VHF/UHF WORLD

Joe Reisert W1JR

optimized 2- and 6-meter yagis

Several years ago I decided to take a different approach to 2-meter EME. The idea was to build an array of eight small Yagis mounted on a short tower. The stacking frame would be attached to a single boom not exceeding 30 feet. Such a system could be mounted conveniently in my back yard with minimum interference to existing structures and would be easily transportable for EME DXpeditions.

It seemed reasonable that a physically small Yagi with a clean radiation pattern and high gain-per-unit boomlength could be designed.[1] Small Yagis require only short, low-loss phasing lines. If this approach was successful on 2 meters, I concluded, the design could later be scaled to 70 cm (432 MHz), where the individual Yagis could be rear-mounted and possibly rotated in polarity for EME operation.[2]

I decided that a 12-foot boom, 144-MHz Yagi might be the ideal answer for the individual antenna; 12-foot boom material is readily available, and short Yagis can be mounted on towers that are only 12 to 15 feet high.

Several designs emerged for both 2 and 6 meters. While some of the results of this study were unexpected, they do answer several frequently asked questions.

where to begin

I started by designing a 2-meter Yagi on a 12-foot boom. Obviously, the boomlength could not exceed 142 inches — which, at 144 MHz, is approximately 1.75 wavelengths. I wanted the sidelobes to be as low as possible, at least 16 to 18 dB in the E plane, and a minimum of 13 dB in the H plane. If improved performance was possible, so much the better.

I studied but quickly discarded the NBS Yagis because the only designs near my requirements, 1.2 or 2.2 wavelengths, were either too short or too long.[3] Then I considered the Greenblum designs.[4] Unfortunately, design information was incomplete; furthermore, previous Yagi designs using the Greenblum tables didn't produce very clean radiation patterns, especially in the H or vertical plane.

Several articles in the *IEEE Proceedings* discussed a method of optimizing Yagi performance through the use of nonequally spaced and nonuniform length elements.[5,6] They started with an initial six-element design using equal spacing and director lengths. The elements were 0.0067 wavelengths in diameter on a 1.49 wavelength boom. The reflector was 0.51 wavelengths long and spaced 0.25 wavelength behind the driven. All directors were equally spaced at 0.31 wavelength and were 0.43 wavelengths long.

They ran a program similar to that used by Morris[7] — the forerunner of the one used by W2PV[8] — on a large IBM computer. It calculated the gain of this antenna at 11.2 dBi, with relatively high first sidelobes.

Maintaining the same reflector length and spacing, *believed to be near* optimum, the director spacings were mathematically iterated (adjusted in small steps) for maximum gain. This step increased the Yagi gain by 1.65 dB to 12.85 dBi. However, the boomlength had increased to 1.70 wavelengths, and all director spacings were now unequal. The pattern was definitely cleaner, but not terrific. The next step involved adjusting the reflector length and spacing, but very little improvement resulted.

A further improvement in the computer program through the use of larger matrices allowed for the simultaneous iteration of element spacing *and* length. The results were quite gratifying. After several optimizations, a new Yagi design with approximately the same boomlength (1.69 wavelengths with a gain of over 13.4 dBi) emerged, showing *an improvement of 2.2 dB* over the original constant length and spacing design and a cleaner radiation pattern.

Some preliminary conclusions can be drawn as a result of this study. With a fixed number of elements, there is a particular boomlength for optimum gain. Furthermore, gain and pattern aren't optimum when constant director length and spacing are used. For best Yagi performance, the boomlength and all element spacings and lengths must be individually optimized.

implementing the design

Limited practical information was, however, available for the "optimized" Yagi design. No element diameter scaling information was available to me at that time (in the mid-1970s) and the diameters recommended were rather impractical — over 0.5 inch at 2 meters! *Therefore I decided to scale* my own design by overlaying the element lengths on an NBS-type of scaling graph.[3] I designed a 144-MHz Yagi using 3/16-inch diameter rod (0.0023 wavelength diameter at 144 MHz).

I built this antenna and tested it on a commercial antenna range. The gain was as predicted. However, the bandwidth for maximum gain was very nar-

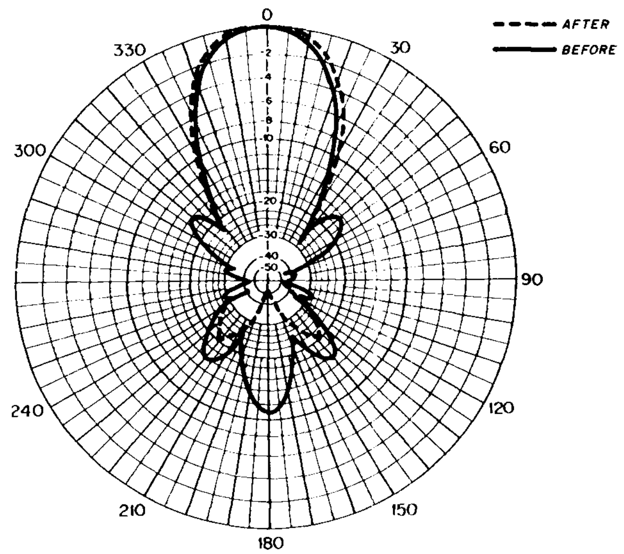

fig. 1. E plane radiation pattern of the original (solid lines) and modified (dotted lines) Yagi. Modifications involved lengthening the reflector and significantly shortening the last director.

row, only about 1.0 MHz at the − 1 dB points, and gain peaked near 146 MHz. Back to the drawing board!

