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QST Issue: Jan 1988
Title: Optimum Design for 432-MHz Yagis, An--Part 2
Author: Steve Powlishen, K1FO

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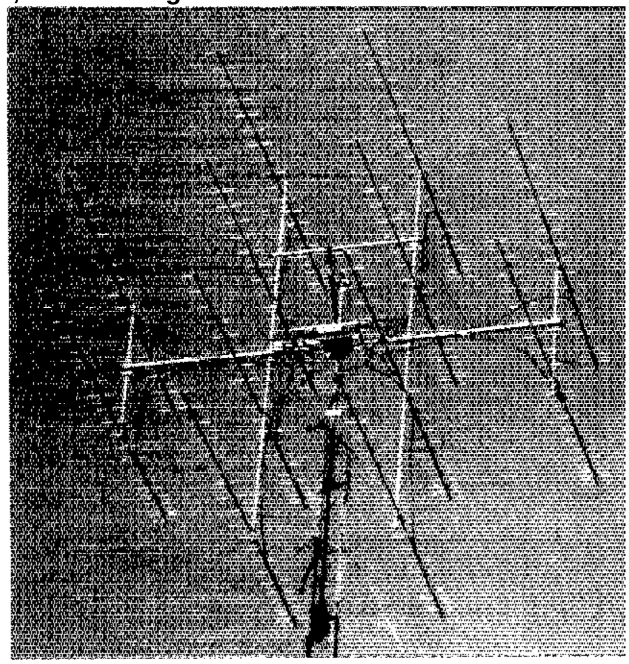
An Optimum Design for 432-MHz Yagis



Part 2: Here is practical construction information for a high-performance antenna that you can build for that *big* signal on 432 MHz.

By Steve Powlishen, K1FO
816 Summer Hill Rd
Madison, CT 06443

Last month, I described the development of the K1FO 22-element Yagi design. This month, I will give complete construction details and show how to scale the dimensions for other boom lengths.

Building the K1FO 22-Element 70-cm Yagi

I highly recommended that you follow *exactly* the construction information given here. If you use boom and element material of the sizes specified, you can build a top-performing Yagi—provided you pay close attention to exactly duplicating the dimensions. Some builders will want to build the Yagi with whatever material is on hand. In addition to the specific information on my mechanical design, I have included some general guidelines for those who are willing to accept the problems faced when construction materials are changed. Please keep in mind that I cannot entertain requests to verify the dimensions, or assist in the construction or debugging, of Yagis that do not exactly follow the dimensions and construction materials recommended in this article. Translated, the last sentence says, "If you change anything, you're on your own!"

Boom Material

Fig 6 shows the boom layout. Round aluminum tubing of 7/8-inch and 1-inch outer diameter (OD) was chosen carefully to provide the highest possible boom strength, while maintaining low wind load and light weight. Round tubing has some disadvantages compared to square tubing: It is more costly to purchase and more difficult to drill accurately. Round tubing does have advantages, however: You can use it to make telescoping boom sections (allowing easy disassembly of the Yagi), and it offers lower wind load and lighter weight than square tubing. The boom could be made out of 3/4- or 7/8-inch-square tubing. The element lengths presented later do not have to be adjusted for square tubing of this size (provided that the same element-mounting method is used).

If you use tubing of a different diameter for the boom, you will need to apply a boom-correction factor. Lengthen each element by 1 mm for each 1/8 inch increase

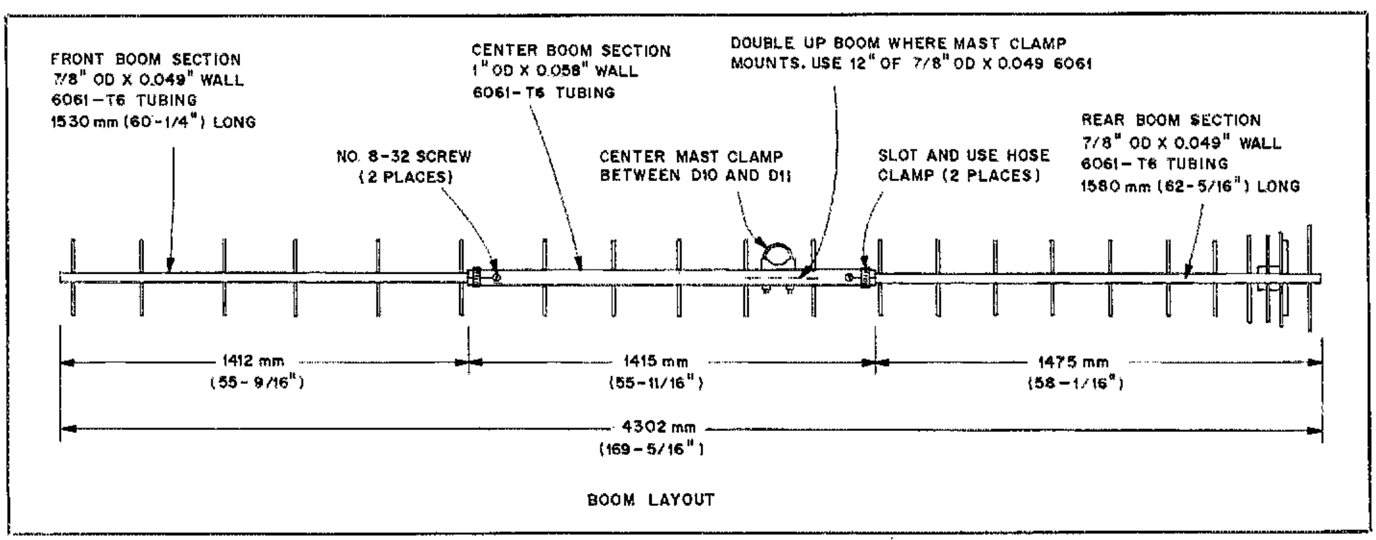


Fig 6—Boom-construction information for the K1FO 22-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna. See text.

in boom diameter; shorten each element by 1 mm for each 1/8 inch decrease in boom diameter.[4] For example, if the entire Yagi is made of 1¼-inch tubing, the reflector, driven element and directors D1-D9 and D14-D20 should be 3 mm longer, while directors D10-D14 should be 2 mm longer. I don't recommend use of a boom larger than 1½ inches OD—such sizes make compensation for boom effects difficult. Do not use square tubing smaller than ¾ inch or round tubing smaller than 7/8-inch and 1-inch OD—these materials are not strong enough.

