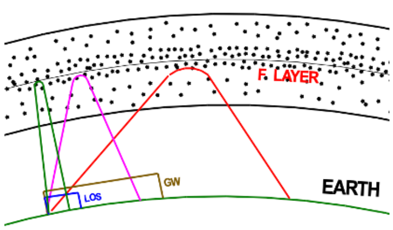
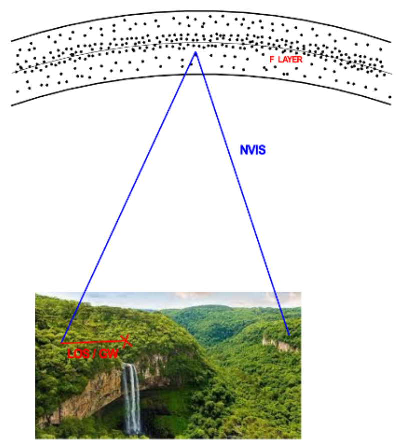
Near Vertical Incident Skywave (NVIS) Communications





www.skywave-radio.org

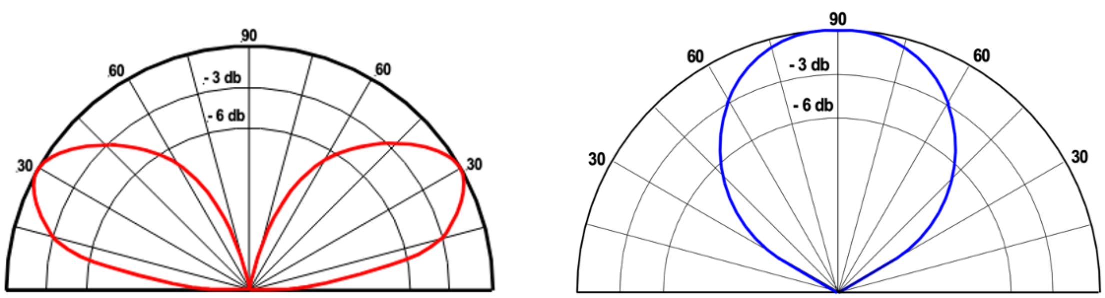
1 Near Vertical Incident Skywave

Near Vertical Incident Skywave (NVIS) radio communications is very important!

It is heavily used for local and regional communications, including in mountainous and jungle regions where other forms of radio communications are impossible. It is extensively used for emergency operations and for modern day military radio communications in adverse terrain.

What is NVIS?

NVIS is simply radio communications using HF signals that are transmitted at high elevation angles, i.e. at greater than 60°. A typical HF antenna pattern is shown on the left in Figure 1. This antenna transmits most of its energy at an angle of 30° or less to achieve long distance communications. In contrast, the pattern for a NVIS antenna is shown on the right. Most of its energy is transmitted straight up. It is the high elevation angle that makes NVIS so important.



Typical HF Antenna Pattern NVIS Antenna Pattern

Figure 1 Typical HF and NVIS antenna patterns (source: author)

NVIS signals are radiated by low horizontal antennas that are less than 1/4 wavelength above ground level. A typical NVIS center fed dipole antenna is shown in Figure 2. Other types of horizontal antennas can also be used as long as they are between 1/8 to 1/4 wavelength high These include Inverted V, end fed, and off center fed antennas.

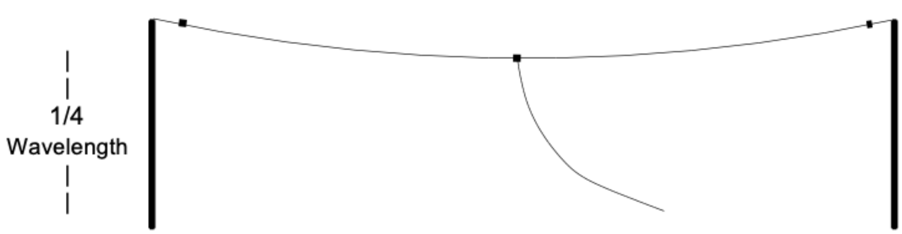


Figure 2 A common NVIS antenna (source: author)

1.1 NVIS Local and Regional Communications

There are 3 modes of local HF propagation: Line of Sight (LOS), Ground Wave (GW), and Near Vertical Incident Skywave (NVIS) as illustrated in Figure 3. These are the only possible modes of local HF communications. In addition, NVIS can communicate with regional radio stations out roughly 300 miles. Because of its high elevation angle, NVIS is the only means of communicating with regional stations.

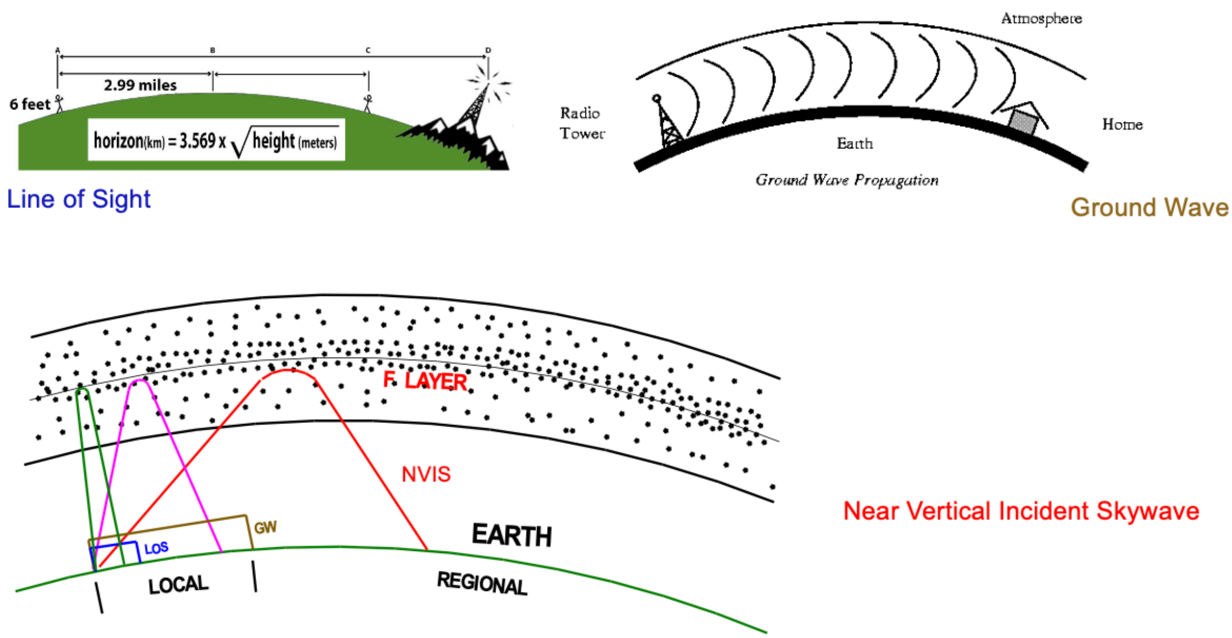


Figure 3 Local and regional HF radio communications

1.1.1 Line of Sight Propagation

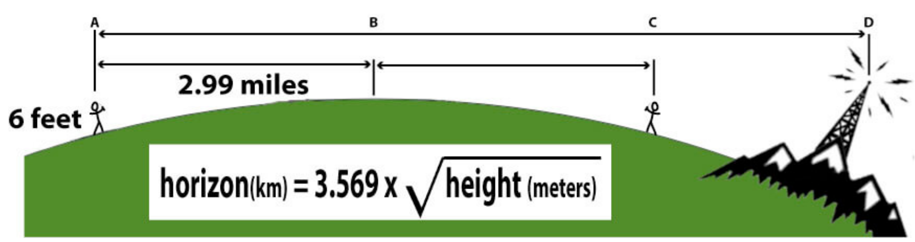


Figure 4 Line Of Site propagation (source: HTQ Solutions)

HF line of sight propagation is very similar to communicating on 2 meters, 220, and 440 MHz. The distance covered by LOS depends on the height of the transmitting and receiving antennas. In Figure 4 the LOS distance between two people with handheld radios is approximately 6 miles. Using the equation above, the line of sight distance from the person on the left to its radio horizon is 2.99 miles. Similarly, the distance from the person on the right to its radio horizon is also 2.99 miles giving a total distance of approximately 6 miles between the two radio operators. The LOS distance between a person with a handheld radio and a repeater on a mountain top can be far greater as the above equation indicates. The HF LOS distance from the author's HF antenna, at a height of 30 ft, to a similar receiving antenna is approximately 13.4 miles, presuming that local hills don't get in the way which unfortunately they do. The actual line of sight distance obtained by the author is more like 8 to 10 miles.

1.1.2 Ground Wave Propagation

Ground wave signals travel along the Earth's surface from the transmitter to the receiving station, as illustrated in Figure 5. The range of ground wave propagation depends on Frequency, Terrain, and Soil Conditions. Ground wave range decreases with increasing frequency. In the table below the range of an 80 meter ground wave signal is 68 miles while that of a 20 meter signal is 30 miles. These are optimistic distances over flat highly conductive ground. Propagation range is much less in mountains regions with rocky soil, perhaps only 15 to 20 miles on 40 meters.

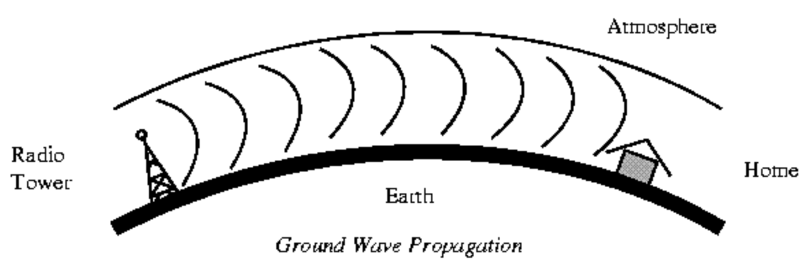


Figure 5 Ground Wave propagation (source: Computer Learning Centre)

Frequency Band	Typical Ground Wave Distance
80 meters	68 miles
40 meters	50 miles
20 meters	30 miles

1.1.3 LOS and GW Are Independent of the Ionosphere

Line of sight and ground wave propagation are always present regardless of the HF antenna being used and conditions in the ionosphere. As illustrated in Figure 6, over 40 miles of dense atmosphere shield line of sight (LOS) and ground wave (GW) signals from chaos in the ionosphere created by solar flares, Coronal Mass Ejections, and other violent solar events.

