By Bill Jones, K8CU

Practical High Performance HF Log Periodic Antennas

This article describes the electrical and mechanical design process for two LPs that cover the HF bands from 10-30 MHz.

How do you go about achieving good DX performance on all HF amateur bands from 10 to 30 MHz without using separate antennas for each band? One alternative that occurred to me was the log periodic (LP) antenna. Although I thought that the penalty for using this type of antenna was poor front-to-back (F/B) ratio and forward gain when compared to other antennas, I decided to take a closer look.

Electrical Design

I had used three-element monoband Yagi antennas for years and considered them to be good DX antennas, so I chose that design as the performance standard for comparison. Using modeling software, I tested several log periodic antennas of six to eight elements with boom lengths of 16 to 20 feet. The software confirmed that these antennas were inferior, just as I expected. I then found that adding more elements on a longer boom would work much better.

The antenna modeling software I used for this project is *NEC-WIRES*, a *NEC2*-based software package from K6STI,[1] and *NEC-Win Plus*, a *Windows*-based product from Nittany Scientific.[2] If you choose to use other software to model log periodic antennas, make sure the software will correctly model the phasing transmission line that runs down the center of the boom and connects each element together. *MININEC* programs won't handle this transmission line properly. *NEC2* antenna models use the *TL* (transmission line) facility for modeling, which produces a nonradiating, lossless mathematical transmission line for the model. Don't expect to model this line accurately with a number of small wires and connections as part of the antenna.

The quantity of model segments for the elements must be odd so that the phasing line is centered. The number of segments per wire is stepped in accord with the wire length and is the nearest odd integer to a calculated number. Starting with eleven segments for the shortest element, longer elements have progressively more segments for the best possible alignment of segment junctions. The *NEC2* antenna file is available and may be downloaded from the author's Web site at **www.realhamradio.com** and imported into your antenna design software:

- .ANT for the VOA Export File (filename LOG.ANT)
- .NWP for the *Nittany NEC-win Plus*+ (filename LOG.NWP)
- .NEC for the *NEC* file (filename LOG.NEC)

I tested dozens of various log periodic arrays—from very small ones to those with impractically long booms. As the boom length and number of elements increased, the F/B ratio became respectable. My final 14-30 MHz antenna has the same gain and F/B characteristics as a set of three-element monoband antennas, with the advantage of a single feed line.

Some log periodic antennas have reduced performance at each end of the desired frequency span. This is because few elements are active at the frequency extremes to provide good gain and F/B ratio. Some antenna designers have resorted to using passive reflectors or directors to boost performance. I tried to modify the antenna element spacing and lengths of traditional log periodic designs and was able to successfully optimize the antenna to give good 14-30 MHz performance without requiring additional passive elements. The optimized antenna has 13 elements and a boom length of 36 feet.

I wanted 30-meter coverage, so I

[1]Notes appear on page 37.

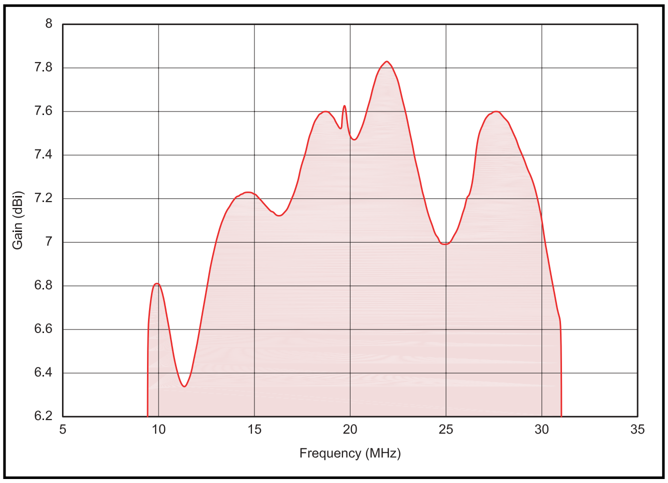

Figure 1—Calculated free-space forward gain for the 15-element 10-30 MHz Log Periodic.

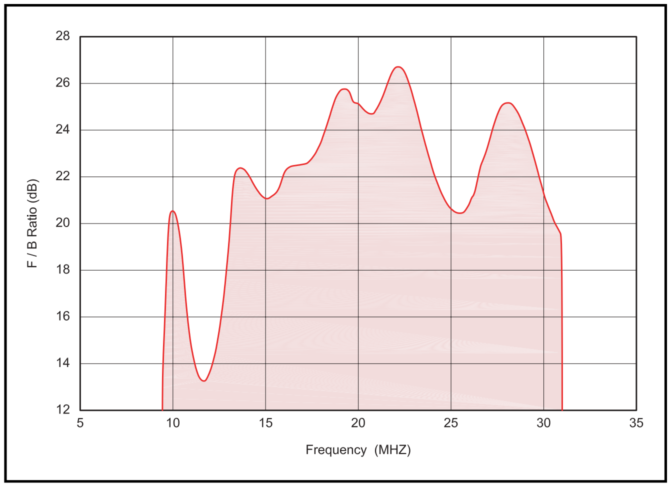

Figure 2—Calculated free-space F/B ratio for the 15-element 10-30 MHz Log Periodic.

