# A SIMPLE 40M VERTICAL FOR DX


## Abstract

Properly designed, efficient, vertical antennas can deliver exciting DX performance compared to horizontal antennas with supports extending to similar heights. This 7 MHz. design is marked by efficiency and simplicity. Elevated radials and capacitive matching contribute to efficiency, while absence of coils and a small number of radials lead to simplicity.

# Design Considerations

To achieve an optimum design, clear objectives must drive design decisions. Design objectives included (1) resonance at 7.14 MHz, (2) 50 Ω input impedance, and (3) an excellent balance of efficiency and construction simplicity. Variables adjusted to achieve the objectives were (1) length and material of the vertical radiator, (2) number and length of radials, (3) height of radials, and (4) the matching network. The design approach was to first, based upon the objectives, choose the overall configuration with approximate lengths and heights, second, to choose the materials for the radiator and radials, and third, to model the design and make final adjustments before construction.

The length of the vertical radiator is perhaps the most critical decision. To achieve high efficiency, the radiator should be ¼ λ or more in height. However, there is a practical upper limit as well. If the radiator is extended too far upward, low-angle radiation suffers as higher-angle lobes form. The length of the radiator also impacts the resistive component of the input impedance. A radiator length of about 100°, or 0.28 λ, is an excellent choice as it provides high efficiency and a resistive input component of about 52 Ω.[1] Using a radiator length greater than 0.25 λ is also desirable in that it will yield an inductive reactance that can easily be canceled with a series capacitance. At 7.14 MHz, 0.28 λ in free-space would be nearly 38.6 feet. However, the required radiator length will be somewhat less, especially when using a robust element of significant diameter. Applying the length factor for the conductor diameter the resulting height is 37.4 feet, approximately 97% of the free-space value.[2] A length of 37.8 feet is chosen for the radials (1% longer that the vertical element).[2]

Next, the number and height of radials are chosen. Experimental results reveal that four radials elevated four feet perform within 0.2 dB of sixty-four radials lying on the ground surface.[3,4] Six radials are chosen for this design. This number exceeds minimum requirements and the end supports for these radials also provide potential guy wire attachment points at 60° intervals for the vertical radiator. Radials are chosen to be horizontal as opposed to slopping downward. The base of the vertical element is 6 feet above the ground, a more than sufficient spacing to yield the advantages of elevated radials. Due to the lay of the land and placing the radials horizontal, the height of the ends of the radials varies from a low of 3.5 feet to high of 7 feet.

Before modeling the design to check performance and fine-tuning the parameters, a few additional design decisions were necessary. Schedule 40 fence railing of 2” O.D. (actual 1.9” O.D.) is chosen for lower 21 feet of the vertical radiator. Schedule 20 fence railing of 1 5/8” O.D. (actual 1.660” O.D.) is chosen for the upper section of the radiator. Aluminum wire, 14 gauge, is selected for the radials (electric fence wire.)

MMANA-GAL™ antenna modeling software is utilized for modeling, it provides accuracy and ease of use. A 60 foot tower is located 80 feet from the location of the vertical radiator. This tower was included in the model as it would probably have some minor effects on the antenna radiation pattern, resonant frequency, and input impedance.

The 21 foot base section, 15.5 foot top section, and 0.9 foot 12 gauge wire from the tuning capacitor to the base section yields an overall radiator length of 37.4 feet.

MMANA-GAL™ antenna software analysis returns Z = 53.1 + j58.8 Ω for a 37.4 foot vertical antenna with six 37.8 foot elevated radials at 7.14 MHz. Figure 1 shows the calculated radiation resistance and inductive reactance of the antenna as a function of frequency for the 40 meter band. 54.5 Ω of capacitive reactance is needed to cancel the antenna inductive reactance. 379 pF provides 58.8 Ω of capacitive reactance at 7.14 MHz. I used a combination of fixed and variable capacitors to achieve a range above and below 379 pF, 494 pF at 7.0 MHz (Z = 50.2 + j46.0), 407 pF at 7.1MHz (Z = 52.3 + j55.1), 343 pF at 7.2 MHz (Z = 54.4 + j64.3), and 296pF at 7.3 MHz (Z = 56.4 + j73.6), depending on the coverage desired. These values indicate that a capacitance range of 250 to 550 pF is adequate for matching the antenna to a 50 Ω feed line over the entire 40 meter band.

