Single Support Gain Antennas for 80 and 160 Meters

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Introduction

On 80 and 160 meters an antenna with modest gain and good front-to-back (F/B) ratio, along with a steerable pattern, can be very effective for contesting. This sounds like your standard HF Yagi, but unfortunately, for most of us at least, full-size rotary Yagis, at the necessary heights (greater than ½ wavelength), are not an option on the low bands. However, many of us do have a single tall support, usually a tower, from which it may be possible to suspend a vertical array.

The family of vertical arrays made with sloping elements from a single central support has many variations. A typical example is the K1WA[1] array shown in Figure 1. In this array each of the elements is a center-fed sloping dipole. One element is driven at a time with the other elements acting as reflectors. The length of the coax from the switch-box on the tower to the center of an element is adjusted so that when open circuited by the relays in the box, that section of feed line provides inductive loading that tunes each element as a reflector. In this example there is one driven element and four reflectors. Multiple reflectors really don't behave very differently from a single reflector (a little better F/B maybe) so the array is basically just a two element Yagi where the pattern is rotated by changing the element driven.

This theme has many variations: 2 or 3-element parasitic or phased array with vertical elements, straight sloping elements, or elements bent back towards the support. The element lengths may be anywhere from one-eighth wavelength to one-half wavelength, with or without loading as required, and center or end fed.

This article shows a number of typical examples to give you some ideas for your own installation. Details of each of the examples can be found in the references at the end of the article. In particular, John Devoldere's *Low Band DXing* [2] is a goldmine of ideas.

Expectations

Before going into the examples, I would like to indicate what performance can reasonably be expected. Even though there are many, many possibilities, in the end the performance will be quite similar between arrays using the same number of active elements. Most of these antennas will take the form of either a 2-element or 3-element array. Many of examples have 3, 4 or even 5 elements but usually only one element is driven (as shown in Figure 1) and the others are either inactive or act collectively as a reflector—ie, basically a 2-element array. In some examples one element will act as a director and another as a reflector—ie, a 3-element array.

Figure 2 is an excerpt from *The ARRL Antenna Book* 2-element phased array pattern diagram.[3] What is shown is the gain over a single element for a 2-element array with various phasings and spacings. The elements are assumed lossless and the ground perfect. The current amplitude is assumed to be equal in both elements and the height of each element is one-quarter wavelength. Note the tradeoff between gain and F/B—you can't maximize both at once! W4RNL has given an extensive discussion of the possibilities and limitations of 2-element arrays in earlier *NCJ* articles[4] and these are recommended reading.

The greatest gain difference (4.5 dB) is for a spacing of one-quarter wavelength and a phase difference of 135 degrees. The gains shown in Figure 2 are of course idealized. In the real world you won't get quite as much due to conductor losses, which can be substantial in the long wire conductors used on the low bands, and imperfections in tuning, spacing, element shapes, ground system, etc. For example, when you go from perfect ground to average ground (conductivity of 0.005 S/m and dielectric constant of 13), the gain difference for