Based on the data taken on the antenna range, I was able to correct my scaling graph. I then scaled the design to 50.1 MHz. It worked like a champ. The lengths and spacings chosen are shown in the first and second columns of **table 1**. A typical antenna radiation pattern is shown in **fig. 1**.

Upon close inspection of the radiation pattern, however, the f/b ratio wasn't worth writing home about. Dave Olean, K1WHS, figured that he could trade gain, if necessary, for a better f/b ratio. He left the element spacings constant, but shortened the last director by almost 10 inches; by lengthening the reflector a few inches, he was able to obtain a nearly infinite f/b ratio, though over only a very narrow bandwidth. The cost was about 1 dB in forward gain. The pattern of the modified Yagi is superimposed on the original design in **fig. 1**. The final element lengths chosen are shown in column 3 of **table 1**.

A close inspection of the patterns illustrated in **fig. 1** shows that the sidelobes aren't as good as my original design goals. Also, the improved f/b design had lower gain than desired. With the help of John Kenny, W1RR, a computer optimization was conducted on a similar six-element Yagi design scaled to 2 meters.* The results were similar to those reported in references 5 and 6. Either maximum gain or reasonable f/b ratio *could* be achieved, *but not simultaneously!*

I decided to make another search and again reviewed the Greenblum designs.[4] Using his designs, I found that eight elements were required for a 1.75-wavelength boom. I quickly calculated a 144-MHz design and W1RR computed the radiation pattern with his program. The gain was right on the money, but as previously speculated, the radiation pattern had very high sidelobes.

Next John ran an optimization routine on my new eight-element design. The input design parameters were maximum gain with all side and rear lobes at least 18 to 20 dB down in the E plane, with the overall boomlength fixed at 1.734 wavelengths (142 inches at 144 MHz).

After many computer iterations, a new design emerged. The pattern looked too good to be true. The gain penalty for a clean radiation pattern was only a few tenths of a dB, not a big compromise for over 13 dBi gain! The bandwidth of the design was also very good — several MHz at the − 1 dB points.

I hurriedly ran out and built the optimized design using leftover materials from Cushcraft 2-meter beams. Cushcraft uses above-the-boom element mounting, which requires a 0.312-inch element extension when mounted on a 1.0-inch diameter boom. A T match with a 4:1 half-wave balun completed the design. Construction details on the final design are shown in **fig. 2**.

Soon afterwards, the improved design was measured on a commercial antenna test range and was found to be satisfactory. A typical radiation pattern is shown in **fig. 3**. All side and rear lobes were about 20 dB down, and the gain was only 0.75 dB less than the NBS 2.2-wavelength design that used a trigonal reflector. Not bad for a design with a lot less hardware, six fewer elements and a 36-inch shorter boom!

Seven more copies were built along with the necessary phasing lines. They were assembled into a "quick and dirty" 2-meter EME array consisting of a 30-foot irrigation tube for the main boom, four 12-foot vertical masts, and a 12-foot portable tower. The spacing was 8-1/2 feet horizontally and 8 feet vertically. The VSWR of the entire array was fine. A photo of the completed array is shown in **fig. 4**.

The rest is history. On October 17, 1981 — even before making a single QSO — we broke it down and immediately set off for Rhode Island, where we fired it up for the first time on EME. In two nights of activity, we worked 25 stations in 16 states off the moon. Several stations completed a 2-meter WAS; only two stations scheduled were missed, but they turned out to be no-shows. Not bad performance for a small transportable array with only 64 elements!

*Yagi analysis programs for computing gain and patterns of specific Yagi designs are readily available.[8-11] However, the programs used to *optimize* Yagi designs are much more complex and not available for distribution. They're experimental, use proprietary software, and usually require a large mainframe computer. Therefore, I'd urge you *not* to contact persons doing such work until their programs are suitable for distribution.

insulated element mounting

Since the original Yagi was constructed, insulated through-the-boom element mounting has become quite popular.[9] Fortunately, the same dimensions as those shown in **fig. 2** can be used, since the correction factor for through-the-boom with insulated elements is about the same as the one used in the original design. Just maintain a 1.0-inch diameter boom and 3/16-inch element diameters with insulators and keepers as described in reference 9. However, the driven element length and/or the lengths and spacings of the T match will probably have to be optimized if low (1.2:1 maximum) VSWR is to be maintained.

I've used the eight-Yagi, 2-meter array on EME for several years. WAC was accomplished with less than 600 watts of output in the shack. Several European stations are using this Yagi on tropo and meteor scatter. Several local Amateurs and I have also used it to put rare grids on the air, since it's so compact and uncluttered.

This Yagi design is highly recommended where a small, simple, high-gain antenna with excellent sidelobe suppression is preferred. It's easily duplicated and can be used singly or as part of an array. Despite its size, four of these Yagis stacked 8-1/2 feet horizontally and 8 feet vertically make a good beginner's 2-meter EME array. Eight are better for the more serious EMEer, yet still affordable.

