HF Tactical NVIS ANTENNAS

Introduction:
A properly designed Near Vertical Incident Skywave (NVIS) antenna will have a directivity pattern that will maximize transmission and reception at high angles while rejecting low angle, long range noise. Further, this antenna must be tunable over at least one octave of frequency to track the local Critical Frequency (CF).
The required directivity pattern is shown in Figure 1.

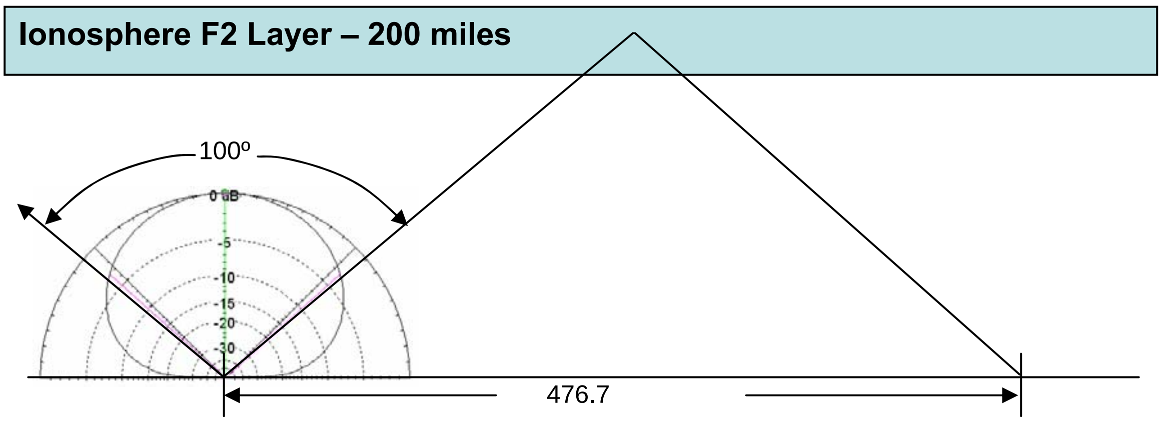


Figure 1: Required NVIS Antenna Vertical Directivity Pattern

The vertical or elevation directivity pattern should have a beam width (-3dB) of approximately 100º and the horizontal or azimuth directivity pattern should be omni-directional. The three-dimensional pattern should look like a toy balloon with the filler at the bottom.

NVIS Noise Reduction
As we have all noticed, the most prevalent noise is long-range lightning from thunderstorm activity in the surrounding states. During summer evening nets, after D-layer absorption has dropped, thunderstorms, several states away can disturb our ARES HF nets. There is little we can do about local thunderstorm noise, but a properly designed NVIS antenna can reduce the distant noise. Note from Figure 1, that distant signals will be arriving at very low angles where the NVIS antenna has minimum gain.

Generating the Correct Antenna Pattern – Optimum Height
The correct antenna pattern, shown in Figure 1, is surprisingly easy to generate. Placing a standard dipole antenna at a height of 0.15 wavelengths or about 36 ft at 3.75 MHz produces the pattern seen in Figures 2 and 3.

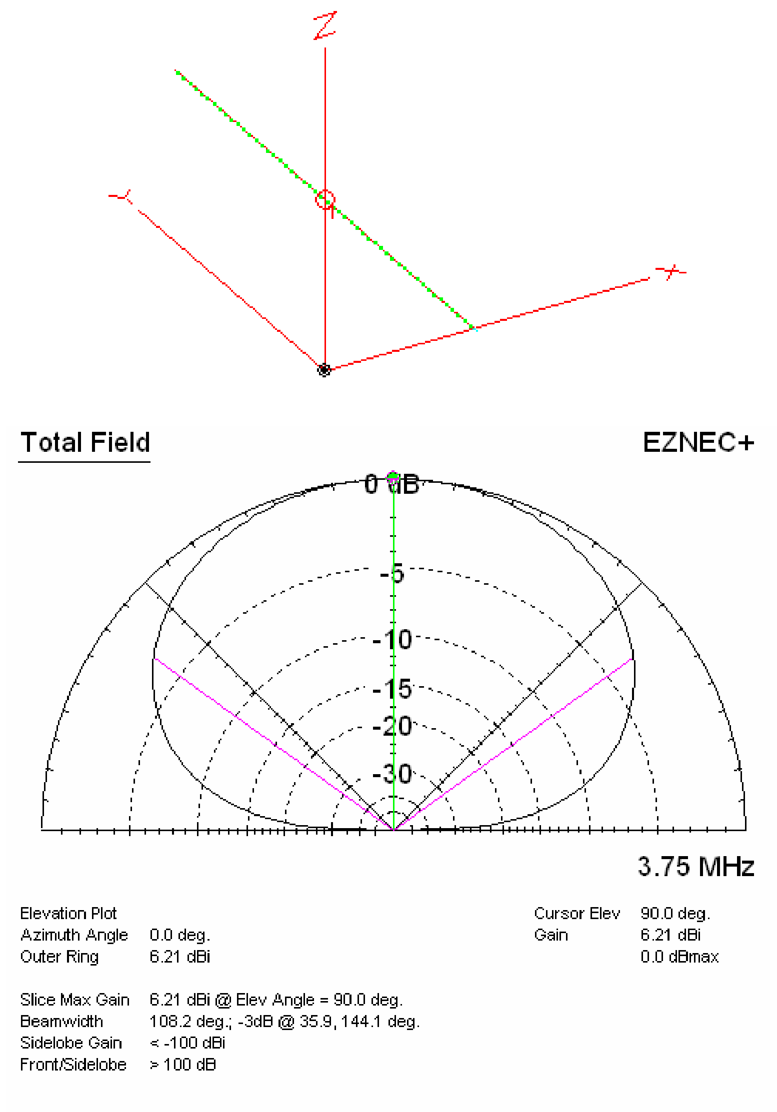


Figure 2: Elevation Pattern of An NVIS 75m Dipole

The azimuth plot is also almost perfectly circular as shown in Figure 8.