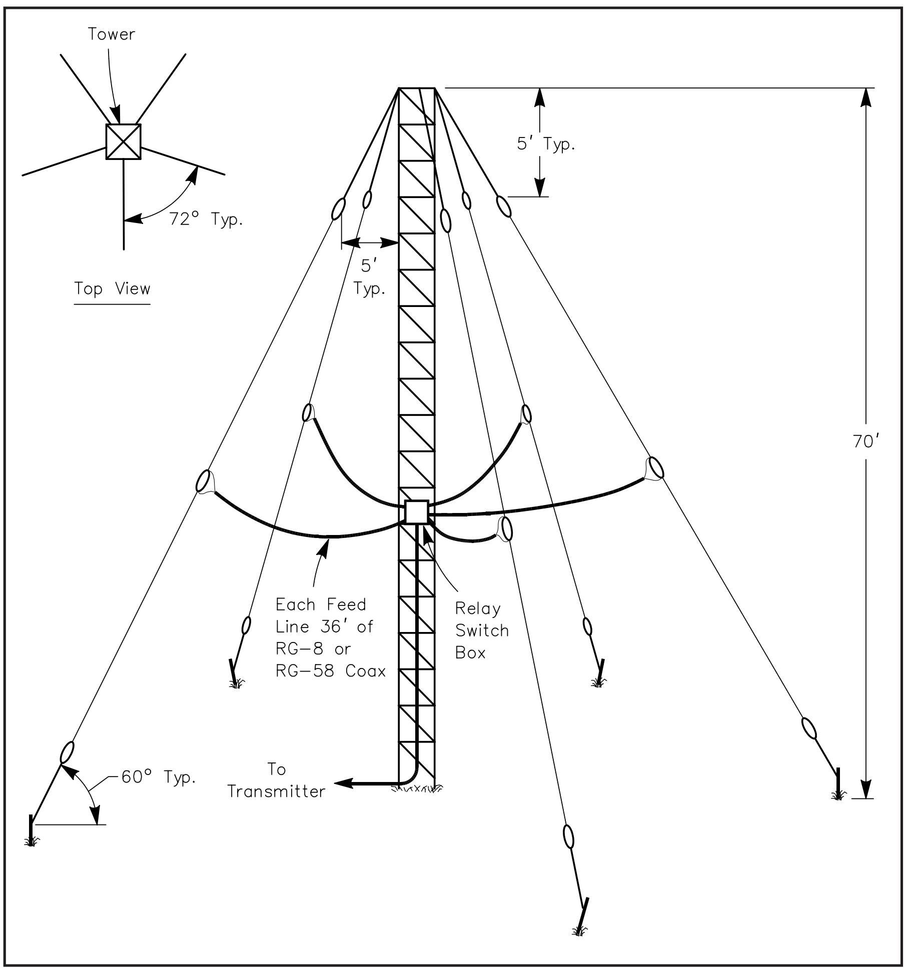


Figure 1—The K1WA Sloper System uses five identical one-half wavelength sloping dipoles spaced uniformly around a tall mast. Each feeder has an electrical length of about 135 degrees.

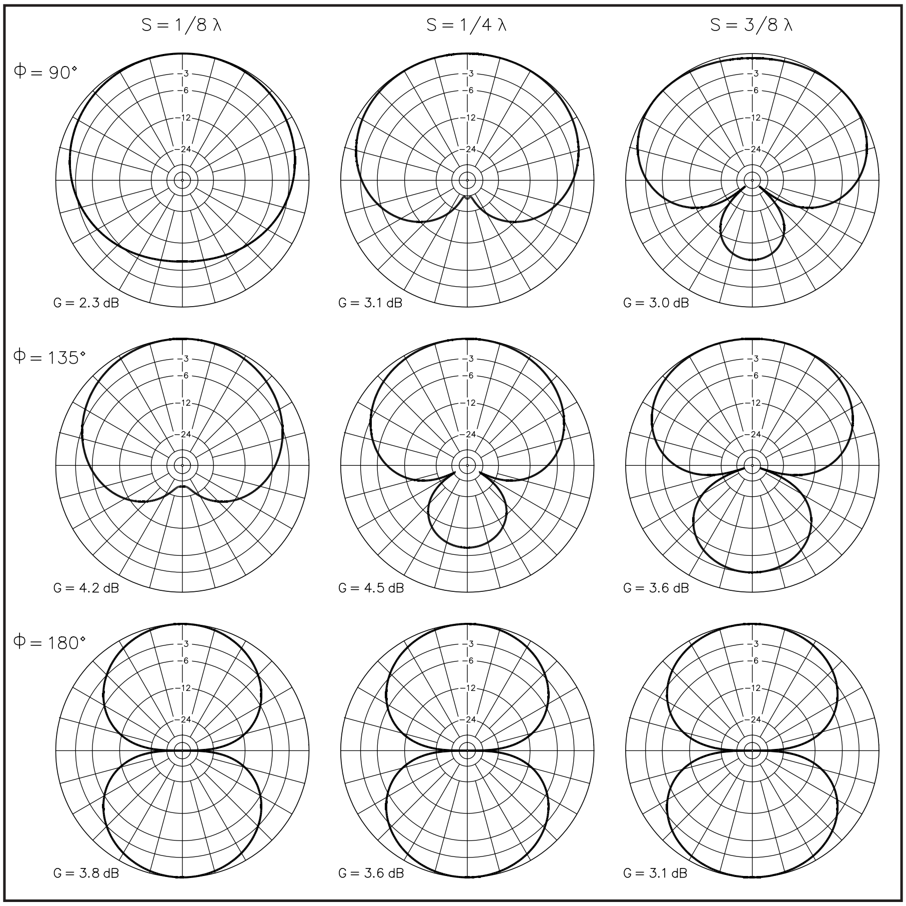


Figure 2—Idealized gain of a 2-element vertical phased array over a single vertical.

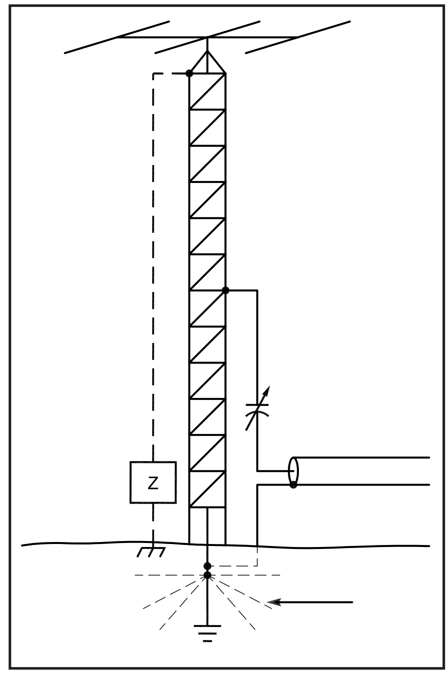


Figure 3—Tower with an HF array and shunt matching and tuning arrangements.

lossless elements drops to 4.3 dB. Adding in a couple of ohms of loss and the gain difference drops another 0.2 dB.

