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A 5 Element Switchable Vertical Parasitic Array for 160 Meters

I have previously written regarding my passion to perfect the 160-meter receive antenna system at W5ZN. While I'm still pursuing even the most minute increase in receive antenna performance, it became obvious that my transmit system required improvement. For the past 15 years, my transmit antenna has been a 135-foot tower with 64 radials tuned with a shunt feed system. Lately, I have struggled to break a pileup or work a station when conditions were good. This should not happen.

In the summer of 2017, I began researching a 5 element parasitic switchable vertical array for 160 meters. This paper outlines my basis for choosing this system over other gain transmitting arrays and details my construction effort.

Why a Parasitic Vertical Array?

I am fortunate to have plenty of room for antennas. I live on a 35-acre plot that is part of an original family farm. I have a full-size 80-meter 4 square and have considered constructing a 160 meter 4-square array. Given the complexity of installing such a system, however I realized that I did not want to replicate my 4 square efforts on 160 meters. One evening, while reviewing *ON4UN's Low-Band DXing*, I reread Chapter 13, section 3.9, on vertical arrays with parasitic elements, where the pioneering work of Bill Hohnstein, KØHA, is discussed. A parasitic vertical Yagi is an antenna with three or more vertical elements — one an active driven element and the rest parasitic.

I concluded:

- ♦ The array can be built around an existing single transmitting vertical.
- ♦ It does not require full-size elements.
- ♦ It can use existing land area around the single transmitting vertical.
- ♦ It offers the same basic gain and front-to-back (F/B) ratio as a 4 square in four switchable directions.
- ♦ It utilizes a simple feed system that does not require phasing. The existing matching network on my single vertical was all I needed.
- ♦ It has a slightly smaller footprint than a 160-meter 4 square array.

I sketched the layout on paper, evaluated the area surrounding the shunt-fed tower, and concluded I had adequate space for all of the components. Before making a final decision, though, I looked at a similar antenna system in use at the station of Tim Duffy, K3LR. Tim graciously showed me the layout of his system and answered all of my questions. At this point, I became obsessed with this project and over the next 2 weeks couldn't think of anything else. Later, I learned that other contesters, including AA1K, VE3EJ, NR5M, and K9CT, are using similar arrays.

The Top-Loaded Vertical Element

My design centered on using top-loaded vertical parasitic elements. It is well known that these are extremely effective — unless placed too close to horizontal, higher-frequency antennas that may impact the radiation pattern. The elements can be easily suspended with catenary lines from the existing vertical tower. The required resonant vertical height can be shorter than 0.25 λ since the T top loading adds overall length. Additionally, no far field horizontal component is present, as the top-load wire is symmetrical to vertical wire. For 160 meters, I utilized a sloping top-loading wire of approximately 65 feet, and a vertical wire length of approximately 75 feet.

Construction Plan

I developed a plan to prioritize the construction subsets of the array:

- ♦ Lay out the components of the system and install base supports for parasitic elements.
- ♦ Install the radial field for all elements.
- ♦ Construct and install parasitic elements.
- ♦ Tune the parasitic elements.
- ♦ Measure forward gain and F/B ratio.
- ♦ Get some on-the-air experience.

Physical Layout

The physical layout is very simple. Elements are spaced 66 feet from the driven element with four parasitic elements spaced 90° around a driven element (see Figure 1).

The decision to begin construction with the radial field as priority number one was driven by the fact this would be the most labor-intensive part of construction and the most important. If I failed to complete the radial field, there would be no need to waste time with the rest of the project, as an effective radial field remains essential for the array's performance with its modeled gain and F/B parameters. It should be noted that parasitic arrays are more greatly affected by a poor ground system; the gain of the array will diminish significantly. It is also important to note that a parasitic array is electrically different than a phased array,

Figure 1 — The 160-meter driven element surrounded by the four parasitic elements.

such as a 4 square, and relies more substantially on a consistent ground resistance evenly distributing current.

Computer modeling by ON4UN indicates that elevated radials will not work with parasitic elements. John modeled different numbers of elevated radials, varied lengths and different orientations, and they all produced a badly distorted pattern.

I installed 120 radials beneath each parasitic element and beneath the driven element, carrying this out utilizing a radial field pattern in a four-step procedure.

- Install 120 radials from the driven element to a 48-foot perimeter wire around the driven element.
- Install radials from each element that intersect the 48-foot diameter perimeter wire
- Install all radials from each element that intersect a cross buss wire between the elements.
- Install all remaining 0.25 λ radials to complete a total of 120 at each element.