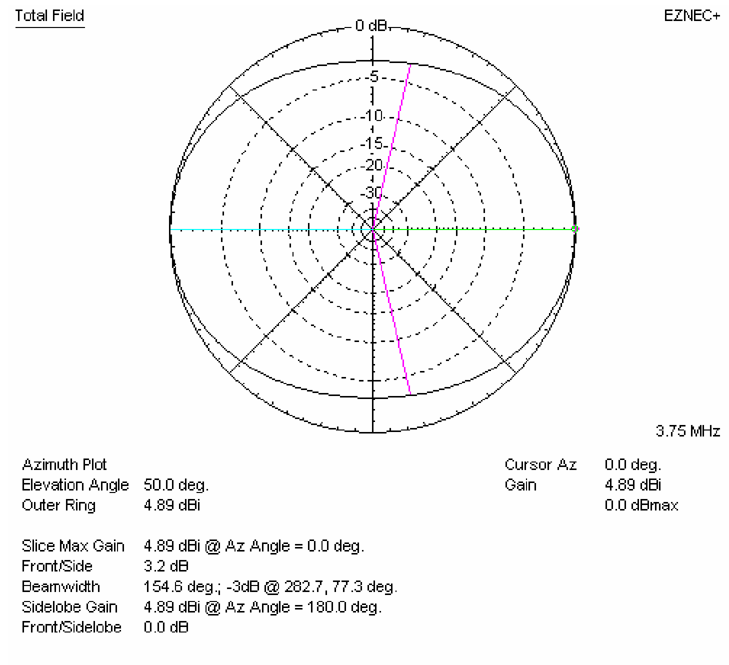


Figure 3: Azimuth Pattern NVIS 75m Dipole

. If this same dipole were placed at 0.5 wavelengths or 131 ft. height, the classical DX elevation and azimuth patterns shown in Figures 4 and 5 are produced.

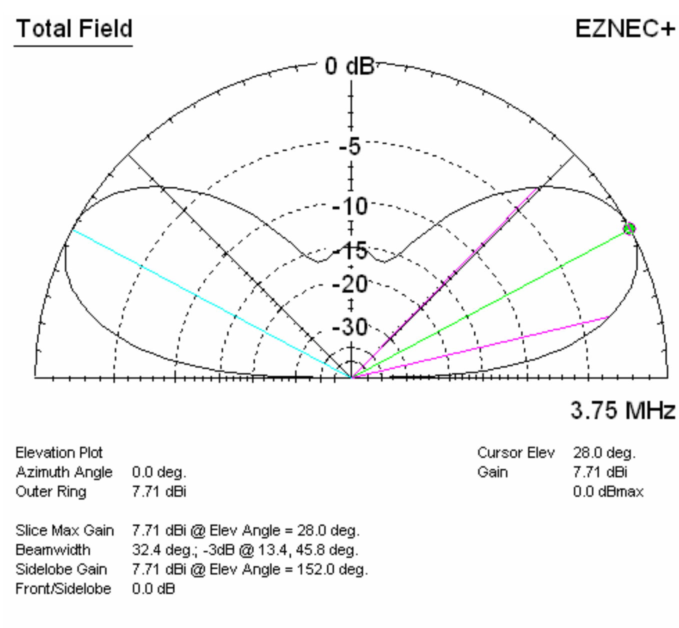


Figure 4: Elevation Plot of 75m Dipole at ½ Wavelength Height

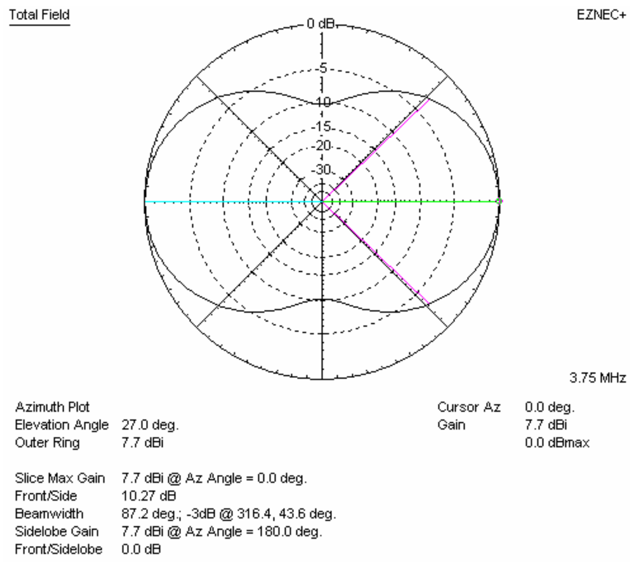


Figure 5: Elevation Plot 75m Dipole at ½ Wavelength Height

As can be seen when comparing Figures 2 and 3 with Figures 4 and 5, the 75m dipole goes from NVIS to DX by changing the height above ground from 0.15 to 0.5 wavelengths. Even the azimuth pattern becomes almost omni-directional as the antenna is lowered. The optimum NVIS height above ground can be seen in Figures 6 and 7 courteous of L.B. Cebik, W4RNL.