The examples in Figure 2 are for both elements driven. However, driving one element and allowing the other element to be parasitically excited (a Yagi!) is just another way to approximate the correct current amplitude and phasing. In the case of parasitic elements you can't control the phase and amplitude as closely as when both elements are driven independently so again the achievable gains and F/B will be somewhat lower. In exchange, the arrangements for pattern rotation may be considerably simpler in the parasitic array.

For a 2-element parasitic array, a gain of about 3-4 dB over a single vertical would be typical, with a F/B of 10-12 dB for a reflector array. In a 3-element array good F/B (greater than 20 dB) and an additional 1-2 dB of gain are possible. In three element arrays, the element impedance can be low however, especially if short, loaded elements are used. That's okay on 20 meters where the element is made from aluminum tubing, but on 160 meters where the element may be #12 wire and about eight times longer, the losses can be substantial. Wire loss is a basic limiting factor in large wire end-fire arrays. It is perfectly possible to build a 3-element array that has less gain than a 2-element array due to losses. Low impedances also mean that ground loss must be carefully controlled. Care in design and implementation is essential.

General Comments

For most, the available support will be a tower of some height, with probably one or more higher frequency Yagis at the top. Every installation will be different due to different tower heights, top loading due to the HF array, etc. Also, the available space around the tower into which one can stretch sloping elements and support lines will differ. For this reason, each installation becomes a unique design. It is essential to carefully plan and model each installation and then properly adjust it to get the predicted performance. What works great at my place may not be worth much at yours!

Some examples use grounded (or driven against ground) elements in the range of one-quarter wavelength to three-eighths wavelength. It is clear from well-known vertical antenna practice that a good ground system is required to minimize local ground losses. There is the misconception that free floating one-half wavelength elements do not need a ground system. While it is true that these antennas will work relatively well without an extensive ground system, they will work even better with one. The problem is the high electric fields near the ends of the elements that may be close to ground. This leads to losses that can be reduced by the use of a ground screen under the elements.

A key decision is whether to use the tower as an element in the array or just let it be neutral and provide mechanical support only. If you want to excite the tower as part of the array you will usually leave the tower grounded (with a good ground system!) because of the cabling going to the HF antennas, rotors, etc. You can match to the tower using shunt feed as shown in Figure 3. It is not necessary that the tower be resonant but if it is far from resonance then tuning it and getting a proper match may be a bit challenging. The usual means for checking tower resonance and tuning or detuning it is to add a shunt wire from near the top of the tower as indicated by the dashed line in Figure 3. If the tower needs to be tuned or detuned, then an impedance can be inserted in this wire as indicated. It is possible to perform both tuning and matching with the shunt wire. When only a single shunt wire is used, rotating the HF array to different positions may alter the tuning somewhat. Using three wires, symmetrically disposed around the tower, will pretty much suppress this and also provide some additional matching opportunities.

Element shape

Different element shapes can be used in these arrays: vertical elements, a sloping element, like K1WA, or a bent element, like K3LR[5] and K8UR[6] as shown in Figure 4. The sloping element will have both vertical and horizontal current components, in proportion to the slope of the element, which contribute both vertical and horizontally polarized radiation. In an array you will find that the horizontal component is essentially that of a low dipole with lots of high angle radiation. Also it will be noticed that as the element phasing is varied, the total pattern (sum of vertical and horizontal components) does not behave the same as the phased purely vertical elements assumed in Figure 2. The result is an absence of a zenith null in the pattern and some reduction in maximum gain in endfire and broadside patterns. This effect can be seen by comparing the elevation patterns of the K1WA array to an early K3LR[5] array as shown in Figure 5. More discussion on this point can be found in my article in *the ARRL Antenna Compendium Volume 7*.[7]

This observation is not meant to imply that sloping elements should not be used. I know of several amateurs using essentially the K1WA array on 160 meters with very good results. It just may be that mixed polarization is a good thing. The point is to recognize that the two different element shapes will produce different radiation patterns and polarization mix. Some people may want the additional high angle. It doesn't cost much in forward gain and it provides a big signal at short distances. In my case, I choose to suppress the high angle radiation in the array and use a dipole for local and up and down the West Coast.

A bent element can be proportioned, as shown by G3LNP,[8] to null out most of the horizontal component and act much more like a straight vertical element.

