What's the Deal About "NVIS"?

*N6BV applies some modern tools to evaluate the
Near Vertical Incidence Skywave operating mode—
or is NVIS actually an operating strategy?*

R. Dean Straw, N6BV

It's about 10 PM and I'm lying in bed reading. Slowly the glass crystals in the chandelier above the bed begin to sway and clink together lightly. My collie at the foot of the bed stirs slightly, yawns and then drops back into his deep sleep. The swaying and clinking continue to build up for about 5 seconds, and then suddenly the little temblor is over. It's just another minor event in earthquake-prone San Francisco. And my snoring dog certainly wasn't much of an early-warning system for earthquakes, as some animals are reputed to be!

Back on October 17, 1989, however, the earth in San Francisco shook much longer and a lot more violently during the Loma Prieta earthquake. More than 60 people in the Bay Area were killed in that tragic event—and it wasn't even close to being the largest earthquake this region has ever experienced. Indeed, one of San Francisco's somewhat less endearing nicknames is "the city that waits to die."

When the *Big One* does come, you can be assured that all the cell phones and the landline telephones will be totally jammed, making calling in or out of the San Francisco Bay Area virtually impossible. The same thing occurred in Lower Manhattan on September 11, 2001. The Internet will also be severely affected throughout northern California because of its trunking via the facilities of the telephone network. Commercial electricity will be out in wide areas because power lines will be down. It's virtually certain that water mains will be out of commission too.

If the repeaters on the hills around the Bay Area haven't been damaged by the

shaking itself, there will be some ham VHF/UHF voice coverage in the intermediate area, at least until the backup batteries run down. But connecting to the dysfunctional telephone system will be difficult at best
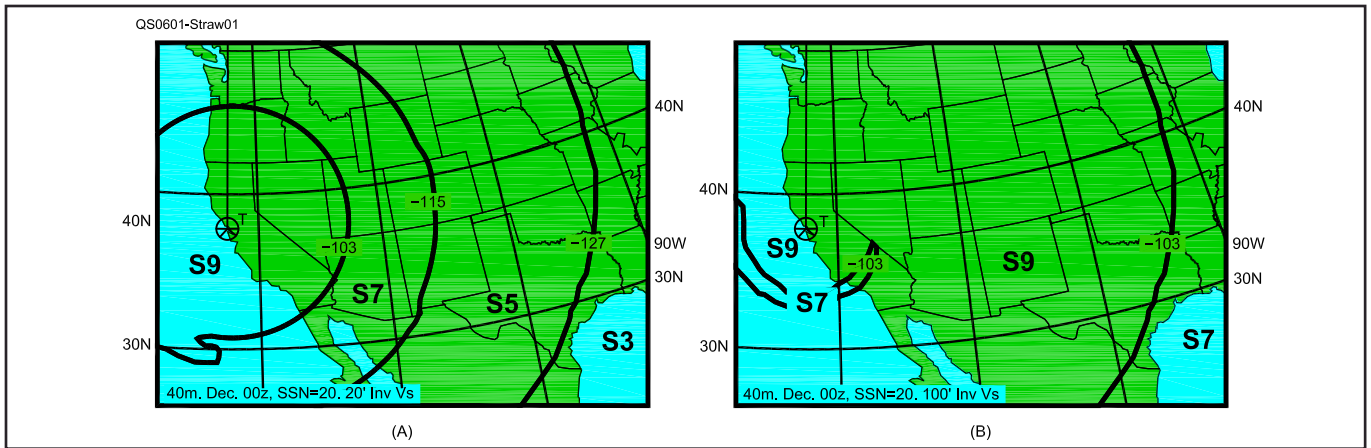

JEFF SCHNELLER, N2HPO

Salvation Army Team Emergency Radio Network (SATERN) volunteers Mark Griggs, KB8YMN (right), and Richard Carey, KB8OTZ, on duty in Mississippi following Katrina.

through amateur repeaters.

With little or no telephone coverage, an obvious need for ham radio communications to aid disaster relief would be from San Francisco to Sacramento, the state capital. Sacramento is 75 miles northeast of the Bay Area, well outside of VHF/UHF coverage, so amateur HF will be required on this radio circuit. On-the-ground communications directly between emergency personnel (including the armed-forces personnel who will be brought into the rescue and rebuilding effort) will often be difficult on VHF/UHF since San Francisco is a hilly place. So HF will probably be needed even for short distance, operator-to-operator or operator-to-communications center work. Throughout the city, portable HF stations will have to be quickly set up and staffed to provide such communications.