All connections were soldered and then coated with liquid tape. I chose not to bury radials and secured them on the ground with radial staples. New grass growth in the spring will cover the wires, and they'll disappear. I used DX Engineering radial plates (see Figure 2). I crimped and soldered the radials to ring terminal lugs and used Penetrox to maintain a good connection over time and prevent galvanic corrosion. The total radial system area covers just under 2 acres, and my construction time, working alone, was 4 weeks.

The Parasitic Element

Each parasitic element must function either as a director or a reflector to provide two-direction coverage. To accomplish this, the element is routed directly to the radial system to function as a director or through a 4 µH inductor to increase its resonant frequency to function as a reflector (see Figure 3).

The parasitic elements were constructed from #12 stranded copper wire. The exact lengths of the vertical and top-load components were achieved through trial and error (see Table 1). From Table 1, start with the lengths noted in the ON4UN Model column. Next, build one element, install it, and tune it to the target frequency of 1904 kHz for a director and 1800 kHz for a director. Experience has proven these two frequencies provide the best forward gain and F/B as starting points. The remaining elements should be constructed identically. I recommend using a rope and pulley to attach the first element to the tower prior to tuning, unless you enjoy climbing 135 feet multiple times to raise and lower the element to adjust its length. The distance from the driven element to first insulator on the

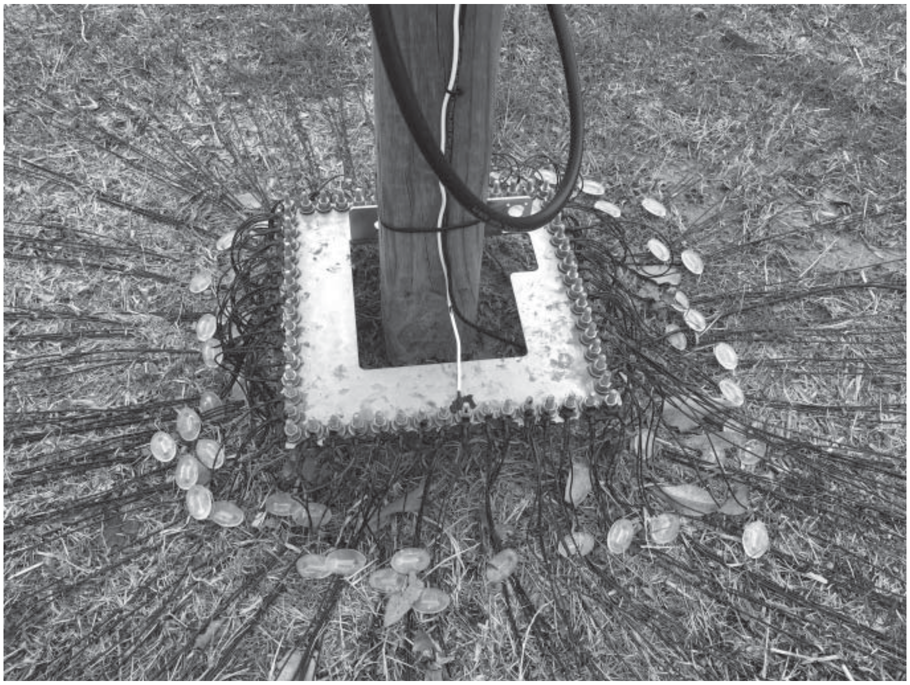

Figure 2 — The DX Engineering radial plate with radials attached.