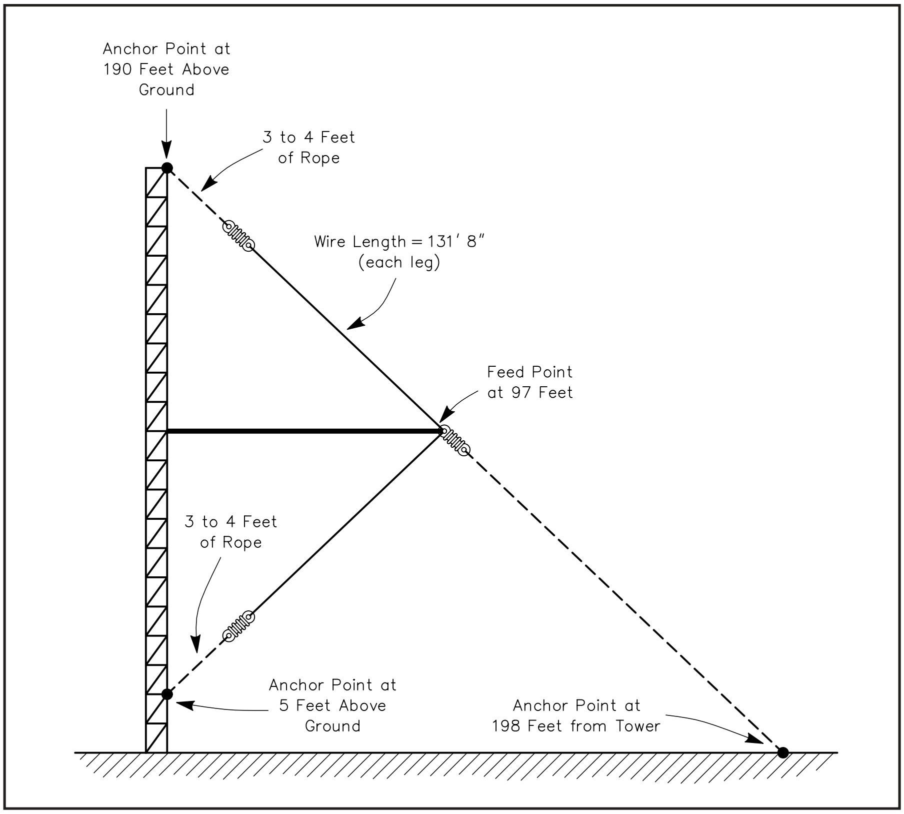


Figure 4—K3LR/K8UR bent element example.

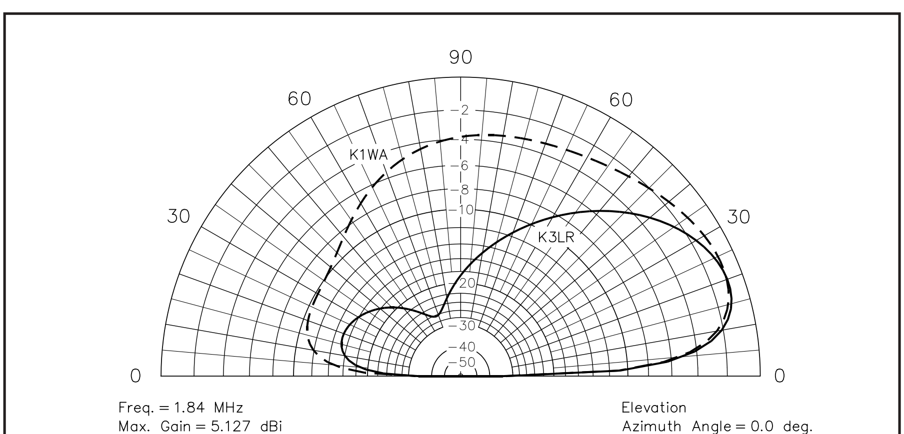


Figure 5—Elevation pattern comparison between straight sloping elements (K1WA) and bent elements (K3LR).

Examples of Sloper Arrays

When a guyed tower is driven, one of the simplest ways to add parasitic elements is to convert the guys into elements using strategically placed insulators as shown in Figure 6.[9] The tower is the driven element and the guys act as reflectors. Relays can be placed at the base of each guy (as indicated in the insert in Figure 6) to connect one guy at a time to act as a reflector and rotate the pattern. When the relay contacts are open the guy is non-resonant and transparent to the array. It is also quite possible to cut the active part of the guy to act as a director and then add a enough inductive loading so that it acts as a reflector. To enable a particular guy to act as a director, the relay can simply short out the loading inductor. When the relay is open the guy is a reflector.