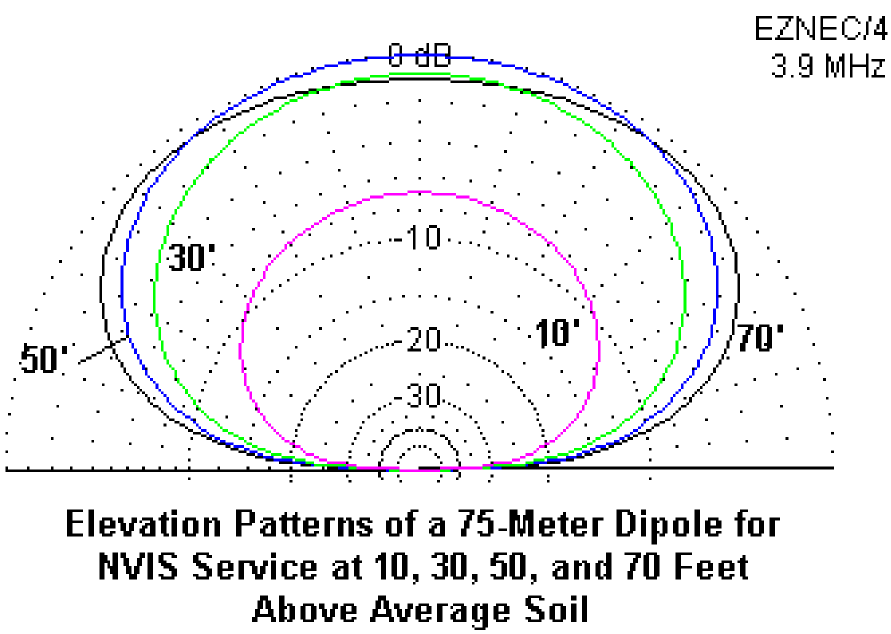


Figure 6: Gain and Elevation Plots of 75m NVIS dipole at Various Heights

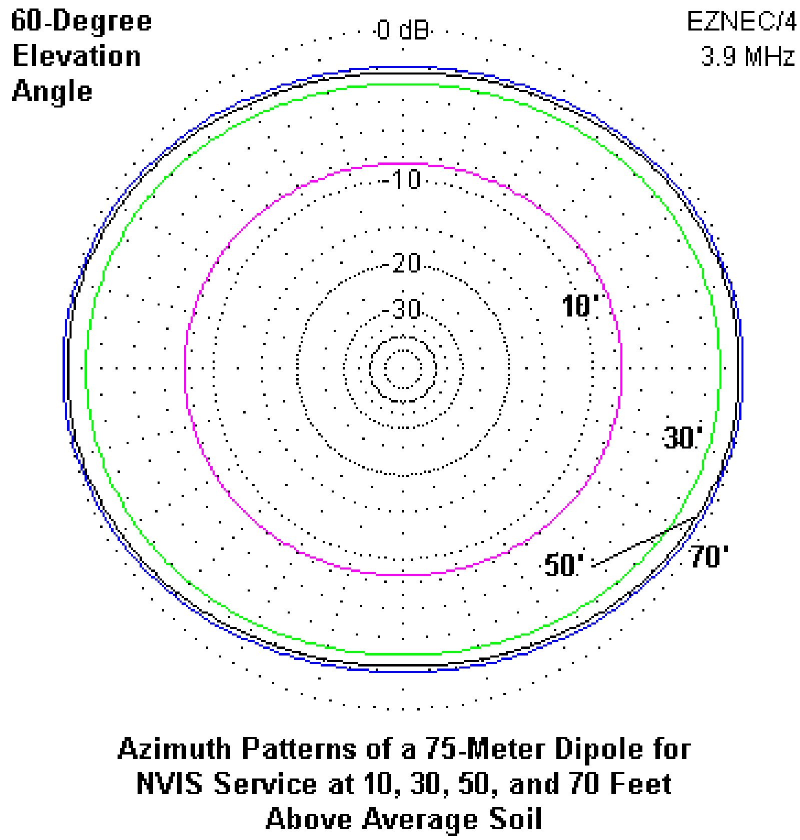


Figure 7: Gain and Azimuth Plots of 75m NVIS dipole at Various Heights

Note that the relative size of each plot, in different colors, represents the gain of the antenna at different heights. As can be seen in Figures 6 and 7, heights of between 30 and 50 ft. or 0.1 to 0.2 wavelengths worked quite well. Therefore, one height of 40 ft would work from 3.75 MHz all the way to 7.2 MHz covering the 75m, 60m and 40m NVIS frequencies.

Generating the Correct Antenna Pattern – Optimum Length

A horizontal dipole that is significantly longer than one-half a wavelength will have an azimuth pattern that departs from omni-directional as shown in Figure 8. For brevity, I have switched to a 3-dimensional plot for the following discussion. The azimuth plot is in the X-Y or horizontal plane. You can see a significant departure from a spherical pattern to that of an elongated ellipsoid (watermelon) shape.

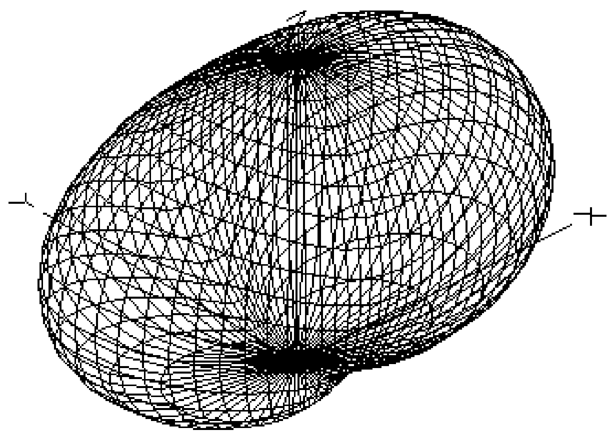


Figure 8: 75m NVIS Dipole Pattern at 40m

While this is still a useable NVIS pattern at twice its design frequency, attaching a 40m dipole to the driven point will significantly improve this pattern as shown in Figures 9 and 10. Antenna height is still 39 ft.

