Design, Construction & Evaluation
of the
8 Circle Vertical Array for Low Band Receiving©

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In recent years, interest in DX'ing on the 160 and 80 meter amateur bands has increased in popularity. This has been driven by a number of factors including ARRL's DX Challenge Award[1] and the expanded volume of low band antenna information in various publications and on the internet. The impact of ON4UN's book[6] and W8JI's web site[7] are not to be underestimated. In addition, the large signal handling capability of amateur radio equipment has improved tremendously in the last two decades. These positive influences have prompted many radio amateurs to increase their knowledge of antenna and propagation characteristics on the low bands. Many have attempted to apply that knowledge by actually constructing and evaluating various antenna designs in different environments including the authors.

W5ZN has many years of experience in designing and evaluating antenna systems for amateur microwave applications[2,3,4,5] and has presented numerous technical papers at conferences of the Central States VHF Society, Southeast VHF Society and the Microwave Update Conference as well as co-authoring the chapter on multi-band feeds in the W1GHZ Microwave Antenna Book[5]. Utilizing these designs at W5ZN resulted in first place finishes and new records in numerous contests. In 1987, after moving from a city lot to a 30 acre field he became interested in expanding his knowledge and experience with receiving antennas for the amateur radio 160 & 80 meter bands.

N4HY has actively designed and modeled numerous antenna systems for multi-station amateur installations. In AMSAT, he was VP of Engineering for 3 years. Bob is the author of numerous papers in amateur radio for the ARRL/TAPR Digital Communications Conference, AMSAT Symposia and QST. He was an active member of FRC for years but has been inactive in HF contesting for 15 years, but is active in VHF+ contesting. He was the 160 meter operator at N2RM during the big years there and has a single op top ten from N2NT in the ARRL DX Contest (SSB); the first time he had seriously single op'd since a teenager. Bob is a proud member of the amateur radio Geek squad. Currently, Bob is a co-developer of the SDR code for Flex Radio's PowerSDR™.

We teamed up to refine the design, document the construction and evaluate the performance of the "W8JI Eight Circle Vertical Array" at Joel's station in north central Arkansas.

1.0 Design of the 8 Circle Array

The primary objective of any low band receiving array is to obtain a directivity pattern that will reduce the impact of various noise sources from multiple directions and locations. Antenna gain is not of specific importance in these designs since the sky noise is sufficiently high that not all of the gain in full size antennas and modern receivers can be used on the low bands. It is better to optimize directivity and ambient noise suppression in the antenna, and to optimize the receivers for large signal handling and dynamic range. It is not the intent of this paper to discuss all of these topics. We suggest a thorough study and understanding of *Low Band DX'ing,* Fourth Edition[6], by John Devoldere, ON4UN, is a requirement prior to proceeding with any low band operation. Chapter 7 is prerequisite for any receiving antenna project. In addition, the specific theory related to end-fire and broad-side arrays in the same chapter must be read and understood as well. The 8 Circle Vertical Array system is based on this theory and cannot be utilized to its full potential without this knowledge. If you don't fully and completely understand this material, read it as many times as necessary to adequately comprehend it along with the wave characteristics and mathematics that encompasses the design.

1.1 Element & Array Design

The 160 meter 8 Circle Vertical Array was designed by Tom Rauch, W8JI, and previewed in the Fourth Edition of *Low Band DX'ing*, Chapter 7 Section 1.30. The array is centered on a shortened top loaded vertical and described in the above reference in section 1.21.1. Additional information on small vertical arrays can be found on Tom's website. [7]

We wished to further evaluate the design of the array and also evaluate an 80 meter version that did not exist (at least at the time of the original analysis which was done before the Devoldere publication of details of the 160m array in *Low Band DX'ing* and after presented to N2NT, W2GD, and K3LR). The most crucial missing piece of all is a step by step HOW-TO in building, tuning, and using the antenna. None chose to build it at the time of the original analysis so it was dropped until W5ZN declared an intention to do so. It is important to understand first and foremost that this is a receiving antenna. Like most receive antennas, it is designed only for this purpose and is wholly unsuitable for transmitting.

One of the ways we make sure it is unsuitable for transmit applications is to utilize impedance matching with a low wattage rating resistor! This resistor will do great things in this application; most prominently it will lower the Q and broaden the response of the antenna at good SWR and match it to widely available and inexpensive coaxial cable. This comes at the expense of gain, but in the overall communications system, coupled with analysis of the noise temperature of the bands (160m as well as 80m), gain is not the primary objective with a low band receiving antenna design and its insertion loss is not harmful. At 160 meters, the array using the elements proposed will have plenty of gain at –8 dBi. This loss actually helps increase the IP^3 of the system, a very important thing on low bands! As such, we believe you should not even need a preamp unless you are installing an incredibly long feedline run from the array center to the shack or feel the need to have one just as a buffer between the antenna and the rigs. That will be for you to determine based on your specific installation and numerous methods for determining this need have been previously published[6,7]. With the theoretical gain given above, this will equate to an MDS in, say, an FT-1000MP that will be –120dBm on this antenna. That is very low for both 160 and 80 meters.

This antenna array will exhibit nearly the same gain and directivity over the entire 160 meter band and even better results should be achieved on 80/75 meters from 3.5 to 3.8 MHz with the 80 meter version. The results of the 160m construction and testing, presented later, do attest to the validity of the analysis. Our recommendation is that the design be skewed toward the bottom of each band.

Of primary importance in the design of low band receiving antennas is the Directivity Merit Factor (DMF, referred to by ON4UN[6]) or a better measure, Receiving Directivity Factor (RDF, the W8JI measure[6,7]) which is the ratio in dB of the forward gain at a desired direction and take off angle to the average gain over the rest of the entire sphere around the antenna. These two "Factors" are described in detail in Sections 1.8 through 1.10 of ref. 6. While this antenna array has some small side lobes (see Fig. 9), they are really nothing to be concerned about and are better than most four squares and yagi's. You can trade off some side lobes for better directivity and this was done in the original analysis discussed above. A 9 element circle array[8], design by John Brosnahan, W0UN, makes these side lobes smaller but it does not increase the directivity factor significantly and has a larger lobe upward that is prone to sky noise. One benefit of W0UN's design is that it can also be used for transmitting but this comes at the expense of a more complicated switching and phasing network than needed for the 8 circle antenna. John's system phases a 3 element parasitic array with a broadside/end-fire cell.

The 8 Circle Vertical Array is inexpensive, easy to build and easy to feed as the utilization of a broadside/end-fire array reduces the complexity of the switching system. An analysis of vertical elements shows why the short vertical element is ideal for low band receive applications.

First, the ground is much less important. There is little ground effect cancellation of radiation. These small vertical elements with a top hat are still quite sensitive and have a low feedpoint impedance after you cancel their capacitive reactance with a small inductor at the base. Since the antenna needs to be broadband, the feed is swamped with a resistor and we should make it as large as practical consistent with the coaxial feedline impedance. This allows us to use the least expensive coax that will permit reliable, robust operation. In this case 75Ω cable is perfect, plentiful, and cheap. Therefore, a short element with a capacitive top and an inductive loading coil at the base with enough resistance to bring the mostly resistive impedance up to 75Ω is nearly ideal. The resistive swamping lowers the Q and increases the operating bandwidth with 75 Ohm cable.

1.2 Modeling the Individual Elements
The best approach is to use the W8JI element. There isn't a great deal of information published about this design, so Bob did our own modeling with EZNEC/4 Professional.

Figure 1 shows the segment layout of the shortened vertical. This vertical contains some minor modifications from W8JI's design based on Bob's studies.

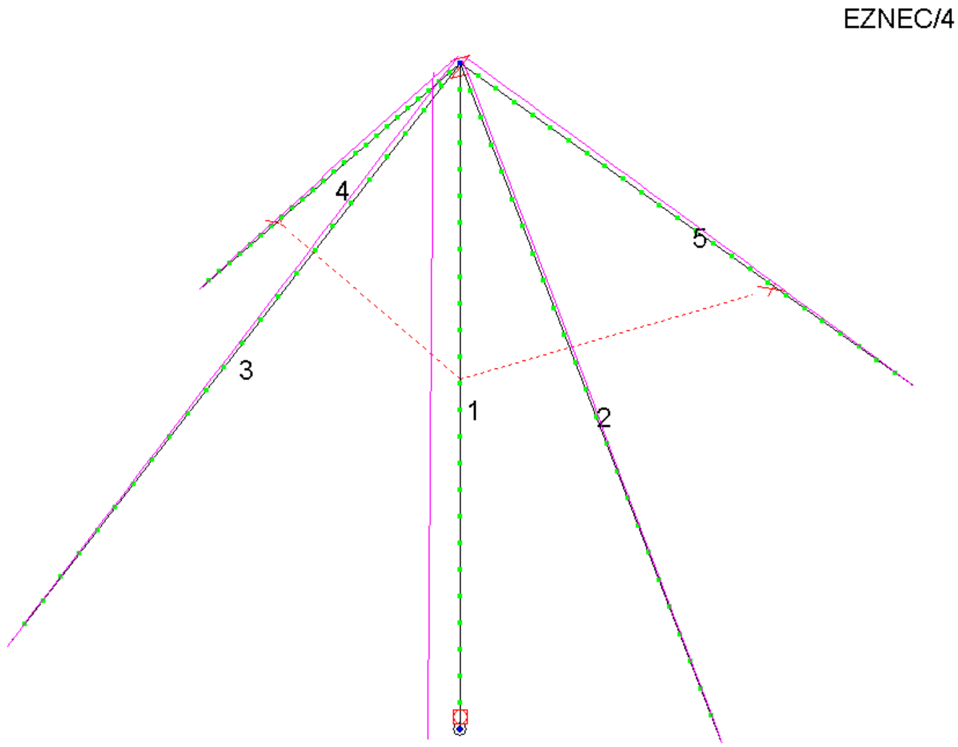


Figure 1: Antenna drawing from EZNec/4 Pro showing analysis segments and bottom load as well as top-hat details (no radials shown here).

The model shown in figure 1 is available from the W8JI site but has been slightly modified based on our analysis. Our model contains the correct number of segments and a better analysis of the loading of both the top-hat and base and does an adequate job of modeling with the radial system. This determination was made because using EZNEC/4 Pro allows for good theoretical ground models. It is here we learned of the importance of the construction details over various quality grounds and how to achieve robust and predictable operation over all sorts of climates and soil conductivities. The160 meter and 80 meter models are approached as lump resistance in the feed with lumped inductance and no attempt is made to account for the resistance of the small inductors except when choosing the appropriate resistor. This is taken care of when we get to setup and tuning.

For 160 and 80 meters, the dimensions of the vertical and top hat wires are all 25 feet in length, with the top-hat wires also acting as guys, 25 feet from the base of the vertical. This allows the top-hat to serve as both capacitive top-loading and provide very good high angle rejection as well. Because the structure is ground mounted and 4 of the elements are active in each of the 8 directions in a broadside/end-fire cell, the rejection above 45° is at least 9 dB down from the main lobe maximum and the suppression goes up with increasing angle and is a key feature of the top-hat because it acts as a shield against a large expanse of the sky and reduces sky noise above the antenna from reaching the receiver. The short, ground-mounted structure provides immunity from man-made noise in all but the immediate vicinity. So performance will be good so long as you minimize line of sight noise sources for the array.

The individual vertical structure is self resonant at 75 meters so we will need to bring the resonant frequency down with a small inductor. On 160 meters, our design indicated the load inductor to be 30 µH with enough resistance to give a low SWR at 1.85 MHz. This will provide less than 1.5:1 VSWR from 1.8 to 1.9 MHz to 75Ω coax. On 80 meters, the design indicates a 2 µH inductor will be required with the addition of enough resistance to give a low VSWR from 3.5-3.8 MHz.

