The Optimized Wideband Antenna
Yagis for 20m - 10m

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Hello again to every one that read the article I had posted here previously. I have updated all of the previous designs and have added some new ones that you may find interesting. In addition to the 48' boom yagi antennas, I have included a 36' boom 15m antenna as well as a 24' boom 10m antenna that work almost as good as their big brothers. Finally I have posted some pictures of these antennas; both at the K3CR and WP3R contest stations.

Notes regarding stacked installations of antennas:

There were originally two separate versions of the 48' boom 20m antenna: one was designed in free-space and worked well as a stand-alone antenna while the other was designed to operate stacked on a 175' tower. The reason for re-optimization in the stack was that the F/B of the original design was degraded when it was placed into the 6/6/6 stack. To improve the stacked F/B, I unfortunately had to sacrifice the excellent VSWR characteristics of the original antenna. In addition, the F/B of the individual stack-optimized antenna is not as good when it is used independently. The only reason the F/B was degraded is that there is a back-lobe generated at the same elevation angle as the main beam: for the 175' tower this is at 7 degrees. Other than this single lobe, the rear suppression of the stack is quite good. In short, I have been thinking that the small increase in stack performance is not worth the compromises in individual antenna performance.

For this reason, I show only the optimum stand-alone design in this article. I should note that any time antennas are stacked, there is the potential for serious effects on both the F/B and VSWR of the antennas. In general practice, yagis are never stacked closer than .7λ. At the K3CR station, the 20m antennas are seperated by .85λ which would allow the stand-alone designs to perform relatively well. The 15m antennas are seperated by 1.3λ : there will eventually be 3 of the 15m antennas on the 185' tower. While a fourth antenna could have been added without problem, modeling showed that the increase in performance would have been undetectable. For the 10m installation, there will be 4 antennas on the 175' tower with a spacing of by 1.25λ. Again, additional antennas could have been added but the performance increase was negligible.

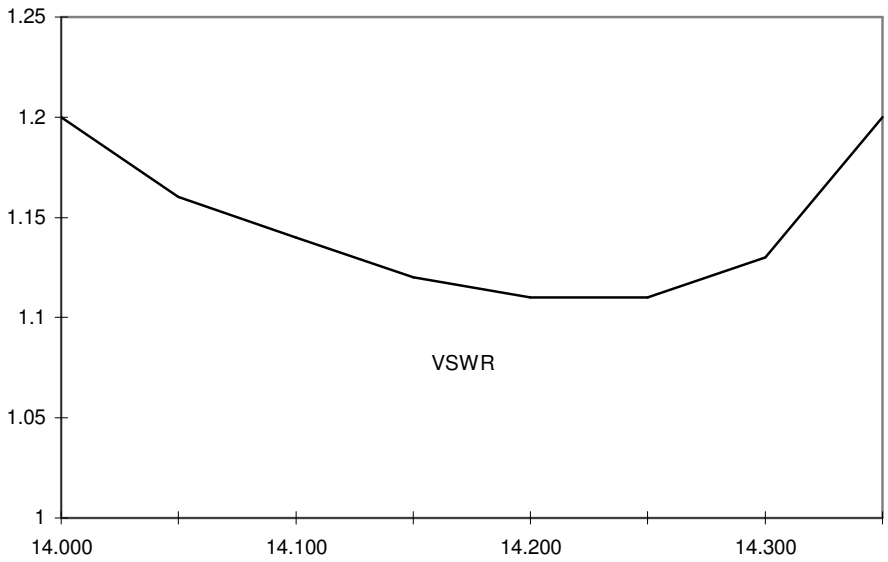
This brings up another question. In the earlier article I posted to WWW.CONTESTING.COM, I mentioned the F/B problems encountered when stacking 6 four element antennas on a large tower. This method will produce a large forward gain but the side-lobe and back suppression will always be limited by the short boom antennas. While there are many advantages to installations such as this, such as the ready availability and low cost of short boom antennas, I still think a smaller number of high performance antennas will produce superior results with less mechanical complexity.

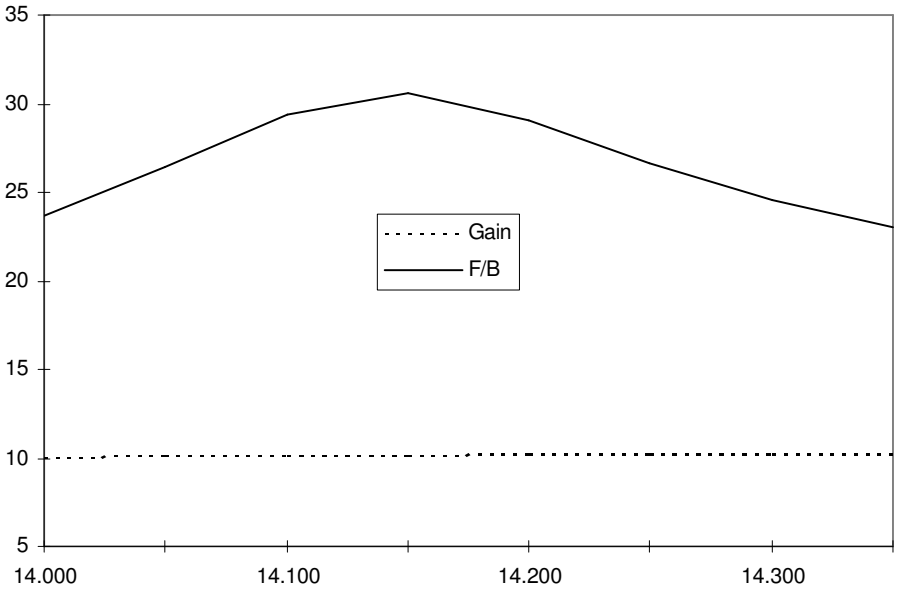
But no matter how good your antennas are, the key to a successful station lies in one simple thing…. RELIABILITY! In stacked installations, the importance of reliable switching and impedance matching systems cannot be over stressed.