The boom materials shown in Fig 6 have been chosen for good strength versus weight. I recommend 0.049-inch-wall tubing for the 7/8-inch boom sections. Tubing with a 0.058-inch wall is suitable, but it is slightly heavier. The 1-inch center section should be 0.058-inch-wall tubing so that the end pieces telescope properly, with a minimum of slack. If a single mast clamp, mounted through the boom, is used, put a short piece of 7/8-inch tubing inside the center section where the mast clamp attaches. This doubles the wall thickness for extra strength. My array of 12 22-element Yagis has already survived ½-inch ice loading in combination with winds stronger than 40+ mi/h.

The boom-section lengths were chosen so the antenna can be broken down and taken on mountaintop trips or to antenna-gain measuring contests. Unfortunately, these lengths result in a lot of wasted aluminum. An alternative construction technique (provided that you do not live in an area where you get heavy icing) is to make the 1-inch center section 48 inches long and appropriately lengthen the 7/8-inch sections. If you do this, remember to apply the boom-correction factors to adjust the lengths of any elements that were mounted in the 1-inch section, but are now mounted in the 7/8-inch section.

Elements are mounted through the boom with black delrin insulators held in place by push-nut retaining rings; see Fig 7. Nylon is an acceptable, but not as desirable, alternative—provided it is black to prevent it from deteriorating because of ultraviolet radiation. Teflon® insulators such as those described by George Chaney, W5JTL, are acceptable as well.[5] If the elements are mounted through the boom and not insulated, lengthen all elements by 5 mm (this applies for the 7/8-inch and 1-inch boom construction *only*). If the non-insulated mounting method is used, be sure that the elements have an excellent element-to-boom contact that will survive weathering effects.

To mount the elements above the boom in insulated blocks, follow the insulated-boom guidelines if the elements are centered at least ¼ inch above the boom. If the elements are closer than ¼ inch above the boom, they will require some lengthening. I am unable to give specific advice on lengthening the elements because I have not experimented with this construction method.

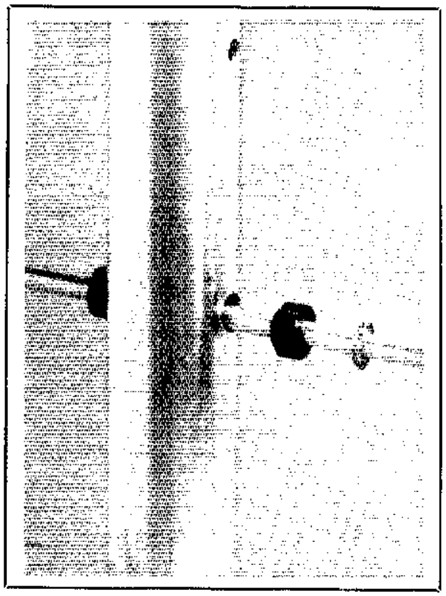


Fig 7—Element-mounting detail. Elements are mounted through the boom using plastic insulators. Push-nut retaining rings hold the element in place.

Use of nonconductive boom materials such as wood or fiberglass is not advised. In terms of strength versus weight and wind load, 6061-T6 and 6063-T6 aluminum tubing are without peer—at least for materials that amateurs can afford! Wood is a poor choice because of its short usable life and poor strength versus wind load and weight. Fiberglass is stronger than wood, but it is not as good as the high-strength aluminum alloys. In addition, fiberglass will deteriorate in sunlight unless it is protected from ultraviolet radiation. If you still insist on using a nonconductive boom material, shorten all elements in the 7/8-inch boom sections by 4 mm, and shorten those in the 1-inch boom sections by 5 mm.