The 75Ω feed point impedance was chosen because of the availability of inexpensive readily available coax (cable TV installation) plus the higher resistance is used to broaden the VSWR since it is accomplished by lowering the Q. This helps guarantee the front end of your receiver sees the kinds of loads it needs to see to perform correctly.

The mounting is not critical and no special fixtures are needed to insulate the vertical element and top hat wires. You will not be able to tell the difference between an insulated bottom from one held off the ground by a fence post (non-conductive of course!).

The design utilizes a top-hat made from #16 wire with the vertical element assumed to be a 1.25 – 1.5 inch diameter vertical pipe.

Even though ground resistance is not particularly important for radiation resistance, as mentioned earlier, you will need at least four ⅛ to ¼ wavelength radials on each element in order to stabilize the feed point resistance over changing ground conditions year round. The exact number and length can be determined with some very easy tests after initial construction which will be covered later. Again, the ground system only needs to be good enough to provide a stable feed point resistance since the object is not super efficiency and gain but directivity and stability of the impedances in all seasons. This will permit the system to be close enough to "perfect" that the modeling applies consistently. Four is likely sufficient and that is what you should start with, but testing can easily be performed after construction to determine the exact number required. One each of these initial radials should be buried beneath each one of the top-hat wires. Depending on your location, just remember that if the radials are under more than just a few inches of water, they are effectively shielded from the antenna and ineffective.

Figure 2 shows the 3D pattern of one of the vertical elements at resonance using 4nec2dx.

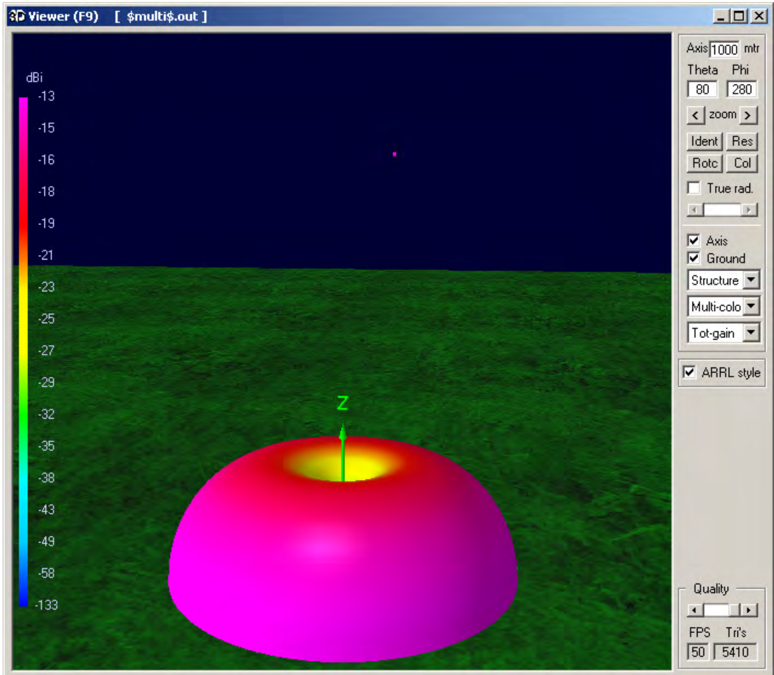


Figure 2: 3D from 4nec2

Figure 3 displays the VSWR profile for Bob's 160 meter design, computed by EZNEC/4 Professional assuming perfect ground, 30 µH base inductor, resistor and 75Ω coax:

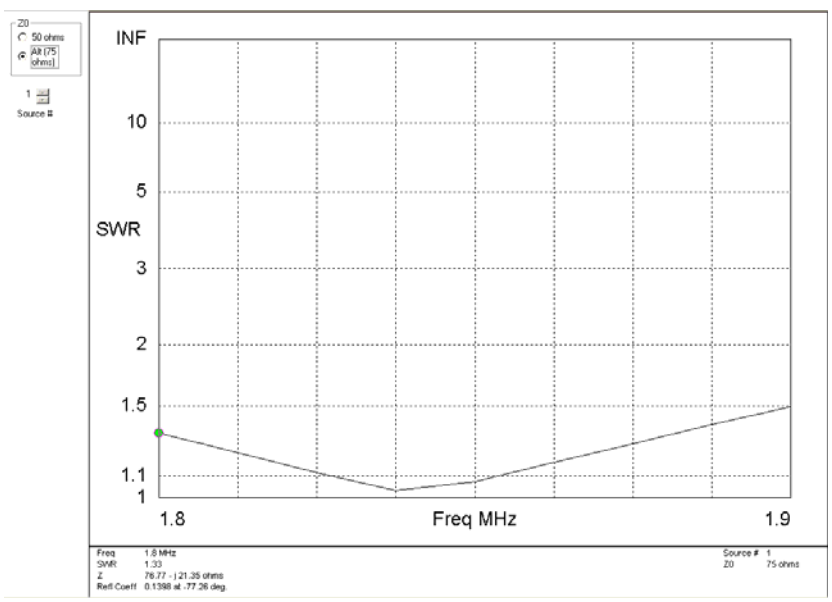


Figure 3: VSWR Profile for the 160 meter Vertical

The 80 meter design VSWR profile, as computed by EZNEC/4 Professional assuming perfect ground, 2 µH base inductor, resistor and 75Ω coax is shown in Figure 4:

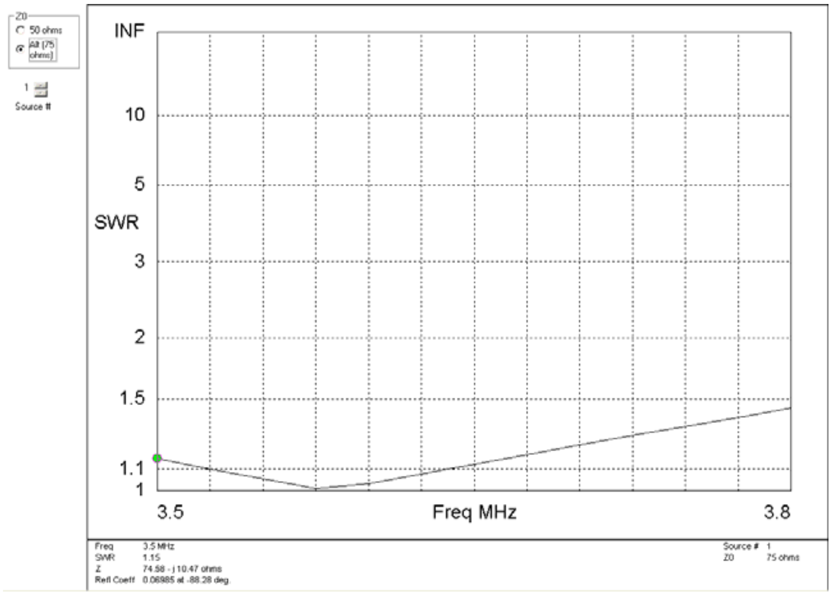


Figure 4: VSWR Profile for an 80 meter Vertical

<u>1.3 Array Geometrics</u>

The 8 Circle Vertical Array is comprised of broadside/end-fire cells. The circle's dimension is determined by the broadside spacing and the end-fire spacing. Much analysis has been performed on the optimum broadside and end-fire spacing so rather than spend time in an effort to determine the same conclusions we will use those results. For those wishing to dig into the theory behind the spacing you can review ref. 6, Chapter 7 Section 1.11 and 1.12.

The optimum broadside spacing for a takeoff angle of 24 degrees, which yields the best attenuation off the sides, is 0.55λ (Chapter 7 Section 1.6 & 1.7, ref. 6). W8JI has suggested the possibility of using a slightly wider spacing of 0.65λ. With this spacing, you will increase the number and/or size of the side lobes but in return you get a narrower 3 dB beamwidth. For those in quiet areas, there is no doubt you should use 0.65λ broadside spacing. If you live near a variety of noise sources you could use 0.55λ broadside spacing to increase the rejection on as many of those sources as possible.

As depicted in Figure 5, once you decide on the broadside spacing and understand that the elements are going to land on a circle, the entire array geometry is determined.

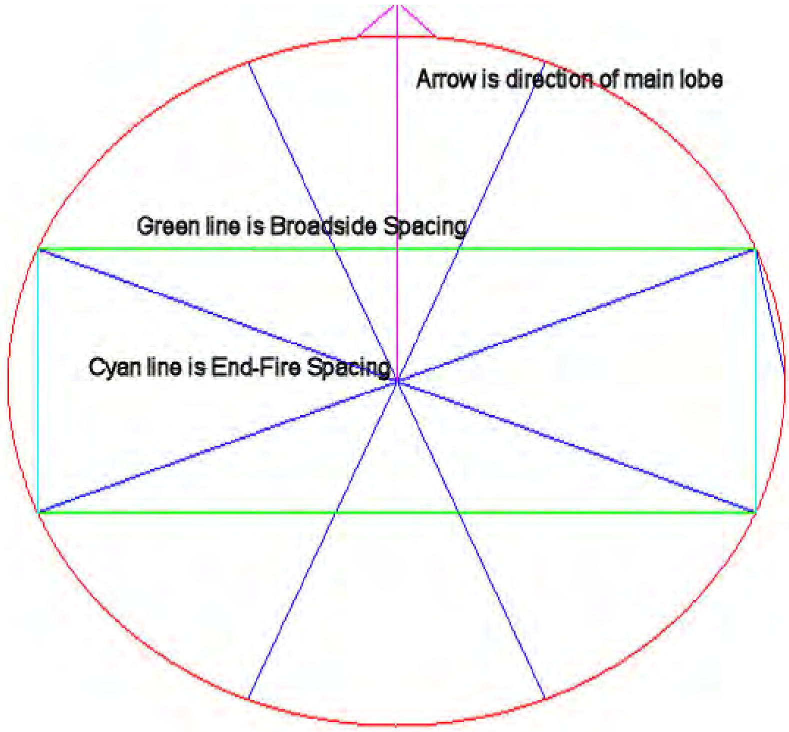


Figure 5: Geometry of 8-circle of broadside/end-fire cells.

The green lines specify the broadside dimension which determines the entire circle as soon as it is specified. The cyan lines are the end-fire spacing which is determined by broadside and circular array. The broadside spacing is the ***ONLY*** degree of freedom in the entire design.

The blue lines represent the individual feedlines to each vertical. These may be any equal length (electrical, not physical) pieces of 75Ω coax. If you make them odd multiples of ¼λ in length (¼λ length of feedline will not reach the center feedpoint of the array) say, ¾λ, then some nice opportunities are available for measuring antenna currents and voltages at the feed points. This is not necessary! They just have to all be equal lengths.

If the forward two elements are combined in phase and the back two elements are combined in phase then run through a phasing line and inverted in a 1:1 INVERTER transformer, then the antenna is beaming in the direction of the arrow.

So, the layout for this specific design is as follows:

Band – Meters	**Broadside Spacing - λ**	**Circle Diameter**
160	0.55	90.1 Meters (296 ft)
160	0.65	106.5 Meters (350 ft)
80	0.55	46.5 Meters (152.5 ft)
80	0.65	55 Meters (180 ft)

1.4 Feeding the Array

Feeding this array is relatively easy. The materials required are:

One - 4:1 UNUN transformer
One - 1:1 Inverter transformer
Nine - DPDT relays & and four diodes.
Two – 75Ω Coaxial Phasing Line

- Two pieces of 75Ω coax connected in parallel to form a 37.5 Ω phase line. The length will be discussed later as there are trade offs to consider.