20m - 6 Element Antenna on a 48’ Boom

Here is a view of the 6/6/6 stack we have at the K3CR station. The tower is government surplus and is equivalent to Rohn 65 except that the tower legs are SOLID 1.5” rod!! The tower is 175’ with the bottom antenna at 60’ on a TIC ring, the middle antenna fixed to Europe and the top antenna turning on a T2X.

The antenna design was optimized in free space and has the following remarkable characteristics across the band: VSWR < 1.2, F/B > 23dB and Gain > 10dBi.





The spacing of each element is shown from the reflector and all lengths represent the **exposed** length of tubing. Double wall sections are indicated below the table. The taper schedule of the elements can be adjusted using YO (using the W6QHS algorithm).

The 20m Antenna

	1	0.875	0.75	0.625	0.5
0.00	48	24	44	36	65.73
90.00	48	24	44	36	58.70
139.52	48	24	44	36	48.80
226.70	48	24	44	36	42.62
388.44	48	24	44	36	42.63
570.00	48	24	44	36	35.39

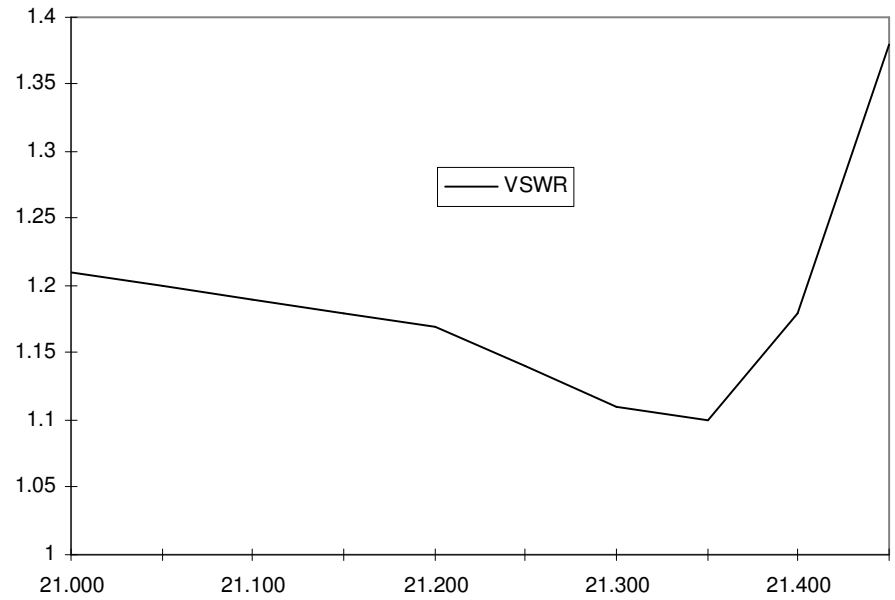
* The 1.000", 0.875" and 0.750" sections are double wall sections

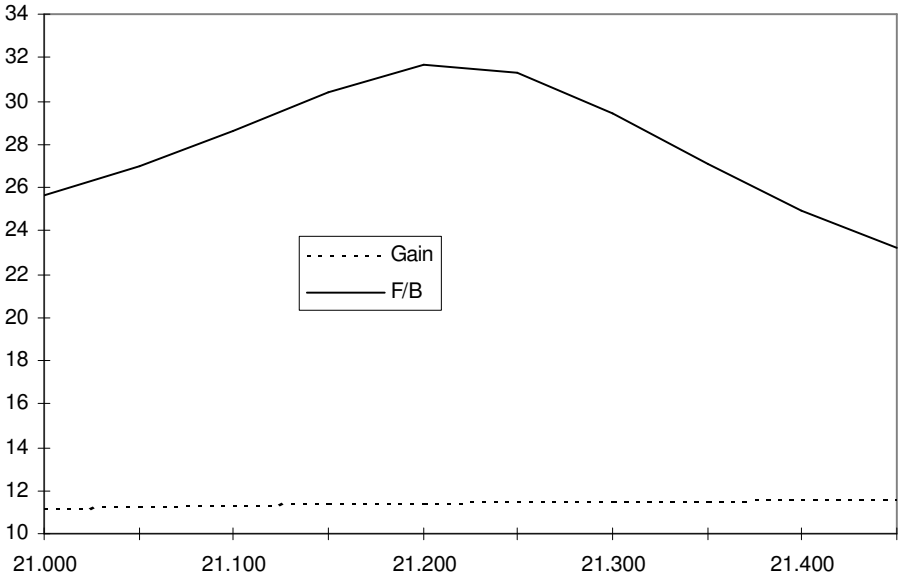
15m - 6 Element Antenna on a 48’ Boom

Below is a view of the 15m antenna being tested on a 55’ crank-up tower at K3CR. Above it is the 7 element 10m yagi discussed later. This single 15m antenna blew away the old W3 15m single band record in the 1998 WPX SSB contest (NW3Z - KB3AFT op). Note the close spacing between the driven element and the first director: this is the fundamental characteristic of the OWA yagi.

This antenna is, without doubt, the best antenna I have ever built. The side and back rejection are absolutely phenomenal and the 1.5 VSWR bandwidth through 100’ of Belden 9913 extends the entire way from 20.000 MHz to 21.500 MHz! The element spacing is rather wide considering the boom length but experimentation showed that the addition of a 7th element did not contribute anything to the performance.

For 15m we were fortunate in that the pattern of the optimized free space design is not degraded at all when placed on the 185’ tower at K3CR. This design has the following free space performance across the band: VSWR < 1.3, F/B > 23dB and Gain > 11.2dBi. When this antenna is modeled on the 120’ tower, such as the one at K3LR, there is some loss of F/B at the top of the band but the overall performance is excellent. The free-space performance of this antenna is shown below.


1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
VSWR
21.000
21.100
21.200
21.300
21.400


34
32
30
28
26
24
22
20
18
16
14
12
10
Gain
F/B
21.000
21.100
21.200
21.300
21.400

The spacing of each element is shown from the reflector and all lengths represent the **exposed** length of tubing. Double wall sections are indicated below the table. The taper schedule of the elements can be adjusted using YO (using the W6QHS algorithm).