Hams used to half jokingly call short range HF communications on 40 and 80 meters "cloud warming." This is an apt description, because the takeoff angles needed to launch HF signals up into the ionosphere and then down again to a nearby station are almost directly upward. Table 1 lists the distance and takeoff angles from San Francisco to various cities around the western part of the USA. The distance between San Francisco and Sacramento is about 75 miles, and the optimum takeoff angle is about 78°. Launching such a high-angle signal is best done using horizontally polarized antennas mounted relatively close to the ground.

Nowadays, the fancy buzzword for this sort of close-in HF operation is "NVIS," which stands for "Near Vertical Incidence Skywave." NVIS gained recognition during the Vietnam War, and later in the Balkans,

Table 1

Average Elevation Angles for Target Destinations from San Francisco

Location	Distance Miles	Average Elevation Angle, Degrees
San Jose, CA	43	80
Sacramento, CA	75	78
Fresno, CA	160	63
Reno, NV	185	60
Los Angeles	350	44
San Diego	450	42
Portland, OR	530	30
Denver, CO	950	18
Dallas, TX	1500	8

Figure 1—At A, Predicted 40 meter geographic coverage plot for a 100 W transmitter in December at 0000 UTC (near sunset), for an SSN (Smoothed Sunspot Number) of 20. The antennas used are 20 foot high Inverted V dipoles. At B, 40 meter coverage for same date and time, but for 100 foot high flattop dipoles. Most of California is well covered with S9 signals in both cases, but there is more susceptibility in the higher dipole case to thunderstorm crashes coming from outside California, for example, from Arizona or even Texas. Such noise can interfere with communications inside California.

when soldiers started to use it for communicating in challenging terrain. I personally still prefer the more colorful term "cloud warming."
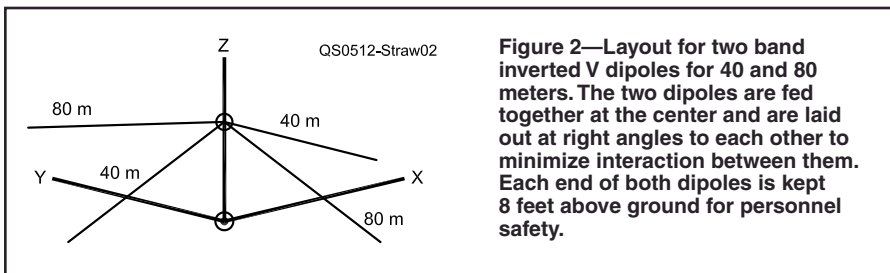
One of the best articles I've seen on NVIS operation was written by Ed Farmer, AA6ZM, in January 1995 *QST*. Ed's article focused on NVIS to use mainly in military applications, with a view on how hams could also benefit from some NVIS techniques. This article represents a ham-focused update to Ed's excellent coverage of NVIS techniques, backed up with some new results from modern software used for propagation and antenna modeling.
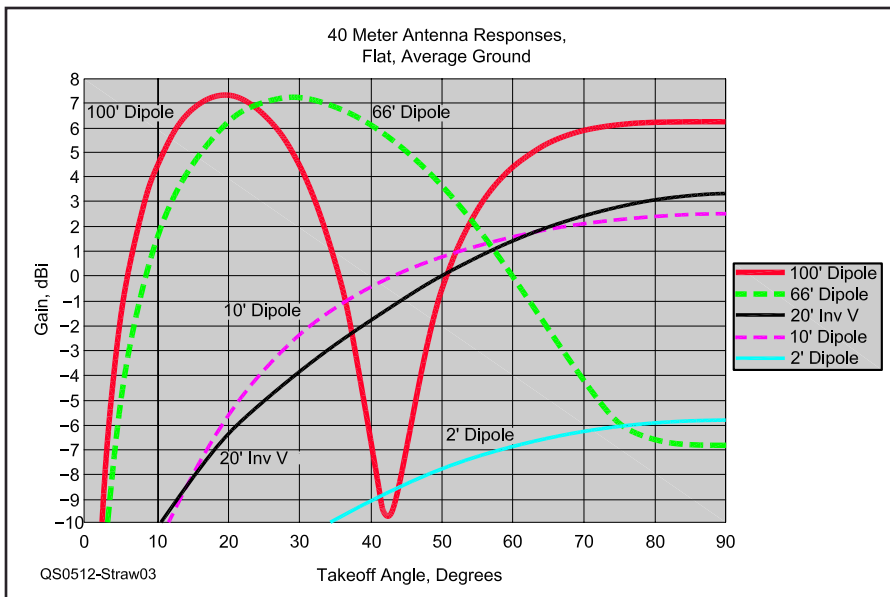
NVIS Geographic Coverage