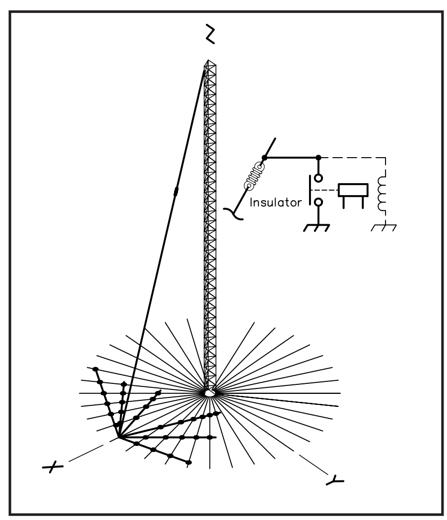
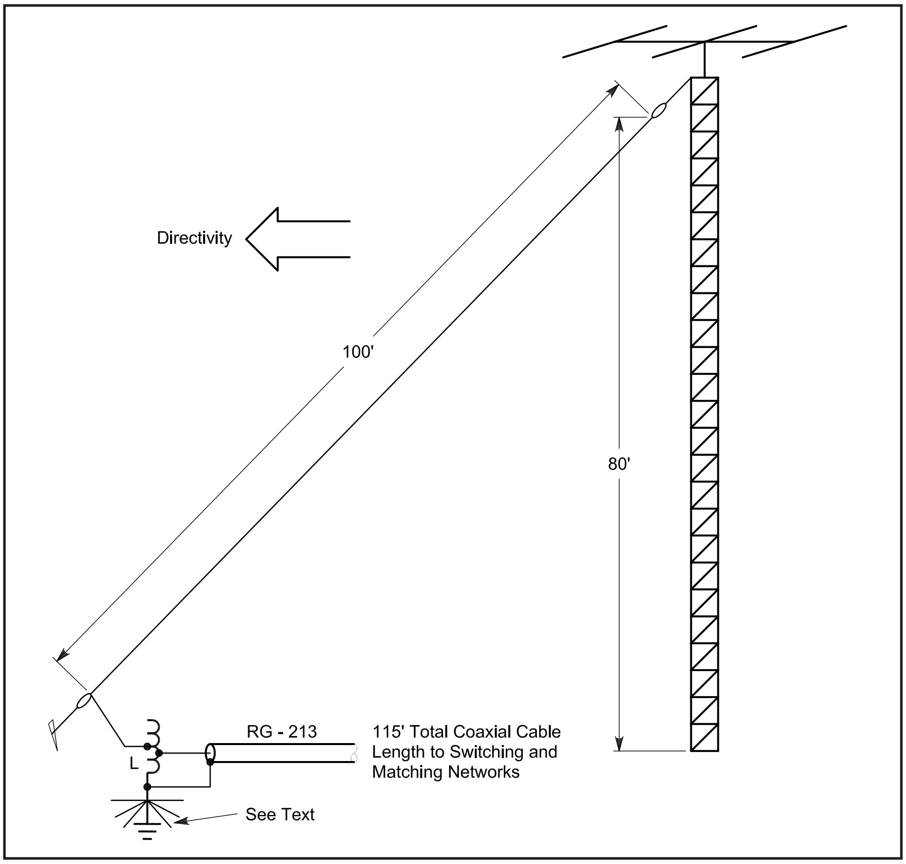


Figure 6—A simple 2-element slant-wire parasitic array.

Figure 7—Single sloping element per 4X4NJ.



4X4NJ has described several arrays[10] for 160 meters, one of which is shown in Figure 7. It is a two element parasitic array and the tower is tuned to act as a reflector. This idea can be extended to multiple elements, spaced around the tower as indicated in Figure 8. Each of the elements is about 100 feet long (0.19 wavelengths at 1.850 MHz) and resonated with a loading coil at the base which also provides a matching opportunity. Because the length of the elements is nearly one-quarter wavelength, the loading coil will be small and not greatly affect efficiency. There are many possible ways to drive the array elements. The tower can be detuned and one element driven with the other elements acting as reflectors like K1WA, or the tower may be driven and the elements tuned as reflectors and directors to form a 3-element parasitic array.

As a phased array, the element phasing can be adjusted to provide several different patterns. However, as indicated by the dashed line in Figure 8, a bent element, with cancellation of the horizontal component, would give better pattern flexibility. Depending on the phasing, this array can be bidirectional endfire, bidirectional broadside, or unidirectional endfire. The unidirectional endfire mode can be adjusted for either maximum gain or F/B. It should be pointed out that because of the relatively close spacing of the elements in most single support sloper arrays, broadside gain is usually modest at around 1-2 dB. Endfire gain can of course be very good if conductor and ground losses can be minimized.

A variation with one-quarter wavelength sloping elements and a driven tower appears in ON4UN's book.[11] Figure 9 shows the array where the elements are made slightly shorter than one-quarter wavelength to act as directors and then converted to reflectors by inserting a small inductance. Note! Each element must be tied into the overall ground system. Also remember that even if you don't use the guys as elements, they must be detuned so that they do not interact with the desired elements. Normally this would be done by breaking up the guys with insulators, or by using non-conductive guys.