Element Material

Element diameters other than 3/16 inch

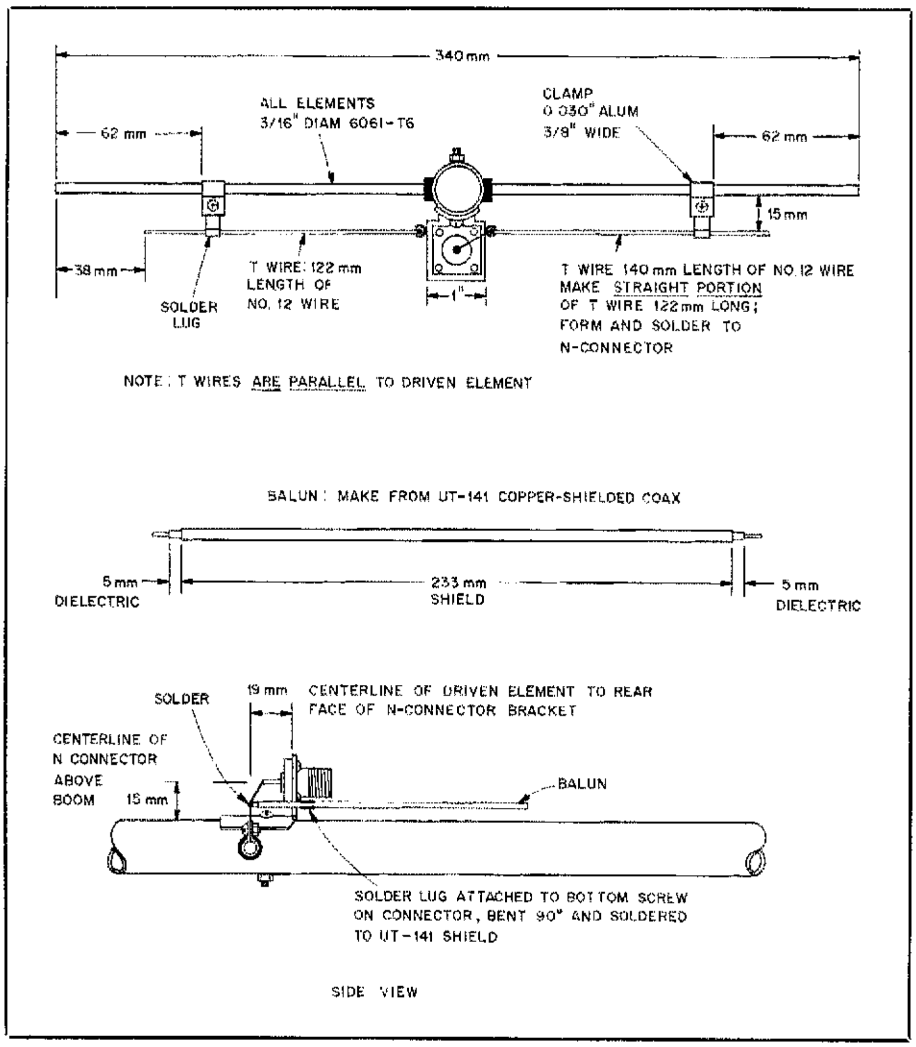


Fig 8—Details of the driven element and T match for the 22-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna. See text.

[4]Notes appear on page 30.

Table 1

Dimensions for the 22-Element 432-MHz Yagi

Element Number	*Element Position (mm from rear of boom)*	*Element Length (mm)*	*Boom Diam (in)*
REF	30	346	
DE	134	340	
D1	176	321	
D2	254	311	7/8
D3	362	305	
D4	496	301	
D5	652	297	
D6	828	295	
D7	1020	293	
D8	1226	291	
D9	1444	289	
D10	1672	288	
D11	1909	286	
D12	2152	285	1
D13	2403	284	
D14	2659	283	
D15	2920	281	
D16	3184	280	
D17	3452	279	
D18	3723	278	7/8
D19	3997	277	
D20	4272	276	

are not recommended. This size represents the best compromise between strength, weight, wind load and wet-weather de-tuning effects. For other element diameters, use the following guidelines—with caution!

- For 1/8-inch-diameter elements, lengthen all elements by 3 mm, but expect worse wet-weather performance and 0.1 dB less gain (caused by resistive losses). Skinny elements are also marginal from a mechanical standpoint. For these reasons, I recommend you stay away from 1/8-inch-diameter material.
- For ¼-inch-diameter elements, shorten all elements by 3 mm. Resistive losses are theoretically 0.04 dB less with ¼-inch-diameter elements, but the added weight and wind load may not make the larger size worthwhile.

Preparing the Boom and Elements

All element lengths and positions are given in metric dimensions, rather than US customary units. See Table 1. Metric dimensions are much easier to work with, especially for cutting and centering elements. If you plan a significant amount of antenna work, buy a good metric scale and tape measure. If you are stuck on using inches, try to keep to 1/32-inch tolerances when converting the given metric dimensions to US customary units.

Note that element positions are referenced from the reflector end of the boom. For example, the reflector position is not at 0, but at 30 mm. This makes it easy to mark the boom for drilling if you have

