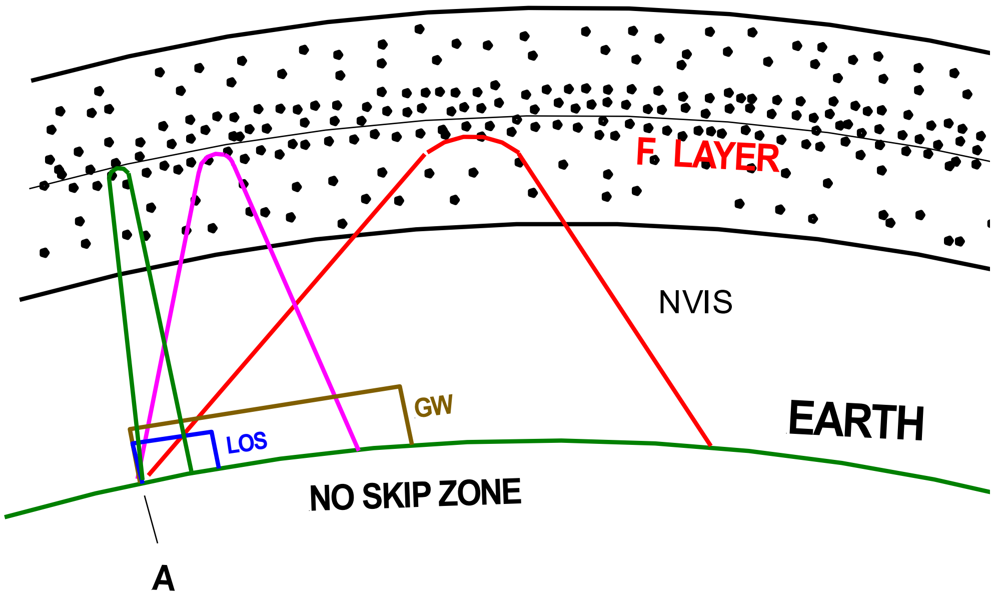
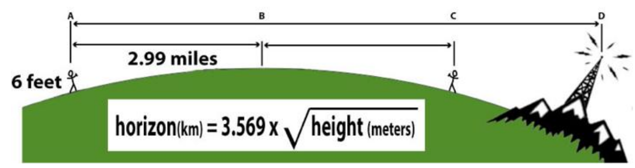
Local HF Communications

