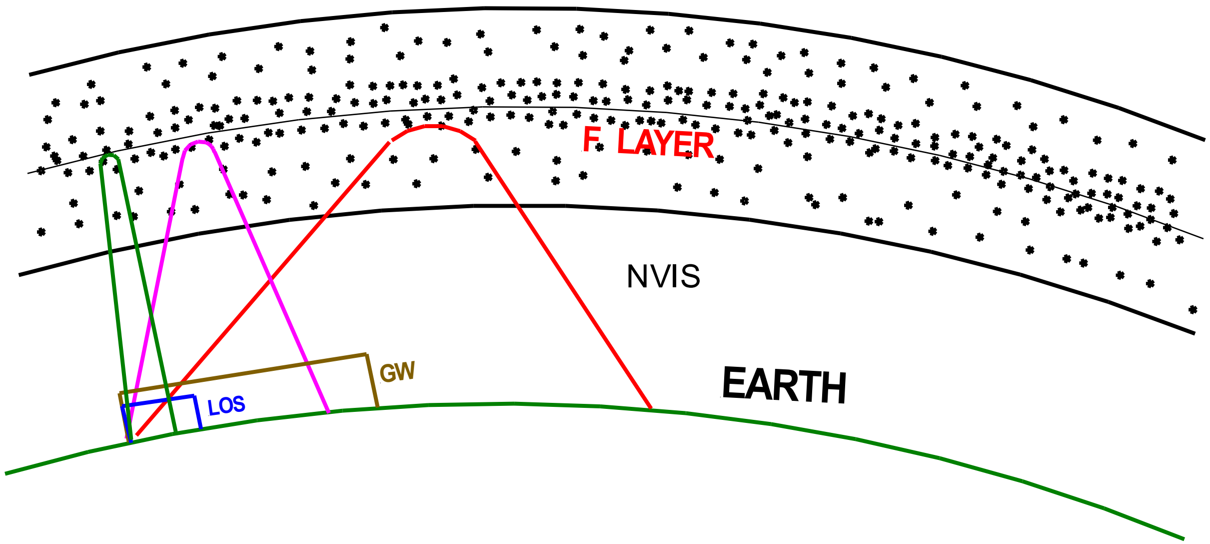
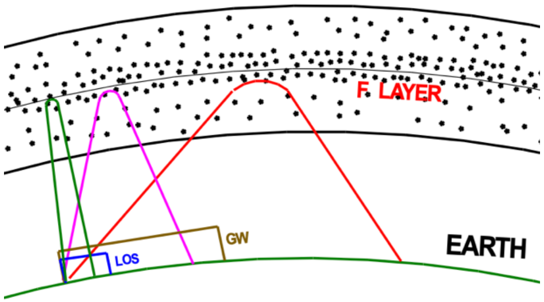
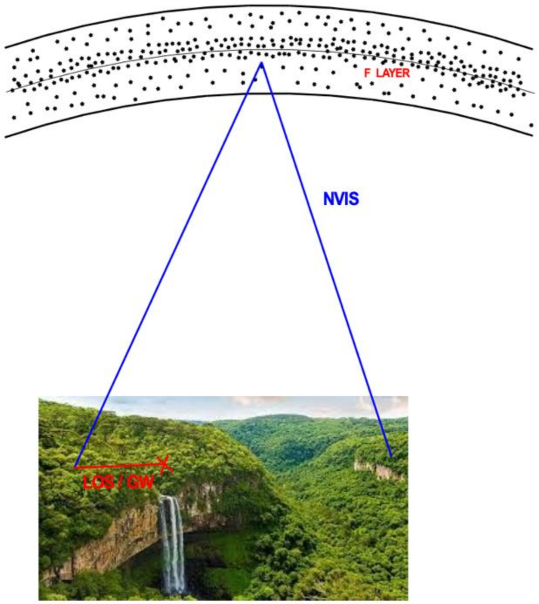
NVIS Communications



Ken Larson KJ6RZ
August 2025
www.skywave-radio.org

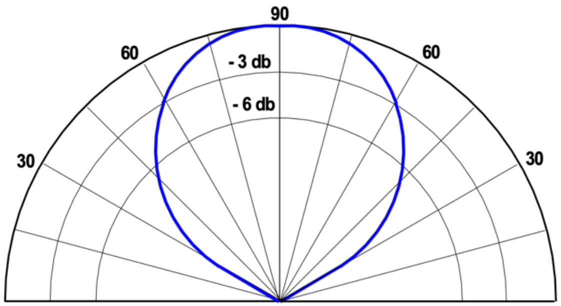
NVIS Is Important !





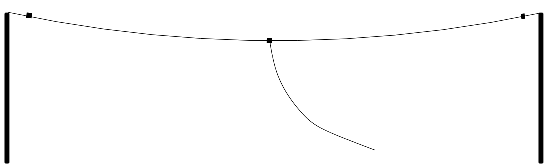
- **Near Vertical Incident Skywave (NVIS) is a powerful mode of HF communications**
- It is heavily used for local and regional radio communications, including
- In mountainous and jungle regions where other forms of radio communications are impossible
- It is extensively used for emergency operations, and
- For military communications

What Is NVIS ?

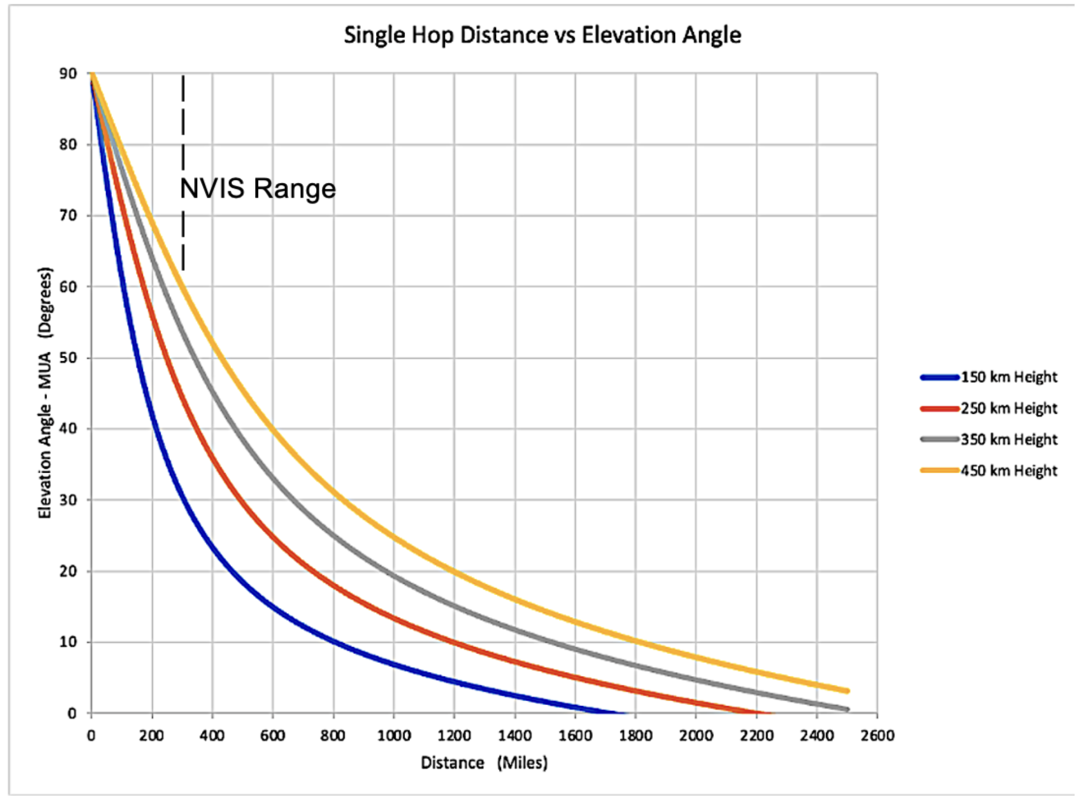


NVIS Antenna Pattern

Author

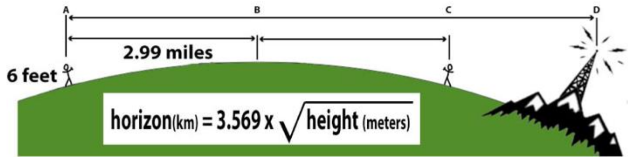


NVIS Antenna

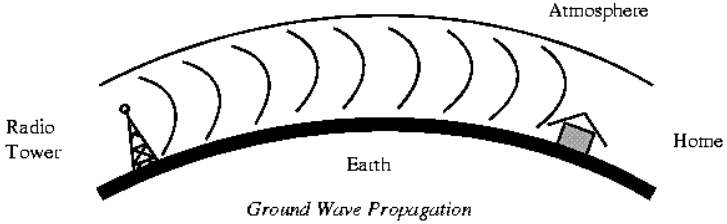


- **NVIS is simply radio communications using HF signals that are transmitted at high elevation angles, i.e. at greater than 60°**
- It is the high elevation angles that makes NVIS so important
- NVIS signals are radiated by low horizontal antennas less than 1/4 wavelength above ground
- NVIS propagation provides local and regional communications out 200 to 300 miles

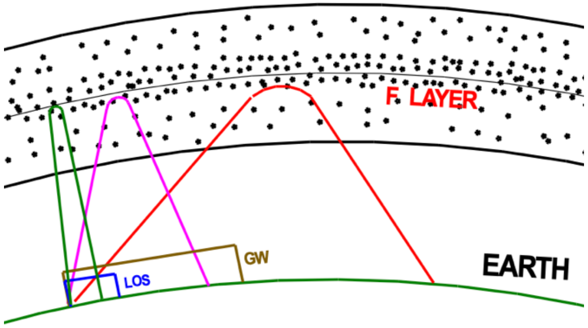
Local HF Communications



Line of Sight



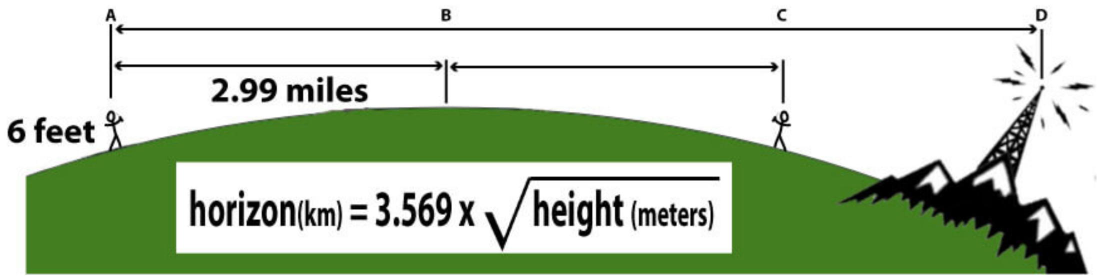
Ground Wave



Near Vertical Incident Skywave

- There are 3 modes of local HF propagation
- Line of Sight (LOS), Ground Wave (GW), and Near Vertical Incident Skywave (NVIS)
- These are the only possible modes for local HF communications

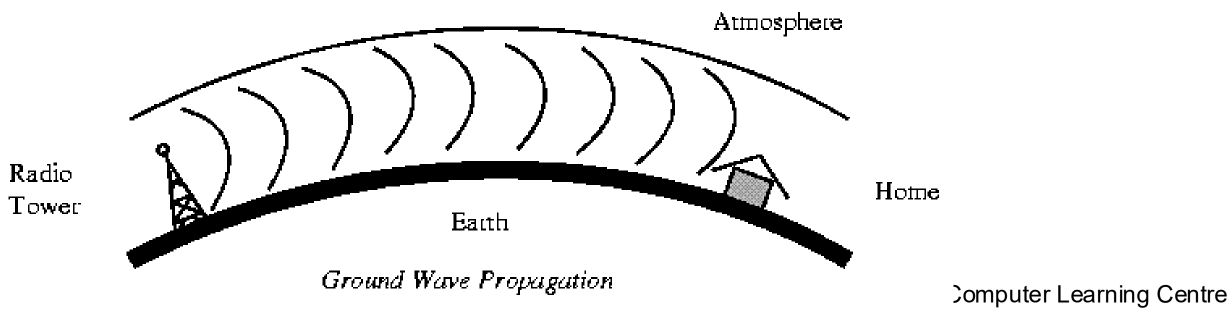
Line of Sight Propagation



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 the figure above the LOS distance between two people with handheld radios is approximately 6 miles
- The LOS distance between a person with a handheld radio and a repeater on a mountain top is greater as the above equation indicates
- The HF LOS distance from my antenna (height = 30 ft) to a similar receiving antenna is approximately 13.4 miles, presuming the local hills don't get in the way which unfortunately they do