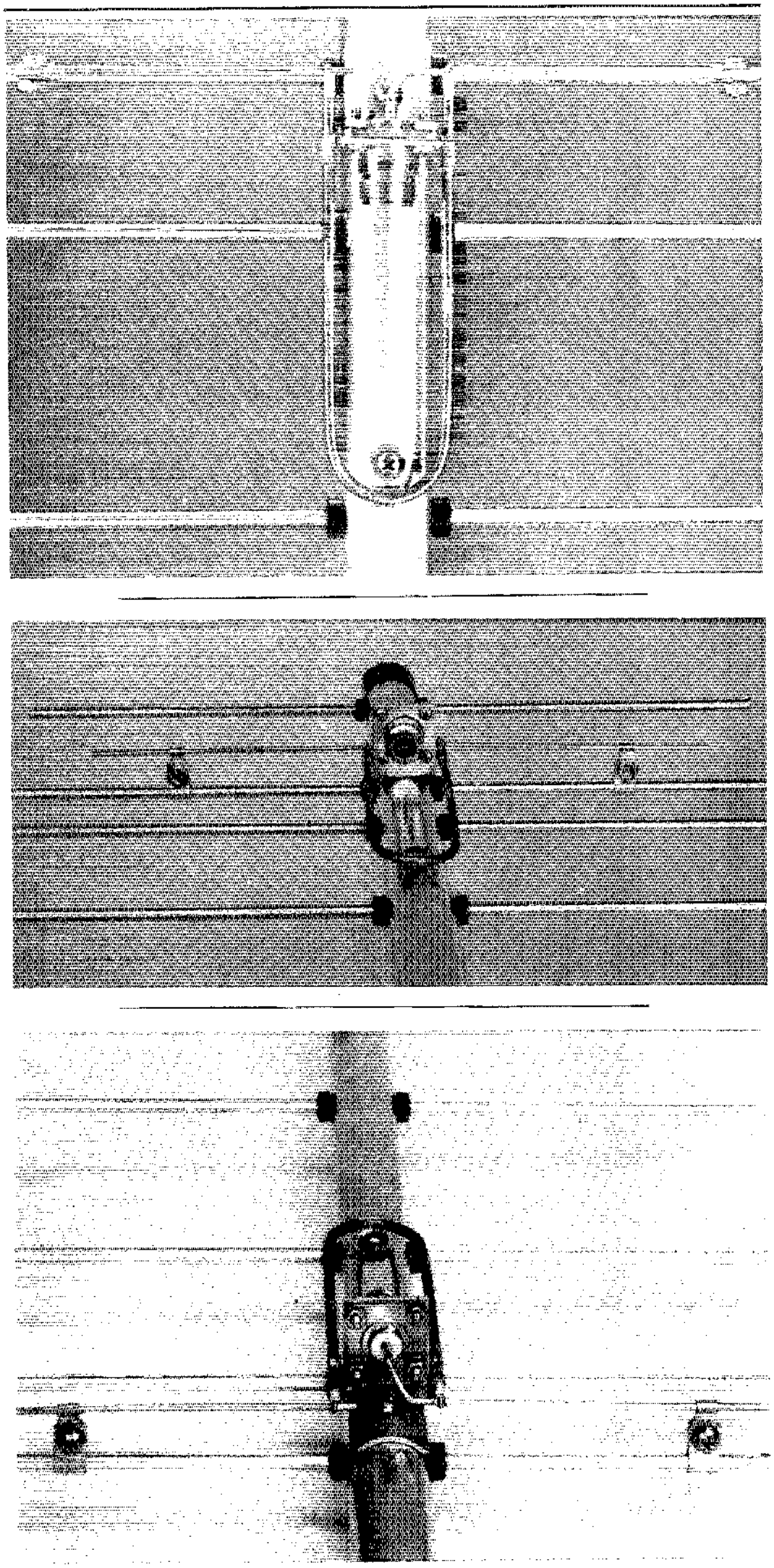


Fig 9—Various views of the driven element and T match.

a good tape measure longer than 4.3 m. Start by cutting all the boom sections to size. Next, slot the ends of the center section and use hose clamps to secure all three boom sections in place. You can then mark the element-drilling positions by putting the tape measure on the end of the boom and simply going down the boom and marking the element locations. Finally, scribe marks in the 7/8-inch boom sections where they meet the center boom section. These marks make final boom assembly easier once the elements are in place.

Keep tolerances to ±0.5 mm if possible. Because the antenna bandwidth is so great, gain is virtually unaffected by 1-mm measurement errors. The pattern, however, may deteriorate if you get too sloppy in your construction methods.

Elements are rough cut easily with a small hacksaw. Using a vise to hold the element stock makes the job much easier. The elements can then be filed to the exact dimension. For measuring element length, I lay a good machinist's scale flat on a workbench and butt it against a straight object (such as a metal bar). Then, I butt the element end against the straight object and mark the length with a sharp scribe. I have no trouble trimming elements to within 0.25 mm using this method.

To finish the elements, I use a file to put a 1-mm chamfer on each end. The chamfer is designed into the element lengths. I feel that it slightly improves wet-weather performance and makes it easier to start the push-nut element retainers.

Table 2

Design Information for K1FO Yagis of Different Lengths

Number of Elements	*Boom Length (λ)*	*Calculated Gain (dBd)*	*Element Number†*	*Base Element Length (mm)*	*Element-Length Correction (mm)*	*Last-Director Spacing (mm)*
11	2.0	11.7	D9	289	−3	1444
12	2.4	12.2	D10	287	−3	1672
13	2.7	12.7	D11	285	−1	1909
14	3.1	13.1	D12	284	−2	2152
15	3.4	13.5	D13	283	−2	2403
16	3.8	13.9	D14	282	−2	2659
17	4.2	14.3	D15	281	−2	2920
18	4.6	14.6	D16	280	−1	3184
19	4.9	14.9	D17	279	−1	3452
20	5.3	15.2	D18	278	0	3723
21	5.7	15.5	D19	277	0	3997
22	6.1	15.7	D20	276	0	4272
23	6.5	15.9	D21	275	0	4550
24	6.9	16.2	D22	275	+1	4828
25	7.3	16.4	D23	274	+1	5109
26	7.7	16.6	D24	274	+1	5390
27	8.1	16.7	D25	273	+1	5672
28	8.5	17.0	D26	273	+1	5955
29	8.9	17.2	D27	272	+2	6239
30	9.3	17.4	D28	272	+2	6524
31	9.7	17.5	D29	271	+2	6809
32	10.2	17.7	D30	271	+2	7094
33	10.6	17.9	D31	270	+2	7380
34	11.0	18.1	D32	270	+2	7666
35	11.4	18.2	D33	269	+2	7952
36	11.8	18.4	D34	269	+3	8239
37	12.2	18.6	D35	268	+3	8526
38	12.7	18.7	D36	268	+3	8813
39	13.1	18.8	D37	267	+3	9100
40	13.5	18.9	D38	267	+3	9389

†Base dimensions for the reflector, driven element and directors D1-D8 are the same as those given in Table 1.

Driven Element

The driven element and T match used on the K1FO Yagis is patterned after the driven element and match on the RIW Products 19-element Yagi. If you cannot figure out exactly how to build the driven element, find someone with an RIW 19 and take a look at it. Fig 8 shows dimensions for the driven element and T match. Fig 9 shows the driven element photographically from different views. Fig 10 shows the general construction of the rear boom section.

If you want to optimize the match for a frequency other than 432 MHz, adjusting the driven-element dimensions should not affect Yagi performance as long as the driven element does not get overly long—more than 343 mm. You can change the size and spacing of the T-match wires, but I do not recommend changing the balun length. The balun length was chosen carefully to be an exact electrical half wavelength. Tests indicate that baluns of other lengths upset pattern balance. The first director position or length could also be adjusted slightly to improve the match, but don't change either dimension by more than 3 mm.