Figure 6 shows the feed arrangement for the broadside/end-fire cell. Upon careful review, it becomes completely clear why this is so easy. The "Front Two" consist of the two elements in the "front" of the 4 element cell coming to a Tee. The "Back Two" are the back elements in the 4 element cell coming to a Tee. Two pieces of equal length 75Ω coax are feeding the front two elements which form a combined impedance of 37.5Ω. The back two elements are the same and again form a combined impedance of 37.5Ω but with a phasing line (180° minus the desired phase angle) consisting of 75Ω coax. The back two elements are then fed through an inverter which allows us to feed them not with our phase angle, but with 180° minus the phase angle which, among other things, allows for a shorter length of phasing line coax.

This phasing line consists of two equal length pieces of 75Ω coax connected in parallel to produce a 37.5Ω impedance to match the element feedline impedance (two 75Ω feedlines in parallel to the back two elements) which should be 180° – 125°, or 55° in length. If you assume a 0.66λ velocity factor this would be a length of 54.2 ft (16.5 meters) for the 160 meter band and 28 ft (8.5 meters) for 80 meters. But remember, always measure, don't assume!

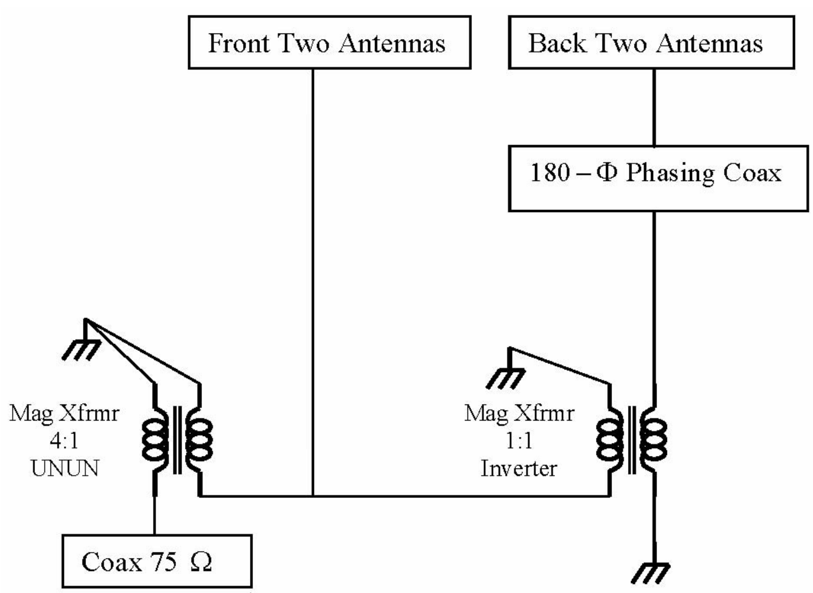


Figure 6: Feed for One Cell

A simple collection of nine DPDT relays or four 4PDT relays with one DPDT can switch the array in 8 directions. One of the nine, or the lone DPDT in the second example, does nothing but swap which side, front or back, sees the 180° minus phasing line coax.

1.5 Modeling the Complete Array Design

With the design assumptions now completed and understood, let us look at the results as an array. Figure 7 shows the EZNEC/4 Professional antenna model of a 4 cell broadside/end-fire array. Figure 8, 9 and 10 display the 2D, 3D and vertical slice pattern for a 160 meter array and Figures 11, 12 and 13 show the 2D, 3D and vertical slice pattern of an 80 meter array.