Figure 1 shows the radiation resistance and the inductive reactance of the antenna as an function of frequency for the 40 meter band. Figure 2 shows the calculated SWR for a 50 Ω feed as a function of frequency before matching the antenna to the feed line. SWR is 2.97:1 at 7.14 MHz.

A view of the antenna and nearby tower is shown in Figure 3. A 3D radiation pattern view is shown in Figure 4 and an azimuth and elevation view is shown in Figure 5


**Figure 1 -- Impedance plot.**

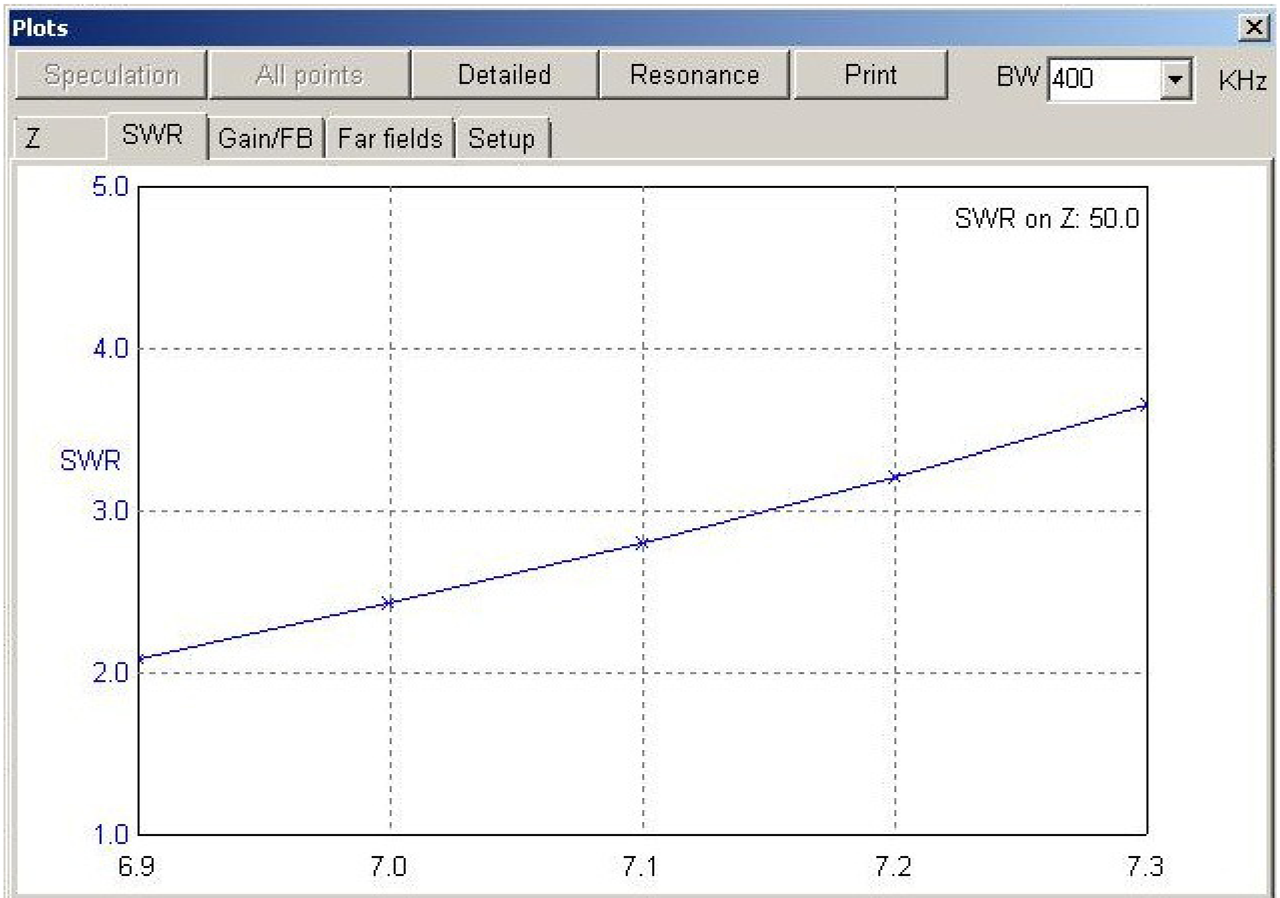


**Figure 2 -- SWR plot.**

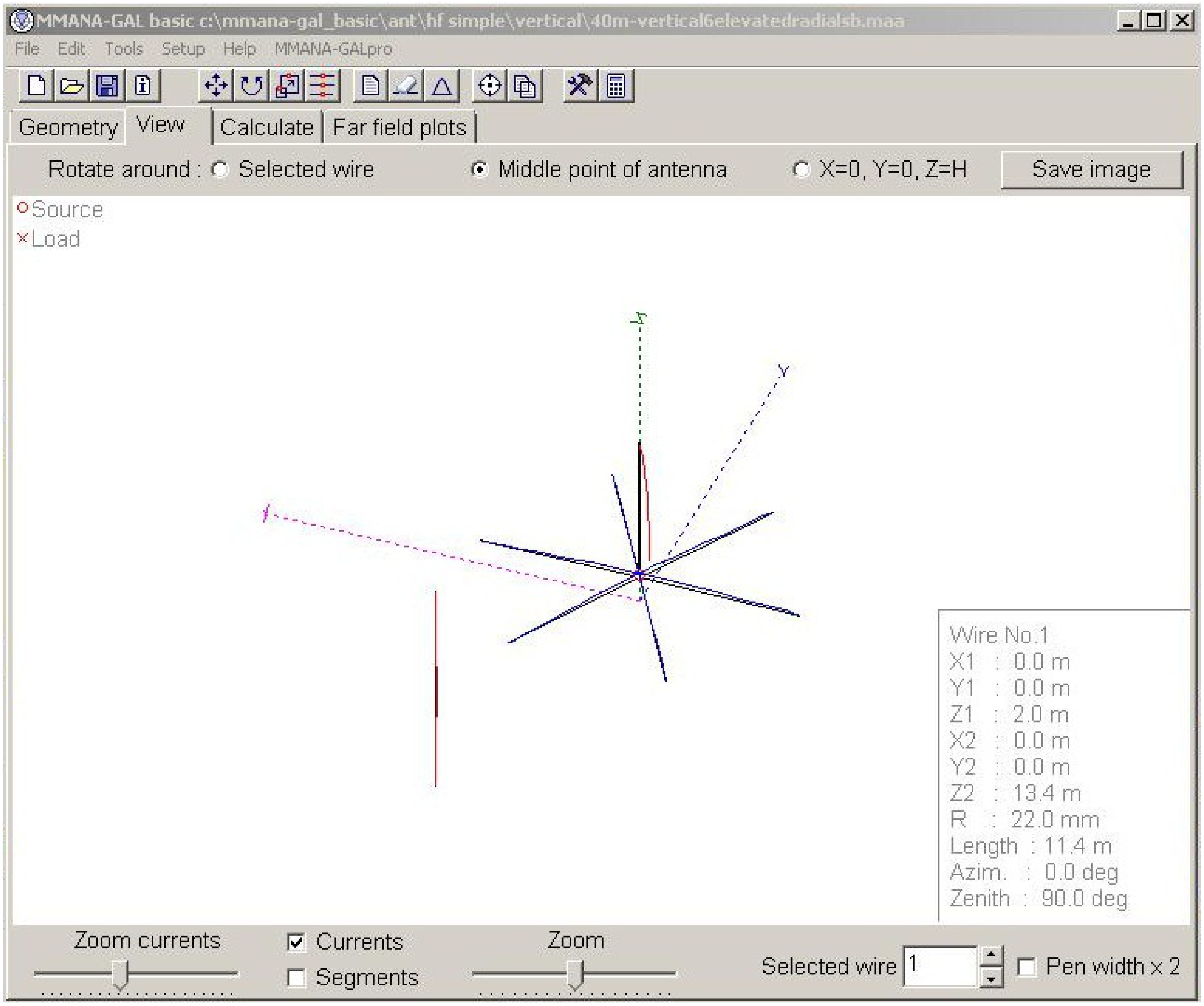


**Figure 3 -- Antenna view with current distribution and tower to the lower left.**

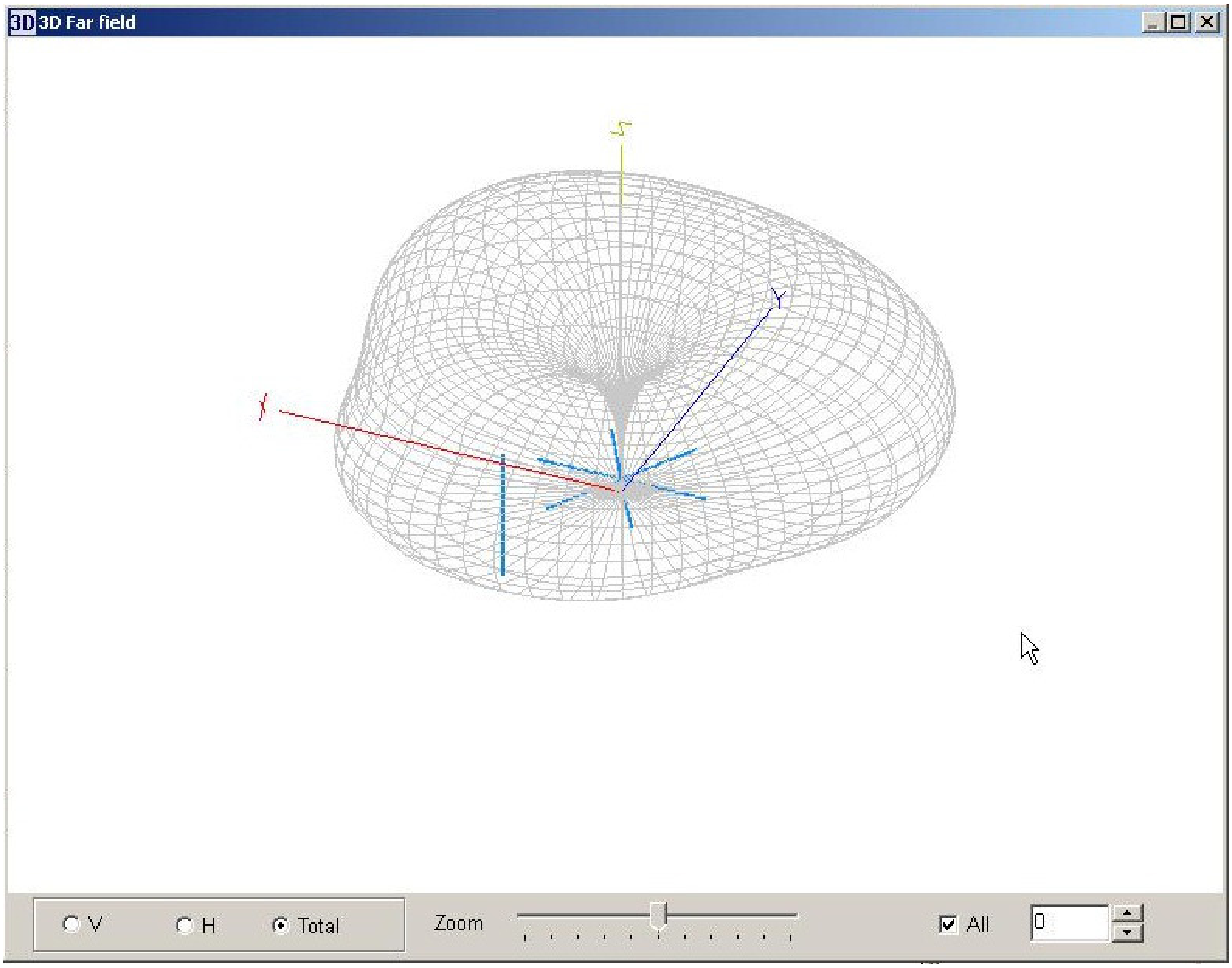