Figure 1A shows the geographic area coverage around San Francisco for a 100 W, 7.2 MHz station using an Inverted V dipole. The center of this antenna is 20 feet above flat ground and the ends are 8 feet high. An actual implementation of such an antenna could be as an 80 meter Inverted V, fed in parallel with a 40 meter Inverted V dipole at a 90° angle. See

Figure 2—Layout for two band inverted V dipoles for 40 and 80 meters. The two dipoles are fed together at the center and are laid out at right angles to each other to minimize interaction between them. Each end of both dipoles is kept 8 feet above ground for personnel safety.

Figure 3—Elevation plots for different 40 meter antennas above flat ground with average ground characteristics (5 mS/m conductivity and dielectric constant of 13). The 10 foot high flattop dipole and the 20 foot high Inverted V dipoles both have close to the same characteristics. Note that there is a null in the response of the 100 foot high flattop dipole at a 42° elevation angle. The gain there is roughly that of a 2 foot high dipole!

Problems with the AS-2259

In military circles, the Inverted V NVIS antenna has acquired an unfortunate reputation. This is because of the standard issue, mil-spec AS-2259 antenna. This design uses a unique, rather funky feed-line system, in which the center support for the two parallel fed Inverted V dipoles consists of eight special push up coaxial tubing sections. These sections also serve as the transmission line. In theory, this should make for an efficient transmission line, but in practice reliability often turned out to be poor. Further, the two crossed dipoles are resonant at 10 and 6.8 MHz. Although the antenna coupler for the radio feeding an AS-2259 could bring the system to resonance, the losses in the coax feed line (including the coax from the base of the AS-2259 to the radio) could be very high below about 5 MHz. The 10 MHz dipole really needs to be resonant close to 3.8 MHz for good two frequency NVIS operation.

From December 2005 QST © ARRL

Figure 2. The 8 foot height puts the ends high enough to prevent RF burns to humans (or most animals).

I generated Figure 1 using the *VOAAREA* program, part of the *VOACAP* propagation-prediction suite, for the month of December. This was for 0000 UTC, close to sundown, for a low period of solar activity (Smoothed Sunspot Number, SSN of 20). The receiving stations were also assumed to be using identical Inverted V dipoles.

You can see that almost the whole state of California is covered with S9 signals, minus only a thin slice of land near the Mexico border in the southeast portion of the state, where the signal drops to S7. Signals from Texas are predicted to be only S5 or less in strength. Signals (or thunderstorm static) coming from, say, Louisiana would be several S units weaker than signals from central Texas.

Now take a look at Figure 1B. Here, the date, time and solar conditions remain the same, but now the antennas are 100 foot high flattop dipoles. California is still blanketed with S9 signals, save for an interesting crescent-shaped slice near Los Angeles, where the signal drops down to S7. Close investigation of this intriguing drop in signal strength reveals that the necessary elevation angle, 44°, from San Francisco to this part of southern California falls in the first null of the 100 foot high antenna's elevation pattern. See Figure 3, which shows the elevation patterns for five 40 meter antennas at different heights. In the null at a 44° takeoff angle, the 100 foot high dipole is just about equal to a 2 foot high dipole. I'll discuss 2 foot high dipoles in more detail later.

For most of California, the problem with 100 foot high 40 meter antennas is that interfering signals from Texas, Colorado or Washington State will *also* be S9 in San Francisco. So will static crashes coming from thunderstorms all over the West and much of the Gulf Coast. (Ed Farmer, AA6ZM, jokingly told me that the Army doesn't have any problem with interfering signals—they just call in an airstrike. We hams don't generally have this ability, although we occasionally call in the FCC.) See Figure 4, which shows a typical distribution of thunderstorms across the US in the late afternoon, California time, in mid-August. There certainly are a lot of thunderstorms raging around the country in the summer.