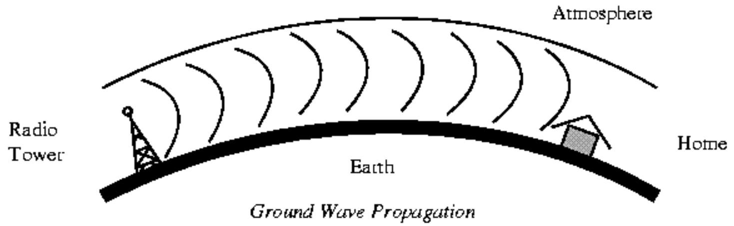


Ken Larson KJ6RZ
August 2025
www.skywave-radio.org

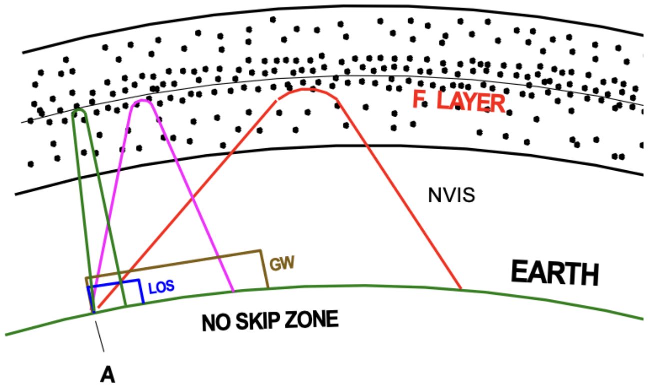
Modes of Local HF Propagation



Line of Sight



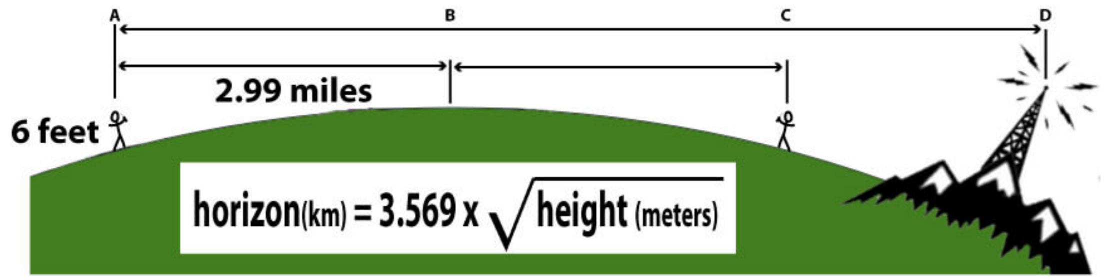
Ground Wave



Near Vertical Incident Skywave

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

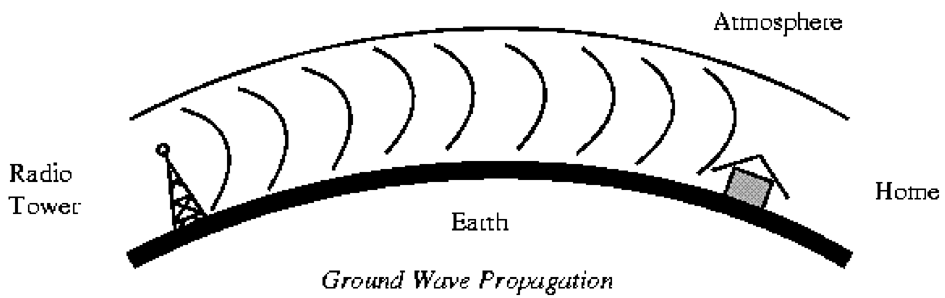
Line of Sight Propagation



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 they do

Ground Wave Propagation

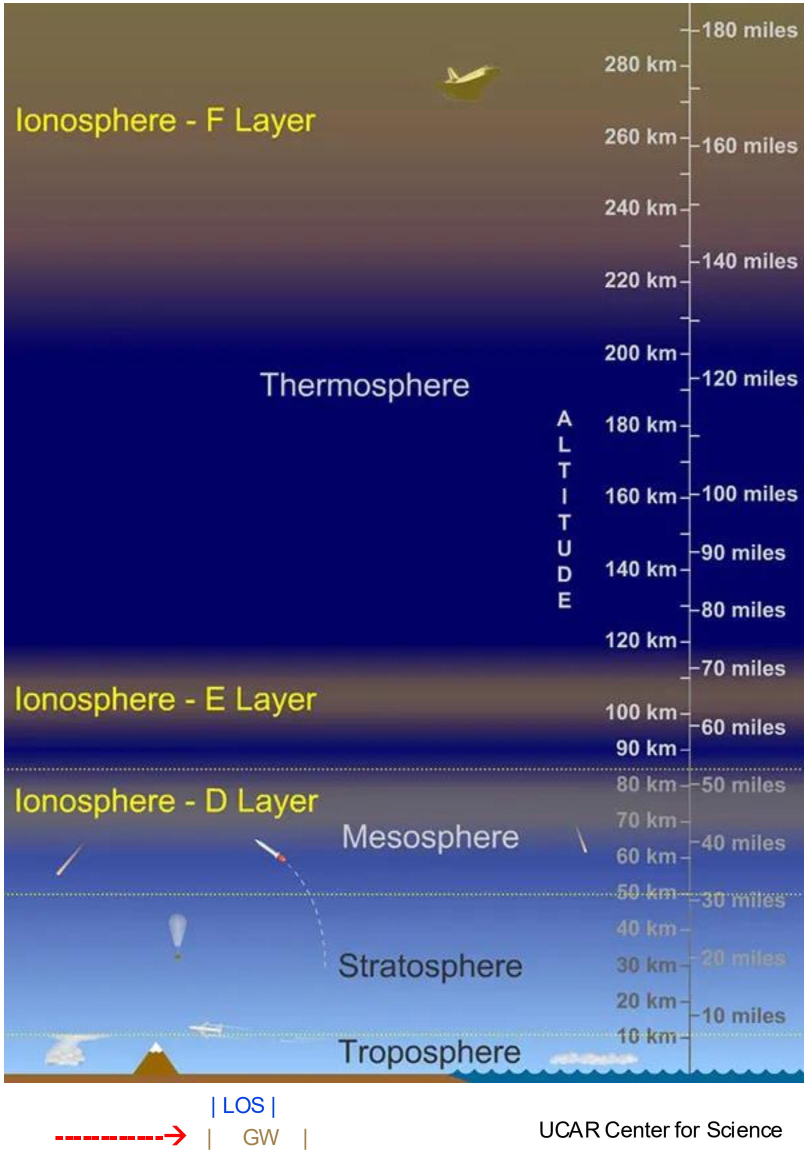


Computer Learning Centre

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 (20 to 25 miles on 40 meters if we are lucky)