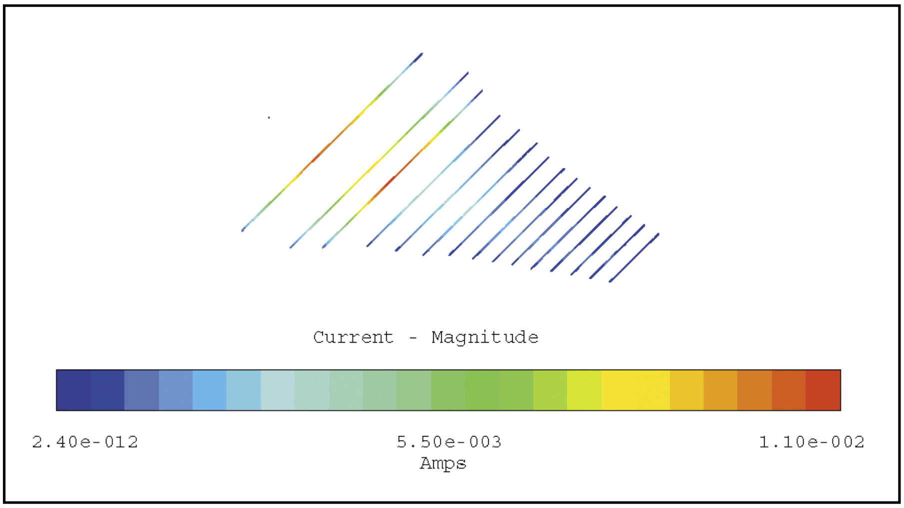

Figure 3—Element current magnitude at 10.1 MHz. Note that while all of the elements show some current, the first and third are the most active.

created a second antenna by adding two more elements, lengthened the boom, and optimized again for the 30-meter band. The new design had a boom length of 48 feet. 30-meter performance was down somewhat from the standard 3-element monoband antenna—within ½ dB in forward gain and a good F/B ratio of 20 dB. Since only two elements were added to give this additional coverage, I decided that reduced forward gain was acceptable.

Sweeping the design frequency in steps of 100 kHz and tabulating the results across the entire operating bandwidth resulted in the gain and F/B ratio plots shown in Figures 1 and 2. It's interesting to note the 30-meter performance of the antenna. Only two elements have been added to give coverage for this band, but the forward gain falls midway between that of a two and three element monoband Yagi. F/B ratio is 20 dB, which is better than a two-element monoband Yagi and almost as good as a full-sized three-element Yagi at 25 dB.

A recently published article[3] stated that all elements in a log periodic antenna are active at all frequencies. All elements are active forward of the one most active at any given frequency. Figure 3 shows a modeling software graphic of element current magnitudes when the array is operating at 10.1 MHz. Significant element current at this frequency is present on some elements other than the two added for 30 meters. This makes sense and explains the improved 30-meter performance.

Another improvement to 10 MHz performance resulted from adding a shorted stub to the rear element. This consists of an electrical length (100% velocity factor) of 78.74 inches of 450 Ω open-wire transmission line connected at the rear element's antenna terminals with the far end shorted. To get the physical length, multiply this by the line's velocity factor. Adding the stub improves F/B ratio on 30 meters, the band on which the rear element has the most effect, by 9 dB without significant effect on gain or SWR on the other bands. As I constructed it, the stub is coiled up and attached to the boom with acceptable results. To eliminate interactions in the coiled line or with the boom pipe, the best solution would be to use a lightweight extension of 1-inch diameter PVC pipe fastened to the boom using stainless hose clamps, with the ladder line then taped to the PVC pipe. The resulting pattern and SWR response make for a nice 30-meter antenna.

The main feed-point impedance of both antennas is 200 Ω. I matched this value to a 50 Ω coaxial line using a homemade broadband 4:1 toroidal balun suitable for legal limit power operation.

Mechanical Design

NEC2 antenna design software uses a single wire of a constant diameter for each element to calculate antenna characteristics. Since most HF antennas require elements of tapering size, a conversion method is required. I used a spreadsheet template from Dave Leeson, W6NL's, Yagi design book,[4] which calculates the conversions from practical elements to their theoretical equivalents. The spreadsheet is constructed with multiple columns—one column per element section. Element section diameters, wall thickness and lengths are entered. The software does more than just tapered element conversion. Antenna element