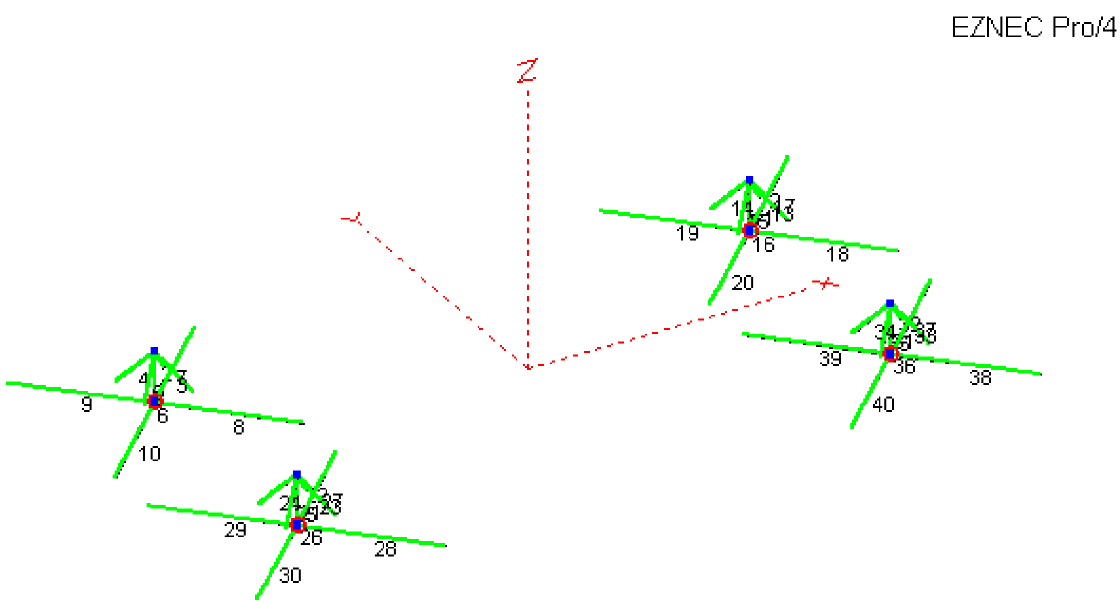


Figure 7: Array of One 4 Cell

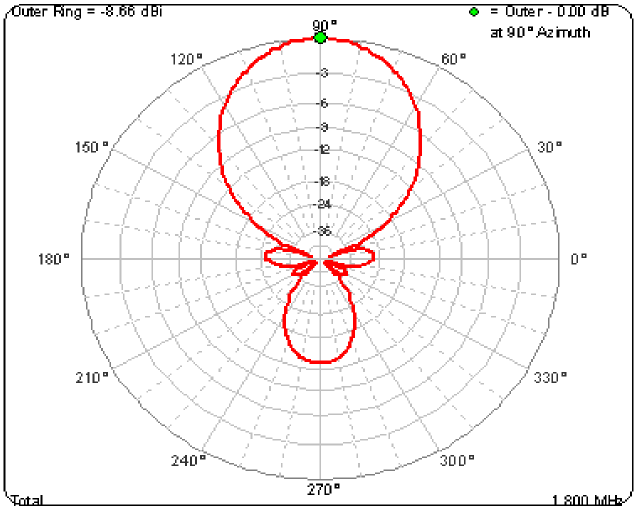


Figure 8: 2D Pattern from EZNec/4 Pro

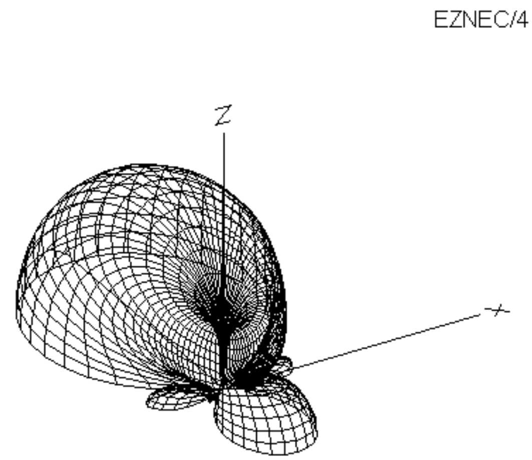


Figure 9: 3D Pattern for 160 meter Array

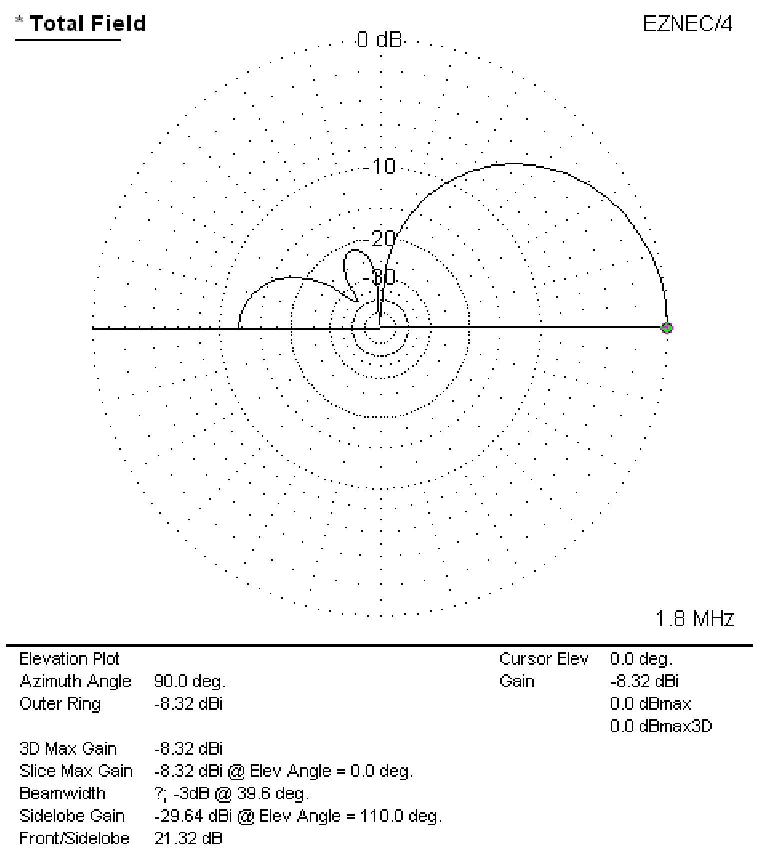


Figure 10: Vertical Slice of 160 meter Pattern

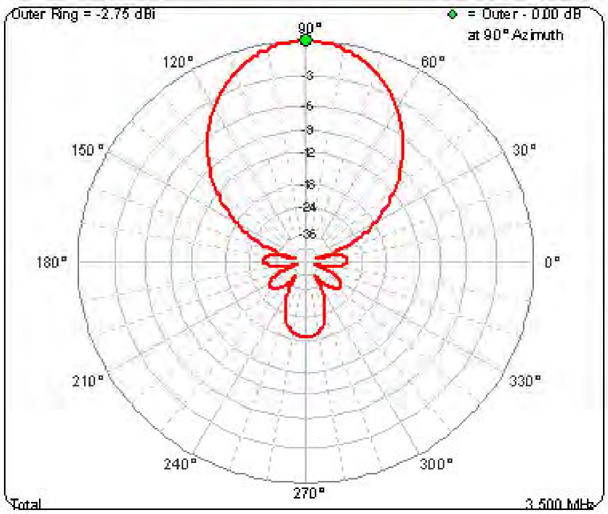


Figure 11: 2D Pattern for 80 meters

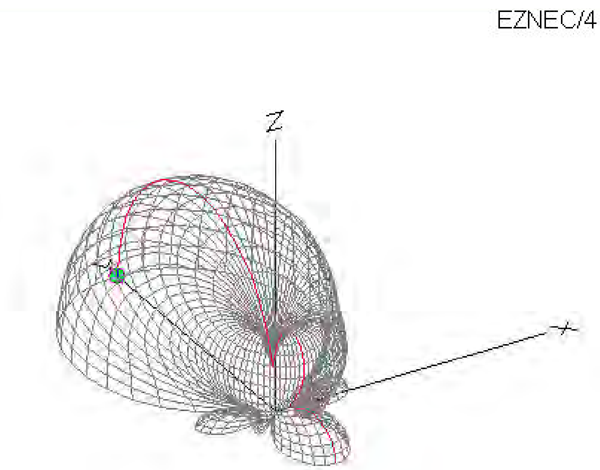


Figure 12: 3D Pattern at 80 meters

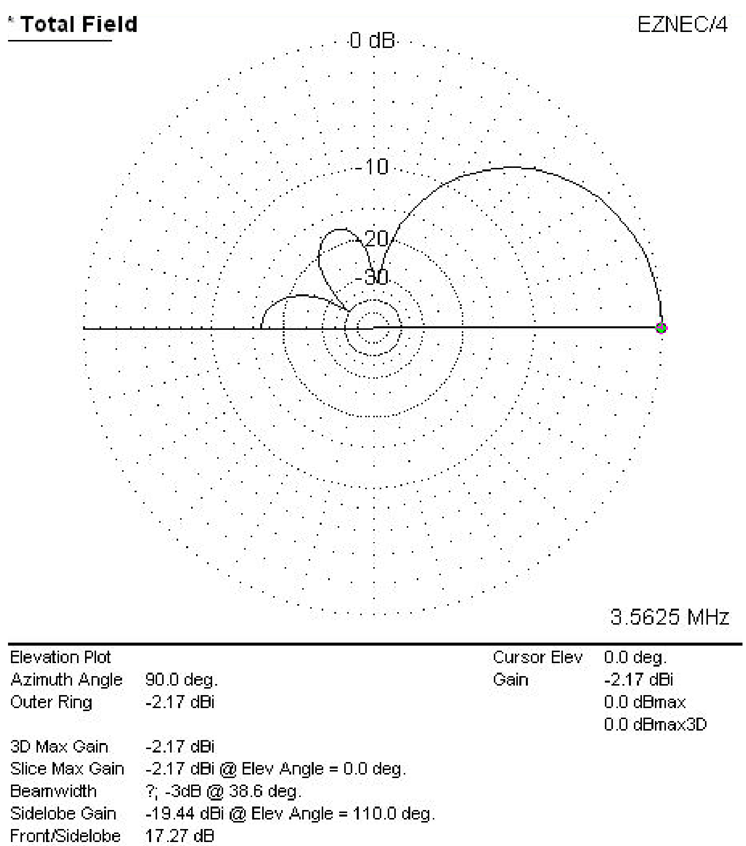


Figure 13: Vertical Slice of 80 meter Pattern

2.0 Construction of the 8 Circle Vertical Array

Once the decision was made to erect a 160 meter 8 Circle Vertical Array at W5ZN, the construction phase began and involved numerous steps to ensure the design parameters were met.

2.1 Location & Physical Layout of the Array

The first step was to select an appropriate location and lay out the circle. It was fortunate W5ZN has an area that seemed ideal for the array out in the field approximately 700 ft from the shack to the proposed center of the array. See Figure 14. The only obstacle to remove and relocate was the SE/NW beverage that ran through the selected area.

The location of the 160 meter transmit antenna, a shunt fed tower with HF yagis seen in Figure 15, had to be taken into consideration as well as the area identified for relocation of the SE/NW Beverage. An existing barb wire fence to the south of the proposed location also had to be evaluated. The western edge of the circle was measured to be 280 ft from the shunt fed transmitting tower, greater than ½λ, and the southern edge was 75 feet from the barb wire fence running east-west.

Figure 14 – Area Selected for Circle Array

Figure 15 – 160 Meter Transmit Antenna (Left Tower)

After we consulted on these dimensions we concluded they should be adequate to prevent interaction with the array. Another concern we had was sloping ground, as can be seen in Figure 14. We concluded that, if the slope was less than approximately 10°, there should be no major impact. So, prior to laying out the circle we needed to verify the slope angle of the ground. The most accurate way to accomplish this would be to use a transit, however since neither of us own one, a less expensive method that is somewhat less accurate but well within acceptable tolerances was employed. A 4 ft level was placed on the ground at the western edge of the proposed circle pointing in the direction of the slope, assuring it was "level". At the far eastern end of the proposed circle at the maximum point of the slope we vertically supported a 10 ft piece of white PVC pipe. While staring down the level to project a "level" straight line to the PVC pipe we marked this point on the pipe. We could then measure this distance down to the ground and use simple trigonometry to calculate the angle of slope. It was calculated that the sloping ground was no more than 2° which relieved some worries!

Now that it was verified to be an acceptable location for the array, it was now time to lay out the circle. Having identified the western edge of the circle by measuring its distance from the transmitting antenna, as well as the southern edge of the circle by measuring its distance from the barb wire fence, we began the layout of the circle. We had previously concluded we would use a broadside spacing somewhere between 0.55λ and 0.65λ, so we settled on a 320 ft diameter circle (0.60λ). This was based on nothing more than a desire to attempt to obtain a slightly narrower forward pattern than 0.55λ spacing provided while trying to reduce the increased number of side lobes realized with 0.65λ spacing. W5ZN owns a 300 ft surveyors tape, so we simply measured 160 ft (the radius of a 320 ft diameter circle) from each of the two previously identified edge points to a center point. From this now identified center point we began measuring out 160 ft in 20 ft spacing segments, marking each edge point with an orange survey flag. In just a short time there was a 320 ft diameter orange flag circle in the field. The measurement practice of "measure twice cut once" was followed to ensure accuracy!

2.2 Element Supports

As noted earlier in the section on modeling, the material and method for supporting and insulating the vertical elements from the ground is insignificant. We picked up four 12 ft treated 2x4's and sawed them in half to produce eight 6 ft posts. Following this a post hole about 18" deep was dug, the 2x4 inserted and packed in with *Quickcrete* to form a solid base. There's no need to mix the Quickcrete with water, just use it as a filling and packing material in the hole. It will absorb the moisture in the ground or during the next rainfall and the moisture will solidify the mix.

2.3 Element Material & Construction

The material used for the vertical elements and the construction technique is not critical as long as you stay within the dimensions of the model in order to replicate it. A variety of acceptable possibilities exist. In this section we will describe the procedure we followed. W8JI has very successfully used other materials (steel conduit and chain link fence top rails) and techniques which provide very strong elements mechanically and excellent results as detailed on his website[6].

We chose to use aluminum tubing (available from Texas Towers, DX Engineering, etc.) for the elements. There was no particular reason for this other than personal preference. We picked up 12 ft lengths of 1¼" diameter aluminum tubing and a supply 1⅛" diameter tubing that has a 0.058" wall thickness. As such the 1⅛" diameter tubing fits right inside the 1¼" tubing. Then the 1⅛" diameter tubing was cut into 2 ft lengths and inserted 1 ft into one each of the 12 ft lengths of the 1¼" tubing and secured the joint with #10 stainless steel screws & nuts. This provided for a 24 ft long element so I then cut an 18" length of 1⅛" diameter tubing, inserting it 6" into what would be the top end of the 24 ft long element and secured it with screws. We now had a very nice 25 ft element. Four holes are drilled at the top 90° apart in order to attach the tophat wires.

For tophat wires we located some cheap #16 gauge speaker wire (16-2 stranded) at Lowes. Separating the two wires is very easy and this wire worked great. Again, there is flexibility with the material but stay with #16 gauge in order to replicate the design model. For guy lines we first used 50 pound fishing line. This worked well for a short period however they began to break (they weren't that tight), possibly from the deer or other wild animals hitting them, so the fishing line was replaced with ⅛" Kevlar® rope from Radio Works. It does not stretch, it is perfect for guying vertical antennas and the Kevlar® rope has held nicely for several months now. For guy anchors, tent stakes are used.

After assembling the elements and tophat wires it was now time to mount the vertical elements to the 2x4 base supports. This can be accomplished in a variety of ways, however while cruising around Lowes one day looking for bargains (W5ZN has no professional or financial connection to Lowes, we just happen to have one near W5ZN and nothing else equivalent within 30 miles). We identified some plastic conduit clamps and some plastic housings with an opening at the top, ideal for mounting the elements and also a means to weatherproof the feed.

Figure 16, 17 and 18 show the 2x4 support, element attachment and completed element.

Figure 16: Vertical Element Installed on 2x4 Base

Figure 17: Vertical Element Sitting Inside Bottom Support Enclosure

Figure 18: One Completed Vertical

2.4 Ground Radial System

As described in the modeling section, some ground radials are required to stabilize the feed point impedance over changing ground conditions throughout the year.

At first we chose to bury four radial wires that were 65 ft long (⅛λ on 160 meters) a few inches in the ground. These were laid out one each under each of the tophat wires. These wires aren't critical and they don't necessarily have to be buried, but they do need to be lying on the ground as a minimum. A large supply of 16 gauge wire was picked up for a cheap price off eBay.

For ground rods, all antenna and shack grounds are using ¾" copper pipes. 10 ft lengths are purchased and then cut in half. An end cap is placed over one end and then driven into the ground. That is relatively easy to do here, especially during the wet winter and spring months. Your specific area may prove difficult or prevent using this method entirely, and that is understood. Just get a good ground rod in the ground. The ground radials and outer shield of the coax connector are all connected to the ground rod. A solder connection is made to the copper pipe ground rod. Figure 19 shows the W5ZN ground radial system installation. The ground rod does nothing to improve the pattern or efficiency of the antenna. It is simply to provide a good DC ground.

2.5 Tuning the Individual Elements

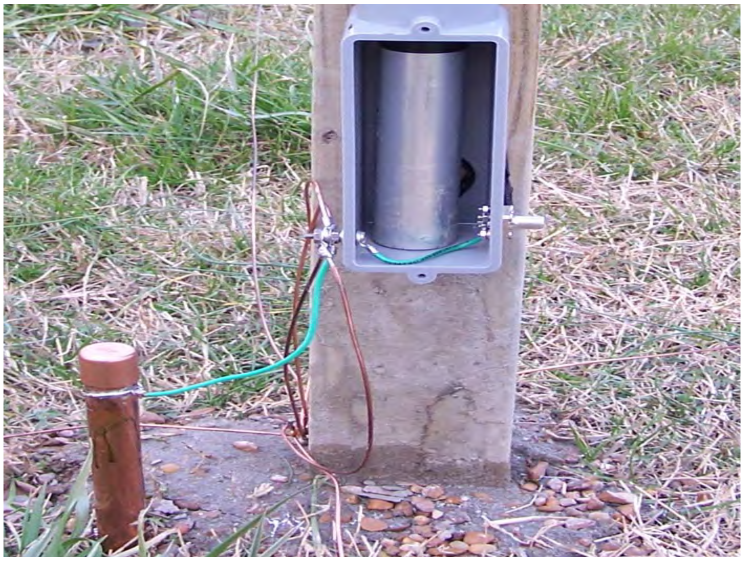


Figure 19: Ground Rod & Radial Attachment

Now that each vertical element was erected and the ground radial system installed, it was time to test and tune each element. Bob and Al Ward, W5LUA, traveled to Arkansas to assist with this process to evaluate actual results with the designed/modeled results. Our first step was to check the self-resonance of each vertical. This is a simple process if you have an antenna analyzer similar to the MFJ-259B. Simply connect the analyzer directly to the vertical element and record the readings. Table 1 shows the results from each element while Figure 20 shows the measurements being taken.