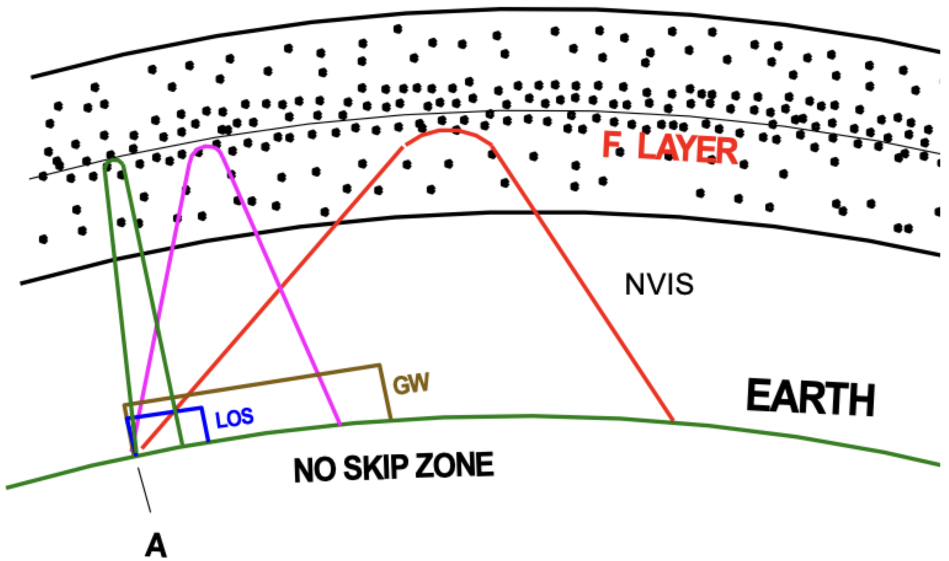
LOS and GW Are Independent of the Ionosphere



UCAR Center for Science

- Line of sight and ground wave propagation are always present whether we like it or not
- In addition, LOS and GW propagation 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

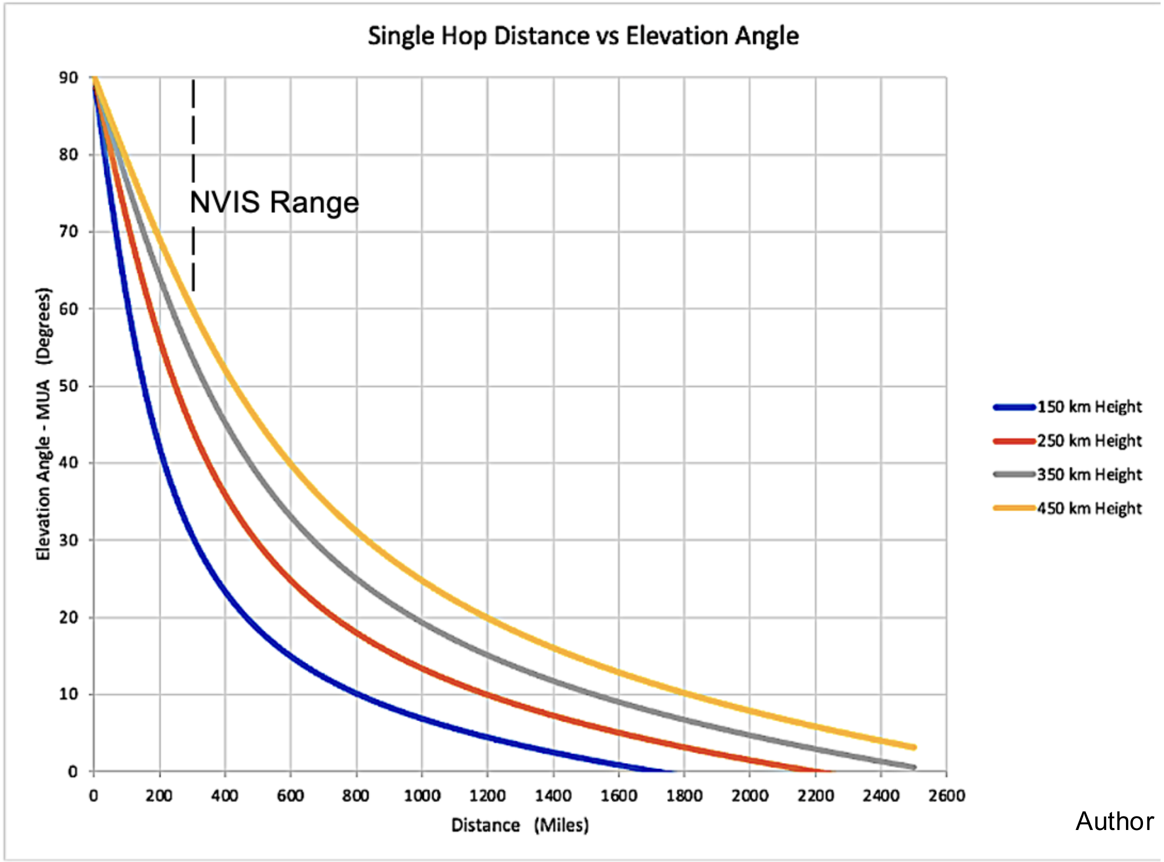
NVIS Propagation



Author

- We need to use NVIS to communicate with stations beyond the range of line of sight and ground wave propagation
- Signals transmitted at high elevation angles, generally greater than 60° , are classified as Near Vertical Incident Skywave (NVIS) transmissions (green, magenta, and red signal paths)
- Unlike LOS and GW, NVIS propagation depends heavily on ionospheric conditions, particularly on the ionosphere's current **critical frequency**

