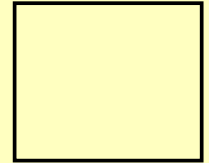




Preliminary Studies of Long-Boom Yagis for 420-450 MHz--Or Fly Me to the Moon. . .



L. B. Cebik, W4RNL (SK)

There are numerous long-boom Yagi designs, but little study of them using the latest antenna modeling software (NEC-4). This study is a small beginning of the process of analyzing the salient performance features of the various designs using models from my small collection. The effort arose from my own interest in determining if one might develop a "perfect" Yagi, and for this reason, it is strictly preliminary. The perfect Yagi does not yet exist.

Long-boom Yagis have an equally long history, but the late 1980s and the early 1990s are the period of the most rapid advances in their design. DL6WU, K1FO, DJ9BV, W1JR, and SM5BSZ are only some of the most noted calls associated with individual or families of Yagis susceptible to mathematical design algorithms. We shall sample efforts from each of these groundbreaking designers. Indeed, we shall sample 10 Yagis, 9 of which are long boom efforts, and one is an explanation of why these notes are only preliminary.

My procedures will be straightforward. I modeled each Yagi design using NEC-4. Some wide-band designs covering all or most of the 70-cm band required slight re-scaling to center the passband. In some instances, the designs had been optimized for one or the other end of the band. In a few cases, the initial model had used NEC-2. By the time we increase frequency to the 70-cm band, there is an offset between NEC-2 and NEC-4 amounting to 5-10 MHz. NEC-4 has revised algorithms for element ends and for the feedpoint split, and is considered more accurate in critical cases. To be fair to the potential of a given design, it was necessary--wherever possible--to so center a design within the band that the operating or 2:1 SWR bandwidth either is in the band or covers all of it and that the peak performance characteristics lie within the band. This latter factor allows anyone to re-scale an array's peak performance region to any desired portion of the band.

Since the models do not include conductive booms, the model descriptions appended to this study represent arrays whose elements are well insulated and isolated from any conductive boom. One can construct an array directly from the model adhering to those conditions. However, if alternative element diameters or alternative boom-mounting methods are required, the builder must apply appropriate compensation techniques. A summary of those techniques and some of the algorithms required for the work appear in "Scaling and Adjusting VHF/UHF Yagis" at my web site (.), with some of the techniques appearing in Chapter 7 of the RSGB volume *The VHF/UHF DX Book*, edited by Ian White, G3SEK.

For each array, I shall provide similar data. First comes a set of vital statistics giving both the physical size of the array and any special modeling notes, followed by an outline sketch of the antenna. Except for a couple of narrow-band designs, each antenna will have a table of modeled performance figures for 420, 435, and 450 MHz. The data will include both horizontal and vertical beamwidths and forward-to-sidelobe ratios in addition to the more expected gain and front-to-back ratios. Following each table will be sample E-plane and H-plane (free-space) patterns for the arrays. I shall add a frequency sweep of the gain and the 180-degree front-to-back ratio and another sweep of the resistance, reactance, and SWR curves. Finally, I shall add some commentary on the array, although the data itself should make most of the commentary obvious.

Because the long-boom Yagis come in various sizes with respect to both the number of elements and the overall boomlength, direct comparison from one design to the next is at best an uncertain enterprise. However, the aggregate results will permit us to draw a number of interesting conclusions about the present state of design and the future of long-boom Yagi design.

Evaluating Long-Boom Yagi Designs

Although somewhat tedious, the process of developing both physical and performance data on long-boom Yagis is very straightforward. Evaluatively interpreting that data is another matter. Evaluation often rests

upon the intended communications task for which one creates a beam. Even within the confines of a given task, there is no fixed agreement on the order in which to place the various facets of Yagi performance.

Forward gain and the front-to-back ratio (taken either as the 180-degree ratio or the worst-case front-to-back ratio) are the most common prime performance figures. Very often, beamwidth--both horizontal and vertical--are simply presumed and go unexamined. Until recently, the forward front-to-sidelobe ratio has been ignored. (See "Long-Boom Yagi Sidelobe Suppression" in the *Proceedings of the 2002 Southeastern VHF Society*, pp. 67-124, for a discussion of this topic.) Nonetheless, some aspects of overall pattern shape as it shifts from one end of the operating passband to the other require non-quantitative commentary at the present stage in the development of studies of long-boom Yagi performance.

It is possible to develop some ad hoc measures of Yagi size that permit a few comparisons and detection of some general trends. Therefore, we shall look at the element density of the designs, using the first 21 directors as a guide--since 21 directors comprise the shortest of the designs that we shall examine. We shall also take a measure of the gain-to-element ratio and the gain-to-boom-length ratio. We shall develop these numbers for either 432 MHz (for the narrow-band designs) or 435 MHz (for the wide-band designs). None of these figures has any long-term merit, but they do permit us to reach a few interesting conclusions about the designs at hand. We shall also look at the range of gain and the range of front-to-back ratios across the operating passband wherever these numbers are notable for the builder.

In the end, comparison and evaluation can only be suggestive and not authoritative, especially for the radio amateur. Every long-boom Yagi goes through two phases in amateur hands. First is the feeling that there is nothing superior to "this" beam as it passes its final tests and adjustments and is declared operational. After some use, the inveterate beam builder acquires the equally strong feeling that there must be a superior design that just has to be built. I shall reserve further general comments for the concluding section.

The tabular data on the performance for each array will include the following categories.

- Forward Gain (dBi): The free-space gain of the forward lobe.
- 180-Deg F-B (dB): The 180-degree front-to-back ratio.
- Worst-Case F-B (dB): The worst case front-to-back ratio relative to the entire rear horizontal semi-circle.
- Horiz. B-W (deg): The E-plane -3-dB beamwidth of the forward lobe.
- Vert. B-W (deg): The H-plane -3-dB beamwidth of the forward lobe.
- Horiz. F-SL (dB): The E-plane forward main-lobe-to-strongest-secondary-lobe ratio.
- Vert. F-SL (dB): The H-plane forward main-lobe-to-strongest-secondary-lobe ratio.
- Note: The notation (+B) indicates forward pattern bulges or merged lobes.
- Feed Z (R+/-jX Ohms): The driven element feedpoint impedance.
- SWR (n Ohms): The SWR relative to a given reference impedance.

1. A 32-Element DL6WU Yagi

Guenter Hoch, DL6WU, is perhaps the most noted designer of long-boom VHF and UHF Yagis. His work appears in its most developed form in Chapters 7 and 10 of *The VHF/UHF DX Book*. In addition, there are numerous programs for designing his beams, the most recent of which is an interesting EXCEL spreadsheet available from David Tanner, VK3AUU, whose own designs will appear later in this study. Since the algorithms describing the DL6WU beams are so well known, we may focus on the data instead of the theory. As with all succeeding data, any references to dimensions in wavelengths are for 432 MHz.

Basic Data:

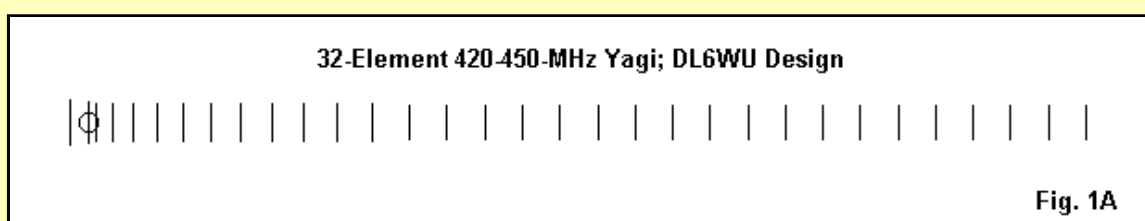
No. of Elements: 32

Boom Length: 7505.2 mm or 10.81 WL

Element Diameter: 4 mm

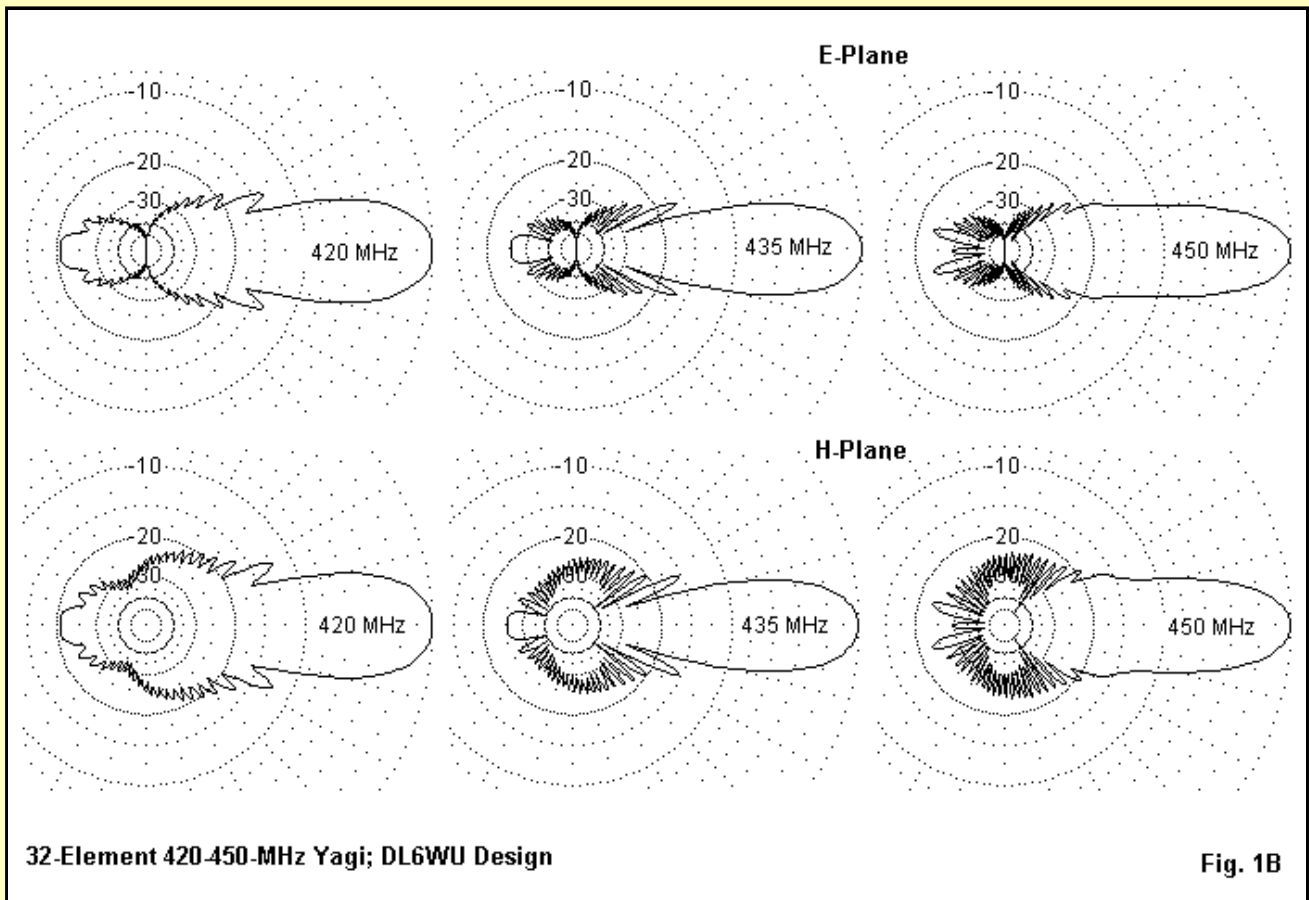
Model Segmentation: 19 segments/element

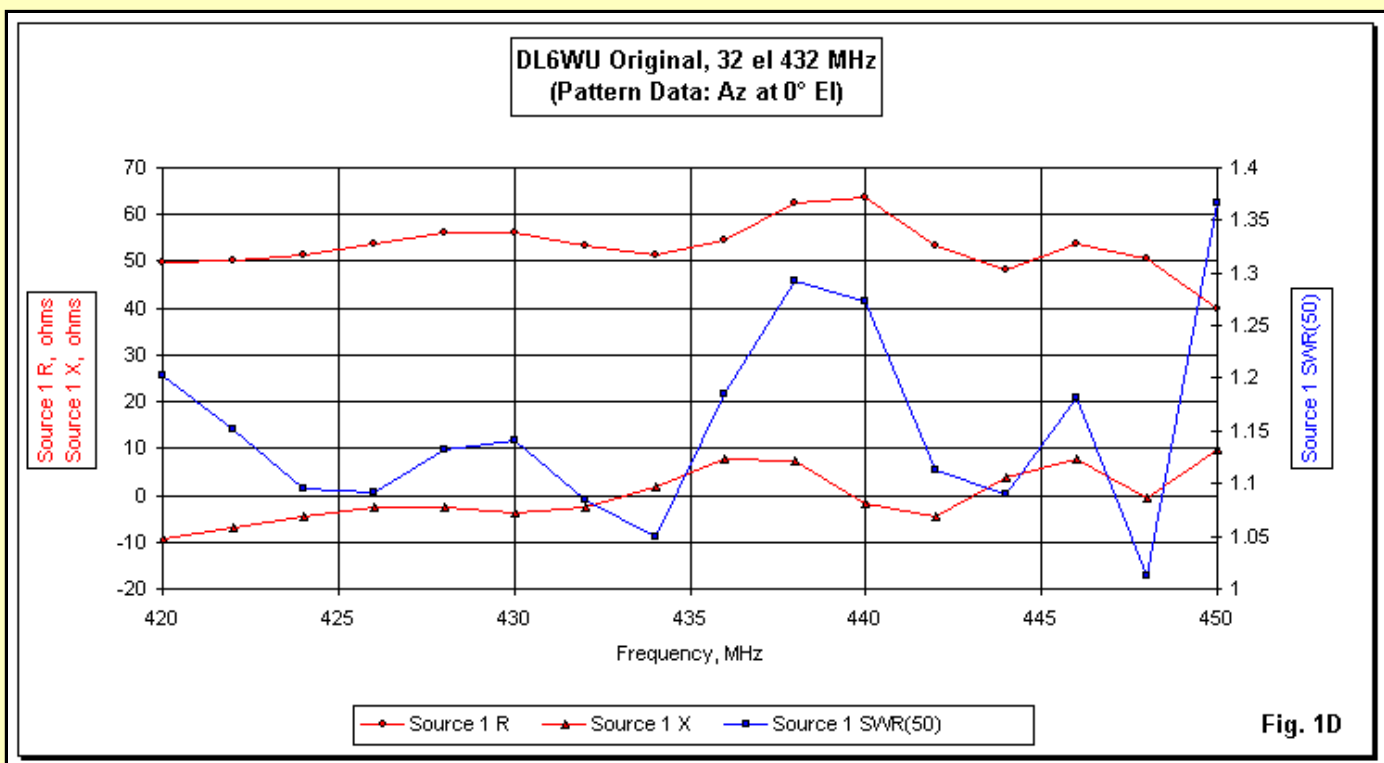
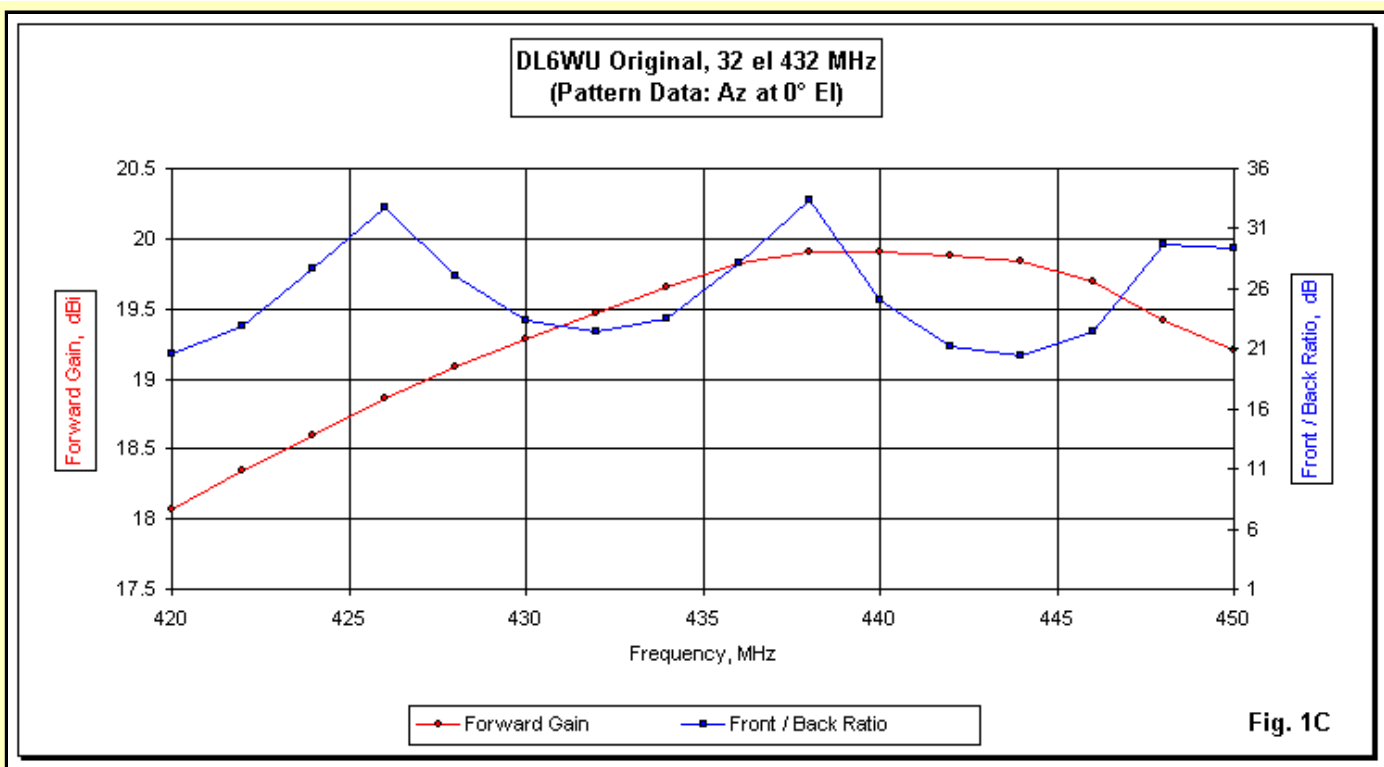
Element Density: .00454 elements/mm of boomlength



Basic Performance Data:	Frequency			
Category	420	435	450	
Forward Gain (dBi)	18.07		19.75	19.21
180-Deg F-B (dB)	20.61	25.28		29.35
Worst-Case F-B (dB)	20.61	25.28		23.44
Horiz. B-W (deg)	23.0	19.8	18.6	
Vert. B-W (deg)	23.6	20.2	19.0	
Horiz. F-SL (dB)	13.52	16.46		21.76 (+B)
Vert. F-SL (dB)	12.31	15.44		19.20 (+B)
Feed Z (R+/-jX Ohms)	49.96 - j 9.24	52.24 + j 4.98		39.83 + j 9.64
SWR (50 Ohms)	1.203	1.113		1.367