Vertical	**Self Resonance**	**Feedpoint Impedance**	**160 Meter Feedpoint Resistance (no matching)**
1	3.90 MHz	20 *j*0Ω	18 *j*321Ω
2	3.85 MHz	19 *j*0Ω	16 *j*321Ω
3	3.90 MHz	22 *j*0Ω	16 *j*321Ω
4	3.92 MHz	21 *j*0Ω	18 *j*328Ω
5	3.92 MHz	18 *j*0Ω	18 *j*328Ω
6	3.90 MHz	18 *j*0Ω	18 *j*328Ω
7	3.90 MHz	18 *j*0Ω	18 *j*321Ω
8	3.90 MHz	22 *j*0Ω	16 *j*315Ω

Table 1: Vertical Element Self Resonance Measurement Results

Figure 20: W5ZN Measuring Self-resonance of Vertical Elements

Needless to say, we were all quite happy with the results which clearly prove the design dimensions!

Now it was time to tune each element. The design indicated an inductor of 30 µH would be required to tune the element down to 160 meters and our resistor should be somewhere around 70 ohms. Our target was to center to zero reactance component between 1.8 and 1.9 MHz.

Figure 21: N4HY is Very Pleased with the Design –vs- Actual Results!

On hand we had some small molded 27 µH and 31 µH inductors and some 75Ω non-inductive resistors, so the first attempt was to try a 27 µH / 75Ω combination. This produced a 160 meter feed point resistance of 100 *j*0Ω, clearly a sufficient amount of inductance but way too much resistance since 75Ω was our target.

We then went to the resistor box and pulled out some 47Ω resistors to try. These were not "non-inductive" but only measured about 1 µH, so we decided to give them a try. Surprisingly, this combination worked pretty well. The feed point resistance came down to about 68Ω but the zero reactance point didn't really move as we had expected since we were using an "inductive" resistor. After scratching our heads for a bit we decided to check our "non-inductive" resistors and discovered they were anything but "non-inductive"! A case in point here: we did a search on the internet for "non-inductive" resistors and found just about all of our hits for "non-inductive" resistors came back to numerous ads that said "non-inductive wire wound resistors". Huh? Obviously a wire wound resistor will not be "non-inductive" so beware! The resistors W5ZN had on hand, which were purchased from a popular surplus dealer in Nebraska, were very clearly marked and identified as "non-inductive resistor", but they weren't. The good news is this is not really necessary for this application as long as you take the inductance of the resistor into account for the overall inductance/resistance combination. You should also be aware that the inductor will have some small amount of resistance as well but again just make sure you account for all of this in your inductor/resistor network. This is easily done when we calculate the overall reactance and SWR at the desired frequency.

Before you begin the tuning process it is a good idea to have a supply of 0.5 and 1.0 µH inductors as well as some 1 to 3Ω resistors on hand for fine tuning, especially if you're a perfectionist!

Once you have the element tuned to a reasonable point, it is now time to check your ground radial system. This is easily done with an antenna analyzer similar to the MFJ unit. When the shell of the coax connector from the analyzer is attached to the radial system then the analyzer believes this is a perfect ground since there is zero ohms resistance (close enough). If, during the following test the value of the feed point impedance changes by more than 5%, the ground radial system is insufficient.

The procedure we used to verify a stable ground is as follows. First, disconnect all of the ground radials, leaving only the ground rod connected to the cable shield and record the feed point resistance. Next, connect one ground radial and then the remaining three, recording the feed point resistance change at each step. If the change is less than 5%, then you have a very good ground radial system that should be stable under changing conditions throughout the year.

We did not. The change we experienced was greater so we chose to add four more radials, bringing our total to 8 for each element. We continued the test by adding two, then the additional two and the change was now within 5% so we were satisfied we had a stable ground radial system. Table 2 shows the typical change in feed point resistance recorded for each of the verticals when adding radials from October with dry ground and Table 3 shows the typical change from readings taking in January with wet ground.

Frequency	Ground Rod Only	1 Radial	2 Radials	4 radials	8 Radials
Self Resonance No RL Matching 80 Meters	38 *j*30Ω	32 *j*0Ω	30 *j*0Ω	30 *j*0Ω	20 *j*0Ω
No RL Matching 160 Meters	42 *j*360Ω	6 *j*300Ω	7 *j*300Ω	8 *j*300Ω	0 *j*310Ω
RL Matching For 160 Meter Resonance	110 *j*0Ω	80 *j*15Ω	81 *j*12Ω	80 *j*10Ω	78 *j*0Ω

Table 2 – Feed point Resistance Change with added ground radials. Readings taken in October with dry ground.

Frequency	Ground Rod Only	1 Radial	2 Radials	4 radials	8 Radials
Self Resonance No RL Matching 80 Meters	42 *j*30Ω	31 *j*10Ω	30 *j*0Ω	28 *j*0Ω	18 *j*0Ω
No RL Matching 160 Meters	40 *j*363Ω	5 *j*306Ω	5 *j*306Ω	5 *j*307Ω	0 *j*323Ω
RL Matching For 160 Meter Resonance	120 *j*0Ω	80 *j*20Ω	80 *j*20Ω	78 *j*20Ω	75 *j*0Ω

Table 3 – Feed point Resistance Change with added ground radials. Readings taken in January with wet ground.

After completing the ground radial test we then performed some fine tuning and tweaking of the inductor/resistor values to bring the feed point resistance into our design range. Table 4 shows the final results along with the required individual inductance and resistance used as well as the total inductance and resistance of the network.

Vert	1.800	1.830	1.860	1.890	*j*0 Bandwidth	Ind	Res	Total Ind & Res
1	74 *j*13Ω	75 *j*0Ω	75 *j*0Ω	76 *j*16Ω	1.815 - 1.862	28 uH	56Ω	28.4 uH 56.5Ω
2	75 *j*10Ω	75 *j*0Ω	76 *j*0 Ω	77 *j*19Ω	1.815 - 1.860	27.5 uH	55Ω	28.6 uH 54Ω
3	76 *j*15Ω	76 *j*0Ω	76 *j*0Ω	76 *j*9Ω	1.817 - 1.868	28 uH	54Ω	28.6 uH 54.5Ω
4	76 *j*15Ω	75 *j*0Ω	75 *j*0Ω	76 *j*15Ω	1.820 - 1.874	28 uH	53Ω	28.3 uH 54Ω
5	76 *j*17Ω	75 *j*0Ω	75 *j*0Ω	76 *j*12Ω	1.824 - 1.878	27.5 uH	53Ω	28.0 uH 54Ω
6	74 *j*11Ω	74 *j*0Ω	75 *j*0Ω	76 *j*20Ω	1.814 - 1.863	28 uH	55Ω	28.5 uH 56Ω
7	75 *j*15Ω	74 *j*0Ω	75 *j*0Ω	75 *j*17Ω	1.818 - 1.868	28 uH	53Ω	28.5 uH 54Ω
8	73 *j*16Ω	73 *j*0Ω	74 *j*0Ω	74 *j*16Ω	1.815 - 1.862	27.2 uH	56Ω	27.7 uH 56.5Ω

Table 4: 160 Meter Results After Tuning

2.6 Feedlines & Phasing Lines

We are using 75Ω coaxial feed line in this array. Joel chose to acquire "flooded" cable so it could be buried without the worry of moisture influx and deterioration. DX Engineering sells good quality RG-75 flooded coax along with very good F-connectors that work great in low band receiving applications. We recommend you bury the feed lines, however if you choose not to, we recommend you use the flooded cable anyway just in case a wild animal wants to chomp on the coax. They most definitely will not enjoy the taste of the flooding compound and will look for another treat!

In order to accurately prepare our phasing lines we decided to measure the velocity factor of our RG-75 cable. Our test setup included an MFJ-259 Antenna Analyzer utilized as our signal generator and a dual trace oscilloscope to measure the signal time delay in a length of cable. We concluded the velocity factor of the cable to be about 80%. From this, we determined our 55° phasing lines should be 66 ft in length. Two of these were prepared per the design.

We then prepared nine RG-75 coaxial lines of equal length (one each to feed each of the 8 verticals and one spare), sufficient to run from the center point to each vertical element with about 5% extra to have some spare.

2.7 Switching Unit

The switching unit schematic is shown in ref. 6 on page 7-34. This reference suggests there are circuit boards available from DX Engineering, however they tell me that is not the case and in error, as the boards were never available. Rather than go through the time and expense of designing and manufacturing a board, we chose to assemble a switching unit using point to point wiring. Figure 22 & 23 shows of the W5ZN unit:

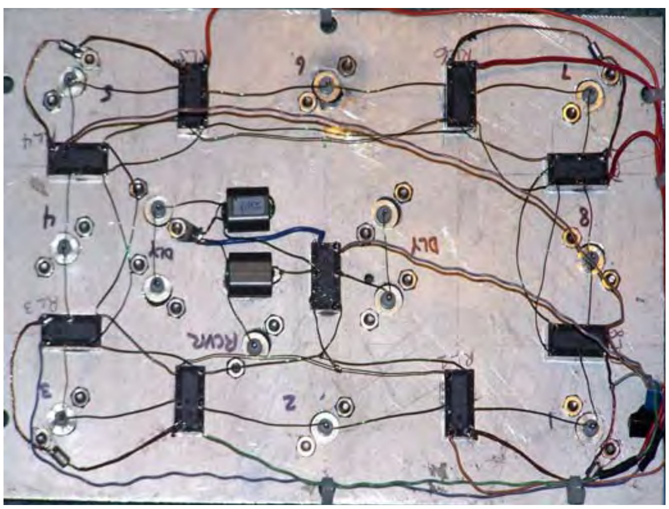


Figure 22: Component Side of Switching Unit

Figure 23: Connector Side of Switching Unit

The components for the switching unit aren't critical. Some chassis mount F connectors and simple (but good) enclosed 12Vdc relays will work just fine, and as noted earlier we used some small gauge enameled wire to connect everything. Don't use wire that is too small which can become brittle and break, but don't use some so large that it is rigid and does not provide some flexibility. If you use point to point wiring just remember the small pins on the relays are strong, but they won't stand up to a lot of stress. Even though is it not what was used, we recommend the use of small gauge stranded wire.

The relay unit was laid out on a piece of paper then a sheet of aluminum was used to mount the relays on and holes were drilled to mount the connectors. Epoxy glue was used to mount the relays upside down on the aluminum sheet and some small, flexible enameled wire was used to connect everything.

After you have the switching unit assembled you can perform some simple tests to ensure everything is working fine. First, make sure all of the relays are working individually and then as a group in the proper sequence by using a simple continuity test with an ohm meter. Now you can inject a signal into the unit using an antenna analyzer or other weak signal source to verify all of the other components are working. Figure 24 shows Joel's test setup while Figures 25, 26 and 27 show some of the results.