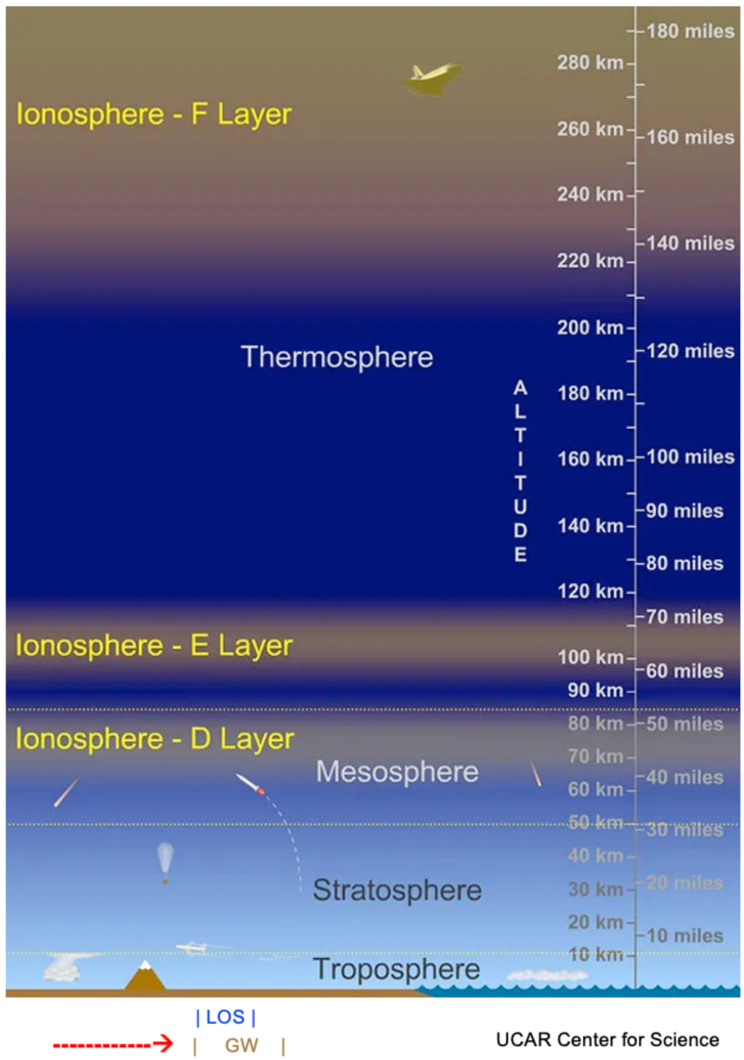


Figure 6 Atmosphere protection of LOS and GW propagation (source: UCAR Center of Science)

1.1.4 NVIS Range

At an elevation angle of 60^{o}, the NVIS propagation range is approximately 100 to 300 miles depending on the height of the ionosphere's F2 region. As illustrated in Figure 7, the NVIS range is around 100 miles at an ionospheric height of 150 km and about 300 miles at a height of 450 km.

Typically the NVIS range varies between 200 to 300 miles. A transition zone of NVIS propagation, with low D Layer absorption, typically extends out 350 to 380 miles. Beyond 400 miles we encounter oblique propagation conditions including long hop distances (greater than 400 miles), moderate to high levels of D Layer absorption, skip zones, Maximum Usable Frequency, etc.

Figure 7 NVIS Range (source: author)

1.1.5 Regional Area Defined

As indicated above, NVIS provides communications extending beyond ground wave range out roughly 300 miles. From a communications perspective this can be defined as the **regional area**. This is a very meaningful definition since NVIS provides coverage to all radio stations in this region and is the only mode of HF communications that can do so.

1.1.6 Local Communication Problem

There is a local communication problem that we need to be aware of. Line of sight (LOS) and ground wave (GW) propagation always exist. Consequently, multi-path interference between NVIS, ground wave, and line-of-sight signals is possible. Multi-path interference occurs when two signals, traveling via different paths, arrive at the receiving site with the same signal strength but out of phase. For example, a NVIS signal reflecting from the ionosphere typically travels over 300 miles to reach a receiving station while a ground wave signal may travel only 20 miles. These two signals will nearly always arrive at the receiving station out of phase. Figure 8 illustrate two signals that are 180° out of phase. In this figure a positive peak occurs in Wave – 1 at the same time as a negative peak in Wave – 2. Consequently, the two signals completely cancel out at the receiver resulting in neither signal being heard.

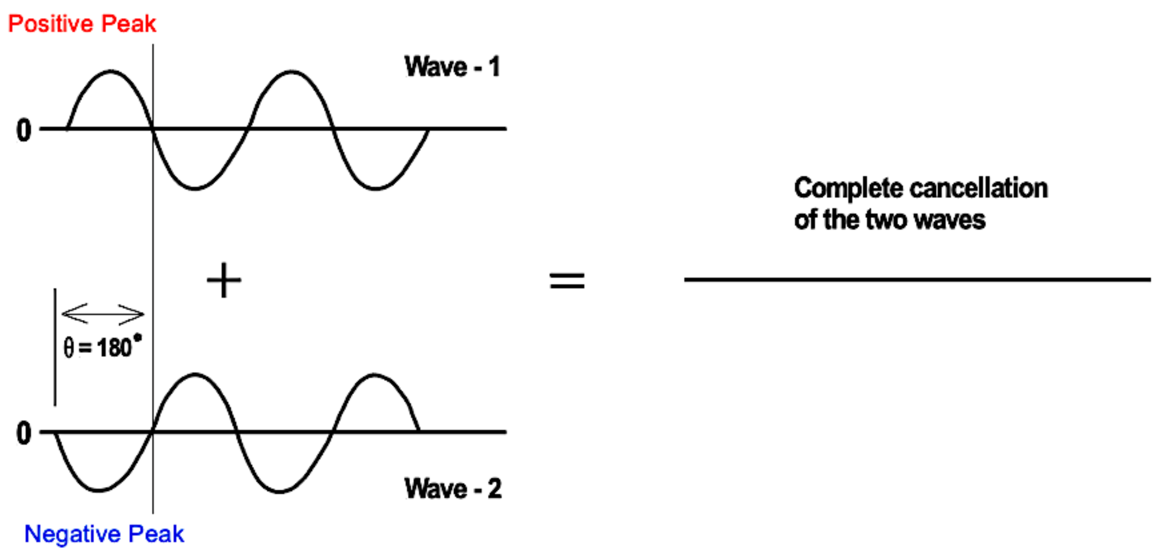


Figure 8 Two waves 180° out of phase (source: author)

Figure 9 further illustrates multi-path interference between ground wave and NVIS skywave signals. Close to the transmitting station, the ground wave signal is stronger and is thus the signal that is received. A little further out ground conditions attenuate the ground wave signal while the strength of the NVIS signal remains about the same. At this distance the strength of the GW and NVIS signals are equal. However, the path followed by the NVIS skywave signal is considerably longer. The two signals arrive at this point out of phase. Multi-path interference occurs resulting in signal degradation, fading and perhaps complete signal loss. Eventually the ground wave signal disappears leaving only the NVIS skywave signal which is received loud and clear without any interference.

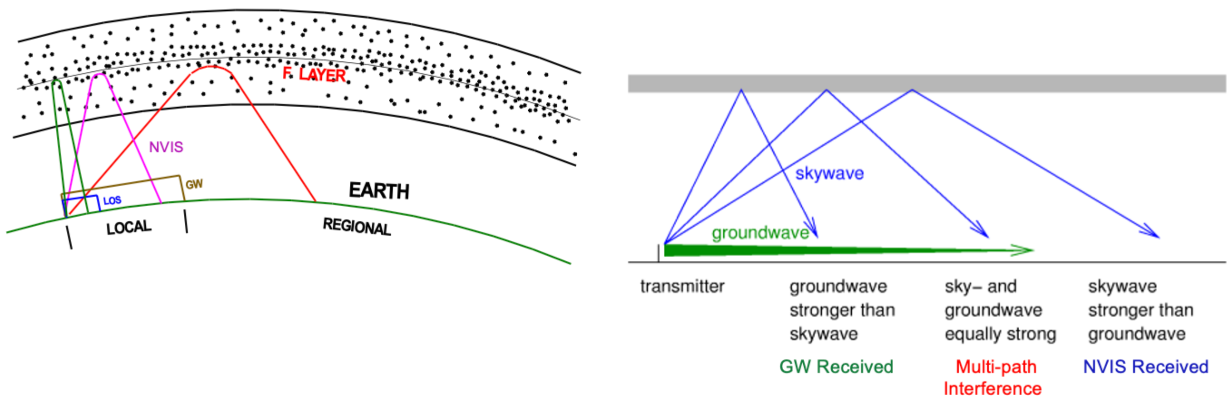


Figure 9 Local Communication Multipath Interference Problem

1.1.7 Communications in Mountainous Terrain

NVIS communications works exceptionally well in mountainous terrain where other forms of radio communications fail. Systems that perform poorly in mountainous regions include: local HF line of sight and ground wave propagation, low angle long distance HF, line of sight VHF, UHF, and often satellite communications. In Figure 10 the NVIS transmission reflects off the ionosphere and “rains” down throughout the entire region. Using NVIS propagation all stations are reached in the central valley, up the sides of the mountain, down into deep canyons on the other side of the mountain, and to other locations over a wide geographical area. No other form of radio communications can do that. The problem is illustrated by the satellite dish in the lower left-hand corner of the figure. Instead of reaching the earth satellite in the upper right corner, the transmission from the antenna dish hits the side of the mountain and is reflected away from the satellite in a completely different direction. Other forms of radio transmissions encounter the same fate. Due to its high elevation angle NVIS is often the only means of radio communications mountainous areas.

1.1.8 NVIS Communications in Jungle Regions

NVIS is usually the only means of radio communications in jungle regions. NVIS signals quickly penetrate the jungle canopy avoiding severe signal attenuation caused by lush often wet jungle vegetation. This is illustrated in Figure 11. In contrast Line Of Sight (LOS) and Ground Wave (GW) signals typically propagate only a mile or two before being completely absorbed by the dense vegetation. Low angle HF signals are also severely attenuated by the vegetation making long distance HF communications from within the jungle impossible.