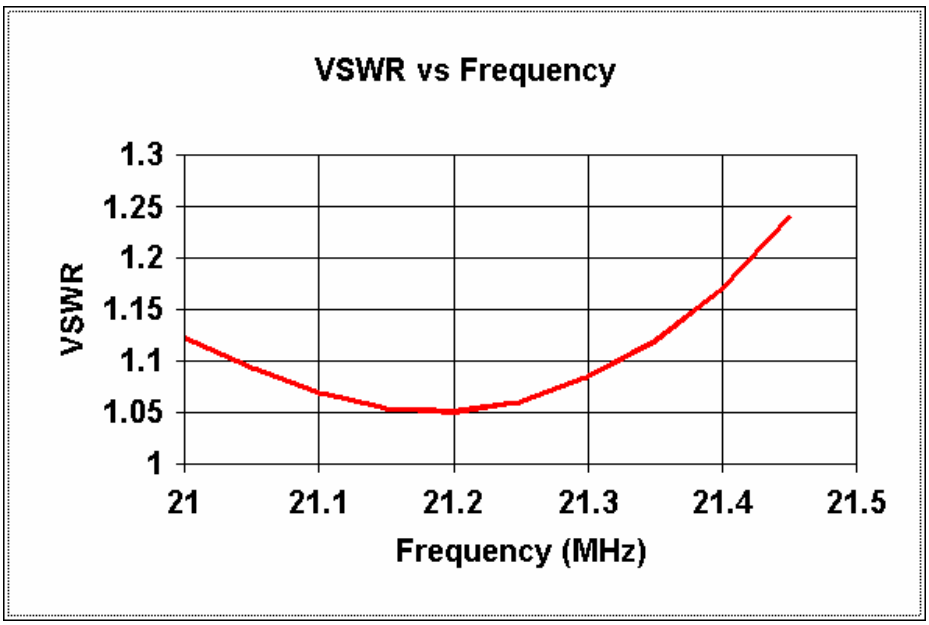
The 15m - 48' Design

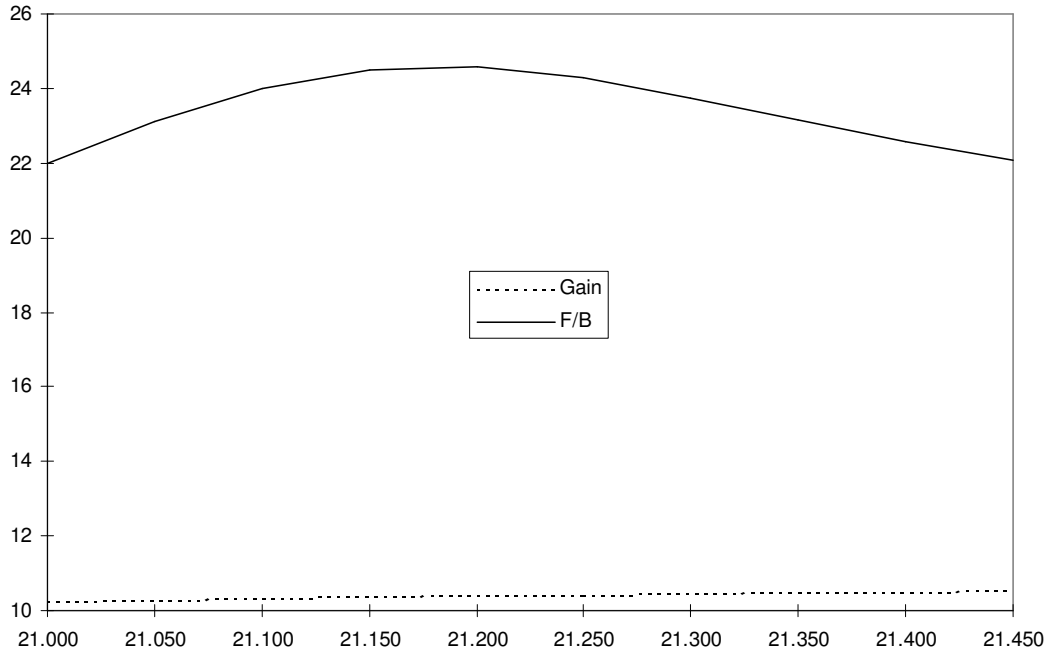
	0.75	0.625	0.5
0	36	24	83.5746
82.4547	36	24	79.2662
118.239	36	24	74.0373
221.131	36	24	70.3034
408.314	36	24	66.9878
570	36	24	63.5933

*the .75" section is double wall

15m - 6 Element Antenna on a 36’ Boom

This antenna is another good performer and was the basis for the 20m/15m interlace built for the WP3R contest station discussed later in the article. It has excellent performance but does not have the superior pattern of the 48’ version.





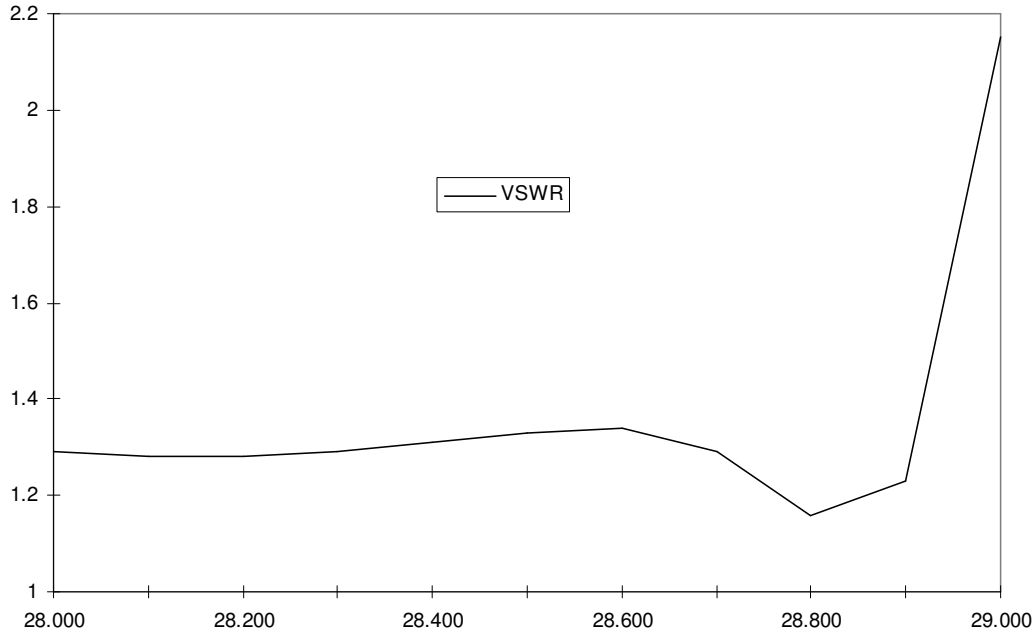
Taper Schedule for 36’ Boom 6 element 15m