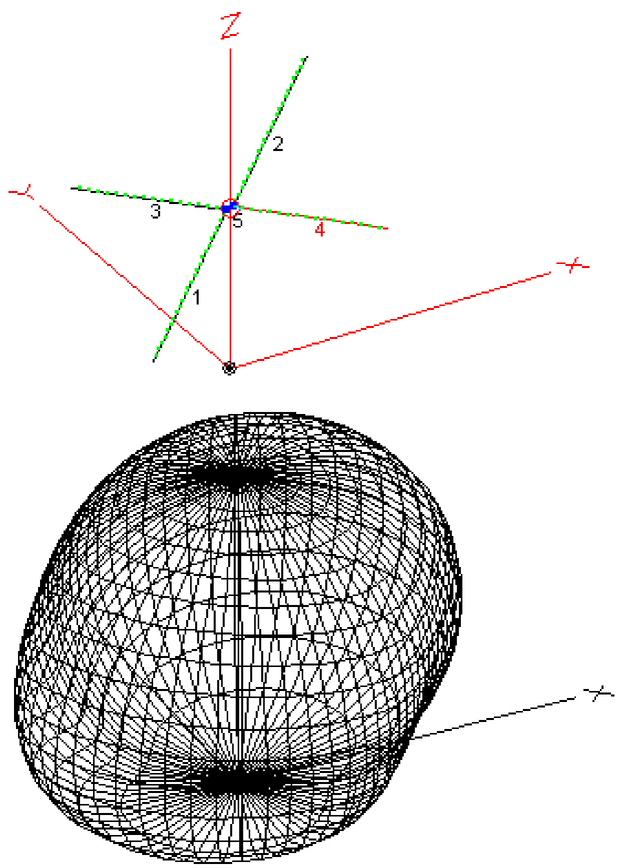


Figure 9: Cross-Dipole Antenna Pattern at 40m

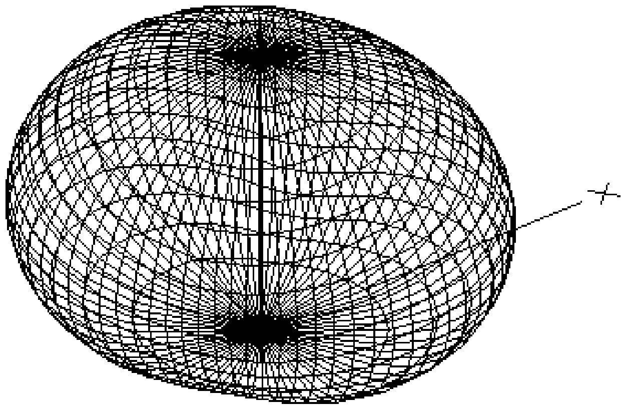
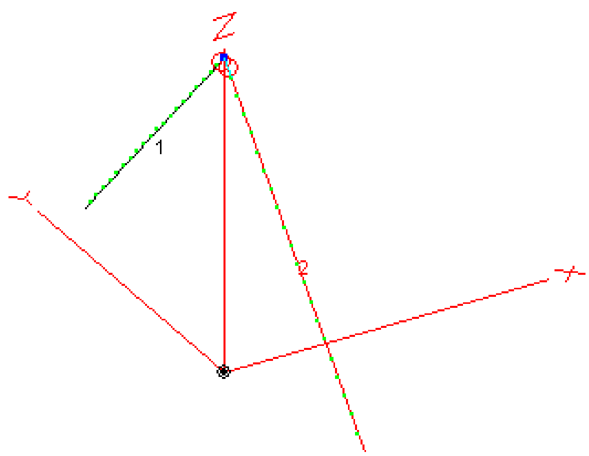


Figure 10: Cross-Dipole Antenna Pattern at 75m

A similar effect can be achieved by raising the apex of the 75m dipole to 50 ft and slopping the legs down at 45º, creating the familiar 75m inverted-V antenna. This will result in good NVIS patterns, shown in Figures 11 and 12, at frequencies between 3.75 MHz and 7.2 MHz but with a penalty of about 3 dB loss in gain at both frequencies when compared to the cross dipoles of Figure 9.