A secondary benefit of this 2-meter array hasn't previously been discussed, but may be worth mentioning. Because of space limitations, I can't fit both a 2-meter and a 135-cm (220 MHz) EME array in my back yard at the same time. But fortunately, if you use the 4.2-wavelength NBS Yagi designs on 135 cm, the mechanical spacings used on 2 meters just happen to be the same as the optimum mechanical spacing for 135 cm.[3] In my case, when I change bands I just swap out the Yagis, reconnect the same phasing lines, change the power dividers, and presto! For just an hour or so of changeover effort, I'm on 135-cm EME. (A photo of this array on a 1984 expedition to New Hampshire, using the same tower and stacking frame, is shown in reference 10).

6-meter Yagi

Shortly after this 2-meter Yagi design was completed, several Amateurs who needed a high-performance, high-

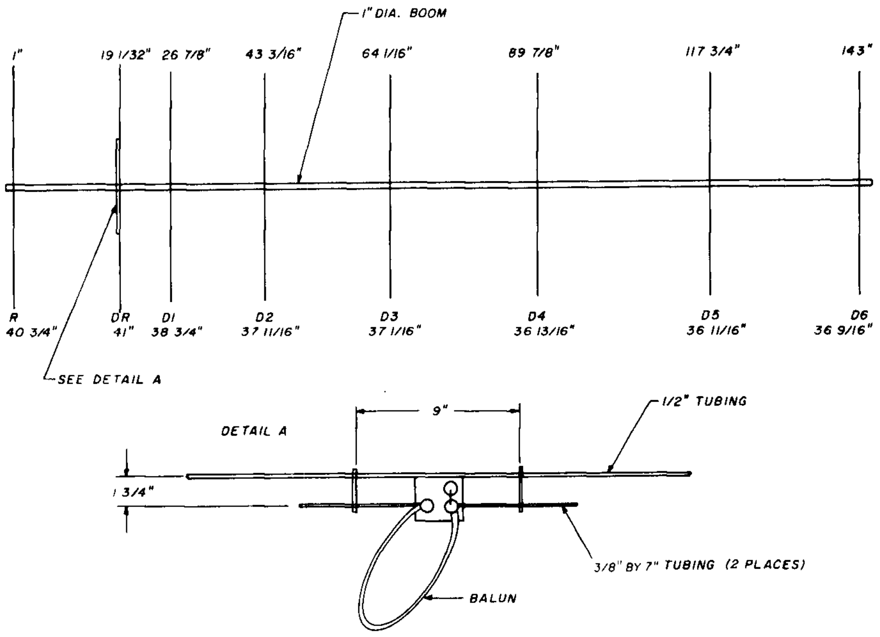

fig. 2. Optimized eight-element, 2-meter Yagi construction details. The reflector and directors are 3/16-inch rod. Element location is referenced from rear of boom to avoid tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 25 inches.

Table 1. Length and spacing for six-element, 6-meter Yagi.

Element	Spacing (inches)	Element length (inches)*	Element length (inches)**
R		113.75	117.0
	59.0		
DR		113.0	113.0
	68.0		
D1		104.75	104.75
	95.5		
D2		103.88	103.88
	75.5		
D3		104.25	104.25
	100.0		
D4		103.88	93.88

*Maximum gain model.

Optimized for best f/b ratio. A 2-inch diameter, 33-1/2 foot boom is used. The elements are 3/4-inch diameter, and are attached to the boom with U-bolt mounting as shown in **fig. 5C. A 0.625-inch element lengthening correction is included for this method of boom mounting.

gain 6-meter Yagi with clean radiation patterns — one that would also be usable on EME — approached me. Their requirements seemed to call for a frequency-scaled copy of the 2-meter design. At 6 meters, this would require a boomlength of about 35 feet.

Several mechanical configurations were evaluated. It appeared that a boom diameter of at least 2 inches was in order. "Through-the-boom" element mounting (**fig. 5A**), either directly in contact with or insulated from the boom, was immediately discarded since it would severely degrade the mechanical strength of the boom. Insulated elements mounted above the boom are advisable, but require special materials (**see fig. 5B**).

Several commercial element mounting methods were also evaluated. Cushcraft uses large diameter (3/4 inch) elements on its 6-meter "Boomer"™ and places a U-bolt directly through the element with a stiffening half-diameter element above and below the element (**fig. 5C**). Wilson antennas (now out of production) used a different mounting method that doesn't pierce the element (**fig. 5D**). Finally, with the help of Don Cook, K1DPP, a homebrew nonpiercing above-the-boom mounting was also fabricated (**fig. 5E**.)

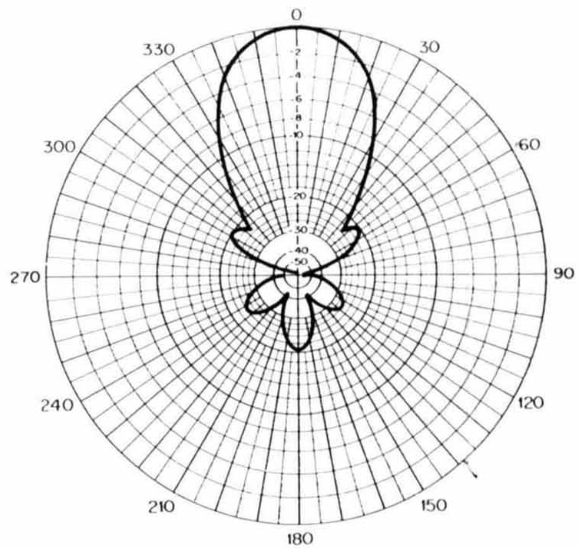

fig. 3. E plane radiation pattern of the optimized 8-element Yagi. Both the 2- and 6-meter models have the same radiation pattern.

