prepare antenna elements 2 through 13. There will be two segments for each element. At the outer tip make a small loop and solder the wrap. The loop will be for the nylon leader. Measure the length plus 0.4 inch for wrapping and soldering the element segment to the feeder. Seven-strand #22 antenna wire is suggested for the element wires. Slide the feed-line insulators to their proper position and secure them temporarily.

The drawings show the necessary transposition scheme. Each element half of elements 1, 3, 5, 7, 9, 11 and 13 is connected to its own side of the feeder, while elements 2, 4, 6, 8, 10 and 12 cross over to the opposite side of the transmission line.

There are four holes in each of the transmission-line insulators (see Fig 22). The inner holes are for the transmission line, and the outer ones are for the elements. Since the array elements are slanted forward, they should pass through the insulator from front to back, then back over the insulator to the front side and be soldered to the transmission line. The small drawings of Fig 22 show the details of the element transpositions.

Everywhere that lines cross, tie them together with nylon line, including all copper-nylon and nylon-nylon junctions. Careful tying makes the array much more rigid. However, all elements should be mounted loosely before you try to align the whole thing. Tightening any line or element affects all the others. There will be plenty of walking back and forth before the array is aligned properly. Expect the array to be firm but not extremely taut.

The Pounder: A Single-Band 144-MHz LPDA

The 4-element Pounder LPDA pictured in **Fig 27** was developed by Jerry Hall, K1TD, for the 144-148 MHz band. Because it started as an experimental antenna, it utilizes some unusual construction techniques. However, it gives a very good account of itself, exhibiting a theoretical free-space gain of about 7.2 dBi and a front-to-back ratio of 20 dB or better. The Pounder is small and light. It weighs just 1 pound, and hence its name. In addition, as may be seen in **Fig 28**, it can be disassembled and reassembled quickly, making it an excellent antenna for portable use. This array also serves well as a fixed-station antenna, and may be changed easily to either vertical or horizontal polarization.

The antenna feeder consists of two lengths of $^1/_2 \times {}^1/_2 \times {}^1/_{16}$-inch angle aluminum. The use of two facing flat surfaces permits the builder to obtain a lower characteristic impedance than can be obtained from round conductors with the same spacing. The feeder also serves as the boom for the Pounder. In the first experimental model, the array contained only two elements with a spacing of 1 foot, so a boom length of 1 foot was the primary design requirement for the 4-element version. **Table 7** gives the calculated design data for the 4-element array.

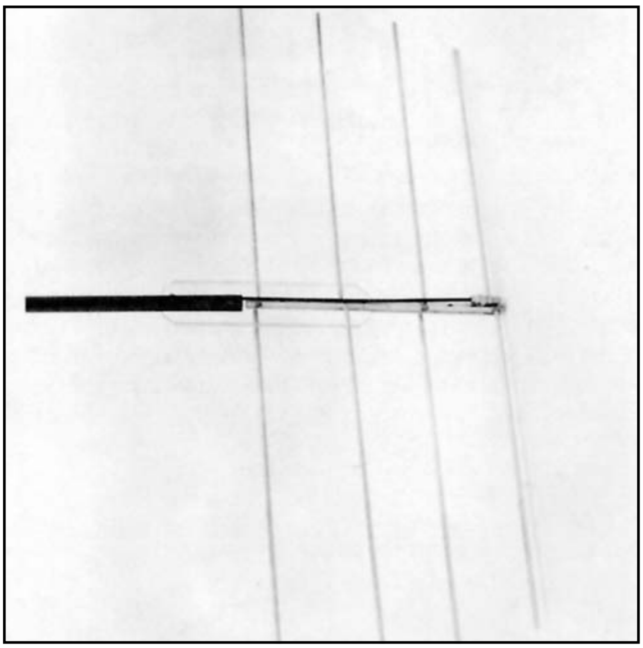

Fig 27—The 144 MHz Pounder. The boom extension at the left of the photo is a 40-inch length of slotted PVC tubing, $^7/_8$-inch outer diameter. The tubing may be clamped to the side of a tower or attached to a mast with a small boom-to-mast plate. Rotating the tubing at the clamp will provide for either vertical or horizontal polarization.