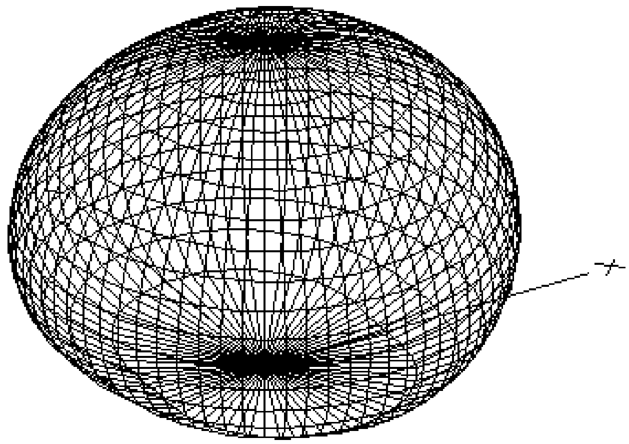


Figure 11: 75m Inverted-V NVIS Antenna at 3.75 MHz

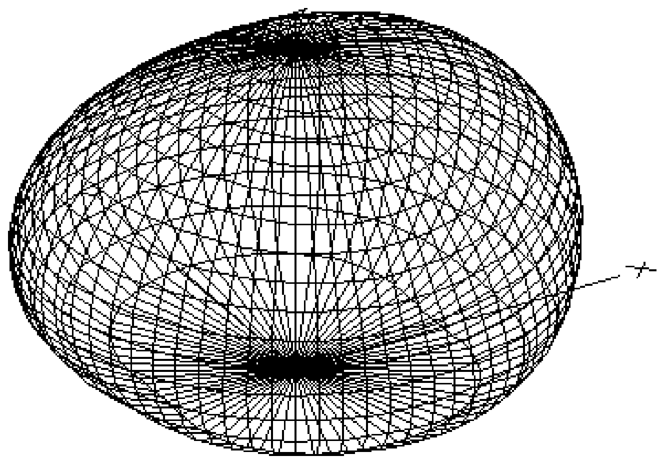


Figure 12: 75m Inverted-V NVIS Antenna at 7.2 MHz

Antenna Impedance Match

Once you have designed a NVIS antenna that can produce proper directivity patterns over the necessary HF tactical NVIS frequency range (3.6 MHz to 7.3 MHz) your task is only one-half complete. This wide-band antenna system must also provide a usable impedance (50 Ω) over this frequency range so it will accept RF power from the transmitter. Standing wave plots (SWR) for both the 75m dipole and the cross-dipole antennas are shown in Figures 13 and 14.