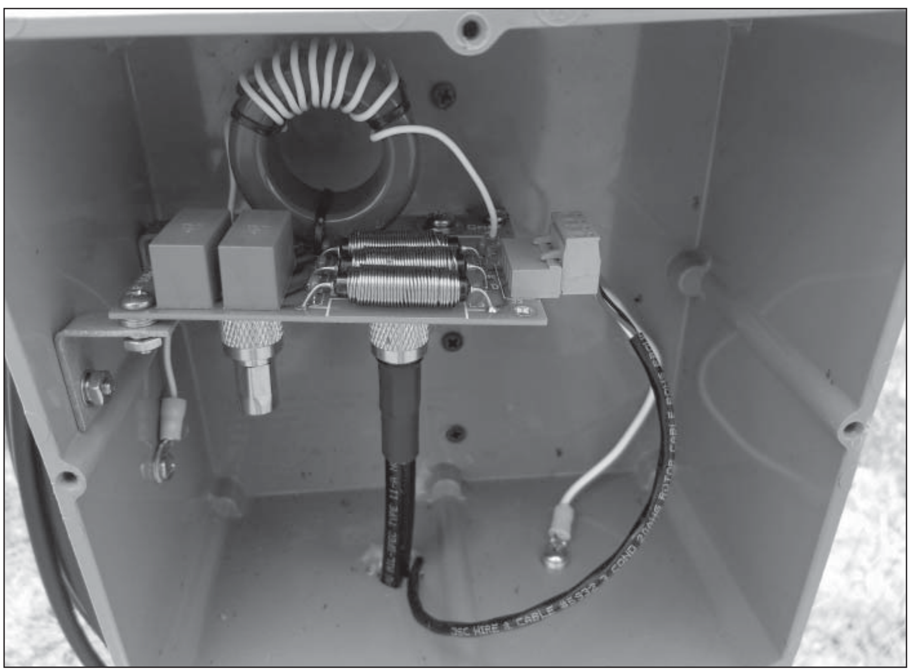

Figure 3 — The switching network allows each parasitic element to switch between functioning as a director or as a reflector.

Table 1

Parasitic element length

	ON4UN Model	K3LR System	W5ZN Initial	W5ZN Final
Top Load	64.7’	58.3’	58.3’	65’
Vertical	75.5’	64.2’	64.2’	75’
Director	1935 kHz	1904 kHz	2070 kHz	1904 kHz
Reflector	1778 kHz	1800 kHz	1950 kHz	1800 kHz

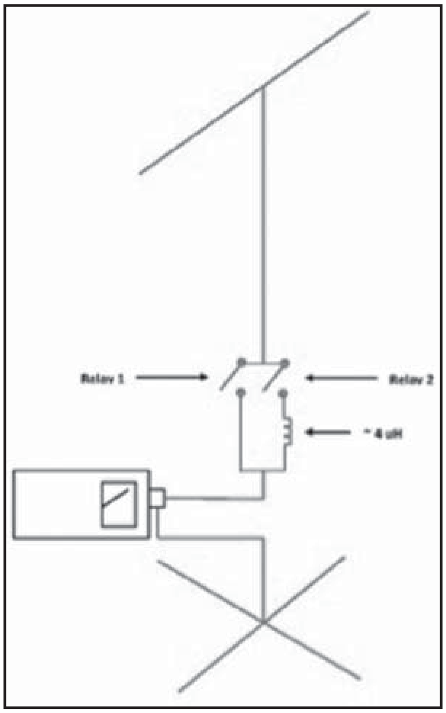

Figure 4 — A schematic depicting the use of a portable antenna analyzer for tuning individual parasitic elements.

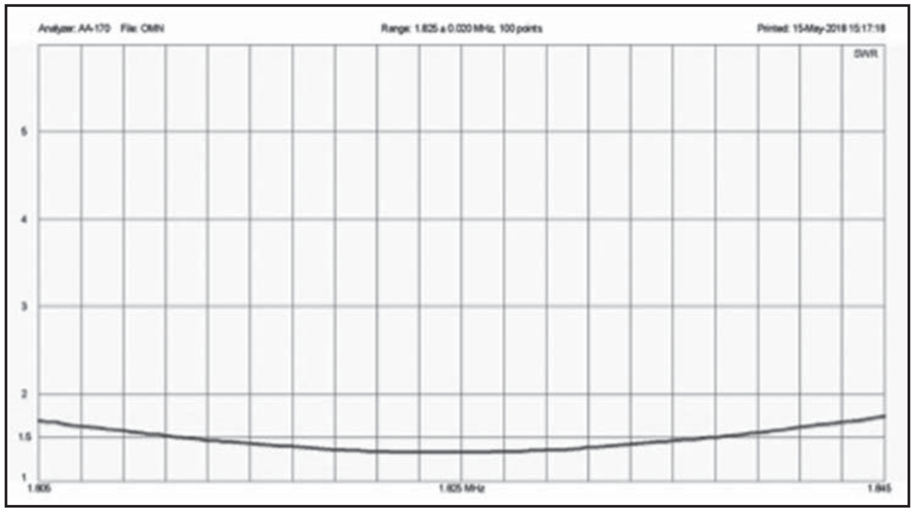

Figure 5 — SWR curve of the array.