The Spitfire array[12] (W1FV/K1VR) shown in Figure 10 is a variation using a driven tower (approximately one-quarter wavelength) and one-half wavelength ungrounded elements for reflector/directors. The changeover from director to reflector is done by connect-

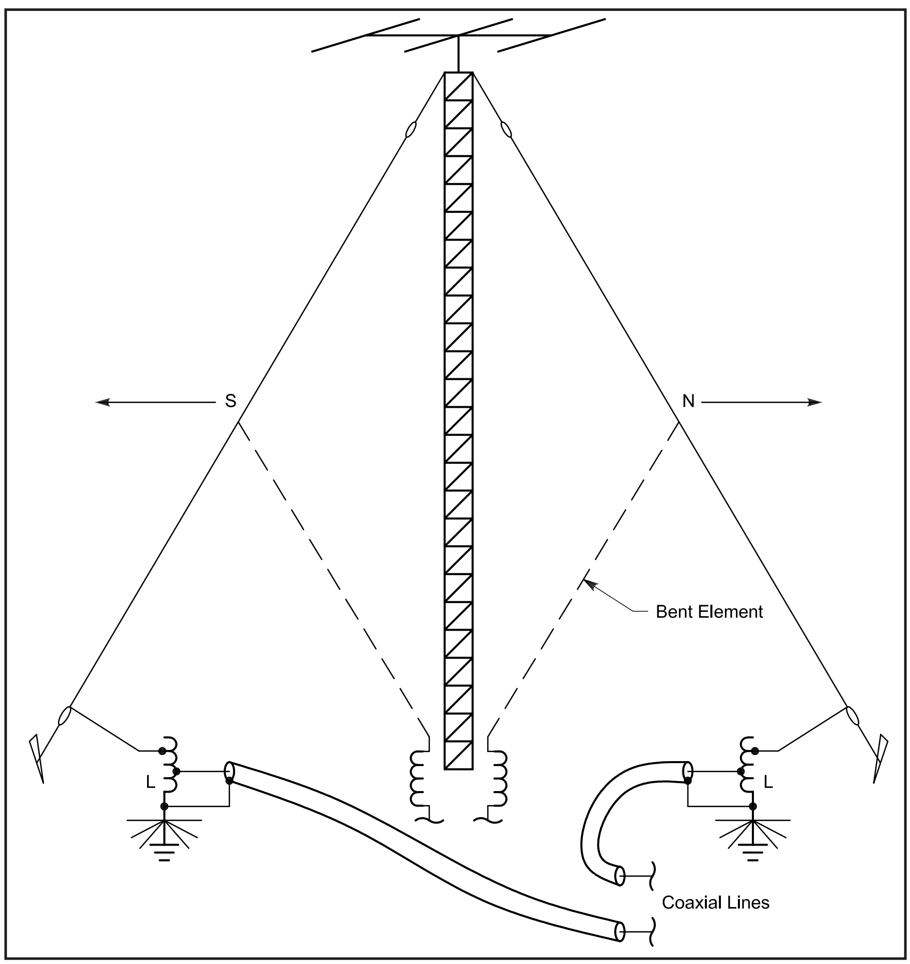


Figure 8—4X4NJ 2-element array.

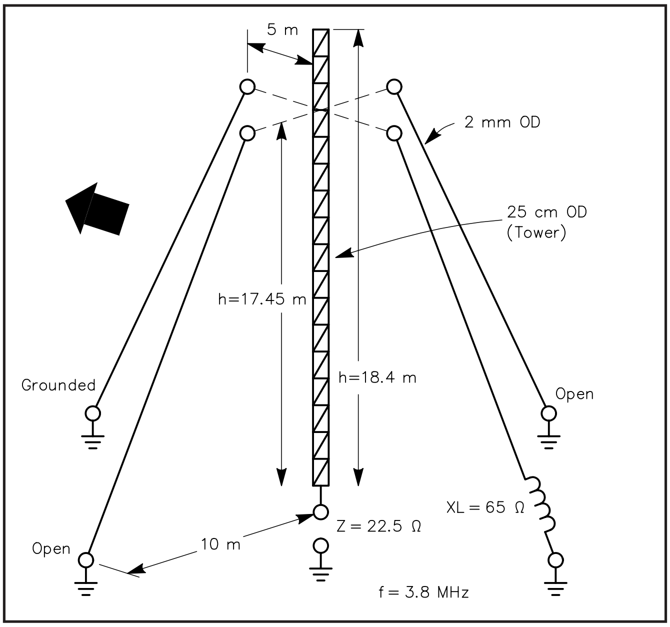


Figure 9—A three element array.