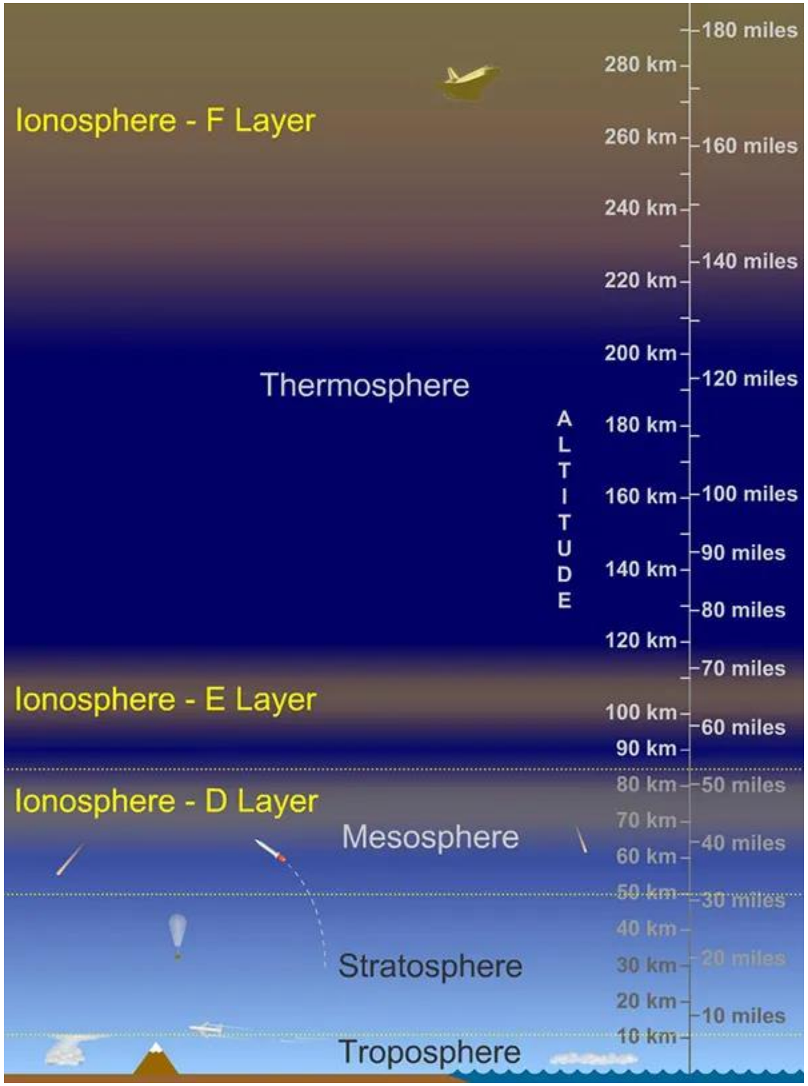
Ground Wave Propagation



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

- Ground wave propagation range depends on Frequency, Terrain, and Soil Conditions
- Ground wave range decreases with increasing frequency as shown in above chart
- Ground wave distances shown above occur over flat terrain and excellent soil
- In Ventura County with many hills, mountains, and rocky soil ground wave propagation range is much less (15 to 20 miles on 40 meters if we are lucky)

LOS and GW Are Independent of the Ionosphere



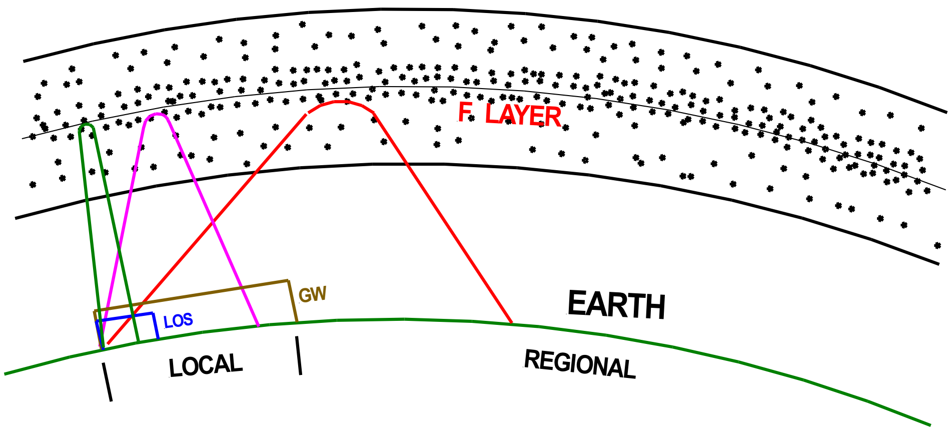
| LOS |

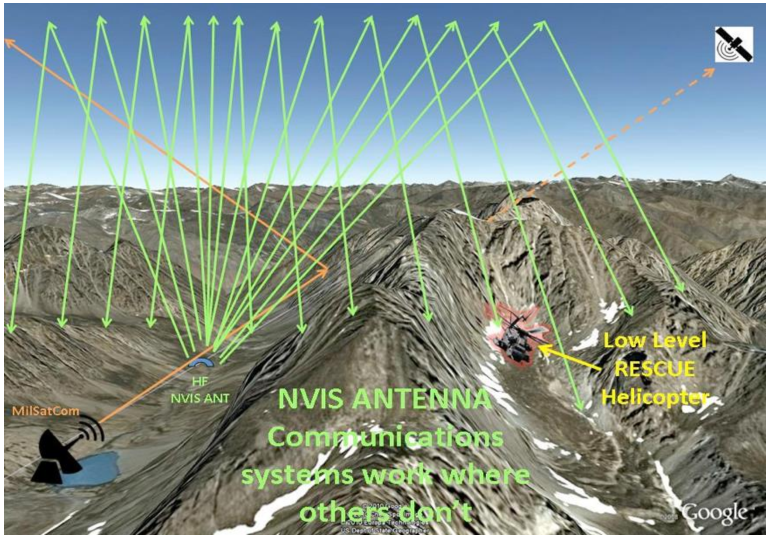
-----------> | GW |

UCAR Center for Science

- Line of sight and ground wave propagation are always present
- In addition, they are not affected by ionospheric conditions
- Over 40 miles of dense atmosphere shield line of sight and ground wave signals from chaos in the ionosphere created by solar flares, Coronal Mass Ejections, and other violent solar events
- LOS and GW signals keep on propagating regardless of what is happening in the ionosphere

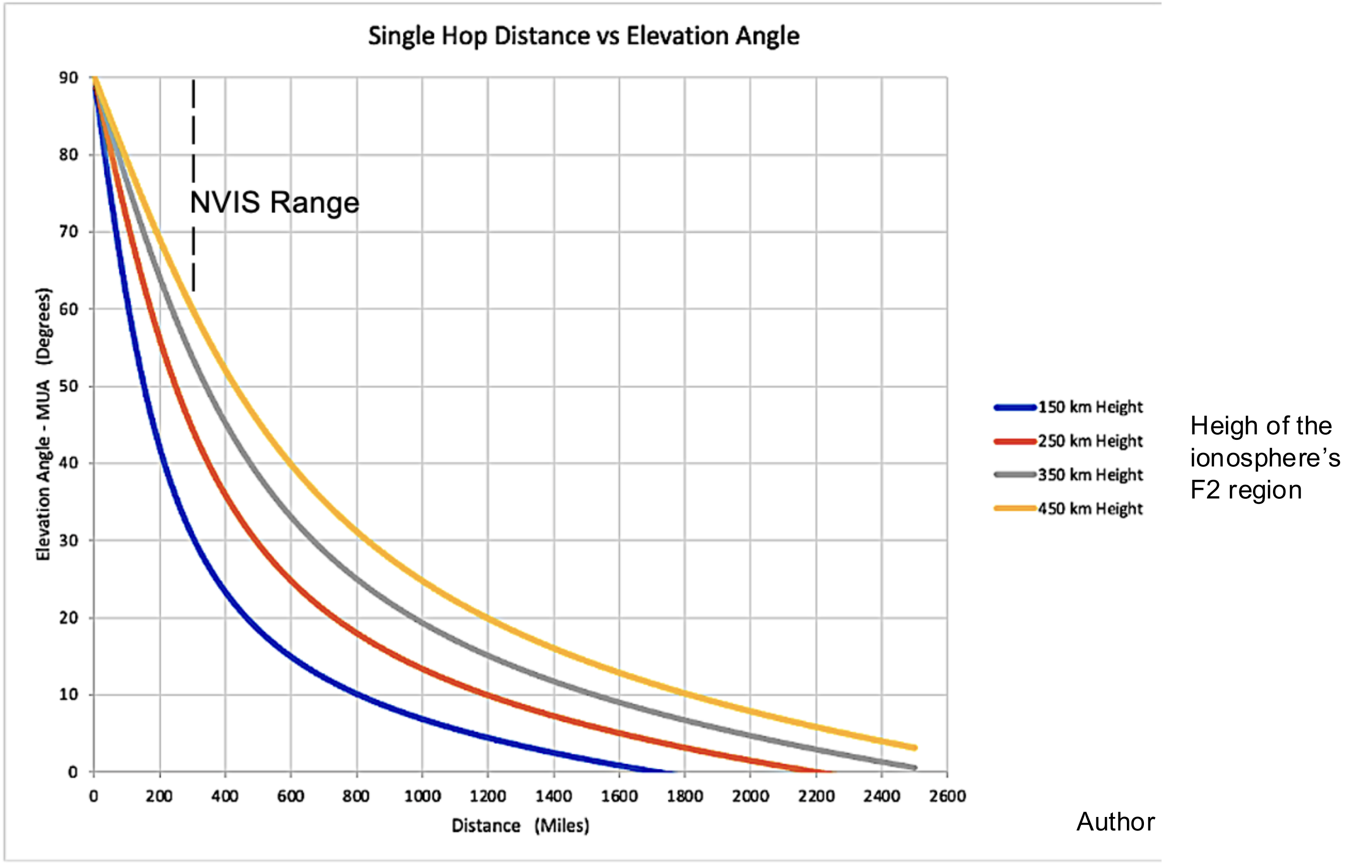
NVIS Coverage





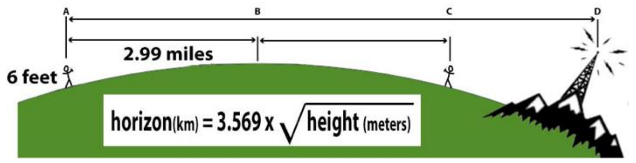
- NVIS along with LOS and GW provide **local** HF communications (green and magenta traces)
- NVIS also provides communications to radio stations within 300 miles of the transmitting station. Stations that are beyond the range of local LOS and GW propagation (the red trace)
- From a communications perspective **regional area** can be defined as the area covered by NVIS propagation
- NVIS provides coverage to **all** radio stations in the regional area
- Unlike LOS and GW, NVIS propagation depends heavily on ionospheric conditions, particularly on the ionosphere's current **critical frequency** (more about that later)

NVIS Range

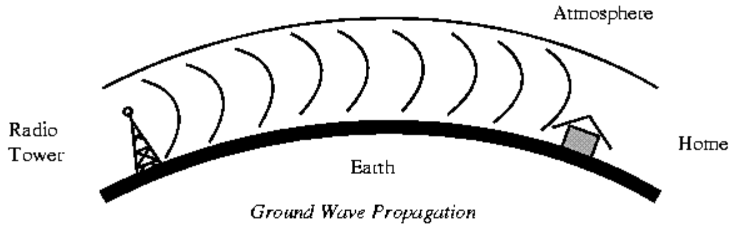


- At an elevation angle of 60°, the NVIS propagation range is 200 to 300 miles
- A transition zone of NVIS propagation, with low D Layer absorption, typically extends out 350 to 380 miles
- Beyond 400 miles we encounter oblique propagation conditions including moderate to high levels of D Layer absorption, skip zones, Maximum Usable Frequency, etc.

