Near Vertical Incident Skywave (NVIS) Antenna

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Overview

The Near Vertical Incident Skywave (NVIS) antenna is one that provides the majority of its radiation at an extremely high angle. That is to say the major lobe is between 75 and 90 degrees to the earth's surface. This will provide excellent omni-directional communication for a distance of 300 to 400 Kilometers. The maximum frequencies involved will be as low as 2 Mhz under very poor conditions to as high as 14 Mhz under excellent conditions, with the average being between 3.5 Mhz (80M) and 7.3 Mhz (40M).

When I first started looking at the NVIS antenna for "local" communication the consensus seemed to be that it was a dipole-type antenna, near 1/8th wave at the operating frequency, above the ground. If you are running the military, non resonant antennas, that seems a fair description. The difference is that many, if not most, horizontally oriented antennas have an NVIS component in their radiation.

How then do we determine what NVIS antenna will best suit our needs? The answer to that question is both simple and yet quite complex. Let me begin by addressing specific parameters that have significant effect in antenna performance. Before we get there, let me say that this is information on how to make it work, NOT a graduate degree treatise on the theory of NVIS.

Height above ground

The antenna height above ground seems to be the single most controversial subject in discussion of NVIS antennas. Some say anything below 1/4 wave works. Others say anything below 1/8th wave and yet others - myself included - use ten to fifteen feet as the optimal height. The university in Missoula Montana has posted some NEC modeled comparisons that you can review. You will note that there is negligable difference in antenna gain between 1/8 wave and 1/4 wave height. There is however a significant difference in the logistics of placing an antenna at 70 some feet in the air versus 35 feet in the air. First, let me give you some of the other rationale on why I chose the ten to fifteen foot height.

The Near Vertical Incident Skywave (NVIS) antenna is a half-wave dipole antenna mounted not over 1/8th wave above ground (at the highest operating frequency). While 1/8th wave works reasonably well, better coverage is obtained if the antenna is mounted at about 1/20th wavelength above ground. A second advantage of lowering the antenna to near 1/20th wavelength is a lowering of the background noise level. At a recent S.E.T. communication on 75 Meters was started with a dipole at approximately 30 feet. We found communication with some of the other participants to be difficult. A second 1//2 wave dipole was built and mounted at 8 feet off of the ground. The background noise level **went from S7 to S3** and communications with stations in the twenty-five and over mile range were greatly enhanced. Simply stated, you want as much of your signal going up as possible and ten to fifteen foot height has shown to function **very** well.

I have had many people write to tell me about the results they obtained simply by lowering an existing antenna to the ten to fifteen foot level. ALL are consistently amazed at how much better the "local" (less than 300 miles) signals are. Most comment at how much stronger local signals are when others are also using NVIS antennas.

A specific example is a friend who lives about 160 miles away with the Continental Divide between us (many mountains in the 12 to 14 thousand foot elevation). Steve built an NVIS antenna to compare with the G5RV he has at 30 some foot height. The signal reports **went up by about 15db**. No other change, just went to an NVIS at fifteen feet and the signal went up considerably. It works!

Any horizontally polarized antenna will have an NVIS component in its radiation. To maximize the NVIS component, you need to run the antenna at ten to fifteen feet above the ground. Will it work if lower? Yes it will, reference WA6UBE tests. Will it work if it is higher? Yes, but the NVIS efficiency goes down. Field tests have proven that maximum NVIS efficiency is obtained at the ten to fifteen foot height for frequencies in the 40M to 75M range.

Modeling

At a local Radio Club meeting one of the Engineers did a presentation on antenna modeling using the NEC software. During this presentation he modeled a 75M dipole first in free space, then at one wave length above ground and then at ten feet above ground. The software showed that *at ten feet the radiation pattern closely resembled a round ball sliced in half and mounted at fifteen degrees above the horizon.* This is a direct correlation to field observations! Man-made noise will tend to be received in the low ten to fifteen degrees above the horizon, thus the lowering of background noise. We have also observed consistent omnidirectional coverage with the signals from NVIS antennas in the ten to fifteen foot height.

As mentioned above, there are NEC plots of an 80M dipole at various heights posted by the university at Missoula, MT available for your review.