Following Hurricane Maria in 2017 all communications to rural areas of Puerto Rico were completely cut off due to severe wind and flood damage. NVIS was used to reestablish communications between the Emergency Operations Center (EOC) in San Juan and these rural communities, often in jungle and mountainous regions of the island.

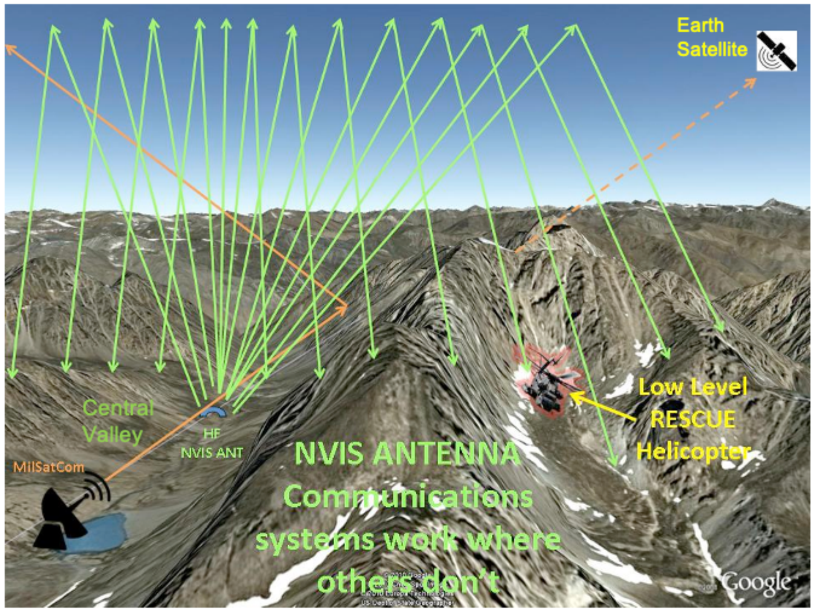


Figure 10 Communications in Mountainous Terrain (source: AFCEA International)

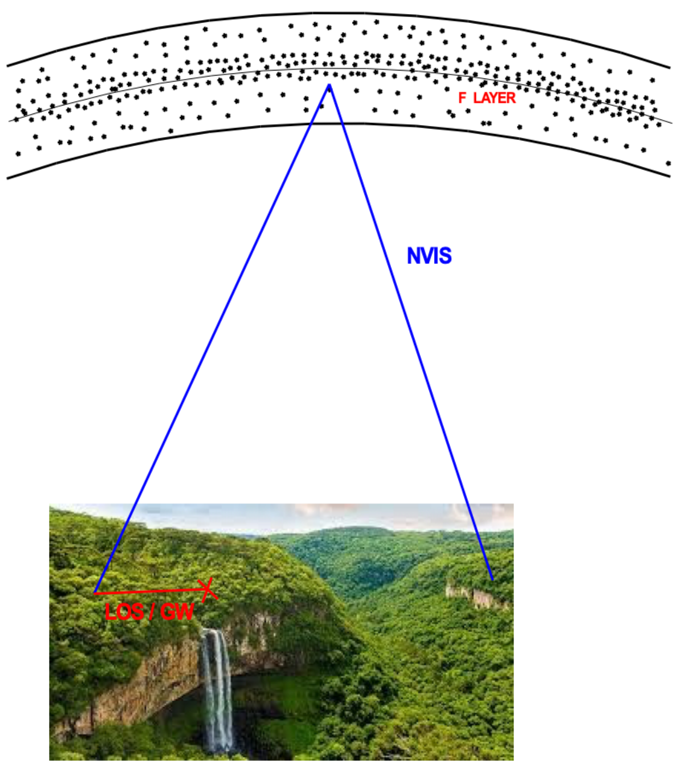


Figure 11 Communications in Jungle Regions (source: author / World Walks)

1.2 Brief History of NVIS Communications

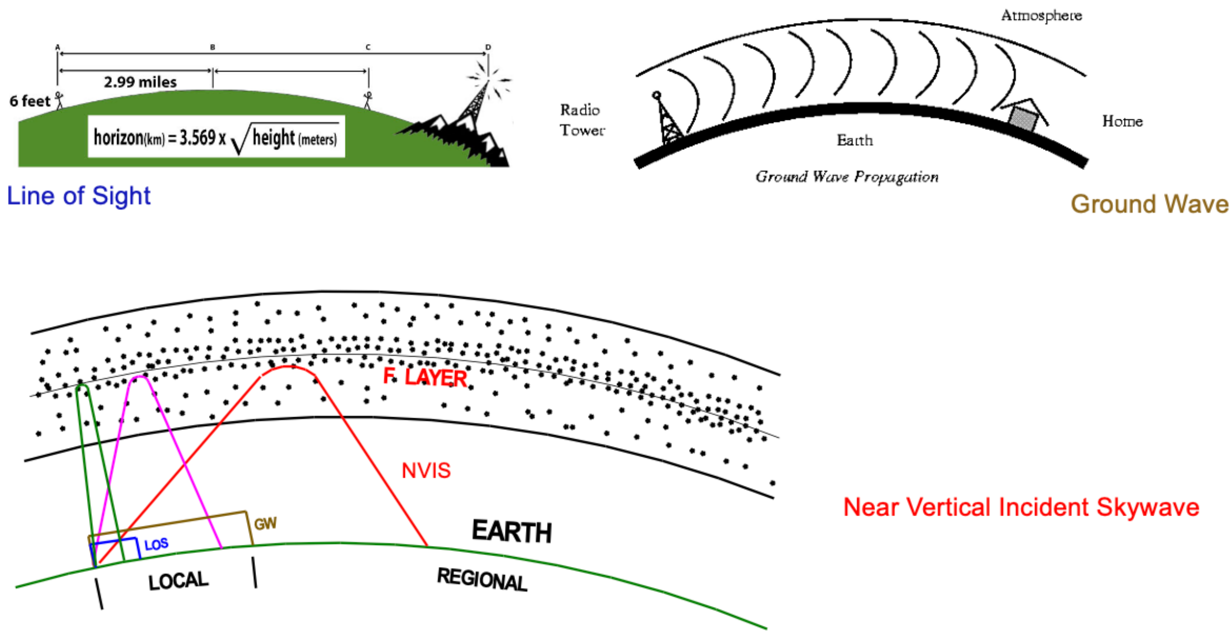


Figure 12 Wireless propagation modes

NVIS has been used since the very beginning of radio. Line of sight, ground wave, and NVIS were the original three propagation modes used by wireless spark gap radio operators. However, the early wireless pioneers had little understanding of these propagation modes. In fact, they had no idea that an ionosphere even existed.

1.2.1 Line of Sight Propagation

In 1888 physicist Heinrich Hertz used line of sight propagation between his crude spark gap transmitter and receiving loop to verify the existence of electromagnetic waves predicted by Maxwell 20 years earlier. The apparatus used by Hertz is illustrated in Figure 13. Experimenting in a relatively long lecture hall, and using the 6 meter to 70 cm frequency bands, he proved conclusively that electromagnetic waves really did exist. It is unlikely that the commercial ramifications of his experiments ever occurred to him. After completing his electromagnetic wave experiments, Hertz went on to study other physical phenomena.

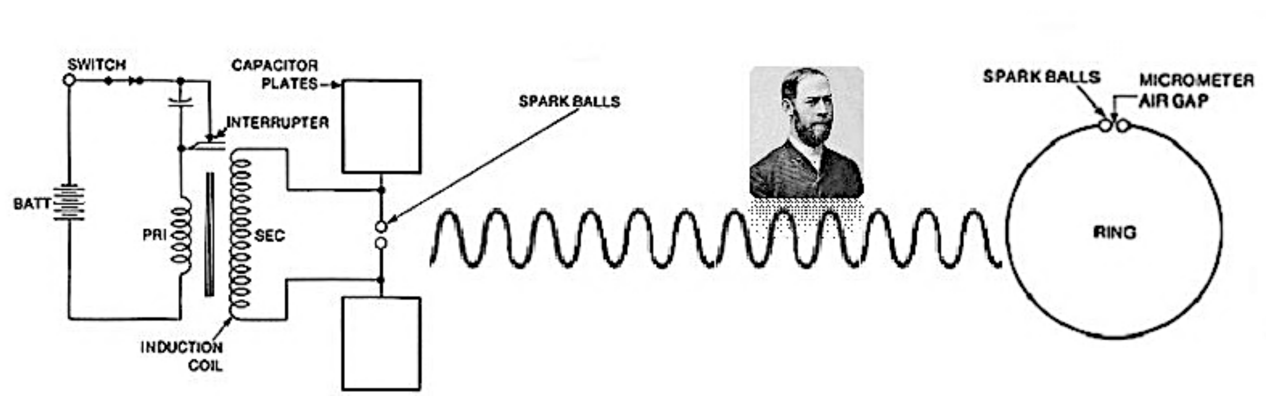


Figure 13 Experimental line of site apparatus used by Hertz (source: Wikipedia)

1.2.2 Ground Wave Propagation

In 1894, 20 year old Guglielmo Marconi understood very well the commercial significance of the experiments performed by Hertz. Marconi visualized a "wireless telegraph system" that would be commercially viable, particularly for communicating with ships at sea.

Working in the attic of his father's estate (Villa Griffone near Bologna, Italy) Marconi repeated the experiments of Hertz. Avoiding the confines of a laboratory, Marconi transmitted line of sight signals out the attic window to the hills a short distance away. Like Hertz, Marconi started experimenting with short horizontal antennas operating in the 2 meter frequency band. At this and higher frequencies, line of sight is the only possible propagation mode. Marconi did not know this. However, he reasoned that larger antennas would allow him to transmit further. Increasing the size of his antennas forced the frequency of his transmissions to drop from VHF down into the HF frequency band. As we have noted earlier, ground wave propagation occurs at HF frequencies with low frequency signals traveling longer distances than higher frequencies. Using his larger antennas and associated ground wave propagation, he achieved distances well beyond the line of sight hills visible from the attic window. Experimenting with antenna designs, he turned a horizontal antenna on end creating the vertical monopole antenna shown in Figure 14. His monopole antenna was 1/4 wavelength tall with the other half of the antenna formed by the conductive ground beneath the antenna. Vertical antennas have better ground wave propagation characteristics than horizontal antennas. Using his vertical antennas produced an immediate jump in the distances that he was able to achieve.