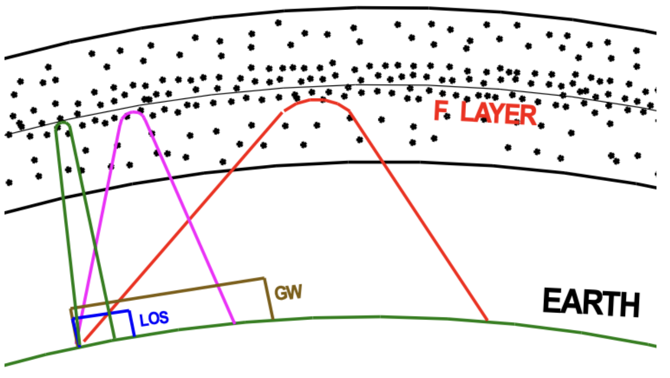
Early Wireless Communications



Line of Sight



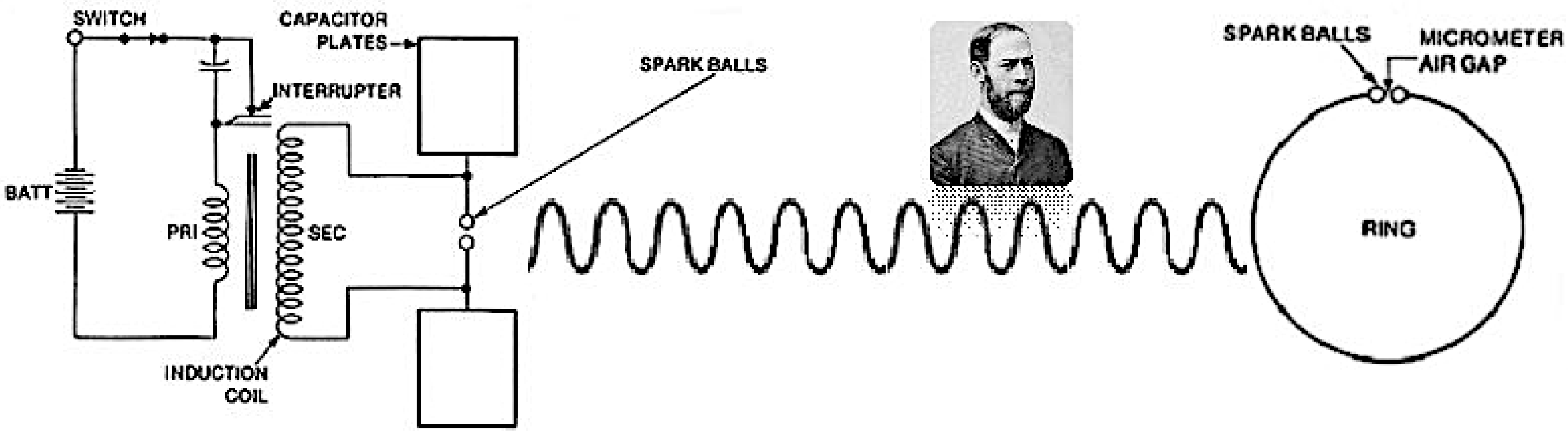
Ground Wave



Near Vertical Incident Skywave

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

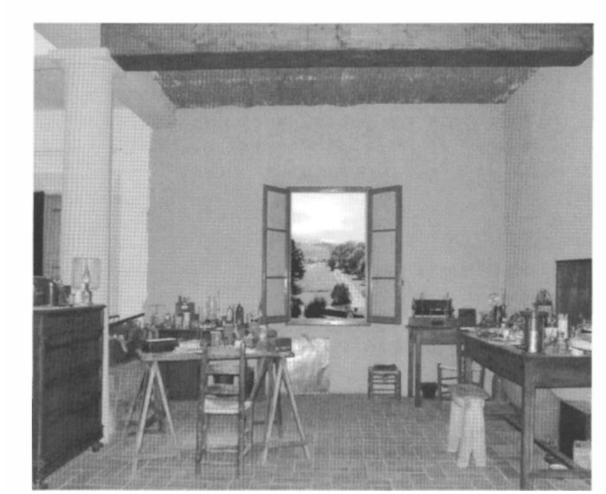
Line of Sight Propagation



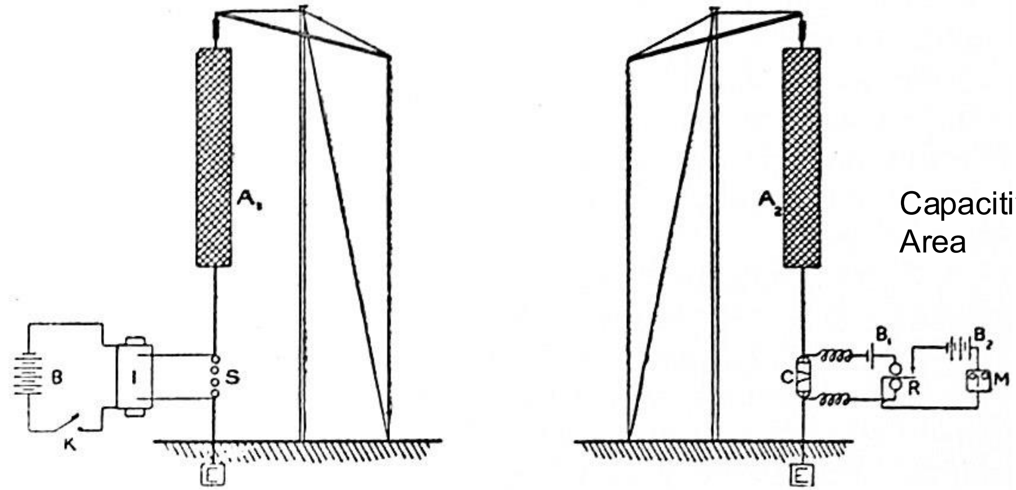
Wikipedia

- In 1888 physicist Heinrich Hertz, working in a relatively large lecture hall, 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
- Hertz performed extensive experiments in what we consider the 6 meter to 70 cm frequency bands proving 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

Ground Wave Propagation



Wikipedia

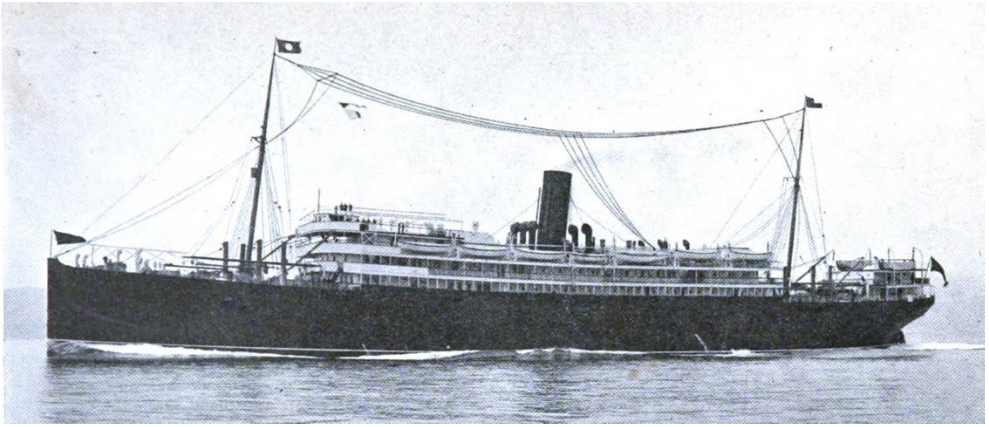


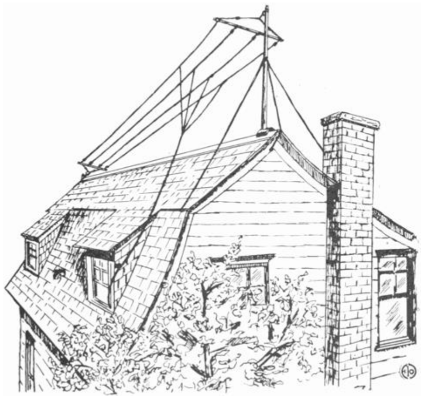
Capacitive Area

Attken

- In 1894, 20 year old Guglielmo Marconi understood very well the commercial significance of the experiments performed by Hertz
- Working in the attic of his father’s estate (Villa Griffone) near Bologna, Italy Marconi repeated the experiments of Hertz attempting to transmit further and further out the attic window to the hills beyond
- In an attempt to achieve longer distances Marconi, using “cut and try experimentation” invented the ground mounted vertical antenna
- With it he achieved excellent ground wave propagation at ever increasing distances

NVIS Propagation





Wikipedia

- 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
- 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)
- Unbeknown to the radio operators, these were NVIS antennas with transmitting distances of 200 to 300 miles
- The short transmit distances gave rise to the Amateur Radio Relay League with hams working all night transmitting messages cross country from one ham station to another

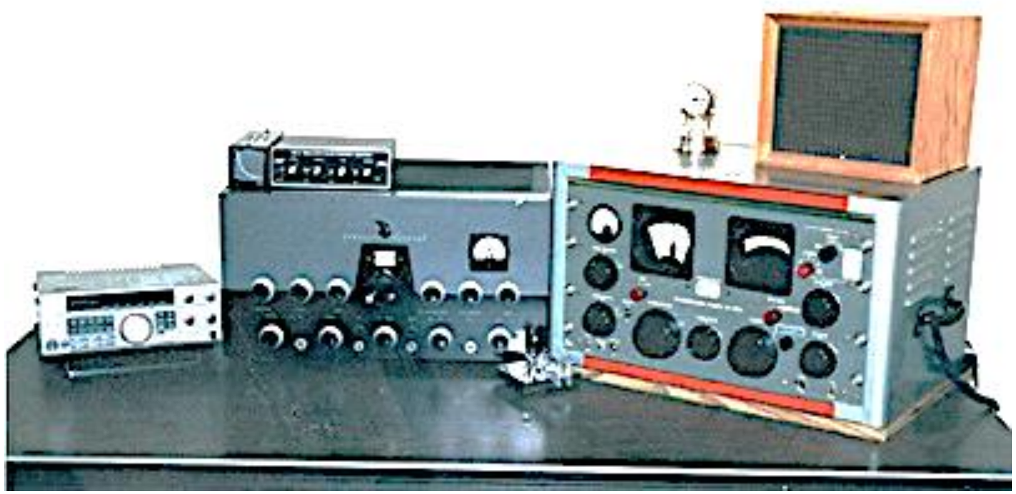
NVIS During WWII and Vietnam

NVIS equipped German armored car

Dmna.ny.gov

- NVIS was first used tactically in WWII by German Army reconnaissance units who were too far forward for ground wave communications with HQ, but too close for normal skywave propagation.
- 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 over come the severe attenuation of ground wave signals by lush jungle vegetation in Burma.
- NVIS was used extensively 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 saved men from their sinking ships
- Rapid development of NVIS technology led to its spectacularly success during the D-Day landings on the beaches of Normandy.
- The U.S. Army used NVIS extensively in Vietnam in regions where dense jungle foliage and mountainous terrain made ground wave and line of sight propagation impossible