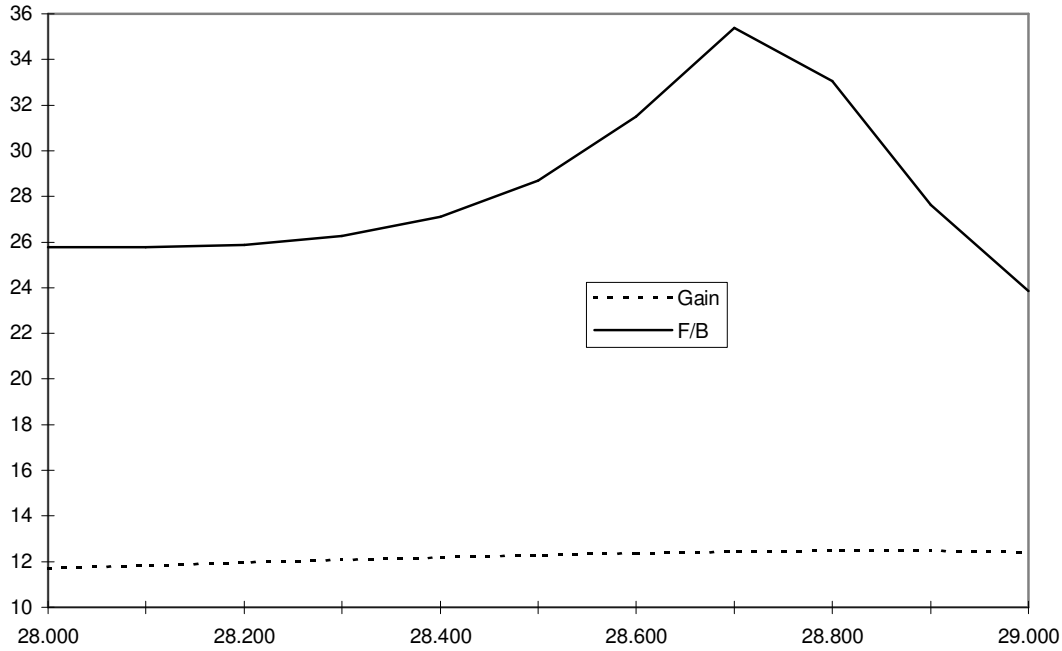
	Diameter		
	0.750	**0.625***	**0.500**
0.0**	36	24	82.38
67.5	36	24	79.08
104.6	36	24	72.63
200.0	36	24	67.24
291.3	36	24	67.22
426.0	36	24	62.60

*The 0.652” section extends the entire length of the 0.750 section for a double wall center
**Where spacing from the reflector is listed in the left column.

10m - 7 Element Antenna on a 48’ Boom

Once again the optimum free space design works on both the 175’ tower at K3CR and the 100’ tower at K3LR. The antenna has the following free-space characteristics.





The spacing of each element is shown from the reflector and all lengths represent the **exposed** length of tubing. Double wall sections are indicated below the table. The taper schedule of the elements can be adjusted using YO (using the W6QHS algorithm).

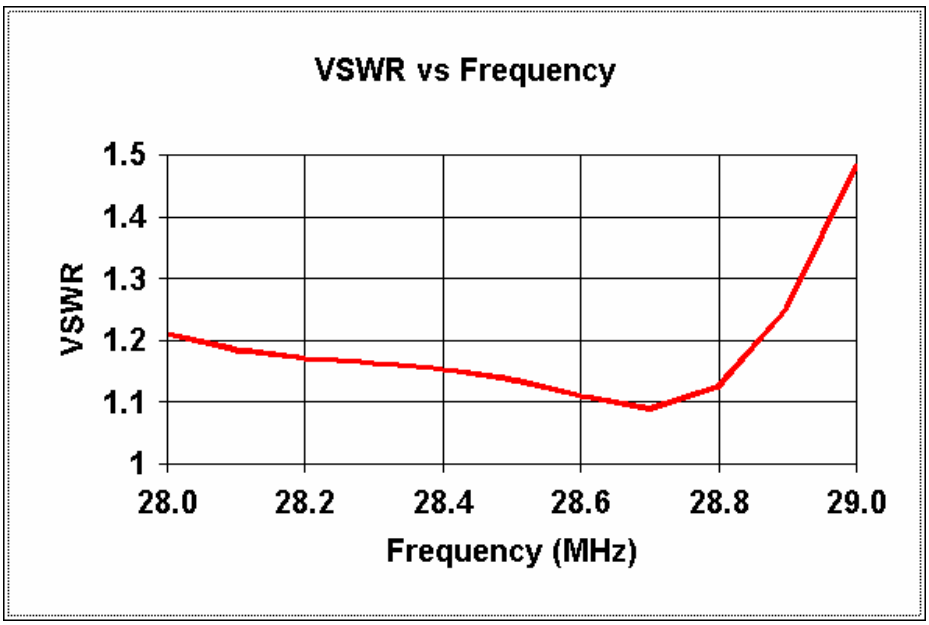
The 10m - 48' Design

	0.75	0.625	0.5
0	24	18	64.81
63.98	24	18	62.13
86.97	24	18	57.49
157.73	24	18	54.84
291.46	24	18	51.47
439.21	24	18	51.07
570	24	18	47.28