Ground

Yet another consideration is the "quality" of the ground below your antenna. By this I mean the conductivity of the ground you are operating above. For any given height (1/8th wave length or less) poor conductivity will attenuate up to 3db more of your signal than high conductivity soil. A very specific example is the ARES installation in Longmont, CO at the Emergency Operations Center. That antenna is mounted ten feet above a flat roof. The base for the roof is a grounded steel plate. This antenna consistently performs as well or better than any other in the state. The reason is simple. A full sized resonant dipole antenna mounted ten feet above an excellent ground.

A specific example of how well the Longmont EOC antenna works is one Sunday when we were testing the antenna, a friend tried his Yaesu FT-817 running on the internal battery pack. As most know, that configuration produces 2.5 watts PEP maximum output. At that power level we received a signal report from NCS in Colorado Springs (90 miles South) of **S9+10db, on 75M** just before the net started.

Another example of how the conductivity affects your signals comes from my area where we regularly use NVIS antennas on 60M to communicate across the Continental Divide. Doing this on a twice weekly basis for more than a year now we have established a base-line for comparison. The week of 9/23/04 we had a slow moving rain storm that put down more than one inch of rain spread evenly over about 36 hours. For those of you that have thirty to fifty inches of rain per year, that would not be much. Here in Colorado that is one-fifteenth of our total annual precipitation. After the rain, under less than optimal band conditions, signals were **UP 6 to 10db!**

Ground mounted Yagi?

One other consideration may be the addition of a "ground" wire positioned to operate as a Yagi type reflector below the driven element. The problem there is that the recommended spacing is .15 wave lengths or about 34 feet for 75M. As noted above reducing the antenna height from 30 feet to 8 feet reduced the background noise level by 4 "S" units thus while the reflector may increase the efficiency of the transmit signal, it reduces the usable signal strengths of received signals. A received signal of S6 would work fine with the antenna at 10 feet but not be heard with the antenna at 30 feet - in the S.E.T. example above.

Ground wire

Yet another approach is to run a "ground" wire at the surface where the antenna is mounted. A good discussion on this is found at an Australian site by Ralph Holland. He did some research on 160M and found that a ground wire at .02 to .06 wave lengths below the driven element produced the best gain. That translates to about 5 to 15 feet at 75M which would be consistent with the heights that produce the best NVIS performance. Others that I have talked with claim at least a 3db improvement with this same approach.

I am just completing some trials with a ground wire (actually two) under the random length wire antenna detailed below. I ran two parallel wires on the surface of the ground, connected to a ground rod at the house end, separated about twelve inches and approximately centered under the random length wire antenna. This configuration produces more than 6 db improvement on the transmit signal and a slight improvement on receive. Well worth the effort.

I am working on a "ground" wire connected to the mounting bracket for the "Ham-stick" dipole (below) running down the side of the mast. The results of preliminary tests were inconclusive. Even well established antennas were not functioning properly the day I was able to test so I discount the transmit results. I did notice a few interesting items while doing the setup. With a ground wire running from the bracket, down the mast and connected to various lengths of wire laying on the pavement, the resonant frequency of the antenna changed slightly (10 Kc shift) and the SWR varied slightly, from 1.5:1 to 1.6:1 to 1.4:1 - depending on the length of wire below the antenna. The lowest SWR was from a half wave length long wire 11 feet below the antenna. Gee, does that imply resonant antennas provide a better matched load? ;-)

Examples

Dual "Ham Stick" version

Another configuration that shows promise is to take two monoband mobile antennas and mount them base to base with one being the driven element and the other being the ground side. Care must be exercised in tuning this configuration that the elements are the same length. In testing this configuration it is interesting to note the change in resonant frequency as the antenna is raised above ground. There was a shift of 50 Kc (higher frequency) in raising the antenna from five feet to ten feet. Raising the antenna above ten feet made no appreciable difference in resonant frequency.

The two monoband mobil whip antenna talked about above has been field tested with excellent results. The 75M version was tested and then we switched to the 40M version. In both cases we found that the twin mobile antennas delivered a signal of 1 to 2 "S" units (read that about 10db) down from a full sized wire dipole at the same height. This is consistent with what you would expect from a loaded antenna. The great part is that the signal on 40M (from the plains of Eastern Colorado to a mountain town behind Pikes Peak - about 100 miles away) was an **S9+10db** from a 100 watt PEP radio.

The ones I used are available at HRO. Antennas are Ironhorse IHF75's and IHF40's (two each) and the Ironhorse IH-DAK-AD adapter. Total cost for four antennas and the mounting bracket is $117.96 including sales tax. I also use Radio Shack tripod and five foot mast sections for simplicity.

What works well?