435-MHz Gain/Element: 0.617
435-MHz Gain/Boom Length (WL): 1.827

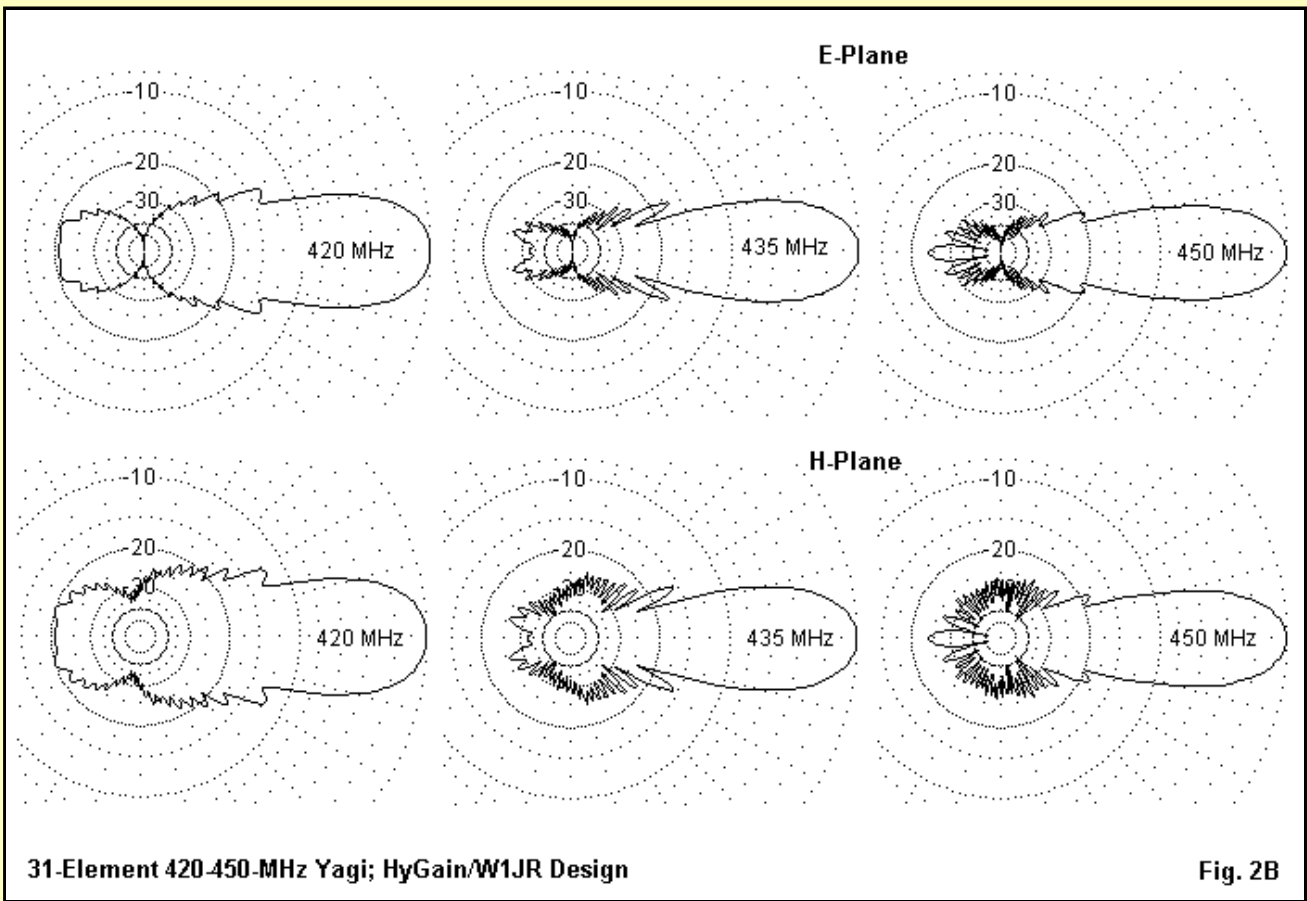




The gain of the wide-band DL6WU array varies by over 1.8 dB across the band, with the peak gain at 440 MHz. Near-peak gain and maximum front-to-back ratio coincide at 438 MHz. For narrow-band use, one may re-scale the array from about 438 MHz to the desired operating frequency within the 70-cm band. Since the frequency sweeps are at 2-MHz intervals, some peaks do not appear. Flattened curves normally mean that a peak value occurs between the point of the flattened line.

The change in the pattern shape--especially evident in the H-plane patterns--as we move across the band reflects the changing roles of the driver and the first director. As we increase frequency, the myriad of secondary lobes shifts rearward as the current magnitude on the first director exceeds that on the driver itself, making the first director a slaved driver for the array. This phenomenon is a common feature of almost all wide-band Yagi arrays.

The front-to-sidelobe ratio of the DL6WU array is fairly low--well under 20 dB--for all but the last 5 MHz of the band. Again, in common with many wide-band arrays, the first forward sidelobes become bulges on the



31-Element 420-450-MHz Yagi; HyGain/W1JR Design

Fig. 2B

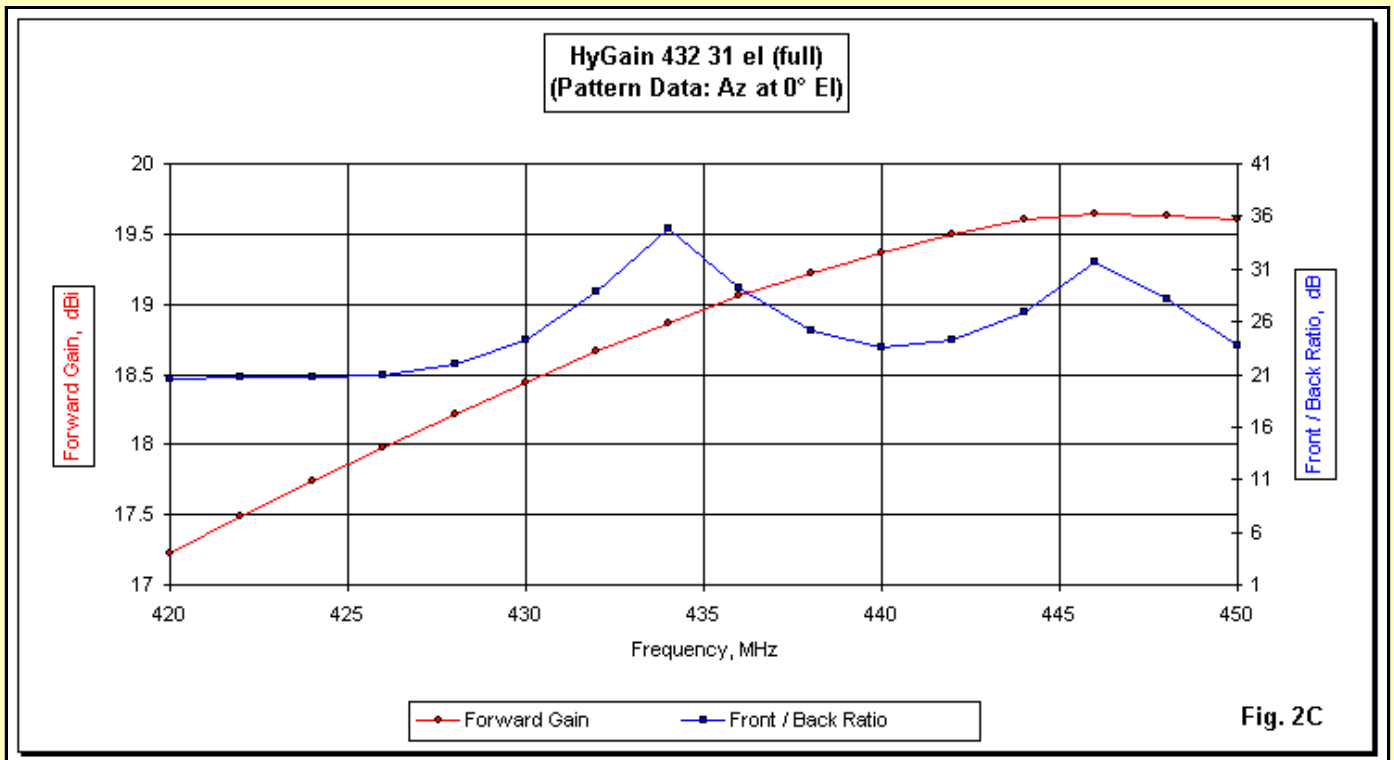


Fig. 2C

27-Element 420-450-MHz Yagi; DJ9BV Design
4 Reflectors, 22 Directors

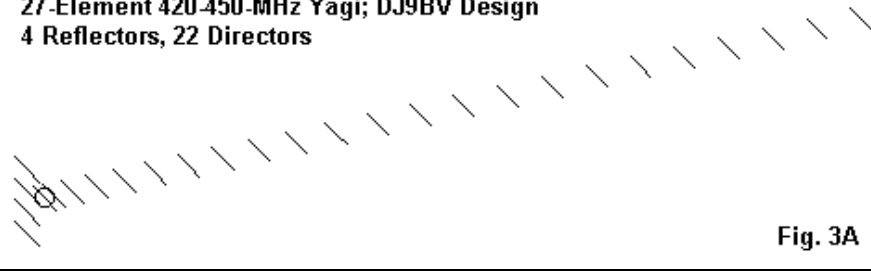
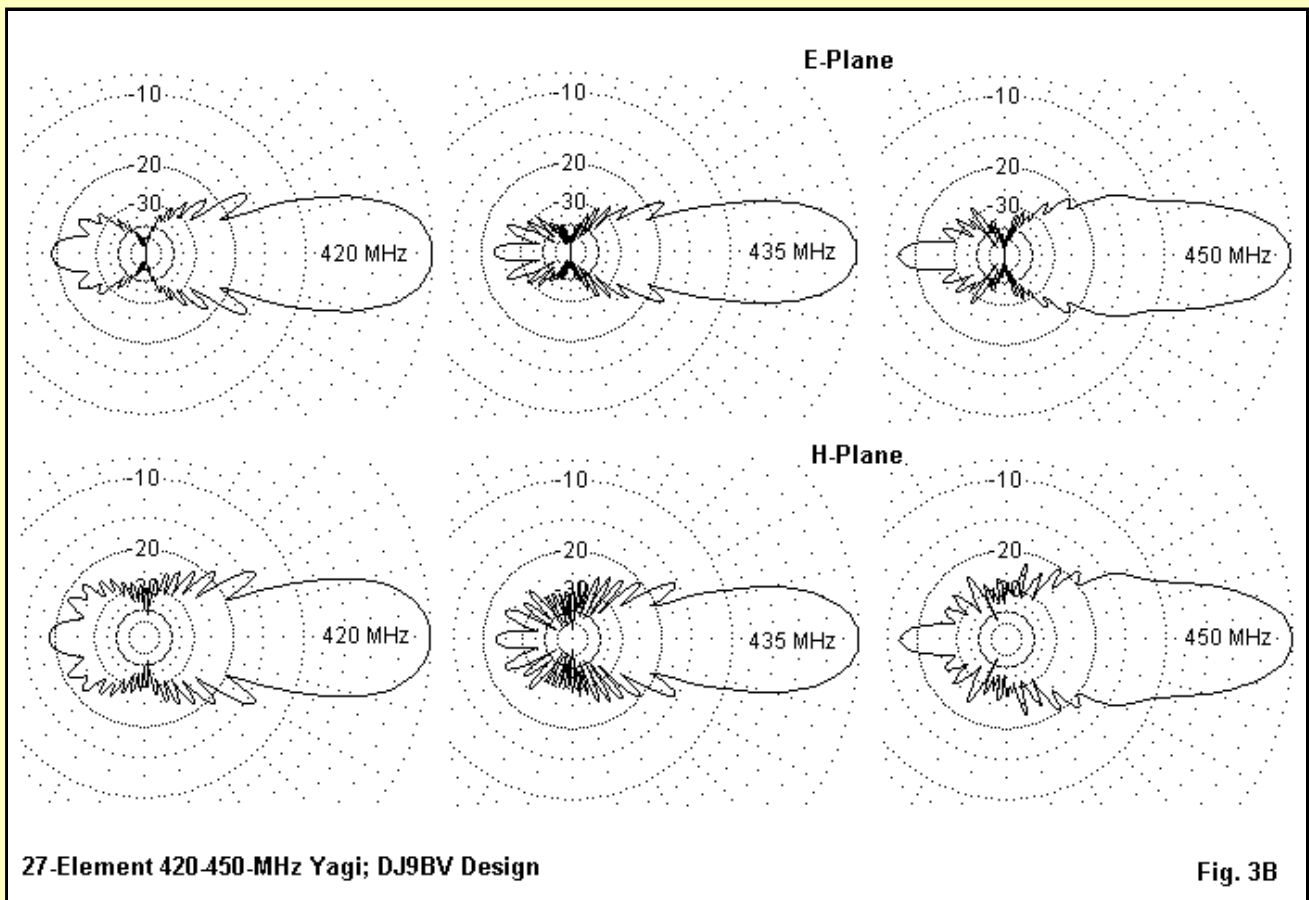


Fig. 3A

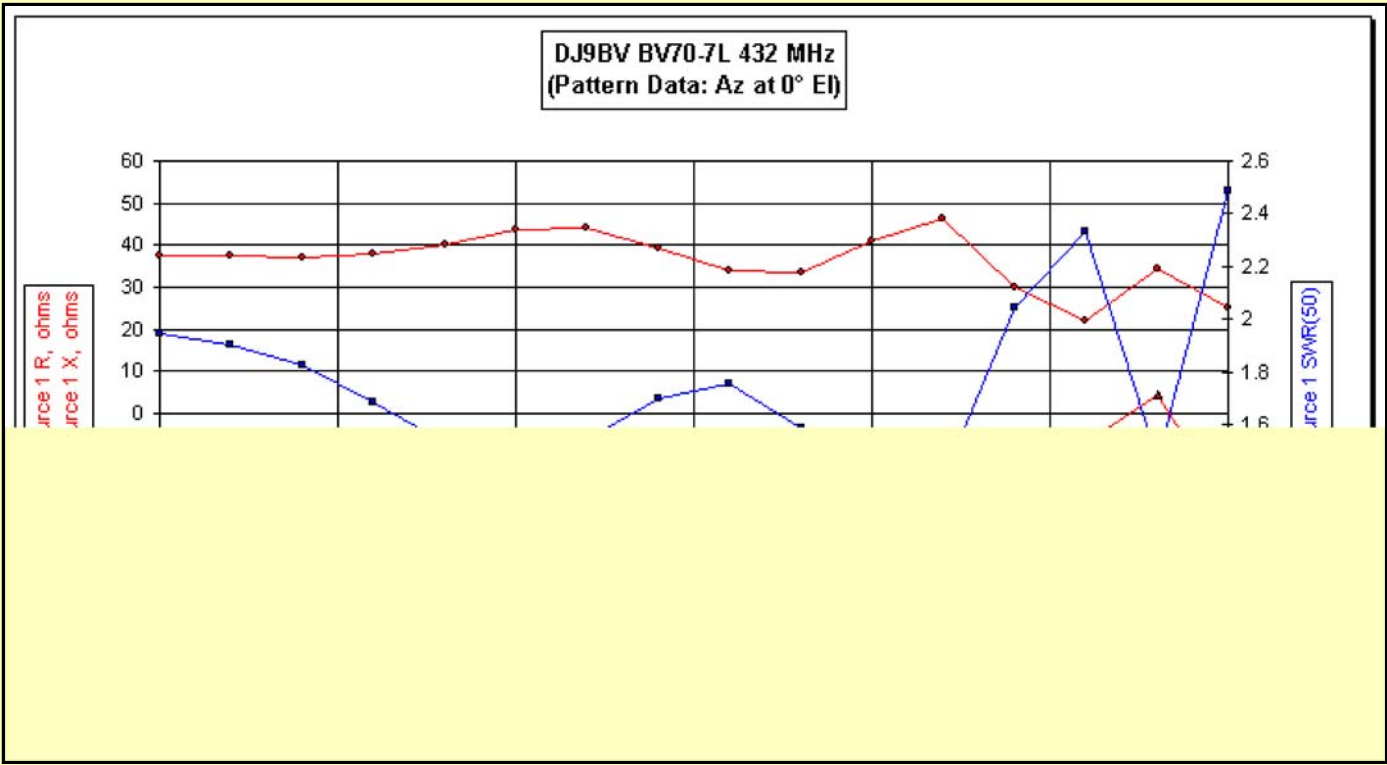
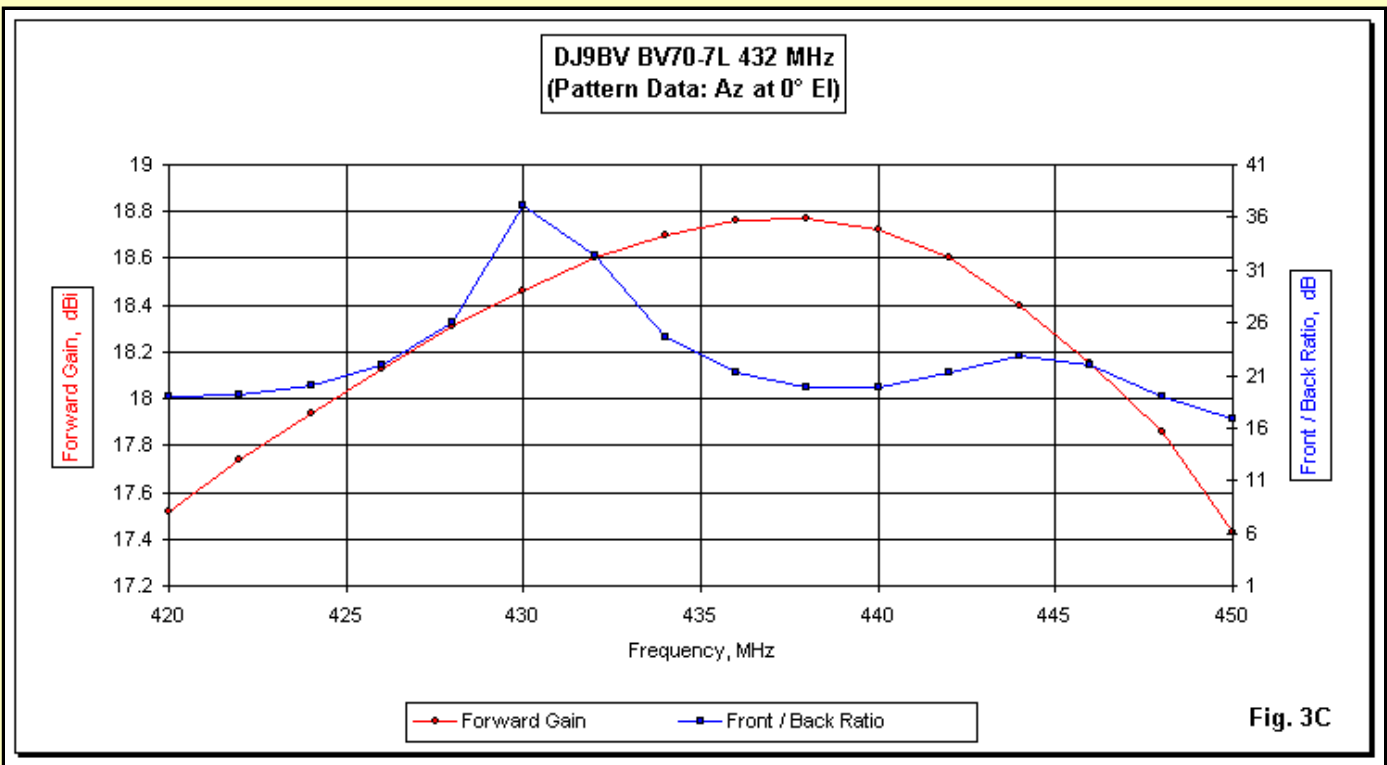
Basic Performance Data:	Frequency			
Category	420	435	450	
Forward Gain (dBi)	17.52		18.74	17.43
180-Deg F-B (dB)	19.00	22.59		16.94
Worst-Case F-B (dB)	19.00	22.59		16.94
Horiz. B-W (deg)	25.6	22.2	21.6	
Vert. B-W (deg)	26.6	23.0	22.4	
Horiz. F-SL (dB)	15.49	17.25		20.77 (+B)
Vert. F-SL (dB)	13.76	15.45		18.25 (+B)
Feed Z (R+/-jX Ohms)	37.66 - j26.66	36.30 - j19.92		25.18 - j22.46
SWR (50 Ohms)	1.994	1.751		2.488