**Figure 4 -- 3D pattern, asymmetry is due to a tower 80 feet away.**

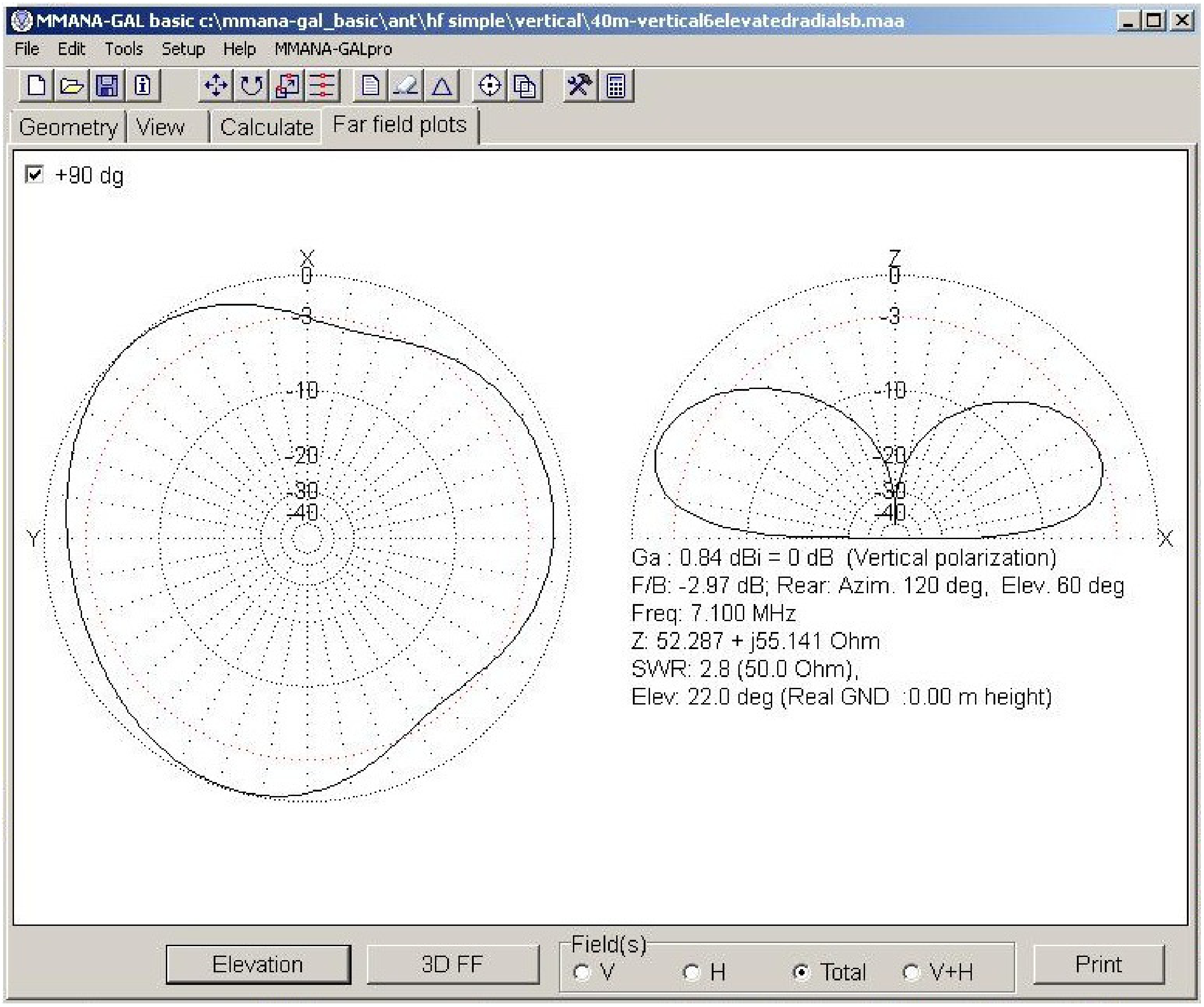


**Figure 5 -- Azimuth and elevation pattern.**

## Construction

Seven 4” x 4” x8' treated posts are set in concrete in the ground.  One post in the center for supporting the antenna and six posts at  60$^o$ intervals around the center post, each at a distance of 40 feet.  Figure C1 shows the posts viewed from my tower.   The radials are supported by insulated electric fence lag bolts and nylon dog bone insulators.  The radials are each attached to the ground of the feed line at the center post.