Construction

You can see the general construction approach for

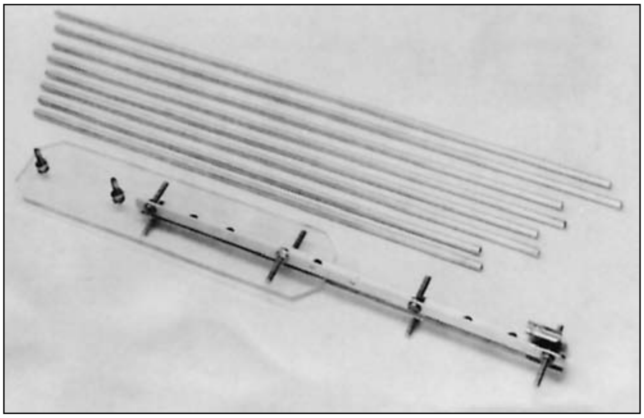

Fig 28—One end of each half element is tapped to fasten onto boom-mounted screws. Disassembly of the array consists of merely unscrewing 8 half elements from the boom. The entire disassembled array creates a small bundle only 21 inches long.

Table 7
Design Parameters for the 144-MHz Pounder

f1 = 143 MHz	Element lengths:
f_n = 148 MHz	ℓ1 = 3.441 feet
B = 1.0350	ℓ2 = 3.165 feet
τ = 0.92	ℓ3 = 2.912 feet
σ = 0.053	ℓ4 = 2.679 feet
Gain = 7.2 dBi = 5.1 dBd	Element spacings:
cot α = 2.6500	d_{12} = 0.365 feet
B_{ar} = 1.2306	d_{23} = 0.336 feet
B_s = 1.2736	d_{34} = 0.309 feet
L = 0.98 feet	Element diameters:
N = 3.90 elements (increase to 4)	All = 0.25 inches
Zt = none	ℓ/diameter ratios:
R_0 = 52 Ω	$\ell 4/diam_4$ = 128.6
Z_{AV} = 312.8 Ω	$\ell 3/diam_3$ = 139.8
σ' = 0.05526	$\ell 2/diam_2$ = 151.9
Z_0 = 75.1 Ω	$\ell 1/diam_1$ = 165.1

Antenna feeder: $^1/_2 \times {}^1/_2 \times {}^1/_{16}''$ angle aluminum spaced $^1/_4''$
Balun: 1:1 (see text)
Feed line: 52-Ω coax (see text)