435-MHz Gain/Element: 0.694
435-MHz Gain/Boom Length (WL): 2.546



27-Element 420-450-MHz Yagi; DJ9BV Design

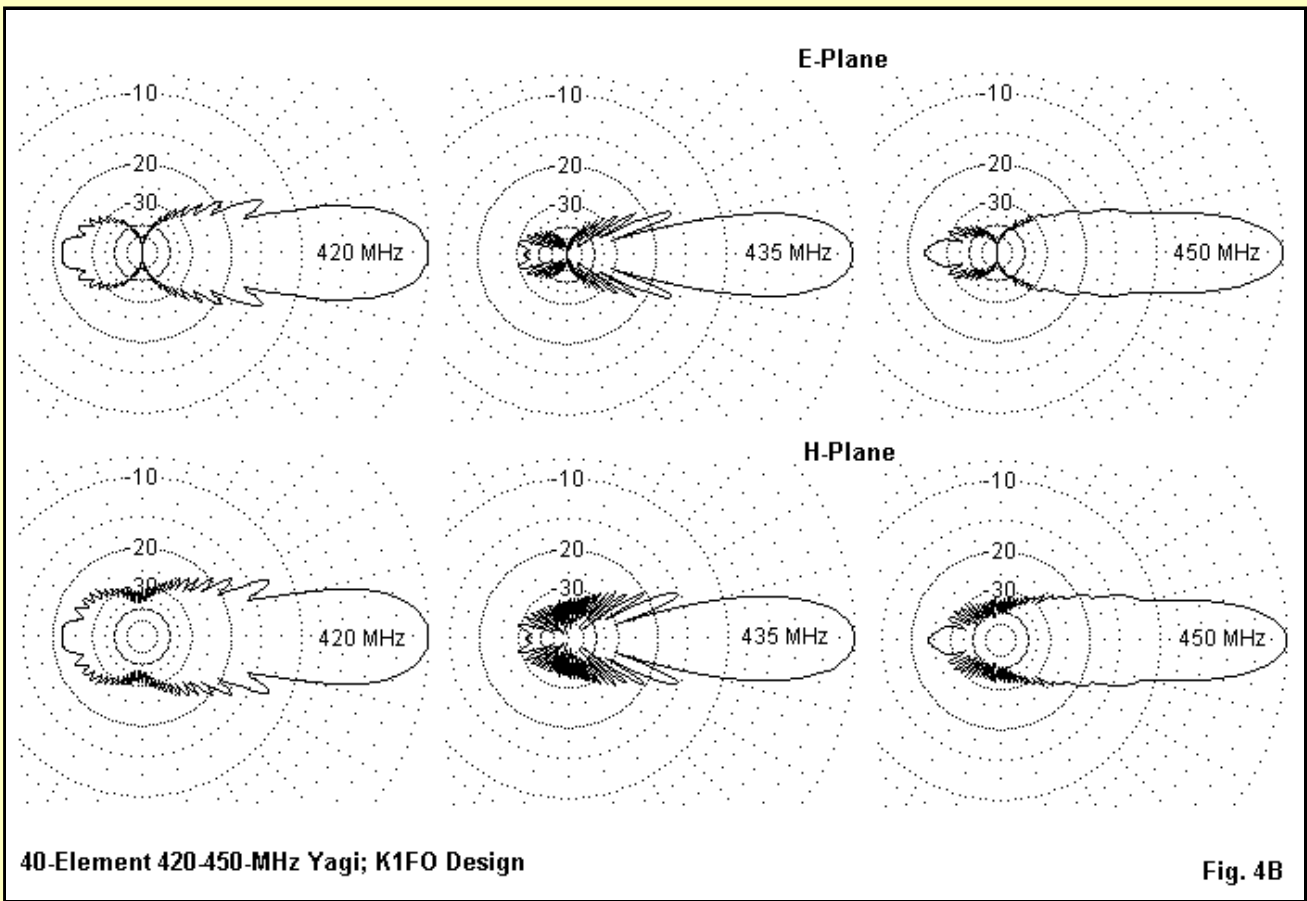
Fig. 3B



I set the dimensions of the DJ9BV array for mid-band to test the overall operating bandwidth. The design falls somewhere between a narrow-band and a wide-band design, covering about 2/3 of the 70-cm band with acceptable front-to-back ratio and 50-Ohm SWR values. However, with judicious revision of the reflector/driver/first-director region, one might improve the SWR curve considerably. The array arose in an era still wedded to the folded dipole driven element as a means of maximizing gain while establishing a 50-Ohm SWR curve.

Relative to our first two samples, the overall pattern shape shows improvements to the front-to-sidelobe ratio. However, the 450-MHz pattern has bulges that one likely should not ignore and which show a melding of the main lobe and the first forward sidelobes. Hence, the high front-to-sidelobe ratio at that frequency has dubious value.

The gain peaks between 435 and 440 MHz, although the front-to-back ratio peaks at a lower frequency. The high levels of gain per unit of boom length and per element have two facets. First, they are naturally



40-Element 420-450-MHz Yagi; K1FO Design

Fig. 4B

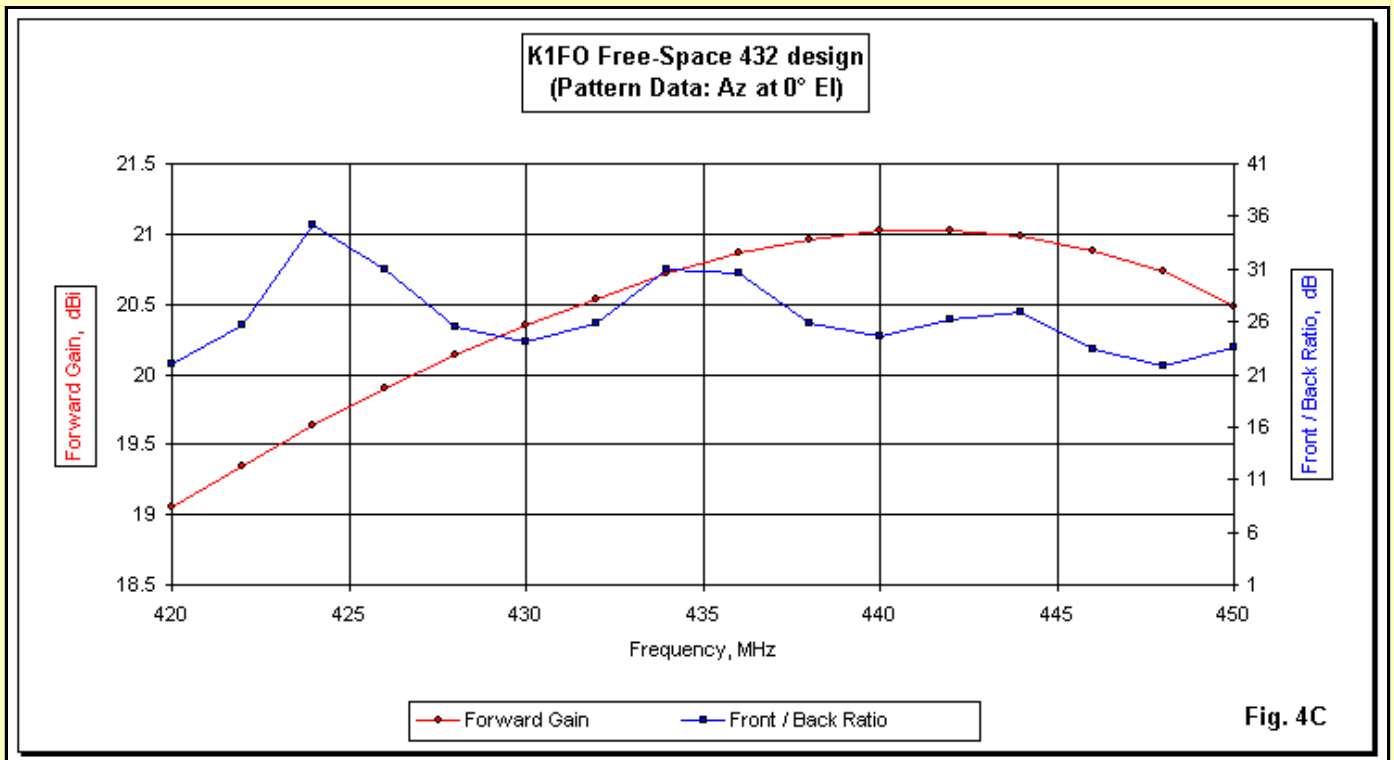
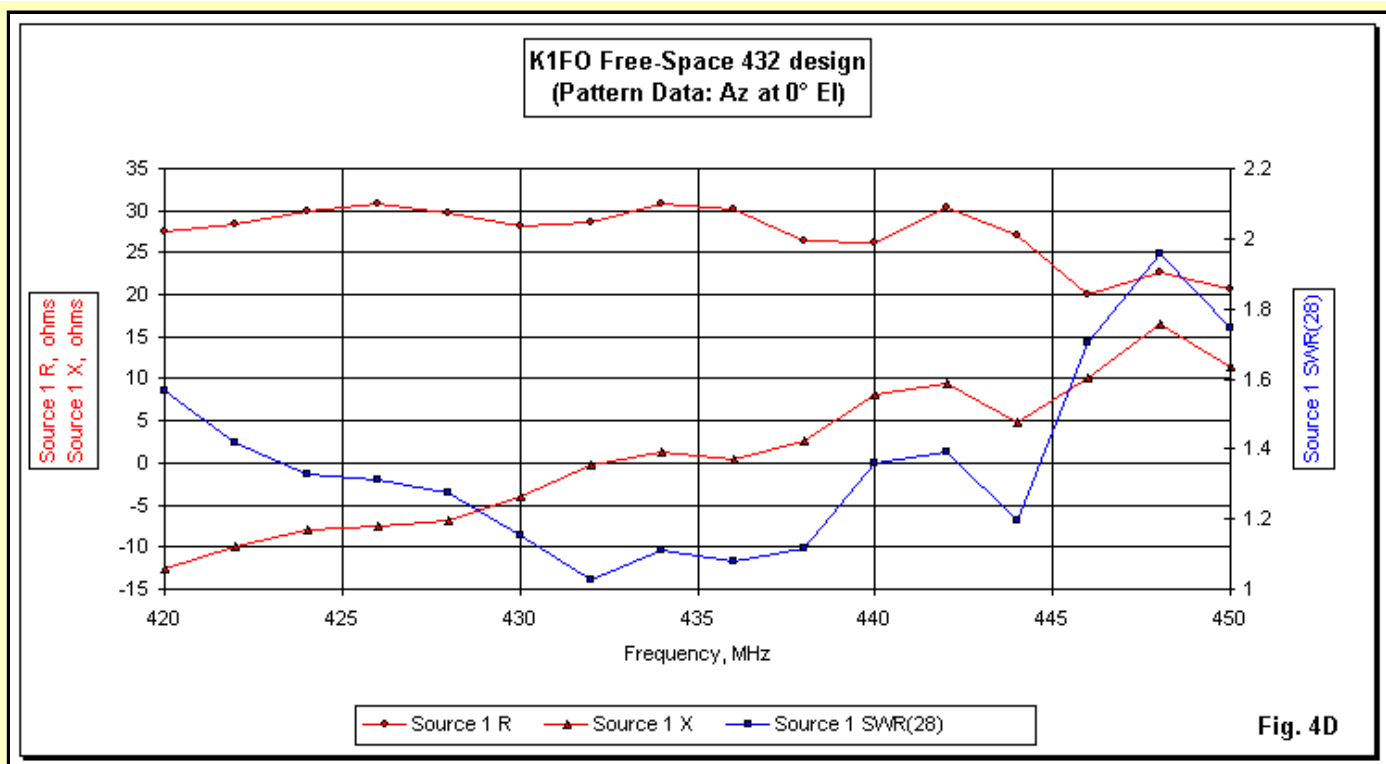


Fig. 4C



The gain factors of the K1FO design naturally decrease relative to earlier sample designs, since the addition of each new director shows a decreasing increment of gain advance. However, the array shows better than 20-dBi free-space gain over more than half the 70-cm band, with peak gain appearing in the 440-442-MHz region. By now, it should be apparent that standard wide-band long-boom Yagi design has this characteristic. Both the 180-degree and the worst-case front-to-back ratios are better than 21 dB across the band.

The gain advance in the long K1FO design is offset partially by generally poorer suppression of the forward side lobes. Indeed, relative to forward sidelobe suppression, the best region of operation appears to be at the upper end of the band, where the pattern takes on the bullet shape, but the narrow beamwidth tends to ameliorate the effect of the bulges created by merged forward lobes. In this case, there may be two sets of forward lobes merged with the main lobe. In concert with the earliest of our samples, as we increase the operating frequency within the design passband, the front-to-side ratio at about 90-degrees to the main lobe decreases, as the first director takes greater control of the current distribution in the directors.

Although the K1FO design has relatively wide operating characteristics, with less than 2-dB change in gain across the band, there is one troublesome aspect to the design. The low design feedpoint impedance--between 25 and 30 Ohms--doubles the losses incurred by any less-than-perfect mechanical junctions at the feedpoint. Models do not analyze the reduction in gain occasioned by such losses. Hence, it becomes important for the user to perform tests and analyses that will determine the total power loss of these factors. The division of power between the radiation antenna and the losses always degrades as we lower the feedpoint impedance. Folded dipoles do not cure the problem, since the impedance transformation includes loss as well as radiation resistance. The ultimate cure, beyond perfecting every mechanical connection in the system, lies in minimizing the number of such connections.

5. A 26-Element SM5BSZ Yagi

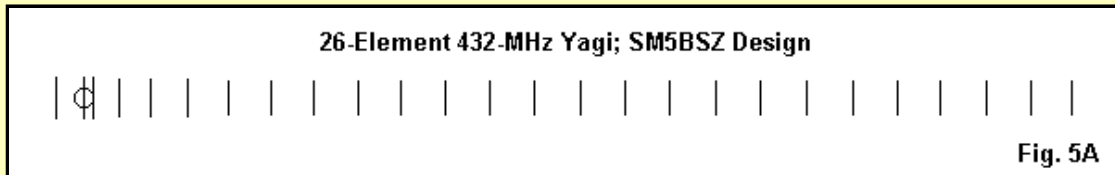
Although wide-band Yagis offer advantages in terms of replication ease and the ability to move a selected operating point to a desired frequency, they do not obtain the maximum gain from a given number of elements. Lief Asbrink, SM5BSZ, has developed (among his many contributions to VHF and UHF work) a narrow-band long-boom Yagi. He uses 26 elements on a 7429-mm boom, that is, 6 fewer elements on the same boom length used in the DL6WU array that we explored at the beginning. The cost of the exercise is a beam with a very narrow operating bandwidth. In fact, the design is not much good only a couple of MHz away from the 432-MHz design frequency. But at that frequency, it shines.

In part, the effectiveness of the design stems from the use of fatter than usual elements: 10 mm. As well, note the lower density level of the elements in the following table of basic data. Within the performance data--given only for 432 MHz--note the relatively high values of the gain per element figure and the gain

per wavelength of boom figure. Because the array is for narrow-band use, the pattern data will only be for 432 MHz, and the performance graphs will cover only 430-434 MHz.

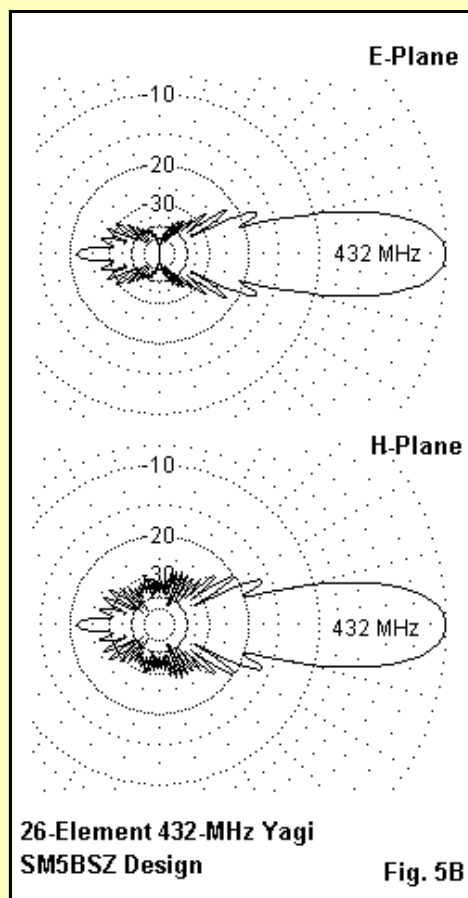
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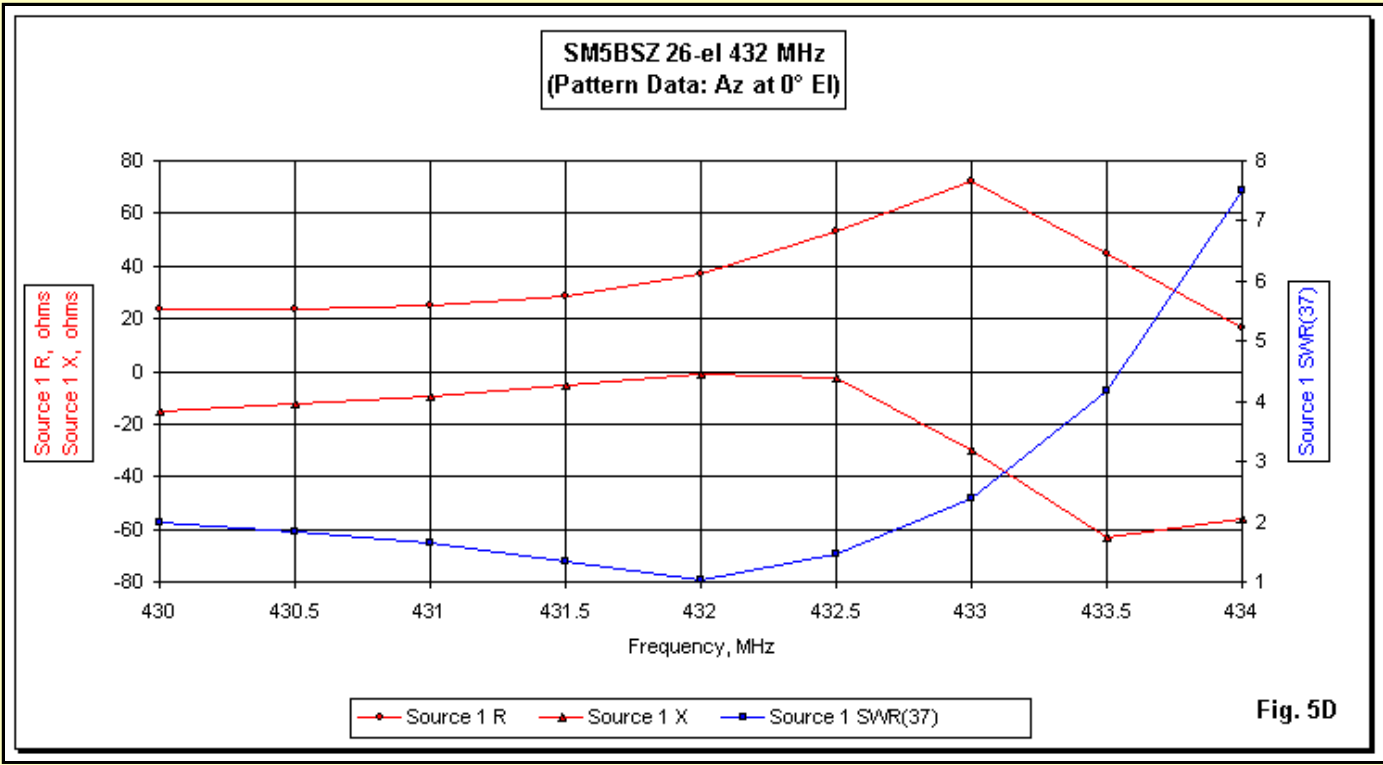
No. of Elements: 26 **Boom Length: 7429.4 mm or 10.70 WL**
Element Diameter: 10 mm **Model Segmentation: 19 segments/element**
Element Density: .00353 elements/mm of boomlength