Making the Yagi for Other Boom Lengths

The variable-spacing geometry allows the K1FO 22-element Yagi to be scaled to other boom lengths. If the antenna is made significantly shorter or longer, adjustments to the element lengths are required. For versions with fewer than 11 elements (2.0-wavelength boom), gain will be considerably less than optimum. Gain improvement for these short Yagis requires optimization of the directors for the specific boom length. Gain is very good out to 40 elements (13.5 wavelength boom). Although the pattern remains excellent for all length Yagis, the first sidelobes do get somewhat stronger as the boom gets longer. To improve the pattern of the longer Yagis, you must optimize director lengths for the specific boom length. Driven-element tuning for an acceptable 50-ohm match is required for each version.

Table 2 summarizes performance and scaling information for Yagis based on the K1FO 22-element Yagi between 11 and 40 elements. The first three columns show the number of elements, the boom length in wavelengths, and the calculated gain for each version.

The *Base Element Length* column shows the base length, in millimeters, for directors D9 and above. (The base length for the reflector, driven element and directors D1-D8 are given in Table 1.) Note that two correction factors *must* be applied to these element lengths.

1) The *Element-Length Correction* column shows the amount to shorten or lengthen *all* elements, relative to base element lengths. For example, if you want to build a 12-element antenna, all elements must be cut 3 mm shorter than the base lengths given.

2) The base element lengths assume that all elements are mounted in a 7/8-inch-diameter boom. For strength, you will probably use a larger-diameter boom for longer Yagis. You *must* make *an additional* element-length adjustment if you mount the elements in a boom other than 7/8 inch diameter. Add 1 mm to the base element length for each 1/8-inch increase in boom diameter. Note that if you use a combination of boom diameters (for example, 7/8-inch tubing at the ends and 1-inch tubing in the center), the boom-correction factor is applied to the elements mounted in the 1-inch section *only*.

The *Last Director Spacing* column gives the spacing, in millimeters, from the reflector end of the boom to the position of the last director. Use this information for element-position information for antennas longer than 22 elements.

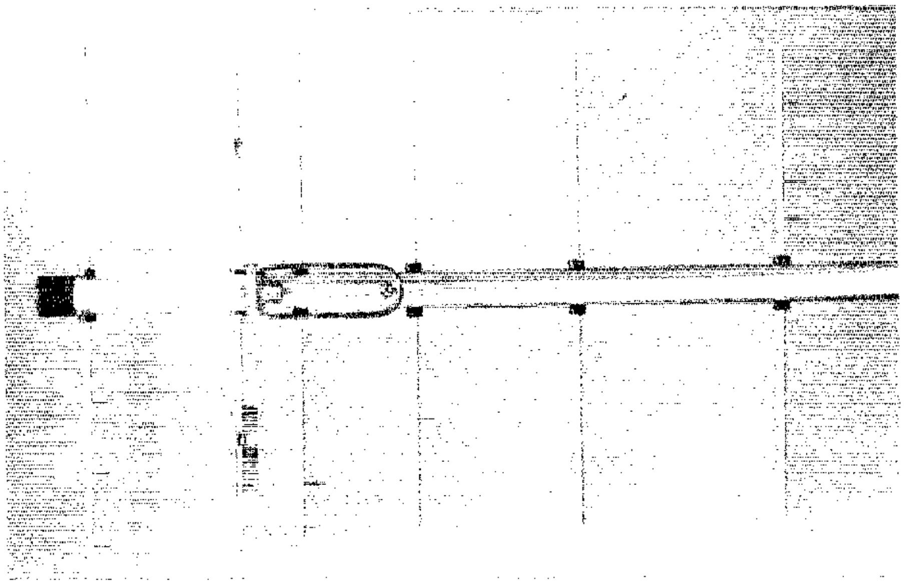


Fig 10—View of the rear boom section showing the general construction methods used.

Here's an example of how to use Table 2. First, select the number of elements desired. Let's build a 7.3-wavelength, 25-element Yagi, with a calculated gain of 16.4 dBd. From the *Element-Length Correction* column, all elements must be lengthened 1 mm over the base dimensions. Remember that the element lengths are for a 7/8-inch boom. From a structural standpoint, it may be desirable to make the 25-element Yagi boom from two 6-foot sections of 1-inch tubing telescoped into a 6-foot center section made from 1-1/8-inch tubing. The elements must be lengthened further for such a boom: All elements in the 1-inch boom sections must be lengthened another 1 mm, and the elements mounted in the 1-1/8-inch boom piece must be made another 2 mm longer. So, taking into account adding both correction factors, the elements in the 1-inch boom section must be a total of 2 mm longer than the base dimension, and the elements mounted in the 1-1/8 boom section must be a total of 3 mm longer.

A 33-Element Yagi

I built and tested a 33-element, 10.6-wavelength (24 ft, 3 in) Yagi from the information computed for Table 2. The theoretical gain of the Yagi is 17.9 dBd, and actual measured gain is closer to 17.7 dBd. Part of this difference appears to be explained by higher resistive losses in the 33-element Yagi, compared to the shorter antenna. The measured E-plane pattern of the 33-element Yagi (Fig 11A) is extremely clean and very close to the predicted pattern (Fig 11B).