**Figure 6 -- 4” x 4” support posts.**

The antenna is insulated from the post by a 9” long 2.0” diameter nylon rod.  A 2” hole was drilled 3” deep into the top center of  the center post, Figures 7 and 8.  The top of the center antenna post is 9” above the attachment point for the radials at a height 5.5”.

**Figure 7 -- Mounting hole for insulator.**

**Figure 8 -- Mounting hole depth.**

One end of the nylon insulator, Figure 9, is turned down to 1.650" so that it will fit in the lower section of the antenna. The resulting insulator fits 3" into the center post. The end of the insulator that fits in the post is rounded so that it will more easily slide into the hole as the antenna approaches vertical. There is 3" of insulator spacing from where the antenna sits on the insulator step and the top of the post that the insulator is setting in, Figure 10.


**Figure 9 -- Base insulator.**

**Figure 10 -- Base insulator configuration.**

As mentioned earlier the antenna is guyed at six points spaced at 60$^o$ intervals around the antenna. The three top guys are at 120$^o$ spacings as are the three lower guys. The lower and upper guys being offset by 60$^o$. Dacron antenna rope, 3/16" diameter, is used for guying. Two high strength plastic insulating guy rings are used (Figure 11), one at 21 feet were the upper pipe telescopes into the lower larger pipe, and the other 10 feet from the base of the lower pipe. The guy rings are doubled resulting in 0.5 inch thick guy rings. They are made of an insulating material and Dacron rope is an insulator, so no other insulators are placed in the guys.


**Figure 11 -- Upper and lower guy rings.**

The upper and lower pipe sections are a very tight friction fit. The upper pipe required sanding in order to fit into the lower pipe. The sanding resulted in a slight taper where sanding of the pipe ended. The sanded end, approximately 3 feet in length, was inserted into the lower pipe until the tapered section was reached forming a very tight fit. The guy rings, upper and lower, are each supported by two halves of two muffler clamps, two 5/16 inch bolts with nuts to secure them, Figure 12. The upper clamp is at the top end of the lower pipe section to support the upper guy ring.