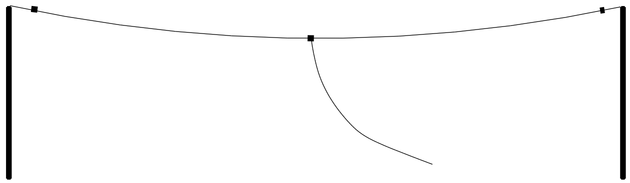
NVIS Range

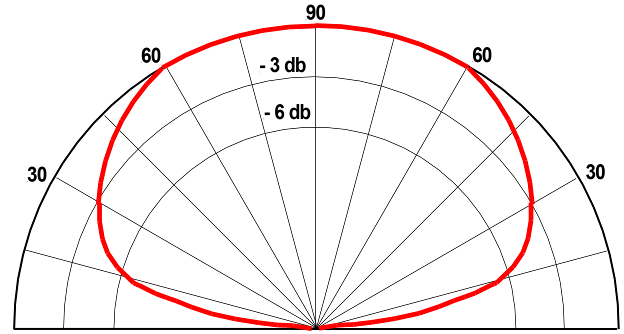


- At an elevation angle of 60°, the NVIS propagation range is 200 to 300 miles
- NVIS like propagation typically extends out 350 to 380 miles
- Beyond 400 miles we encounter oblique propagation conditions where the rules are different

Antennas

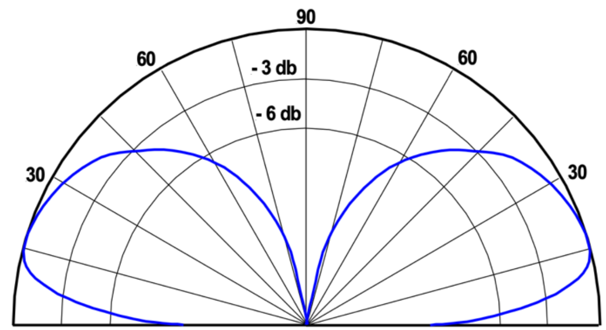
Horizontal Antenna





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

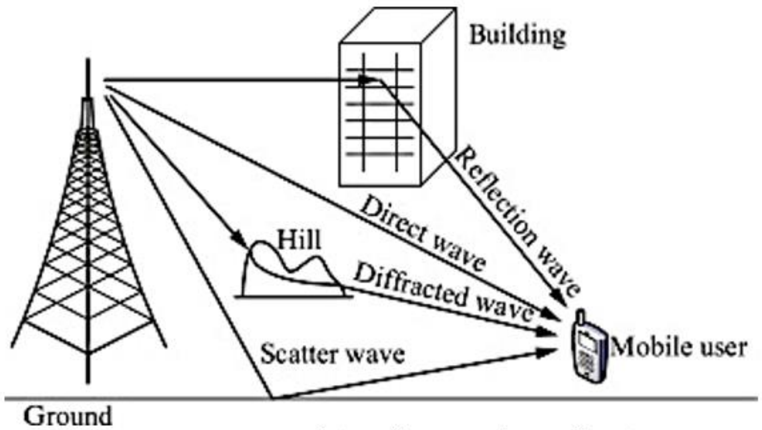
Vertical Antenna



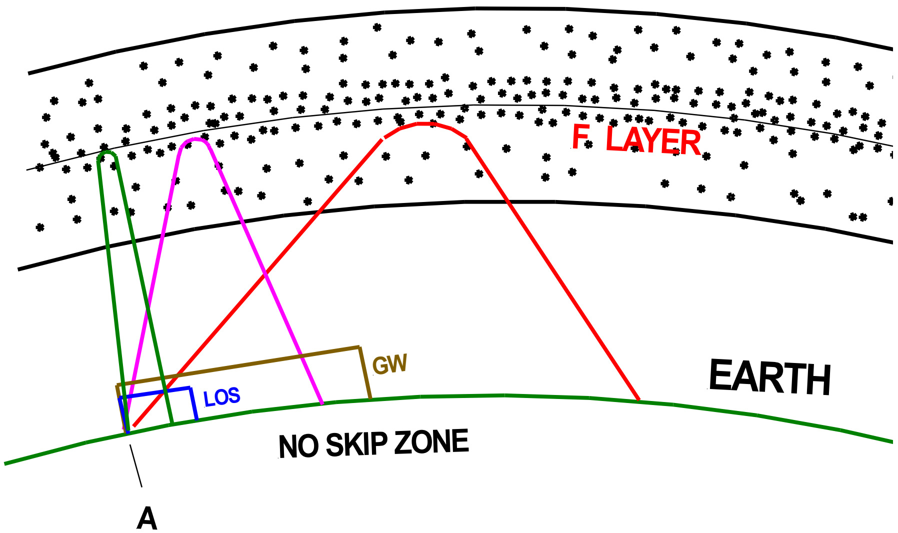
1/4 Wave Vertical Antenna Over Very Good Ground