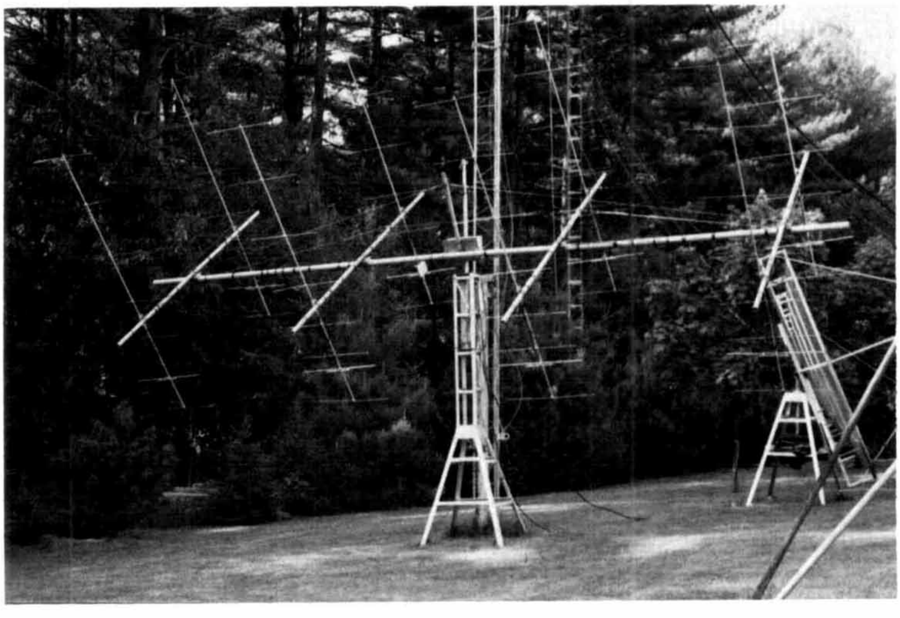

fig. 4. 2-meter EME array uses eight of the optimized Yagis.

The final element mounting scheme chosen was that shown in **fig. 5D**, since many of the older Wilson eight-element antennas are still available and easily modified for the new design. However, any of the above-the-boom mounting schemes shown will work satisfactorily. If you don't have an old Wilson beam to modify, I recommend the element mounting scheme shown in **fig. 5E**. More on this shortly.

Based on the use of an obsolete Wilson eight-element Yagi, the 2-meter design was scaled to 50.1 MHz. This design uses a 4-foot section of 5/8-inch diameter tubing for the inner portion of the elements and 1/2-inch diameter tubing for the outer portion of the elements. Construction details are shown in **fig. 6**.

Several 6-meter Amateurs have used this design. Each has used a slightly different set of tubing for the driven element matching, so the sizes shown for the driven element matching assembly may need some final adjustment. Either the length of the driven element and/or the length and spacing of the matching section may have to be changed slightly to suit your individual design.

If you build your own from scratch, the element mounting schemes shown in **figs. 5C, D** or **E** are recommended. The elements used may be either 1/2-, 5/8-, or 3/4-inch diameter tubing, or you can use graduated tubing as shown in **fig. 6**, since the difference in tuning is negligible (less than 100 kHz). If you use insulated mounted elements as shown in **fig. 5B**, each of the elements should be shortened approximately by 5/8 inch.

If you're building from scratch, I

recommend the use of a 30-foot length of irrigation pipe measuring 2 inches in diameter. This is available in farming supply stores. To obtain the required 35-1/2 foot length, a 1-7/8 inch outside diameter tube can be telescoped into the end of the tubing near the last director. Suitable tubing can be obtained from WD4BUM.**

Any boom this length and size should be supported from above. Two suggested methods are shown in **fig. 7**. This beam is large and has a high wind load, so any short cuts can turn into an expensive disaster.

If you decide to build your own, use the element mounting method shown in **fig. 5E**. A 2-inch wide aluminum channel measuring 1/2 inch thick and 5 to 6 inches long is recommended. It's easy to file out a semicircular groove in the channel to match the boom curvature. *Don't file too deeply; the strength of the channel will be diminished if you go all the way down to the base plate.*

The elements are held to the channel with short pieces of aluminum straps approximately 1/2 inch wide, 1/16 inch thick, and 2-1/2 inches long. These straps are held in place with stainless steel screws, nuts, and washers. For best element alignment, each channel should be attached to the boom using two U-bolts. Suitable stainless steel U-bolts can be purchased from suppliers such as WB9IPG*** or homebrewed.

At the suggestion of K1DPP, I made my own U-bolts using 3/16-inch diameter stainless steel welding rods available from a local welding supply house. All that was required was a 10-32 die, a die handle, and some patience. If you'd like to try this, First de-burr the edges of the rod and then cut the required length of threads on both ends. Next, place a 2-inch diameter tube upright in a bench vise. Place about a 6-inch piece of suitable diameter tubing over each threaded end of the rod. Then carefully bend the rod around the 2-inch diameter tube until the desired U-shape is obtained.

