NVIS – Near Vertical Incident Skywave Antenna:
The Emergency Communications Antenna

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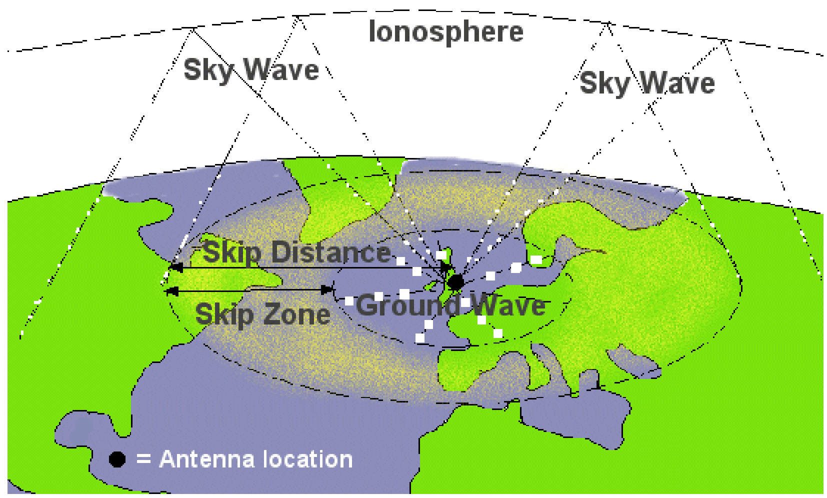
Introduction

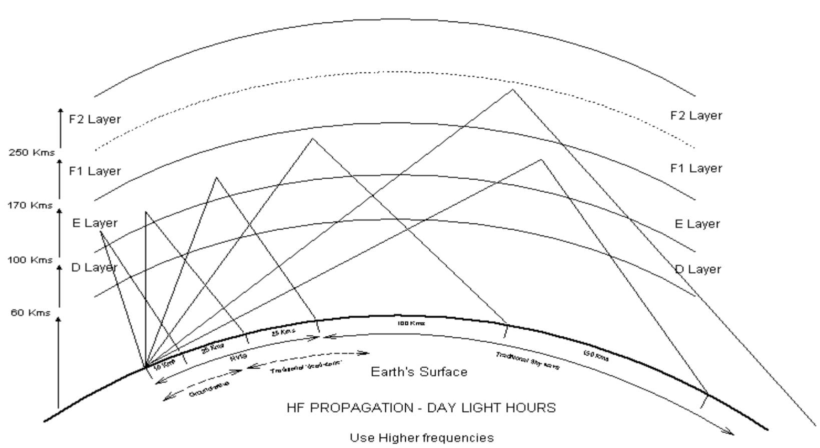
The antenna axiom, “the higher, the better,” is true for working distant stations. Generally antennas that are installed physically high up tend to have more of their radiated energy leaving the antenna at a lower angle . This causes the skip distance of our signal to be as far away as possible. Depending on the sunspot cycle, time of day, and transmitter frequency, that distance can be from 300 miles at 3.5 mhz to worldwide communications at 14-28 mhz.



But what if we need reliable communications with a station 25 or 100 miles away. Regardless of frequency, our signal skips over the close-in station and no communication is possible. Yes, there is ground wave, but in our mountainous terrain, ground wave may be only a few miles, and then not very reliable. What do we do to eliminate this “skip zone?”

Our answer is not to increase power, try to set up VHF repeaters, or other drastic measures. The answer is simple, install an NVIS antenna, select the appropriate operating frequency, and reliable communications from 0 to 300 miles becomes very achievable.