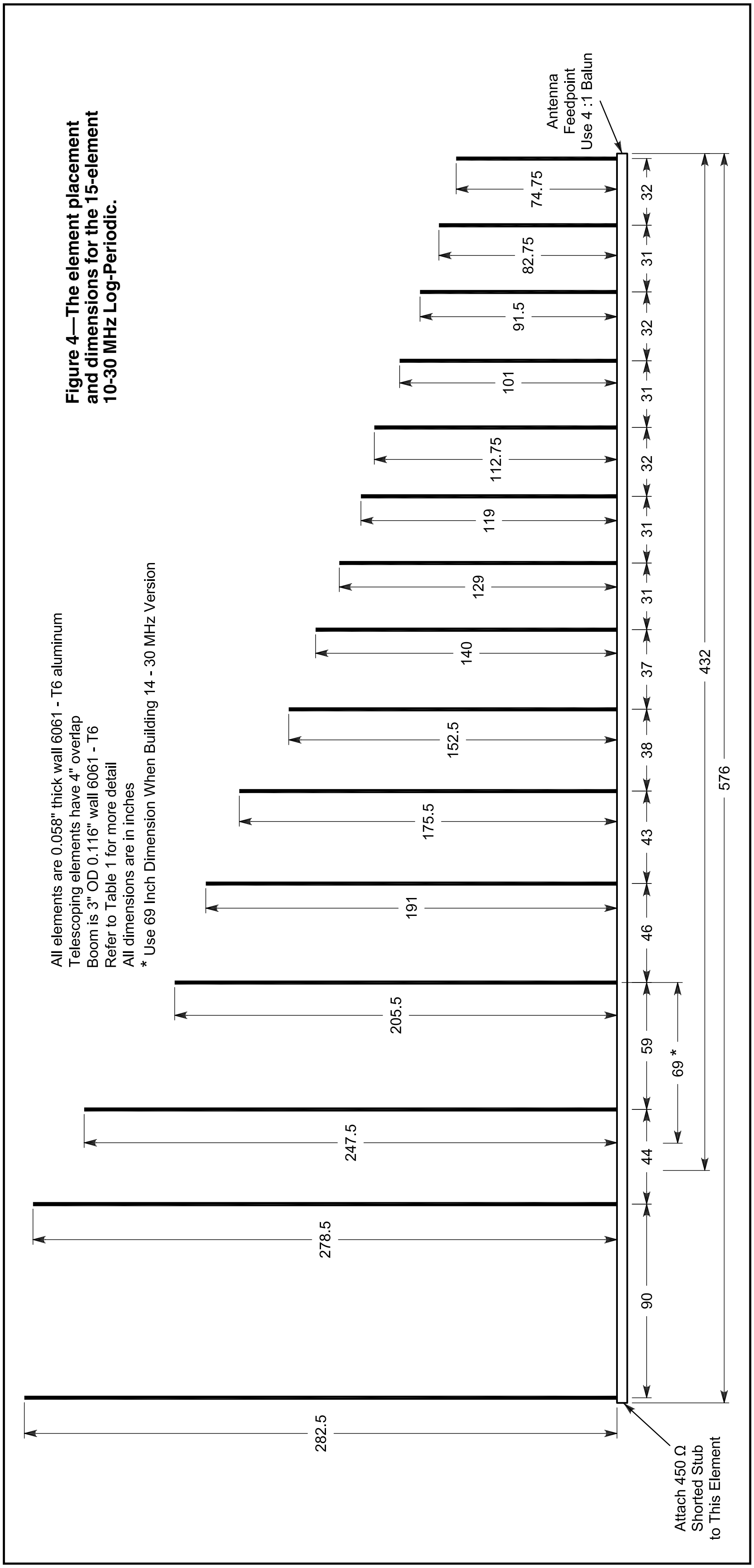

Figure 4—The element placement and dimensions for the 15-element 10-30 MHz Log-Periodic.

weight, wind speed survival, ice loading characteristics, and more are calculated as you design each element. Many of Leeson's ideas for Yagi antenna physical design in this book apply directly to log periodic antennas. Reading this book and applying the mechanical design fundamentals along with using the software is recommended without hesitation. Using it, you can make mechanically reliable antennas that perform electrically as intended.

Another spreadsheet template, entitled "Calculation of Element Strength and Equivalent Length," calculates the wind speed survival of an element. My county in Ohio has a 70 MPH requirement.[5] Enter the physical tubing diameters and lengths for the element, adjusting the lengths of each tapered section to keep the calculated reactance as close to 0 Ω as possible. (When the spreadsheet shows a low reactance, the tapered element is equivalent to the *NEC-2* single diameter length.) If the wind speed survival of each element section is at or above your required wind speed survival, and the element section is practical to build, you are done. If not, increase the diameter, wall thickness, or shorten the lengths of individual element sections (always keeping the reactance near zero) until the element design will survive at the required wind speed. High wind speed survival speeds are relatively easy for the shorter elements. Those in the 14 MHz range and below require more care.

Once each element is designed, the weight and area calculations of each are then used in another spreadsheet that calculates boom survival characteristics in a similar way. Start with single elements, and then work on the boom and boom guys.

The advantage of this spreadsheet technique is simplicity and speed. You are only working on one element (or boom) at a time, and the spreadsheet runs very quickly, even on older computers. The spreadsheets are provided in *Lotus 1-2-3* format (WKS) and will work with practically any spreadsheet program, such as Borland/Corel *Quattro Pro* or Microsoft *EXCEL*. This algorithm for tapered element conversion is summarized in *The ARRL Antenna Book*.[6]

Construction

The center section of the 10 MHz and the 14-30 MHz elements are different because the larger 10 MHz elements are 50 feet long and require a heavier boom to element mounting method. The tubing diameter of the 14-30 MHz elements is all standardized at an initial 1-inch diameter, while the two 10 MHz elements start out at 2 inches. Each element type has a standardized construction method. All use the same tubing diameters and initial lengths, then taper in a uniform fashion. The individual element's final tip length then determines the resonant frequency. The complete set of element tubing sizes and dimensions is shown in Table 1. Note that these dimensions are for the exposed lengths of tubing visible after assembly. Four inches of tubing overlap are required for assembly where a smaller tube fits closely into the next larger tube.

The larger antenna may be built from the smaller one by adding a boom extension and two elements. With one exception, the element lengths and boom spacing on the smaller antenna remain the same when the larger antenna components are added. The boom position of the largest element on the smaller antenna moves 10 inches. More details of these changes and the element layout are shown in Figure 4.