The signal-to-noise and signal-to-interference ratios for a 20 foot high Inverted V dipole will be superior for medium-range distances, say out to 500 miles from the center, compared to a 100 foot high antenna. The 20 foot high antenna can discriminate against medium-angle thunderstorm noise in the late afternoon coming from the Arizona desert, although it wouldn't help much for
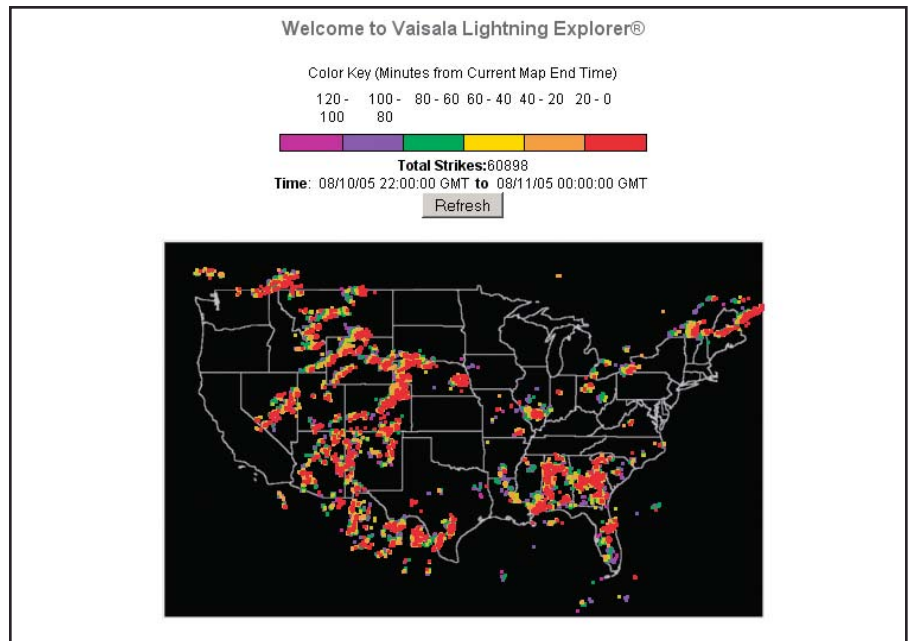
Figure 4—The distribution of lightning strikes across the USA for August 10, 2005 from 2200 to 0000 UTC, in the afternoon California time. There are lots of lightning strikes in the US during the summer—60,898 of them in this two-hour period!
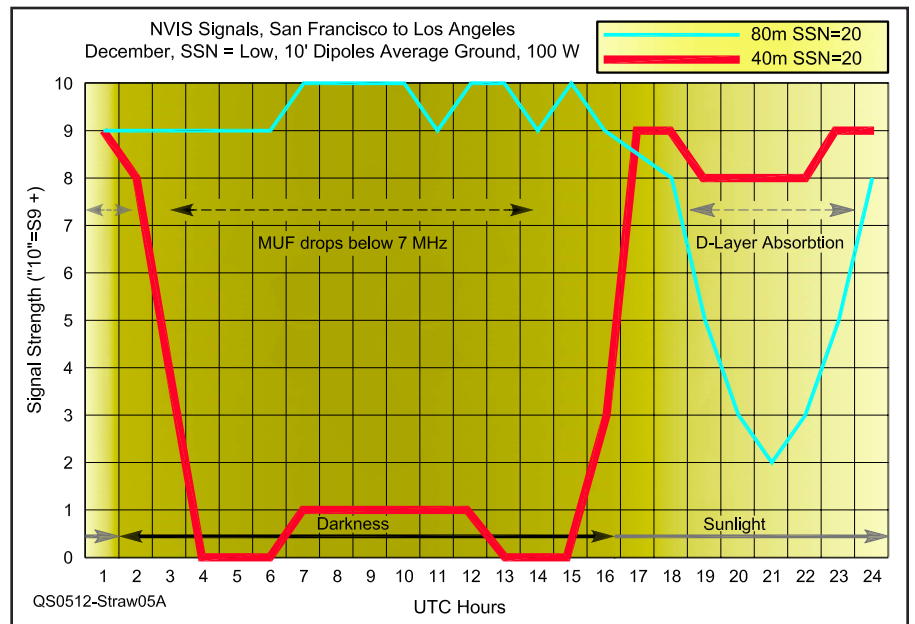