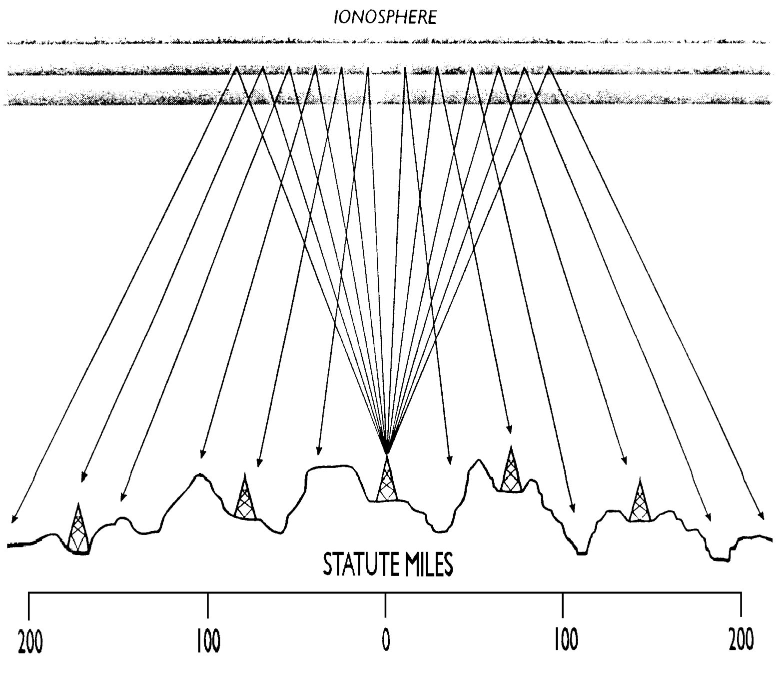
Propagation



As the signals leave the antennas, they travel up and are refracted off the various ionosphere layers. The lower the signal’s incident angle and the higher the layer of refraction, the farther away from the transmitter the signal returns to earth.

For most hams’ “typical operation,” we seldom care where our signal lands. We are interested in communication with anyone. Sometimes, we choose frequencies to increase our chances to "work" a station in a far-distant place. Some hams pour over propagation charts, design elaborate antennas, and operate at all hours of the day and night to "bag that rare one."

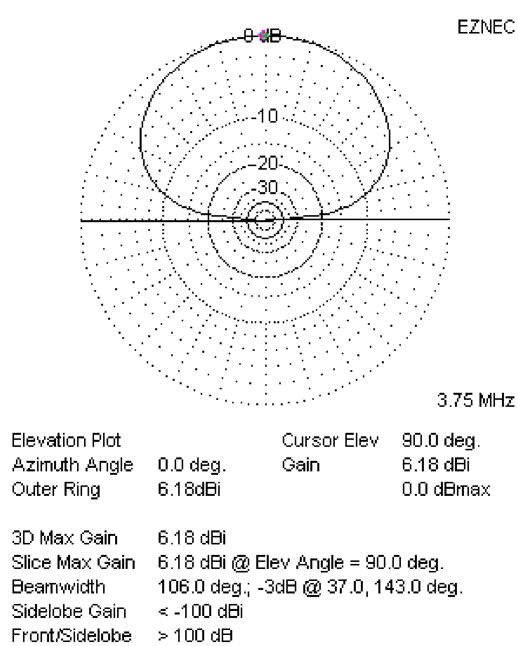
When close-in, reliable communications is need, guess-work and luck is not good enough. Our understanding of frequency verses propagation becomes even more critical. What we need is propagation that covers from about 10 miles up to 400 miles with no skip zones.



We can see from the diagram to the left, that signals which leave our antenna in a near-vertical direction will travel up to the ionosphere and are reflected back. It is like spraying a hose in a fine droplet pattern, straight-up. The droplets of water fall back to earth in a pattern that covers the ground evenly with moisture close to where we are standing. The pattern from an NVIS antenna does much the same with the transmitted signal. The majority of the signal is transmitted between 75 and 90 degrees straight-up. In fact the 3D antenna pattern looks like a bowl set upside down.

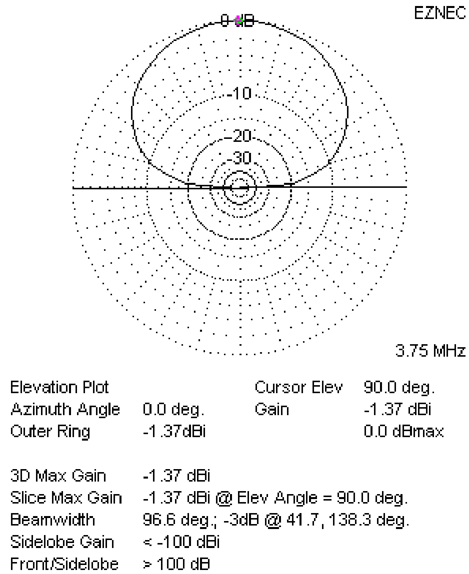
The Antenna

The simplest NVIS antenna is a dipole cut for resonance on the operating frequency and installed at 1/8 wavelength above the ground. For the ARES ssb frequency of 3928 khz, the antenna would be about 120 feet long and mounted at 30 feet. With our rocky, dry ground, lowering the antenna to 20 feet may be advisable as the effective ground lies below the surface of the actual ground. In fact any height from laying the wire on the ground, to an 1/8 wavelength will work. The main difference between the higher antenna and the lower antenna is the gain or loss of the antenna.