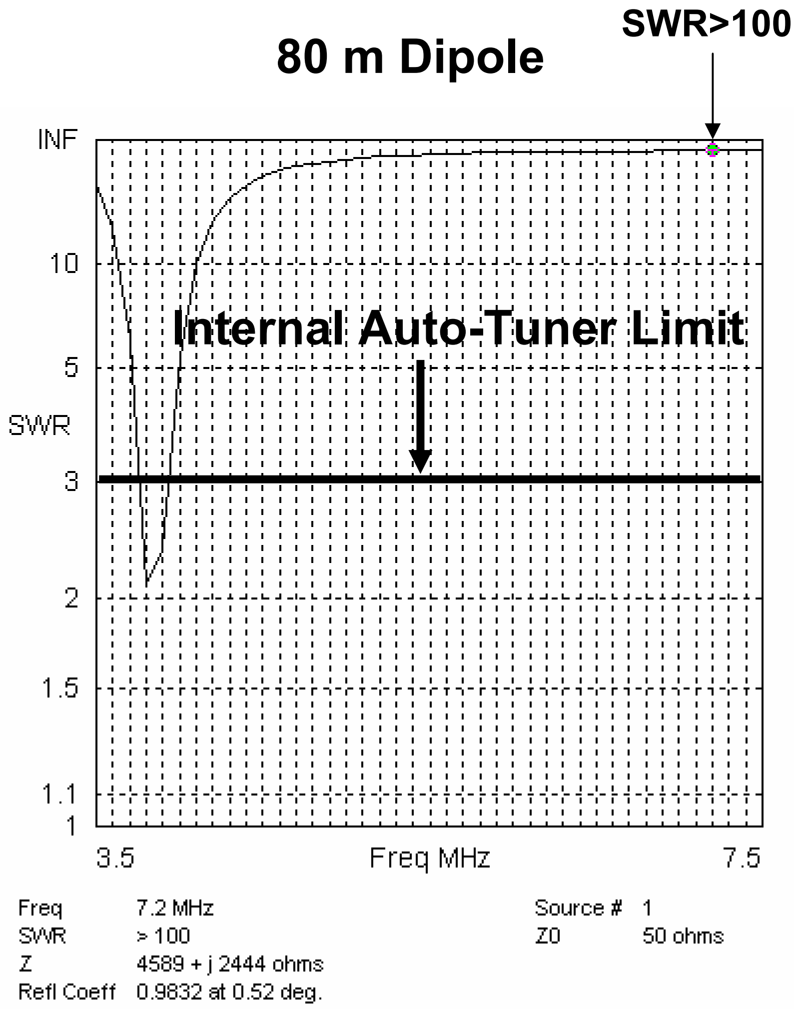


Figure 13: SWR Plot of 75m NVIS Dipole

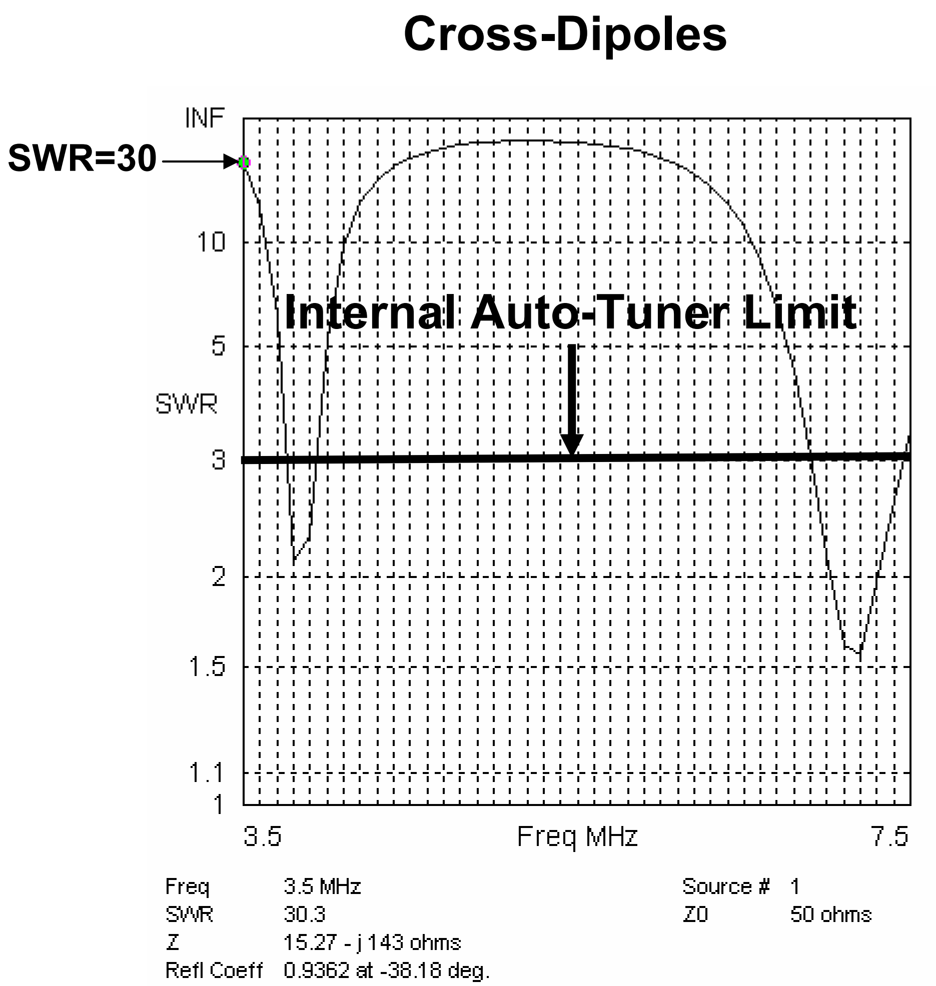
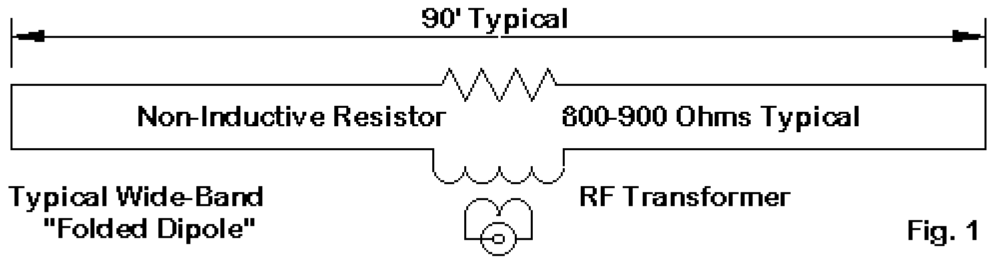


Figure 14: SWR Plot of Cross-Dipole NVIS Antenna

Also shown on each of these two plots is the typical 3:1 SWR internal auto-tuner limit of today's modern HF transceivers. Note that the typical required SWR tuning range for MARS frequencies can be greater than 100:1 for an 75m dipole and even for the cross-dipole antenna, as high as 30:1. To follow is an incomplete list of possible solutions to this problem:

A. **Separate Tuned Wires For Each Frequency** – A "fan-dipole" antenna with separate resonant ½ wavelength wires for each frequency (75m, 60m and 40m) can be constructed. This will require extensive measurement and trimming since there will be interaction between the separate dipoles. If this antenna is moved for portable operation, it will need to be retuned.
B. **Terminated Folded Wide-Band Dipole (B&W series)** – Several companies make special wide-band folded dipoles with a termination load resistor and matching transformer as shown in Figure 15 (Fig. 1).