Figure 5—VOACAP calculations for a 350 mile path from San Francisco to Los Angeles, using 10 foot high flattop dipoles. This plot shows the signal strength in S Units ("S10" = S9+10) for a worst-case month/SSN combination—winter solstice, in December, for a low level of solar activity (SSN = 20). The 40 meter signal drops to a very low level during the night because the MUF drops well below 7.2 MHz. The 80 meter signal drops in the afternoon because of D-layer absorption. For 24 hour communications on this path, the rule of thumb is to select 40 meters during the day and 80 meters during the night.
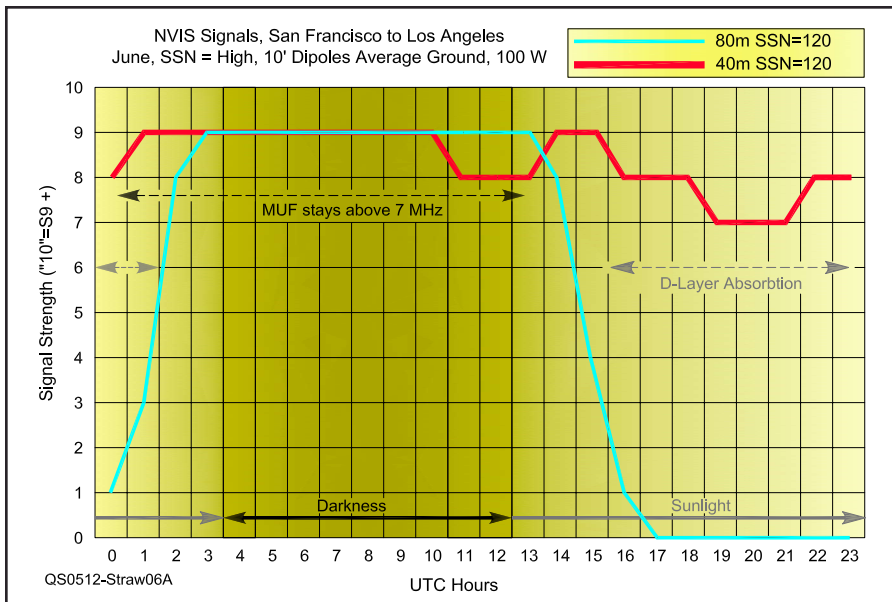
thunderstorms in the Sierra Nevada in central Nevada, which are arriving in San Francisco at high angles, along with the desired NVIS signals.

This is the essence of what NVIS means. NVIS exploits the difference in elevation pattern responses of low horizontally polarized antennas compared to higher horizontal
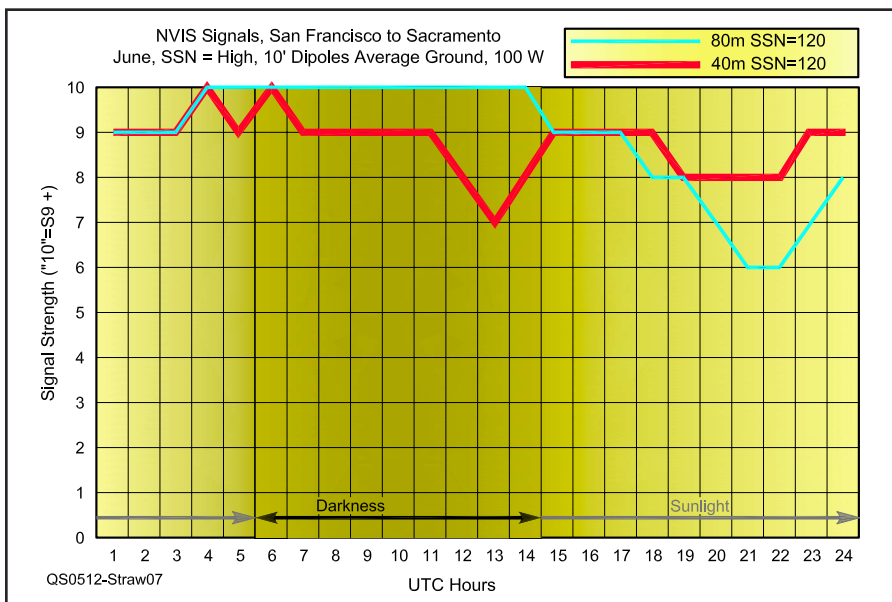
antennas, or even verticals. Over the years, many hams have been led to believe that higher is always better. This is not quite so true for consistent coverage of medium or short distance signals!

If NVIS only involved putting up a low horizontally polarized antenna on 40 meters the story would end here. However,

Figure 6—Signal strengths for the San Francisco to Los Angeles path for a worst-case month/SSN combination—summer solstice, in June, for a high level of solar activity (SSN = 120). Now 80 meters drops out more dramatically during the daylight hours, due to increased D-layer absorption. At this high level of solar activity, 40 meters remains open 24 hours with reasonable signal levels. However, the NVIS rule-of-thumb still holds: Use 40 meters during the day; 80 meters at night.

Figure 7—Signal strengths for a 75 mile path—San Francisco to Sacramento. This is for June and SSN = 120. Either band could be used successfully over the full 24 hour period because signal levels are always higher than S6. But the simple NVIS rule-of-thumb still holds: Use 40 meters during the day; 80 meters at night. This simplifies giving instructions to operators unaccustomed to the use of HF.

real cloud warming is more complicated. It also involves the intelligent choice of more than just one operating frequency to achieve reliable all day, all-night communications coverage.