The EZNEC pattern shows the radiation pattern for an antenna mounted 1/8 wavelength off the ground. Notice that most of the energy is between about 30 degrees both sides from vertical. This where we want the energy to go. Notice the gain of the antenna is about 6 db. This over perfect ground. It will be less over actual ground, but ant any rate, the antenna will have a positive gain.

With is this diagram, we have lowered the antenna from 1/8 wavelength (32 ft.) to 9 feet. Notice that the pattern is nearly identical. However, the antenna gain has dropped from 6 dbi to -1.37 dbi. This means that the signal radiated off the 9 ft. high antenna is less than 1/4th the signal radiated off the 32.5 ft. high antenna. While this seems significant, the questions is "Is this loss actually significant in received signal strength?"



Path Losses

Lets take a look at the received signal strength as transmitted by different transmitter output levels. The large table, *Very Close-in stations,* shows the received signal strength for both the 1/8 wavelength (32.5 ft.) and the 9 ft. antenna height.

Even with the low antenna of only 9 ft., the received signal strength is still an S7. Most receivers have a noise floor of better than -125 dbm. However, the average noise level of 75/80 meters is about -112 dbm or an S3. That means that for a +10 dbm SNR (signal to noise ratio), the received signal strength must be -102 dbm or an S4-5. Notice that regardless of which antenna is used, the received signal strength is at least -82 dbm or S7 with using one watt at 9 ft. . .So even an inefficient antenna will work quite well for close-in communication.

Distance between Stations in Communication

Both antennas have a -3db bandwidth of approximately 100 degrees or 50 degrees either side of vertical. We can calculate the take-off angles required to communicate with close-in stations at various distances. Once we assume the height of the F2 -layer, simple geometry is all that is needed. The following table summarizes the antenna take-off angles needed when the F2 layer is 250 miles up.

Separation Distance	Take-off Angle
25.0	87.14
50.0	84.29
75.0	81.47
100.0	78.69
125.0	75.96
150.0	73.30
175.0	70.71
200.0	68.20
225.0	65.77
250.0	63.43

For very close-in stations [2]

Transmitter Output, W	db output	Transmitting Antenna Height 32.5 ft. Gain	Total Signal Out	Path Loss [1]	Receiving Antenna Height 32.5 ft. Gain	Signal At Receiver Input	S-Meter Reading	Plus
100.0	50.0	6.2	56.2	-110.0	6.2	-47.6	S9	25
50.0	47.0	6.2	53.2	-110.0	6.2	-50.6	S9	22
25.0	44.0	6.2	50.2	-110.0	6.2	-53.6	S9	19
5.0	37.0	6.2	43.2	-110.0	6.2	-60.6	S9	12
1.0	30.0	6.2	36.2	-110.0	6.2	-67.6	S9	5

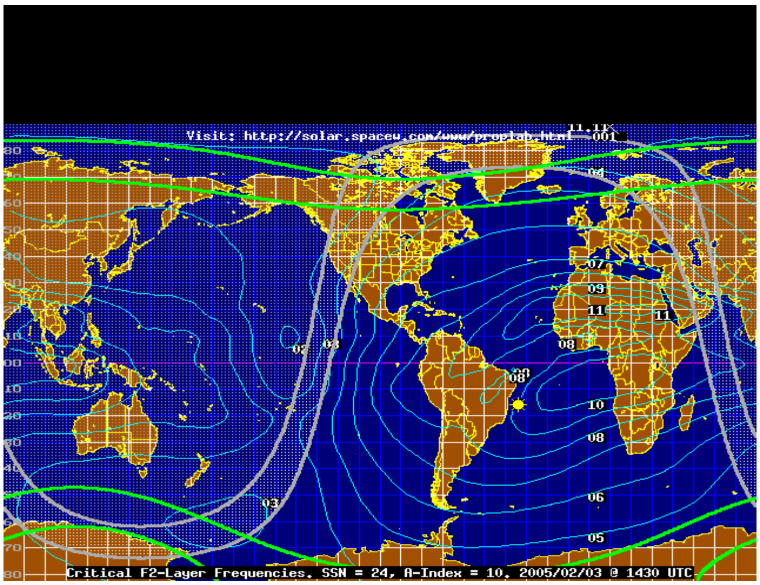
Note: -73 db is S9 at 50 ohm input.

[1] As calculated by the "TwoHop" propagation program with my adjustments. Does not include transmission line losses.
[2] Stations within 50 miles of each other.