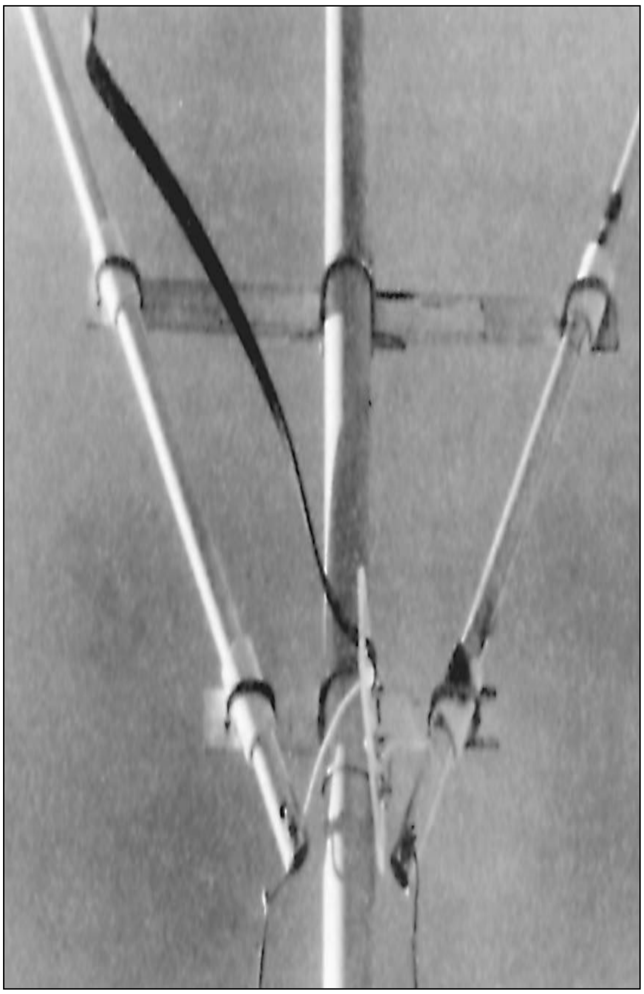

Fig 29—A close-up view of the boom, showing an alternative mounting scheme. This photo shows an earlier 2-element array, but the boom construction is the same for 2 or 4 elements. See the text for details.

Fig 30—The feed arrangement, using a right-angle chassis-mounted BNC connector, modified by removing a portion of the flange. A short length of bus wire connects the center pin to the opposite feeder conductor.

the Pounder in the photographs. Drilled and tapped pieces of Plexiglas sheet, 1/4-inch thick, serve as insulating spacers for the angle aluminum feeder. Two spacers are used, one near the front and one near the rear of the array. Four #6-32 × 1/4-inch pan head screws secure each aluminum angle section to the Plexiglas spacers, as shown in **Figs 29** and **30**. Use flat washers with each screw to prevent it from touching the angle stock on the opposite side of the spacer. Be sure the screws are not so long as to short out the feeder! A clearance of about 1/16 inch is sufficient. If you have doubts about the screw lengths, check the assembled boom for a short with your ohmmeter on a Megohm range.

Either of two mounting techniques may be used for the Pounder. As shown in Figs 27 and 28, the rear spacer measures 10 × 2 1/2 inches, with 45° corners to avoid sharp points. This spacer also accommodates a boom extension of PVC tubing, which is attached with two #10-32 × 1-inch screws. This tubing provides for side mounting the Pounder away from a mast or tower.

An alternative support arrangement is shown in Fig 29. Two 1/2 × 3-inch Plexiglas spacers are used at the front and rear of the array. Each spacer has four holes drilled 5/8 inch apart and tapped with #6-32 threads. Two screws enter each spacer from either side to make a tight aluminum-Plexiglas-aluminum sandwich. At the center of the boom, secured with only two screws, is a 2 × 18-inch strip of 1/4-inch Plexiglas. This strip is slotted about 2 inches from each end to accept hose clamps for mounting the Pounder atop a mast. As shown, the strip is attached for vertical polarization. Alternate mounting holes, visible on the now-horizontal lip of the angle stock, provide for horizontal polarization. Although sufficient, this mounting arrangement is not as sturdy as that shown in Fig 27.

The elements are lengths of thick-wall aluminum tubing, 1/4-inch OD. The inside wall conveniently accepts a #10-32 tap. The threads should penetrate the tubing to a depth of at least 1 inch. Eight #10-32 × 1-inch screws are attached to the boom at the proper element spacings and held in place with #10-32 nuts, as shown in Fig 28. For assembly, the elements are then simply screwed into place.

Note that with this construction arrangement, the two halves of any individual element are not precisely collinear; their axes are offset by about 3/4 inch. This offset does not seem to affect performance.