Examination of the dimensions for this

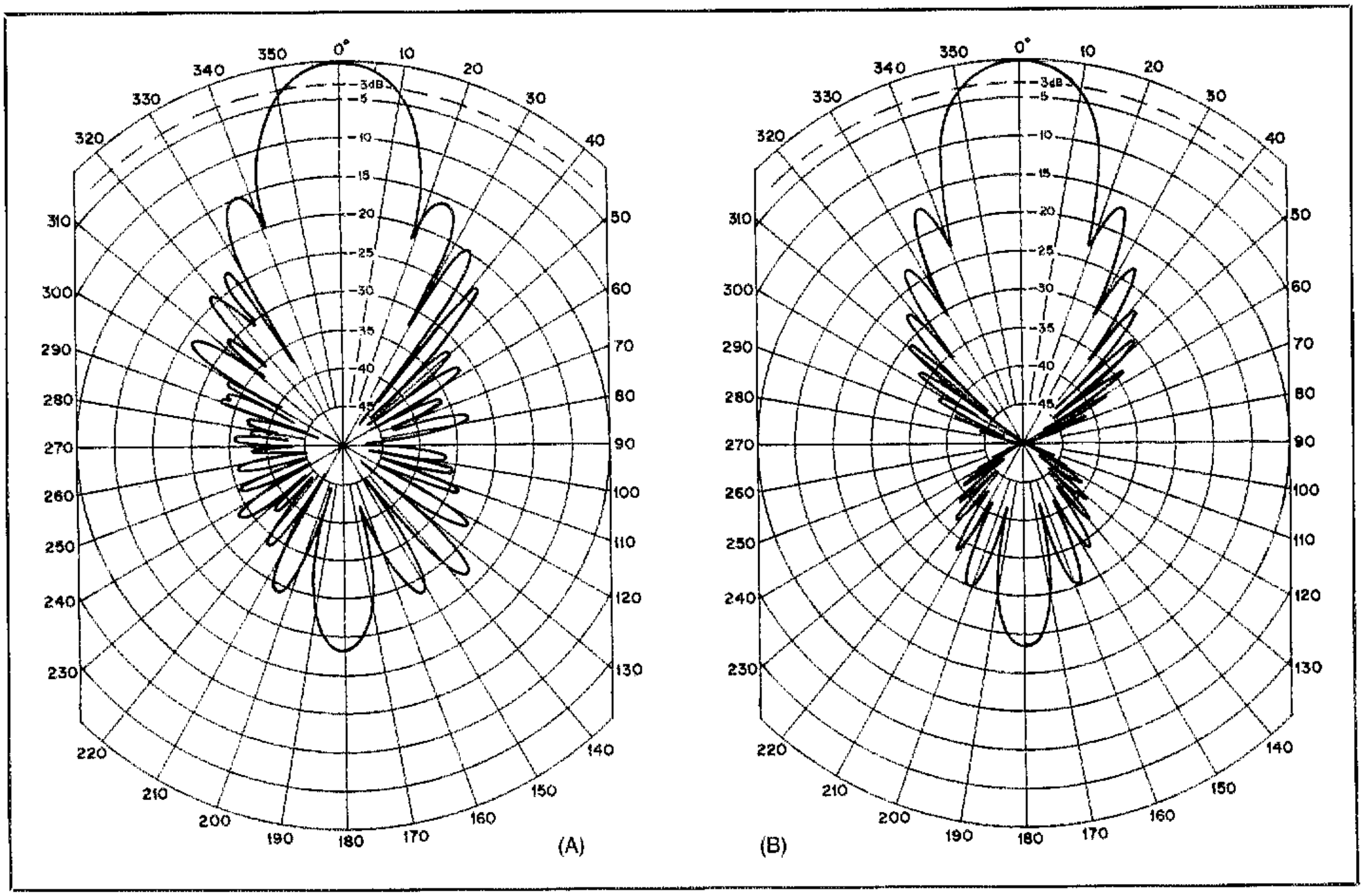


Fig 11—Measured (A) and predicted (B) E-plane patterns for the 33-element K1FO Yagi. Note: These antenna patterns are drawn on a linear dB grid, rather than the standard ARRL log-periodic grid. The linear dB grid shows sidelobes in greater detail and allows close comparison of sidelobes among different patterns. Sidelobe performance is important when stacking antennas in arrays for EME work.

Table 3

Dimensions for the 33-Element 432-MHz Yagi

Element Number	Element Position (mm from rear of boom)	Element Length (mm)	Boom Diam (in)
REF	30	348	
DE	134	342	
D1	176	323	
D2	254	313	
D3	362	307	
D4	496	303	1
D5	652	299	
D6	828	297	
D7	1020	295	
D8	1226	293	
D9	1444	291	
D10	1672	290	
D11	1909	288	
D12	2152	287	
D13	2403	286	1-1/8
D14	2659	285	
D15	2920	284	
D16	3184	284	
D17	3452	283	
D18	3723	282	1-1/4
D19	3997	281	
D20	4272	280	
D21	4550	278	
D22	4828	278	
D23	5109	277	1-1/8
D24	5390	277	
D25	5672	276	
D26	5956	275	
D27	6239	274	
D28	6524	274	1
D29	6809	273	
D30	7094	273	
D31	7380	272	

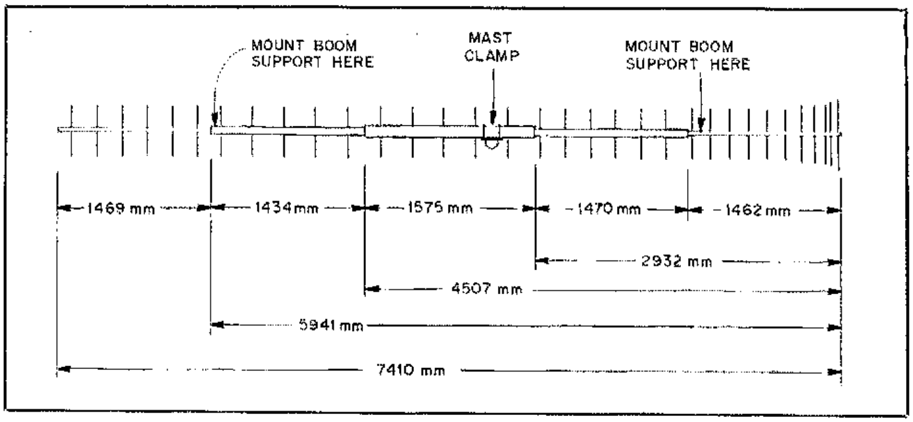


Fig 12—Boom-construction information for the K1FO 33-element Yagi. Lengths are given in millimeters to allow precise duplication of the antenna. See text.