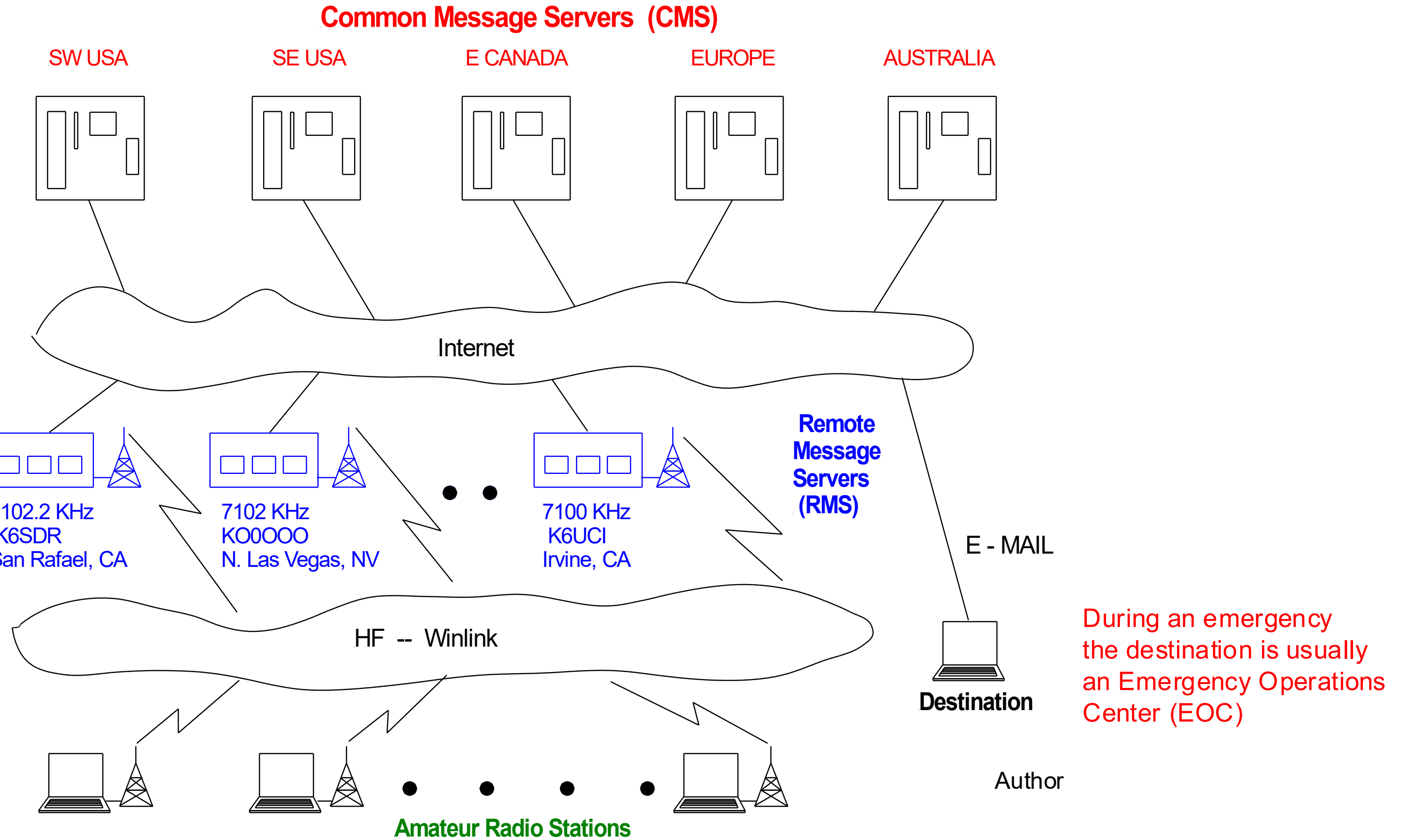
Local Communications on 80 Meters



Author

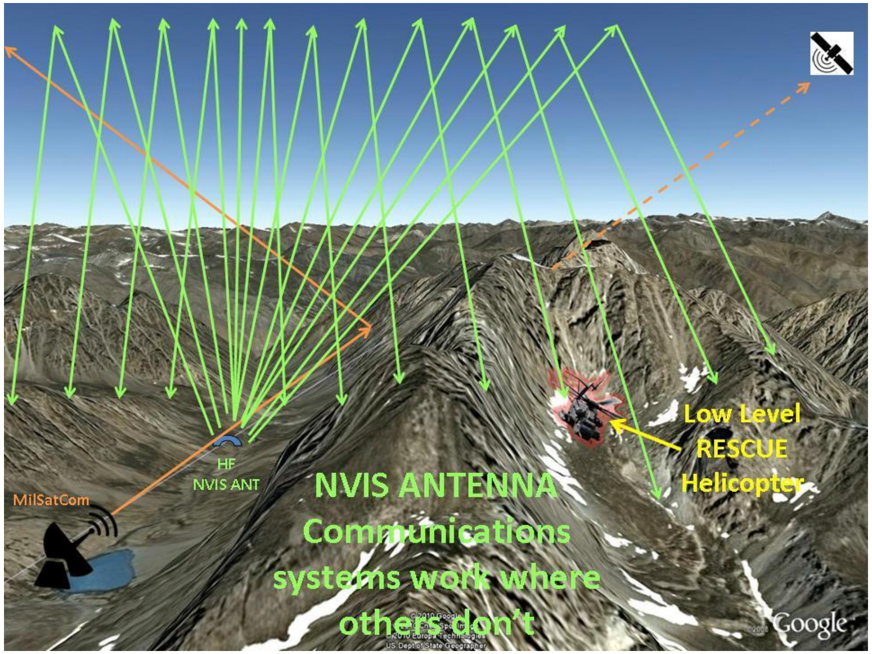
- Throughout the 1950 and 60s, NVIS on 80 meters were the propagation mode and frequency band of choice for emergency communications and local social nets in the same way that 2 meters is used today
- The large physical size of HF vacuum tube transmitters (center) and receivers (right) made them impractical 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

Winlink Communications



- The Winlink network permits amateur radio operators to send e-mail to destinations anywhere in the world via radio links to Winlink Remote Message Servers (RMS HF radio stations)
- During emergencies, Winlink provides a vital means of communications with the outside world for emergency responders working in a disaster zone
- NVIS is often the best means of communications between emergency responders and Winlink RMS stations (typically there are a large number of RMS stations in a NVIS region)

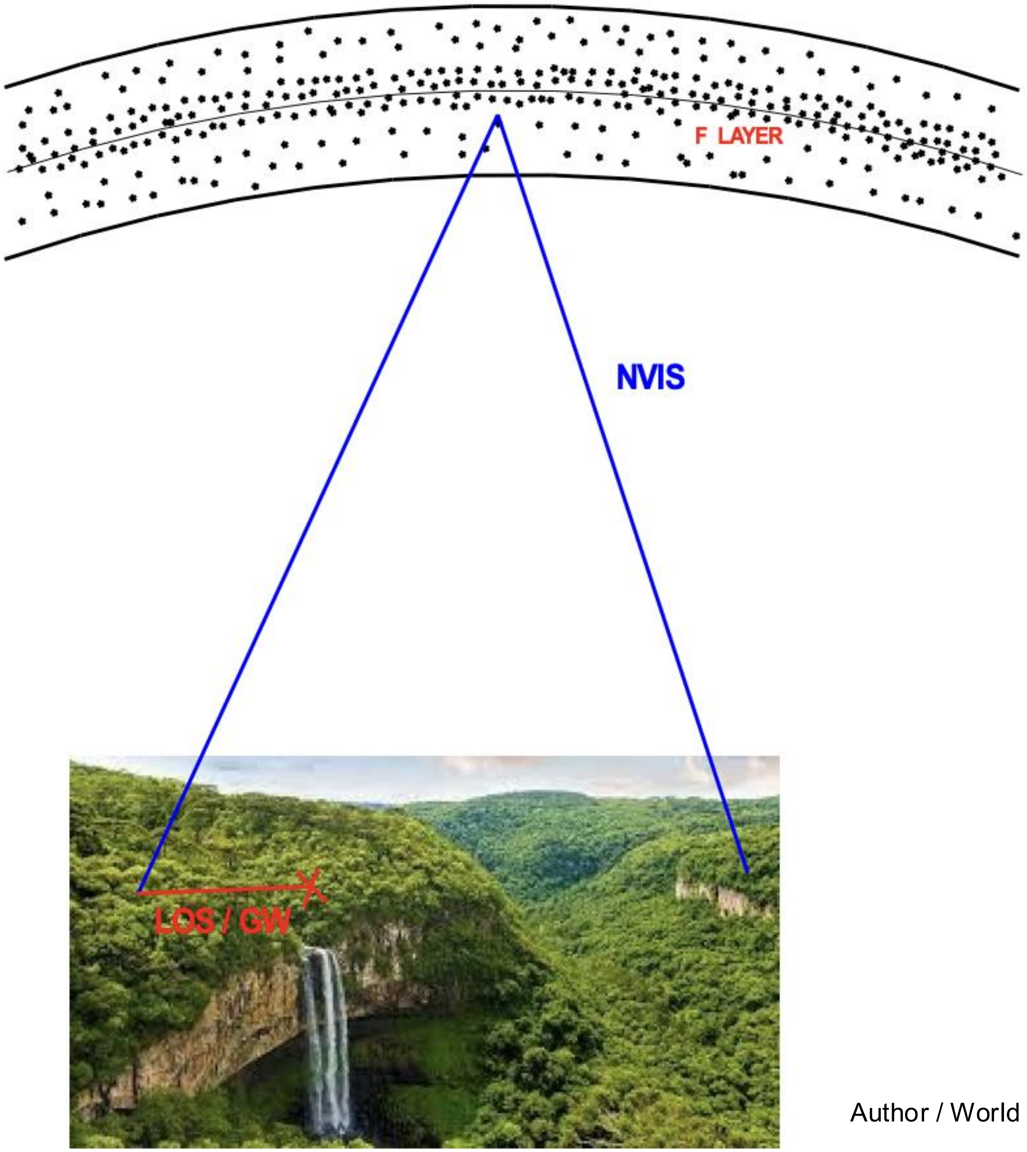
NVIS Communications in Mountainous Terrain



AFCEA International

- NVIS communications work well in mountainous terrain where other forms of radio communications do not
- Radio systems precluded from use in mountainous terrain include: low angle long distance HF, line of sight VHF, UHF, and often satellite communications
- Local HF line of sight and ground wave propagation is also precluded
- Due to its high elevation angle NVIS is often the only means of radio communications into and out of deep mountain valleys and canyons

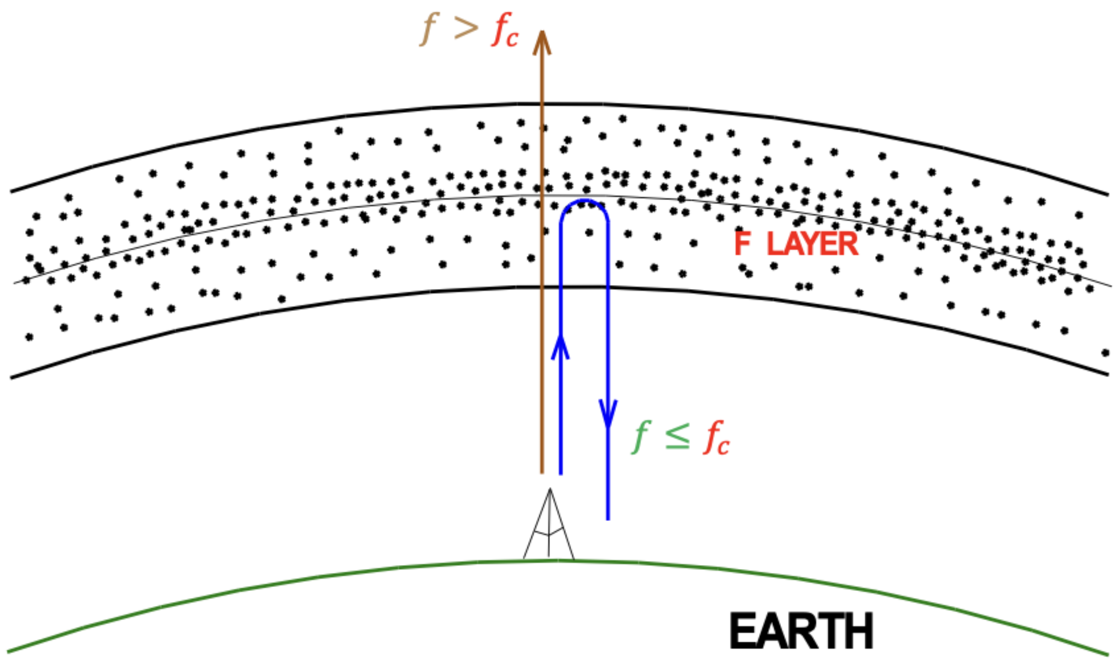
NVIS Communications In Jungle Regions



Author / World Walks

- NVIS signals quickly penetrate the jungle canopy avoiding severe signal attenuation caused by lush often wet jungle vegetation
- 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 jungle vegetation