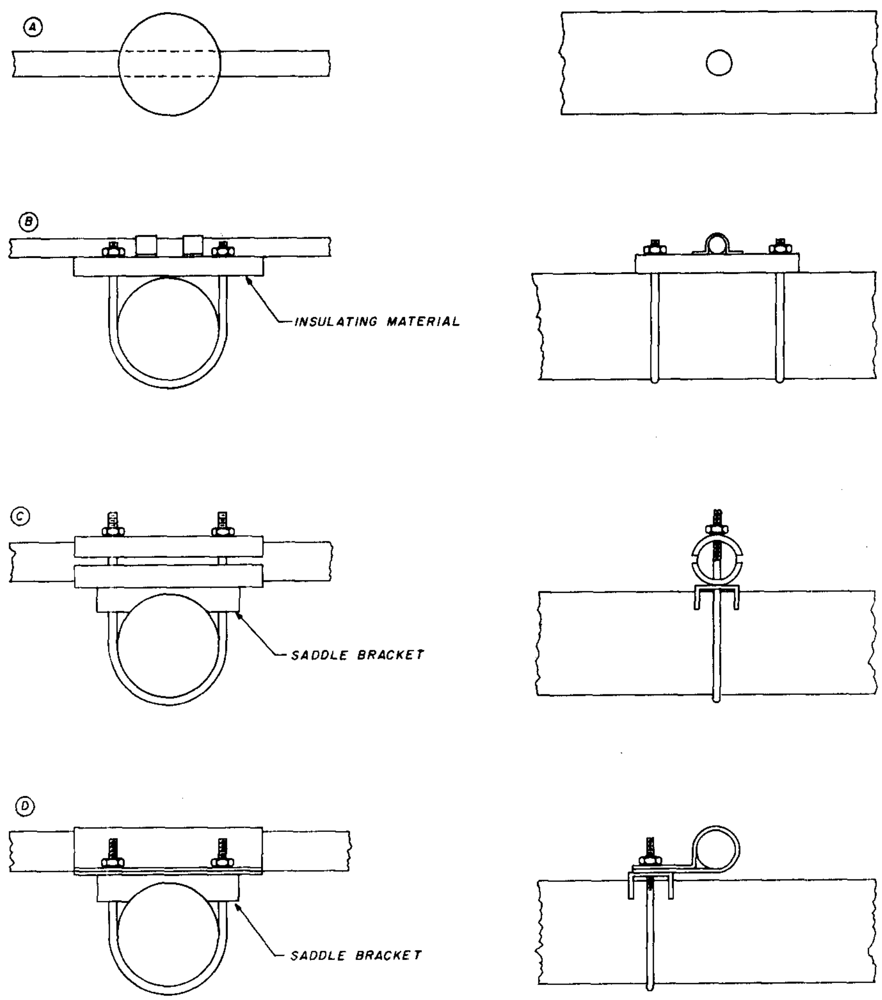

fig. 5. Typical element mounting methods: (A) through-the-boom insulated, or in direct contact with the boom; (B) insulated above the boom; (C) element held in contact with the boom by a U bolt; (D) element held by special bracket. (Because of last-minute production problems, fig. 5E will appear next month. — Ed.)

6-meter results

The performance of the 6-meter Yagi design has been gratifying to all who built one. Some Amateurs used it in contests to set high scores. Compared with most other designs, the pattern is very clean, and the gain definitely matches or exceeds that of any other 6-meter Yagi designs, even those with more elements or longer boomlengths.

Ray, WA4NJP, who's been active on 6 meters for many years and has used several different Yagi designs, recently built a large array for 6-meter EME. After finding his results only marginal, he asked for my recommendation.

I gave him the details shown in **fig. 6**, and he built four of the 6-meter Yagis, stacking them 28-1/2 feet in the E plane and 24 feet in the H plane. He started hearing EME echoes on 50 MHz immediately. Recent tests have yielded EME echoes regardless of where the moon is in the sky; previously, he could use the moon only when it was at low elevations to obtain horizon gain. Echoes more than 10 dB above the noise are now quite common off the moon — even on SSB!