Basic Performance Data:	Frequency
Category	432
Forward Gain (dBi)	20.52
180-Deg F-B (dB)	21.29
Worst-Case F-B (dB)	21.26
Horiz. B-W (deg)	18.0
Vert. B-W (deg)	18.4
Horiz. F-SL (dB)	17.14
Vert. F-SL (dB)	16.21
Feed Z (R+/-jX Ohms)	36.69 - j 1.36
SWR (37 Ohms)	1.038

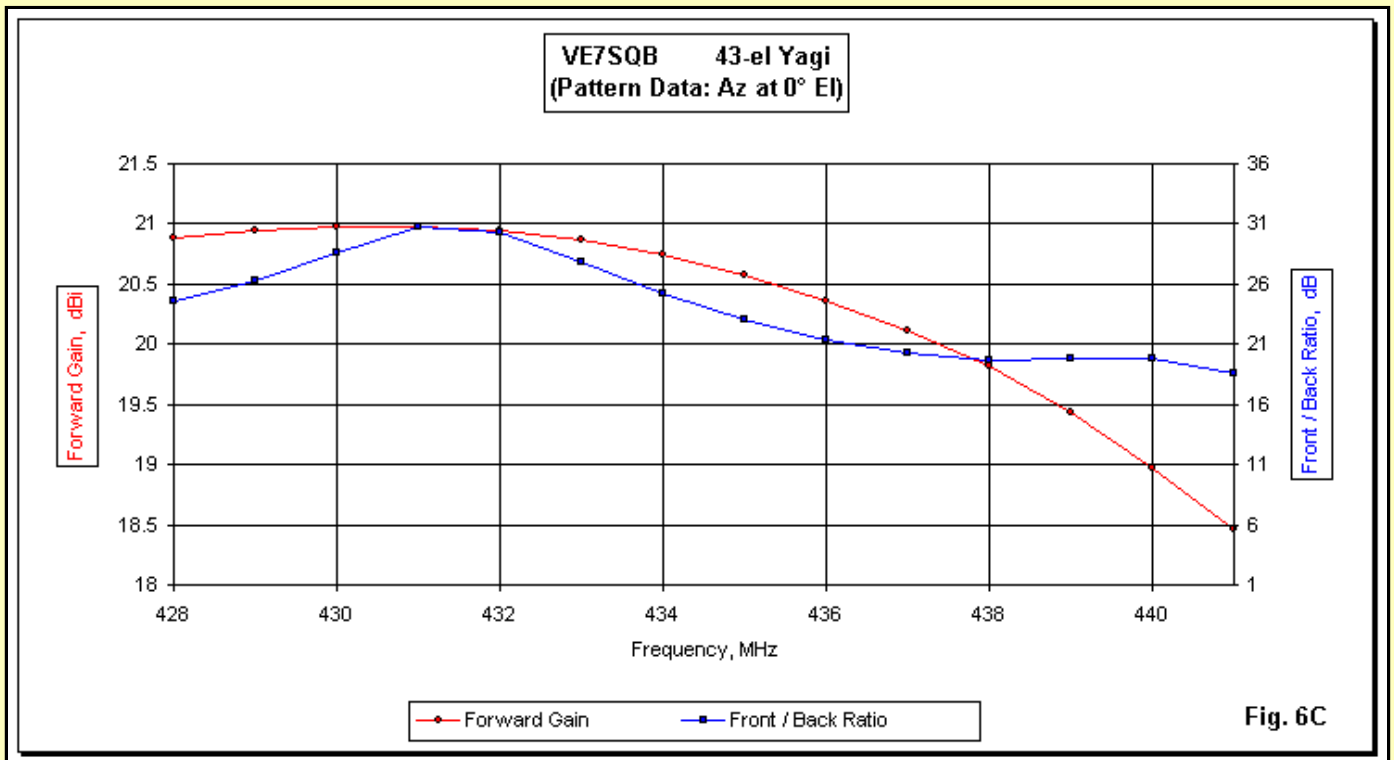
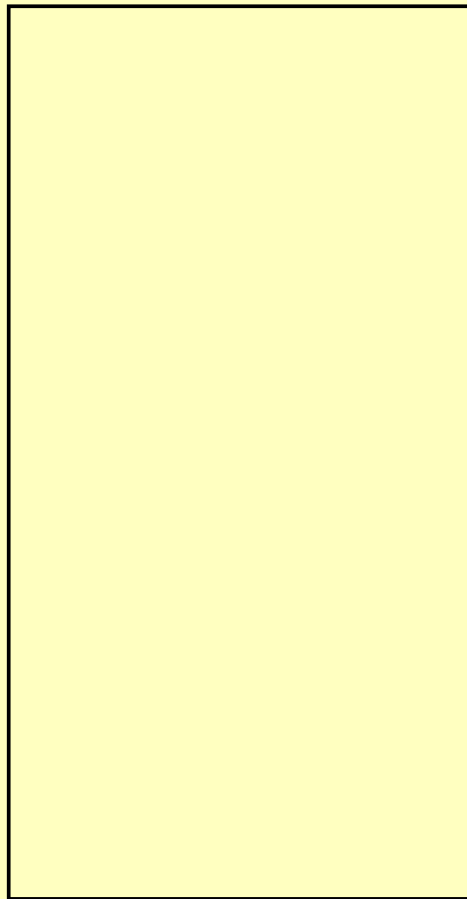
435-MHz Gain/Element: 0.789
435-MHz Gain/Boom Length (WL): 1.916

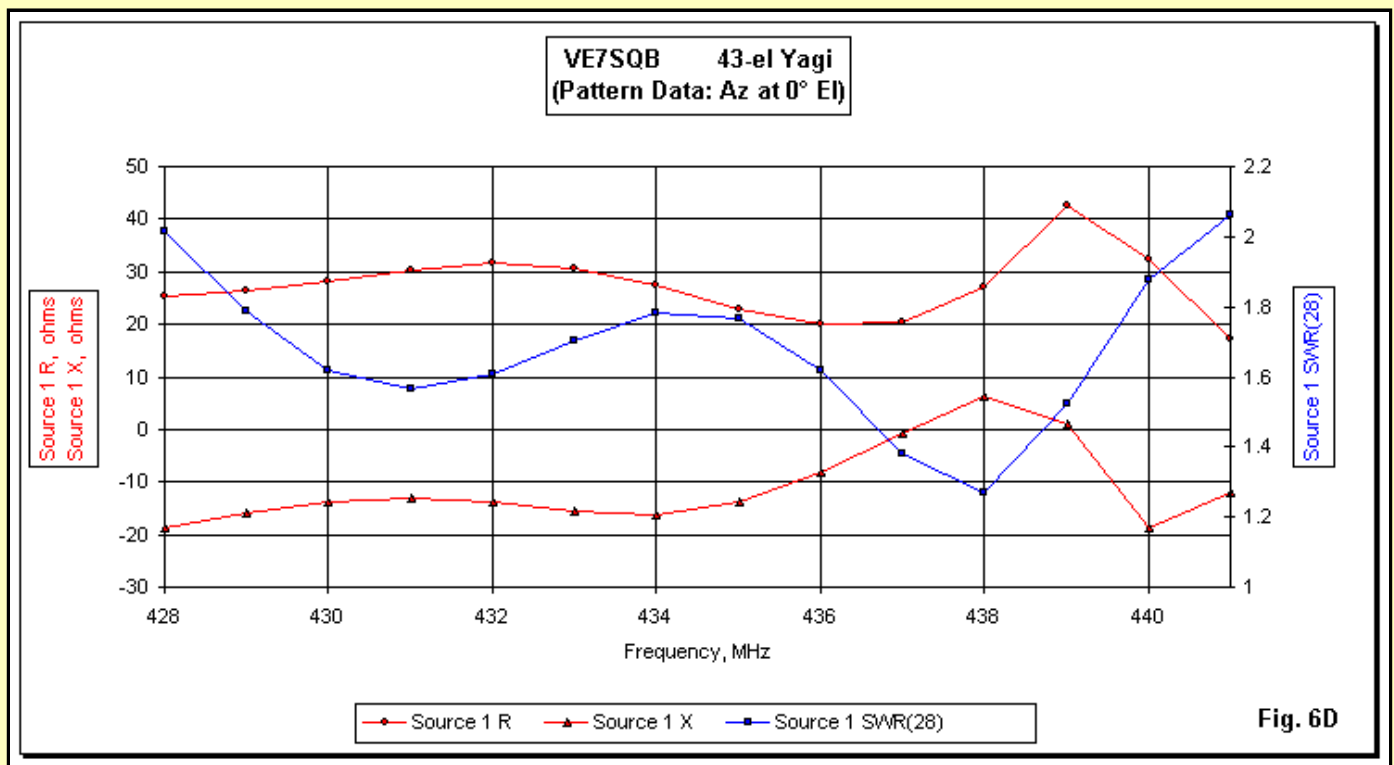




It is likely that only a master antenna builder may replicate this antenna adequately, especially if one must make adjustments for the method of element-to-boom mounting. However, the array does illustrate how much gain one may squeeze out of the least number of elements on a given boom length. As well, comparing this array's peak performance to the wide-band arrays of relevantly similar lengths, we can obtain some idea of how much performance at a given frequency that we sacrifice to obtain the wide-band characteristics designed into those arrays. These are aspects of array performance too little appreciated by many operators trying to decide upon an array for a given task. In the end, if one builds the antenna oneself, the final decision must be a considered balance of the desired performance level vs. the degree of difficulty in replicating a design, with an honest consideration of one's shop skills and tools. Since SM5BSZ is "in the industry," he undoubtedly has access to the finest fabrication tools and has a track record that suggests his skills are unsurpassed.

6. A 43-Element VE7BQH Yagi





Although the original 2-meter version of this array was designed to solve the boom-length problem at that lower frequency region, the 70-cm version that I have modeled gives us an example of what we can do with wire. Although it is much longer than the SM5BSZ narrow-band array, the VE7BQH Yagi uses very thin elements. Element diameter and the level of mutual coupling between elements play important roles in developing gain from a given arrangement of elements. I am often surprised by the number of arrays that I encounter where one or more directors are almost inactive. If you wish to hand optimize a Yagi design, pay close attention to the current levels on each element and watch for pattern changes as the levels vary during your adjustments. Of course, we can monitor current on all elements of a Yagi more easily in models than we can with physical elements.

The SM5BSZ and the VE7BQH Yagis are two radically different approaches to narrow-band Yagi design. Both produce high gain, but both are deficient in terms of overall pattern shape, especially with respect to the suppression of side lobes. Perhaps other design approaches can yield somewhat better results.

7. A 41-Element VK3AUU Yagi

David Tanner, VK3AUU has done some extensive design work in a somewhat different direction from the one taken by other designers of wide-band Yagis. First, he has striven to improve--at least for part of the operating passband--the overall pattern shape, including the suppression of forward sidelobes. Second, he has attempted to optimize the spacing of the reflector, driver, and first director in an interesting manner to achieve a very low 50-Ohm SWR across the passband--that is, all of the 70-cm band. Although the effort is related to the WA3FET/NW3Z techniques for the optimized wideband antenna set-up (OWA), there are certain distinct features to the VK3AUU design.

DL6WU used spacings of 0.200 and 0.075 wavelength, respectively, for the reflector/driver and driver/first-director. Most other designers have followed suit, with minor variations in the reflector/driver spacing, but with a driver/first-director spacing above 0.075. The typical OWA array will use a reflector/driver spacing of just over 0.1 wavelength, with a driver/first-director spacing in the vicinity of about 0.055 wavelength. Of course, the exact spacings depend to some extent upon the length-to-diameter ratio of the elements in order to achieve a smooth 50-Ohm SWR curve with maximum values under about 1.3:1 across a passband. On a band as wide as 70 cm, obtaining the desired curve with normal element diameters (1/8" to 1/4") is not easy. As well, the second and third directors of a standard OWA configuration have roughly equal lengths.

VK3AUU employs a wider reflector/driver spacing (0.19-0.20 wavelength) together with a very narrow driver/first-director spacing (0.033 to 0.038 wavelength) to obtain very broad SWR curves. The models that we shall examine are adapted from 2-meter versions, and the elements have been standardized at a 4-mm diameter. We shall start with a planar Yagi having 41 elements.

Basic Data:

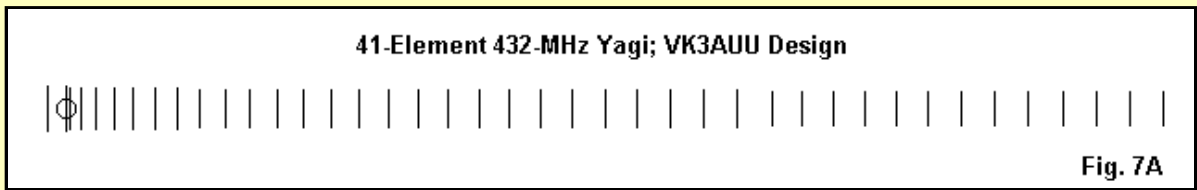
No. of Elements: 41

Boom Length: 7723.3 mm or 11.13 WL

Element Diameter: 4 mm

Model Segmentation: 19 segments/element

Element Density: .00622 elements/mm of boomlength



Basic Performance Data:

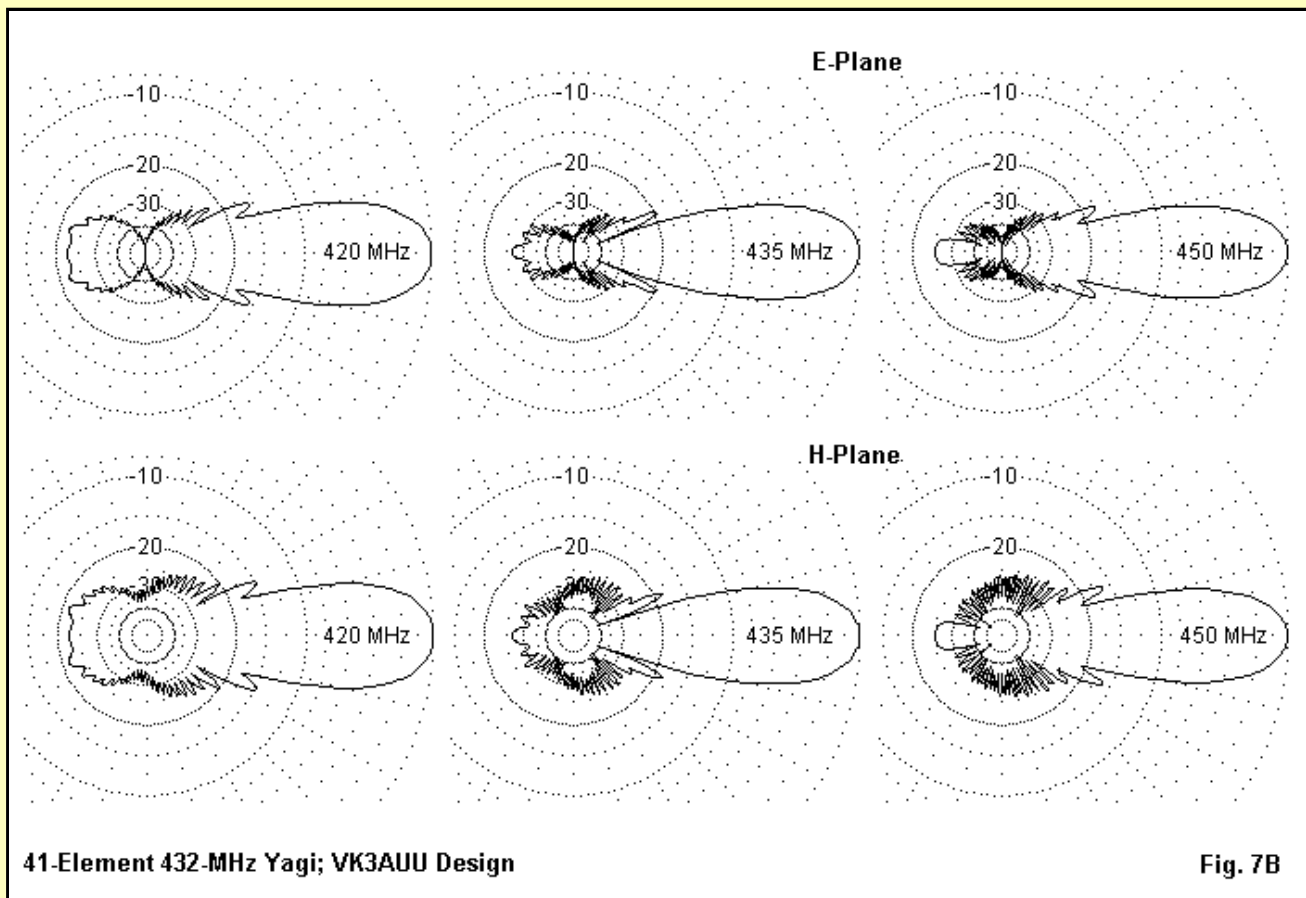
Category	420	435	450
Forward Gain (dBi)	18.56	19.73	19.67
180-Deg F-B (dB)	22.30	26.35	25.17
Worst-Case F-B (dB)	22.30	26.35	25.17
Horiz. B-W (deg)	22.8	20.6	19.8
Vert. B-W (deg)	23.6	21.2	20.2
Horiz. F-SL (dB)	15.74	19.52	17.51
Vert. F-SL (dB)	14.57	18.51	16.26
Feed Z (R+/-jX Ohms)	49.14 - j 4.41	50.56 - j 1.41	44.39 - j 3.53
SWR (28 Ohms)	1.095	1.031	1.150