Figure 24: Switching Unit Test Setup consisting of just the MFJ-259 and dual trace oscilloscope (The other equipment is not used for this test)

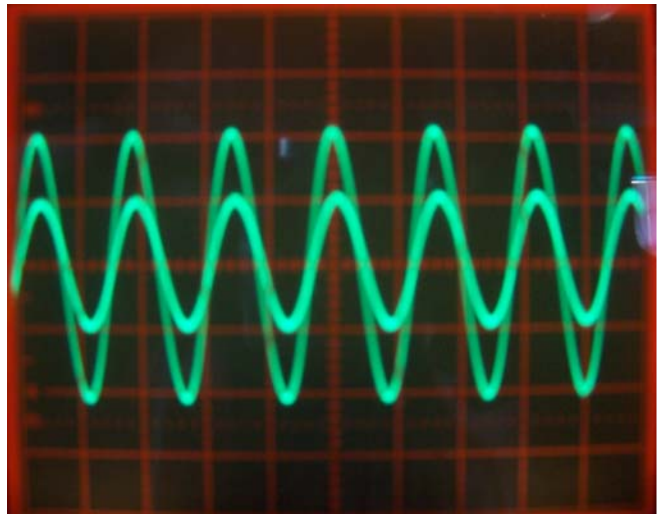


Figure 25: 1.83 MHz Signal through the 4:1 UNUN showing a 2:1 voltage ratio (4:1 Impedance Ratio)

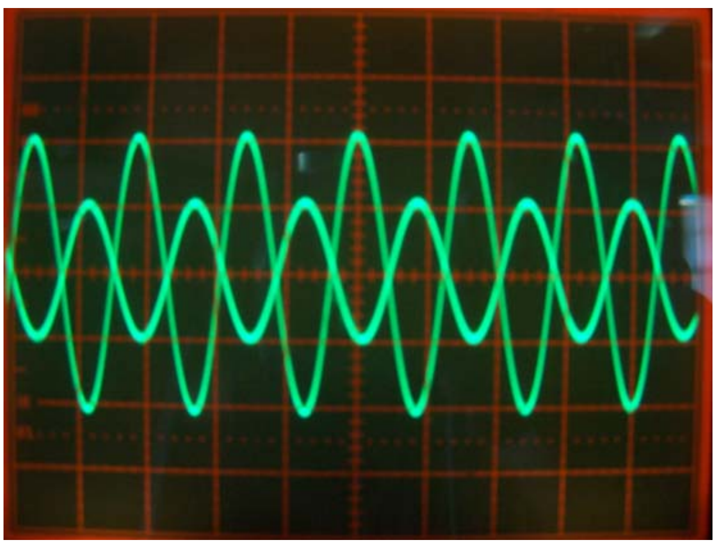


Figure 26: 1.83 MHz signal through the 4:1 UNUN and 1:1 Inverter (180°)

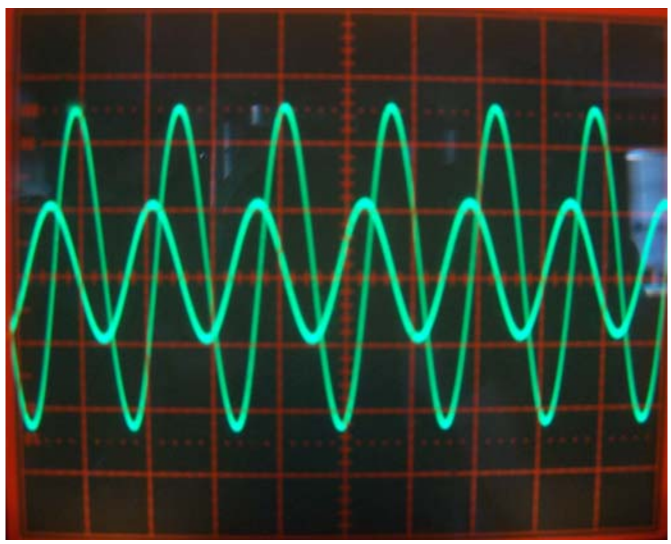


Figure 27: 1.83 MHz signal through 4:1 UNUN, 1:1 Inverter and Phase Lines

The switching unit is really simple and straightforward, however there are a couple of points that need to be highlighted. First, make sure you note the wiring sequence "swap" when you go from relay 4 to relay 5. Again, this is a simple process just make sure you are aware of it and wire it correctly, otherwise the unit will not switch the elements properly.

The second point is the 1:1 Inverter and the 4:1 UNUN. These are very simple to construct and are explained in detail in ref. 6. Binocular cores seem particularly useful for low band receive antenna applications. The Fair-Rite 2873000202 core that W8JI has popularized is easy to locate and purchase, easy to wind and works great. We used small gauge enameled wire, however this is not necessary and any small gauge wire will work as long as it is insulated. The 1:1 Inverter is described on page 7-17 of ref. 6. Just twist two wires together, make three passes through the core, and connect it as shown. You are in business!

The 4:1 UNUN is equally straightforward, however please pay attention. This is an UNUN, not a BALUN. The UNUN is constructed by just wrapping a core with four primary turns and 2 secondary turns. You can checked it on an oscilloscope and it will show a perfect 2:1 voltage ratio (the equivalent of a 4:1 impedance ratio) UNUN. The switching unit photo in Figure 22 actually shows the core with a BALUN winding as Joel wound the first one without thinking and just wrapped a few turns with a ‘center tap”. This photo was taken before the error during construction was discovered. It has since been replaced with the UNUN as described. You can see the center tapped point from the back of the core connected to the relay. So, even though the sketch in the switch drawing suggests this is a center tapped wound transformer, just remember you need an UNUN, not a BALUN. To mount the cores to the aluminum sheet a small rubber grommet is glued to the sheet and then glued the core to the rubber grommet.

Once the switching unit was installed, a ground rod is installed and connected to the aluminum sheet. Figure 28 shows the finished installation and Figure 29 shows the rubber trash can be used for weather proofing to protect the switching unit from the elements.

Figure 28 Installed Switching Unit at the Center of the Array

Figure 29: Completed Installation with Weather-proof cover

3.0 Evaluation of the 8 Circle Vertical Array

Evaluation of any antenna system requires that you have a realistic understanding of what to expect! In the case of low band receiving antennas, some radio amateurs have erroneously assumed that after installing a beverage or similar receiving antenna you will automatically begin to miraculously hear stations that never existed at your location before. The most important factor in being able to hear stations on the low bands is propagation characteristics. Joel listened for two 160 meter seasons as east coast stations boasted about how strong VQ9LA was without a peep of a signal into Arkansas. No receive antenna would have changed this. Finally one night the propagation came to W5 land and thanks to low noise receiving antennas VQ9LA is in the log at W5ZN. So don't expect to begin to magically hear stations that just never existed before. What should immediately become apparent is that your noise floor will decrease. Since DX signals on the low bands are weak signals, this component alone should allow you to hear stations that previously were buried in the noise.

Remember, your goal is to improve your DMF or RDF (refer to Section 1.1) which will in turn reduce the amount of noise (both man-made and natural) and QRM collected by the receive antenna system in a particular direction and allow you to hear weak stations when propagation permits.

3.1 Noise Evaluation

Joel's first step in the evaluation was to record noise floor levels on the various 160 meter antennas installed at W5ZN. He has some significant noise sources in two directions so a combination of low noise receiving antennas benefits him greatly. Table 5 shows a comparison of the noise floor for the W5ZN 160 meter antennas.

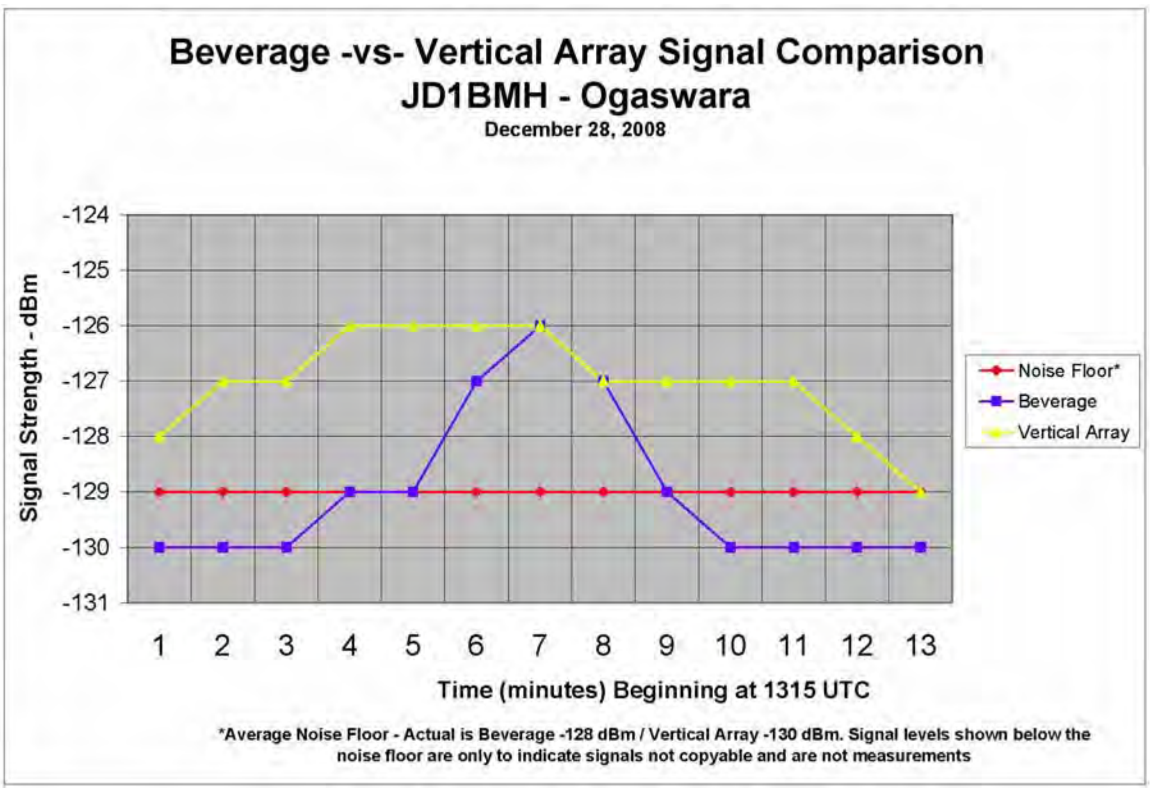
Direction	**8 Circle Vertical Array Noise Floor**	**Beverage Noise Floor**	**W5UC Modified K9AY Loop**	**Shunt Fed 135' HF Tower 160 Meter Xmit**	**½ λ Inverted Vee**
N	-129 dBm	-125 dBm	N/A	-100 dBm[2]	-105 dBm[2]
NE	-125 dBm	-120 dBm	-132 dBm[1]	-100 dBm[2]	-105 dBm[2]
E	-125 dBm	-124 dBm	N/A	-100 dBm[2]	-105 dBm[2]
SE	-126 dBm	-123 dBm	-130 dBm[1]	-100 dBm[2]	-105 dBm[2]
S	-126 dBm	-120 dBm	N/A	-100 dBm[2]	-105 dBm[2]
SW	-125 dBm	-120 dBm	-132 dBm[1]	-100 dBm[2]	-105 dBm[2]
W	-126 dBm	-125 dBm	N/A	-100 dBm[2]	-105 dBm[2]
NW	-130 dBm	-128 dBm	-132 dBm[1]	-100 dBm[2]	-105 dBm[2]

