# Near Vertical Incident Skywave (NVIS) Antenna

Latest update: June 2016


## Display

One feature of the ionosphere is its ability to reflect radio waves. However, only radio waves within a certain frequency range will be reflected and this range varies with a number of factors.

The most widely used instrument for ionospheric measurement is the ionosonde. The ionosonde is essentially a high frequency radar which sends short pulses of radio energy into the ionosphere. If the radio frequency is not too high, the pulses are reflected back to earth.

The ionosonde records the time delay between transmission and reception of the pulses. By varying the frequency of the pulses (typically 1-22MHz), a record is obtained of the time delay at different frequencies. This record is referred to as an ionogram.

The highest frequency which the ionosphere will reflect vertically is called foF2. These foF2 measurements from various sites can be used to create a map of foF2. The data used to produce the map of the USA region are from USAF observing sites and obtained from Space Environment Centre, Boulder Colorado.

Please see "NVIS Propagation Display" in the LINKS section for current maps that are generated from this method.

One item that some who write for QST fail to understand is that these maps give you an accurate indication of which band/s is/are open for NVIS work. As you can see in the maps here on 11/19/07 at 13:00Z the US experienced a rather full range of bands that could have been used. It ran from 160M on the West to 75M in the mid section to 60M on the East coast. Notice that 40M was **NOT** open above 30 Degrees North ANYWHERE in the world. That would exclude the vast majority of the United States for 40M NVIS work, on that day.

Anyone that makes a blanket statement that you can use 40M NVIS during the day and 75M NVIS at night, has not fully researched their "information". It varies significantly with the sunspot cycle and how far North or South of the equator you live.

## Antenna

**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 out to a distance of 300 to 500 Kilometers. The maximum frequencies involved will be as low as 1.8 Mhz under very poor conditions to as high as 14 Mhz under excellent conditions (which we have not seen in many years), with the most usable being between 3.5 Mhz (80M) and 7.3 Mhz (40M).**

I find it amazing the number of people that can read the previous paragraph and not understand it. One individual wrote to ask if 440Mhz would work for NVIS. One word answer . . . NO.

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.

One thing that many people either ignore or have never learned is every horizontal antenna has an NVIS component in its radiation. Similarly, every horizontal antenna has a component that is most useful for DX. Your decision then is to pick the configuration that either favors or optimizes the properties you want. To me, local communication on HF says NVIS.

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 - say ten to fifteen feet works very well. ***You will note that there is negligible 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.*

L.B. Cebik (W4RNL) in his page on NVIS height shows in the chart at about mid web page that the height, in the 1/8 to 1/4 wave length above ground, has very little difference in gain. In fact, if you roll in the next parameter, ground (detailed below), height can easily have much less effect than ground.

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.
(Kind of a "well duh", isn't it?)

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 **the best NVIS efficiency is obtained at the ten to fifteen foot height** for frequencies in the 40M to 75M range.

## 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 (1/4th 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 several years 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 almost 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!**

The chart in L.B. Cebik's (W4RNL) web page shows that any NVIS above excellent ground out performs an antenna above good ground at optimal height! Humm, does that imply that we have found the single most important parameter in NVIS?

## 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. Once again, this presumes a .15 wave length spacing.

## 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 we have seen produce the best NVIS performance. Others that I have talked with claim at least a 6db improvement with this same approach.

I have completed 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.

As a side note to the above statement, I also notice an improvement if I "water" my ground rod just prior to operation. I actually pour about one gallon of water on the ground around the ground rod. If it seeps in very quickly, I go get another gallon. This has made a noticable improvement in both transmit and receive signals. (Tells you how really dry some parts of Colorado are, doesn't it.)

Over the winter I noticed that the signals (transmit and receive) seemed to be deteriorating. Once Spring thaw came I went out to check the ground wire under my random length wire antenna. It turns out that the ground wire was in about five pieces. I pulled out all of the pieces and installed a new loop of grounded wire, with the expected results. The antenna is now back to full performance.

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 because 40M has not been open for NVIS for months thus 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? ;-)

## 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 omni-directional coverage with the signals from NVIS antennas in the ten to fifteen foot height.

## Location

Where you live/work in the US has perceptible effect in what results you get with NVIS. By that I mean that the further North you live the lower the maximum frequency you can successfully use for NVIS. This becomes much more evident and important when the sun spot cycle is at or very near the minimum. Add to that the effects of seasonal changes which amplify the sunspot effects and you can see at least one full band difference in NVIS usable frequencies. During the Winter and under sunspot lows you can easily see two band differences.

The sage "wisdom" tell us that you use 75/80M at night and 40M during the day. **NOT** true during the sun spot minimums. There are significant portions of the US that have not had 40M open for NVIS propagation from 2005 to 2008. How can you use a band that is not open? You can't. Additionally the same "wisdom" tells us that 75M will go away early in the day. During sunspot highs I'll easily believe that. During sunspot lows 75M is very often open for NVIS until well past noon, local time. - - Almost like real estate it's location, location, location.

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## What works?

The differences in performance between various antenna configurations seem to fall into the following approximate rankings (best performance to least efficient).

1. Full wave length loop (not practical for most of us)
2. Half wave length dipole with the feed point lower than the ends yet about fifteen foot height.
3. Half wave dipole - inverted V configuration (approximately **-4.5db** below the "saggy" dipole above!)
4. Random length wire
5. "Dual Ham-stick" dipole
6. Antenna below 4 feet high

Each of the antenna configurations above (with the possible exception of the last) **WILL** be enhanced with a good ground wire below them. Any full length wire will enhance performance but resonant lengths and good ground connections will - naturally - provide the best performance gains.

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: 09/28/16

- **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 a few auto tuners, (some MFJ autos are very picky) but a good manual tuner will produce good to excellent results. The LDG Z11 Pro is one that works quite well. 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 (can't tell you why it made a difference, but it did). 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**: 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.

  Take two mono-band mobile antennas and mount them base to base with one being the driven element and the other being the ground side. Use care 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 noticeable 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.

- 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.

- 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. The Concept is now available, but I have not yet done the experimants.

- 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 usual, 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, you will have the height at 35 feet or more. Since efficient 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 was designed as a gain antenna for **20M**. Many people have found that the G5RV works on many other bands but the 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 reasonable antenna. Please see W8JI's information page for more detail on the G5RV.

## 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