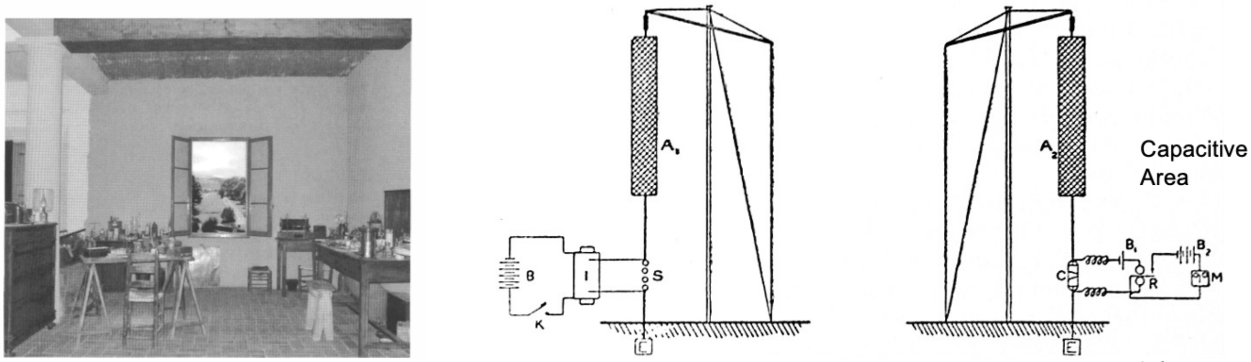


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Figure 14 Marconi’s attic laboratory and his first vertical antenna

1.2.3 NVIS Propagation

Tall vertical antennas were too large to mount on ships and too expensive for amateur radio operators. Instead, they used various versions of horizontal antennas, as illustrated in Figure 15. These antennas were considerably less than 1/4 wavelength above ground (or water) given the very low frequencies that they were using (typically 500 to 1,000 KHz). Unknown to the wireless operators, these antennas were in fact NVIS antennas with transmitting distances of 200 to 300 miles. The short transmit distances gave rise to the Amateur Radio Relay League. Amateur radio operators worked all night transmitting messages cross country relaying the messages from one amateur radio station to another.

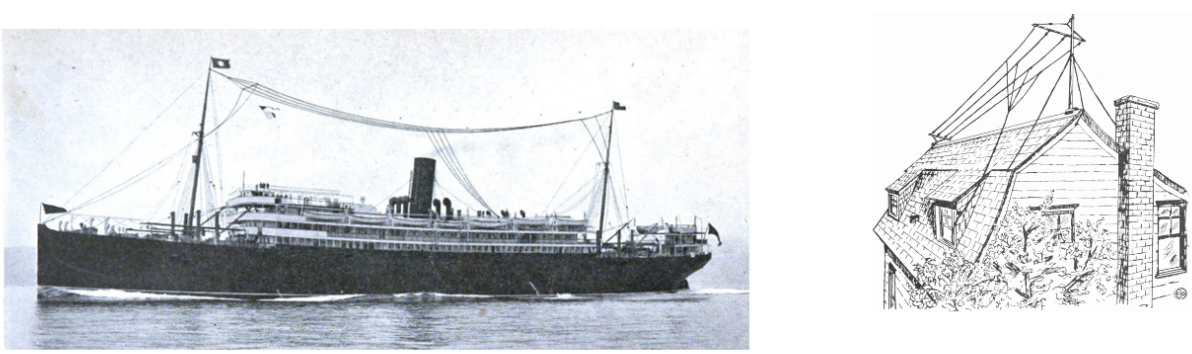

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Figure 15 Early shipboard and shore NVIS antennas

1.2.4 NVIS during WWII and Vietnam

NVIS was first used tactically in WWII by German Army reconnaissance units. These reconnaissance teams were too far forward for ground wave communications back to HQ, but too close for normal skywave propagation. NVIS propagation was the solution. The apparatus above the vehicle in Figure 16 is a magnetic loop NVIS antenna.

Figure 16 NVIS equipped German armored car

NVIS was also used in WWII by Allied Forces. Early in WWII studies by the British Army concluded that NVIS was the only practical means of field radio communications under adverse ground and mountainous conditions. They further concluded that NVIS was the only way to overcome the severe attenuation of ground wave signals by lush jungle vegetation in Burma.

NVIS was widely used in the South Pacific by Coastwatchers. Operating from mountainous jungle islands deep behind enemy lines, they sent critical intelligence to Allied Forces, rescued downed fliers, and helped save men from ships that had been sunk or heavily damaged.

In the mid-1960s the U.S. Army tested NVIS communications in the jungles of Thailand using small modern tactical HF radio sets. The tests were very successful leading to deployment of NVIS equipment during the Vietnam conflict. NVIS signals transmitted nearly straight up quickly penetrated the jungle canopy avoiding heavy signal attenuation in the dense jungle vegetation. NVIS was also critical for "valley-to-valley" communications, allowing units to remain in contact by transmitting over intervening hills and mountain peaks.

1.2.5 Local Communications on 80 Meters

Throughout the 1950 and 60s, NVIS on 80 meters was the propagation mode and frequency band of choice for emergency communications and local social nets in the same way that 2 meters is used today. The large physical size of HF vacuum tube transmitters (center) and receivers (right in Figure 17) made them impractical for use at VHF and UHF frequencies. The introduction of small semiconductor transceivers (left) changed all of that. Beginning in the early 1970s inexpensive VHF and UHF transceivers and repeaters became widely available resulting in the transition of emergency communications and social nets from 80 to 2 meters.

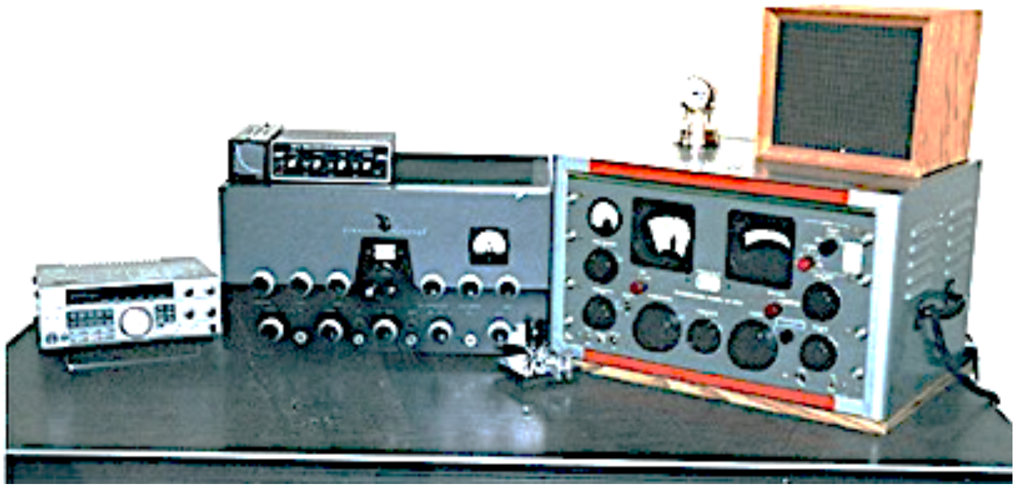


Figure 17 Author's radio equipment in 1990

1.3 NVIS Propagation

NVIS communications depends directly on the ionosphere's critical frequency.

As illustrated in Figure 18, Critical Frequency $\mathbf{f_c}$ is the **highest** frequency signal that can be transmitted straight up and reflected back down to Earth (blue trace). All signals lower in frequency than $\mathbf{f_c}$ are also reflected back to Earth.

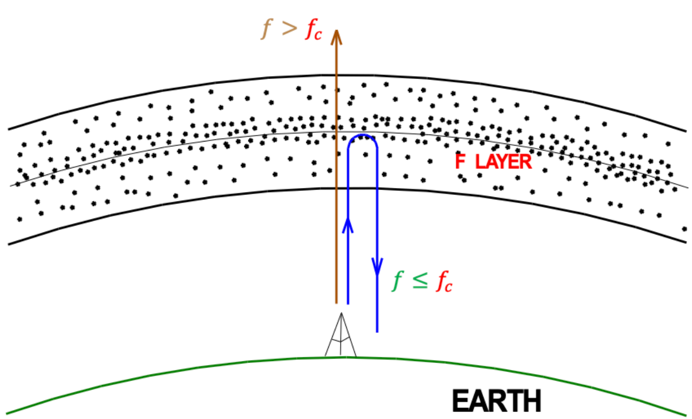


Figure 18 Critical frequency defined (source: author)

Signals higher in frequency transmitted straight up penetrate the ionosphere and are lost to outer space (brown trace).

1.3.1 Ionosondes

Ground based sounders, known as ionosondes, are used to determine the ionosphere's critical frequency. A map of ionosonde locations around the world is provided in Figure 19. The location of a particular ionosonde is determined by clicking on the link provided in the figure and then clicking on the ionosonde (blue dot) of interest. For example, the ionosonde located in California is near Vandenburg AFB.

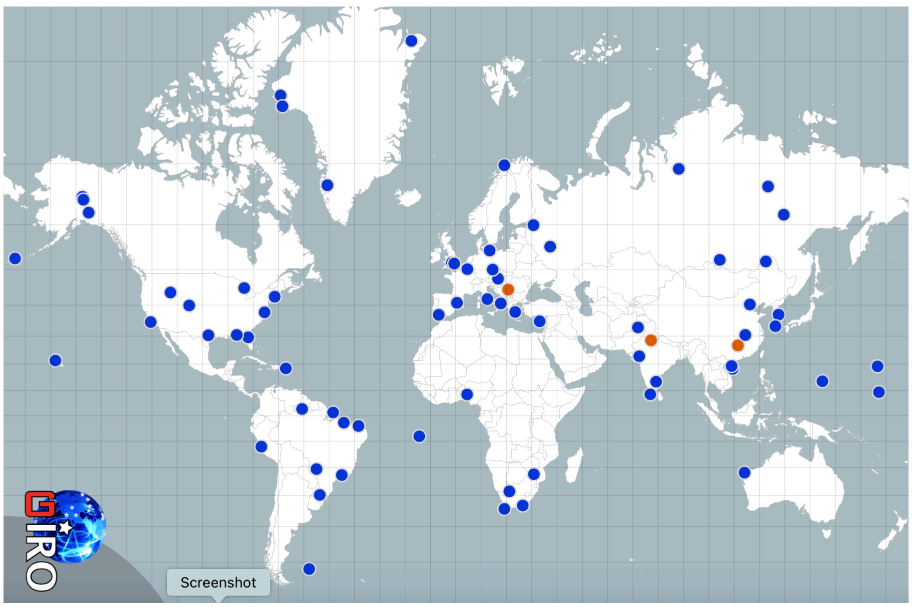


Figure 19 World Map of Ionosondes stations (source: Lowell Digisonde International https://digisonde.com)

Figure 20 shows a typical ionosonde system. The system consists of a computer (data processor) controlling a transmitter and receiver plus associated antennas. The computer synchronizes the transmitter and receiver to the same frequency. Under computer control a pulse is transmitted straight up at a particular frequency. The pulse reflects from the ionosphere and is detected by the receiver. The receiver sends the signal to the computer for display on the ionosonde's screen. The transmit – receive frequency is incremented by the computer and the above processes repeated. As the frequency is slowly increased, a point is reached at which the transmitted pulse is no longer received. That is, the transmitted pulse penetrates the ionosphere instead of being reflected back to Earth. The frequency of the last reflected pulse is the ionosphere's critical frequency at the ionosonde's location. The process is actually more involved, but this is the general idea.