**Figure 12 -- Guy Ring Support.**

## Raising the Antenna

Guys are attached to the guy ring thimbles and the antenna is placed as shown in Figure 13 prior to raising. The rope looped around the antenna on the top side of the upper guy ring is attached to a tower 80 feet away via a 3:1 mechanical advantage pulley system. Once the antenna was raised to about a 30 degree angle by a very agile person walking up the ladder, it is pulled up by the rope. Four people were present for the raising. One person on each of the two guys to the left and right of the pull up direction to stabilize the antenna as it is raised, as it wants to swing to the right or left, and the other two on the pull up rope.

The base insulator must be held over the center post and guided into the mounting hole in the post. As the antenna is being raised the base wants to slide off of the post due to the large horizontal force generated in the direction of the base.  This problem is solved by attaching two 2"x4"s to the center post to guide the insulator base into the post mounting hole.  Once the antenna is near vertical the insulator will slide into the hole in the post.  The antenna is checked for vertical and the 6 guys tensioned and tied accordingly.  The completed antenna is shown in Figure 14.

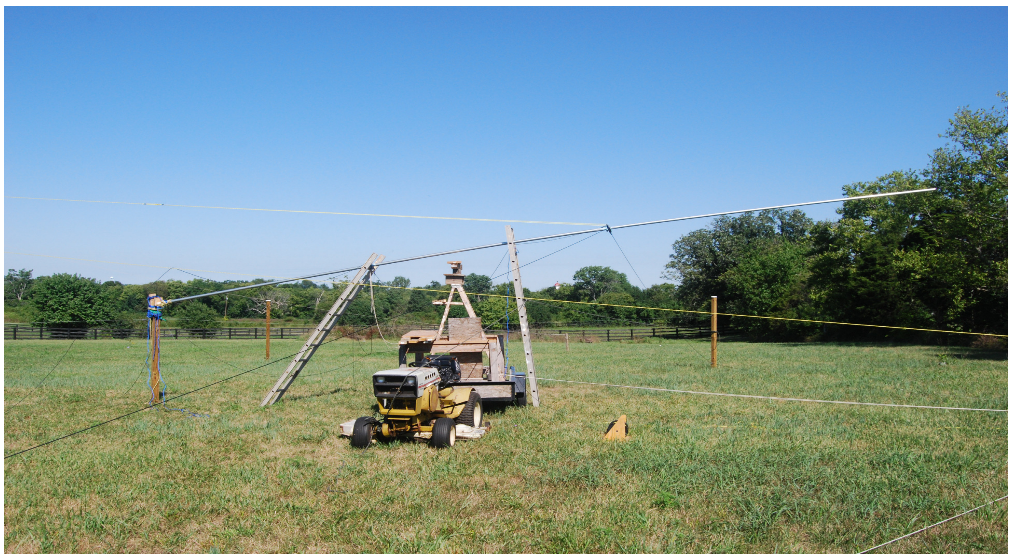

**Figure 13 -- Pre-raising position.**

**Figure 14 -- Completed 40 meter antenna.**

## Antenna Matching

The antenna matching network, shown in Figure 15, consists of a fixed and variable capacitor mounted in a water tight plastic electrical junction box. The matching capacitor assembly is fed directly with the coax from the current balun assembly just below the capacitor housing box. The current balun at the base of the tuning capacitor housing is 7 turns of RG-213 wound on 5 FT-240 #31 mix stacked toroids. The balun is described in detail in a previous QST article "*You Can Build This Novel High Impedance Choke Balun for Under $50*"[7]. The balun provides over 5000 Ω impedance at 7 MHz.

The variable transmitting capacitor is 250 pF, and the two 500 pF doorknob capacitors (5 KV rating), when in series, provide a value of 250 pF. Resonance is at approximately 430 pF. In theory with perfect components, at resonance (SWR=1.0:1) and 1500W input to the 50 Ω coax, the peak voltage on the coax is 388V. The voltage across the variable capacitor is 402 V at $-90^{o}$. Any higher voltage across the variable capacitor is expected to be much less than it's 3.5 KV rating and the two in series door knob capacitors are rated at 5 KV each.