- High angle NVIS signals are produced by horizontal antennas that are less than ¼ wavelength above ground
- Vertical antennas are not well suited to NVIS propagation but provide better ground wave propagation than horizontal antennas
- Line of sight propagation is provided by both horizontal and vertical antennas

Local HF Communication Problems

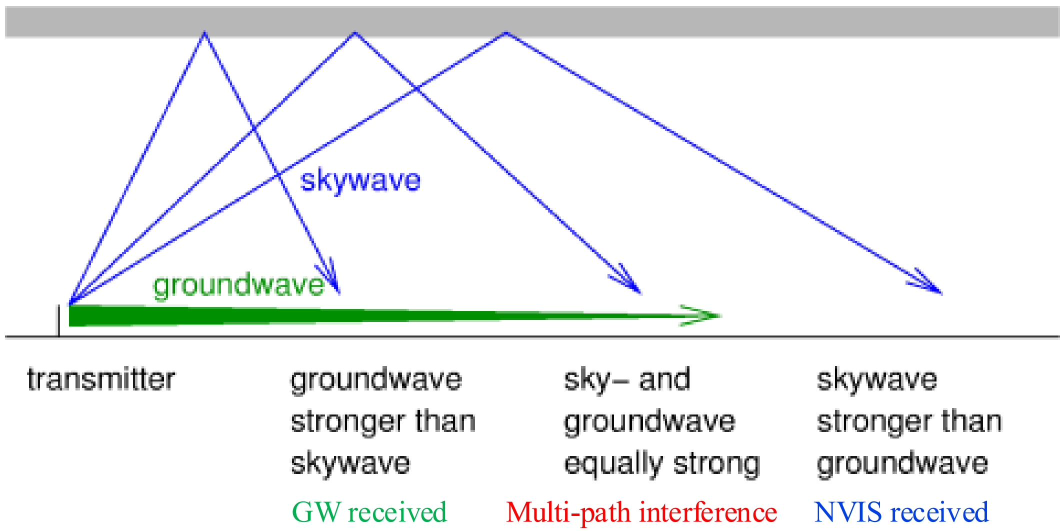


https://www.sciencedirect.com



- HF line of sight signals suffer the same reflection, diffraction, and scattering problems as VHF and UHF signals, potentially producing LOS multi-path interference 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 occur

Local HF Multipath Problems



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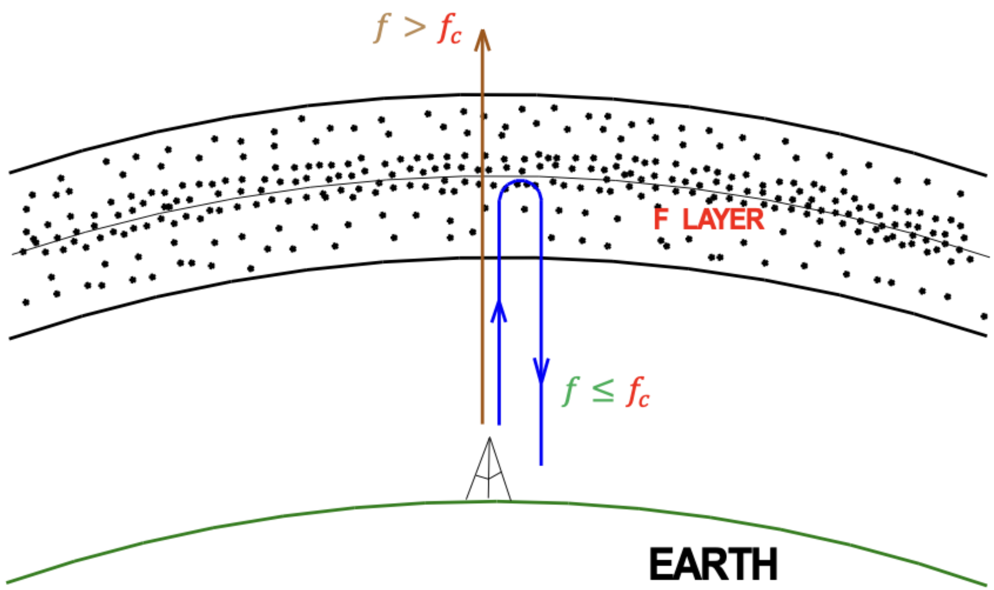
- The strongest signal (LOS, GW, or NVIS) will be received without difficulty resulting in excellent local HF communications
- However, severe multi-path interference problems occur when NVIS skywave and ground wave signals are equally strong
- In addition ground and skywave signals interfere with line of sight and visa versa when signals are the same strength
- Multi-path interference problems result in signal degradation and fading