**George Shira, WD4BUM, Route 7, Box 258, Anderson, South Carolina 29624.

***H. C. Van Valzah Company (WB9IPG), 1140 Hickory Trail, Downers Grove, Illinois 60515.

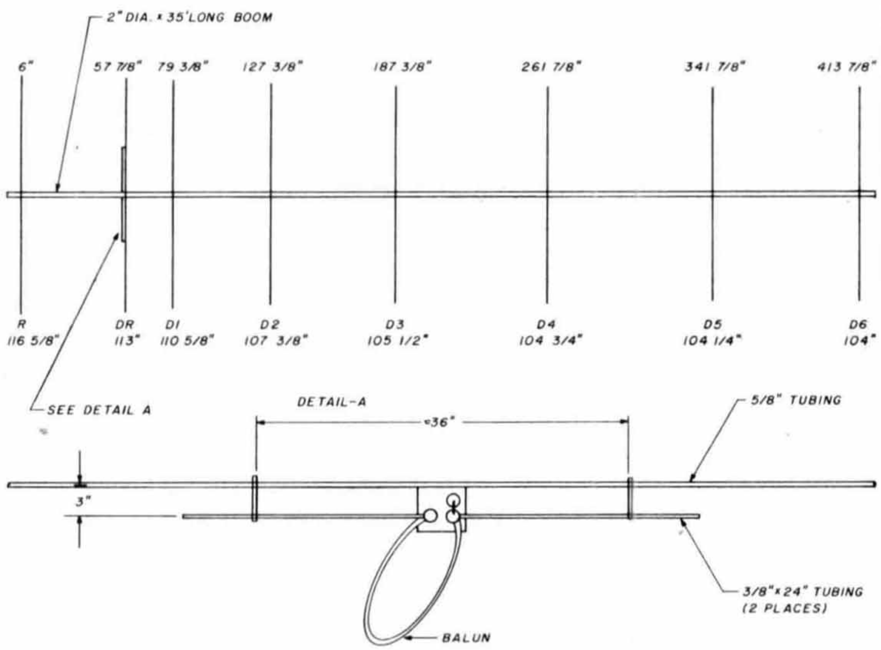

fig. 6. Optimized eight-element, 6-meter Yagi construction details. Element location referenced from rear of boom to prevent tolerance buildup. A 4:1 half-wave type balun made from RG11 75-ohm coax is used. Overall length of the balun including connectors is 78 inches. Coax can be coiled up in a 6- to 9-inch diameter and taped to boom.

summary

Since these Yagis were originally designed, additional data has indicated that optimum boomlengths exist for Yagi antennas, especially those shorter than 4 wavelengths.[1] The optimum boomlength for short Yagi designs seems to be an odd multiple of quarter-wavelengths (i.e., 0.25, 0.75, 1.25, and 1.75 wavelengths). If these boomlengths are used with the proper number of elements, optimum gain and pattern can often occur simultaneously. According to my analysis, the optimum number of elements for any specific boomlength seems to follow those recommended by Greenblum.[4] Furthermore, the use of a T match with a built-in 4:1 half-wave type balun, as shown in **figs. 2** and **6**, is strongly suggested.

This month's column was primarily aimed at the design of shorter boomlength Yagis. Emphasis was on performance, with high gain-per-unit boomlengths and clean radiation patterns. Several designs for 2 and 6 meters that meet the criteria specified above were discussed. These designs should be just the ticket for those who want high performance with an antenna they can modify or build for themselves.

acknowledgements

Any project this size requires plenty of help. I'd especially like to thank John Kenny, W1RR, for his work on optimizing the designs. Thanks also to Dave Olean, K1WHS, for his assistance with measurements and the optimization of the f/b ratio on the six-element 6-meter design. Stan Jaffin, WB3BGU, has been particularly helpful in analyzing my results and comparing notes on this and other designs. Thanks also go to Don Cook, K1DPP, for his help with the 6-meter antenna mounting brackets and hardware. Finally, thanks to Ray Rector, WA4NJP, for trusting my designs enough to build his large 6-meter EME array that works so well. I hope I didn't forget anyone!

new records

In last month's column I predicted

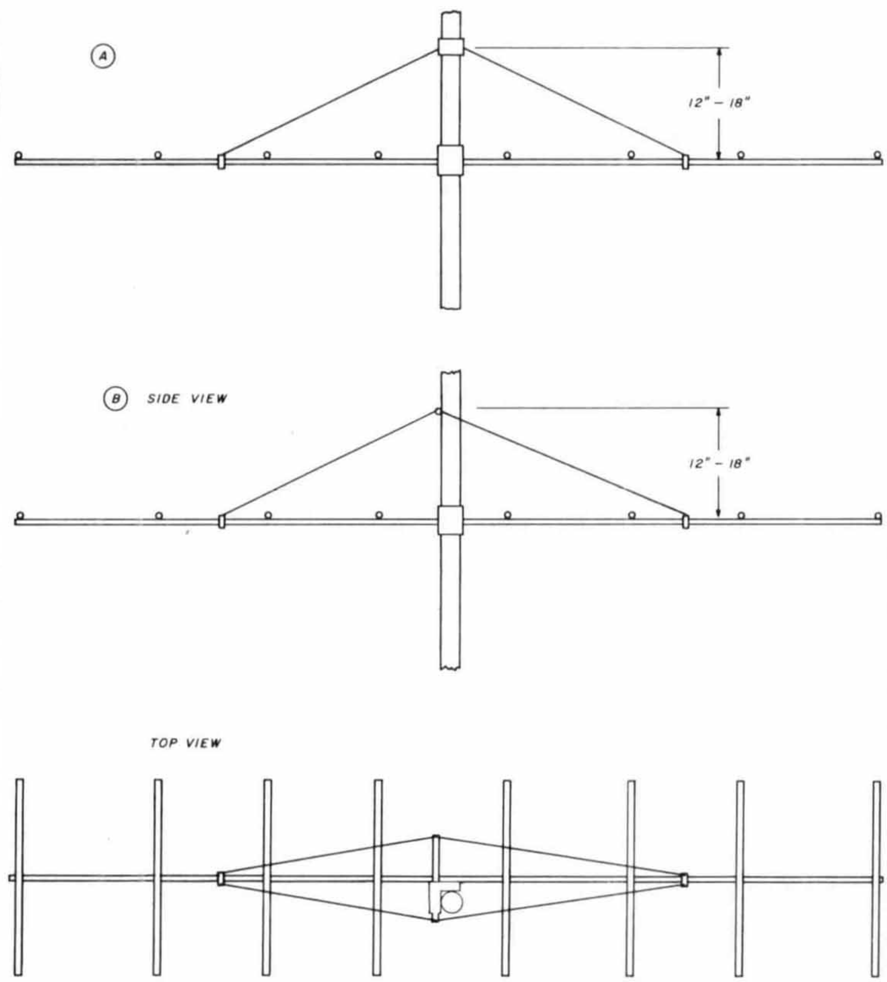

fig. 7. Recommended boom mounting method for extra strength: (A) use 1/2-inch or larger diameter tubing approximately 10 feet long mounted about 18 inches above the boom at the center. Flatten tubing ends and attach to mast and boom with U bolts. (B) Use Phillystran™ or equivalent cable mounted as shown to prevent swaying (side and top views).