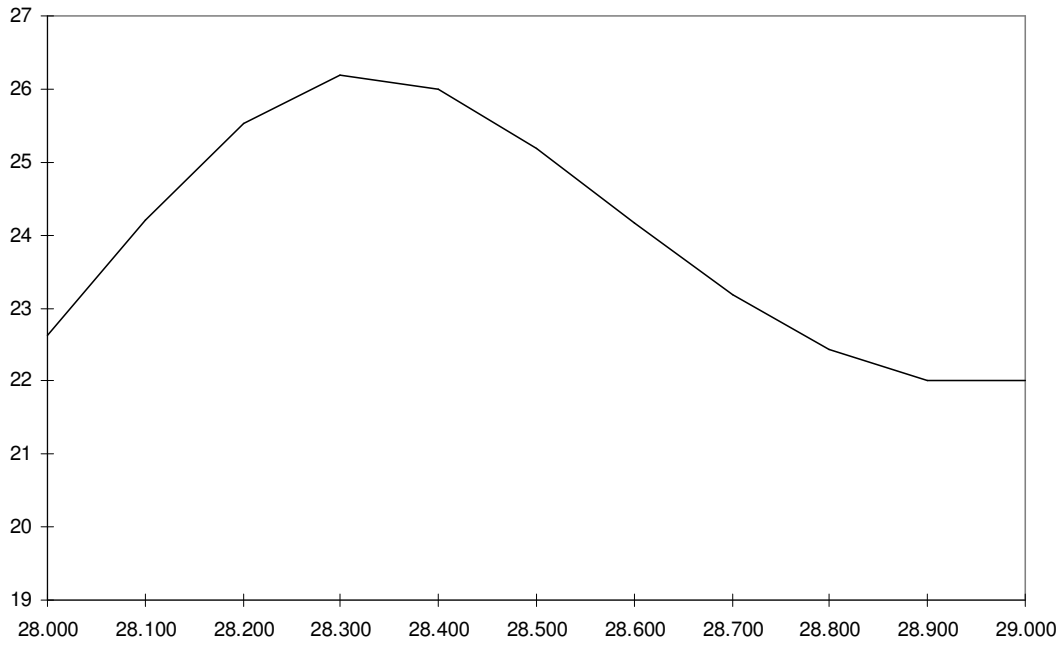
*The .75" Section is a double wall

10m - 6 Element Antenna on a 24' Boom

This antenna was designed and built for the WP3R contest station and is mounted at 30' on a TIC ring. The gain was taylored so that the 3db beamwidth of the antenna entirely covers the US without having to rotate the antenna. A picture of the antenna is shown with the 20/15 interlace discussed in the next section.



The gain of the antenna is pretty much flat across the band at a little over 10dBi and the F/B is shown below.



10m Elements

Diameter	0.750	0.625	0.500
Exposed Length	24	18	tip length
Total Tubing Length	24	42	tip+4"

	spacing from reflector	tip length
reflector	0	65.52
driven element	43.86	61.59
director 1	69.18	55.90
director 2	131.3	53.88
director 3	192.7	54.17
director 4	282.0	49.57

The 20/15m 12 Element Interlace for WP3R

I designed this antenna specifically for the WP3R contest station in Puerto Rico owned by Jim Breakall, WA3FET. The tower is on a hilltop about 1 mile outside the Arecibo Observatory and overlooks the entire area, including a great view of the Atlantic Ocean to the north. We constructed this station over a 3 week period in March 1998 and it was first activated in the ARRL SSB contest with impressive results. A 60' tower was the tallest one that could be erected on the hilltop so it was decided that 20m and 15m monoband antennas would be combined on the top of the tower (with separate feedlines) while a 10m monobander would be placed at 30' on a TIC Ring-rotator. The 20m portion of this antenna is almost identical to the 48' monobander discussed previously in the article. In order to fit the 15m antenna into the 48' boom, I started out using the 36' boom 15m antenna discussed previously.

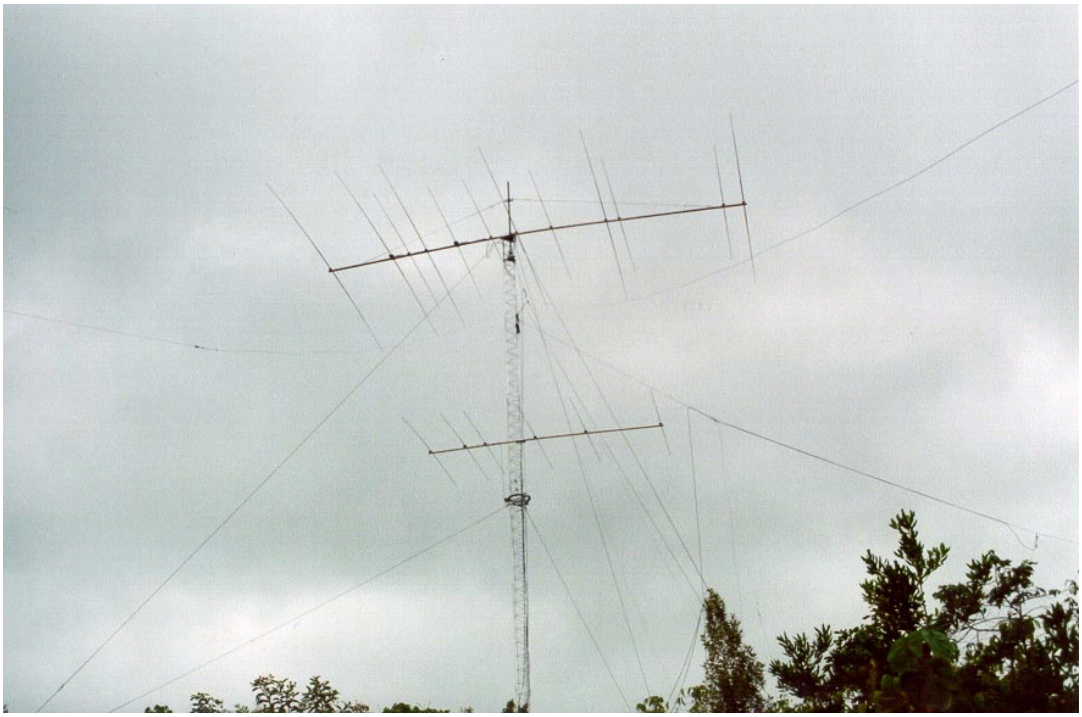
While the 20m performance was unaffected by the interlacing, much optimization had to be performed to bring the 15m statistics back up to their monoband performance. The first major design step was the discovery that the entire 15m antenna had to be placed in front of the 20m driven element in order to get the design to function properly. After this point, computer optimization was used to tweak the antenna to it final stage.