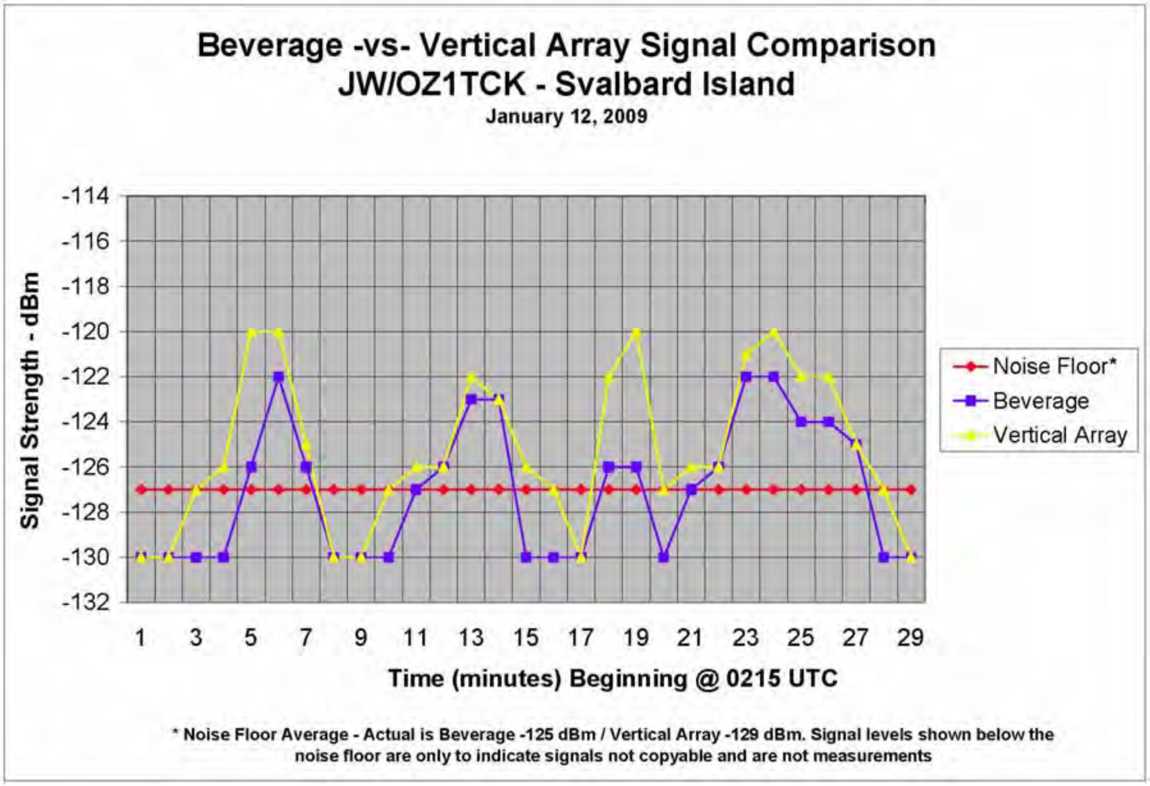
Table 5 – Noise floor measurements comparing the 8 Circle Vertical Array, Beverages, Loop, Shunt-fed Tower and Inverted Vee at W5ZN. Measurements were taken with a 250 Hz bandwidth at a Sampling Rate of 48 KHz. [1] Loop has considerably less gain than the Beverage or Vertical Array which equates to not only a lower noise floor but much lower signal levels as well and traditionally requires a preamp [2] and is omni directional.

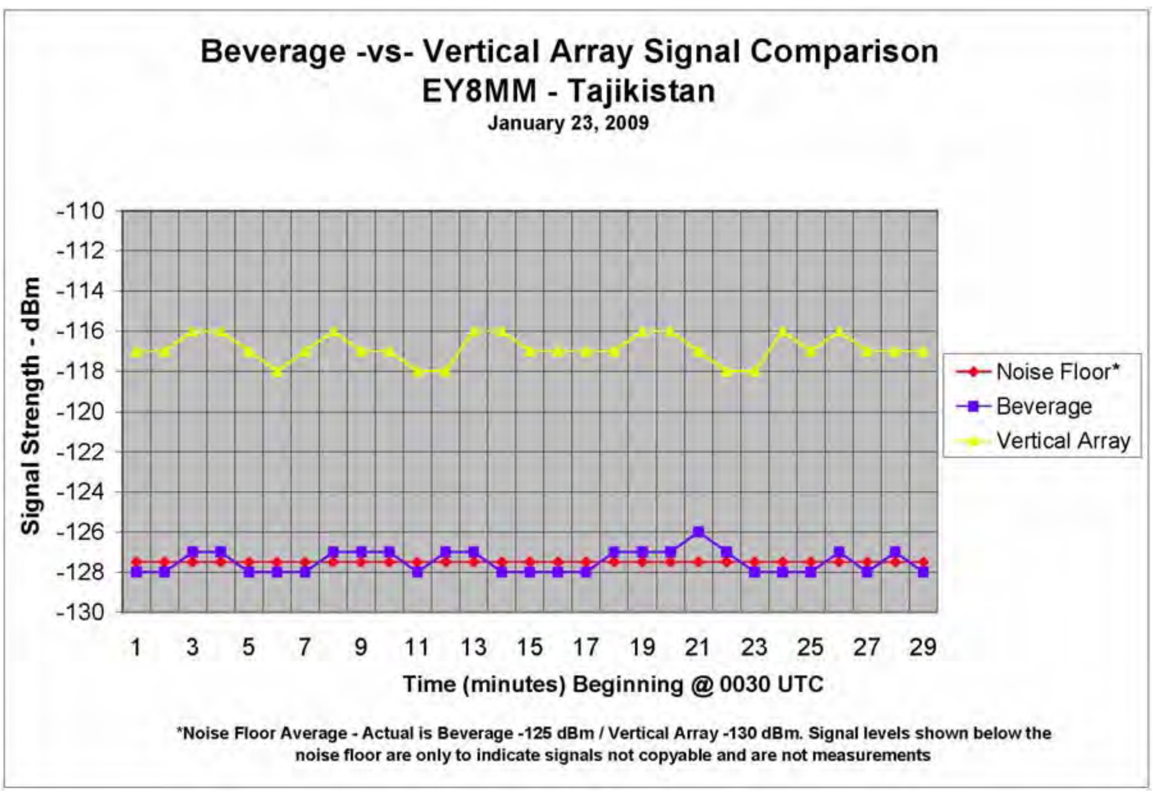
3.2 Signal Comparison, F/B Ratios, F/S Ratios

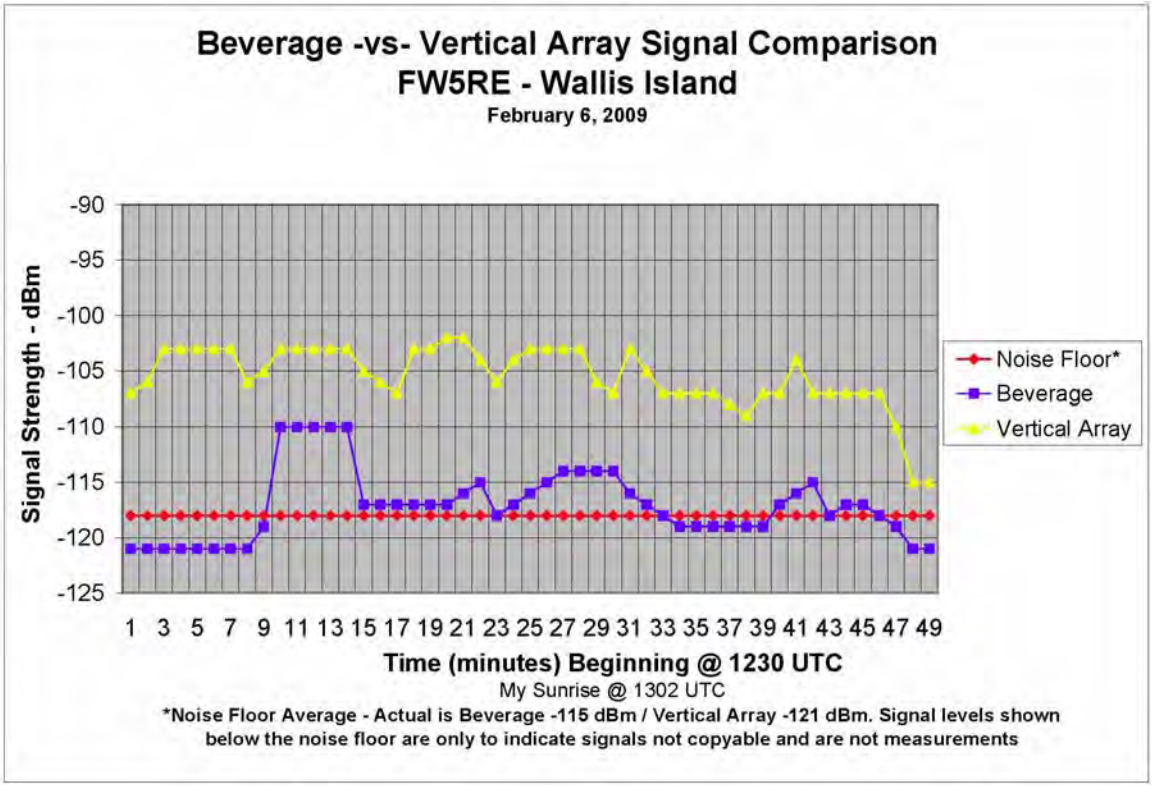
A table of on-the-air F/B and F/S measurements from various stations is contained in Appendix A.

The following charts depict signal comparisons between the 8 Circle Vertical Array and Joel's Beverage antennas taken at different times of the day to different parts of the world. Obviously, the signal arrival angle will play an important part in signal strength and readability, however the charts below are typical for each DX station and represent the ability to hear a station earlier than with the Beverages and to also hear the station for a period of time after they can no longer be copied on the Beverages. At the peak propagation period, however, there is no noticeable or recordable differences between the two receive antenna systems.




Beverage -vs- Vertical Array Signal Comparison
JW/OZ1TCK - Svalbard Island
January 12, 2009
Signal Strength - dBm
-114
-116
-118
-120
-122
-124
-126
-128
-130
-132
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Time (minutes) Beginning @ 0215 UTC
Noise Floor*
Beverage
Vertical Array
* Noise Floor Average - Actual is Beverage -125 dBm / Vertical Array -129 dBm. Signal levels shown below the noise floor are only to indicate signals not copyable and are not measurements


Beverage -vs- Vertical Array Signal Comparison
EY8MM - Tajikistan
January 23, 2009
Signal Strength - dBm
-110
-112
-114
-116
-118
-120
-122
-124
-126
-128
-130
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Time (minutes) Beginning @ 0030 UTC
Noise Floor*
Beverage
Vertical Array
*Noise Floor Average - Actual is Beverage -125 dBm / Vertical Array -130 dBm. Signal levels shown below the noise floor are only to indicate signals not copyable and are not measurements



4.0 Summary

The 8 Circle Vertical Array is a significant addition to the low band receive antennas at W5ZN. It is now the primary system used for receiving on 160 meters. It will not replace the other receive antennas because as unpredictable as 160 meters is, you never know when a propagation anomaly may occur that may present itself better to one of the other antennas, however that situation has not yet been seen.

The 80 meter version is now in construction at W5ZN as of the writing of this paper and will be evaluated during the Winter 2009/2010 low band season and the results published as well.

The amount of time and effort invested in this project was considerable. That was due to the fact that only a very small amount of general information was available on this antenna array. Our hope is this paper will provide encouragement for others to try this array and the amount of time required will be reduced significantly. For 160 meters, this array takes up a circle diameter of less than 350 ft with an additional 65 feet for radials. That is less than a 1 wavelength beverage on 160 meters and 8 directions can be obtained. So, if you're space limited for a Beverage array but can afford the real estate for an 8 Circle Vertical Array, give it a try. You will NOT be disappointed!