A log periodic antenna requires each element center to be split and insulated from the supporting boom. The insulating center for the large 2-inch elements is a solid rod of PVC, UHMW, or similar insulating material, 1.875 inches in diameter and 12 inches long. One rod is required for each of the two larger elements.[7] Since this isn't a standard diameter, it will be necessary to turn a larger diameter rod to this size using a lathe. Most machine shops can handle this job for you. Use a section of 2-inch diameter aluminum tubing to verify proper fit. Thanks to George Crego, WD8ATX, for his expert lathe work making my insulators. The mechanical drawing for the larger 2-inch 10 MHz element is shown in Figure 5.

The boom guy detail of Figure 5 shows how 0.25-inch-thick 3-inch aluminum angle is used as the basis for the boom guy anchors. Galvanized 1-inch closed-end eyebolts are attached to the aluminum angle, which is attached to the boom using one McMaster #8896T57 3-inch stainless U-bolt clamp. One U-bolt is required for each boom guy. Two identical U-bolts are also used to attach the 2-inch element-mounting bracket to the boom.

Surrounding the aluminum element is a 12-inch long piece of Schedule 40 PVC pipe with a 1/4-inch slit cut lengthwise in it. This allows the PVC pipe to compress securely around the aluminum element. A pair of 1/4-20 × 2.5-inch stainless steel machine screws with double nuts serves as terminals to connect the phasing transmission line. This assembly is then mounted using four McMaster #3042T57 stainless U-bolts on a support plate made of 3-inch aluminum angle, 8 inches long. These two larger elements are about 50 feet long, and this mounting arrangement has proven to be trouble-free. All elements are mounted below the boom.

The insulating center for the smaller 14-30 MHz elements was originally made with a custom designed UHMW polyethylene block with an integral ultraviolet light inhibitor that has worked well in this application. To make it easier for others to duplicate this antenna design, I have redefined the elements to now use commercially available components.[8]

The mechanical drawing for the smaller 14-30 MHz element is shown in Figure 6. The construction method for the smaller elements uses similar, but smaller components. A solid fiberglass rod of 7/8-inch diameter fits inside the two 1-inch diameter aluminum element ends. One-inch PVC pipe with a 1/4-inch slot cut lengthwise fits around each tubing end. This assembly is supported by two aluminum saddles mounted on a flat 1/4 inch thick aluminum plate measuring 8 × 3.5 inches. Stainless machine screws with double nuts serve as the element electrical terminals. The entire element plate assembly is held to the boom using two McMaster #8896T57 stainless U bolts.

Closed-end 1/8-inch aluminum pop rivets are used to join the overlapping tub-

Table 1
Aluminum Tubing Construction Lengths for 10-30 MHz Log Periodic Antenna

Element Spacing on Boom (Inches)	*Element Resonance (MHz)*	*Half-element Tubing Sizes (inches)*
0	10.33	2.000 × .058 × 36 1.875 × .058 × 32 1.750 × .058 × 32 1.625 × .058 × 32 1.500 × .058 × 32 1.375 × .058 × 32 1.125 × .058 × 32 1.125 × .058 × 53
90	10.48	2.000 × .058 × 36 1.875 × .058 × 32 1.750 × .058 × 32 1.625 × .058 × 32 1.500 × .058 × 32 1.375 × .058 × 32 1.250 × .058 × 32 1.125 × .058 × 48.5
134 (124 for 14-30 MHz version only)	11.69	1.000 × .116 × 72 0.875 × .058 × 68 0.750 × .058 × 68 0.625 × .058 × 39.5
193	14.0	1.000 × .116 × 72 0.875 × .058 × 68 0.750 × .058 × 65.5
239	15.05	1.000 × .058 × 72 0.875 × .058 × 68 0.750 × .058 × 51
282	16.35	1.000 × .058 × 72 0.875 × .058 × 68 0.750 × .058 × 35.5
318	18.7	1.000 × .058 × 72 0.875 × .058 × 68 0.750 × .058 × 12.5
355	20.3	1.000 × .058 × 72 0.875 × .058 × 68
386	22.0	1.000 × .058 × 72 0.875 × .058 × 57
417	23.85	1.000 × .058 × 72 0.875 × .058 × 47
449	25.15	1.000 × .058 × 72 0.875 × .058 × 40.75
480	28.0	1.000 × .058 × 72 0.875 × .058 × 29
512	30.85	1.000 × .058 × 72 0.875 × .058 × 19.5
543	34.0	1.000 × .058 × 72 0.875 × .058 × 10.75
575	37.5	1.000 × .058 × 72 0.875 × .058 × 2.75

ing sections together. Two were used to join the smallest sizes, while eight were used for the largest. Just prior to assembly, coat the overlapping area with a thin coating of aluminum joint compound (Penetrox or equivalent) to inhibit corrosion between the aluminum tubing sections. Stainless or galvanized hardware is used throughout, not just on the electrical connections.

I chose a boom diameter of three inches for both antennas. The mechanical properties of this boom were tested using the mechanical design template from W6NL's book. Boom guys are necessary to keep the boom straight. I checked for possible interaction between the metal boom guy wires and the elements using the *NEC-2* design software. No problems were discovered, probably because the guys are parallel to the boom and at a right angle to the elements. This eliminates the need for Kevlar guy cable. For these antennas, $^3/_{16}$-inch EHS guy wire works well. Use the mating grips for clean and good looking boom guys.