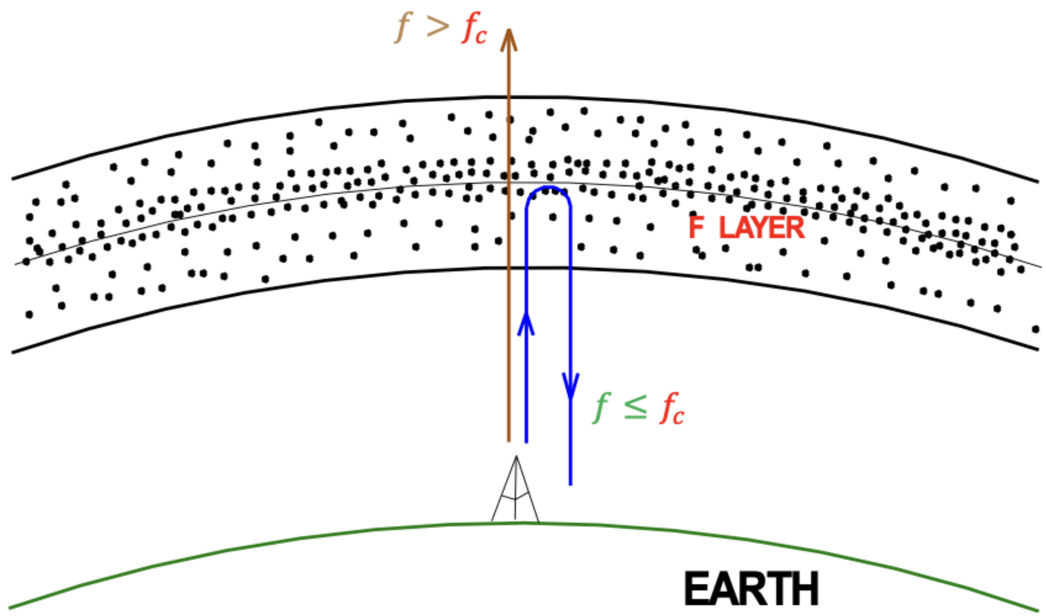
What is Critical Frequency ?



Author

- 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
- NVIS propagation is only possible if the NVIS transmitting frequency is below the current critical frequency