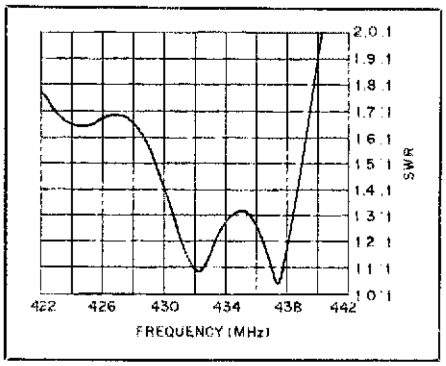


Fig 13—SWR performance of the K1FO 33-element Yagi in dry weather.

Yagi (Table 3) is also useful in determining how to adjust the Table 2 dimensions for other diameter booms and greater numbers of elements. Note that not all element lengths for the 33-element Yagi correspond exactly to the table. I adjusted some elements to optimize the pattern at this specific boom length and to achieve an excellent driven-element match.

Boom-construction details are shown in Fig 12. The boom for the 33-element Yagi starts out with 1-inch-OD × 0.049-inch-wall 6061 tubing. This telescopes into 1-1/8-inch-OD × 0.058-inch-wall tubing. A center section of 1¼-inch-OD × 0.058-inch-wall 6061 tubing completes the boom. Each of the five boom sections is approximately 5 feet long. This construction method increases the strength of the boom (to help eliminate sag and vibrations), and, as with the 22-element Yagi, makes the antenna easy to break apart for portable operation.

The 24-foot boom requires a support to minimize sag. Computer calculations indicate that the 3-4 inches of sag in the unsupported boom reduced antenna gain by 0.1 dB and caused significant distortion in the H-plane pattern. The support is made from a combination of ¾-inch and 7/8-inch tubing. A 12-inch piece of 1-1/8-inch tubing, slipped inside the center boom section, strengthens the wall where the mast clamp mounts.

Like the 22-element antenna, the driven element on the 33-element Yagi was optimized with a sophisticated network analyzer. The longer Yagi also demonstrates excellent SWR bandwidth and an SWR at 432 MHz of close to 1.1:1 (see Fig 13). This is a good demonstration that a "gimmick" driven element is not needed to obtain a good match with a wide bandwidth on a long UHF Yagi. Note that the SWR is less than 1.33:1 for over 8 MHz. Wet-weather performance is also very good, with the center frequency shifting in a similar magnitude to the 22-element Yagi. Details of the long Yagi driven element are given in Fig 14.

Stacking distances for the 33-element Yagi have been calculated to be optimum at 85 inches E plane and 80 inches H plane. Stacking distances for antennas of other boom lengths can be interpolated from those calculated for the 22- and 33-element Yagis.

Variations on the K1FO 22-element design that are built with a significantly different number of elements may not work exactly as predicted. Although virtually any length Yagi should give excellent performance, some physical tweaking may be necessary to obtain maximum performance. Specifically, versions with boom lengths less than 4.6 wavelengths are generally 0.2 dB lower in gain than what is theoretically possible for such boom lengths. This is caused by the "universal" spacings that are used. The DE to D1 spacing is closer than needed for such short Yagis. In addition, some element-length tweaks are needed to obtain the last

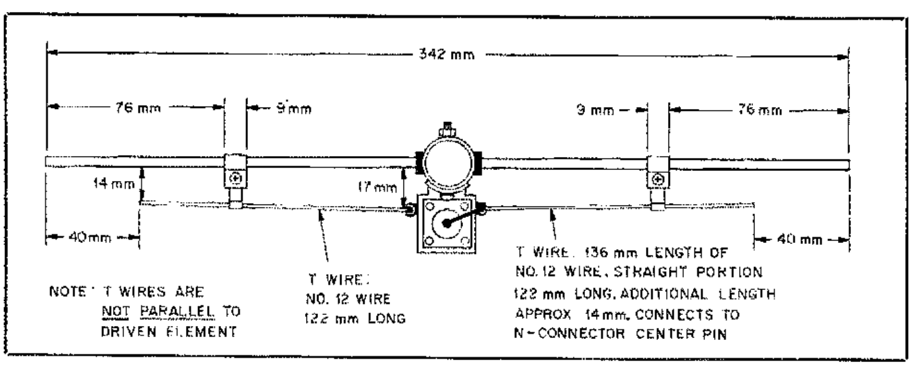


Fig 14—Details of the driven element and T match for the 33-element Yagi. See Fig 8 for additional information. Lengths are given in millimeters to allow precise duplication of the antenna. See text.

few tenths of a decibel of gain on shorter versions.

Before we get too carried away with long Yagi designs, let's return to the original premise of this article. In a practical array, we must consider the weight and wind load of the array.

Let's compare two arrays: (1) eight of the 22-element, 14-foot-long Yagis; and (2) four of the 33-element, 24-foot-long Yagis. Measured gain is 15.7 dBd for the 22-element Yagi and 17.7 dBd for the 33-element Yagi. Phasing lines will have 0.3 dB loss for the eight-Yagi array and 0.2 dB for the four-Yagi array. This gives an overall gain of 24.0 dBd for the array of eight 22-element Yagis. The array of four longer Yagis has a total expected gain of 23.3 dBd—or 0.7 dB less than the eight-Yagi array.