NVIS Depends On The Ionosphere's Critical Frequency



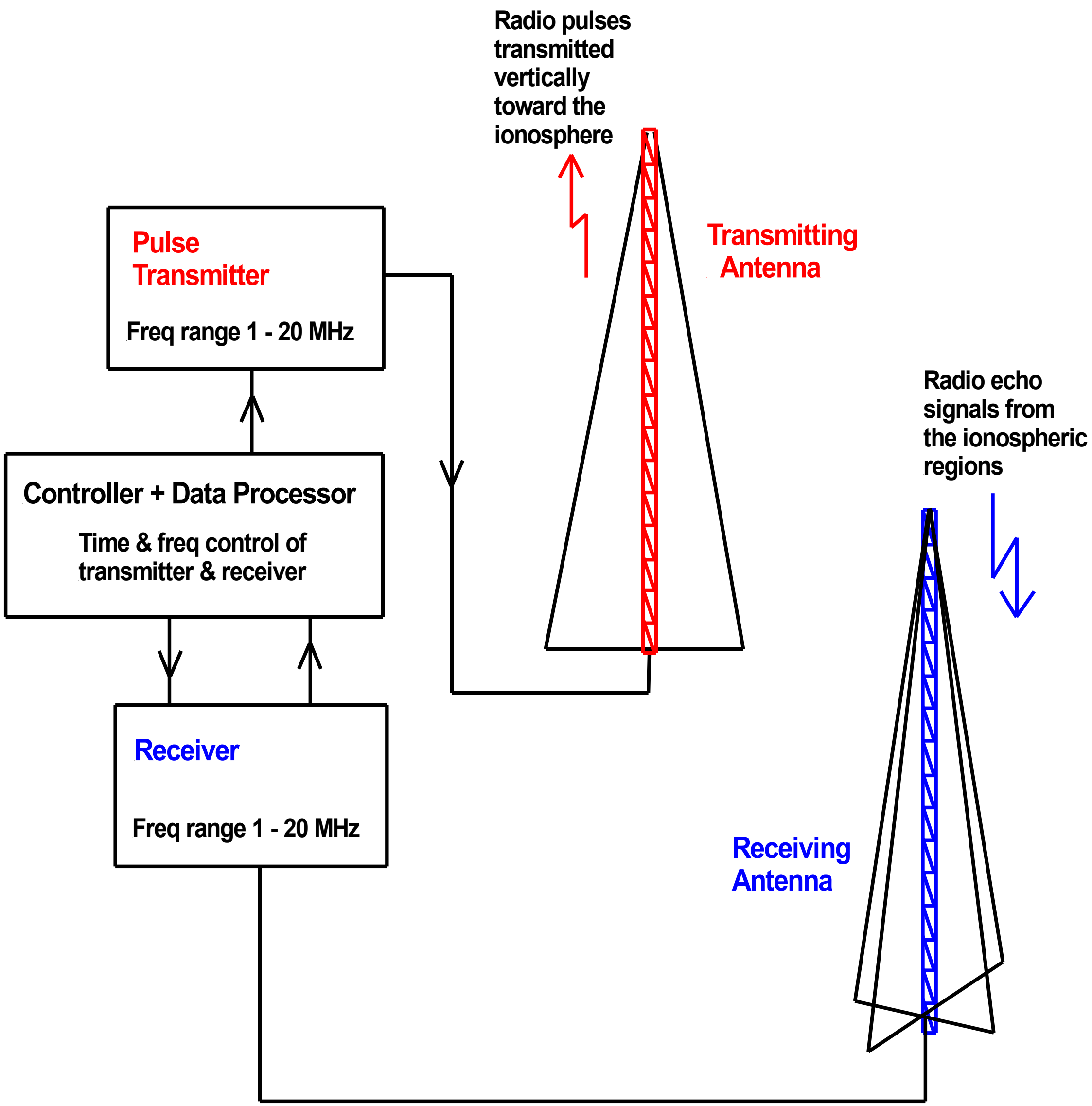
Author

- The ionosphere's Critical Frequency $\mathbf{f_c}$ is the **highest** frequency signal that can be transmitted straight up and reflected back down to Earth
- Signals higher in frequency transmitted straight up will penetrate the ionosphere and be lost to outer space
- All signals lower in frequency than $\mathbf{f_c}$ will be reflected back to Earth, these are the NVIS frequencies

Determining the Current Critical Frequency

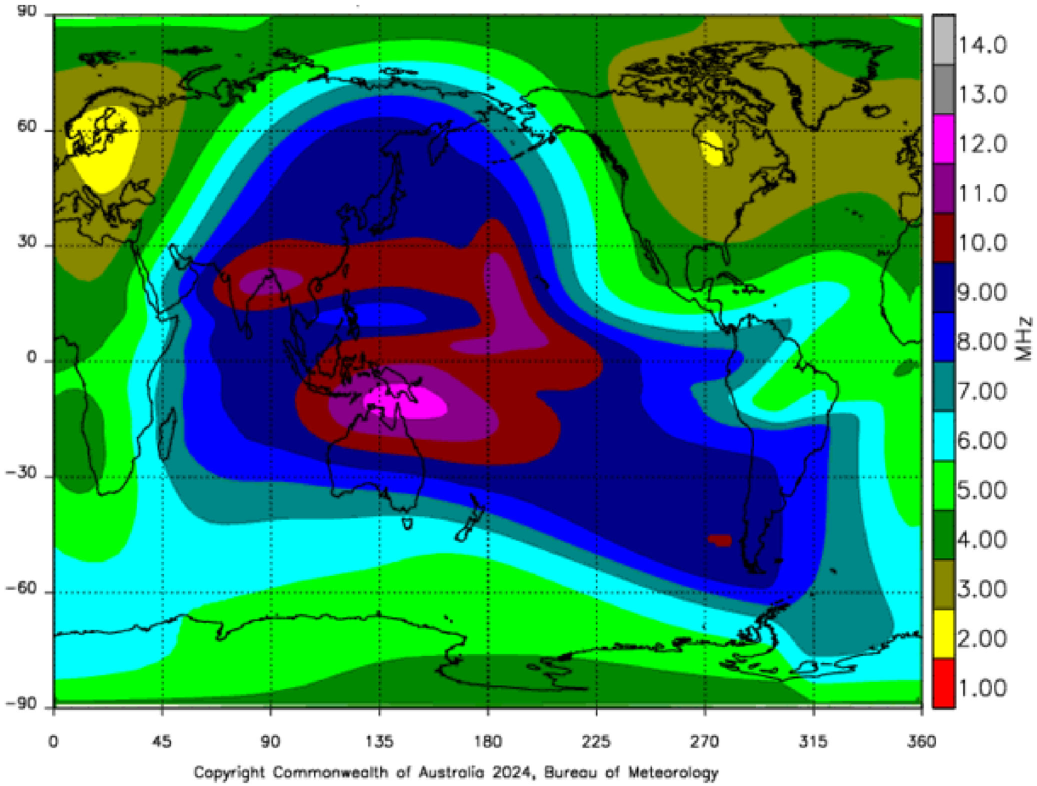
- Ground based sounders, known as ionosondes, are used around the world to determine local critical frequencies
- Our closest ionosonde in California is located just south of Vandenburg AFB

Ionosonde controller & data processor



spaceacademy.net.au

Global Critical Frequency Map



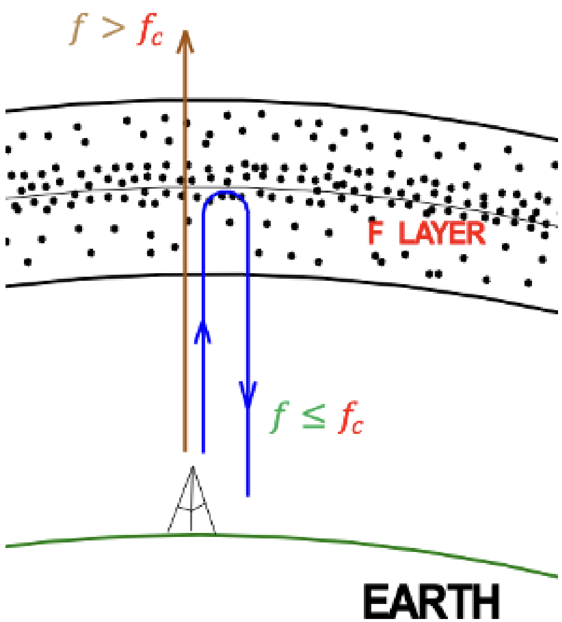
This chart shows the Critical Frequency for January 31, 2024 at 03:00 UT

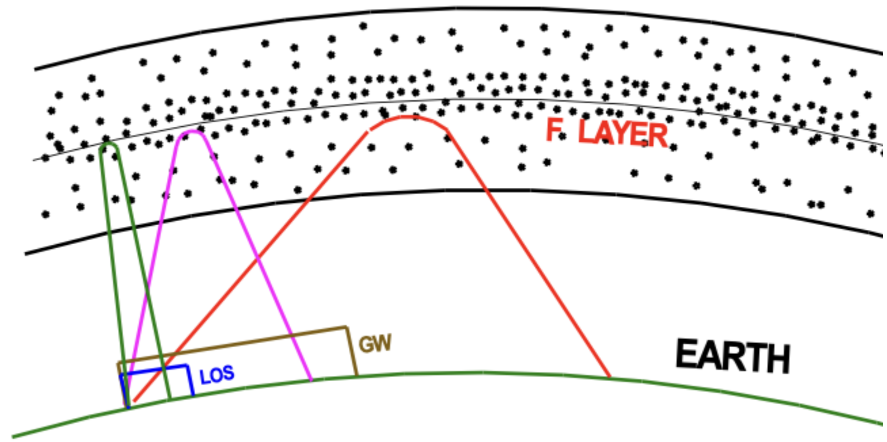
Over California the Critical Frequency was between 4 to 5 MHz

Critical frequency in Northern Europe was 2 MHz

- 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 critical frequency map is updated every 15 minutes
- The map is created automatically from reports received from ionosonde monitoring stations around the world

NVIS Propagation vs Critical Frequency

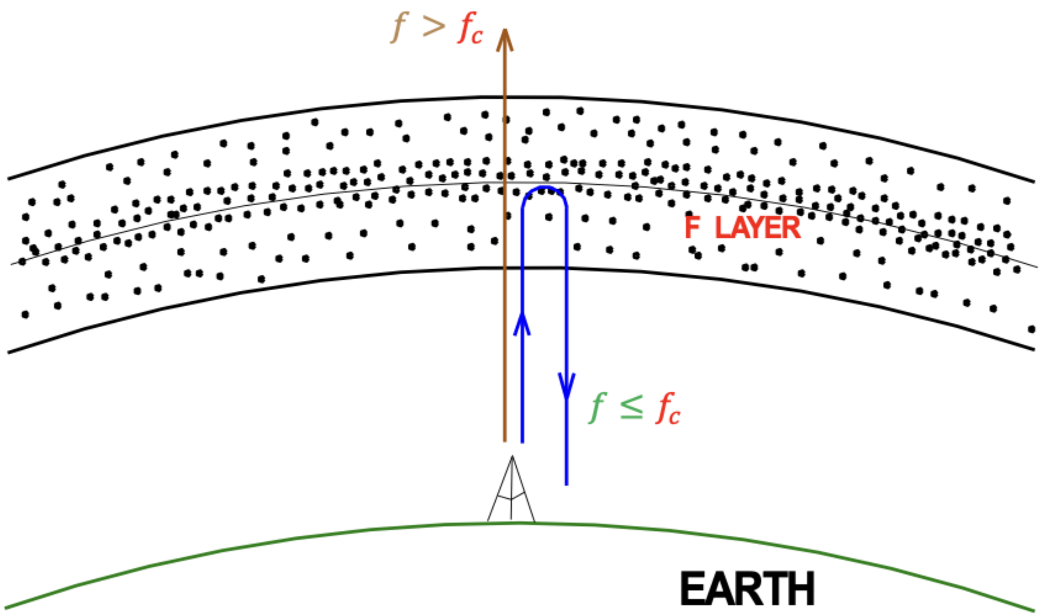




Author

- **NVIS propagation is only possible if the NVIS transmitting frequency f is below the ionosphere's critical frequency f_c** → 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 for frequencies below the critical frequency**