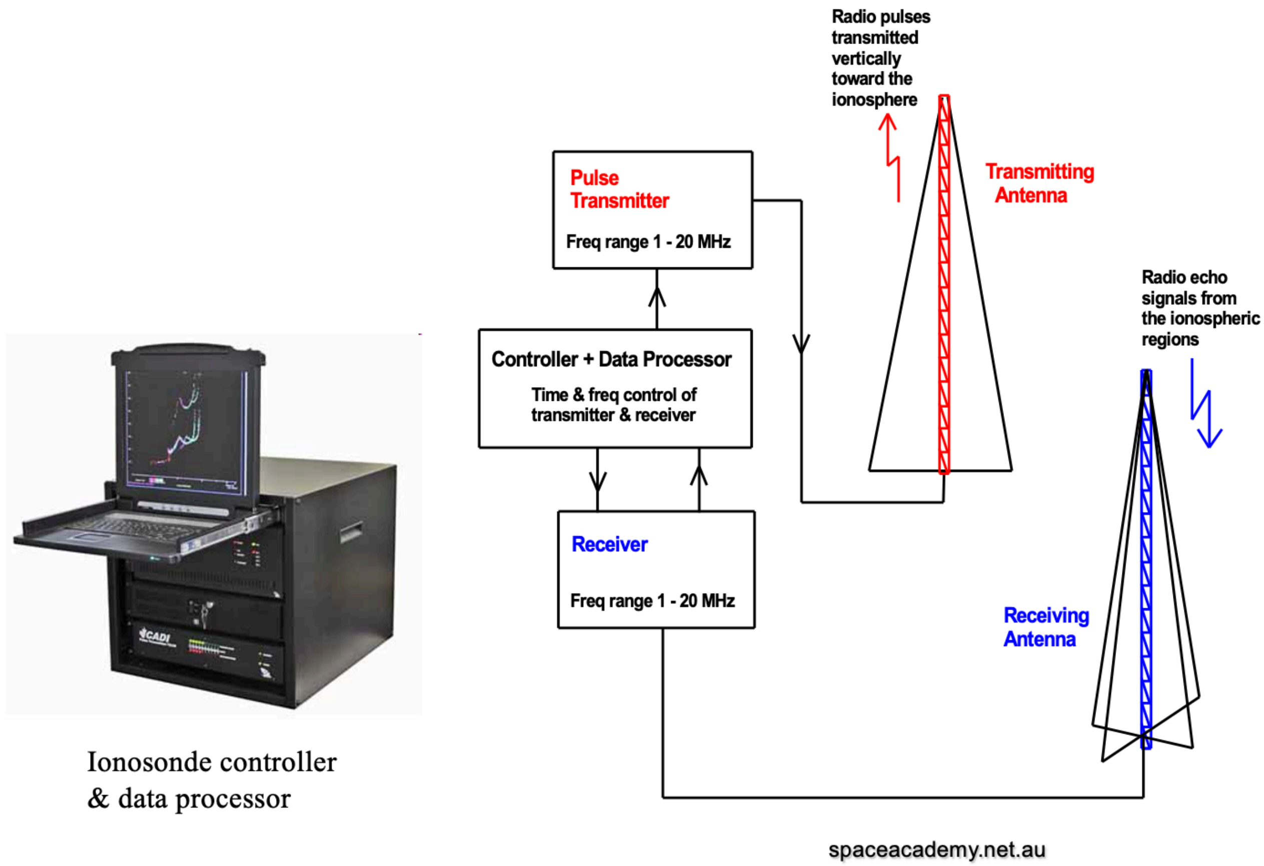


Figure 20 Ionosonde System (source: spaceacademy.net.au)

Knowing the critical frequency is very important for NVIS as well as all HF communications. So where do you find the ionosphere's current critical frequency?

The Australian Government produces a global F2 critical frequency map that is available under the Current Conditions tab on the www.skywave-radio.org website. The map is created automatically from reports received from ionosonde monitoring stations around the world and updated every 15 minutes. A typical critical frequency map is shown in Figure 21.

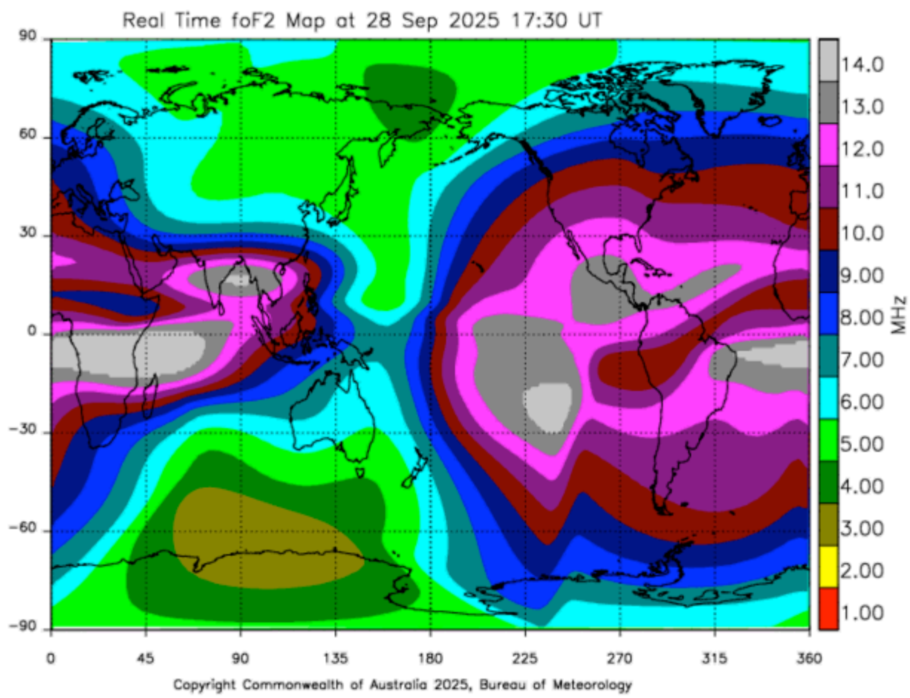


Figure 21 Critical frequency map for September 28, 2025 at 17:30 UT (10:30 PDT)

This particular map shows the critical frequency for September 28, 2025 at 17:30 UT (10:30 Pacific Daylight Time). Over California the critical frequency was 11 MHz.

1.3.2 NVIS Propagation vs Critical Frequency

NVIS propagation is only possible if the transmitting frequency f_{NVIS} is below the ionosphere's critical frequency fc. This makes sense. Critical frequency is the highest frequency that can be transmitted straight up and reflected back to Earth. A higher frequency signal transmitted nearly straight up (an NVIS signal) will penetrate the ionosphere and be lost to outer space. Thus, NVIS communications is only possible on frequencies below the critical frequency.

For example, excellent NVIS propagation occurs on 40 (7.0 MHz} and 80 meters (3.5 MHz) at a critical frequency of 8 MHz. But, 40 meter NVIS will no longer be possible if the critical frequency drops below 7 MHz. In contrast, NVIS propagation will remain strong on 80 meters with a 7 MHz critical frequency. So, if we have been operating on 40, we will need to change our operating frequency to 80 meters when the critical frequency drops below 7 MHz. Frequency agility is an important aspect of NVIS communications.

1.3.3 NVIS Fading

Critical frequency continuously drifts up and down in frequency. A critical frequency of 7 MHz may drift up to 7.6 and then down to 6.5 MHz. Consequently, a 40 meter (7.2 MHz) signal will fade in and out as the critical frequency drifts above and below the transmitting frequency. Operating at a frequency 10% below the critical frequency is necessary to avoid fading. Using the 10% rule, the lowest allowed critical frequencies for NVIS operations on 40, 60, 75, and 80 meters are shown in the following chart.

Frequency Band	Lowest Critical Frequency
40 Meters	8 MHz
60 Meters	6 MHz
75 Meters	4.4 MHz
80 Meters	4.1 MHz

1.3.4 Availability of NVIS Propagation

Figure 22 and Figure 23 show the typical winter and summer critical frequencies for solar maximum and solar minimum.