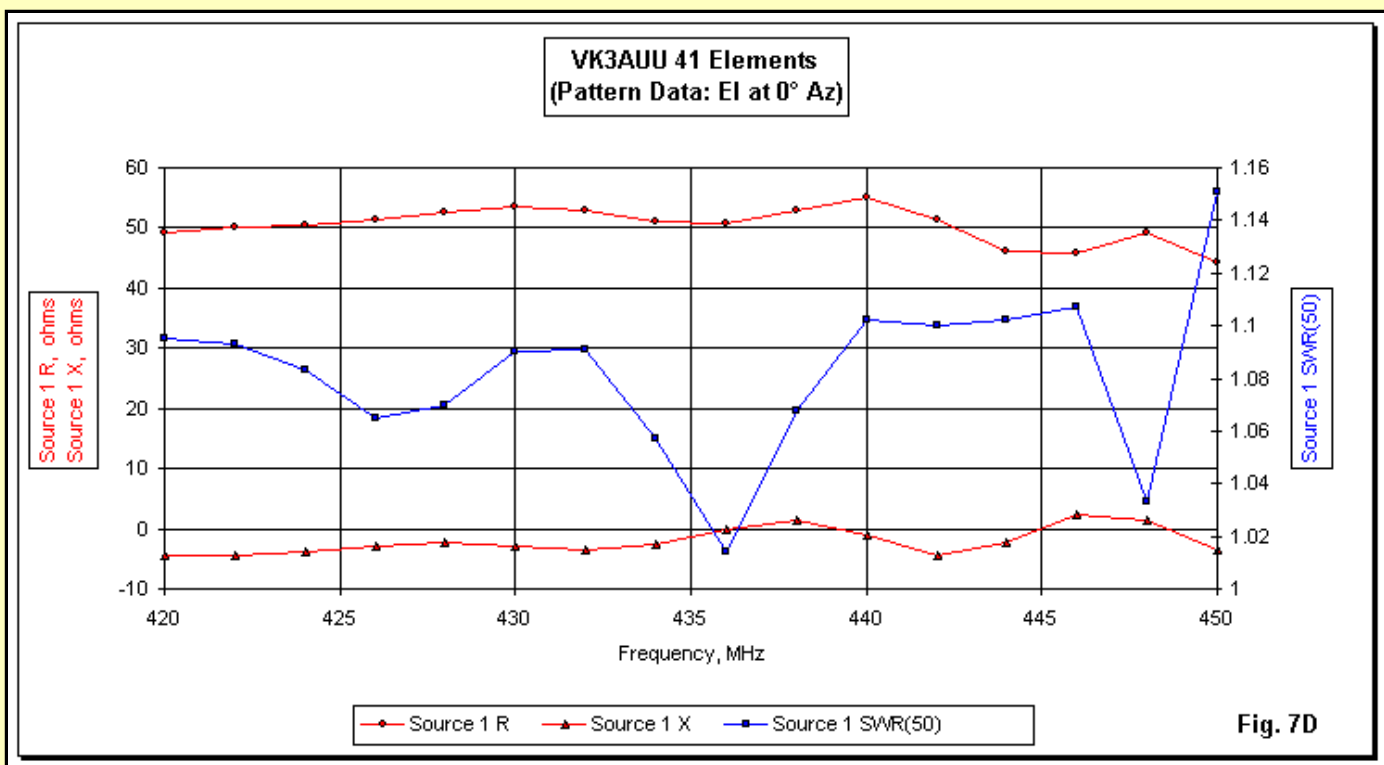
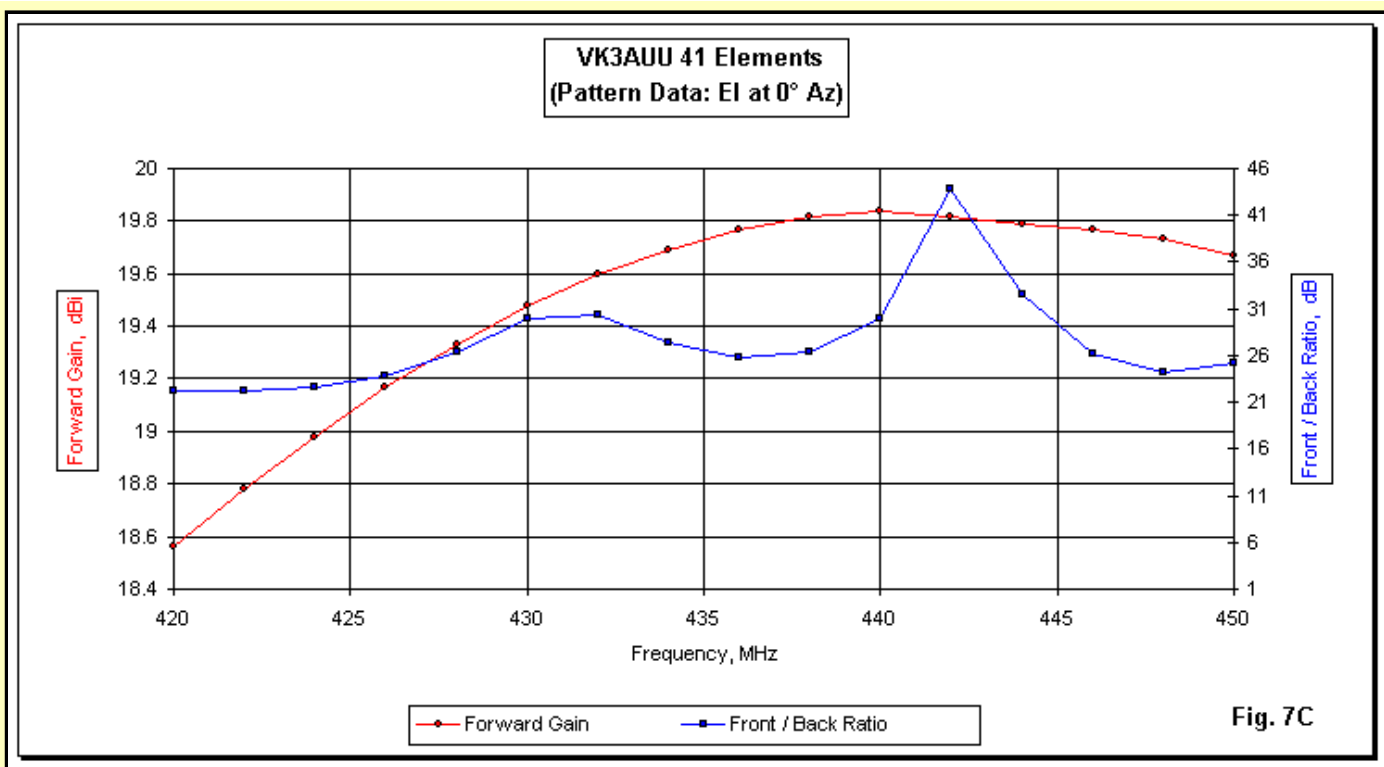
435-MHz Gain/Element:

0.481

435-MHz Gain/Boom Length (WL):

1.773

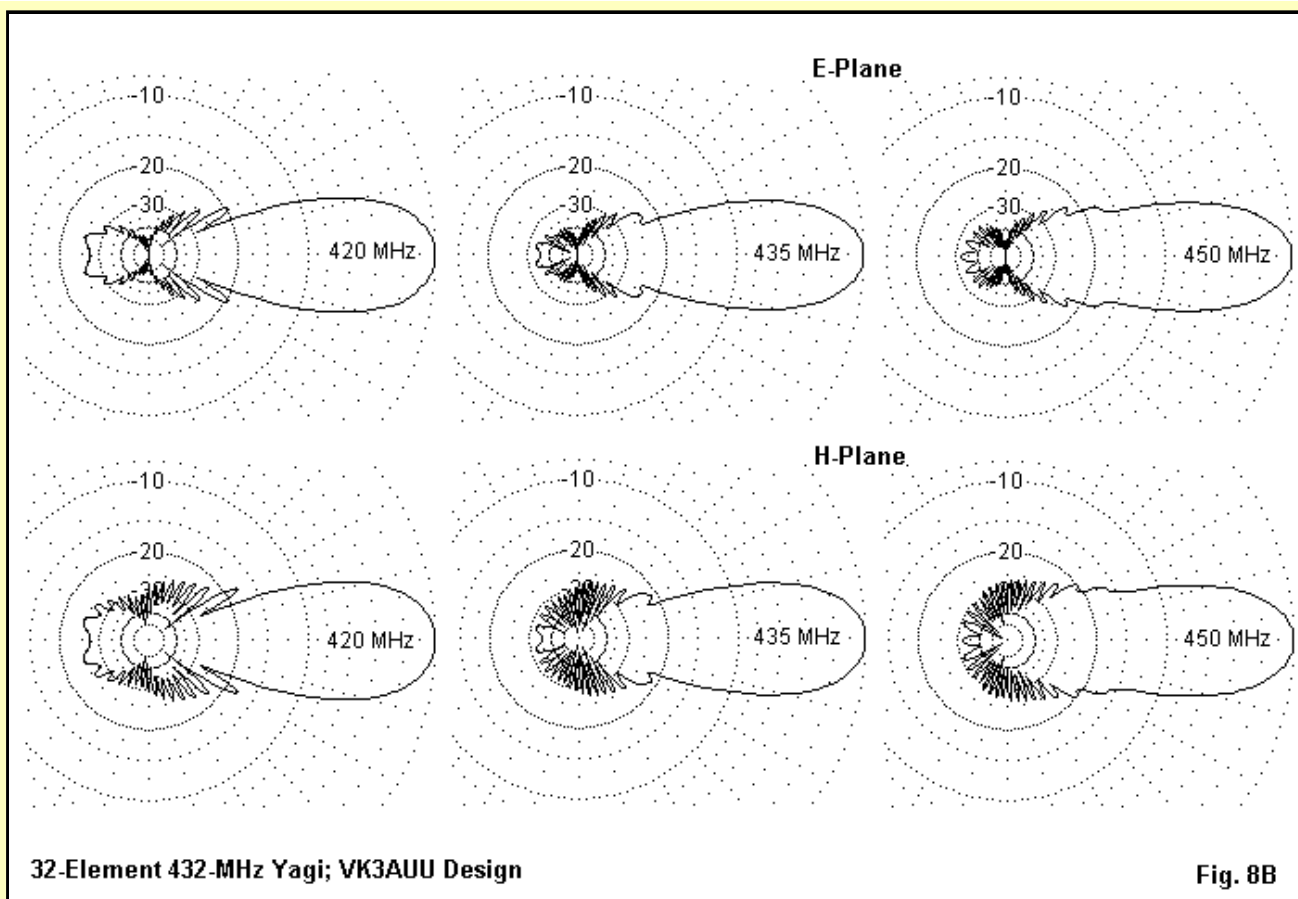




One feature that the VK3AUU design shares in common with standard OWA techniques is the ability to center the performance characteristics of an array within an operating passband. Although not completely centered, the gain curve peaks at about 440 MHz, lower than most other wide-band designs.

The forward sidelobe suppression is not yet a full-band phenomenon. Rather, it peaks in the center third of the band and tapers off on either side of that region. Suppression is nearly 20 dB in the E-plane and slightly less in the H-plane. The suppression is superior to other wide-band designs in this study at 420 MHz. Unfortunately, the change of pattern in those designs from a teardrop to a bullet defeats an effective comparison at 450 MHz. However, it is notable that the VK3AUU design retains its tear drop pattern throughout the 70-cm band.

One key to the improvement of pattern shape is the higher element density used by VK3AUU. The element density of 0.00622 elements per mm is about 23% higher than the next most dense array (0.00506) in the collection of Yagis that we have so far studied. The boom length is barely longer than the DL6WU design,



32-Element 432-MHz Yagi; VK3AUU Design

Fig. 8B

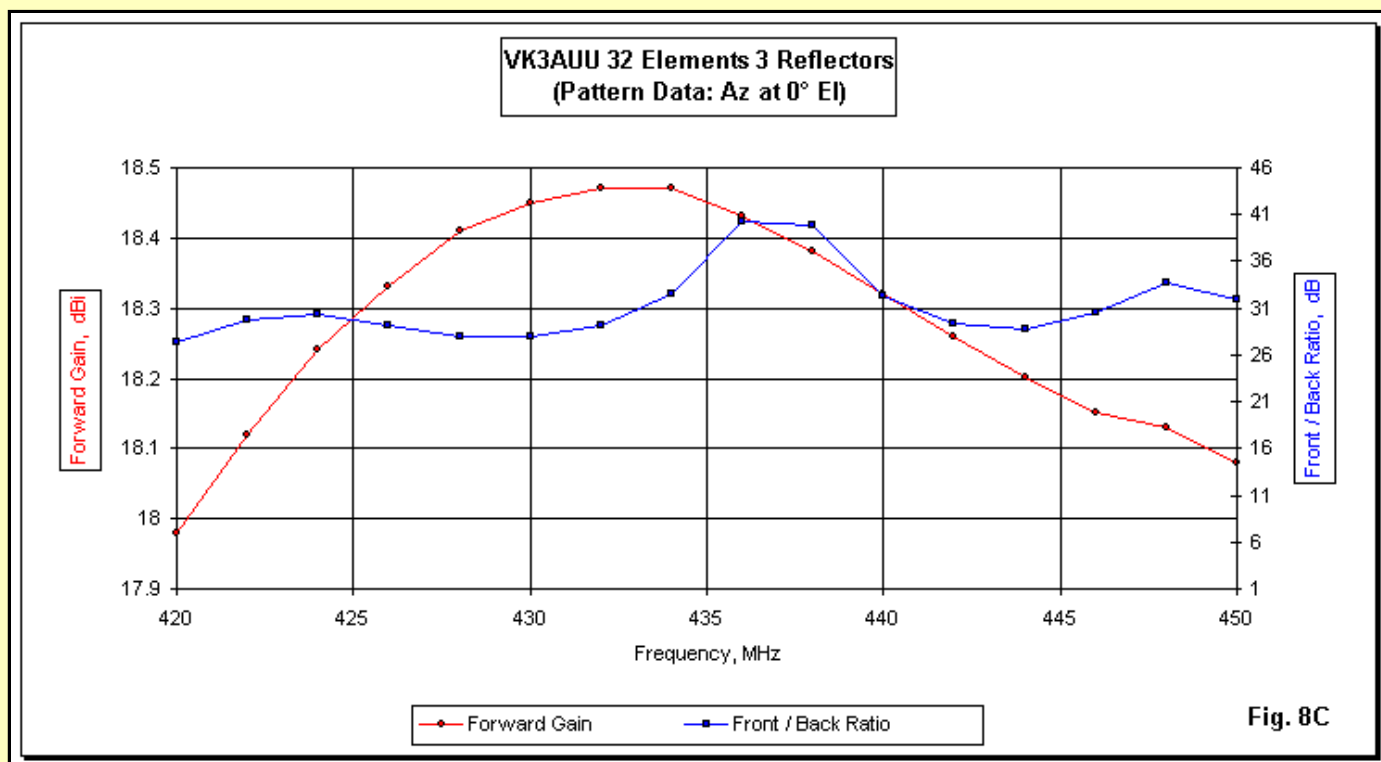


Fig. 8C

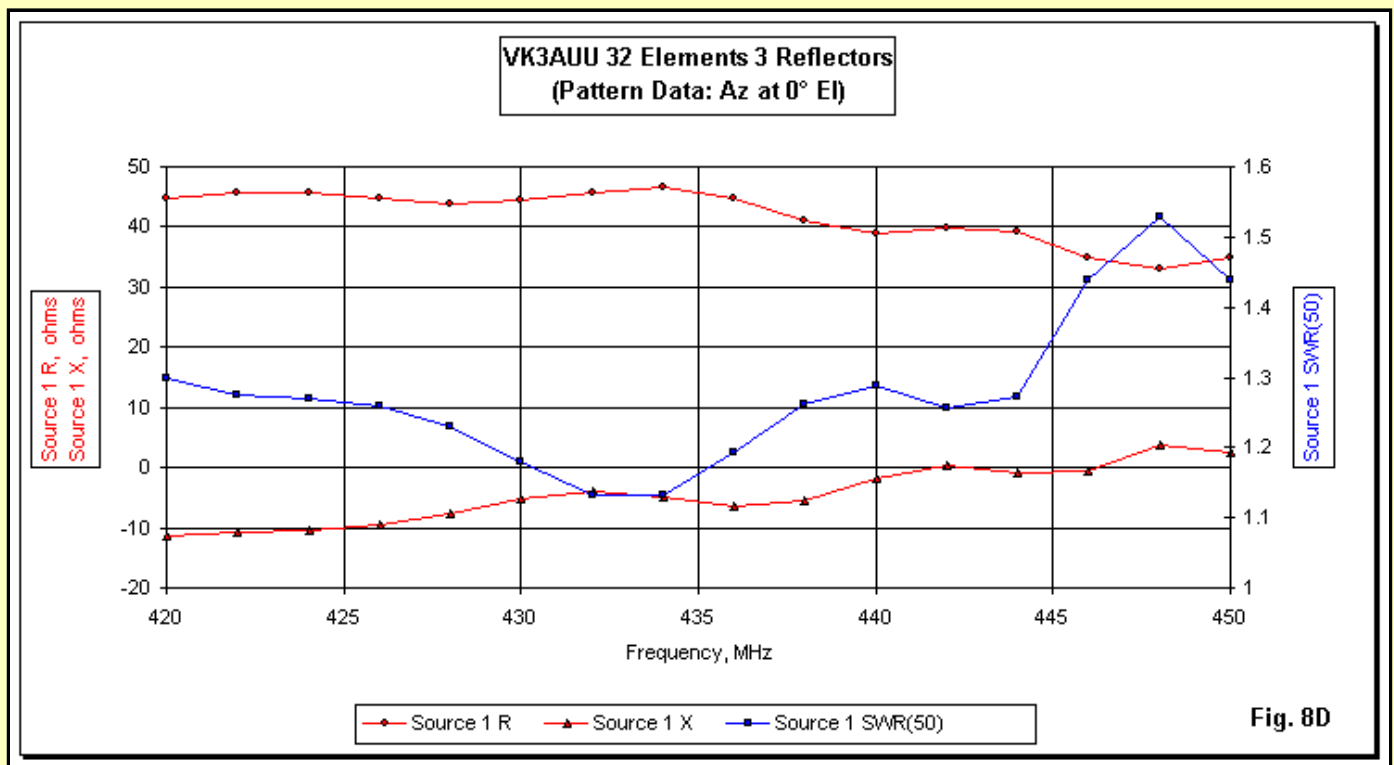


Fig. 8D

In this array, the gain curve is almost perfectly centered in the overall passband. However, the patterns at 450 MHz have degraded slightly so that they are approaching the bullet shape that merges forward sidelobes into the main pattern. In some sense, then, the development of this offshoot array is not fully complete.

Nevertheless, the array improves both horizontal and vertical front-to-sidelobe ratios by over 4 dB relative to the 41-element planar array that we just examined. Except for the lowest portion of the band, the front-to-sidelobe ratio is better than 20 dB. The only other array with a similar boom length is the DJ9BV Yagi with its plane of 4 reflectors. The VK3AUU array with its "tilt-back" reflector system achieves nearly 6 dB better front-to-sidelobe ratios with only about 0.5 dB gain variation across the passband and comparable gain levels to the DJ9BV Yagi. The improvements accrue not only to the redesign of the added reflectors in accord with principles I laid out in the sidelobe suppression study, but as well to the increased element density. For similar boom lengths, the VK3AUU Yagi employs 6 additional directors.

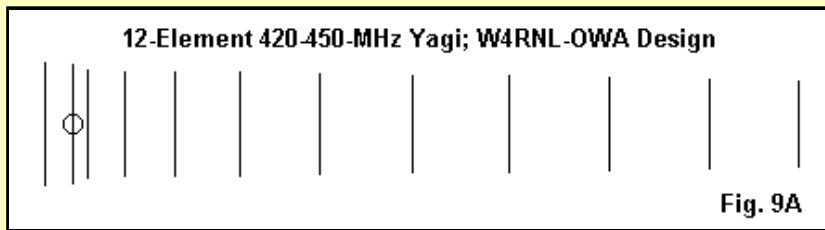
9. A 12-Element OWA Yagi

We now come to the point of showing why the present study is preliminary. The search for a "perfect" Yagi includes not only the standard operating parameters of gain, front-to-back ratio, and SWR bandwidth. As well, it encompasses pattern shape. Pattern shape refers partly to the visual shape, that is, the ideal tear drop pattern. It also refers partly to the suppression of all sidelobes to the degree feasible.

To set a reference point for such a shape, I am adding to this study a Yagi design that is not a long-boom array as defined by the preceding examples. Indeed, the boom is under 3 wavelengths. The design is an OWA array scaled and adjusted from past 2-meter examples, but with 4-mm diameter elements. Stretching the 2-meter passband to cover the 70-cm band requires considerable adjustment, since the 4 MHz of 2 meters is only 12 of the 30 MHz of 70 cm. Still, it is a possible task.