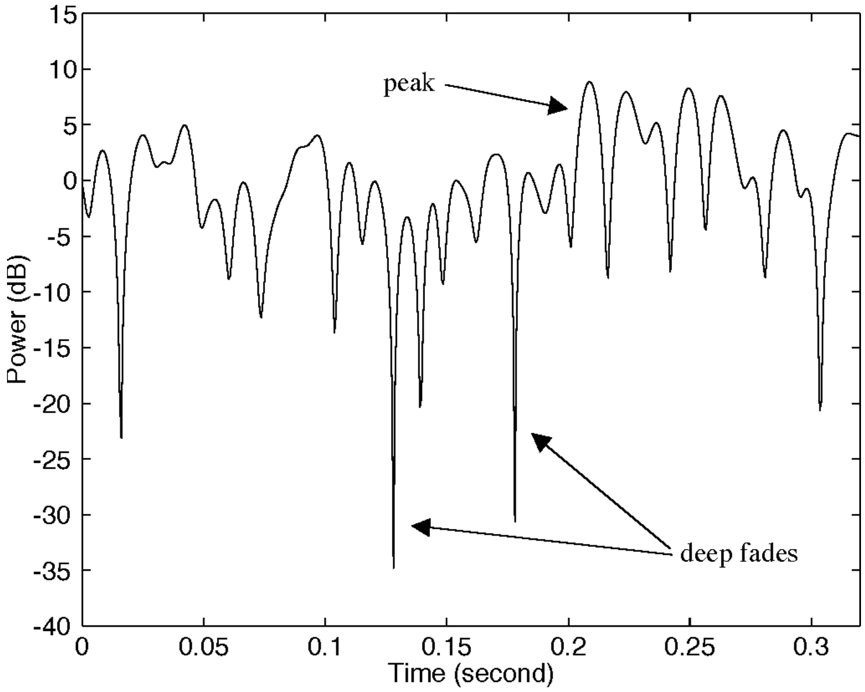
NVIS Propagation vs Critical Frequency Example



Author

- For example, if the current critical frequency is 8 MHz, then NVIS propagation will be excellent on 40 and 80 meters since both frequency bands (7.0 MHz and 3.5 MHz respectively) are below the 8 MHz critical frequency.
- However, if the critical frequency drops to 6 MHz, then NVIS propagation will no longer be possible on 40 meters, but it will still be good on 80 meters
- If the critical frequency drops to 6 MHz or lower we must change our operating frequency from 40 to 80 meters

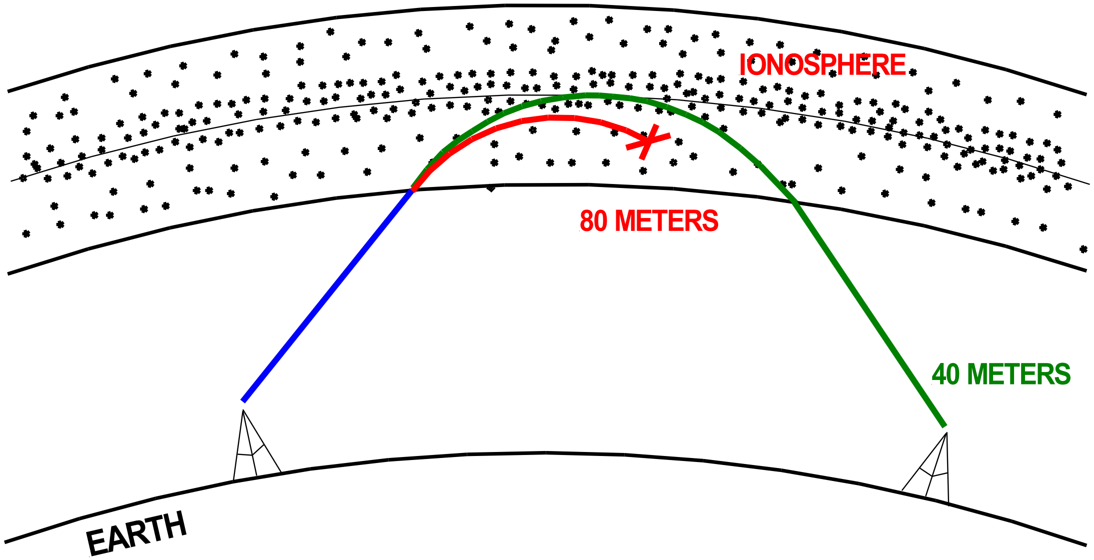
NVIS Fading



Ericsson Inc

- Critical frequency continuously drifts up and down in frequency
- A critical frequency of 7 MHz may drift to 7.6 MHz and then down to 6.5 MHz
- Consequently, a 40 meter (7.2 MHz) signal fades in and out as the critical frequency drifts above and below the transmitting frequency
- To avoid fading operating at a frequency at least 10% below the critical frequency is recommended

D – Layer Absorption

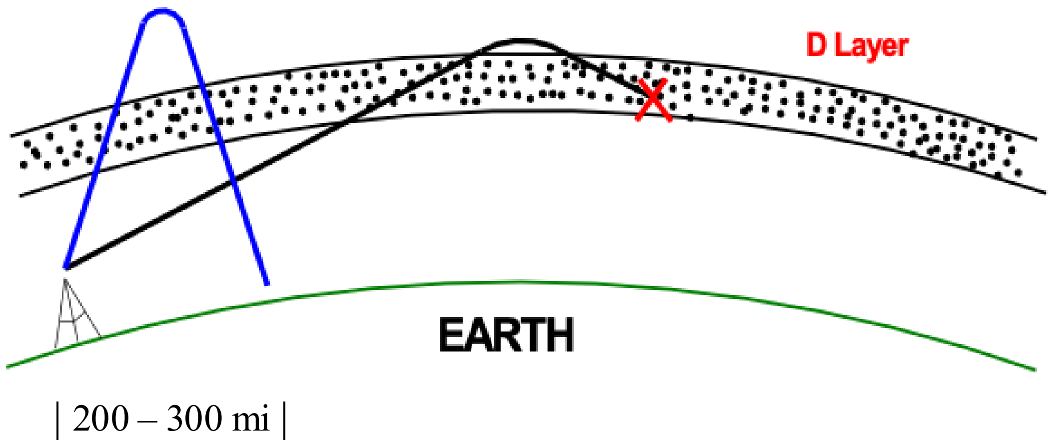


$$\text{Absorption} \propto \frac{1}{f^2}$$

Author

- D Layer absorption is inversely proportional to frequency squared
- For example: absorption is 4 times greater on 80 meters than on 40 meters
- To minimize D-Layer absorption, operate on the highest available frequency band
- If both 40 and 80 meters are below the critical frequency, operate on 40 meters to minimize D-Layer absorption

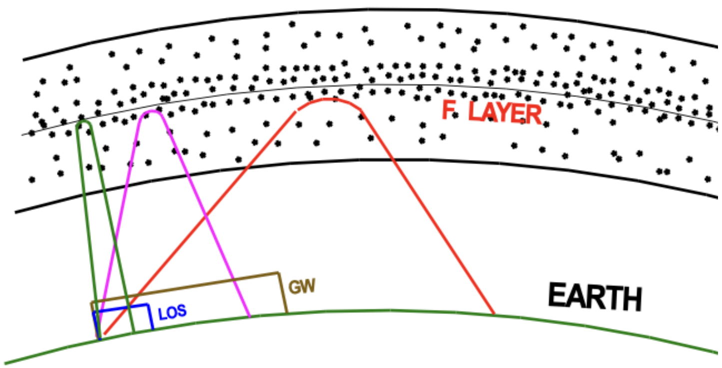
40 Meter Mid Day NVIS is Excellent



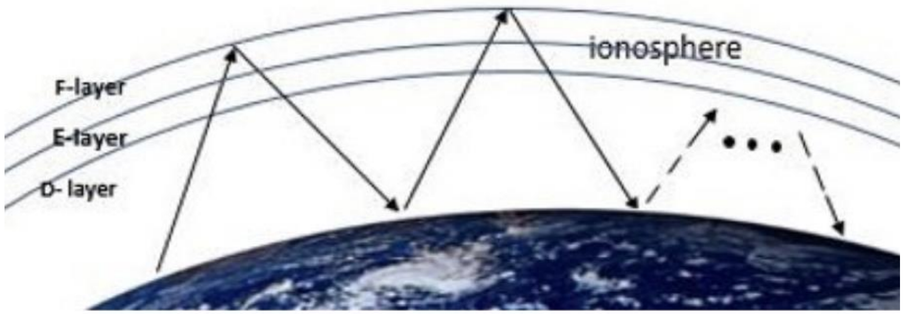
Author

- Excellent 40 meter NVIS occurs throughout the day, in particular during mid day when D-Layer absorption is greatest
- The reason for this is that the high elevation angle NVIS signals (blue trace) 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 per day 7 days per week
- NVIS is a powerful mode !

Low Power NVIS Communications



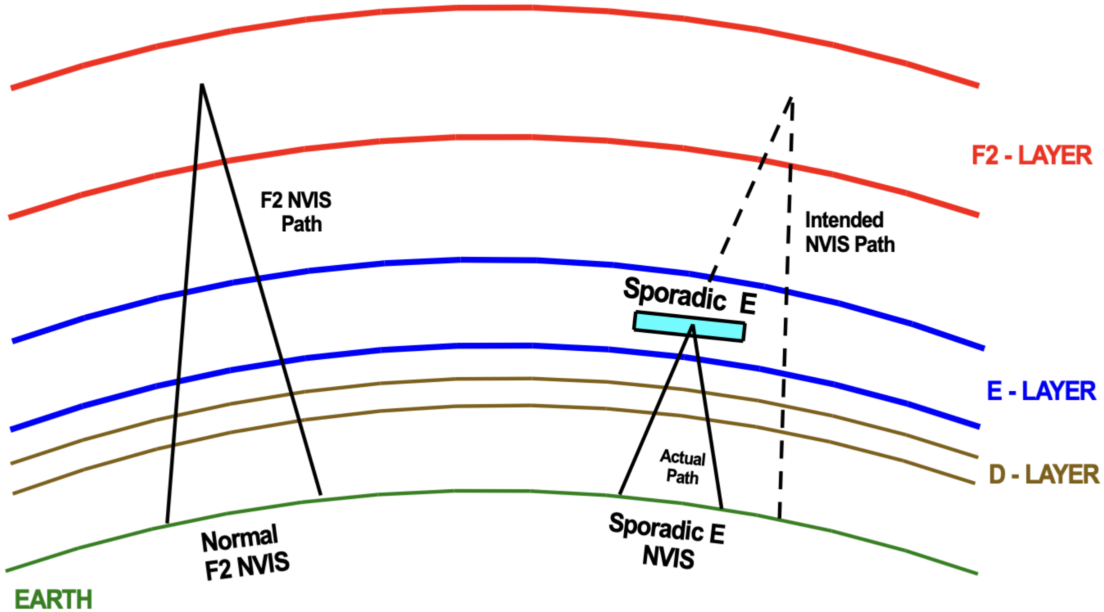
Author



ResearchGate

- NVIS Operation at higher power levels is necessary under adverse conditions and when fighting multipath interference problems
- Typically, however, excellent NVIS communications is achieved using 10 to 15 Watts
- The reason is that NVIS path lengths are very short (a single short hop through the ionosphere) incurring very little signal attenuation
- In comparison, a low angle long distance multi-hop signal covering thousands of miles is highly attenuated by the time it reaches the receiving station
- Battery power is often utilized for 2 meter and 440 local communications at 10 to 15W
- The low power requirements of NVIS means that regional HF emergency communications out 200 to 300 miles can also be conducted utilizing battery power --- This is important!