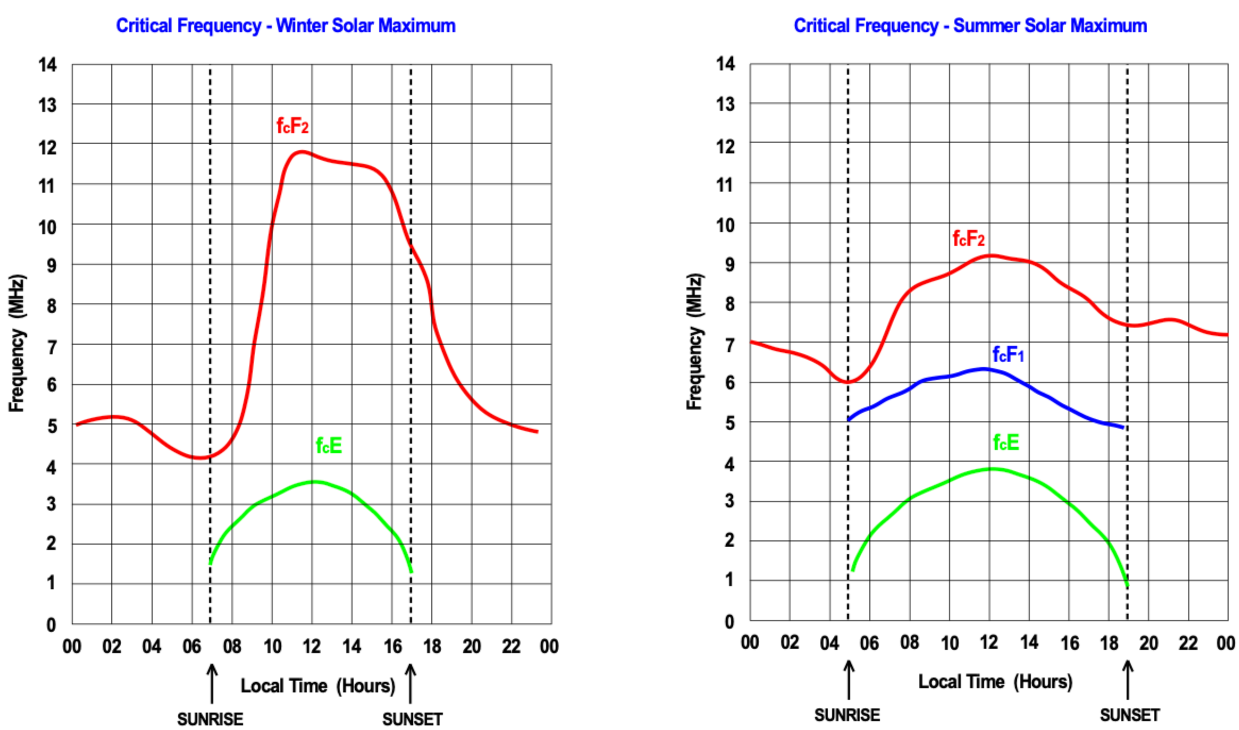


Figure 22 Winter and summer critical frequencies during solar maximum (source: author)

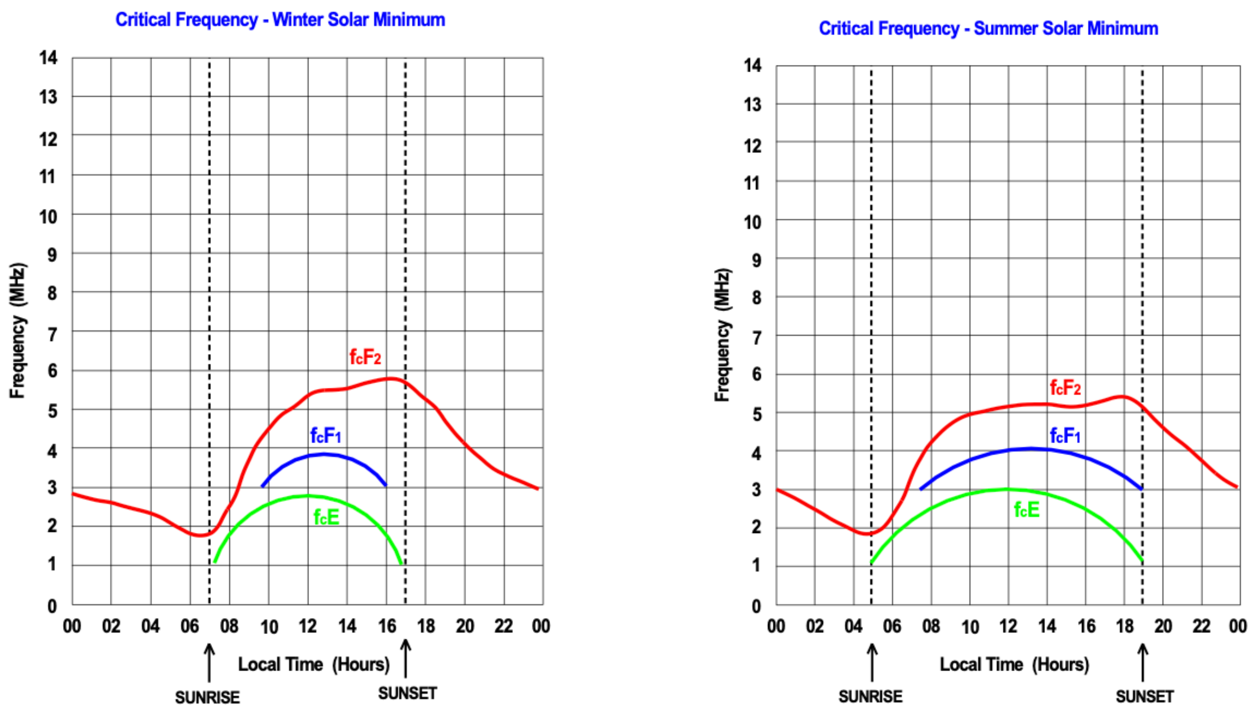
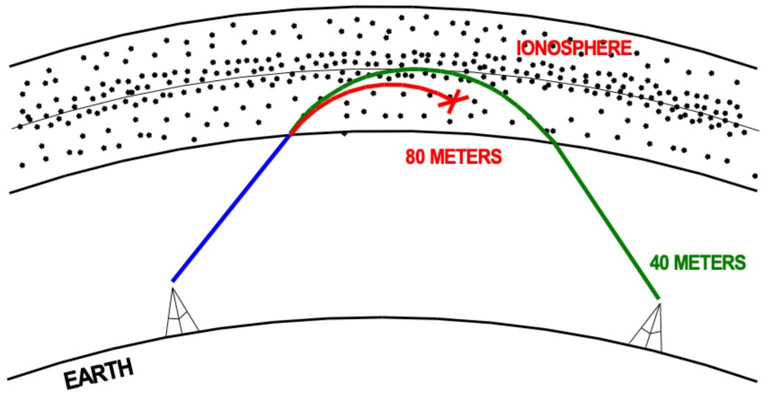


Figure 23 Winter and summer critical frequencies during solar minimum (source: author)

According to these figures, 40 meter NVIS, with its mandatory 8 MHz or higher critical frequency, is available throughout the years of solar maximum. However, during solar minimum the critical frequency is always below 6 MHz, not sufficient to support 40 meter NVIS. 60 meter NVIS operation with its required minimum critical frequency of 6 MHz is questionable. During solar minimum 80 meter NVIS is available from roughly 0900 in the morning to 2000 in the evening. It is often the only available NVIS band, and it is not available at night.

1.3.5 D Layer Absorption

As illustrated in Figure 24, D-Layer absorption is inversely proportional to frequency squared. For example, absorption is 4 times greater on 80 than on 40 meters. To minimize D-Layer absorption, operate on the highest available frequency band that is at least 10% below the critical frequency. If both 40 and 80 meters are below the critical frequency, operate on 40 meters to minimize D-Layer absorption. Figure 24 illustrates this point. In this figure 40 and 80 meters are both below the critical frequency, but 80 meter signals are absorbed in the D-Layer while the 40 meter signals are not.



$$\text{Absorption} \propto \frac{1}{f^2}$$

Figure 24 D Layer absorption (source: author)

1.3.6 40 Meter Mid-day NVIS Communications

In the years close to solar maximum, excellent 40 meter NVIS coverage occurs throughout the day, in particular during mid-day when D-Layer absorption is greatest. The reason for this is that high elevation angle NVIS signals (blue trace in Figure 25) pass through the D-Layer quickly incurring little absorption. However, long distance low angle 40 meter signals spend more time passing through the D-Layer often resulting in complete D-Layer absorption. This is very important. Using NVIS propagation**,** 40 meters during the day and 80 meters at night, we can reliably communicate nearly 24 hours a day 7 days a week in the years near solar maximum.

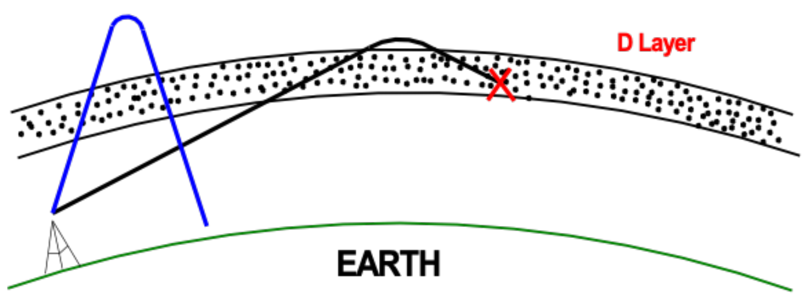


Figure 25 Mid-day 40 meter NVIS communications (source: author)

HF communication becomes more difficult during solar minimum. NVIS is no longer possible on 40 and questionable on 60 meters. However, because of its high elevation angle, 80 meter NVIS may be possible during the day in the same way that 40 meter daytime NVIS is available during solar maximum.

1.3.7 Low Power NVIS Communications

Excellent NVIS communications is achieved using 10 to 15 watts during solar maximum. The reason for the low power requirement is that NVIS path lengths are very short (a single short hop through the ionosphere) incurring very little signal attenuation. In comparison, the low angle multi-hop signal shown in Figure 26 experiences significant absorption with each pass through the D-Layer, once on the way up to the ionosphere and again on its return path back to earth. In addition, the signal is further attenuated with each reflection from ground. These signal losses occur with each hop over and over again resulting in a highly attenuated signal by the time it reaches the receiving station. Consequently, power levels of 100 watts or more are generally required for multi-hop communications.

The low power requirements for NVIS means that regional HF emergency communications out 200 to 300 miles can be achieved using battery power in the same way that batteries are utilized for 2 meter and 440 local communications. During solar maximum, battery powered stations can often handle all of our emergency communication needs on HF, VHF, and UHF.