Basic Data:

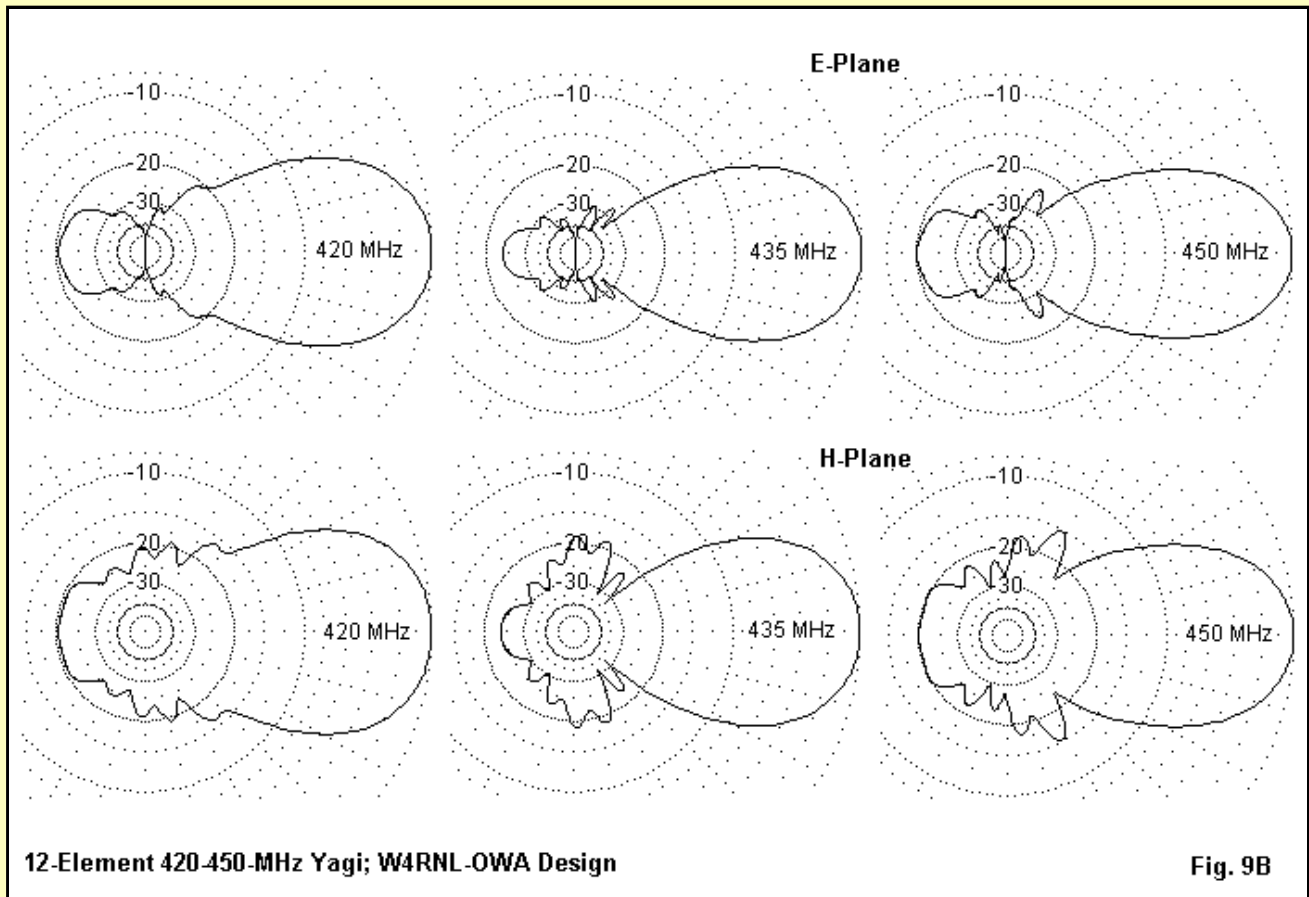
No. of Elements: 12 **Boom Length: 1997.7 mm or 2.88 WL**
Element Diameter: 4 mm **Model Segmentation: 19 segments/element**
Element Density: .00601 elements/mm of boomlength

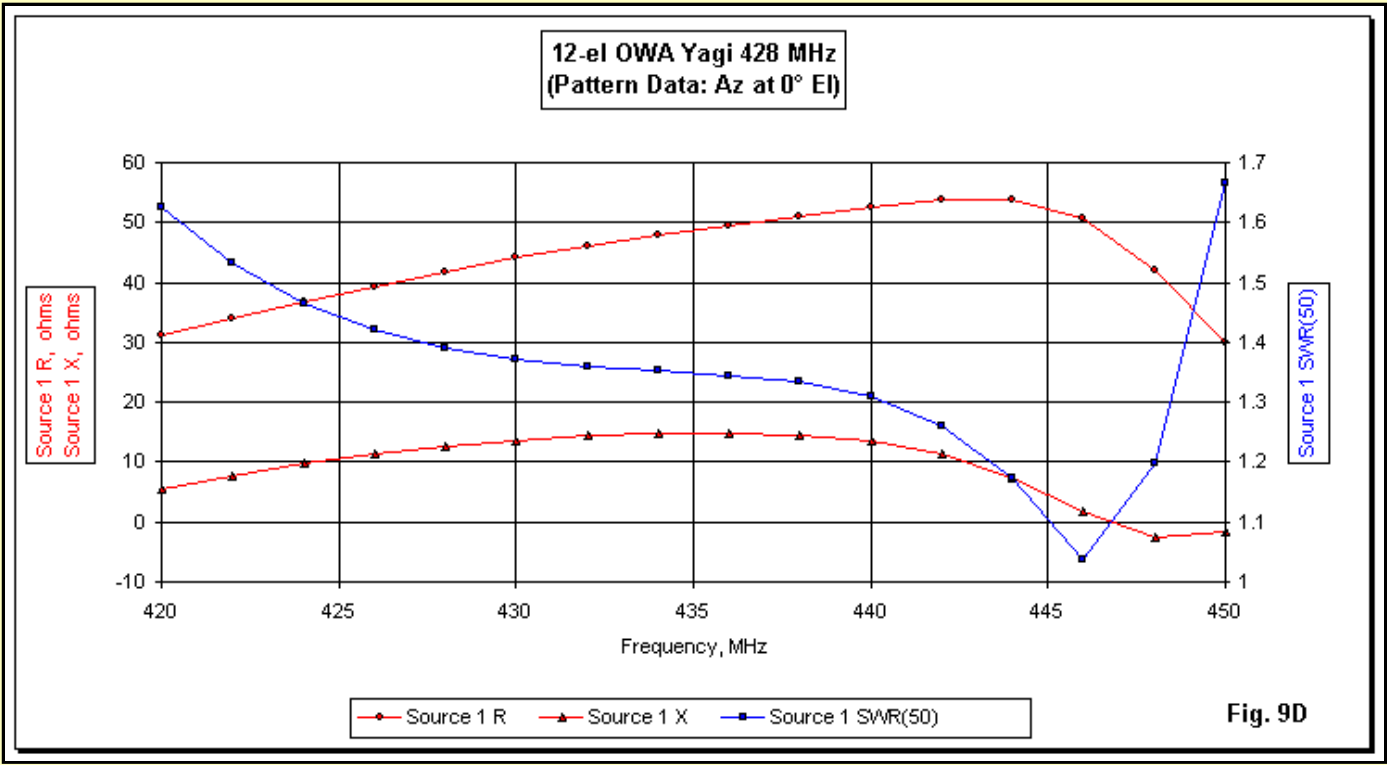
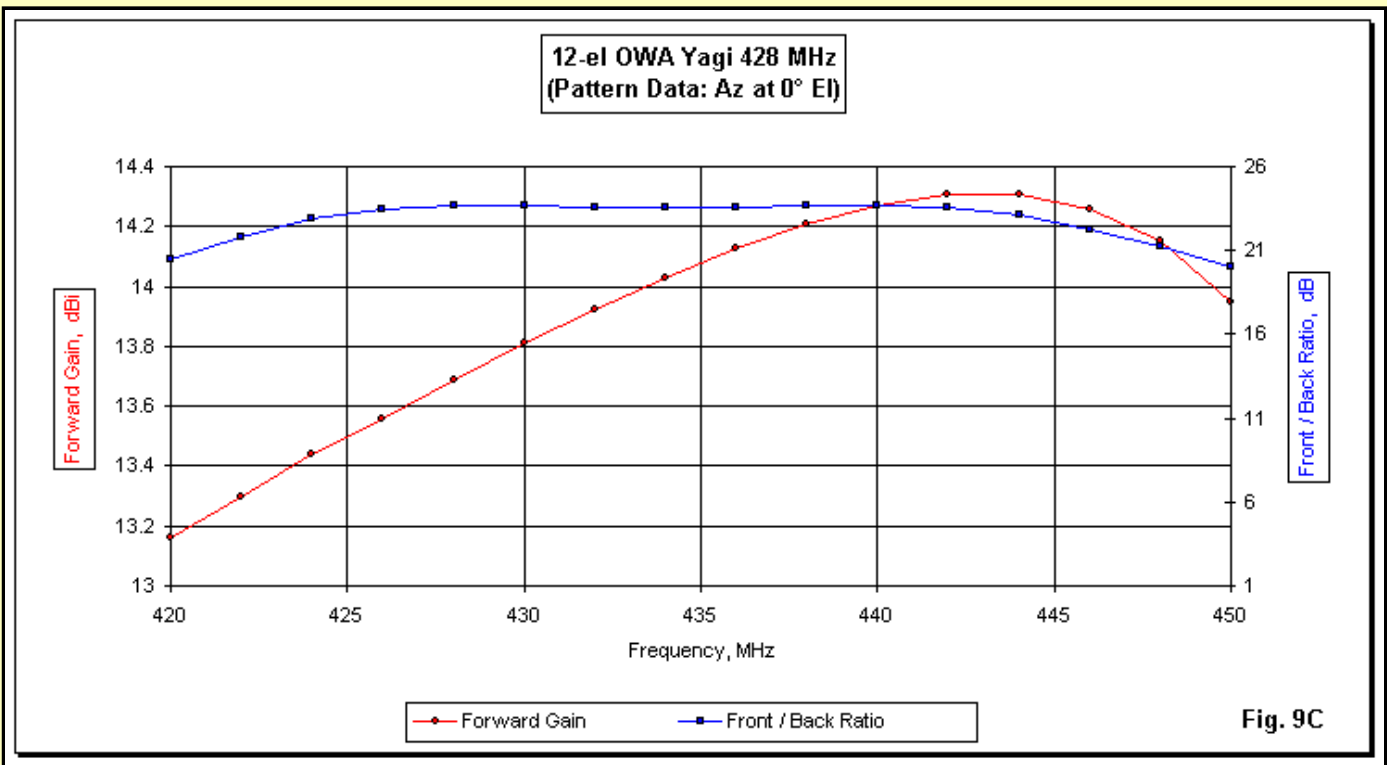


Basic Performance Data:

Category	420	435	450
Forward Gain (dBi)	13.16	14.08	13.95
180-Deg F-B (dB)	20.51	23.59	20.06
Worst-Case F-B (dB)	20.51	23.59	20.06
Horiz. B-W (deg)	41.8	38.4	35.6
Vert. B-W (deg)	47.2	42.5	39.2
Horiz. F-SL (dB)	20.81	27.70	23.63
Vert. F-SL (dB)	15.96	18.60	15.31
Feed Z (R+/-jX Ohms)	31.32 + j 5.34	48.76 + j14.78	30.05 - j 1.62
SWR (28 Ohms)	1.626	1.349	1.666

435-MHz Gain/Element: 1.173
 435-MHz Gain/Boom Length (WL): 4.890

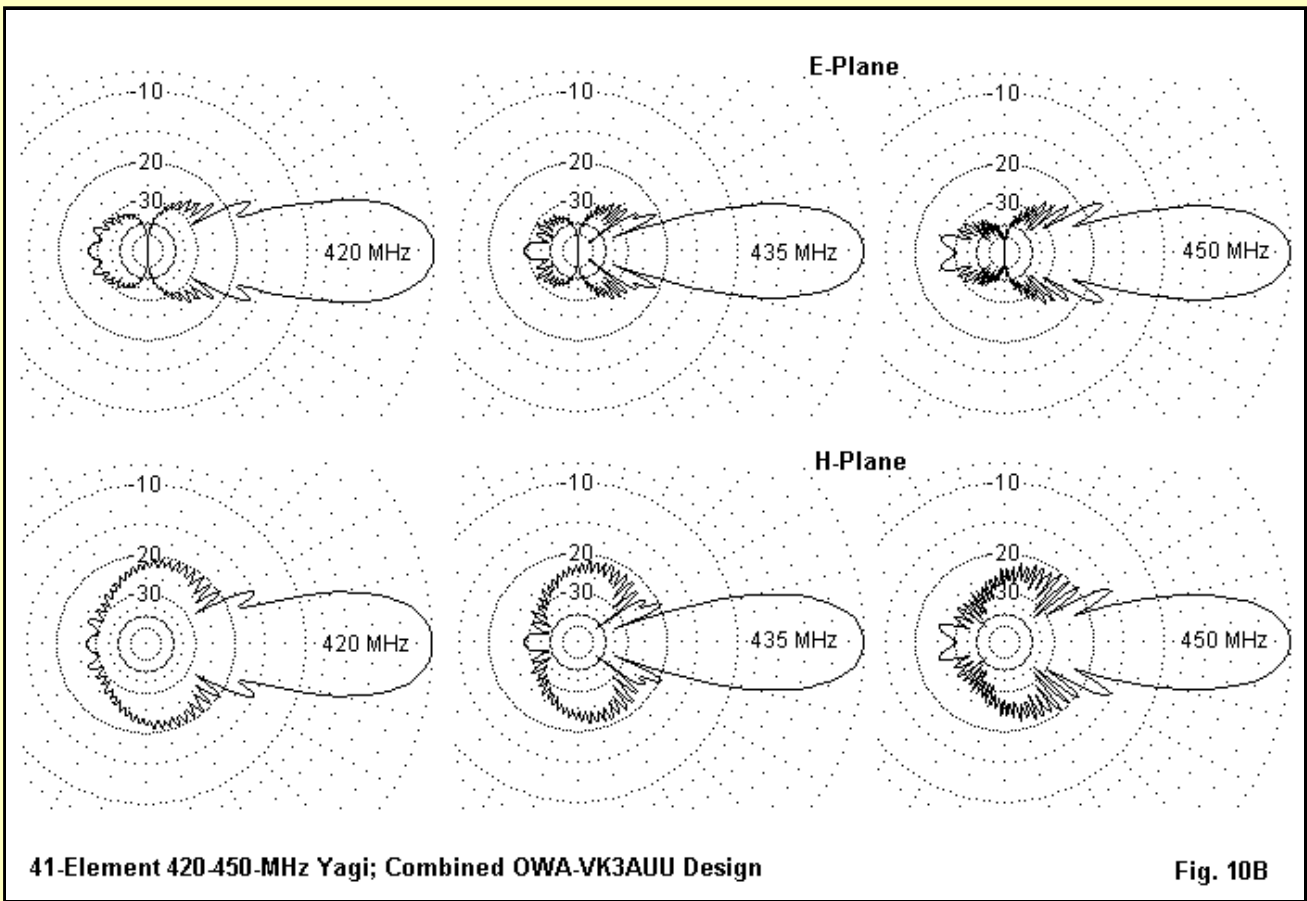




Translating the 2-meter 12-element OWA Yagi to 70 cm has left some work yet to be done. The gain curve is not fully centered in the passband. As well, although the SWR curve has the characteristic OWA shape, the band-edge values are higher than desired. Moreover, the average value of the resistive component of the impedance might be increased slightly.

Nevertheless, the horizontal front-to-sidelobe ratio is greater than 20 dB across the band. As with the 2-meter version of this Yagi, the vertical front-to-sidelobe values lag seriously behind, although adding tilt-back reflectors would effect considerable improvement. The pattern shapes are consistently tear-drop across the band, although there is a bit of evidence at 420 MHz of main and sidelobe merging.

The use of this short-boom array (as measured on the 70-cm band) is to set a quasi-standard. The array shows what can be done across the band, especially with respect to pattern shape and horizontal sidelobe suppression. Although the VK3AUU 41-element array achieves equivalent horizontal sidelobe suppression



41-Element 420-450-MHz Yagi; Combined OWA-VK3AUU Design

Fig. 10B

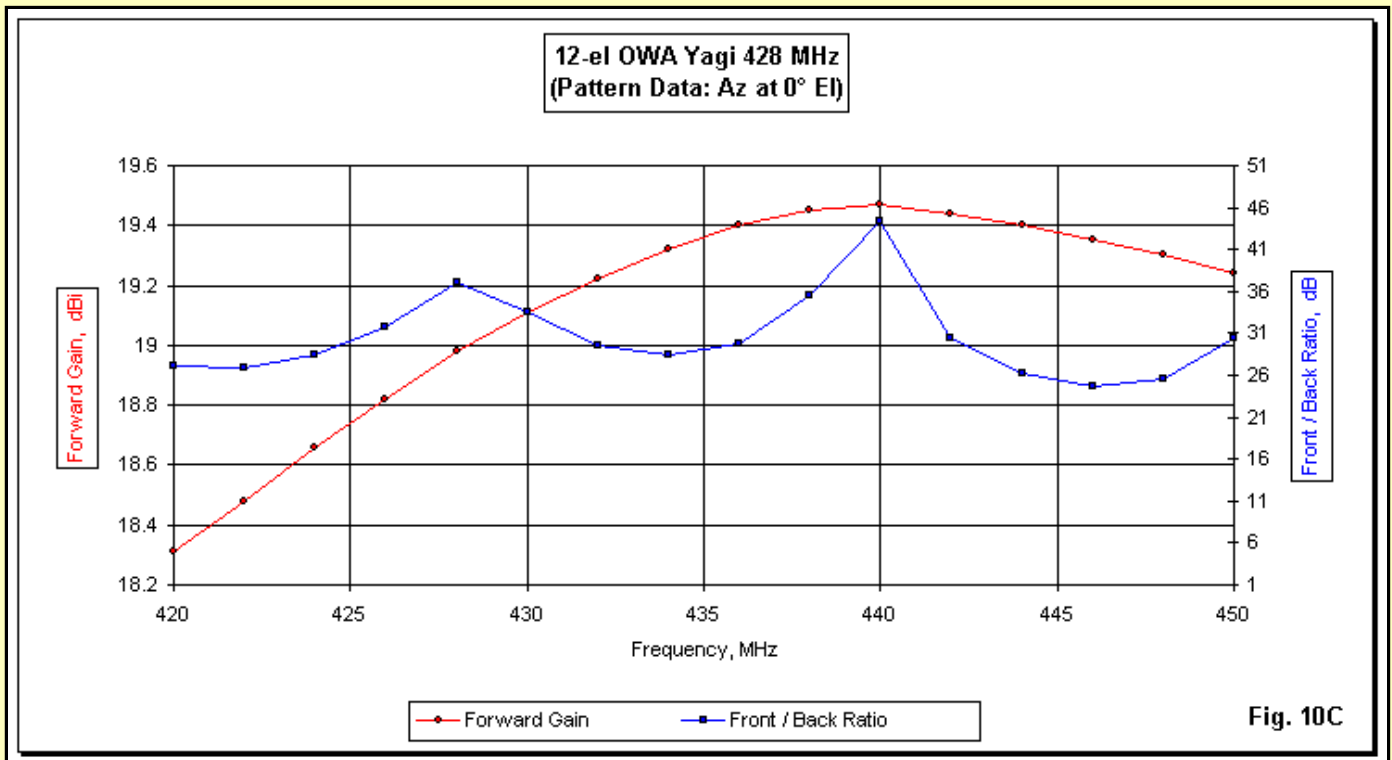
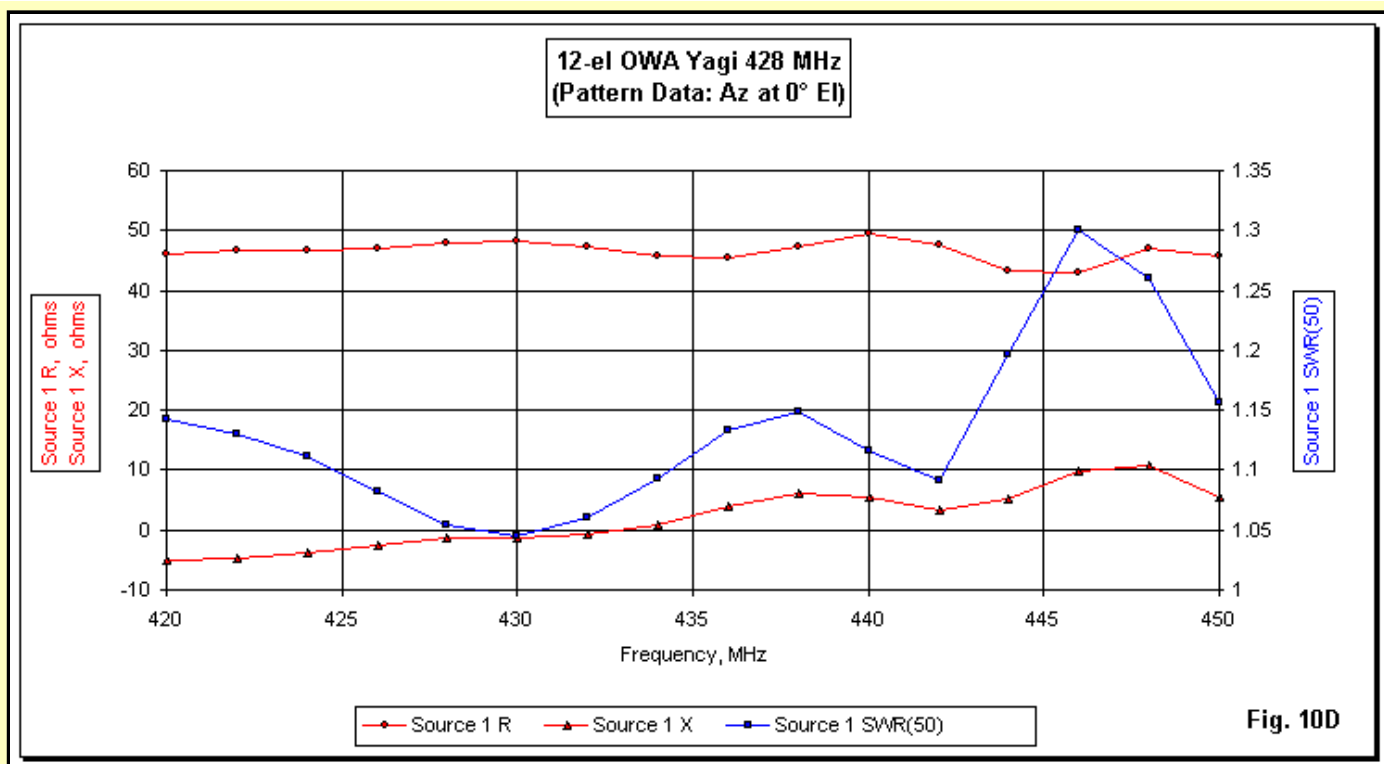