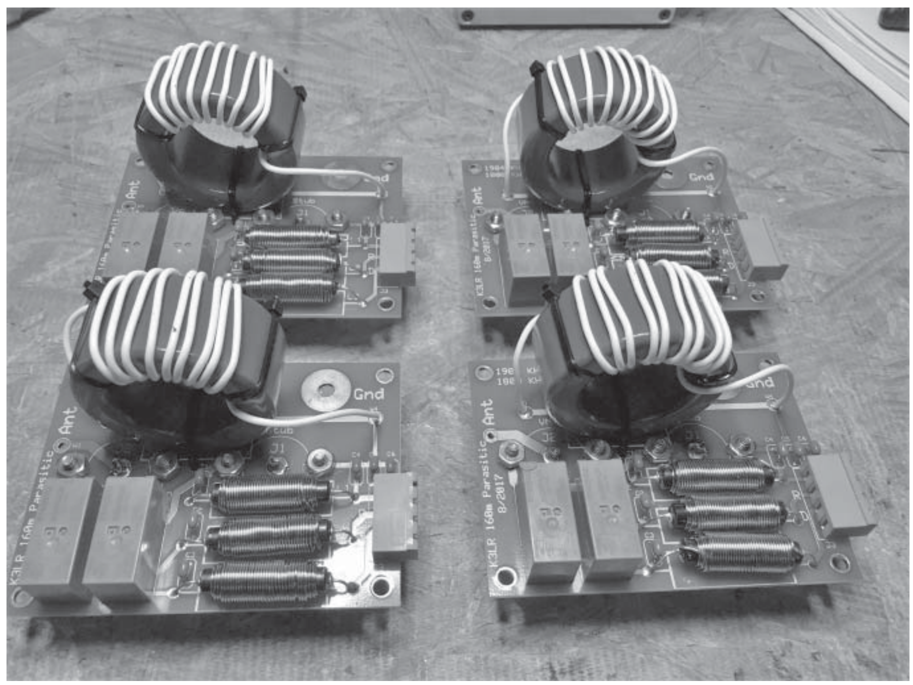

Figure 6 — W8WWV-designed board with relays and the inductor for element switching.

top-loading segment will be approximately 45 feet. The total distance from the driven element to the end tie point for the catenary line will be approximately 265 feet.

Element Tuning

Tuning each element is easier than you'd imagine. Simply connect an antenna analyzer between the vertical element and the radial system (see Figure 4), switch in the vertical wire directly to the radials, and adjust the length to the desired director frequency (1904 kHz). Next switch in the vertical wire and inductor to the radials and adjust the turns spacing on the inductor for the desired reflector frequency (1800 kHz).

The array has an omnidirectional mode when all four parasitic elements are "floating," but this situation creates a difference in feed-point impedance due to interaction from the parasitic elements when the array is active. As a result, the resonant frequency will be different. The primary purpose of the omnidirectional mode is received-signal comparisons and not transmitting. If all parasitic elements are tuned to the same frequency, then the resonant frequency and SWR should remain the same when switching directions. The result should be a very low 1.1:1 SWR with a 1.5:1 bandwidth of approximately 40 kHz (see Figure 5. Fine tuning the array to realize maximum F/B and gain can be accomplished by driving approximately 1 to 2 miles in each of the four directions with a low-level signal source. Drive to the opposite direction, e.g. southwest for the northeast direction, and select the northeast direction for the array. Transmit from the distant low-level signal source and adjust the turns spacing on the reflector element inductor for lowest signal (maximum F/B). This will result in maximum forward gain. [These steps will require a second licensed operator to assist. — *Ed.*]

Array Switching

Directional switching of the array may be accomplished in a number of ways. Very simply, the use of two relays at each element will allow selection of the forward direction element to be connected directly to the radial system as a director and the rear element to be connected through the inductor to the radial system so it acts as a reflector.

Greg Ordy, W8WWV, designed a circuit board for K3LR that contains two relays and the inductor to accomplish this, and it's the system I use (see Figure 6). A plastic box is used as the board housing (see Figure 3) in order to provide insulation from the element. The control unit for the relays can be any simple switch. 12 V dc is applied to the two active elements to engage the appropriate relay. Unused elements are not connected to their radials and "float." For this, I pressed into service an Ameritron 5-position antenna relay switch box from my junk box.

What the Heck is That Roll of Cable?

Since these elements are parasitic, you may wonder what purpose the roll of coaxial cable and connection to the switch board serves (see Figure 7). The 160-meter array is close to my 80-meter 4 square, so I use a 160-meter 0.25 λ shorted stub at each element to reduce or eliminate any potential interaction. The stub is invisible on 160 meters, since it appears "open." On 80 meters, however, this is a 0.5 λ and appears as a "short" at the feed point, thus eliminating/minimizing interaction between the two arrays.