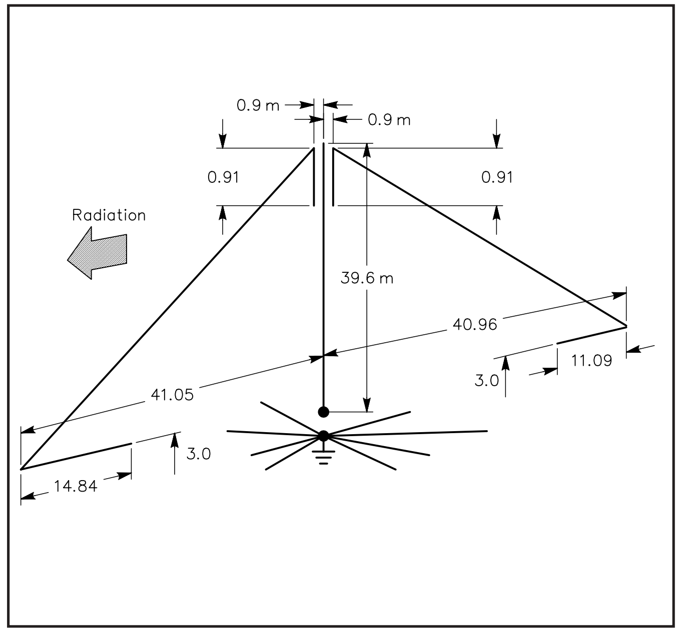


Figure 10—The Spitfire array.

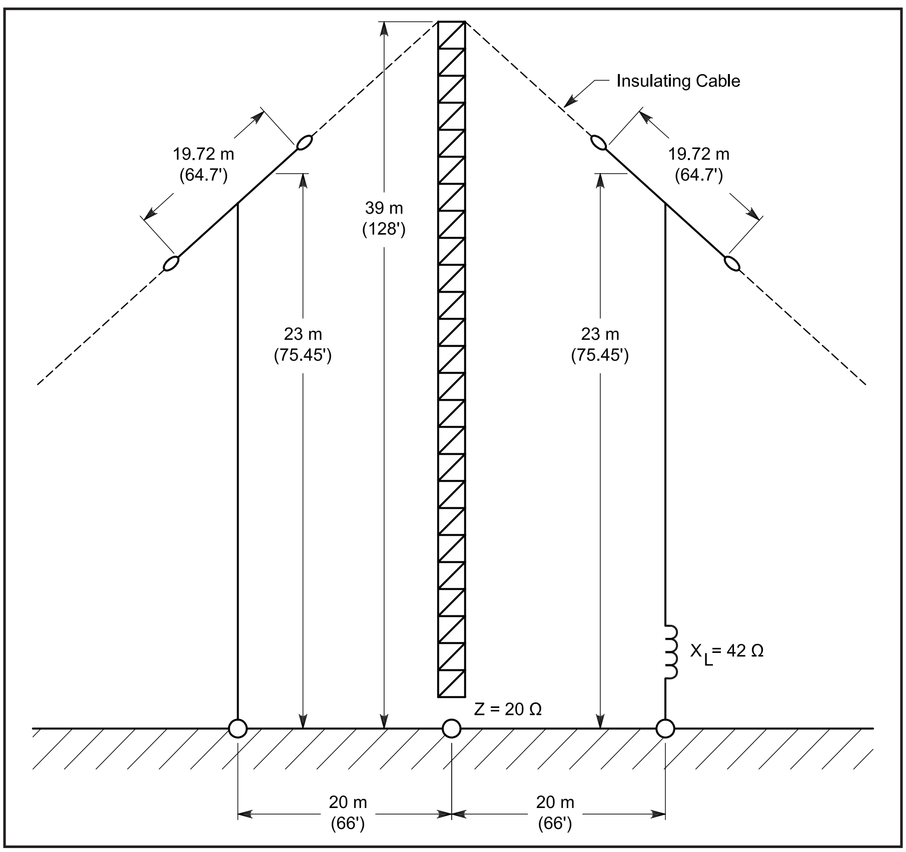


Figure 11—A three element array with vertical top-loaded elements.

ing an additional length of wire to the bottom ends as indicated. One disadvantage is that the relays in this case must be rated for 5 kV or more. A vacuum relay would be typical. Also you have to be careful to decouple the relay coil drive lines from the HV RF on the contacts. Even though the parasitic elements are not directly grounded, it is still important to have a ground screen under the elements due to the very high fields present near the element bottom ends and of course the driven element requires a ground system.