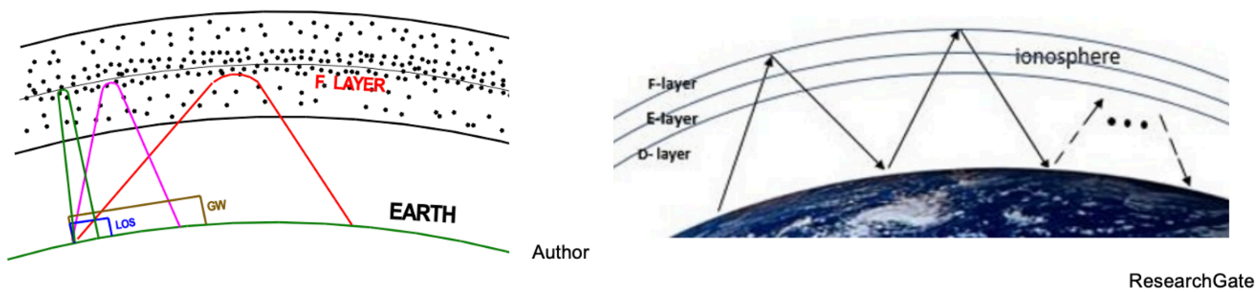


Figure 26 NVIS vs long distance low angle propagation

The situation is much different during solar minimum when the only available NVIS communications is on 80 meters during the day and early evening. The problem is D-Layer absorption. 40 meter NVIS propagation throughout the day is excellent in the years near solar maximum because the high angle 40 meter NVIS signals quickly passed through the D-Layer with minimal absorption. The same sort of phenomenon could occur with daytime 80 meter NVIS signals in the years of solar minimum. However, absorption on 80 is four times greater than that on 40 meters. To compensate for increased absorption, higher power levels of 100 watts or more will typically be required for successful daytime 80 meter NVIS communications.

1.3.8 Sporadic E Effect on NVIS Propagation

Sporadic E patches have an interesting and profound effect on NVIS propagation. As illustrated in Figure 27, a NVIS signal reflected from a sporadic E (E_S) patch never reaches the F2 layer. Consequently, NVIS propagation is independent of the F2 critical frequency when a Sporadic E patch is present, specifically, the strict NVIS requirement for $f_c > f_{NVIS}$ does not apply. Instead NVIS propagation continues to occur as long as the Sporadic E patch is present, even if the F2 layer critical frequency is far below the NVIS frequency.

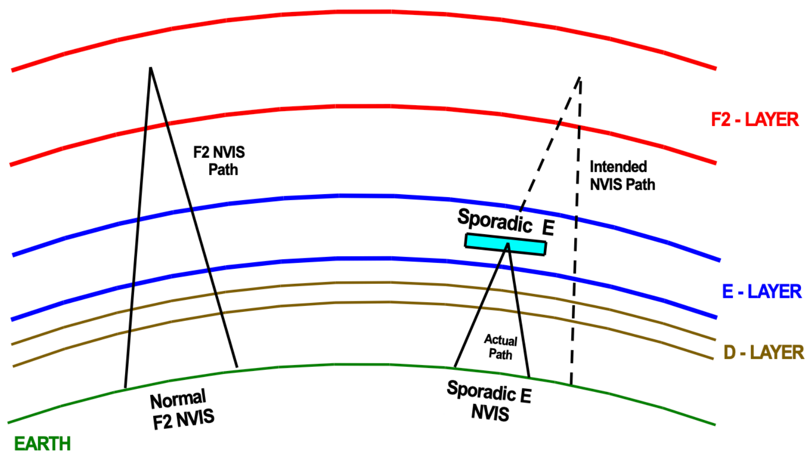


Figure 27 Sporadic E effect on NVIS propagation (source: author)

1.4 NVIS Antennas

Horizontal antennas 1/8 to 1/4 wavelength above ground radiate high angle NVIS signals. Horizontal dipole, Inverted V, end fed, and off center fed antennas all work well. The vertical radiation pattern for a 1/2 wavelength dipole antenna 1/4 wavelength above ground in shown on the right in Figure 28. Notice that most of the antenna's radiation is at angle of 60 to 90 degrees, nearly straight up.

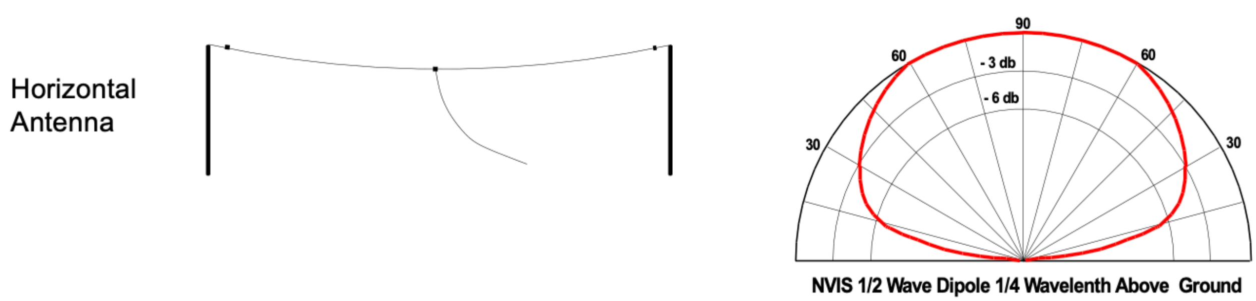


Figure 28 Horizontal NVIS antenna and radiation pattern (source: author)

Figure 29 Vertical antenna radiation pattern (source: author)

Vertical antennas are not well suited to NVIS but provide better ground wave propagation than horizontal antennas. The radiation pattern for a vertical antenna in shown in Figure 29. Notice that this antenna does not have a NVIS component. Nearly all of its radiation is at an angle of 45 degrees or less, peaking at 15 degrees. This is an excellent antenna for long distance and ground wave communications but not for NVIS.

1.4.1 Frequency Agile Antennas

As described earlier, frequency agility is an important aspect of NVIS communications. The antenna system shown in Figure 30 is designed for that purpose. It consists of 3 Inverted V antennas connected together at the center and driven by a signal coax cable. The antennas are tuned for 40, 60, and 80 meters. At an apex height of 32 feet, the 40 meter antenna is 1/4 wavelength above ground while the 80 meter antenna is at a height of 1/8 wavelength, as required for NVIS communications. 60 meters is an ideal NVIS band when the critical frequency is below 40 meters and D-Layer absorption on 80 meters is excessive.

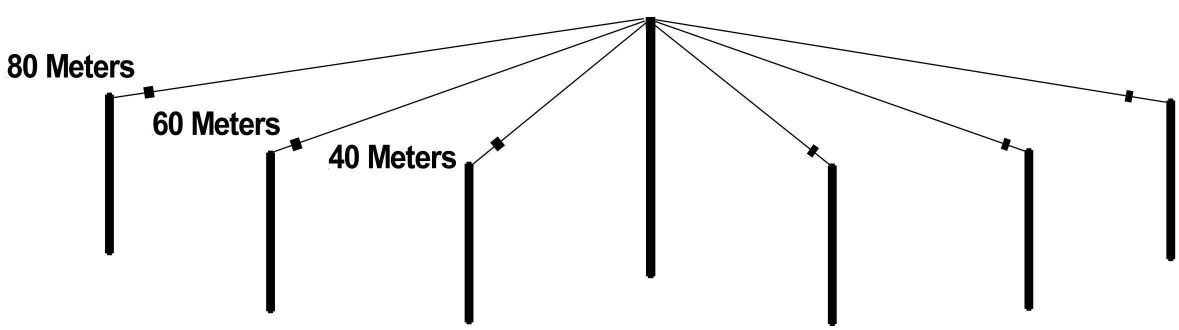


Figure 30 Multiband NVIS Inverted V antenna system (source: author)

1.4.2 General Purpose and NVIS Specific Antennas

The -3db point in an antenna pattern is the elevation angle at which the antenna's signal strength drops 3db below its peak value. For NVIS the peak value occurs at 90°. The -3db point for a NVIS antenna 1/4 wavelength above ground its approximately 30° as illustrated by the red trace in Figure 31. The single hop distance for signals transmitted at this elevation angle is 600 miles when the height of the ionosphere is roughly 350 km. The vertical radiation pattern of a NVIS antenna improves slightly by dropping its height from 1/4 to 1/8 wavelength as shown by the blue trace Figure 31. However, for an antenna 1/8 wavelength above ground its -3db elevation angle is approximately 45° with a corresponding single hop distance of roughly 400 miles.

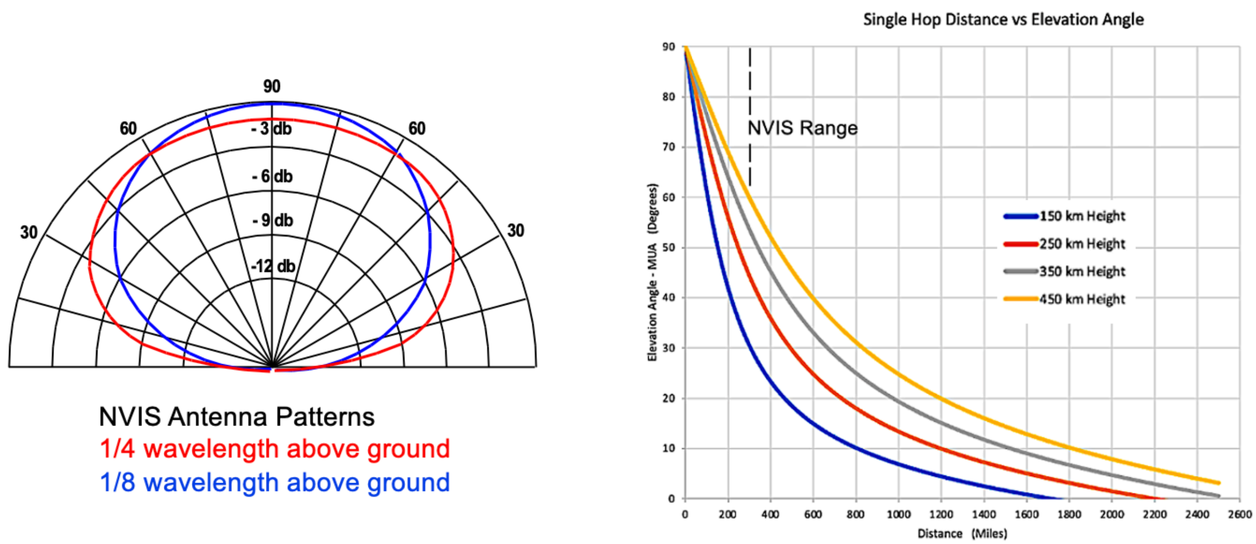
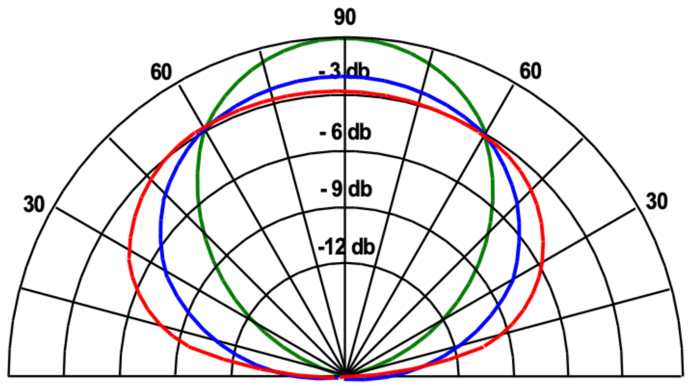


Figure 31 NVIS antenna radiation patterns (source: author)

These single hop distances apply to long distance low angle propagation, not to NVIS. So why are we talking about them here. The answer is in Figure 32.