that before the April issue was printed, the 33-cm (903 MHz) record would again be broken.[12] On Christmas Eve, 1986, another unexpected Midwest tropo opening occurred; this time, Sam, W2PGC (FN02OR), completed a two-way QSO with Gary, K3SIW/9 (EN52WA), for a record-shattering distance of 478 miles (769 km). Both stations were using modest setups, 10 and 70 watts, respectively, and single-loop Yagi antennas. Signals were S9 each way, and the contact was completed on two-way SSB. Congratulations to Sam and Gary.

East Coast VHF Society

One of the first of its kind, the East Coast VHF Society is now being reactivated by president Russ Pillsbury, K2TXB, vice-president Roger Amidon, K2SMN, secretary Allen Katz, K2UYH, and treasurer Tom Kirk, KA2VAD. There are plans for a newsletter and an annual flea market, as well as antenna and noise figure measuring contests in July. Equipment loan and activity to various rare grids are also planned. Contact K2UYH for further information.

MININEC 3 is available

From time to time I've mentioned computer-aided antenna modeling programs. Till now, these computer programs were either difficult to obtain, not generally available, or suitable only for mainframe or other large computers.

All that has changed. MININEC 3 is now available for general distribution for use on IBM and IBM-compatible personal computer systems. This program is faster than its predecessor and has more available options. To obtain your copy, send an MS DOS-formatted, double-sided, double-density disk with sufficient return postage and a note requesting a copy of MININEC 3 to Jim Logan, Code 822, Naval Ocean Systems Center, 271 Catalina Boulevard, San Diego, California 95152-5000.

important VHF/UHF events

May 2-3	West Coast VHF Conference (contact WB6GFJ)
May 5	Predicted peak of the Eta Aquarids meteor shower at 1300 UTC
May 8	ARRL 902-MHz Spring Sprint Contest (Friday evening)
May 9	2304 EME special by WA2WEB (contact K2UYH for skeds)
May 14	ARRL 1296-MHz Spring Sprint Contest (Thursday evening)
May 15	EME perigee
May 15-17	13th Annual Eastern VHF/UHF Conference, Nashua, New Hampshire (contact W1EJ)
May 23-24	ARRL 50-MHz Spring Sprint Contest (Saturday evening)
June 7	Predicted peak of the daytime Arietids meteor shower at 1900 UTC
June 10	Predicted peak of the Zeta Perseids meteor shower at 0400 UTC
June 13	EME perigee
June 13-15	ARRL June VHF QSO Party
June 20-21	SMIRK 6-Meter QSO Party Contest (contact KA0NNO)
June 21	±1 month. Peak of Sporadic E propagation

references

1. Joe Reisert, W1JR, "VHF/UHF World: Yagi Facts and Fallacies," *ham radio*, May, 1986, page 103.
2. Joseph H. Reisert, Jr., W6FZJ/1, "VHF Antenna Arrays for High Performance," *QST*, December, 1974, page 38.
3. Joseph H. Reisert, Jr., W1JR, "How to Design Yagi Antennas," *ham radio*, August, 1977, page 22.
4. Carl Greenblum, "Notes on the Development of Yagi Arrays," *QST*, August, 1956, page 11.
5. David K. Cheng and C. A. Chen, "Optimum Element Spacings for Yagi-Uda Arrays," *IEEE Transactions on Antennas and Propagation*, September, 1973, page 615.
6. C. A. Chen and David K. Cheng, "Optimum Element Lengths for Yagi-Uda Arrays," *IEEE Transactions on Antennas and Propagation, January, 1975, page 6.*
7. *I. Larry Morris, "Optimization of the Yagi Array, 1," PhD Thesis, Harvard University, October, 1964.*
8. *James L. Lawson, W2PV, "Yagi Antenna Design: Performance Calculations," ham radio*, January, 1980, page 22.
9. Joe Reisert, W1JR, "VHF/UHF World: A High-Gain 70-CM Yagi," *ham radio*, December, 1986, page 75.
10. Joe Reisert, W1JR, "VHF/UHF World: 220-MHz EME Requirements," *ham radio*, September, 1984, page 45.
11. Stanley Jaffin, WB3BGU, "Applied Yagi Antenna Design," Part 6, *ham radio*, October, 1984, page 89.
12. Joe Reisert, W1JR, "VHF/UHF World: 33-CM Update," *ham radio*, April, 1987 page 00.

ham radio

shown in *The Nautical Almanac* with the tabular method described in reference 9. For example, if the moon's position was at GHA 66 degrees with a north declination of 18 degrees, 26.5 minutes, we knew it would appear directly overhead in San Juan, Puerto Rico. This was a tedious procedure; sometimes we'd goof, but that was part of the challenge on EME communications.