Purely vertical elements can also be used by suspending them from the guy wires and allowing a portion of the guy to act as top loading, as shown in Figure 11.[11]

Comments on Tuning and Adjustment

I have built a number of arrays of this type for 160 meters. I usually begin by carefully modeling the proposed array using *EZNEC* or similar software, being very careful to include conductor losses. Once I think I have a winner I then go out and erect the array. But before adjusting it, I go back to the modeling and model one element at a time, keeping the element lengths the same as the full model, with the other elements either open or absent. What I am looking for is the self-resonant frequency of each element, with the other elements not present, using the dimensions from the complete array model. I then go the actual array and repeat the exercise, only this time adjusting each element to be resonant at the same frequency as the modeling gives for each element in the absence of the other elements. During this part of the tuning process, the other elements are either lowered to the ground or open-circuited so they do not affect the element being adjusted. Resonance can be determined with a dip meter (monitored with a receiver for calibration!). I do this for each element in turn.

Final adjustments for matching should be done with the entire array up. You can also touch up the F/B by placing a source several wavelengths away to minimize the received signal. One word of caution is in order, however. The received signal will be ground wave at a very low angle, minimizing what is not necessarily the same as maximizing F/B at the higher angles more typical of backward lobes.

One point often overlooked in large wire arrays is the effect of insulation on the resonant length of an element. Standard electrical wire insulation can shift the resonance downward 3-4 percent, seriously mistuning a parasitic element. This shows up during tuning by the need to shorten an element by several feet to obtain the desired self-resonant frequency when insulated wire is used in the field but un-insulated wire in the model. This can be a bit disconcerting if you don't expect it.

Conclusion

I think the forgoing discussion makes very clear the wide range of possibilities for creating a directive array with a switchable pattern when a single support of modest height is available. These arrays can be made from simple components: wire, insulators, and sections of transmission line. For the most part they are quite economical. But for all that they can still be very effective and are possible to implement even in modest size lots. Hopefully this discussion has shown you just how flexible the arrangements are and there is probably a solution for almost any situation.

The discussion is just an overview. If you want to build one of the antennas then you should read carefully the references that are full of practical details. In general each installation will be unique and require a design developed for that situation.

Acknowledgment

I would like to thank Mark Perrin, N7MQ, and George Cutsogeorge, W2VJN, for reading and commenting on the draft article. They helped to reduce the confusion quotient drastically.

Notes

[1]*The ARRL Antenna Book*, 19th edition, 2000, p 6-32. This antenna is also in earlier editions.

[2]John Devoldere, ON4UN, *Low Band DXing*, ARRL, 3rd edition. See examples in chapters 11 and 13.

[3]ARRL Antenna Book, 19th edition, 2000, page 8-8

[4]LB Cebik, W4RNL, "Some Notes on Two-Element Horizontal Phased Arrays," in four parts, *NCJ*, Nov/Dec 2001, pp 4-10; Jan/Feb 2002, pp 4-9; Mar/Apr 2002, pp 3-8; and May/Jun 2002, pp 3-8.

[5]Christman, Duffy, and Breakall, The 160-Meter Sloper System at K3LR, *QST* Aug 1994, pp 36-38. See also *The ARRL Antenna Compendium Volume 4*, pp 9-17

[6]D. C. Mitchell, K8UR, The K8UR Low-Band Vertical Array," *CQ*, Dec 1989, pp 42-45.

[7]R. Severns, N6LF, "Getting the Most from Half-Wave Sloper Arrays," *ARRL Antenna Compendium Volume 7*, Fall 2002.

[8]Tony Preedy, G3LNP, "Single Support Directional Wires," *RADCOM*, Aug and Sep 1997, pp 38-39 and 76-78.

[9]John Stanley, K4ERO, "The Tuned Guy Wire—Gain for (Almost) Free," *ARRL Antenna Compendium Volume 4*, pp 27-29.

[10]Riki Kline, 4X4NJ, "Build a 4X Array For 160 Meters," *QST*, Feb 1985, pp 21-23 and 45. Reprinted in *ARRL's More Wire Antenna Classics II*, 1999, pp 6-21 through 6-24.

[11]John Devoldere, ON4UN, *Low Band DXing*, ARRL, 3rd edition, p 13-48.

[12]John Devoldere, ON4UN, *Low Band DXing*, ARRL, 3rd edition, p 13-50.

Additional useful references

E.T. Ford, "A Directional MF Transmitting Antenna Comprising a Single Guyed Mast and a Sloping-Wire Parasitic Reflector," ICAP 83, IEE conference publication No. 219, part 1, 1983, pp 235-239. Synopsis of this paper can be found in John Belrose, VE2CV, *QST* Technical Correspondence, Sep1984, p 40.

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Erwin David, G4LQI, *HF Antenna Collection*, RSGB, 1989, 82-90.

Les Moxon, G6XN, *HF Antennas for all Locations*, RSGB, 2nd edition 1993, pp 227-230.

Al Christman, KB8I, "*The Slant-Wire Special*," *ARRL Antenna Compendium Volume 4*, pp 1-7. See also follow-up in *QST* May 1997, Technical Correspondence, pp 74-75.

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