Figure 5 shows the signal strength predicted using *VOACAP* for the 350 mile path from San Francisco to Los Angeles for the month of December for a period of low solar activity (SSN of 20). The antennas I used in this case are 10 foot high dipoles, just for some variety. These act almost like 20 foot high Inverted V dipoles. I chose December at a low SSN as a worst-case scenario because the *winter solstice* occurs on December 21. This is the day that has the fewest hours of daylight in the year. (Contrast this with the *summer solstice*, on June 21, which has the

most hours of daylight in the year.) Note that the upper signal limit in Figure 5 is "S10"—a fictitious quantity that allows easier graphing. S10 is equivalent to S9+, or at least S9+10 dB.

The 40 meter curve in Figure 5 shows that the MUF (maximum usable frequency) actually drops below the 7.2 MHz amateur band after sunset. The signal becomes quite weak for about 14 hours during the night, from about 0300 to 1700 UTC. In a period of low solar activity the 40 meter band thus becomes strictly a *daytime band* on this medium-distance path.

The 80 meter curve in Figure 5 shows strong signals after dusk, through the night and up until about an hour after sunrise. After sunrise, 80 meters starts to suffer absorption in the D layer of the ionosphere and hence the signal strength drops. Here, 80 meters is a true *nighttime band*.

Let's see what happens from San Francisco to Los Angeles during a period of high solar activity (SSN of 120) during the summer solstice in June. Figure 6 shows that 40 meters now stays open all hours of the day due to the greater number of hours of sunlight in June and because the ionosphere becomes more highly ionized by higher solar activity. Meanwhile, 80 meters still remains a nighttime band during these conditions on this path.

Now, let's look at a shorter-distance path—our 75 mile emergency communications path from San Francisco to Sacramento. We'll again use June during the summer solstice, at a high level of solar activity (SSN of 120) because this represents another worst-case scenario. Figure 7 shows that 40 meters remains open on this path all day, dropping to a lower signal level just before sunrise. At sunrise, the MUF drops close to 7.2 MHz. 80 meters is still mainly a nighttime band to Sacramento, even though it does yield workable signal levels even during the daylight hours. However, 40 meters is better from 1200 to 0400 UTC, so 40 would be still the right daytime band for this path during the day.
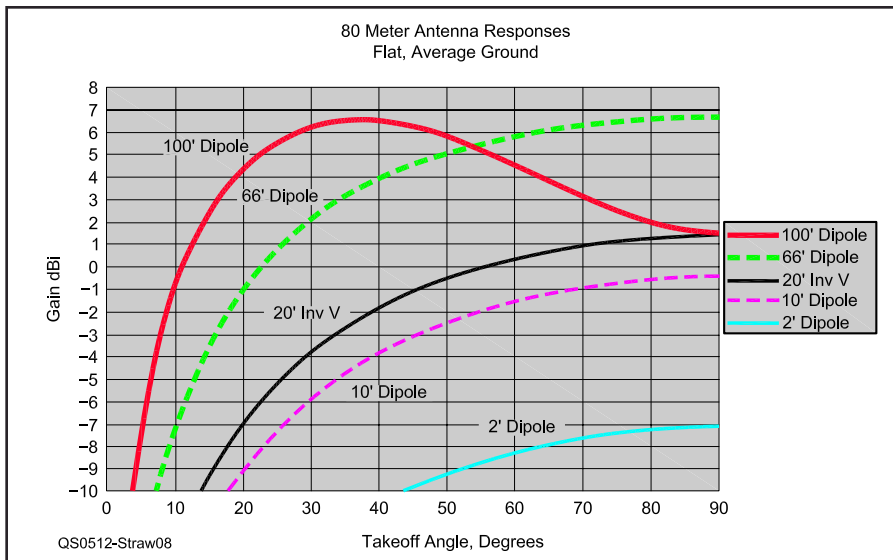
Choosing the Right Frequency

You can see that a pattern is developing here for efficient NVIS short/medium-distance communications:

- You should pick a frequency on 40 meters during the day.
- You should pick a frequency on 80 meters during the night.
- You should choose an antenna that emphasizes moderate to high elevation angles, from 40° to almost directly overhead at 90°.