Fig. 10C



The hybrid array achieves about 1 dB of further sidelobe suppression over the original VK3AUU 41-element Yagi, but the suppression is not close to uniform across the entire band. As well, the gain has suffered a small decrease, although this is both marginal and expected relative to the OWA core of elements. As well, the gain curve is not well centered, but parallels the curve for the original VK3AUU beam design. The front-to-back ratio--taken as either the 180-degree or the worst-case value--is smoother across the band. Hence, the results of the experiment are mixed, with some improvements and some deficiencies, but all at the margins of the performance of the 41-element VK3AUU Yagi.

In a more important sense, the experiment is a major failure. The creation of a hybrid array did not provide smooth sidelobe suppression all across the 70-cm band, as in the case of the small 12-element Yagi. However, this result was not wholly unexpected. The family of OWA Yagis for 2-meters grew in length by a complex procedure of adding one element at a time and adjusting it and the preceding director to achieve the desired combination of pattern shape, gain curve, and SWR curve. So far, I have uncovered no algorithm to automate this process. The spacing for each additional element is variable, and it may even be the case that the usual rule, by which we place a new director at an equal or greater space than the preceding one, might require discarding.

The entire study, then is preliminary, because much more work remains ahead in the search for the nearly perfect Yagi.

Conclusions (So Far)

We may summarize the results of this preliminary study in the following set of entries in our notebooks.

Gain: We may obtain forward gain with an adequate front-to-back ratio in a variety of ways, depending on the operating bandwidth that we desire. The SM5BSZ array shows how to do this with a minimum number of fat elements for a given boom length, while the long VE7BQH ladder Yagi shows how to replicate the gain using thin wire. For wide bandwidths, there is little to choose among the DL6WU, W1JR, or K1FO arrays--adjusted for similar boom lengths and number of elements--except for certain preferences of feedpoint impedance or other minor factors.

Operating Bandwidth: For most long-boom UHF Yagi operations, bandwidth is not a major concern, since operations tend to cluster near certain specific frequencies. However, for the home beam builder, a wide bandwidth offers greater assurance of successful replication of a given design, as well as ease of scaling the array from an initial design frequency to the one specifically desired. As well, it is more likely that the recalculation of elements for new element diameters or for insulated through-boom mounting will result in a working array whose performance is close to the values reported by the initial model.

Modeling: Almost all of the models in this study require more than 500 total segments to achieve adequate convergence of results. As well, for serious design work at UHF frequencies, NEC-4 is the modeling core of choice to avoid the frequency offset of NEC-2. (Even the best version of MININEC tend to calibrate the necessary frequency corrections to NEC-2. Hence, before using any MININEC program for serious UHF array design, be sure to calibrate it to NEC-4.) The upshot is that serious design efforts require a serious investment in software and the licenses that may go with a package.

Pattern Shape: The most interesting challenge yet to be faced in the improvement of long-boom Yagis lies in the area of achieving a consistent tear-drop pattern across the 70-cm band with improved forward sidelobe suppression. Initial experiments suggest that increased element density can go some distance toward this goal, but that element density alone may not achieve results that cover the entire band. Hence, there are an unlimited number of experiments that await us in the arena of using variable element spacing to see if we can extend the consistent E-plane patterns of shorter Yagis to long-boom arrays. Once we have reached the goal for E-plane patterns, improving the H-plane patterns should be straightforward through the use of added tilt-back reflectors.

In the end, I can do little better than to repeat myself: much more work remains ahead in the search for the nearly perfect long-boom Yagi.

Appendix: EZNEC Model Descriptions of Yagis Used in This Study

=====

1. DL6WU 32 el 435 MHz Frequency = 435 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,170.300, 0.000	0.000,-170.30, 0.000	4.00E+00	19
2	138.800,165.000, 0.000	138.800,-165.00, 0.000	4.00E+00	19
3	190.800,150.800, 0.000	190.800,-150.80, 0.000	4.00E+00	19
4	315.800,149.600, 0.000	315.800,-149.60, 0.000	4.00E+00	19
5	465.000,147.800, 0.000	465.000,-147.80, 0.000	4.00E+00	19
6	638.400,146.100, 0.000	638.400,-146.10, 0.000	4.00E+00	19
7	832.800,144.600, 0.000	832.800,-144.60, 0.000	4.00E+00	19
8	1040.90,143.200, 0.000	1040.90,-143.20, 0.000	4.00E+00	19
9	1259.50,142.100, 0.000	1259.50,-142.10, 0.000	4.00E+00	19
10	1488.60,141.100, 0.000	1488.60,-141.10, 0.000	4.00E+00	19
11	1728.00,140.200, 0.000	1728.00,-140.20, 0.000	4.00E+00	19
12	1977.80,139.400, 0.000	1977.80,-139.40, 0.000	4.00E+00	19
13	2238.00,138.700, 0.000	2238.00,-138.70, 0.000	4.00E+00	19
14	2508.70,138.000, 0.000	2508.70,-138.00, 0.000	4.00E+00	19
15	2786.30,137.400, 0.000	2786.30,-137.40, 0.000	4.00E+00	19
16	3063.90,136.900, 0.000	3063.90,-136.90, 0.000	4.00E+00	19
17	3341.40,136.400, 0.000	3341.40,-136.40, 0.000	4.00E+00	19
18	3619.00,135.900, 0.000	3619.00,-135.90, 0.000	4.00E+00	19
19	3896.60,135.400, 0.000	3896.60,-135.40, 0.000	4.00E+00	19
20	4174.20,135.000, 0.000	4174.20,-135.00, 0.000	4.00E+00	19
21	4451.80,134.600, 0.000	4451.80,-134.60, 0.000	4.00E+00	19
22	4729.40,134.200, 0.000	4729.40,-134.20, 0.000	4.00E+00	19
23	5007.00,133.800, 0.000	5007.00,-133.80, 0.000	4.00E+00	19
24	5284.50,133.500, 0.000	5284.50,-133.50, 0.000	4.00E+00	19
25	5562.10,133.100, 0.000	5562.10,-133.10, 0.000	4.00E+00	19
26	5839.70,132.800, 0.000	5839.70,-132.80, 0.000	4.00E+00	19
27	6117.30,132.500, 0.000	6117.30,-132.50, 0.000	4.00E+00	19
28	6394.90,132.250, 0.000	6394.90,-132.25, 0.000	4.00E+00	19
29	6672.50,131.950, 0.000	6672.50,-131.95, 0.000	4.00E+00	19
30	6950.10,131.650, 0.000	6950.10,-131.65, 0.000	4.00E+00	19
31	7227.60,131.400, 0.000	7227.60,-131.40, 0.000	4.00E+00	19

32 7505.20,131.150, 0.000 7505.20,-131.15, 0.000 4.00E+00 19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1 10 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

2. HyGain/W1JR 432 31 el Frequency = 435 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,167.290, 0.000	0.000,-167.29, 0.000	4.60E+00	19
2	122.738,162.653, 0.000	122.738,-162.65, 0.000	4.60E+00	19
3	172.028,151.925, 0.000	171.905,-151.93, 0.000	4.60E+00	19
4	294.763,148.832, 0.000	294.763,-148.83, 0.000	4.60E+00	19
5	438.765,145.739, 0.000	438.765,-145.74, 0.000	4.60E+00	19
6	607.891,144.193, 0.000	607.898,-144.19, 0.000	4.60E+00	19
7	794.413,142.742, 0.000	794.413,-142.74, 0.000	4.60E+00	19
8	997.366,140.425, 0.000	997.366,-140.43, 0.000	4.60E+00	19
9	1209.02,138.491, 0.000	1209.02,-138.49, 0.000	4.60E+00	19
10	1430.33,138.491, 0.000	1430.33,-138.49, 0.000	4.60E+00	19
11	1663.25,136.944, 0.000	1663.25,-136.94, 0.000	4.60E+00	19
12	1905.82,135.398, 0.000	1905.82,-135.40, 0.000	4.60E+00	19
13	2157.09,134.624, 0.000	2157.09,-134.62, 0.000	4.60E+00	19
14	2412.24,134.239, 0.000	2412.24,-134.24, 0.000	4.60E+00	19
15	2673.18,133.466, 0.000	2673.18,-133.47, 0.000	4.60E+00	19
16	2939.91,132.692, 0.000	2939.91,-132.69, 0.000	4.60E+00	19
17	3209.55,132.692, 0.000	3209.55,-132.69, 0.000	4.60E+00	19
18	3479.19,131.919, 0.000	3479.19,-131.92, 0.000	4.60E+00	19
19	3749.79,131.919, 0.000	3749.79,-131.92, 0.000	4.60E+00	19
20	4019.43,131.146, 0.000	4019.43,-131.15, 0.000	4.60E+00	19
21	4290.03,131.146, 0.000	4290.03,-131.15, 0.000	4.60E+00	19
22	4559.67,128.536, 0.000	4559.67,-128.54, 0.000	4.60E+00	19
23	4829.31,127.763, 0.000	4829.31,-127.76, 0.000	4.60E+00	19
24	5099.91,127.763, 0.000	5099.91,-127.76, 0.000	4.60E+00	19
25	5369.54,127.763, 0.000	5369.54,-127.76, 0.000	4.60E+00	19
26	5640.15,126.217, 0.000	5640.15,-126.22, 0.000	4.60E+00	19
27	5909.78,126.605, 0.000	5909.78,-126.61, 0.000	4.60E+00	19
28	6179.42,126.605, 0.000	6179.42,-126.61, 0.000	4.60E+00	19
29	6450.03,125.831, 0.000	6450.03,-125.83, 0.000	4.60E+00	19
30	6719.66,125.831, 0.000	6719.66,-125.83, 0.000	4.60E+00	19
31	6990.27,125.831, 0.000	6990.27,-125.83, 0.000	4.60E+00	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1 10 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

3. DJ9BV BV70-7L 432 MHz

Frequency = 435 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,-170.00,225.000	0.000,170.000,225.000	4.00E+00	19
2	0.000,-170.00, 75.000	0.000,170.000, 75.000	4.00E+00	19
3	0.000,-170.00,-75.000	0.000,170.000,-75.000	4.00E+00	19
4	0.000,-170.00,-225.00	0.000,170.000,-225.00	4.00E+00	19
5	115.000,-160.00, 0.000	115.000,160.000, 0.000	4.00E+00	19
6	170.000,-153.50, 0.000	170.000,153.500, 0.000	4.00E+00	19
7	295.000,-150.50, 0.000	295.000,150.500, 0.000	4.00E+00	19
8	445.000,-148.50, 0.000	445.000,148.000, 0.000	4.00E+00	19
9	620.000,-147.00, 0.000	620.000,147.000, 0.000	4.00E+00	19
10	815.000,-146.00, 0.000	815.000,146.000, 0.000	4.00E+00	19
11	1025.00,-144.50, 0.000	1025.00,144.500, 0.000	4.00E+00	19
12	1245.00,-143.00, 0.000	1245.00,143.000, 0.000	4.00E+00	19
13	1475.00,-141.00, 0.000	1475.00,141.000, 0.000	4.00E+00	19
14	1715.00,-141.00, 0.000	1715.00,141.000, 0.000	4.00E+00	19
15	1965.00,-141.00, 0.000	1965.00,141.000, 0.000	4.00E+00	19
16	2225.00,-139.00, 0.000	2225.00,139.000, 0.000	4.00E+00	19
17	2495.00,-139.00, 0.000	2495.00,139.000, 0.000	4.00E+00	19
18	2775.00,-139.00, 0.000	2775.00,139.000, 0.000	4.00E+00	19
19	3055.00,-137.50, 0.000	3055.00,137.500, 0.000	4.00E+00	19
20	3335.00,-137.50, 0.000	3335.00,137.500, 0.000	4.00E+00	19
21	3615.00,-137.50, 0.000	3615.00,137.500, 0.000	4.00E+00	19
22	3895.00,-136.00, 0.000	3895.00,136.000, 0.000	4.00E+00	19
23	4175.00,-136.00, 0.000	4175.00,136.000, 0.000	4.00E+00	19
24	4455.00,-136.00, 0.000	4455.00,136.000, 0.000	4.00E+00	19
25	4735.00,-135.00, 0.000	4735.00,135.000, 0.000	4.00E+00	19
26	5015.00,-135.00, 0.000	5015.00,135.000, 0.000	4.00E+00	19
27	5295.00,-135.00, 0.000	5295.00,135.000, 0.000	4.00E+00	19

----- SOURCES -----

Source	Wire Seg.	Wire #/Pct Actual	From End 1 (Specified)	Ampl.(V, A)	Phase(Deg.)	Type
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1	10	5 / 50.00	(5 / 50.00)	1.000	0.000	V
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Ground type is Free Space

4. K1FO Free-Space 432 design

Frequency = 432 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,168.055, 0.000	0.000,-168.05, 0.000	4.71E+00	19
2	102.810,165.089, 0.000	102.810,-165.09, 0.000	4.71E+00	19
3	144.330,155.698, 0.000	144.330,-155.70, 0.000	4.71E+00	19
4	221.437,151.249, 0.000	221.437,-151.25, 0.000	4.71E+00	19
5	328.201,147.789, 0.000	328.201,-147.79, 0.000	4.71E+00	19

6	460.668,145.812, 0.000	460.668,-145.81, 0.000	4.71E+00	19
7	614.883,143.835, 0.000	614.883,-143.84, 0.000	4.71E+00	19
8	788.870,142.847, 0.000	788.870,-142.85, 0.000	4.71E+00	19
9	978.673,141.858, 0.000	978.673,-141.86, 0.000	4.71E+00	19
10	1182.32,140.870, 0.000	1182.32,-140.87, 0.000	4.71E+00	19
11	1397.82,139.881, 0.000	1397.82,-139.88, 0.000	4.71E+00	19
12	1623.21,138.892, 0.000	1623.21,-138.89, 0.000	4.71E+00	19
13	1857.50,137.904, 0.000	1857.50,-137.90, 0.000	4.71E+00	19
14	2097.72,137.410, 0.000	2097.72,-137.41, 0.000	4.71E+00	19
15	2345.85,136.915, 0.000	2345.85,-136.92, 0.000	4.71E+00	19
16	2598.92,136.421, 0.000	2598.92,-136.42, 0.000	4.71E+00	19
17	2856.93,135.927, 0.000	2856.93,-135.93, 0.000	4.71E+00	19
18	3117.91,135.432, 0.000	3117.91,-135.43, 0.000	4.71E+00	19
19	3382.85,134.938, 0.000	3382.85,-134.94, 0.000	4.71E+00	19
20	3650.75,134.444, 0.000	3650.75,-134.44, 0.000	4.71E+00	19
21	3921.61,133.950, 0.000	3921.61,-133.95, 0.000	4.71E+00	19
22	4193.46,133.455, 0.000	4193.46,-133.46, 0.000	4.71E+00	19
23	4468.28,132.961, 0.000	4468.28,-132.96, 0.000	4.71E+00	19
24	4743.10,132.961, 0.000	4743.10,-132.96, 0.000	4.71E+00	19
25	5020.89,132.467, 0.000	5020.89,-132.47, 0.000	4.71E+00	19
26	5298.67,132.467, 0.000	5298.67,-132.47, 0.000	4.71E+00	19
27	5577.45,131.973, 0.000	5577.45,-131.97, 0.000	4.71E+00	19
28	5857.21,131.973, 0.000	5857.21,-131.97, 0.000	4.71E+00	19
29	6137.96,131.478, 0.000	6137.96,-131.48, 0.000	4.71E+00	19
30	6419.70,131.478, 0.000	6419.70,-131.48, 0.000	4.71E+00	19
31	6701.44,130.984, 0.000	6701.44,-130.98, 0.000	4.71E+00	19
32	6983.18,130.984, 0.000	6983.18,-130.98, 0.000	4.71E+00	19
33	7265.90,130.490, 0.000	7265.90,-130.49, 0.000	4.71E+00	19
34	7548.63,130.490, 0.000	7548.63,-130.49, 0.000	4.71E+00	19
35	7831.36,129.995, 0.000	7831.36,-130.00, 0.000	4.71E+00	19
36	8115.08,129.995, 0.000	8115.08,-130.00, 0.000	4.71E+00	19
37	8398.79,129.501, 0.000	8398.79,-129.50, 0.000	4.71E+00	19
38	8682.51,129.501, 0.000	8682.51,-129.50, 0.000	4.71E+00	19
39	8966.22,129.007, 0.000	8966.22,-129.01, 0.000	4.71E+00	19
40	9251.92,129.007, 0.000	9251.92,-129.01, 0.000	4.71E+00	19

----- SOURCES -----

Source	Wire Seg.	Wire #/Pct Actual	Wire #/Pct From End 1 (Specified)	Ampl.(V, A)	Phase(Deg.)	Type
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1	10	2 / 50.00	(2 / 50.00)	1.000	0.000	V
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Ground type is Free Space

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5. SM5BSZ 26-el 432 MHz Frequency = 432 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn.	--- End 1 (x,y,z : mm)	Conn.	--- End 2 (x,y,z : mm)	Dia(mm)	Segs
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1	0.000,161.689, 0.000	0.000,-161.69, 0.000	1.00E+01	19
2	199.598,156.474, 0.000	199.598,-156.47, 0.000	1.00E+01	19
3	272.708,153.315, 0.000	272.708,-153.32, 0.000	1.00E+01	19
4	456.677,145.693, 0.000	456.677,-145.69, 0.000	1.00E+01	19
5	696.427,142.075, 0.000	696.427,-142.07, 0.000	1.00E+01	19
6	961.601,138.577, 0.000	961.601,-138.58, 0.000	1.00E+01	19
7	1263.05,135.693, 0.000	1263.05,-135.69, 0.000	1.00E+01	19