Transmitter Output, W	db output	Transmitting Antenna Height 9 ft. Gain	Total Signal Out	Path Loss [1]	Receiving Antenna Height 9 ft. Gain	Signal At Receiver Input	S-Meter Reading	Plus
100.0	50.0	-1.4	48.6	-110.0	-1.4	-62.8	S9	10
50.0	47.0	-1.4	45.6	-110.0	-1.4	-65.8	S9	7
25.0	44.0	-1.4	42.6	-110.0	-1.4	-68.8	S9	4
5.0	37.0	-1.4	35.6	-110.0	-1.4	-75.8	S8	
1.0	30.0	-1.4	28.6	-110.0	-1.4	-82.8	S7	

Selecting the Correct Frequency

Besides having low antenna height, the next most important factor is selection of the proper operating frequency. We need to select a frequency that is reflected by the F2-layer, but is not absorbed or significantly degraded by the D-layer. The higher the frequency, the less the D-layer will affect the signal. However, too high a frequency, and the signal will pass through the F2-layer.



Fortunately, we can determine the best operating frequency from propagation information on the internet and some relatively simple calculations. A good place to find the F2 critical frequency is at http://www.spacew.com/www/fof2.html. An example is shown to the left.

This map shows the F2 critical frequency, f_o for the entire world. It is updated every five minutes so the map is very current. Other good URLs for links to many propagation information sites are http://solar.spacew.com/ and http://www.qsl.net/va3rj/prop_links.html.

Once we know the critical frequency, we can determine the proper operating frequency. The theory behind the selection is straight-forward. We need to select the frequency that is the highest possible without passing through the F2-layer. There are three concepts to recognize.

First, the critical frequency for the F2-layer is f_oF2 or just f_o. This is the highest frequency that will be reflected back to earth from the F2-layer when hitting the F2-layer at a perpendicular angle, i.e. the angle of incidence is 0 degrees.. Go higher in frequency and the signal will pass thorough the F2-layer into space and is lost for communications.

Second, MUF, or maximum useable frequency, the highest frequency we can use and still achieve good reflection/refraction off the F2-layer. The formula for MUF is:

$$\mathbf{MUF = f_o/\sin(\alpha)}$$

where f_o is the critical frequency and α is the angle of incidence.

The MUF therefore is a function of the critical frequency and the angle at which the signal hits the F2-layer. Note that the frequency can be increased as the angle of incidence is lowered. In NVIS operations, we want the signal to "hit" the F2-layer at nearly a 90 degree angle. The sine of 90 degrees is 1. In fact the sine does not fall below 0.95 until the incident angle is below 72 degrees. Since nearly all the useable radiation falls within the 90 degrees + or – 20 degrees, for an NVIS antenna, the MUF is essentially the critical frequency.

The third concept is FOT, frequency of optimum traffic. The FOT is the frequency where nearly 100% communication is achievable. The formula for FOT is:

$$\mathbf{FOT = MUF * .85}$$

Or for an NVIS antenna

$$\mathbf{FOT = f_o * .85}$$

A amateur radio operators, we are limited to ham bands for operation. Thus, our frequency selection becomes choosing the 160, 80, 60, or 40 meter bands for our communications. As a side note, the importance of the 60 meter band becomes apparent when considering reliable emergency communications. The gap between the 80 and 40 meter bands is very large when there is a need to establish a reliable, close-in communication link.

Finally, the FOT will change from daylight to nighttime. During the day, the F1 and F2-layers separate and the D-layer forms. This favors the use of 40 meters due to much greater absorption of 80 meter signals by the D-layer. During the gray light times, 60 meters may be come the FOT.

At night, the D-layer disappears and the F1-layer merges with the F2-layer. Thus, during the day, FOT will be higher than in the nighttime. During sunspot minimums, the FOT may even be in the 160 meter range during the night. However, using 160 meter, horizontal antennas can be a problem because of size.

Using EZNEC, if the 3.715 mhz dipole is used at 1.8 mhz, the antenna losses at 30 feet height are about -3 to -4 db loss. This still means that the received signal should be greater than 10 db over the noise level when a 25 watt or greater transmitter is used. At`1.8 mhz, even though the SWR of the antenna system is very high, the additional losses due to SWR are minimal.

In Summary

In order to achieve reliable , close-in communications, normal amateur antennas may not work. To achieve reliable communications, NVIS techniques are needed. A simple resonate dipole installed at a height up to 1/8 wavelength works very well as the majority of the radiated signal goes straight up.

This "Near Vertical Incident Skywave" hits the F2-layer and is reflected back to earth equally covering the surface with signals from 10 to about 400 miles from the transmitting station. It is necessary to select the proper operating frequency in order to achieve the optimum NVIS operation. Choosing frequencies near 85% of the F2-layer critical frequency are best for use.