On-the-Air Results

The results documented on the air so far indicate a realized forward gain of 5 dB, and a F/B of approximately 25 dB. Reports from the Reverse Beacon Network (RBN) indicate a significant improvement over the single vertical, and my performance in DX pileups has improved significantly.

One of the most pleasing reports came from 9MØW Spratly 160-meter operator Jeff, K1ZM, who reported, "Your signal was better than *most*. About RST 339 which may not sound *loud*, but compared to all the others at RST 219, you were *loud*."

Acknowledgements

I want to acknowledge the generous mentoring that Tim Duffy, K3LR, provided in sharing his experience with the array and allowing me to travel to the K3LR station and see his installation. In addition, Jon Zaimes, AA1K, had installed this array at his station in Delaware and shared an enormous amount information from his experience.

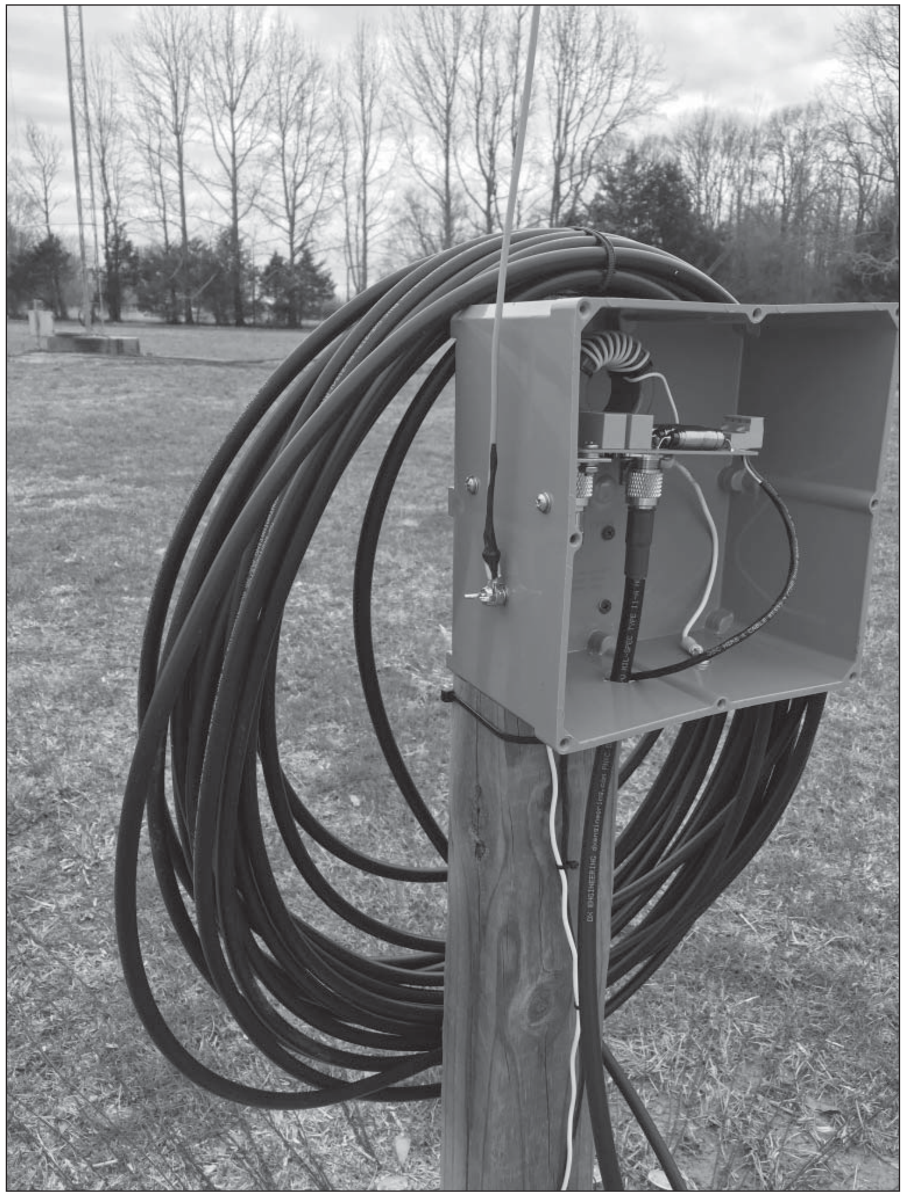

Figure 7 — The coaxial stubs minimize interaction between the 160-meter parasitic array and the adjacent 80-meter 4 square array.