The Feed Arrangement

Use care initially in mounting and cutting the elements to length. To obtain the 180° crossover feed arrangement, the element halves from a single section of the feeder/boom must alternate directions. That is, for half-elements attached to one of the two pieces of angle stock, elements 1 and 3 will point to one side, and elements 2 and 4 to the other. This arrangement may be seen by observing the element-mounting screws in Fig 28. Because of this mounting scheme, the length of tubing for an element "half" is not simply half of the length given in Table 7. After final assembly, halves for elements 2 and 4 will have a slight overlap, while elements 1 and 3 are extended somewhat by the boom thickness. The best procedure is to cut each assembled element to its final length by measuring from tip to tip.

The Pounder may be fed with RG-58 or RG-59 coax and a BNC connector. A modified right-angle chassis-mount BNC connector is attached to one side of the feeder/boom assembly for cable connection, Fig 30. The modification consists of cutting away part of the mounting flange that would otherwise protrude from the boom assembly. This leaves only two mounting-flange holes, but these are sufficient for a secure mount. A short length of small bus wire connects the center pin to the opposite side of the feeder, where it is secured under the mounting-screw nut for the shortest element.

For operation, you may secure the coax to the PVC boom extension or to the mast with electrical tape. You should use a balun, especially if the Pounder is operated with vertical elements. A choke type of balun is satisfactory, formed by taping 6 turns of the coax into a coil of 3 inches diameter, but a bead balun is preferred (see Chapter 26). The balun should be placed at the point where the coax is brought away from the boom. If the mounting arrangement of Fig 29 is used with vertical polarization, a second balun should be located approximately 1/4 wavelength down the coax line from the first. This will place it at about the level of the lower tips of the elements. For long runs of coax to the transmitter, a transition from RG-58 to RG-8 or from RG-59 to RG-9 is suggested, to reduce line losses. Make this transition at some convenient point near the array.

No shorting feeder termination is used with the array described here. The antenna feeder (phase-line) Z_0 of this array is in the neighborhood of 120 Ω, and with a resulting feed-point impedance of about 72 Ω. The theoretical mean SWR with 52 Ω line is 72/52 or 1.4 to 1. Upon array completion, the measured SWR (52-Ω line) was found to be relatively constant across the band, with a value of about 1.7 to 1. The Pounder offers a better match to 72-Ω coax.

Being an all-driven array, the Pounder is more immune to changes in feed-point impedance caused by nearby objects than is a parasitic array. This became obvious during portable use when the array was operated near trees and other objects… the SWR did not change noticeably with antenna rotation toward and away from those objects. Consequently, the Pounder should behave well in a restricted environment, such as an attic. Weighing just one pound, this array indeed does give a good account of itself.

Log Periodic-Yagi Arrays

Several possibilities exist for constructing high-gain arrays that use the log periodic dipole array concept. One technique is to add parasitic elements to the LPDA to increase both the gain and the front-to-back ratio for a specific frequency within the passband of the LPDA. The LPDA-Yagi combination is simple in concept. It utilizes an LPDA group of driven elements, along with parasitic elements at normal Yagi spacings from the active elements of the LPDA.

The LPDA-Yagi combinations are endless. An example of a single-band high-gain design is a 2- or 3-element LPDA for 21.0 to 21.45 MHz with the addition of two or three parasitic directors and one parasitic reflector. The name Log-Yag (log-cell Yagi) array has been coined for these hybrid antennas. The LPDA portion of the array is of the usual design to cover the desired bandwidth, and standard Yagi design procedures are used for the parasitic elements. Information in this section is based on a Dec 1976, *QST* article by P. D. Rhodes, K4EWG, and J. R. Painter, W4BBP, "The Log-Yag Array."