"What about 60 meters?" you might ask. The characteristics on 60 meters fall between

80 Meter Antenna Responses
Flat, Average Ground

Figure 8—Elevation response patterns for 80 meter antennas over average soil. The shapes track each other rather well, remaining parallel for heights from 2 to 66 feet over flat ground. The 2 foot dipole is substantially down, about 9 dB, from the 20 foot Inverted V dipole at all angles.

at operating HF, I would tell them to operate on the higher frequency band during the day and on the lower frequency band at night.
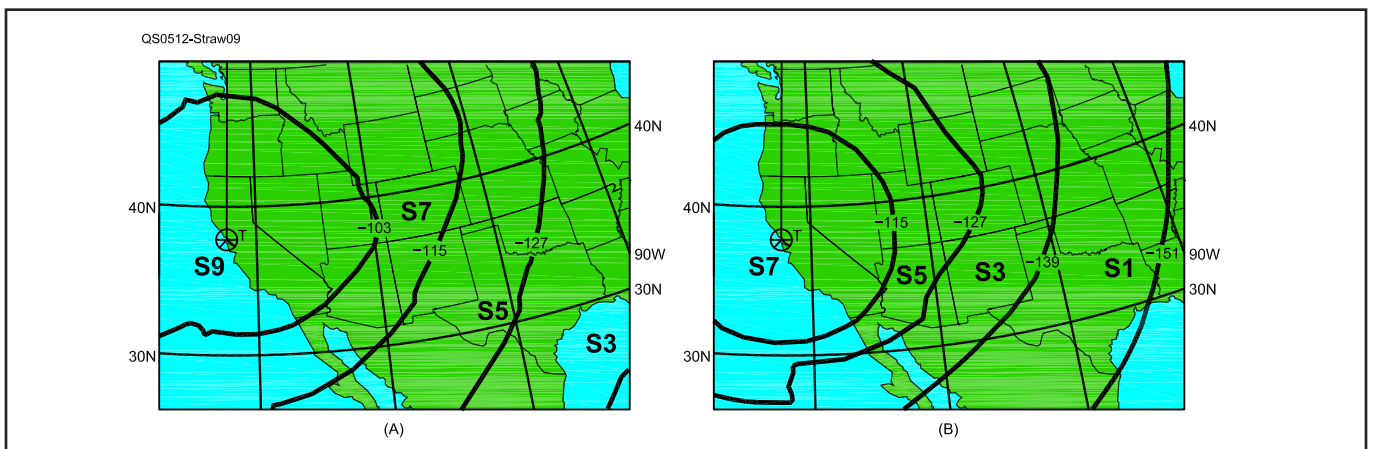
Some Other Observations About NVIS—Antenna Height

Earlier I briefly commented about really low antennas for NVIS. Some NVIS aficionados have advocated placing dipoles only a few feet over ground, something akin to saying, "If low is good for NVIS, then lower must be even better." Now I'm not claiming that a very low antenna *won't* work in specific instances—for example, covering a small state such as Rhode Island or even just the San Francisco Bay Area.

It certainly is convenient to mount a 40 meter dipole on some 2 foot high red traffic cones! I'd be very skeptical, however, about the ability of such antennas to cover all of a large state, such as California or Texas, especially on 80 meters. Figure 8 shows the computed elevation responses for a number of 80 meter antennas, including a 2 foot high dipole.

Figure 9B shows the 80 meter geographic coverage plot for 2 foot high dipoles, compared with the plot in Figure 9A for 20 foot high Inverted V dipoles on both ends of the path. The 2 foot high dipoles produce about 2 S-units less signal across all of California than the 20 foot high Inverted V dipoles, at 0300 UTC in December, with an SSN of 20. The reason is that a low dipole will suffer more losses in the ground under it.

The differential between California signals and possible interfering signals from, say, New Mexico, is predicted to be four S-units, the same as it is for the higher Inverted V dipole at 20 feet. Thus there is no real advantage in terms of signal-to-interference ratio or signal-to-noise ratio (for thunderstorm static crashes) for either

40 and 80 meters, although it resembles 40 meters more closely. The power output limit of 50 W (to a dipole or equivalent) and the five available channels limit flexibility in using this band. Under the appropriate conditions, however, it remains a useful option.

What about 160 meters? For 100 W level radios, even at the worst-case month or during high solar activity, the MUF doesn't fall below 3.8 MHz often enough to destroy the ability to communicate, even for short distances. That is a relief, considering that installing a 160 meter half wave dipole involves a 255 foot wingspan, and it would need to be elevated at least 30 feet in the center. A short loaded vertical such as a 160 meter mobile whip would have poor response at the high elevation angles needed for NVIS. You could probably put

a monster 160 meter horizontal dipole up at a permanent location, but hauling such a thing around in the field would not be easy.