Adding a Reflector element below a NVIS dipole enhances the antenna's vertical radiation pattern 2 to 3 db compared to a NVIS dipole 1/4 wavelength above ground. This improved performance is illustrated by the green trace in the Figure 32. The reflector element is placed 0.15 wavelengths below the dipole and is 5% longer. The -3db angle for this 2 element antenna is about 60° with a single hop distance of around 200 miles. The 2 element configuration is strictly a NVIS antenna. A simple dipole 1/4 wavelength above ground is a more general purpose antenna. It provides good NVIS capabilities, nearly as good as the 2 element antenna. In addition, it provides long distance multi-hop communications with hops of up to 600 miles.



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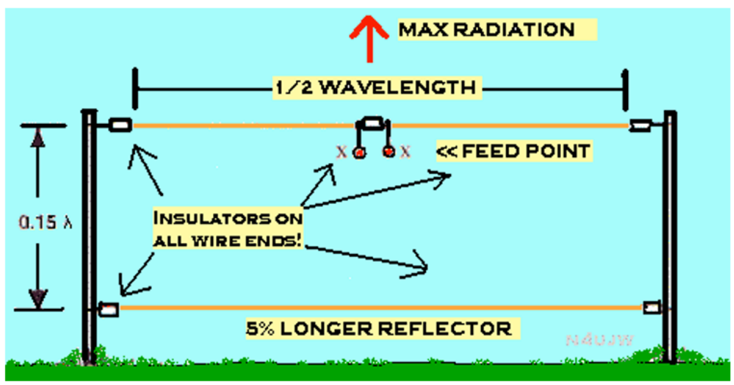

Off Grid Ham

Figure 32 Two element NVIS antenna

1.4.3 Mobile NVIS Antennas

Various NVIS mobile antenna configurations are shown in Figure 33.

A vertical whip antenna mounted on the back of a vehicle does not provide any NVIS capability. However, when the vehicle is stationary, bending the whip back away from the vehicle at an angle of 45^{o} or more does provide a reasonable degree of NVIS connectivity. In this configuration the vehicle body radiates as much energy as the whip itself, creating what in affect is a short center fed mostly horizontal dipole suitable for NVIS communications. This approach was widely used during the Vietnam conflict.

The whip antenna is bent over the center vehicle. The performance of this configuration is much less than that of the vehicle on the left, but it does provide some degree of NVIS capability while the vehicle is on the move.

The military vehicle on the right has a magnetic loop antenna mounted on the vehicle's roof which provides fairly good NVIS connectivity while the vehicle is stationary and moving

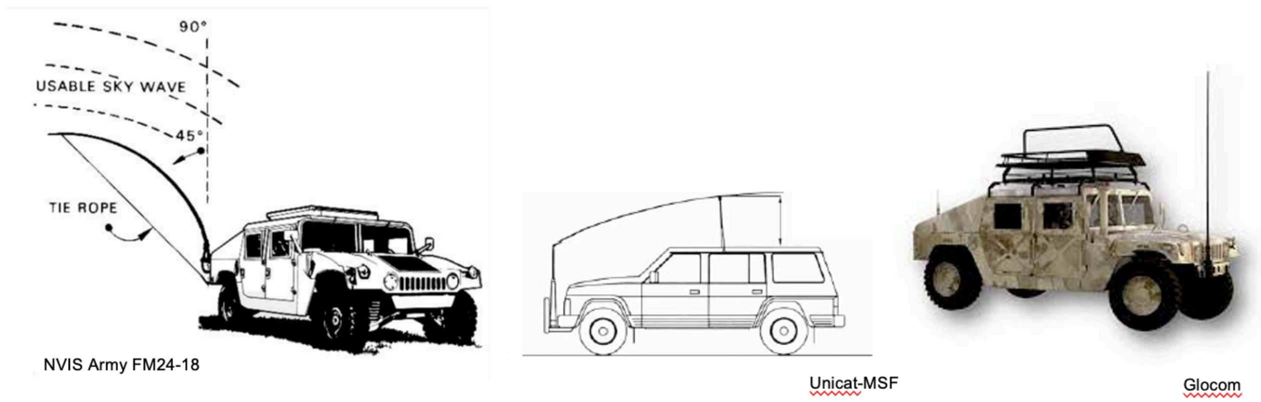

Figure 33 Various NVIS mobile configurations

1.4.4 Omnidirectional Antenna Characteristics

An important characteristic of NVIS antennas is that they are omnidirectional.

A standard dipole 1/2 wavelength above ground, optimized for long distance communications, radiates most of its energy broadside to the antenna as illustrated in Figure 34. The directional characteristics of this antenna is emphasized by the horizontal radiation pattern on the left. However, because of its close proximity to ground, a NVIS antenna is omnidirectional radiating equally well in all directions as illustrated by the radiation pattern on the right. This is important when installing a NVIS antenna in the field. It means that the antenna can be pointed in any direction that simplifies the installation without regard to the locations of the intended receiving stations.

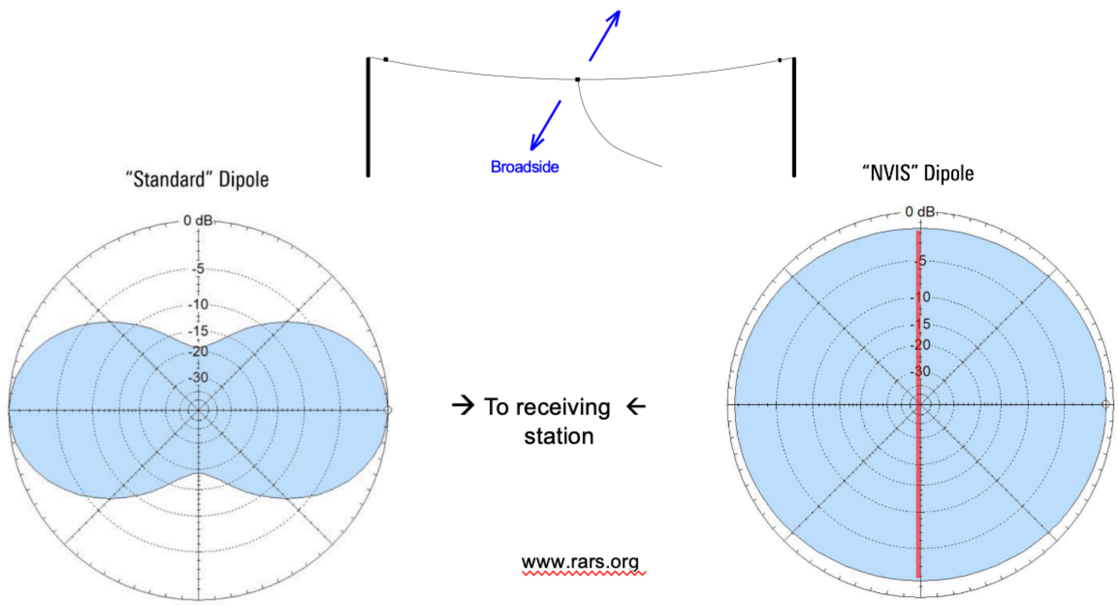

Figure 34 Omnidirectional characteristics of a NVIS antenna (source: www.rars.org)

1.5 Author's NVIS Story

Quite some time ago my wife and I pulled into a wonderful little campground in southwestern Canada along a small river. The area was completely surrounded by high mountains. As we pulled in it occurred to me that I had not seen a telephone, or any signs of civilization in a hundred miles. There certainly were not cell phones or repeaters around.

I wondered how people at the campground would call for help if there were a serious emergency. Amateur radio to the rescue !!! I fired up my radio to see who I could contact. At the time I was using a 40 meter 8 ft long "Ham Stick" antenna mounted vertically from the top of the RV's ladder. The RV was similar to the one shown in Figure 35. Normally this configuration worked quite well. When I turned on the radio all bands were completely dead. I was not quite sure why that was since the radio bands had been quite active.

I had heard of NVIS and wondered if that would help in this mountainous area? I decided to give it a try. I climbed up on top of the RV, disconnected the vertical antenna from the ladder and remounted it horizontally. When I turned the radio back on, 40 meter signals were booming in. I easily worked stations in Portland, Seattle, Vancouver, and many places in between. That NVIS thing really worked!

Figure 35 An RV similar to that used by the author

1.6 Author's Current NVIS Configured RV

The author's current RV configured for NVIS operation is shown in Figure 36.

We tend to think of NVIS antennas as being large, but they don't have to be. The 40 meter NVIS antenna shown in the figure is constructed from two 8 ft long "Ham Stick" antennas connected together in a shortened dipole configuration approximately 15 ft above ground.

This design was specifically selected to permit the RV to serve as a self-contained communications van capable of supporting HF, VHF, and UHF operation wherever needed. The white vertical 2m/440 MHz antenna is visible to the left of the NVIS antenna in Figure 36. It is mounted in the front part of the RV. A full size 40 meter dipole is used whenever space is available. However, space and the surround situation are often not conducive for a full size antenna. When that is the case operation reverts to the ham stick antenna. The situation is similar for providing power to the RV. External commercial AC power is used if available. If not, batteries or the RV's generator is used to power the communications equipment. Portable power and the 40 meter ham stick antenna provide full standalone capability.

This system works well. It has been used during California fires, during emergency preparedness exercises, and public service events. It has also been used in conjunction with the WinLink system to maintain communications with the family when on the road in remote locations.

NVIS is a powerful mode of HF communications that is extensively used!

Why? (1) NVIS low power requirements (2) Few terrain problems (3) Minimal D-Layer absorption (4) No skip zone (5) fewer fading problems (6) Fewer multi-path interference problems (7) No backscatter and (8) Uses easy to install omnidirectional antennas.

Figure 36 Author's RV configured for NVIS operation

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