THE LOG-YAG ARRAY

The Log-Yag array, with its added parasitic elements, provides higher gain and greater directivity than would be realized with the LPDA alone. Yagi arrays require a long boom and wide element spacing for wide bandwidth and high gain, because the Q of the Yagi system increases as the number of elements is increased or as the spacing between adjacent elements is decreased. An increase in the Q of the Yagi array means that the total operating bandwidth of the array is decreased, and the gain and front-to-back ratio specified in the design are obtainable only over small portions of the band. [Older Yagi designs did indeed exhibit the limitations mentioned here. But modern, computer-aided design has resulted in wideband Yagis, provided that sufficient elements are used on the boom to allow stagger tuning for wide-band coverage. See Chapter 11.—*Ed.*]

The Log-Yag system overcomes this difficulty by using a multiple driven element cell designed in accordance with the principles of the log periodic dipole array. Since this log cell exhibits both gain and directivity by itself, it is a more effective wide-band radiator than a simple dipole driven element. The front-to-back ratio and gain of the log cell can then be improved with the addition of a parasitic reflector and director.

It is not necessary for the parasitic element spacings to be large with respect to wavelength, since the log cell is the determining factor in the array bandwidth. As well, the element spacings within the log cell may be small with respect to a wavelength without appreciable deterioration of the cell gain. For example, decreasing the relative spacing constant (σ) from 0.1 to 0.05 will decrease the array gain by less than 1 dB.

A Practical Example

The photographs and figures show a Log-Yag array for the 14-MHz amateur band. The array design takes the form of a 4-element log cell, a parasitic reflector spaced at 0.085 λ_{max}, and a parasitic director spaced at 0.15 λ_{max} (where λ_{max} is the longest free-space wavelength within the array passband). Array gain is almost unaffected with reflector spacings from 0.08 λ to 0.25 λ, and the increase in boom length is not justified. The function of the reflector is to improve the front-to-back ratio of the log cell, while the director sharpens the forward lobe and decreases the half-power beamwidth. As the spacing between the parasitic elements and the log cell decreases, the parasitic elements must increase in length.

The log cell is designed to meet upper and lower band limits with $\sigma = 0.05$. The design parameter τ is dependent on the structure bandwidth, B_s. When the log periodic design parameters have been found, the element length and spacings can be determined.

Array layout and construction details can be seen in Figs 31 through 34. Characteristics of the array are given in **Table 8**.

The method of feeding the antenna is identical to that of feeding the log periodic dipole array without the parasitic elements. As shown in **Fig 31**, a balanced feeder is required for each log-cell element, and all adjacent elements are fed with a 180° phase shift by alternating connections. Since the Log-Yag array will be covering a relatively small bandwidth, the radiation resistance of the narrow-band log cell will vary from 80 to 90 Ω (tubing

Table 8
Log-Yag Array Characteristics

1) Frequency range	14 to 14.35 MHz
2) Operating bandwidth	B = 1.025
3) Design parameter	$\tau = 0.946657$
4) Apex half angle	$\alpha = 14.921°$; cot $\alpha = 3.753$
5) Half-power beamwidth	42° (14 to 14.35 MHz)
6) Bandwidth of structure	Bs = 1.17875
7) Free-space wavelength	λ_{max} = 70.28 feet
8) Log cell boom length	L = 10.0 feet
9) Longest log element	$\ell 1$ = 35.14 feet (a tabulation of element lengths and spacings is given in Table 9)
10) Forward gain (free space)	8.2 dBi
11) Front-to-back ratio	32 dB (theoretical)
12) Front-to-side ratio	45 dB (theoretical)
13) Input impedance	Z_0 = 37 Ω
14) SWR	1.3 to 1 (14 to 14.35 MHz)
15) Total weight	96 pounds
16) Wind-load area	8.5 sq feet
17) Reflector length	36.4 feet at 6.0 foot spacing
18) Director length	32.2 feet at 10.5 foot spacing
19) Total boom length	26.5 feet