This antenna is an absolute monster but was installed without hitch. The Rohn 55 tower was embedded directly into a 2 cubic yard base and I made the decision to drop all of the guy wires from the tower so the antenna could be hauled straight up the side of the tower. If we had not been able to do this, I'm not sure how successful we would have been due to the extremely small area at the top of the hill. As it was, the antenna barely fit end to end when we were assembling it on the ground! Special thanks needs to be given to Pedro, NP4A, and Papo, KP4TG, for helping get this antenna off the ground!

The picture to the left shows me bolting the antenna onto the mast. The 15m first director and 20m second director were removed for safety in hoisting the antenna.

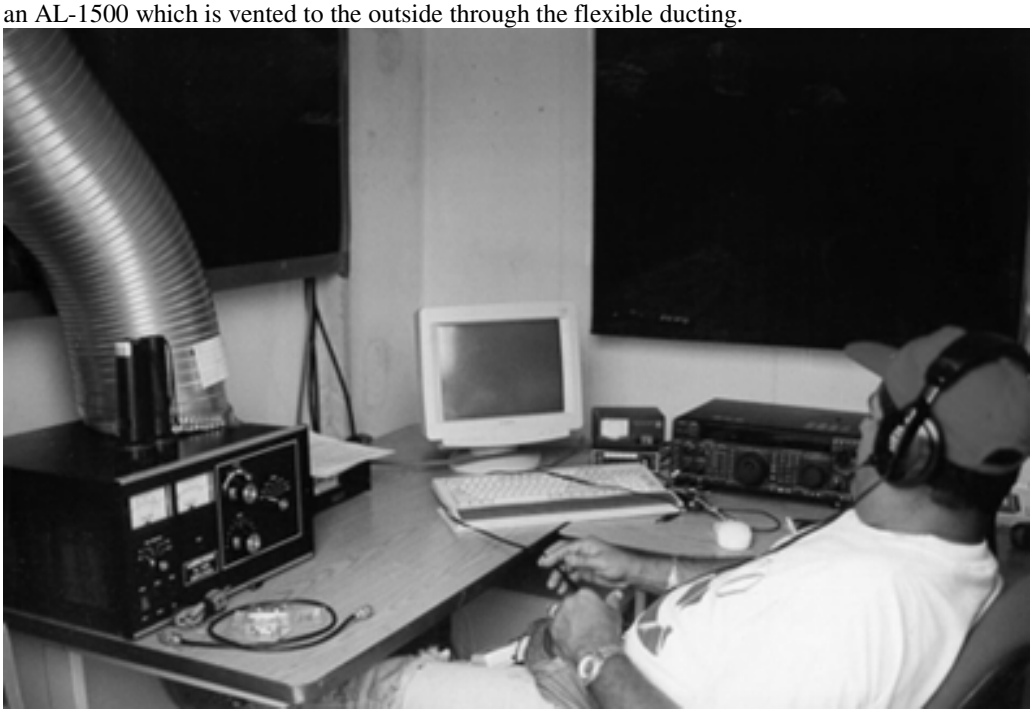
So far, the station has been activated for two contests: ARRL DX Phone and WPX Phone (all of the pictures in this article are from ARRL DX). For ARRL, it looks like we took 3rd place for SOAHP. We ended up missing 2nd place by a mere 71 Q's according to the internet postings. This was due to some problems that KB3AFT(op) had adapting to the food of Puerto Rico. He did an amazing job overcoming the illness that took out 2 hours of prime 40m operation and hung in to finish the contest strong. For WPX, WA3FET got behind the mike for a 15m single band effort and it looks as if a new NA record was set! We are anxiously awaiting all of the official results for this one. Congratulations to both of these guys for their tremendous jobs operating the contests. My idea of operating is getting on long enough to see if the antenna is working…. once I know that things are working fine its time to build a new antenna!

Here is a view of the antenna system immediately before the contest. For 3 weeks we had nothing but sunny skies and blistering heat but the sky really opened up over the weekend! The 10m antenna was mounted above the TIC Ring as can be seen in this picture. We were having some difficulty with the rotor and since we had no need to turn any of the antennas for ARRL DX, I simply bolted the antenna to a tower leg. The rotor has since been aligned and the 10m antenna is mounted on it (this is at the 30' level). To the right of the photograph you can see the 3 element wire yagi for 40m. The boom was a rope catenary that ran about 500' across a valley to a secondary hill top that was within 10 degrees of the direction of central stateside! For 80 and 160 there is an inverted-V with a common feedpoint. We are looking up between one of the legs: the 80m element and insulator is seen to the left of the picture while the 160m leg continues past the camera to the upper right.