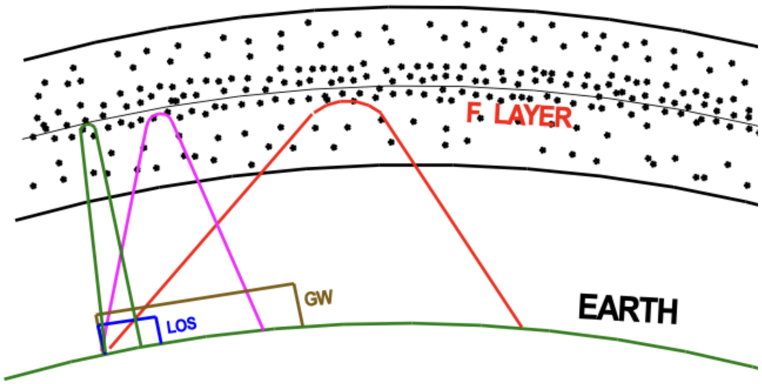
Sporadic E Affect on NVIS Propagation

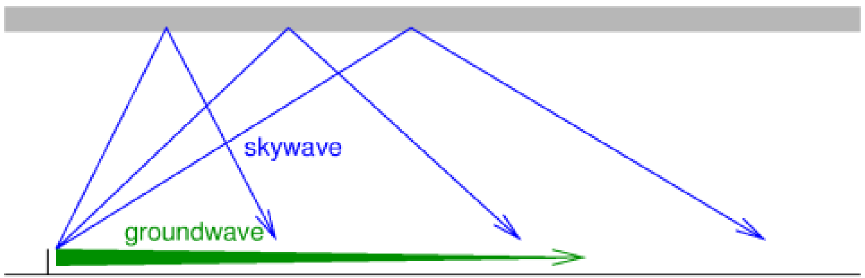


Author

- Sporadic E patches have a profound affect on NVIS propagation
- A NVIS signal reflected from a 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 $f_cF2 > f_{NVIS}$ does not apply
- Instead NVIS propagation occurs as long as the Sporadic E patch is present, even if the F2 layer critical frequency is far below the NVIS frequency

NVIS Local Communication Problems

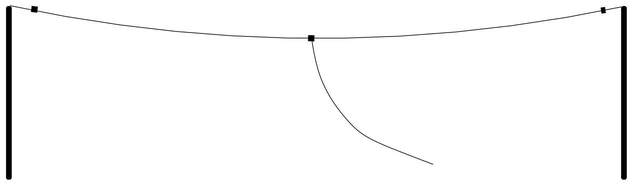


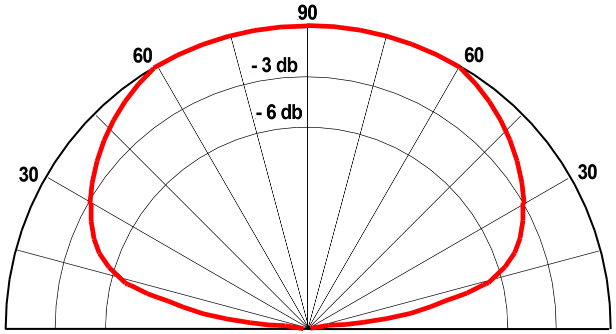


- Line-of-site (LOS) and ground wave (GW) propagation always exist
- Consequently, multi-path interference problems between NVIS, ground wave, and line-of-site signals can sometimes occur
- Multi-path interference occurs when two signals (NVIS and GW for example) traveling via different paths arrive at the receiving site with the same signal strength but out of phase
- The two signals will completely cancel out if they are 180° out of phase, meaning that neither signal is heard by the receiving station
- Multi-path interference problems result in signal degradation and fading

NVIS Antennas

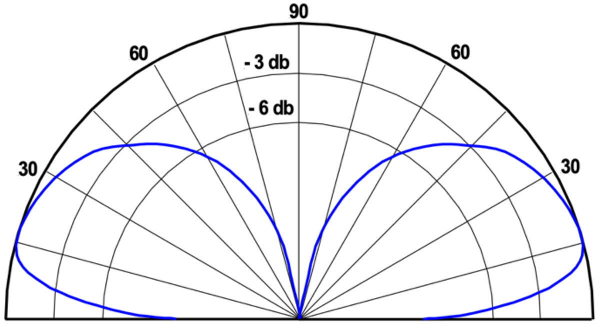
Horizontal Antenna





NVIS 1/2 Wave Dipole 1/4 Wavelenth Above Ground

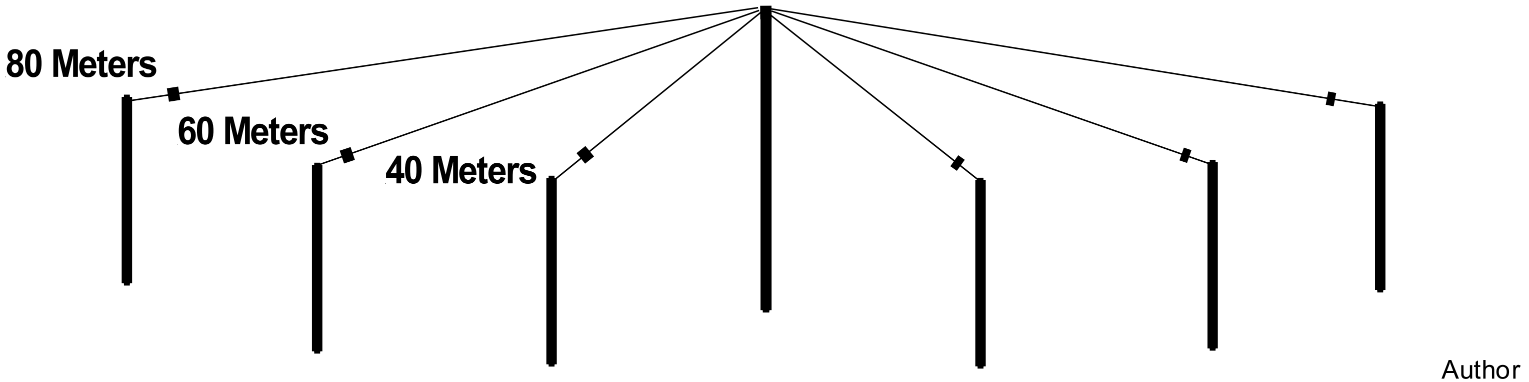
Vertical Antenna



1/4 Wave Vertical Antenna Over Very Good Ground

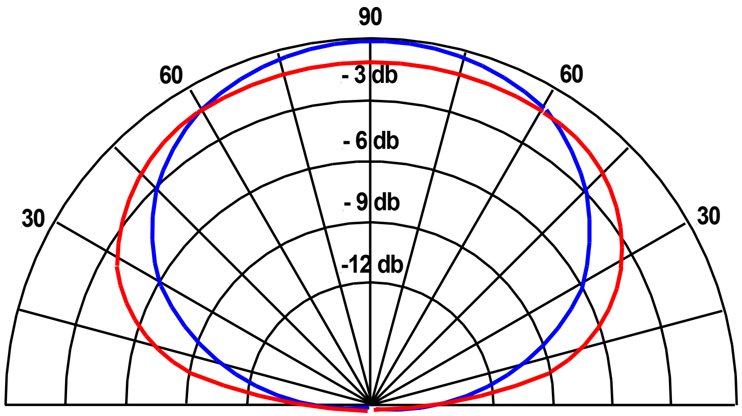
- Horizontal antennas that are less than 1/4 wavelength above ground radiate high angle NVIS signals
- Vertical antennas are not well suited to NVIS but provide better ground wave propagation than horizontal antennas
- Line of sight propagation is provided by both horizontal and vertical antennas

Multi-band Inverted V NVIS Antenna



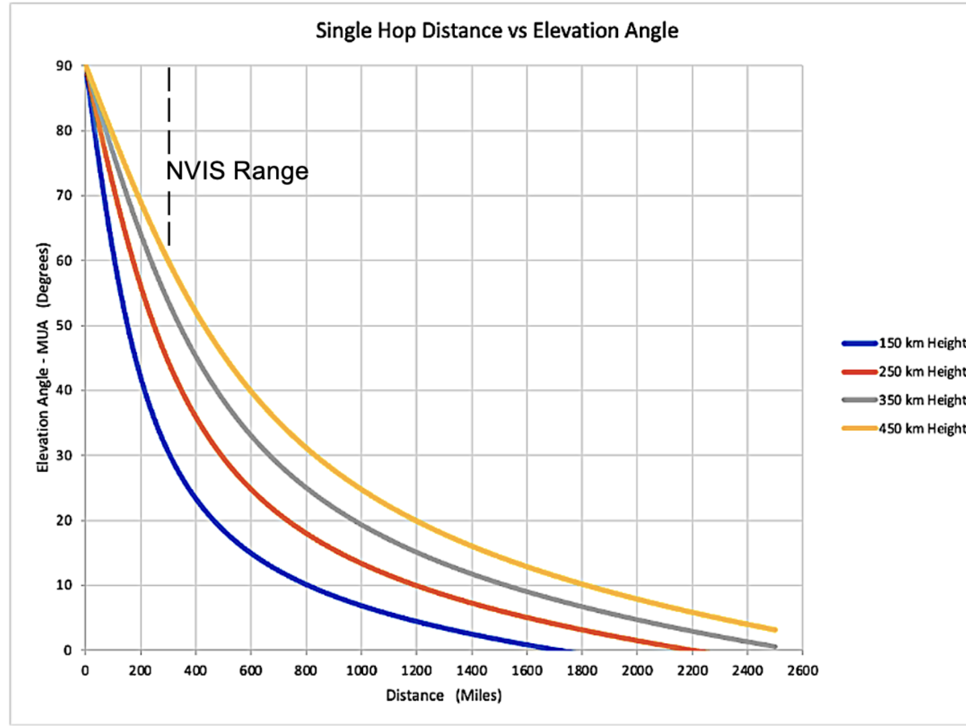
- A multi-band Inverted V antenna covering 40, 60, and 80 meters is an excellent NVIS antenna system
- At an apex height of 32 feet, the 40 meter antenna is 1/4 wavelength above ground while the 80 meter antenna is 1/8 wavelength above ground
- 60 meters is an ideal NVIS band when the critical frequency is below 40 meters and D-Layer absorption on 80 meters is excessive

Height Above Ground



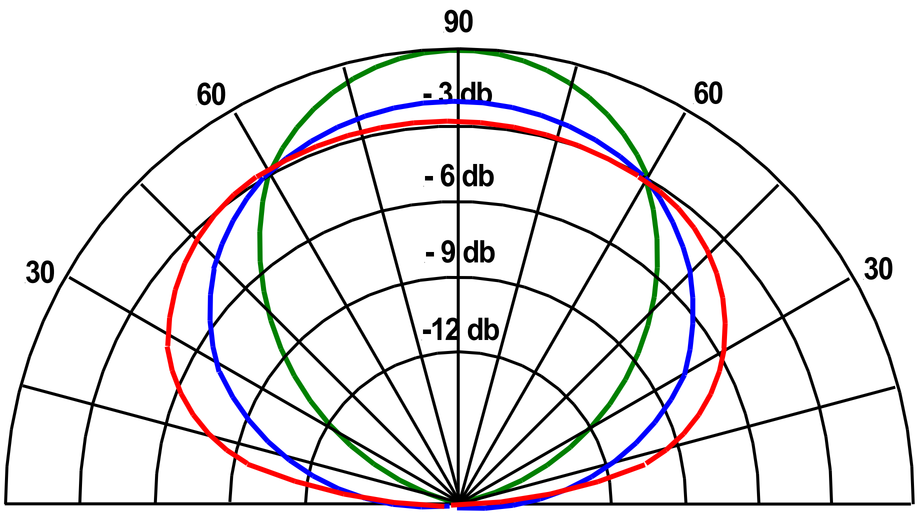
NVIS Antenna Patterns
1/4 wavelength above ground
1/8 wavelength above ground