NVIS Propagation vs Critical Frequency Example

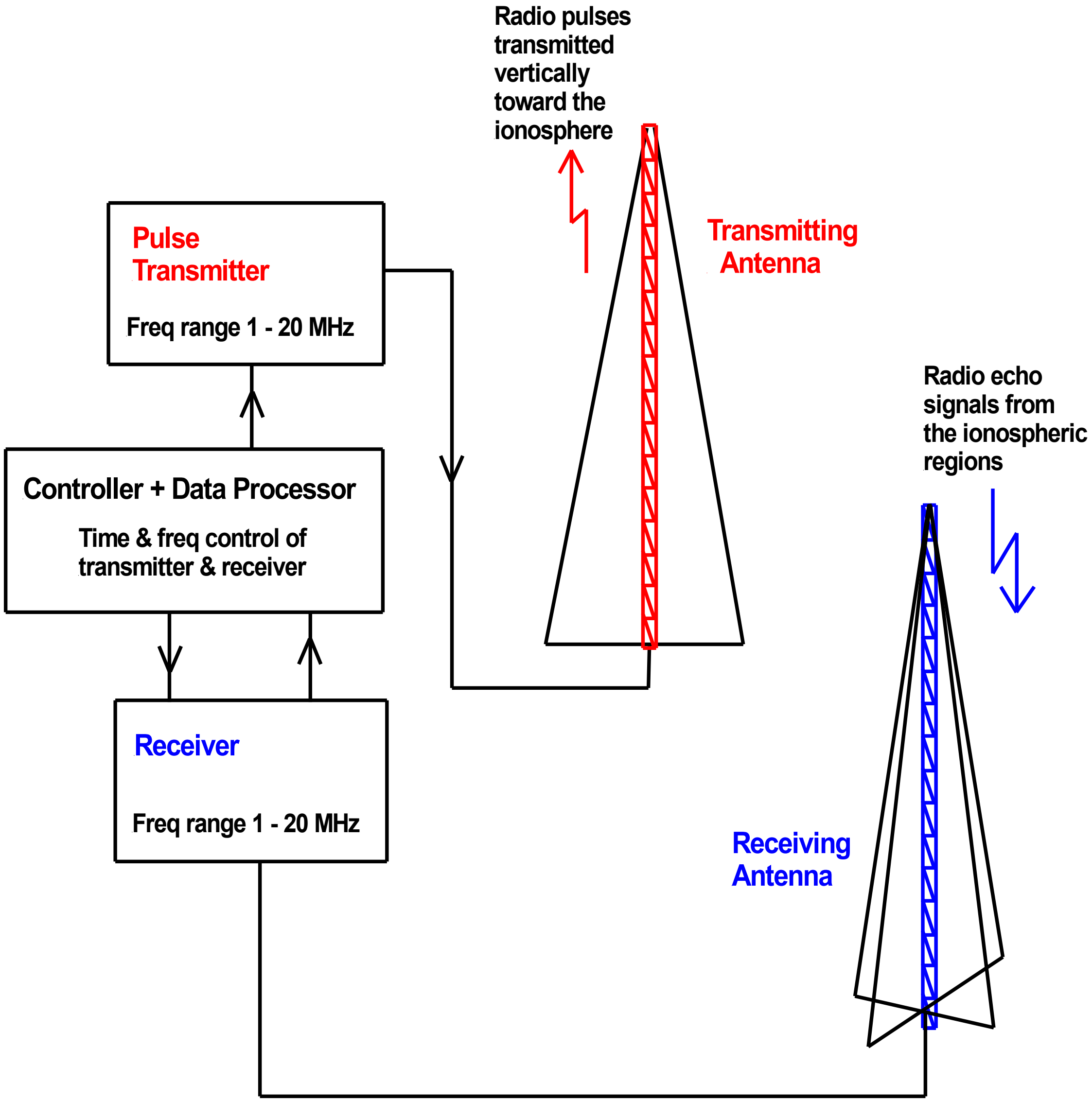


- For example, if the current critical frequency is 8 MHz, then NVIS propagation will be excellent on 40 and 80 meters since both frequency bands (7.0 MHz and 3.5 MHz respectively) are below the 8 MHz critical frequency.
- However, if the critical frequency drops to 6 MHz, then NVIS propagation will 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 local CW Net operating frequency from 40 to 80 meters

Determining the Current Critical Frequency

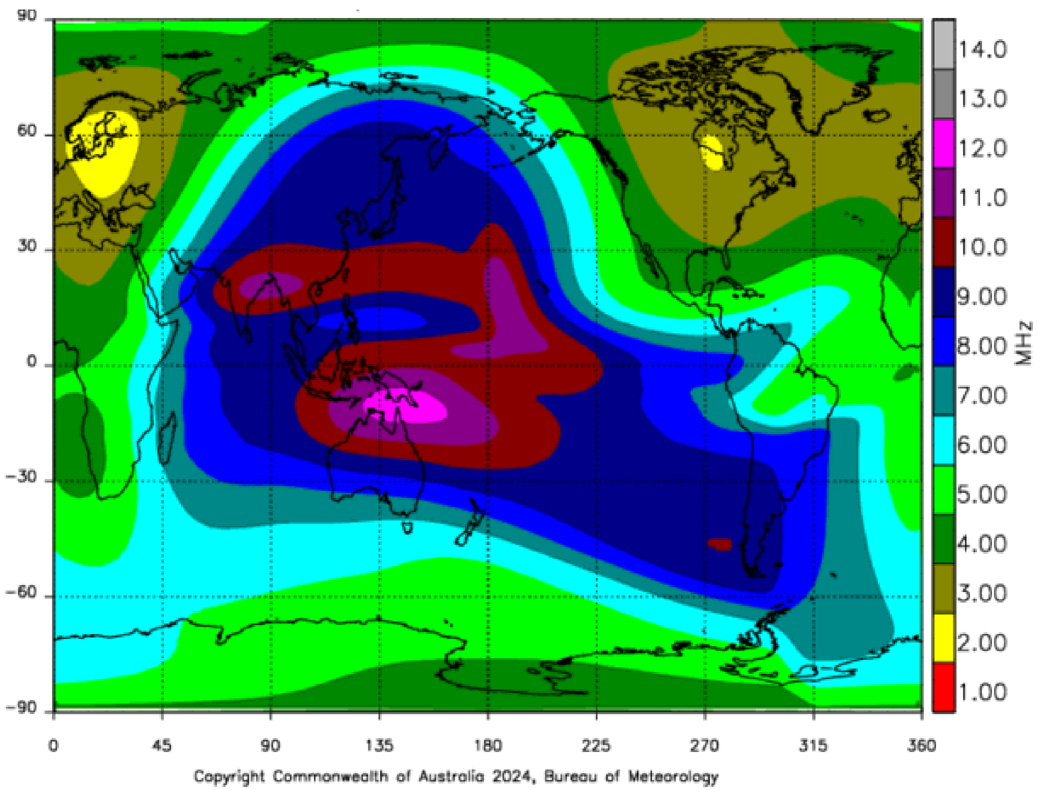
- Ground based sounders, known as ionosondes, are used around the world to determine local critical frequencies
- Our closest ionosonde is located just south of Vandenburg AFB