There are many configurations that will work well. I will detail those that seem most useful as I am able to verify the results. Each will either be a link or details of what really works. I have come across far too many claims of extraordinary performance that no one else seems to be able to duplicate. Thus this section.

Last update: 12/15/04

- **Random wire**: An LDG 4:1 balun feeding 112 feet of number 14 wire with an average height of ten feet works quite well. Please note: It will **NOT** work with many auto tuners, but a good manual tuner will produce good to excellent results. Make sure you have a very good ground! A ground at the balun and at the rig may not be sufficient. One at the balun, one at the tuner and one at the rig work well. This is multi-band (75M, 60M and 40M) NVIS and is acceptable for general use on other bands. See the comments above about running a grounded wire underneath this antenna for better efficiency.

- **Dual Ham-Stick** detailed above. This is a portable antenna that does well under ARES/RACES operating conditions. One person can put this up and have it operational in under five minutes! A side advantage of this antenna is its comparatively small size. It is only sixteen feet in length, which makes it much more reasonable for temporary installations.

- Quick and Easy NVIS from your vehicle. Thanks to K6SOJ.

- I have continued to work on the multi-band NVIS with good results. I have single elements that tune up to 1.5:1 on 75M (the worst SWR), with 60M and 40M well below that. I then combined the 40M and 75M elements with almost no change in resonance and minimal change in SWR (they both went up by .1:1). The starting point for this is a Multi-band NVIS but details show significantly different leg lengths than I am using. The second source for information was a PowerPoint presentation from N7NVP and W6QJI. Mine end up being 219/F(Mhz)=length(feet) for each leg for mono or dual band operation (with no tuner). Tri-band operation require either a tuner or 1) lengthen the 40M and 60M elements slightly 2) shorten the 75M elements slightly.

  Test results are shown in a PowerPoint presentation that has been converted to HTML for viewing without PowerPoint (best viewed in IE - UGH!).

- I have another version of the tri-band antenna (just above) that is almost one half the size shown above but exhibits about -1 db compared to the NVISfan. I will detail full results here as soon as they are available.

- Gary Wilson, K2GW - the SNJ SEC, sent me copies of his writeup on a multi-band NVIS based on the BuddiPole antenna. He calls it the N-Vee.

- Gary, K2GW, has another multi-band NVIS plus 2M! This includes 2 pictures at the bottom of the page. K2GW NVIS.

- Do you have input? Let me know.

Enhancements to Existing Designs

I think every one of us has come across an antenna design that can be improved upon. This segment is to document those enhancements that have proven to be well worth the time. The modifications included here have been received via E-mail and are presented with the Name and Call of the author.

What works but is average at best

The classic G5RV, 102 feet long - fed with 35 feet of 450 ohm twin lead, is average at best. Least you now have steam coming out of your ears, let me explain why. The inventor - I think you know him as G5RV - created a **gain antenna for 20 Meteres**. Many people find that the G5RV antenna design functions well as an all band antenna if you use a tuner. How does it do that? Very simply, it uses the 450 ohm twin lead as a portion of the radiating element on bands such as 75M, which introduces vertical as well as horizontal polarization to the transmitted signal. If you care to look more closely about why, we find that the (approximate) feed point impedance is 50 ohms, producing a current maximum and voltage minimum. As we look at the theory associated we find that maximum radiation occurs in areas of maximum current, thus more of the signal is radiated in the vertical portion of the antenna than the horizontal portion which reduces the NVIS efficiency. In addition, to work many of the "other bands", ones that the frequency is high enough that no antenna will function as NVIS, you will have the height at 35 feet or more. Since optimal NVIS radiation occurs at ten to fifteen feet above the ground, the 35 (or more) foot height also reduces the NVIS efficiency of the antenna.

The G5RV antenna design, used at other than 20M, is a compromise. As with virtually all compromises, it loses efficiency when operated outside of the design criteria. Does that mean or imply that it is bad? No, only that there are more efficient NVIS antennas that would allow you to do the same job with less power. If you only have room for one antenna, the G5RV is a good all-around antenna.

Links to other NVIS information

- **NVIS Propagation display.**
- A good description of the NVIS and how it functions is at http://www.qsl.net/wb5ude/nvis/index.html
- ECom description is at http://www.w0ipl.com/ECom/ECom-sc.htm#knowureq
- Tactical application information is at http://www.tactical-link.com/field_deployed_nvis.htm
- L.B. Cebik, W4RNL, has excellent theory information at http://www.cebik.com/radio.html