Wind-load area of the 22-element Yagi is 0.8 square foot; the 33-element Yagi has an area of 2.8 square feet. The total array wind-load area must include the stacking frame, phasing lines, mounting plates and so on. When everything is included, the eight-Yagi array has a wind-load area of approximately 15 square feet. Wind-load area is 19 square feet for the four-Yagi array. Thus, the eight shorter Yagis have higher gain *and* less wind-load area! Even if the eight 22-element Yagis were arranged two wide and four high (so they would be better for use on terrestrial paths as well as for EME), the center of the array would not have to be mounted as far above the top guys as the four 33-element Yagis to allow for elevation movement. Note that if we wanted to build a four-Yagi array with gain equal to the eight smaller Yagis, we would have to use 37-element, 28-foot-long Yagis. The wind-load area of such an array would be almost 21 square feet.

Conclusion

I delayed publishing this information on the 22-element Yagi until I was sure that it performed as well as predicted. In October 1986, I replaced my 12 RIW 19 Yagis with 12 of the 22-element Yagis. I then spent two frustrating months coping with an array that never seemed to work the way it should. After a long string of problems (including water in two different phasing lines, a cracked shield on another line, and not one but *two* bad relays), the array is finally in full working order. The array uses the same phasing lines that were on the old array. Because these lines are a little short, the new array uses 64- × 60-inch spacing; the net array gain is 0.2 dB lower than the maximum possible for an optimally spaced array.

Sun noise is 15.0 dB during quiet sun periods, a solid 1.5 dB higher than with the old array. Earth noise (a measure of pattern quality independent of gain) is 5.0 dB, more than 0.5 dB better than the old array. Milky Way noise (the noise measured between cold sky and the center of our galaxy) is 5.3 dB.[6] Other celestial measurements are 3.0 dB on Cygnus, 2.9 dB on Cassiopeia and 1.2 dB on Taurus. These readings give an approximate total system temperature of 81 kelvins (K). Subtracting receiver noise (25 K) and phasing line noise (26 K), the total antenna noise is 29 K—a truly outstanding figure. Calculations by Rainer Bertelsmeier, DJ9BV, indicate an even lower array noise for the 22-element Yagi. More information on this subject can be found in an article by DJ9BV in the fourth 1987 issue of the West German VHF/UHF magazine, *DUBUS*.

The 22-element, 6.1-wavelength (14-ft) Yagi combines light weight, low wind load, excellent gain for its size, a clean pattern and a wide gain bandwidth in one package. In addition, its geometry is adaptable to virtually any boom length. If you don't have the facilities to drill booms or cannot locate the parts required, Tom Rutland, K3IPW, makes available Yagi kits and components for the 22-element, 33-element and variations on this design.[7] My thanks to Tom Kirby, W1EJ, for his hard work in determining the basic design geometry for these Yagis.

Notes

[4]The actual correction in element length for each 1/8 inch of boom diameter change is 0.8 mm (1/32 inch). If a boom size is used that is significantly larger than 7/8 inch, the exact correction (0.8 mm) should be used.

[5]G. Chaney, W5JTL, "PTFE VHF Antenna Insulators," *Ham Radio*, Oct 85, pp 98-101.

[6]Sagittarius is the constellation used for array aiming. Because of the low elevation and non-point-source nature of the Milky Way, comparison of noise readings between different stations at different locations is not always meaningful.

[7]Rutland Arrays, 1703 Warren St, New Cumberland, PA 17070.

Strays

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☐ Bernie Cutler, KB6NR, on being awarded an Emmy from the Academy of Television Arts and Sciences, for Art Direction of the series "Max Headroom."

I would like to get in touch with...

☐ husbands and wives who both hold an Extra class license, to join Extra Class Couples. Bill Prechtl, W3KO, 295 Strapper Rd, Bridge City, TX 77611.

☐ anyone with information on hospitals equipped with ham gear. Jeff Howell, WB9PFZ, #20 Catalina Estates, Charlestown, IN 47111-1608.

☐ any ham diagnosed as having Amyotrophic Lateral Sclerosis (Lou Gehrig's Disease). Lloyd Kincaid, 14319 Duncannon Dr, Houston, TX 77015.

☐ hams who are bilateral amputees. Joseph Schwartz, K2VGV, 11 Windham Loop, #1JJ, Staten Island, NY 10314.

☐ any hams who served aboard the *USS Culebra Island* during WW II. John Jones, N4QBP, 2000 S Eads St, #712, Arlington, VA 22202.

☐ anyone who has successfully put an electronic bias switch in a Drake L-7 linear amplifier and maintained clean audio on SSB. E. G. Drummond, WR4R, US 13-Box 186, Nelsonia, VA 23414.

☐ Breezeshooters. Seeking information regarding the location of the organization's original constitution and by-laws. BREEZESHOOTERS, INC, c/o Bud Faulhaber, N3DOS, 1059 Balmoral Dr, Pittsburgh, PA 15237.

☐ anyone who has had experience operating ham radio from the Colorado River in the Grand Canyon. Need information on antennas, frequencies and propagation characteristics for emergency communication. John Meyer, N3EFG, RD 1, Box 101A, Clarks Summit, PA 18411.

QEX: THE ARRL EXPERIMENTERS' EXCHANGE AND AMSAT SATELLITE JOURNAL

AMTOR and the AX.25 protocol are modern developments used for exchanging error-free data. Good efficiency, low undetected error rate, robustness and reliability are important attributes in an HF data transmission system. Both AMTOR and AX.25 have certain features that make them a likely candidate for such a system, yet there is room for improvement. Multipath propagation and modem design affect HF communications as well, and must be considered when designing an HF data transmission system.

The December issue of *QEX* includes articles on:

- "New Directions in HF Data Transmission Systems—Part 1," by Barry McLarnon, VE3JF
- "Far-Field Fallacy," by H. Paul Shuch, N6TX
- "The Morphological Table—An Invention Generator," by Nick Leggett, N3NL
- "Traveling-Wave Tubes," by Geoff Krauss, WA2GFP

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