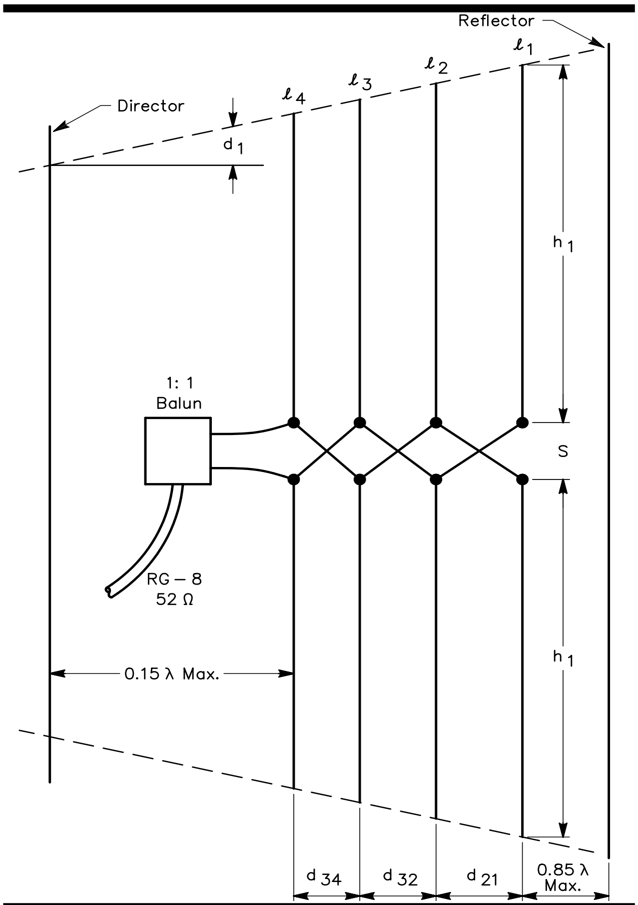

Fig 31—Layout of the Log-Yag array.

Table 9
Log-Yag Array Dimensions

Element	*Length Feet*	*Spacing Feet*
Reflector	36.40	6.00 (Ref. to ℓ1)
ℓ1	35.14	3.51 (d_{12})
ℓ2	33.27	3.32 (d_{23})
ℓ3	31.49	3.14 (d_{34})
ℓ4	29.81	10.57 (ℓ4 to dir.)
Director	32.20	

elements) depending on the operating bandwidth. The addition of parasitic elements lowers the log-cell radiation resistance. Hence, it is recommended that a 1:1 balun be connected at the log-cell input terminals and 50-Ω coaxial cable be used for the feed line.

The measured radiation resistance of the 14-MHz Log-Yag is 37 Ω over the frequency range from 14.0 to 14.35 MHz. It is assumed that tubing elements will be used. However, if a wire array is used, then the radiation resistance R_0 and antenna-feeder input impedance Z_0 must be calculated so that the proper balun and coax may be used. The procedure is outlined in detail in an earlier part of this chapter. However, programs such as *LPCAD28* are also suitable to automate the calculations.

Table 9 has array dimensions. **Tables 10** and **11** contain lists of the materials necessary to build the Log-Yag array.