Some Other Observations About NVIS—Strategy

The subtitle of this article asks the question whether NVIS is an operating *mode* or whether it is actually an operating *strategy*. I maintain that NVIS is a strategy. It involves choosing both appropriate frequencies and then appropriate antennas for those frequencies. Figure 7 does show that on short distance paths, such as between San Francisco and Sacramento, you could stay on 80 meters all day and night. But if you have to give a single rule-of-thumb to operators who are not very experienced

Figure 9—Geographic coverage plots for December, SSN = 20, 0300 UTC. At A, antennas are 20 foot high Inverted V dipoles over Average soil. At B, antennas are 2 foot high flattop dipoles over Average soil. The response for the 2 foot high antennas is down about 2 S units, 8 to 12 dB for a typical communications receiver.

This article was written before the tragedy on the US Gulf Coast wrought by hurricane Katrina in September 2005. As usually happens in such natural disasters, Katrina brought most forms of communication to their knees. Fiber-optic lines going across a major bridge over Lake Pontchatrain were wiped out and numerous cell towers were brought down. Water flooded telephone facilities, crippling many landline telephone circuits. Police and fire communication systems were either destroyed or severely affected. There were reports of multiple agencies all trying to share one VHF channel in New Orleans. Who rose to the occasion to help? Hams, of course, as we always have when faced with such dire circumstances.

Although some Amateur Radio VHF/UHF repeaters were, amazingly enough, still intact, much communication was handled on HF, often using NVIS techniques, but some through multiple relays halfway across the country and then back to the affected area again.

One lesson was learned (and re-learned): So-called "broadband" antennas using resistance-loading—such as T2FD (tilted terminated folded dipoles)—often didn't radiate enough signal for adequate results on 40 and 80 meters. When these were replaced with simple two band 80 and 40 meter Inverted V dipoles (as described in this article) the results were far more reliable.

The lessons learned will be discussed for months, if not years, in both amateur and professional circles. Amateur Radio and NVIS played a key role keeping public-service agencies on the air in the aftermath of Katrina.—*N6BV*

height. This is because the shape of all the response curves in Figure 7 below 20 feet essentially track each other in parallel.

The lower the antenna, however, the lower the transmitted signal strength. Physics remains physics.

Low Antennas and Local Powerline Noise

Some advocates of really low antennas have stated that the received noise is much lower than that received from higher antennas, and this therefore leads to better signal-to-noise ratios (SNR). How much this is true depends on the source of the noise. If the noise comes from distant thunderstorms, then the SNR advantage going to a 2 foot antenna from a 20 foot high one is insignificant, as Figure 9 indicates.

If noise is from an arcing insulator on a HV power line half a mile away, that noise will arrive at the antenna as a ground-wave signal. I calculate that the 2 foot antenna receives 4.4 dB less noise by groundwave than a 20 foot high Inverted V dipole. However, at an incoming elevation angle of 45°—suitable for a signal going from Los Angeles to San Francisco—the signal would be down 7.1 dB on the low dipole compared to the higher antenna. The net loss in SNR for the 2 foot high dipole is thus 7.1–4.4 or 2.7 dB. Close, but no cigar. Summarizing about really low NVIS antennas:

- A 2 foot high dipole yields weaker signals, but without an SNR advantage compared to its more elevated brethren.
- A 2 foot high dipole is a lot easier to trip over at night. I would call this a "knee biter" (or maybe an "ankle biter" if you're really tall).
- You (and your dog) can easily get RF burns from an antenna that is only 2 feet off the ground.

This is not a winning strategy to make friends or QSOs, it seems to me. But still, a really low dipole may serve your short-range communication needs just fine. But remember, that just as "higher is better" isn't universally true for NVIS (or even longer range) applications, "lower is better" isn't a panacea either.

Summary

The use of NVIS strategies to cover close-in and intermediate distance communications involves the intelligent choice of low HF frequencies. As a rule-of-thumb for ham band NVIS, I would recommend that 40 meters be used during the day; 80 meters during the night.

Next, NVIS involves the choice of antennas suitable for this strategy. Horizontally polarized dual-band 80 and 40 meter flattop dipoles that are mounted higher than about 10 feet high will work adequately for portable operations. Dual-band 80 and 40 meter Inverted V dipoles supported 20 feet above the ground at the center can also work well in portable operations.

Single-band 40 meter flattop antennas about 30 feet high and 80 meter flattop antennas about 60 feet high can do a good job for fixed locations.

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