**Figure 15 -- Matching unit**

I tune the variable capacitor at the base for the lowest SWR at the transmitter end of the feed line.

## Evaluation

SWR vs frequency data as measured with an LP-100A at the source end of the coax is shown in Figure 16. The plot shown is with a tuned series capacitance of approximately 430 pF for a minimum at 7180 kHz. As shown the SWR is less than 1.5:1 over the 40 meter band. The base capacitor could certainly be used to fine tune the SWR at other frequencies. The SWR value of 1.0:1 is at 7180 kHz. The SWR at the design goal (7140 kHz) is 1.1:1. Certainly an acceptable value.

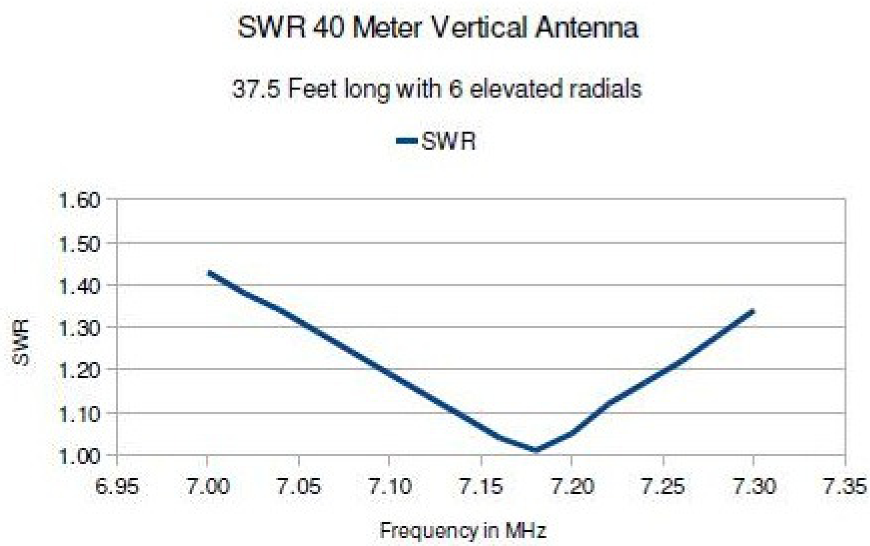


**Figure 16 -- SWR vs Frequency.**

Comparing the vertical with an inverted V antenna with the apex at approximately 35 feet and oriented east – west, generally the vertical is noticeable better for distant stations. Stations in Europe and on the USA west coast generally are stronger on the vertical, at times the difference is between hearing them and not. Stations several hundred miles distance are generally better on the inverted V antenna, which is a near vertical incident radiator vs the vertical antenna which radiates mainly in the low angles.

An interesting phenomena of the vertical antenna is that I have not noticed any increase in noise pick up as compared to my inverted V antenna, other than sometimes noise will show up stronger on one antenna than the other. Although the vertical antenna is rumored to be a noisy antenna, I am not noticing it.  However, the inverted V antenna does have a large vertical pickup angle.  The antenna is located away from any city so man made noise is minimal.  The quite location along with the distant signal improvement makes the additional work required for elevated radials and cost of the vertical worthwhile.

Although quantitative test are not feasible, qualitatively speaking, tests with a station in CA and working stations in Europe indicate approximately a 6 dB improvement.

# BIBLIOGRAPHY

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[4]ARRL Antenna Handbook, 20$^{th}$ Ed., 2003, Chapter 6, pp 6-8.

[5]ARRL Antenna Handbook, 20$^{th}$ Ed., 2003, Chapter 26, pp 25.

[6]ARRL Antenna Handbook, 20$^{th}$ Ed., 2003, Chapter 26, pp 23.

[7]J Campbell, K4ZHM, “*You Can Build This Novel High Impedance Choke Balun for Under $50*”, QST XXX, pp xxx

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