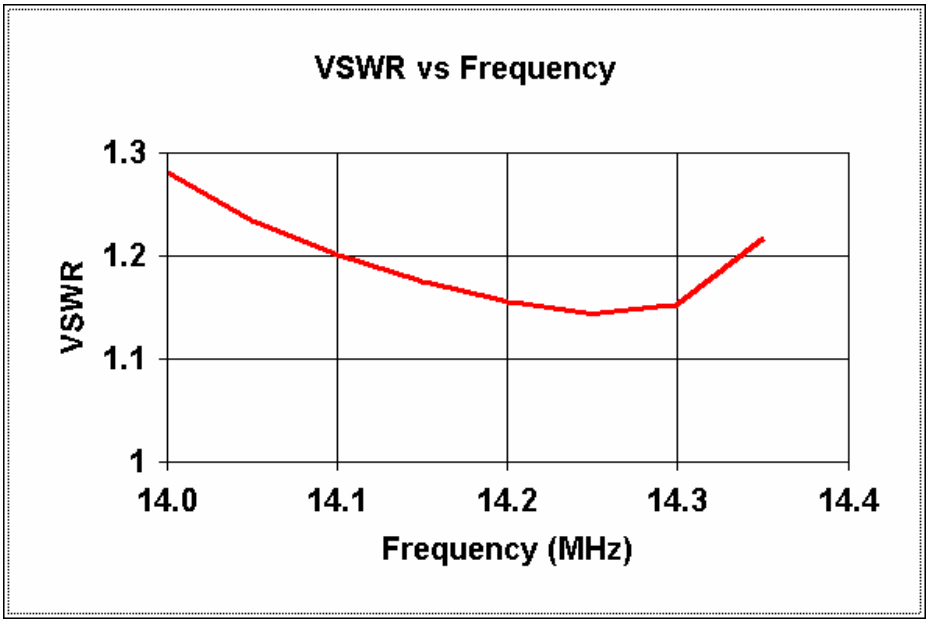


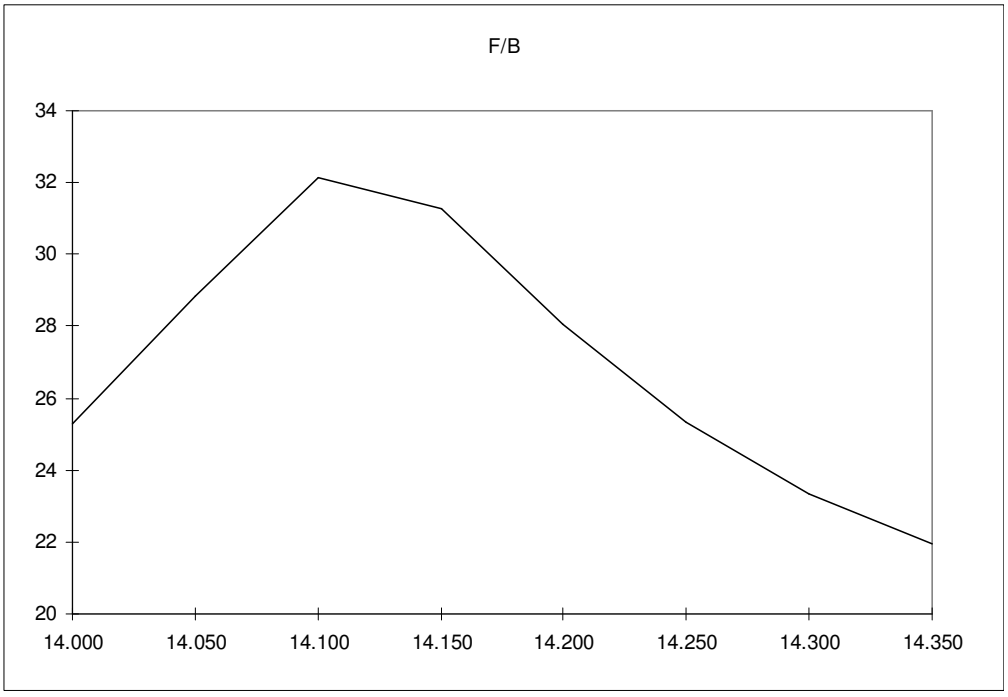
Below is a view to stateside from the base of the tower. Note the Atlantic Ocean is in view for the entire photograph!!

And here is the man! Angel, WP3R, tests out the station before the contest. Equipment is FT1000MP and an AL-1500 which is vented to the outside through the flexible ducting.