Later some fortunate EMEers with access to large mainframe computers and moon orbital prediction programs could print out a year's worth of data showing the ***local azimuth and elevation*** angles of the moon every 10 or 15 minutes of the day. With personal computers, that's changed; accurate moon position programs are now available even for the least expensive PCs. One of the most popular is the one written by Lance Collister, WA1JXN. Just input your latitude and longitude and the program displays or prints out your ***local azimuth and elevation*** to the moon as well as the GHA, declination, and right ascension for any day, time, or increment of time desired.* **Figure 3** shows a sample printout; other output data shown will be discussed shortly.

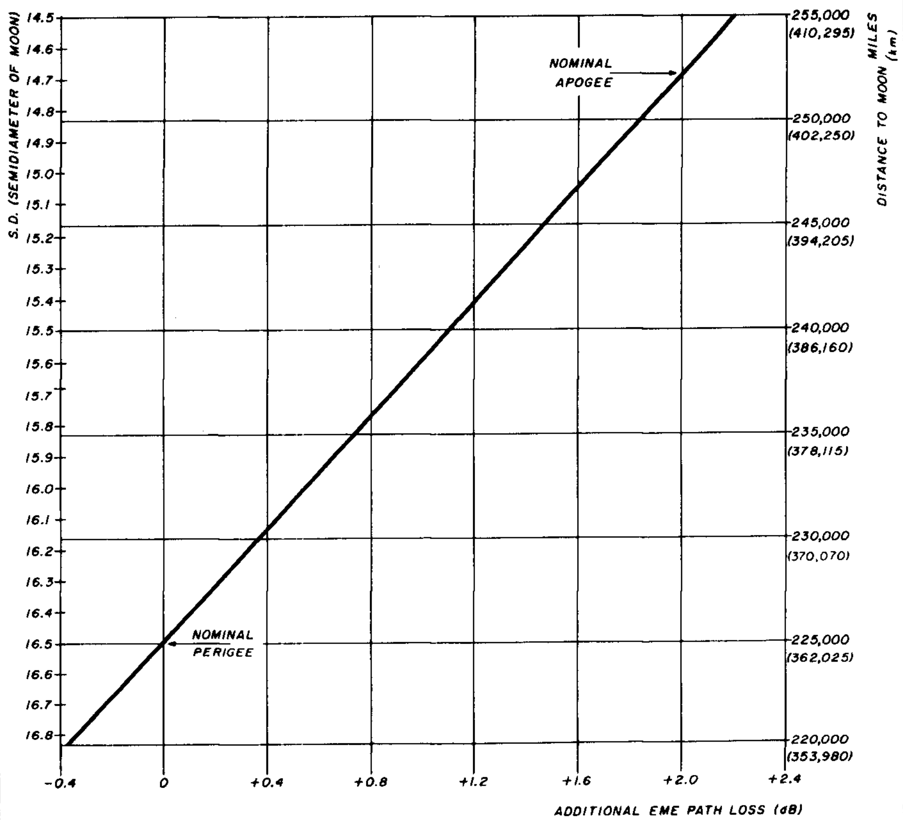

fig. 2. This graph shows the variations in EME path loss versus the distance to the moon. S.D. is the semidiameter, as explained in the text. To find additional attentuation to the moon, draw a line horizontally from either the S.D. or distance side to the pivot line and drop down to the additional path loss.

the EME window

For successful EME echoes, the moon must be above your horizon. You don't actually have to be able to ***see the moon*** for successful EME operation; you just have to be sure that you'd be able to see it if the skies were clear. The moon isn't usually visible to the naked eye — especially in daylight — when it's within one to two days of its new moon phase, but this may still be acceptable for EME operation.

Most EMEers know their local antenna azimuth and elevation limits based on the size of the antenna structure and any local obstructions. They translate these local parameters into GHA and declination limits. If you have a few different days of EME printout, typically one at maximum northerly, one at maximum southerly, and another at zero moon declination, you can easily determine your EME window. Then it's just a simple matter of comparing your window with the window of the station you want to reach to see whether you have a ***common window*** at the desired schedule time. If you do, contacts at distances greater than 10 to 11,000 miles (16 to 18,000 km) are possible.

When 2-meter EME operation took off in the early 1970s, there were many stations using large tropo antenna arrays that were rotatable only in azimuth. Therefore, they could operate EME only when the moon was low on the horizon — usually referred to as a ***rising or setting moon*** — typically below 10 degrees of elevation.

This concept was further expanded and standardized by Bob Sutherland,

→

*For a copy of this program suitable for IBM compatibles or the Apple Macintosh, send a double-sided, double-density diskette with sufficient return postage to Gene Shea, KB7Q, 417 Staudaher Street, Bozeman, Montana 59715.

short circuits

HW-101 readout

In **fig. 2** (top board schematic) of NU4F's article, "A True-Frequency Digital Readout for the HW 101" (January, 1987, page 8), the connection between the 600-ohm resistor and the 1.0-MHz timing crystal, which goes to pin 6, U5, is also shown connected to the run from pins 1, 2, 4, 5, and 8. This connection should go only to pin 6, U5.

U13 through U16 were omitted from the parts list on page 12; these are 74LS00 Quad NAND gates.

2-meter Yagi

In **fig. 2** of W1JR's May column (see page 95), the spacing of the first director is shown as 26 7/8 inches. This should have been indicated as 26 7/16 inches. According to the author, this discrepancy would probably not affect performance.