The booms are 6061-T6 aluminum, 3-inch OD × 0.125-inch wall. I used two 24-foot pieces of 3-inch diameter aluminum pipe for the 48-foot boom. The 36-foot boom was made with a 24-foot piece joined to a 12-foot piece. I connected both boom pieces together using a larger outside pipe as a coupler between each section. The boom coupler is made of a 4-foot length of 6061-T6 Schedule 40 aluminum pipe that is 3.5-inch OD × 0.216-inch wall. Pipe doesn't fit closely like tubing does, but the joint was close enough to be practical. I considered using 0.025-inch thin metal shims to make up for the somewhat loose connection, but it wasn't necessary. Use two 2 × 13 × 5 inch galvanized bolts at right angles through the entire boom joint to secure the boom splice section to each boom end. Four boom bolts are required for each antenna.

Any boom sag resulting from a slightly loose boom joint is removed when the boom guys are tightened. Boom guy tension is determined by hanging the antenna at the center of gravity from a cable. With the antenna elements level, sight along the boom and adjust the turnbuckles until it looks straight. The larger 48-foot boom requires four boom guys, while the 36-foot version needs only two. Once in the air, the perfectly straight boom looks great and it stays that way. The mechanical drawing for the boom couplers and vertical guy support is shown in Figure 7.

Make sure to align the eyebolt holes in the vertical boom support to be directly over the boom. This will prevent the boom from bowing when the turnbuckles are adjusted. Two $^1/_2$ × 12 inch galvanized turnbuckles are used for the 36-foot boom antenna. The 48-foot boom version requires four turnbuckles and eye bolts. The vertical boom support is fabricated from a single 2-foot length of $^1/_4$-inch thick, 3-inch aluminum angle.

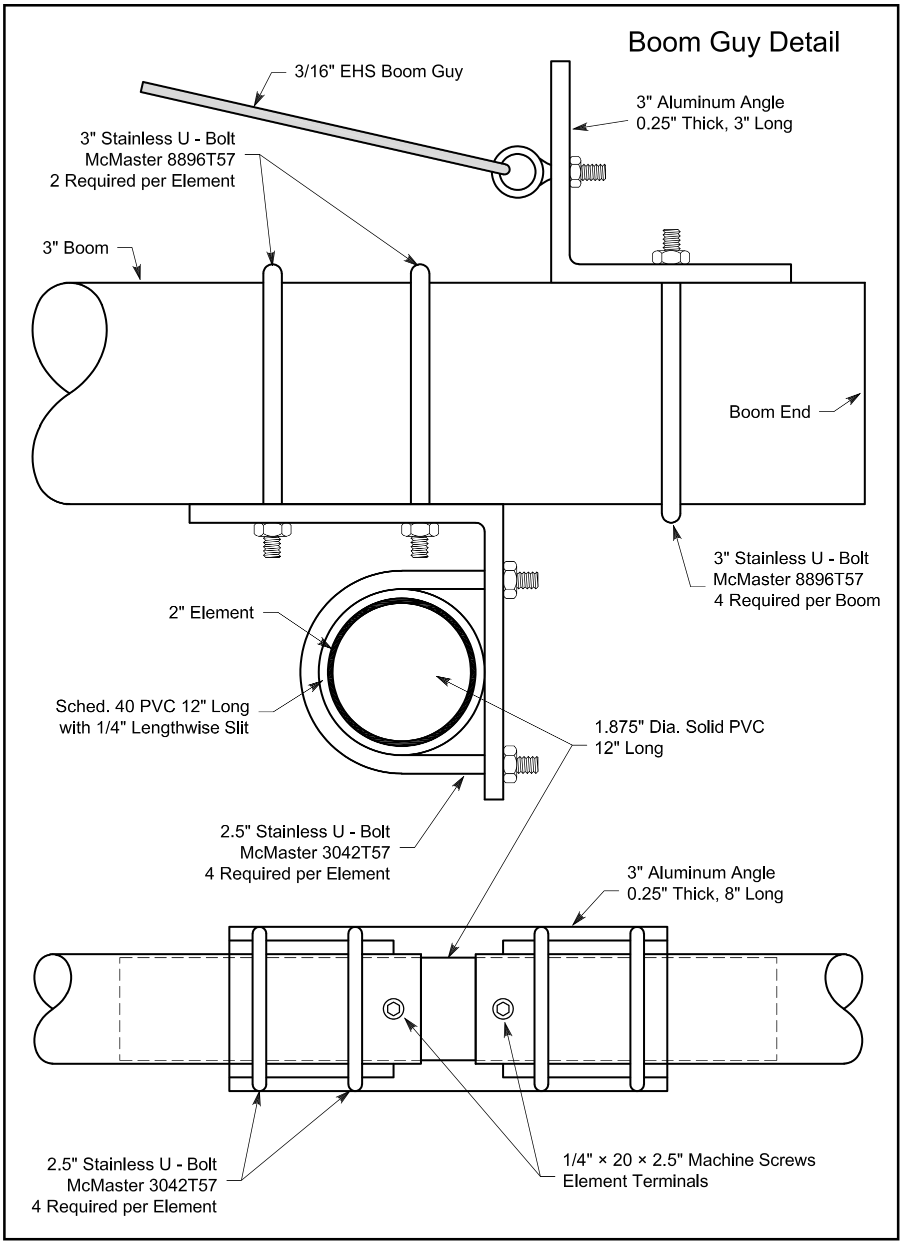

Figure 5—Construction details for the 10 MHz element.