From: http://www.cebik.com/wire/wbfd.html



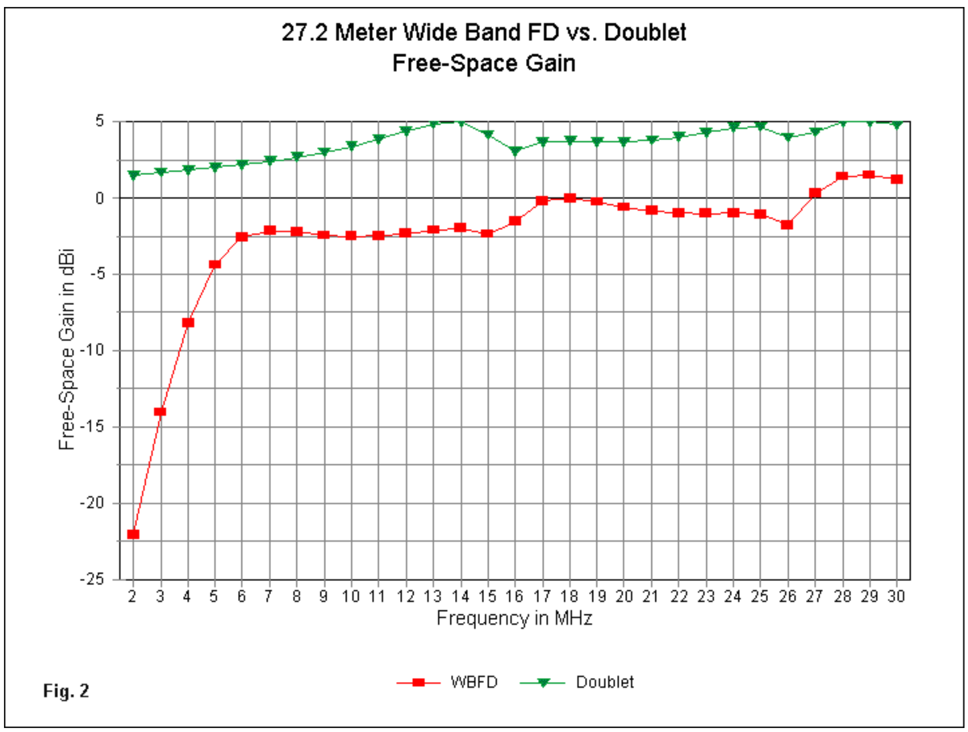
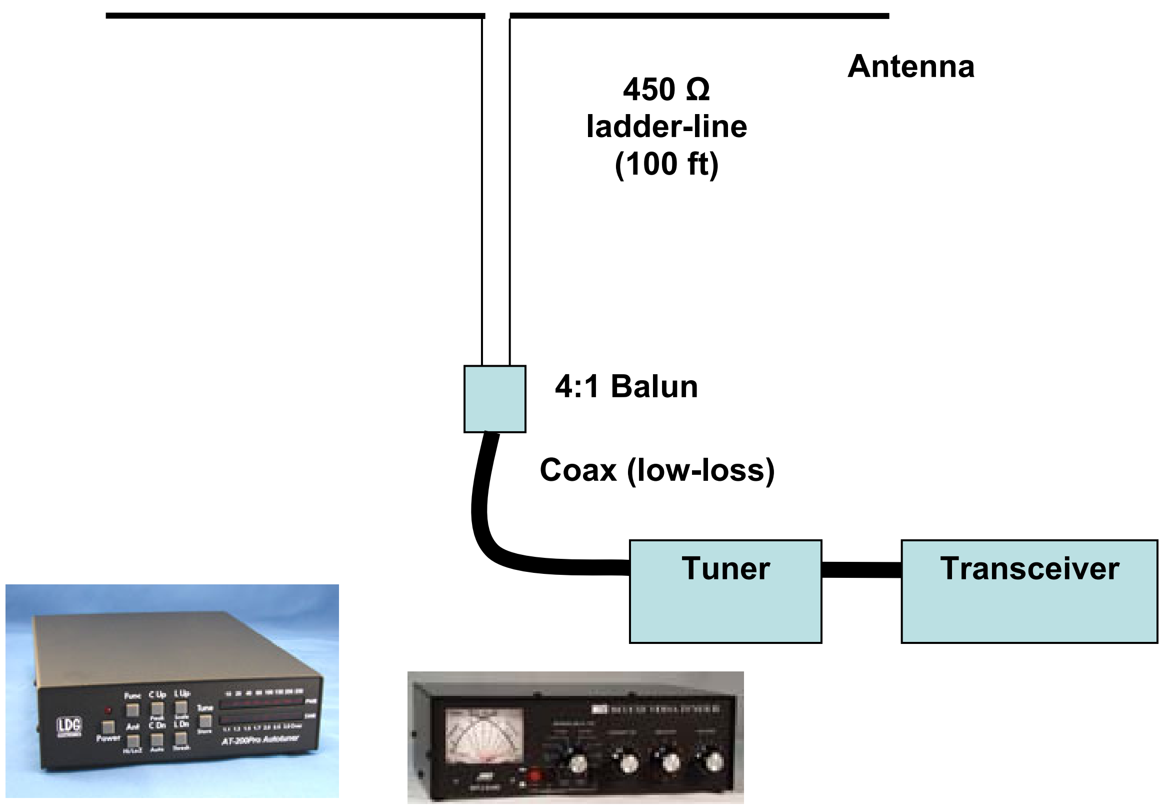


Figure 15: Terminated Folded Wide-Band Dipole Performance

These type of antennas have SWR that vary only about 2:1 over frequency ranges from 2 to 30 MHz. The problem is that they are considerably less efficient that the same length dipole (Doublet) as shown in Figure 15. The difference in gain (5-6 dB) translates into an efficiency difference of about 75% when compared to a dipole of the same length.

C. Tuner Located at the Rig – The high SWR at most frequencies can cause significant losses in the transmission line if it is not extremely low loss. For example, given that RG-8U has a loss of 0.55 dB/100 ft, then a SWR of 20 at the load would add an additional 2.5 dB for a total of 3.05 dB or one-half power. The losses for SWR values of 100 would leave very little signal at the antenna. At this same frequency, the losses for 450 Ω ladder-line is not measurable.

Figure 16 shows a typical arrangement for minimizing losses when a tuner is use at the rig location. Low loss 450 Ω Ladder-Line is used for the majority of the transmission line run. Near the entrance to the shack, a 4:1 balun and a short length of low-loss coax (RG-8 or Belden 9913 for example) are used to complete the connection between the antenna and the antenna tuner. If proper high-voltage bulkhead feed-throughs are available, the ladder-line can be connected directly to the antenna tuner, eliminating the losses in the balun and coaxial cable.



LDG-AT 200 Pro MFJ – 949E

Figure 16: Wiring Arrangement For A Tuner Located At Rig

The antenna tuner must be able to handle 100 watts (or your actual power) at SWR ratios of at least 20:1. The impedance matching for a wide range antenna tuner is typically stated as 6 to 1000 Ω.

D. Tuner At The Antenna – The method favored by the military and marine antenna designers is to place an auto-tuner at the antenna as shown in Figure 17. These tuners can typically tune an antenna as short as 8 ft from 3.5 MHz to 30 MHz. They require about 1 ampere at 13.5 VDC to provide power to the microcomputer located within the housing. The SGC and MFJ antenna tuners need only this DC power and about 10 watts of RF to allow the auto-tuner to match the antenna to the 50 Ω coaxial cable. DC can be transmitted up the coaxial cable and separated at the top and bottom using coaxial line isolators, available from both companies. The ICOM AH4 has both a coaxial cable and a 4 wire control cable and is designed to only operate with compatible ICOM HF transceivers (Ham and Marine). The three auto-tuners shown are water-tight but their plastic housing must be shaded from the Texas sun. In addition, the sensitive electronics must be protected from EMP (Electromagnetic Pulse) damage from nearby lightning strikes. I am presently using a high-voltage relay, energized from the microcomputer DC line, to disconnect and short the tuner to ground when not in use. A schematic of this protective circuit can be seen in Figure 18.