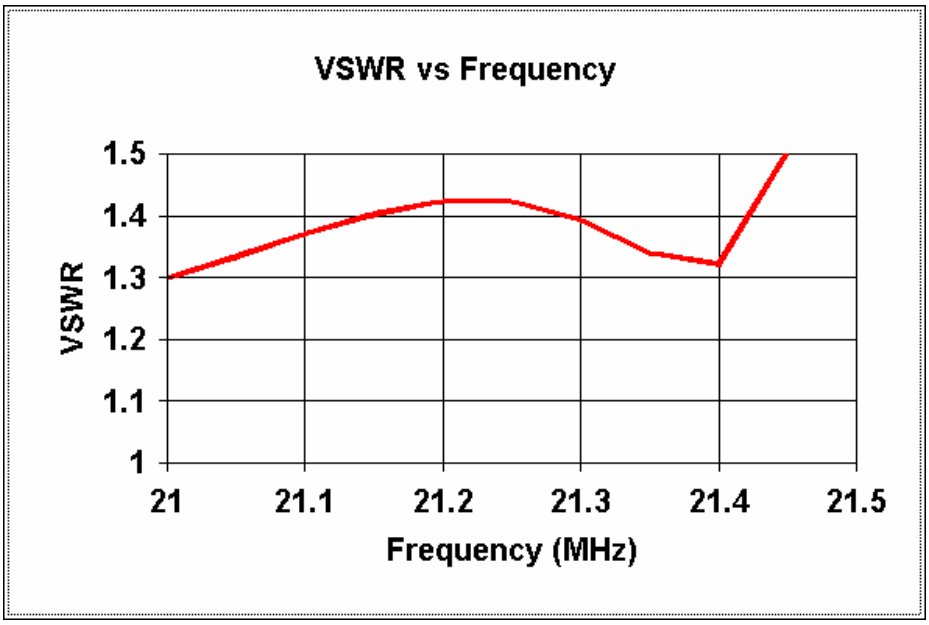


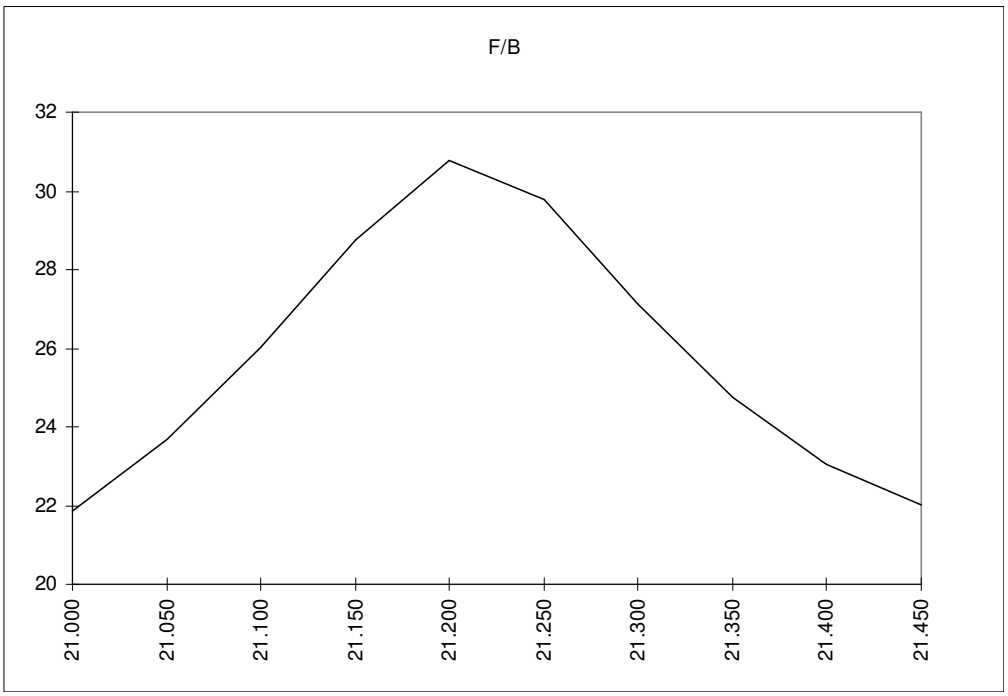
The information for the 20m antenna is below. The gain ranges from 10.1 dBi to 10.3 dBi.





The performance for the 15m antenna is shown below. The gain is 9.3 dBi at the bottom of the band and increases to 10.8 dBi near the top of the band.





The taper schedule for the antenna is as follows. The first table shows the inner half-element which is the same for all. Note that the inner section is acutally triple walled for the 20m elements: these design come directly from the ARRL Antenna Handbook 120mph specifications. The tip lengths are listed in the second table.

20m Elements

Diameter	1.250	1.125	1.000	0.875	0.750	0.625	0.500
Exposed Length	48	0	24	20	42	20	tip length
Total Tubing Length	48	48	72	48	66	66	tip+4"

	spacing from 20m reflector	tip length
reflector	0	65.73
driven element	90	58.53
director 1	139.52	48.39
director 2	266.7	42.06
director 3	388.44	42.06
director 4	570	34.64

15m Elements

Diameter	0.875	0.750	0.625	0.500
Exposed Length	36	36	18	tip length
Total Tubing Length	36	72	22	tip+4"

	spacing from 20m reflector	tip length
reflector	115	55.94
driven element	182.5	50.11
director 1	231.1	45.16
director 2	314.45	43.83
director 3	406.3	42.68
director 4	543.9	37.74

The Yagis - General construction notes

Construction of the Elements
The elements are made of standard .058" wall 6061-T6 aluminum tubing which is available from a large number of sources throughout the country. The taper schedules, which have around 90mph wind survivability, are variants of those shown in the ARRL Antenna Handbook. Where the tubing overlaps, the joint is coated with anti-oxidant and secured with 4 aluminum pop rivets set 90 degrees apart.

Mounting the Elements on the Boom
The parasitic elements are mounted to the boom using four U-Bolts and a plate is made of 4" x .375" thick aluminum bar stock. The plate is 8" long for the 20m elements and 6" long for the 15m and 10m elements. Because the OWA yagi uses a direct dipole feed, the driven element must be split in the center as well as insulated from the boom. To insulate the element, the mounting plate is made of 3/8" thick Garolite, a phenolic material that is available in sheets from many suppliers. A gap of 2" is left in the center of the driven element and a 24" section of fiberglass rod of appropriate diameter is inserted inside the tubing to provide strength and to prevent crushing. Two U-Bolts are used on each half of the driven element for additional support. It is important to note that when measuring the driven elements, all measurements are made from the center of the gap, not the beginning of the tubing. For example, if the taper schedule calls for 48" of 1.000" tubing for the inside part of the element half, the tubing is actually cut to 47" to leave the gap in the center. Use a high quality 1:1 current balun to feed the antenns; personally I prefer the 5kW rated models from Radio Works.

Boom Supports
All of the antennas at K3CR use 48' booms, which must be vertically guyed to eliminate most of the sag. The 20m antennas use a boom of 3"(.125" wall) aluminum while the 10 and 15m antennas use a 2.5" (.125" wall) boom. Stainless Steel Eye-Bolts are put through the boom and Phillystran™, a PVC protected kevlar rope, is used for the support cables. Because Phillystran is non-conductive, interaction is avoided.

Conclusions

Well I hope you have gotten something out of this! I'm sure that there are things that I forgot to say but you should be able to take the information I've given and get some pretty good antennas built. If you build any of these antennas please drop me a line to let me know how everything worked out for you. I hope to see many of you at Dayton this year: I'm sure you'll find me hanging around with such shady characters as WA3FET, WP3R and KB3AFT and always near the contest activities… hopefully somewhat sober!

73 Nathan NW3Z
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Nathan Miller, NW3Z, *has been extensively involved in the modeling and testing of HF antenna systems since 1994. He received his BS degree with honors from Penn State University in 1996 and will receive his MSEE degree in August 1998. While completing his MS degree, he has acted as an antenna consultant to the Arecibo Observatory and the US Coast Guard Academy and has participated in several government research contracts. He has also written articles for several publications, including QST and NCJ. Currently, he is a serving line officer in the US Navy and will be reporting to USS Barry (DDG-52) upon completion of Surface Warfare Officers' School in Newport, RI.*