The characteristic impedance of the element phasing transmission line is 325 Ω. This value was chosen for best SWR performance as shown in Figure 8. The measured results agree closely with this graph. I made this using 14-gauge solid copper wire with a spacing of $^1/_2$ inch. I made small insulating standoffs from a plastic block and supported the wires every 18 inches along the boom. Keep the wire spacing close to the desired $^1/_2$-inch spacing and support the phasing line an inch from the boom. To make this phasing line easier to fabricate, consider using commercially available high power 300 Ω twin-lead.[9] Don't use the common TV variety or 450 Ω open-wire line. Remember to connect each element out of phase with the next element by flipping the twin-lead one-half turn between elements. Keep the phasing line spaced an inch from the boom.

The feed-point balun is made using 11 bifilar turns of 14 gauge Teflon-covered wire wound on a relatively low permeability F240-67 ferrite core that fits inside a PVC pipe for weather resistance.[10] Commercial alternatives are also available.[11]

The two antennas were mounted on a

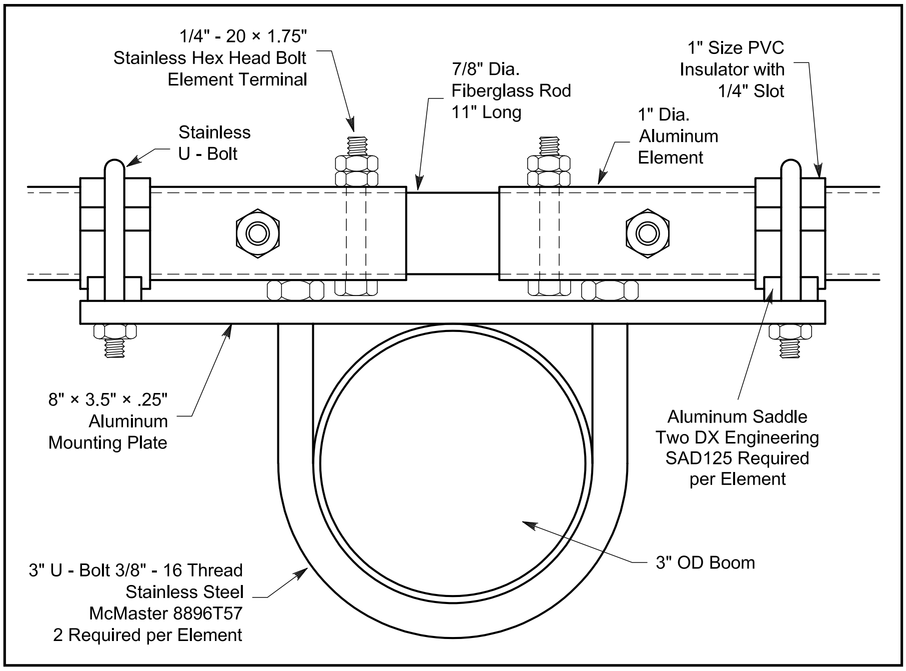

Figure 6—Construction details for the 14-30 MHz elements.

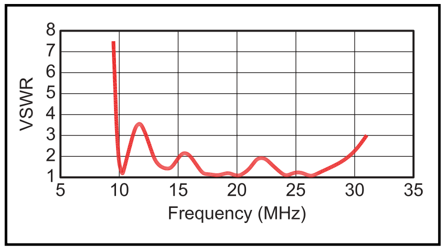

Figure 8—This graph shows the calculated SWR from 10-30 MHz.