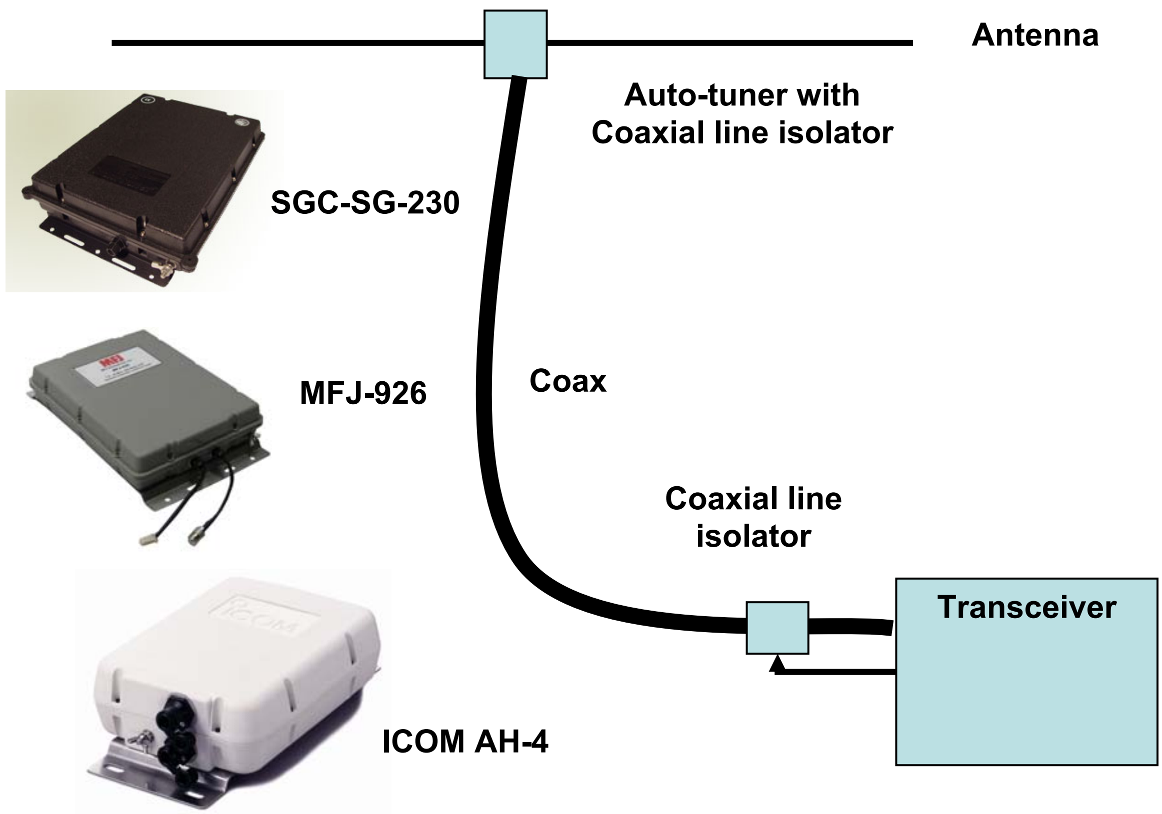


Figure 17: Tuner At The Antenna

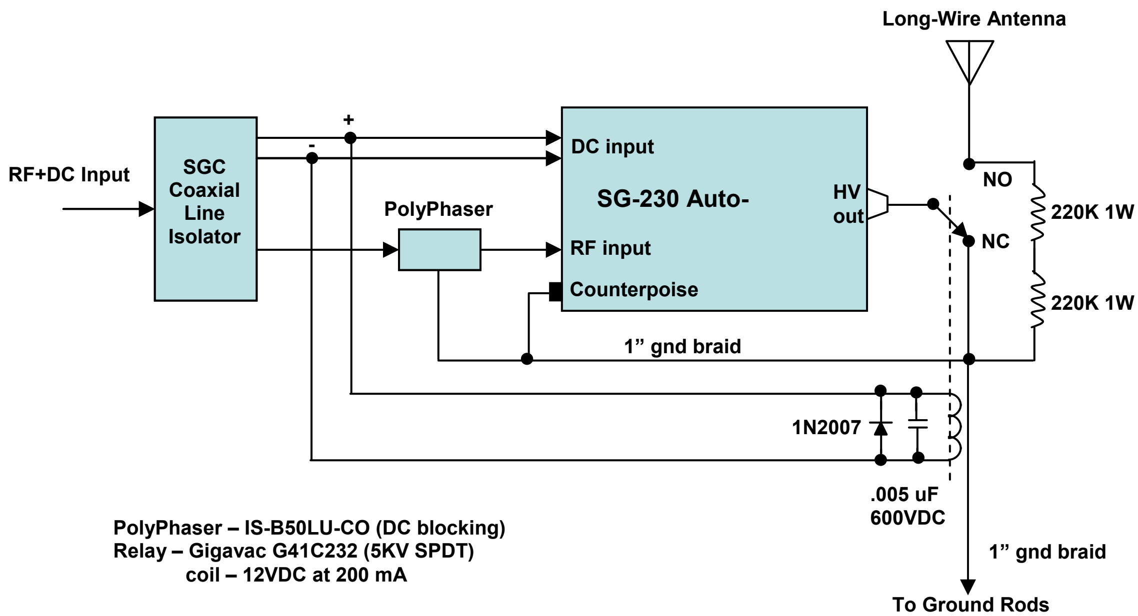


Figure 18: Auto-Tuner Lightning Protection Circuitry

In conclusion, a tactical HF NVIS antenna consists of a horizontal radiator at a height of approximately 0.15 wavelengths that has a special matching network that allows operation over a frequency range from 3.5 to 7 MHz. The length of this radiator needs to less than one-half wavelength or sloped to maintain an omni directional horizontal directivity pattern. A much more detailed discussion of this subject can be found on the Texas Army MARS website - http://www.txarmymars.org/downloads/NVIS-Antenna-Theory-and-Design.pdf