8	1575.39,133.940, 0.000	1575.39,-133.94, 0.000	1.00E+01	19
9	1887.06,132.676, 0.000	1887.06,-132.68, 0.000	1.00E+01	19
10	2206.07,131.604, 0.000	2206.07,-131.60, 0.000	1.00E+01	19
11	2525.12,130.660, 0.000	2525.12,-130.66, 0.000	1.00E+01	19
12	2847.01,129.601, 0.000	2847.01,-129.60, 0.000	1.00E+01	19
13	3174.21,128.579, 0.000	3174.21,-128.58, 0.000	1.00E+01	19
14	3502.56,127.808, 0.000	3502.56,-127.81, 0.000	1.00E+01	19
15	3831.20,127.191, 0.000	3831.20,-127.19, 0.000	1.00E+01	19
16	4160.04,126.592, 0.000	4160.04,-126.59, 0.000	1.00E+01	19
17	4489.54,125.870, 0.000	4489.54,-125.87, 0.000	1.00E+01	19
18	4822.54,124.914, 0.000	4822.54,-124.91, 0.000	1.00E+01	19
19	5157.94,123.992, 0.000	5157.94,-123.99, 0.000	1.00E+01	19
20	5492.39,123.535, 0.000	5492.39,-123.54, 0.000	1.00E+01	19
21	5828.46,123.460, 0.000	5828.46,-123.46, 0.000	1.00E+01	19
22	6154.77,124.262, 0.000	6154.77,-124.26, 0.000	1.00E+01	19
23	6469.18,126.082, 0.000	6469.18,-126.08, 0.000	1.00E+01	19
24	6805.75,124.226, 0.000	6805.75,-124.23, 0.000	1.00E+01	19
25	7133.67,123.389, 0.000	7133.67,-123.39, 0.000	1.00E+01	19
26	7429.41,131.275, 0.000	7429.41,-131.27, 0.000	1.00E+01	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
 Seg. Actual (Specified)

1 10 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

6. VE7BQH 43-el "ladder" Yagi Frequency = 432 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,170.873, 0.000	0.000,-170.87, 0.000	1.06E+00	19
2	104.400,165.673, 0.000	104.400,-165.67, 0.000	1.06E+00	19
3	145.546,162.555, 0.000	145.546,-162.55, 0.000	1.06E+00	19
4	224.865,159.242, 0.000	224.865,-159.24, 0.000	1.06E+00	19
5	333.284,155.954, 0.000	333.284,-155.95, 0.000	1.06E+00	19
6	470.410,155.767, 0.000	470.410,-155.77, 0.000	1.06E+00	19
7	624.401,153.524, 0.000	624.401,-153.52, 0.000	1.06E+00	19
8	803.685,153.354, 0.000	803.685,-153.35, 0.000	1.06E+00	19
9	993.819,153.932, 0.000	993.819,-153.93, 0.000	1.06E+00	19
10	1200.61,151.128, 0.000	1200.61,-151.13, 0.000	1.06E+00	19
11	1422.07,151.171, 0.000	1422.07,-151.17, 0.000	1.06E+00	19
12	1645.73,150.329, 0.000	1645.73,-150.33, 0.000	1.06E+00	19
13	1886.25,149.556, 0.000	1886.25,-149.56, 0.000	1.06E+00	19
14	2132.79,149.182, 0.000	2132.79,-149.18, 0.000	1.06E+00	19
15	2382.16,148.885, 0.000	2382.16,-148.88, 0.000	1.06E+00	19
16	2623.40,148.528, 0.000	2623.40,-148.53, 0.000	1.06E+00	19
17	2901.15,147.908, 0.000	2901.15,-147.91, 0.000	1.06E+00	19
18	3167.57,147.526, 0.000	3167.57,-147.53, 0.000	1.06E+00	19
19	3433.98,148.885, 0.000	3433.98,-148.88, 0.000	1.06E+00	19
20	3705.32,148.443, 0.000	3705.32,-148.44, 0.000	1.06E+00	19
21	3974.44,146.583, 0.000	3974.44,-146.58, 0.000	1.06E+00	19
22	4249.19,146.404, 0.000	4249.19,-146.40, 0.000	1.06E+00	19
23	4524.94,147.747, 0.000	4524.94,-147.75, 0.000	1.06E+00	19

24	4806.30,145.640, 0.000	4806.30,-145.64, 0.000	1.06E+00	19
25	5080.16,147.135, 0.000	5080.16,-147.14, 0.000	1.06E+00	19
26	5355.87,145.325, 0.000	5355.87,-145.33, 0.000	1.06E+00	19
27	5631.46,145.410, 0.000	5631.46,-145.41, 0.000	1.06E+00	19
28	5905.37,146.787, 0.000	5905.37,-146.79, 0.000	1.06E+00	19
29	6189.16,144.832, 0.000	6189.16,-144.83, 0.000	1.06E+00	19
30	6471.13,144.459, 0.000	6471.13,-144.46, 0.000	1.06E+00	19
31	6738.14,144.323, 0.000	6738.14,-144.32, 0.000	1.06E+00	19
32	7011.75,146.234, 0.000	7011.75,-146.23, 0.000	1.06E+00	19
33	7287.17,144.680, 0.000	7287.17,-144.68, 0.000	1.06E+00	19
34	7565.60,144.764, 0.000	7565.60,-144.76, 0.000	1.06E+00	19
35	7855.32,146.149, 0.000	7855.32,-146.15, 0.000	1.06E+00	19
36	8126.24,144.008, 0.000	8126.24,-144.01, 0.000	1.06E+00	19
37	8397.17,144.153, 0.000	8397.17,-144.15, 0.000	1.06E+00	19
38	8656.70,146.209, 0.000	8656.70,-146.21, 0.000	1.06E+00	19
39	8939.55,147.160, 0.000	8939.55,-147.16, 0.000	1.06E+00	19
40	9226.88,145.801, 0.000	9226.88,-145.80, 0.000	1.06E+00	19
41	9515.61,147.976, 0.000	9515.61,-147.98, 0.000	1.06E+00	19
42	9808.55,144.960, 0.000	9808.55,-144.96, 0.000	1.06E+00	19
43	10042.1,150.015, 0.000	10042.1,-150.01, 0.000	1.06E+00	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1 10 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

7. VK3AUU 41 el Frequency = 432 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,-167.05, 0.000	0.000,167.054, 0.000	4.00E+00	19
2	133.100,-169.89, 0.000	133.100,169.890, 0.000	4.00E+00	19
3	156.082,-153.60, 0.000	156.082,153.597, 0.000	4.00E+00	19
4	236.694,-151.55, 0.000	236.694,151.550, 0.000	4.00E+00	19
5	341.372,-149.79, 0.000	341.372,149.795, 0.000	4.00E+00	19
6	463.106,-148.04, 0.000	463.106,148.039, 0.000	4.00E+00	19
7	598.160,-146.28, 0.000	598.160,146.284, 0.000	4.00E+00	19
8	743.727,-144.82, 0.000	743.727,144.822, 0.000	4.00E+00	19
9	898.641,-143.36, 0.000	898.641,143.359, 0.000	4.00E+00	19
10	1061.50,-142.19, 0.000	1061.50,142.189, 0.000	4.00E+00	19
11	1231.37,-140.73, 0.000	1231.37,140.726, 0.000	4.00E+00	19
12	1407.31,-139.85, 0.000	1407.31,139.849, 0.000	4.00E+00	19
13	1588.86,-138.68, 0.000	1588.86,138.678, 0.000	4.00E+00	19
14	1775.79,-137.80, 0.000	1775.79,137.801, 0.000	4.00E+00	19
15	1967.38,-136.92, 0.000	1967.38,136.923, 0.000	4.00E+00	19
16	2163.19,-136.05, 0.000	2163.19,136.046, 0.000	4.00E+00	19
17	2363.43,-135.17, 0.000	2363.43,135.168, 0.000	4.00E+00	19
18	2567.18,-134.58, 0.000	2567.18,134.583, 0.000	4.00E+00	19
19	2774.67,-133.71, 0.000	2774.67,133.706, 0.000	4.00E+00	19
20	2985.42,-133.12, 0.000	2985.42,133.120, 0.000	4.00E+00	19
21	3199.45,-132.54, 0.000	3199.45,132.535, 0.000	4.00E+00	19
22	3416.52,-132.24, 0.000	3416.52,132.243, 0.000	4.00E+00	19

23	3636.62,-131.66, 0.000	3636.62,131.658, 0.000	4.00E+00	19
24	3859.30,-131.07, 0.000	3859.30,131.073, 0.000	4.00E+00	19
25	4084.78,-130.78, 0.000	4084.78,130.780, 0.000	4.00E+00	19
26	4312.59,-130.49, 0.000	4312.59,130.488, 0.000	4.00E+00	19
27	4542.98,-129.90, 0.000	4542.98,129.903, 0.000	4.00E+00	19
28	4775.93,-129.61, 0.000	4775.93,129.610, 0.000	4.00E+00	19
29	5011.69,-129.32, 0.000	5011.69,129.318, 0.000	4.00E+00	19
30	5221.61,-129.03, 0.000	5221.61,129.025, 0.000	4.00E+00	19
31	5435.15,-128.73, 0.000	5435.15,128.733, 0.000	4.00E+00	19
32	5652.20,-128.73, 0.000	5652.20,128.733, 0.000	4.00E+00	19
33	5872.77,-128.44, 0.000	5872.77,128.440, 0.000	4.00E+00	19
34	6096.85,-128.15, 0.000	6096.85,128.148, 0.000	4.00E+00	19
35	6321.51,-127.86, 0.000	6321.51,127.855, 0.000	4.00E+00	19
36	6552.60,-127.56, 0.000	6552.60,127.562, 0.000	4.00E+00	19
37	6787.21,-127.27, 0.000	6787.21,127.270, 0.000	4.00E+00	19
38	7020.65,-126.98, 0.000	7020.65,126.977, 0.000	4.00E+00	19
39	7257.59,-126.98, 0.000	7257.59,126.977, 0.000	4.00E+00	19
40	7488.69,-126.68, 0.000	7488.69,126.685, 0.000	4.00E+00	19
41	7723.30,-126.39, 0.000	7723.30,126.392, 0.000	4.00E+00	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
Seg. Actual (Specified)

1 10 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

8. VK3AUU 32 el, triple reflector Frequency = 432 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	-16.312,-195.75,203.576	-16.312,195.747,203.576	4.00E+00	19
2	-16.312,-195.75,-203.58	-16.312,195.747,-203.58	4.00E+00	19
3	0.000,-169.97, 0.000	0.000,169.973, 0.000	4.00E+00	19
4	138.980,-169.16, 0.000	138.980,169.158, 0.000	4.00E+00	19
5	165.406,-155.94, 0.000	165.406,155.945, 0.000	4.00E+00	19
6	247.293,-153.82, 0.000	247.293,153.824, 0.000	4.00E+00	19
7	356.585,-151.87, 0.000	356.585,151.867, 0.000	4.00E+00	19
8	483.820,-150.07, 0.000	483.820,150.072, 0.000	4.00E+00	19
9	625.084,148.278, 0.000	625.084,-148.28, 0.000	4.00E+00	19
10	777.114,-146.81, 0.000	777.114,146.810, 0.000	4.00E+00	19
11	938.931,-145.18, 0.000	938.931,145.179, 0.000	4.00E+00	19
12	1109.23,-144.04, 0.000	1109.23,144.037, 0.000	4.00E+00	19
13	1286.71,-142.41, 0.000	1286.71,142.406, 0.000	4.00E+00	19
14	1470.38,-141.59, 0.000	1470.38,141.590, 0.000	4.00E+00	19
15	1660.26,-140.29, 0.000	1660.26,140.285, 0.000	4.00E+00	19
16	1855.68,-139.47, 0.000	1855.68,139.469, 0.000	4.00E+00	19
17	2055.67,-138.49, 0.000	2055.67,138.491, 0.000	4.00E+00	19
18	2260.22,-137.51, 0.000	2260.22,137.512, 0.000	4.00E+00	19
19	2469.67,-136.70, 0.000	2469.67,136.696, 0.000	4.00E+00	19
20	2682.38,-136.04, 0.000	2682.38,136.044, 0.000	4.00E+00	19
21	2899.33,-135.07, 0.000	2899.33,135.065, 0.000	4.00E+00	19
22	3119.55,-134.58, 0.000	3119.55,134.576, 0.000	4.00E+00	19
23	3343.03,-133.92, 0.000	3343.03,133.923, 0.000	4.00E+00	19

24	3570.09,-133.60, 0.000	3570.09,133.597, 0.000	4.00E+00	19
25	3800.09,-132.94, 0.000	3800.09,132.945, 0.000	4.00E+00	19
26	4032.71,-132.46, 0.000	4032.71,132.455, 0.000	4.00E+00	19
27	4268.25,-132.13, 0.000	4268.25,132.129, 0.000	4.00E+00	19
28	4506.41,-131.80, 0.000	4506.41,131.803, 0.000	4.00E+00	19
29	4746.86,131.150, 0.000	4746.86,-131.15, 0.000	4.00E+00	19
30	4990.56,-130.82, 0.000	4990.56,130.824, 0.000	4.00E+00	19
31	5242.09,-130.50, 0.000	5242.09,130.498, 0.000	4.00E+00	19
32	5464.59,-130.33, 0.000	5464.59,130.335, 0.000	4.00E+00	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
 Seg. Actual (Specified)

1 10 4 / 50.00 (4 / 50.00) 1.000 0.000 V

Ground type is Free Space

9. 12-el OWA Yagi 432 MHz Frequency = 435 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,173.000, 0.000	0.000,-173.00, 0.000	4.00E+00	19
2	74.760,167.500, 0.000	74.760,-167.50, 0.000	4.00E+00	19
3	114.010,152.013, 0.000	114.010,-152.01, 0.000	4.00E+00	19
4	213.913,148.577, 0.000	213.913,-148.58, 0.000	4.00E+00	19
5	342.638,148.577, 0.000	342.638,-148.58, 0.000	4.00E+00	19
6	515.959,147.985, 0.000	515.959,-147.99, 0.000	4.00E+00	19
7	726.597,142.822, 0.000	726.597,-142.82, 0.000	4.00E+00	19
8	974.179,138.231, 0.000	974.179,-138.23, 0.000	4.00E+00	19
9	1230.90,134.650, 0.000	1230.90,-134.65, 0.000	4.00E+00	19
10	1497.68,131.088, 0.000	1497.68,-131.09, 0.000	4.00E+00	19
11	1762.79,127.507, 0.000	1762.79,-127.51, 0.000	4.00E+00	19
12	1997.69,122.402, 0.000	1997.69,-122.40, 0.000	4.00E+00	19

----- SOURCES -----

Source Wire Wire #/Pct From End 1 Ampl.(V, A) Phase(Deg.) Type
 Seg. Actual (Specified)

1 11 2 / 50.00 (2 / 50.00) 1.000 0.000 V

Ground type is Free Space

10. OWA-VK3AUU Hybrid Yagi Frequency = 435 MHz.

Wire Loss: Aluminum -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

----- WIRES -----

Wire Conn. --- End 1 (x,y,z : mm) Conn. --- End 2 (x,y,z : mm) Dia(mm) Segs

1	0.000,180.000, 0.000	0.000,-180.00, 0.000	4.00E+00	19
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2	78.760,167.500, 0.000	78.760,-167.50, 0.000	4.00E+00	19
3	112.000,152.000, 0.000	112.000,-152.00, 0.000	4.00E+00	19
4	217.913,147.000, 0.000	217.913,-147.00, 0.000	4.00E+00	19
5	346.638,147.000, 0.000	346.638,-147.00, 0.000	4.00E+00	19
6	467.107,-148.04, 0.000	467.107,148.039, 0.000	4.00E+00	19
7	602.160,-146.28, 0.000	602.160,146.284, 0.000	4.00E+00	19
8	747.727,-144.82, 0.000	747.727,144.822, 0.000	4.00E+00	19
9	902.641,-143.36, 0.000	902.641,143.359, 0.000	4.00E+00	19
10	1065.50,-142.19, 0.000	1065.50,142.189, 0.000	4.00E+00	19
11	1235.37,-140.73, 0.000	1235.37,140.726, 0.000	4.00E+00	19
12	1411.31,-139.85, 0.000	1411.31,139.849, 0.000	4.00E+00	19
13	1592.86,-138.68, 0.000	1592.86,138.678, 0.000	4.00E+00	19
14	1779.79,-137.80, 0.000	1779.79,137.801, 0.000	4.00E+00	19
15	1971.38,-136.92, 0.000	1971.38,136.923, 0.000	4.00E+00	19
16	2167.19,-136.05, 0.000	2167.19,136.046, 0.000	4.00E+00	19
17	2367.43,-135.17, 0.000	2367.43,135.168, 0.000	4.00E+00	19
18	2571.18,-134.58, 0.000	2571.18,134.583, 0.000	4.00E+00	19
19	2778.67,-133.71, 0.000	2778.67,133.706, 0.000	4.00E+00	19
20	2989.42,-133.12, 0.000	2989.42,133.120, 0.000	4.00E+00	19
21	3203.45,-132.54, 0.000	3203.45,132.535, 0.000	4.00E+00	19
22	3420.52,-132.24, 0.000	3420.52,132.243, 0.000	4.00E+00	19
23	3640.62,-131.66, 0.000	3640.62,131.658, 0.000	4.00E+00	19
24	3863.30,-131.07, 0.000	3863.30,131.073, 0.000	4.00E+00	19
25	4088.78,-130.78, 0.000	4088.78,130.780, 0.000	4.00E+00	19
26	4316.59,-130.49, 0.000	4316.59,130.488, 0.000	4.00E+00	19
27	4546.98,-129.90, 0.000	4546.98,129.903, 0.000	4.00E+00	19
28	4779.93,-129.61, 0.000	4779.93,129.610, 0.000	4.00E+00	19
29	5015.69,-129.32, 0.000	5015.69,129.318, 0.000	4.00E+00	19
30	5225.61,-129.03, 0.000	5225.61,129.025, 0.000	4.00E+00	19
31	5439.15,-128.73, 0.000	5439.15,128.733, 0.000	4.00E+00	19
32	5656.20,-128.73, 0.000	5656.20,128.733, 0.000	4.00E+00	19
33	5876.77,-128.44, 0.000	5876.77,128.440, 0.000	4.00E+00	19
34	6100.85,-128.15, 0.000	6100.85,128.148, 0.000	4.00E+00	19
35	6325.51,-127.86, 0.000	6325.51,127.855, 0.000	4.00E+00	19
36	6556.60,-127.56, 0.000	6556.60,127.562, 0.000	4.00E+00	19
37	6791.21,-127.27, 0.000	6791.21,127.270, 0.000	4.00E+00	19
38	7024.65,-126.98, 0.000	7024.65,126.977, 0.000	4.00E+00	19
39	7261.59,-126.98, 0.000	7261.59,126.977, 0.000	4.00E+00	19
40	7492.69,-126.68, 0.000	7492.69,126.685, 0.000	4.00E+00	19
41	7727.30,-126.39, 0.000	7727.30,126.392, 0.000	4.00E+00	19

----- SOURCES -----

Source	Wire Seg.	Wire Actual	#/Pct From End (Specified)	Ampl.(V, A)	Phase(Deg.)	Type
1	10	2 / 50.00	(2 / 50.00)	1.000	0.000	V

Ground type is Free Space

Updated 04-28-2003. First prepared for the South-East VHF Society, April 26, 2003.



[Go to Amateur Radio Page](#)