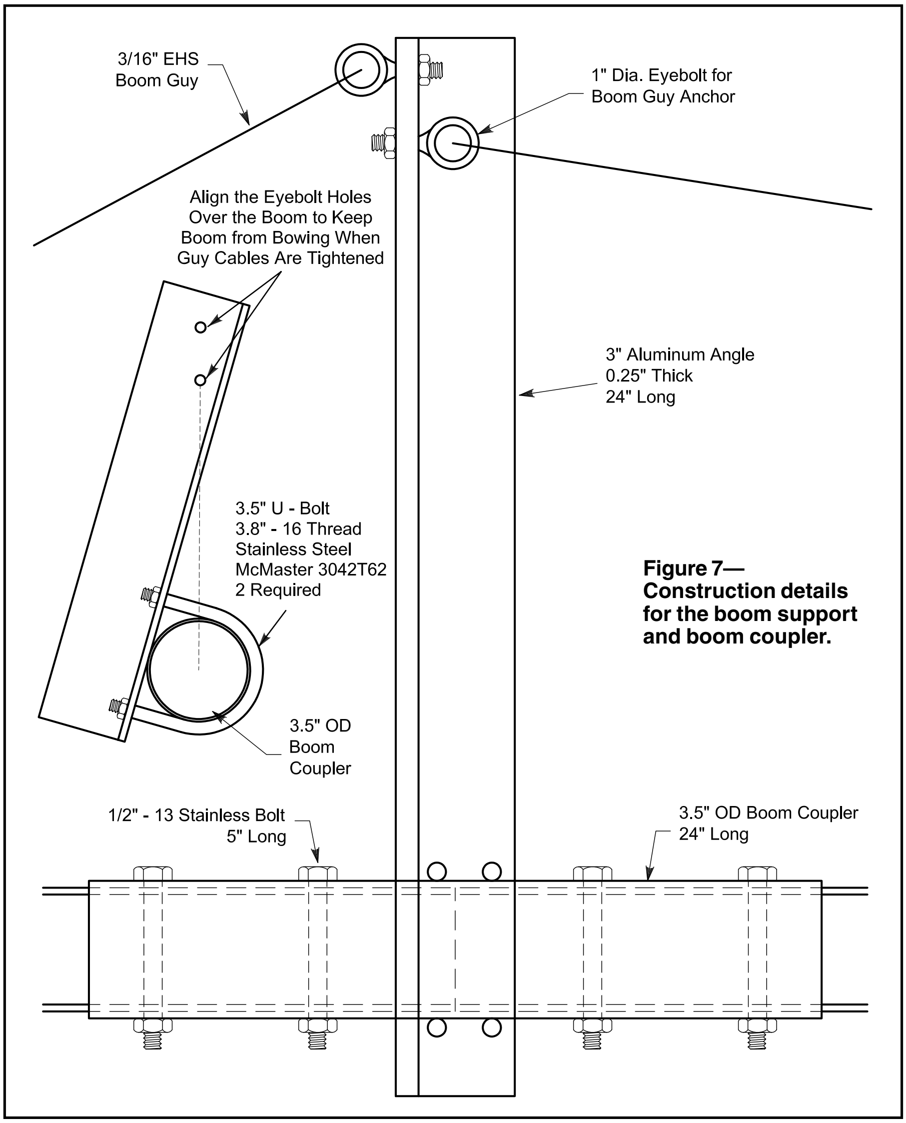

Figure 7—Construction details for the boom support and boom coupler.

100-foot tall RTS rotating tower made of Rohn 55 tower sections. On 14-30 MHz I have a stacked array of the two antennas, with the 48-foot boom antenna at a height of 88 feet, and the 36-foot boom antenna at a height of 44 feet, for a separation of 44 feet. On 30 meters, I have a single gain antenna at a height of 88 feet. Tower guy wire placement prevented the stacking of two identical larger antennas. The boom-to-tower mount is a flat aluminum plate 24 × 12 × 0.25 inches thick. The antenna mounts to it using four 3.5-inch U bolts that fit around the boom section coupling. The plate is secured to the tower using U bolts that fit the Rohn 55 tower legs. A similar plate could be used to make a mount for a single vertical mast.[12] A homemade bottom-both-upper antenna switch using vacuum relays and a stack-matching network allows flexible antenna switching.

Material Sources

The best sources I have found for the aluminum tubing elements are the advertisers in *QST*. They were cheaper than a local supplier, and they had all sizes necessary for these antennas. I have had good luck using the 6063 alloy. The 6-foot sizes required for these antennas may be shipped by UPS. I found the long aluminum pipes for the boom at a local supplier. It costs a lot to ship this material, so look for it locally first. The stainless U-bolt hardware may be hard to find locally. Specific U bolts used in these antennas are identified on the mechanical drawings with the supplier's part number. Other sources may be helpful in supplying these and other necessary parts.

Conclusion

I'm happy with these antennas since they meet my design objective. The performance of the large antenna on 30-meters has been gratifying. Prior antennas on this band were dipoles or verticals. Going to a gain antenna with a good F/B ratio was a pleasant change.

These antennas have been in service since 1995. Seven years later, no problems have developed, due in part to the mechanical design method and conservative construction. No maintenance of any kind has been necessary. Electrical performance has been very good, and the flexible stack arrangement and independent antenna selection have proven to be useful.

Notes

[1] Brian Beezley, K6STI, 3532 Linda Vista, San Marcos, CA 92069; **k6sti@n2.net**. (No longer sold.)

[2] Nittany Scientific, 1733 West 12600 South, Suite 420, Riverton, UT 84065, 801-446-1426; **sales@nittany-scientific.com**; **www.nittany-scientific.com**.

[3] L.B. Cebik, W4RNL, "Notes on Standard Design LPDAs for 3-30 MHz PT2: 164-Foot Boom Designs" *QEX*, Jul/Aug 2000, p 17.

[4] David B. Leeson, W6QHS, *Physical Design of Yagi Antennas*, ARRL, 1992. The software is available for download at **www.arrl.org/notes**. The software is also available on the author's Web site, **www.realhamradio.com**.

[5] Leeson, Figure 2-3, p 2-8. A registered PE who also used this local wind speed number independently evaluated my tower installation. Look up your county's minimum wind speed rating with Champion Radio's wind speed locator at **204.27.195.206/champion/windspeed.html**.

[6] R. Dean Straw, Ed., *The ARRL Antenna Book*, 19th Ed., ARRL, 2000, p 2-17.

[7] Aluminum tubing, guy wire, guy grips, and turnbuckles are available from Texas Towers, **www.texastowers.com**.

[8] A suitable commercial choice is Harbach stainless saddle clamps available from DX Engineering, **www.dxengineering.com**. See their Hints and Ideas page for SAD 125 information on using these clamps as insulated supports. Specific U-bolt part numbers are those of McMaster-Carr Supply Co, **www.mcmaster.com**. They also have the PVC rod used for two of the element insulators, closed end aluminum pop rivets, solid fiberglass and UHMW rod, eyebolts, tubing plastic end caps, and general stainless and galvanized hardware. Two-inch diameter, solid UHMW rods are sold by McMaster-Carr Supply in 1-foot increments as their part number 8701K49. Another source for the solid fiberglass rod is Max Gain Systems, **www.mgs4u.com**.

[9] High-power 300 W #18 ladder line (#562) is available from The RF Connection **www.therfc.com**. The conductors are 19 strands of Cu-clad with poly jacket.

[10] Jerry Sevick, W2FMI, *Transmission Line Transformers*, ARRL, 1987, section 8-3.