Author

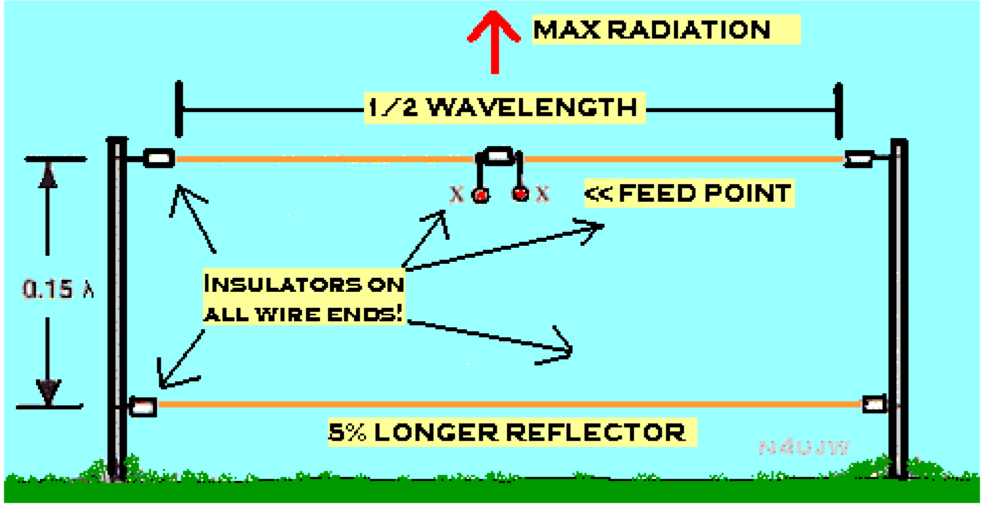


- The -3db point in an antenna pattern is the elevation angle at which the antenna's signal strength drops 3db below its peak value (for NVIS its peak value occurs at 90 ^{o})
- The -3db point for a NVIS antenna 1/4 wavelength above ground its approximately 30^{o}
- At this elevation angle its single hop distance is roughly 600 miles
- The vertical radiation pattern of a NVIS antenna improves slightly by dropping its height from 1/4 to 1/8 wavelength above ground
- However, for a antenna 1/8 wavelength above ground its -3db elevation angle is approximately 45^{o} with a corresponding single hop distance of roughly 400 miles

2 Element NVIS Antenna



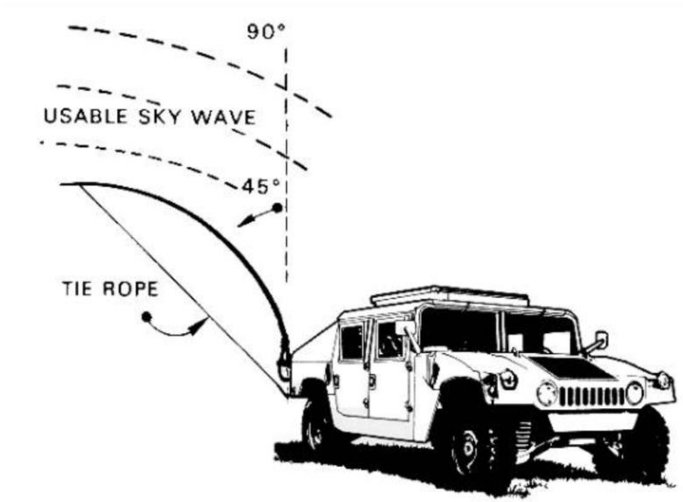
Author



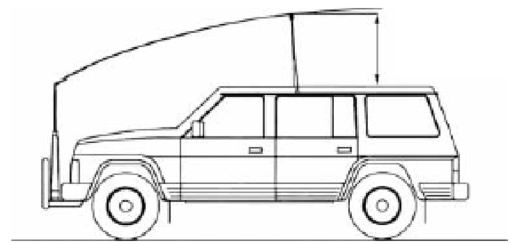
Off Grid Ham

- Adding a Reflector element below a NVIS antenna enhances the antenna's vertical radiation pattern 2 to 3 db compared to a NVIS dipole 1/4 wavelength above ground
- 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 providing good NVIS capabilities, nearly as good as the 2 element antenna
- In addition it provides longer distance multi-hop communications with hops of up to 600 miles

Mobile NVIS Antennas



NVIS Army FM24-18

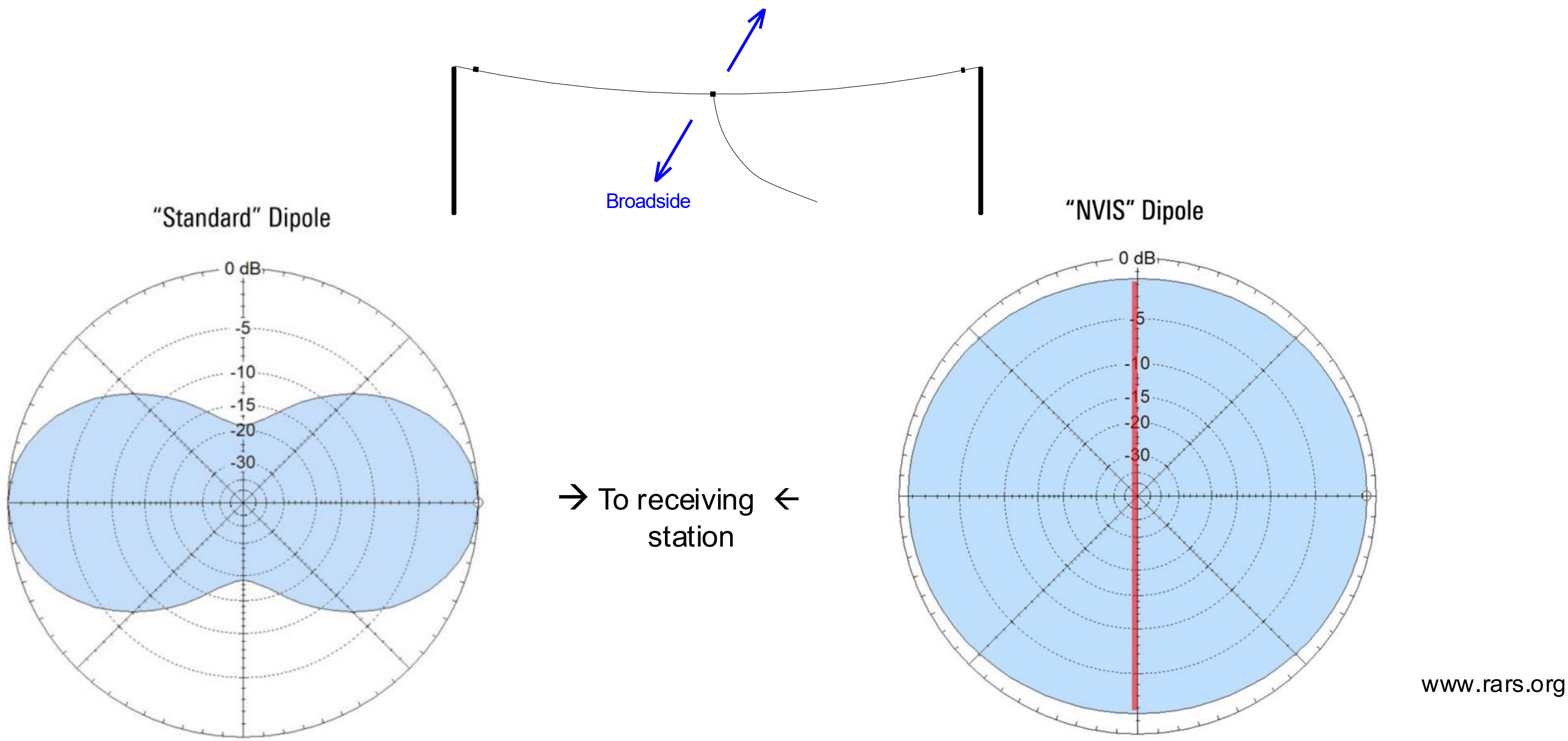


Unicat-MSF

Glocom

- A vertical whip antenna mounted on the back of a vehicle doesn't 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
- 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

Omnidirectional



- A standard dipole for long distance HF communications is oriented so that the direction of the intended receiving station is broadside to the antenna
- However, NVIS antennas are omnidirectional
- Consequently, the orientation of a NVIS antenna relative to the receiving station is unimportant

Author’s NVIS Story

Notice the ladder on the back of the RV. A 40 meter 8 ft Ham Stick antenna was originally mounted vertically from the top of the ladder. Normally it worked quite well. In the mountains it did not work at all. No signals could be heard. It was remounted horizontally from the ladder in hopes of creating a make shift NVIS antenna. It worked!

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.

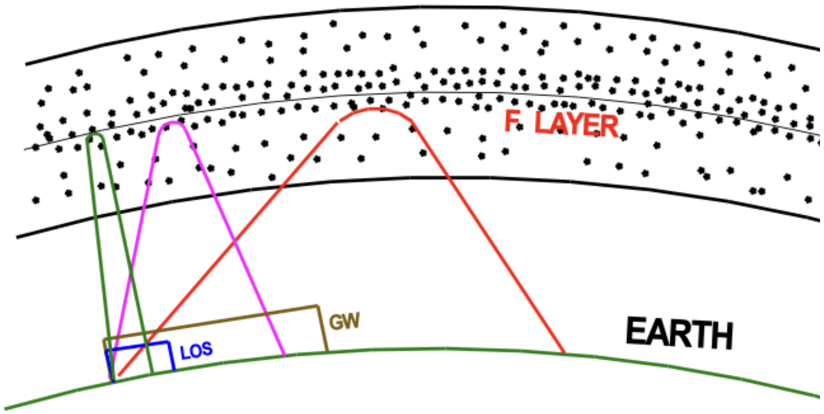
I wondered how people at the campground would call for help if there were a serious emergency. Amateur radio to the rescue !!! I fired up my radio to see who I could contact. At the time I was using a “Ham Stick” 8 foot 40 meter vertical antenna mounted on top of the RV’s ladder. When I turned on the radio all bands were completely dead. I was not quite sure why that was since the radio bands had been quite active.

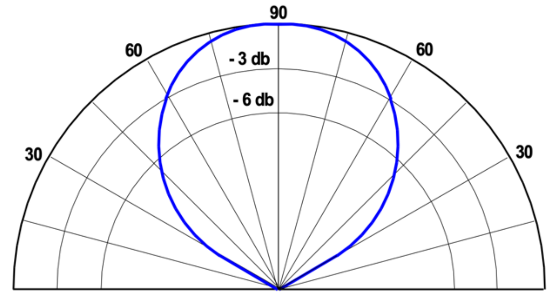
I had heard of NVIS and wondered if that would help in this mountainous terrain? I decided to give it a try. I climbed up on top of the RV, disconnected the vertical from the ladder and remounted it horizontally. When I turned the radio back on, 40 meter signals were booming in. I easily worked stations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

Author's Current RV Configured For NVIS

- Author's 40 meter NVIS antenna constructed from two 8 ft "Ham Stick" antennas connected together in a shortened dipole configuration approximately 15 ft above ground

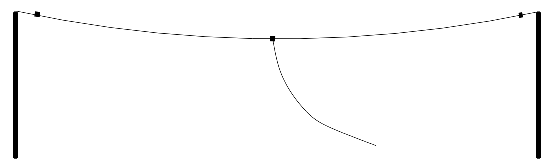
NVIS Conclusion





NVIS Antenna Pattern

Author



NVIS Antenna

- **NVIS is a powerful mode of Local and Regional HF communication**
- Using NVIS propagation (40 meters during the day and 80 meters at night) we can reliably communicate nearly 24 hours per day 7 days per week
- The low 10 to 15 watt power requirement for NVIS means that regional HF emergency communications out 200 to 300 miles can be conducted utilizing batteries
- NVIS is often the only means of radio communications in mountainous and jungle regions
- A prime applications of NVIS is Winlink emergency communications
- NVIS antennas are simple low to the ground omnidirectional horizontal antennas that are easy to install particularly in the field when needed for emergency communications

That’s It Folks

HF Radio is fun

Plus

It provides communications when all else fails !