References:

1. ARRL DX Challenge Award http://www.arrl.org/news/stories/2001/05/08/3/
2. J. Harrison, W5ZN, "Horns for the Holidays", *Proceedings of Microwave Update '97,* ARRL, 1997, pp.147-149.
3. J. Harrison, W5ZN, "W5ZN Dual Band 10 GHz / 24 GHz Feedhorn", *Proceedings of Microwave Update '98,* ARRL, 1998, pp. 189-190.
4. J. Harrison, W5ZN, "Further Evaluation of the W5LUA & W5ZN Dual Band Feeds", *Proceedings of Microwave Update '99*, ARRL, 1999, pp. 66-84.
5. P. Wade, W1GHZ & J. Harrison, W5ZN, "Multi-band Feeds for Parabolic Dish Antennas", *W1GHZ Microwave Antenna Book*, Chapter 6, W1GHZ, 2000, http://www.w1ghz.org/antbook/chap6_9p1.pdf
6. J. Devoldere, ON4UN, "Low Band DX'ing", Fourth Edition, ARRL 2005, ARRL – *The National Association for Amateur Radio* http://www.arrl.org
7. T. Rauch, W8JI, http://www.w8ji.com, W8JI, 2008, http://w8ji.com/small_vertical_arrays.htm
8. J. Devoldere, ON4UN, "Low Band DX'ing", Third Edition, ARRL 1999, pp. 11-68 to 11-71 ARRL – *The National Association for Amateur Radio* http://www.arrl.org

Biography's:

Joel Harrison, W5ZN

First licensed as WN5IGF in 1972, Harrison went on to acquire his General, Advanced and Amateur Extra licenses as WB5IGF. He's had his current call sign since 1996.

He has many interests in Amateur Radio including VHF/UHF/Microwave weak signal communication, EME, low band DXing & contesting. His Amateur Radio operating awards include DXCC Honor Roll, DXCC Challenge, 9 Band DXCC, 11 Band VUCC (50 MHz through 24 GHz), 6 Meter WAS & WAC, 2 Meter WAS & WAC and Satellite WAS and WAC. He held the ARRL June VHF Contest Single Operator World Record from 1996 to 2006 and held the 80 meter record for the W5 call area in the ARRL International DX Contest, CW, from 2006-2009. In 2001, the Central States VHF Society awarded him the Mel S. Wilson Award for continuous service and dedication toward promoting VHF & UHF activity, and in 2008 La Federacion Mexicana de Radioexperimenatdores awarded him the prestigious Azteca Diploma for 25 years of service to Amateur Radio. He is member of the Collierville Millimeter Wave Society, a life member of the Central States VHF Society and ARRL and currently serves as President of ARRL, The National Association for Amateur Radio.

Joel began his formal education studying Industrial Electronics at Arkansas State University and then traveled overseas to further his education in Germany, Norway and Denmark, completing his curriculum at the Electric Power Research Institute. In 1983 he became the first person in the world to qualify an automated ultrasound imaging system for use in the nuclear power industry, and in 1995 received Special Recognition for Contributions from the American Society for Nondestructive Testing.

In 2008 he was appointed by Arkansas Governor Mike Beebe to serve on the Board of Directors of the Arkansas Science & Technology Authority. Joel is Manager, NDE Technology for the Washington Division of URS (United Research Services) in Princeton, NJ, which serves the nuclear power, government, space and infrastructure markets.

More information about Joel can be found at www.w5zn.org.

Dr. Robert McGwier, N4HY

Bob has been licensed since the early 1960's when he was WN4HJN. He received N4HY in 1976 when he decided he did not want to be N4BM (with apologies to the current owner of that call).

Bob holds a BSEE and BS in Mathematics from Auburn and Ph.D. in Applied Mathematics from Brown University. He serves as Chairman of the ARRL Software Defined Radio Working Group. Bob is the immediate past Vice President of Engineering for AMSAT. Bob's early work included writing the Quiktrak satellite tracking software package for the Commodore, Radio Shack, and then PC computers. He has worked on several satellite projects and was a co-designer of the Microsat satellites and on the early design teams for AO-40. With Tom Clark, K3IO, he started the AMSAT/TAPR digital signal processing project. Bob received the 1990 Dayton Hamvention® Award for Technical Achievement for his work with AMSAT, TAPR, and the ARRL. Recent DSP and software-defined radio activities include authoring the DSP software (DttSP: in PowerSDR) along with Frank Bickle, AB2KT.

Bob is employed with the Center for Communications Research in Princeton, N.J.

<u>**Joel's Acknowledgements**</u>:

Al Ward, W5LUA has been a close personal friend, mentor and advisor on many amateur radio and life applications for several years. I greatly appreciate his openness in allowing me to bounce ideas off of him and to ask questions that had obvious answer that I only came to realize after they were asked and he explained them in a practical manner I could understand. His persistence in challenging me to pursue the facts in practical and theoretical matters and his time in traveling to Arkansas on many occasions to assist with this and many other pojectts at W5ZN is greatly appreciated. Thanks Al!

Bob McGwier, N4HY, the co-author of this paper. Aside from Al Ward, no one has instilled in me a burning desire to study and acquire advanced personal knowledge about math, physics and electronics as Bob. His knowledge and experience far exceed what I possess, however his practical approach to teaching has driven me to learn more about HF antenna systems than I ever thought I would comprehend and as a result an outstanding 160 meter receive system now exists at W5ZN. Thanks Bob!

And to my wife Kim, KB5YIQ, who tolerates all of this nonsense, allows me to do all these things and have fun!

Bob's Acknowledgements:

It was so great to have Joel get this antenna in his head and to see its possibilities. I have wanted to build this for years but living on a ½ lot in East Windsor, NJ is not conducive to this. I have a forest over wet lands behind my house which is great for nearly hidden wires but not ground mounted antennas.

She who must be obeyed is N2HPE, my partner and friend since 1970. No man alive has a more understanding spouse.

Joel Harrison, W5ZN

Bob McGwier, N4HY

Appendix A

Date	Call	Noise Floor dBm	Front dBm	Back dBm	F/B Ratio dBm	Side dBm	F/S Ratio dBm
19-Nov-08	NS8S	-112.7	-78.5	-92.8	-14.3	-98.1	-19.6
Poor Condx	K9MMS	-112.7	-79.0	-93.9	-14.9	-94.9	-15.9
Band noisey	W4ZV	-112.7	-75.7	-91.2	-15.5	-98.7	-23.0
	W5UN	-112.7	-60.8	-68.5	-7.7	-73.5	-12.7
	W1AW	-112.7	-79.0	-93.9	-14.9	-100.0	-21.0
	KA9S	-112.7	-90.6	NIL	N/A	NIL	N/A
	ER4ER	-112.7	@ Noise	NIL	N/A	NIL	N/A
	UX1UA	-16.0	@ Noise	NIL	N/A	NIL	N/A
20-Nov-08	VE3CUI	-114.4	-80.7	-101.1	-20.4	-104.1	-23.4
Moderate Condx	PJ2/K8ND	-117.7	-91.2	-107.2	-16.0	NIL	N/A
Band quite	K4PI	-112.7	-62.4	-79.0	-16.6	-84.5	-22.1
	AA1K	-112.7	-85.1	-100.0	-14.9	-103.0	-17.9
	K1GUN	-112.7	-86.2	-98.3	-12.1	-106.1	-19.9
	N4IS	-118.2	-72.9	-93.4	-20.5	-96.2	-23.3
	RZ0AF	-117.7	@ Noise Q5	NIL	N/A	NIL	N/A
	K6ND	-117.1	-92.3	-103.9	-11.6		0.0
	RZ0AF	-118.2	-113.4	NIL	N/A	NIL	N/A
	W8JI	-117.7	-61.3	-79.0	-17.7		61.3
	JA8BNP	-118.8	-106.1	NIL	N/A	NIL	N/A
	JA4DHN	-118.8	-106.1	NIL	N/A	NIL	N/A
	JA Pileup	-118.8	-107.0	NIL	N/A	NIL	N/A
SR 1245z	HL3IUA	-121.1	101.7	NIL	N/A	NIL	N/A
	W0FLS	120.4	-79.6	-97.2	-17.6		0.0
	W8TE	-123.2	-90.6	-105.5	-14.9	-109.4	-18.8
1302Z	JA9LJS	-124.9	-108.8	NIL	N/A	NIL	N/A
	JA5BIN	-124.9	-108.8	NIL	N/A	NIL	N/A
	K5NZ	-124.9	-69.1	-85.6	-16.5	-93.9	-24.8
1310Z	JA2BDR	-124.9	-112.2	NIL	N/A	NIL	N/A
	UA0LCZ	-124.9	-112.2	NIL	N/A	NIL	N/A
	JA1BLY	-126.0	-117.1	NIL	N/A	NIL	N/A
	JA1SYY	-126.0	-117.1	NIL	N/A	NIL	N/A
1318Z	JA3SDJ	-126.0	-117.1	NIL	N/A	NIL	N/A

Date	Call	Noise Floor dBM	Front dBm	Back dBm	F/B Ratio dBm	Side dBm	F/S Ratio dBm
20-Nov-08	K8FC	-126.0	-90.6	-108.6	-18.0	-110.2	-19.6
2300z	K1LZ	-124.3	-83.4	-95.6	-12.2	-99.4	-16.0
	KA1J	-124.3	-80.7	-91.2	-10.5	-97.8	-17.1
	W9DX	-118.2	-74.6	-89.2	-14.6	-91.2	-16.6
	N9NJ	-118.2	-77.5	-89.5	-12.0	-92.8	-15.3
	FM5BH	-118.2	-92.8	-107.7	-14.9	NIL	N/A
	E77DX	-114.6	-99.7	NIL	N/A	NIL	N/A
21-Nov-08	UA6LV	-115.7	@ Noise Q5	NIL	N/A	NIL	N/A
Good Condx	PJ2/K8ND	-118.0	-88.7	-101.1	-12.4	NIL	N/A
	W1AW	-118.0	-84	-97.8	-13.8	-100.8	-16.8
	N1LN	-117.1	-82.3	-93.9	-11.6	-97.5	-15.2
	F6ELN	-119.0	-114.0	NIL	N/A	NIL	N/A
	K1LZ	-119.0	-81.5	-96.1	-14.6	-100.8	-19.3
	W3GH	-119.0	-66.5	-82.3	-15.8	-90.1	-23.6
0130Z	ER4ER	-116.3	@ Noise Q5	NIL	N/A	NIL	N/A
	IV3RPK	-118.0	@ Noise Q5	NIL	N/A	NIL	N/A
	VP5/W7VV	-118.0	-96.7	-110.0	-13.3	NIL	N/A
	EL2DX	-118.0	-108.3	NIL	N/A	NIL	N/A
	ZP6CW	-126.2	-107.2	NIL	N/A	NIL	N/A
	CX3CE	-126.0	-103.5	NIL	N/A	NIL	N/A
	OZ8ABE	-118.2	-100.3	NIL	N/A	NIL	N/A
0345Z	SV3RF	-117.4	-91.2	-115.7	-24.5	NIL	N/A
	G3PQA	-117.7	-93.9	-109.1	-15.2	NIL	N/A
	W1AW	-115.1	-71.8	-89.0	-17.2	-91.2	-19.4
	W8FJ	-115.1	-72.5	-90.8	-18.3	-98.0	-25.5
	S59A	-117.0	-95.0	NIL	N/A	NIL	N/A
0430z	CT1JLZ	-117.4	-85.5	-101.8	-16.3	NIL	N/A
	ES5QX	-118.0	-106.9	NIL	N/A	NIL	N/A
	G3SED	-116.5	-88.5	-98.6	-10.1	-112.4	-23.9
	SM6CLU	-121.6	-105.5	NIL	N/A	NIL	N/A
1100z	HK1X	-121.6	-117	NIL	N/A	NIL	N/A
	HC5WW	-121.6	-114.7	NIL	N/A	NIL	N/A
	JA8ISU	-126.1	-100.2	-111.6	-11.4	NIL	N/A
1240z	UA0ZL	126.6	-112.4	NIL	N/A	NIL	N/A