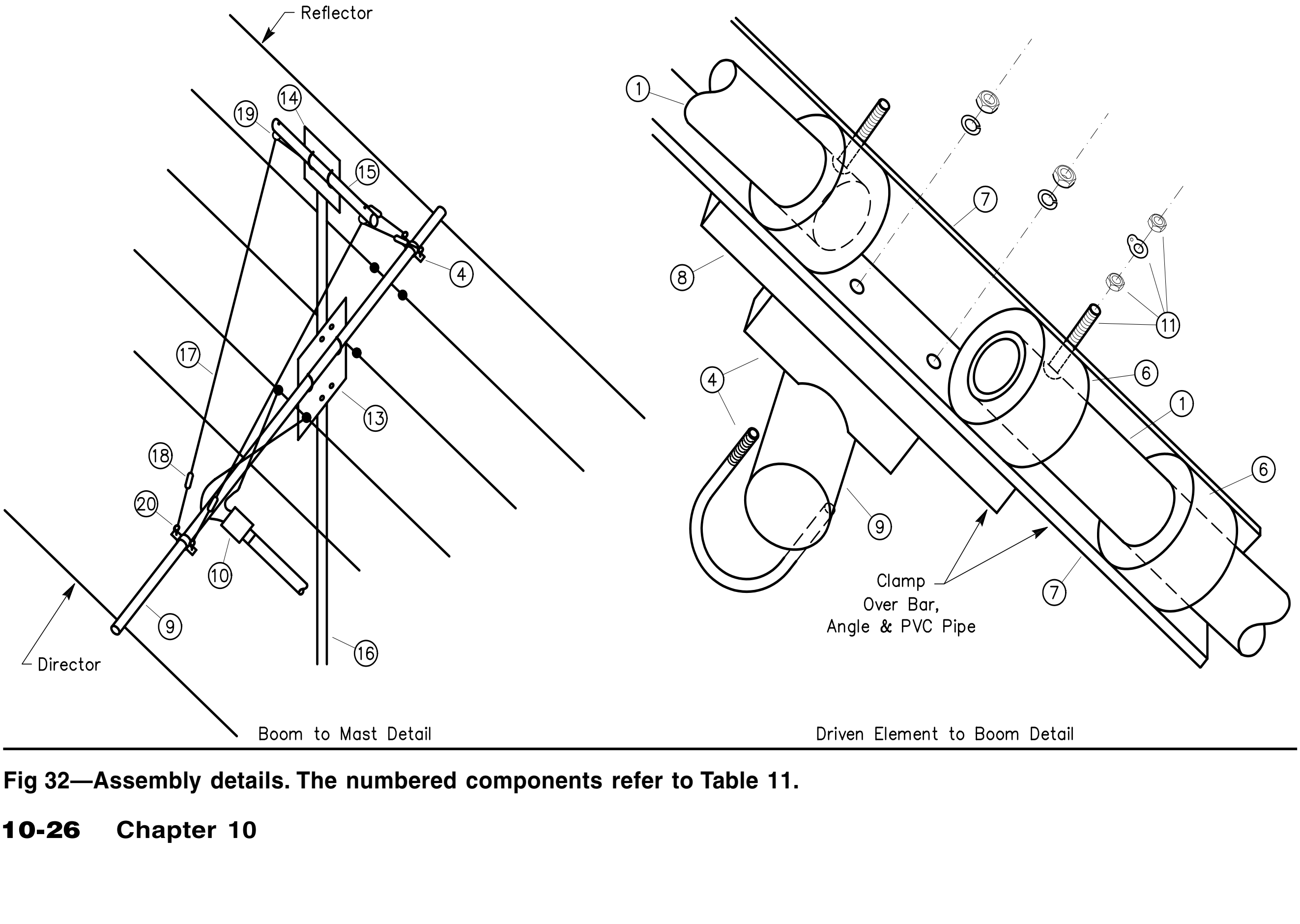

Fig 32—Assembly details. The numbered components refer to Table 11.

Table 10
Element Material Requirements: Log-Yag Array

	1-in. Tubing		*7/8-in. Tubing*		*3/4-in. Tubing*		*1 1/4-in. Angle*	*1 1/4-in. Bar*
	Len. Feet	*Qty*	*Len. Feet*	*Qty*	*Len. Feet*	*Qty*	*Len. Feet*	*Len. Feet*
Reflector	12	1	6	2	8	2	None	None
ℓ1	6	2	6	2	8	2	3	1
ℓ2	6	2	6	2	8	2	3	1
ℓ3	6	2	6	2	6	2	3	1
ℓ4	6	2	6	2	6	2	3	1
Director	12	1	6	2	6	2	None	None