[11] An assembled high power 4:1 balun is available from Amidon Corp, **www.amidon-inductive.com/associates_prod_baluns.htm** as part number W2FMI 4:1-HBHT200. W4COX also offers a suitable balun; part #C-4, 5K, **w4cox.hypermart.net**.

[12] *The ARRL Antenna Book* (see Note 6) chapter on construction and antenna materials contains alternative construction methods and many helpful hints on other related topics. Aluminum tubing specifications, element assembly, element clamping techniques, tips on antenna longevity and more are discussed in detail.

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NEW BOOKS

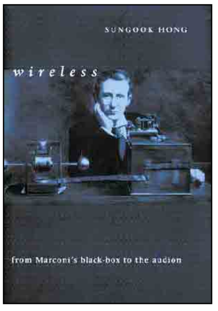
WIRELESS: FROM MARCONI'S BLACK-BOX TO THE AUDION

By Sungook Hong

Published by the MIT Press, Massachusetts Institute of Technology, Cambridge Massachusetts 02142; **mitpress.mit.edu**. *First edition, 2001, hardcover, 6×9 inches with black and white photographs and illustrations. ISBN 0-262-08298-5, 272 pp. $34.95*

Reviewed by Gil McElroy, VE3PKD

◊ Guglielmo Marconi is one of those figures in the early history of wireless and radio communications who have never seemed to shake off controversy. Though generally accepted as valid, his claim to have successfully made the first transatlantic wireless transmission on December 12, 1901 is still subject to debate by some scholars. And he has been accused by many over the decades of having pilfered ideas and the inventions of others. Marconi has had his ups and downs, and in *Wireless: From Marconi's Black-Box to the Audion*, University of Toronto professor Sungook Hong seeks to reclaim the high ground for this seminal figure. Along the way, he offers fascinating insights into the historical context for such inventions as the vacuum tube, and why Marconi's first transatlantic transmission was the three dits of the Morse code letter "S."



Marconi's initial experiments with wireless were conducted at his family's home in Italy, but in early 1896, he moved to England (his mother's homeland) to continue his work in earnest. While he impressed some of the leading British wireless researchers, the 22 year-old Italian upstart succeeded in ruffling the feathers of others. Foremost amongst those was Oliver Lodge, a pioneer in British wireless circles who would proclaim technological precedence over Marconi. Hong delves in detail into Lodge's claim of having successfully demonstrated a wireless telegraphy system before Marconi, arguing that a combination of wounded professional pride and nationalistic fervor led Lodge and his apologists to assert themselves against Marconi and build a claim upon the flimsiest of evidence.

Perhaps the most interesting aspect of *Wireless* is Hong's examination of the professional relationship between Marconi and John Ambrose Fleming, inventor of the vacuum tube. In 1899, well before that achievement, Fleming was formally involved with Marconi as a scientific advisor, acting as an important intermediary between the self-taught inventor and the British scientific establishment, and beginning work on developing the technology that would be needed to make a transatlantic attempt. (The Morse Code letter "S" was chosen for the attempt because of a defect in the transmitter; when keyed, it was unable to produce dashes without generating a dangerous arc across the spark gap apparatus.) A professor of Electrical Engineering at University College in London, Fleming brought to Marconi's work a solid foundation in electrical theory and practice that would prove invaluable. Fleming was aware of the importance of his contributions, and was disappointed by the lack of recognition afforded them, especially following the success of the transatlantic transmission for which he was given virtually no credit.

The strain between Marconi and Fleming reached the breaking point during what came to be known as the "Maskelyne Affair." On June 4, 1903, Fleming delivered a public lecture in London on Marconi's newly developed system of tuning as a means of avoiding interference between separate wireless signals. To demonstrate its importance, a series of prearranged transmissions were to be received at the lecture site. To Fleming's anger and great embarrassment, they were deliberately interfered with by another station that transmitted the word "rats" and an unflattering limerick about Marconi. The culprit was one Nevil Maskelyne, a self-taught wireless experimenter who had become a major critic of Marconi's after an unsuccessful attempt at devising a wireless system for the insurance company Lloyd's of London (which then turned to Marconi to provide them with a proven communications system). Fleming's credibility was damaged by the event, and his value to Marconi diminished. When his contract expired several months later, it was not renewed.

It was Fleming's desire to rehabilitate himself in Marconi's eyes and reestablish a working professional relationship that, in part, led to his invention of a high-frequency ac rectifier—the vacuum tube—a year later. It succeeded, and in 1905 he rejoined the Marconi Company in his old position of scientific advisor. Though Fleming's claim to the invention is not in question, he saw the device as little more than a useful laboratory tool. Hong asserts Marconi's visionary preeminence by stating that it was he, not Fleming, who "transformed the thermionic valve into a sensitive detector for wireless telegraphy." In doing so, he transformed wireless.

Wireless is marred only by minor, albeit annoying, errors. A photograph of Marconi posing with the wireless apparatus he brought to England from Italy is misdated as having been taken in 1869 (five years before his actual birth) when in fact it was the year of his move to England, and radio pioneer (and co-inventor of coaxial cable) Lloyd Espenschied's name is consistently misspelled. However, Sungook Hong's cogent arguments for reasserting Marconi's right to a place at the apex of the wireless pantheon makes *Wireless: From Marconi's Black-Box to the Audion* a valuable addition to the growing body of literature devoted to achievements of this complex and controversial figure.