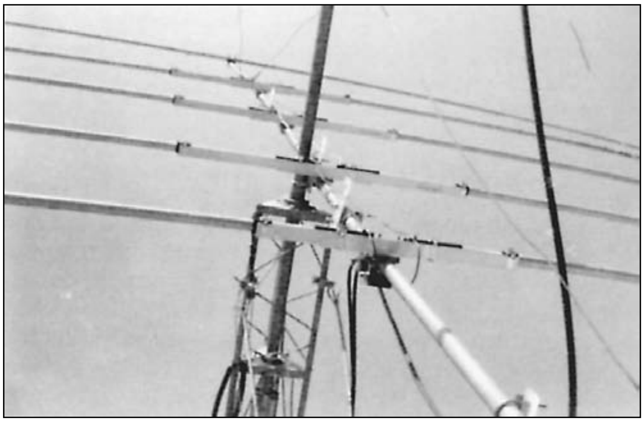

Fig 33—The attachment of the elements to the boom.

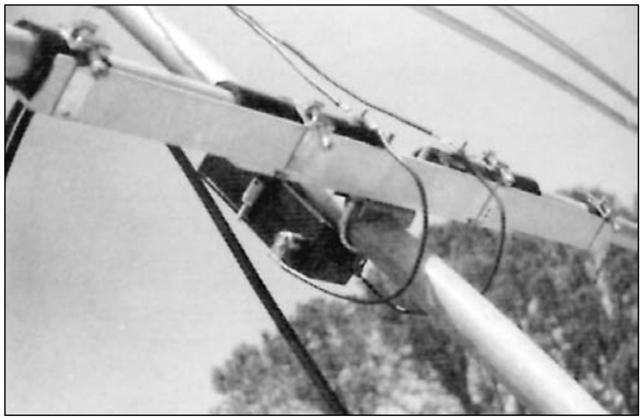

Fig 34—Looking from the front to the back of the Log-Yag array. A truss provides lateral and vertical support.

Table 11
Materials List, Log-Yag Array

1) Aluminum tubing—0.047 in. wall thickness
   1 in.—12 ft lenths, 24 lin. ft
   1 in.—12 ft or 6 ft lengths, 48 lin. ft
   7/8 in.—12 ft or 6 ft lengths, 72 lin. ft
   3/4 in.—8 ft lengths, 48 lin. ft
   3/4 in.—6 ft lengths, 36 lin. ft
2) Stainless steel hose clamps—2 in. max, 8 ea
3) Stainless steel hose clamps—1 1/4 in. max, 24 ea
4) TV-type U bolts—1 1/2 in., 6 ea
5) U bolts, galv. type: 5/16 in. × 1 1/2 in., 6 ea
5A) U bolts, galv. type: 1/4 in. × 1 in., 2 ea
6) 1 in. ID water-service polyethylene pipe 160 lb/in.^{2} test, approx. 1 3/8 in. OD, 7 lin. ft
7) 1 1/4 in. × 1 1/4 in. × 1/8 in. aluminum angle—6 ft lengths, 12 lin. ft
8) 1 in. × 1/4 in. × 1/4 in. aluminum angle—6 ft lengths, 6 lin. ft
9) 1 1/4 in. top rail of chain-link fence, 26.5 lin. ft
10) 1:1 toroid balun, 1 ea
11) No. 6-32 × 1 in. stainless steel screws, 8 ea
    No. 6-32 stainless steel nuts, 16 ea
    No. 6 solder lugs, 8 ea
12) #12 copper feed wire, 22 lin. ft
13) 12 in. × 6 in. × 1/4 in. aluminum plate, 1 ea
14) 6 in. × 4 in. × 1/4 in. aluminum plate, 1 ea
15) 3/4 in. galv. pipe, 3 lin. ft
16) 1 in. galv. pipe—mast, 5 lin. ft
17) Galv. guy wire, 50 lin. ft
18) 1/4 in. × 2 in. turnbuckles, 4 ea
19) 1/4 in. × 1 1/2 in. eye bolts, 2 ea
20) TV guy clamps and eyebolts, 2 ea

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