Ionosonde controller & data processor



spaceacademy.net.au

Global Critical Frequency Map



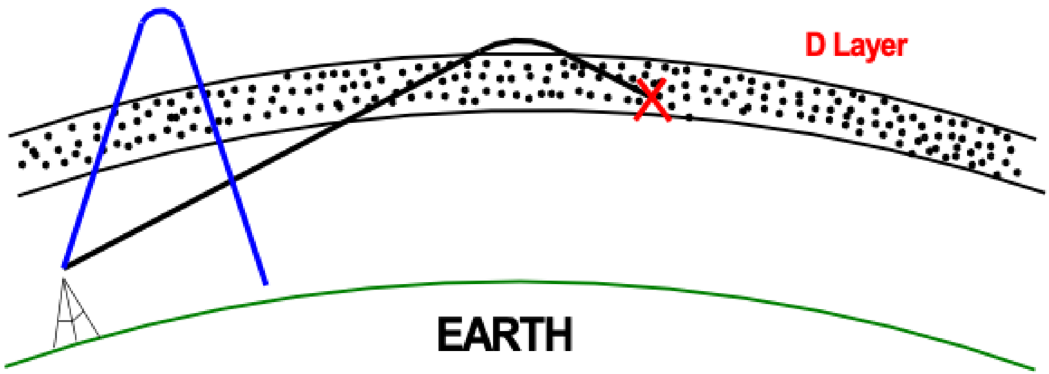
This chart shows the Critical Frequency for January 31, 2024 at 03:00 UT

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

40 Meter Mid Day NVIS is Excellent



Author

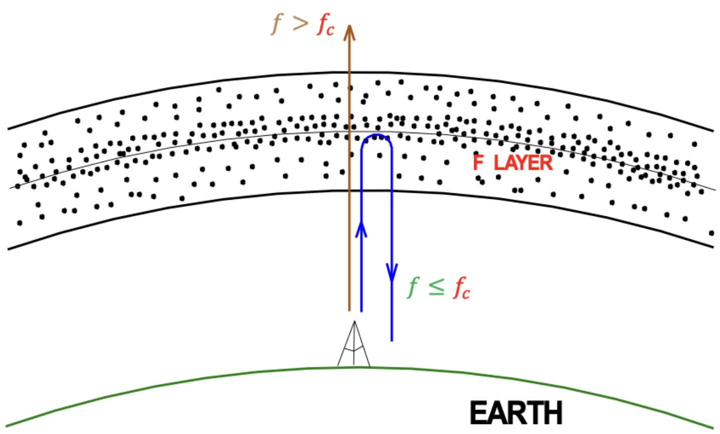
- Excellent 40 meter NVIS occurs throughout the day, in particular during mid day when D-Layer absorption is greatest
- The reason for this is that the high elevation angle NVIS signals (blue trace) pass through the D-Layer quickly incurring little absorption
- However, long distance 40 meter signals 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 !

NVIS Low Power Capability

Time	Frequency MHZ	Call	Distance Miles	Contact Duration (sec)	Power Watts	Antenna	Comments
1202	7.1021	W6BI	11	26	80	Yellow	Simi Valley, CA ----- Multipath problems?
				25	40		
				39	20		
1212				38	10		
1214	7.1065	KD6LLB	13	18	80		Oxnard, CA
1215				18	40		
1216				16	20		
1217				18	10		
1228	7.1005	AJ7C	31	16	80		Culver City, CA
1229				16	40		
1231				29	20		
1240				25	10		
1514	7.1060	N7OP	52	25	80		Lancaster, CA ---- Poor conditions
1518				49	40		
1520				92	20		
1522				nc	10		
1258	7.0835	KF6NYM	55	16	80		Santa Barbara, CA
1259				17	40		
1300				16	20		
1301				17	10		
1311	7.1000	KD6UCA	275	21	80		La Honda, CA (SW of San Jose)
1312				16	40		
1313				19	20		
1315				16	10		
1316	7.1000	K9ONR	311	16	80		Walnut Creek, CA
1318				17	40		
1319				17	20		
1321				18	10		

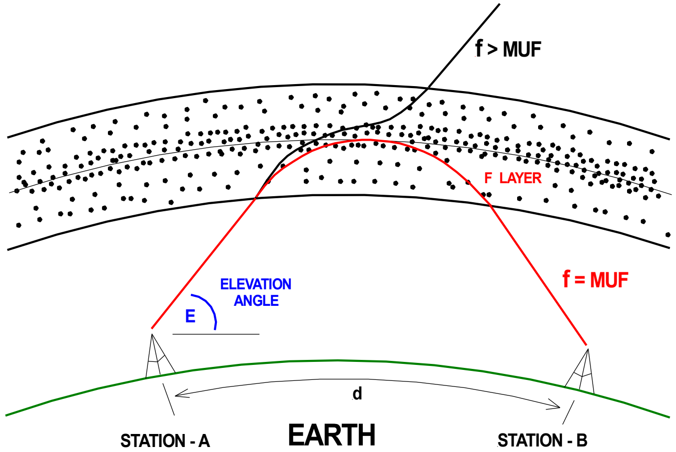
- NVIS Operation at higher power levels is necessary under adverse conditions and when fighting multipath interference problems
- Typically, however, excellent NVIS communications is achieved using 10 to 20 Watts
- Battery power is often utilized for 2 meter and 440 local communications at 10 to 20W
- The low power capability of NVIS means that regional HF emergency communications out 200 to 300 miles can also be conducted utilizing battery power --- This is important!

Critical Frequency vs MUF



Critical Frequency

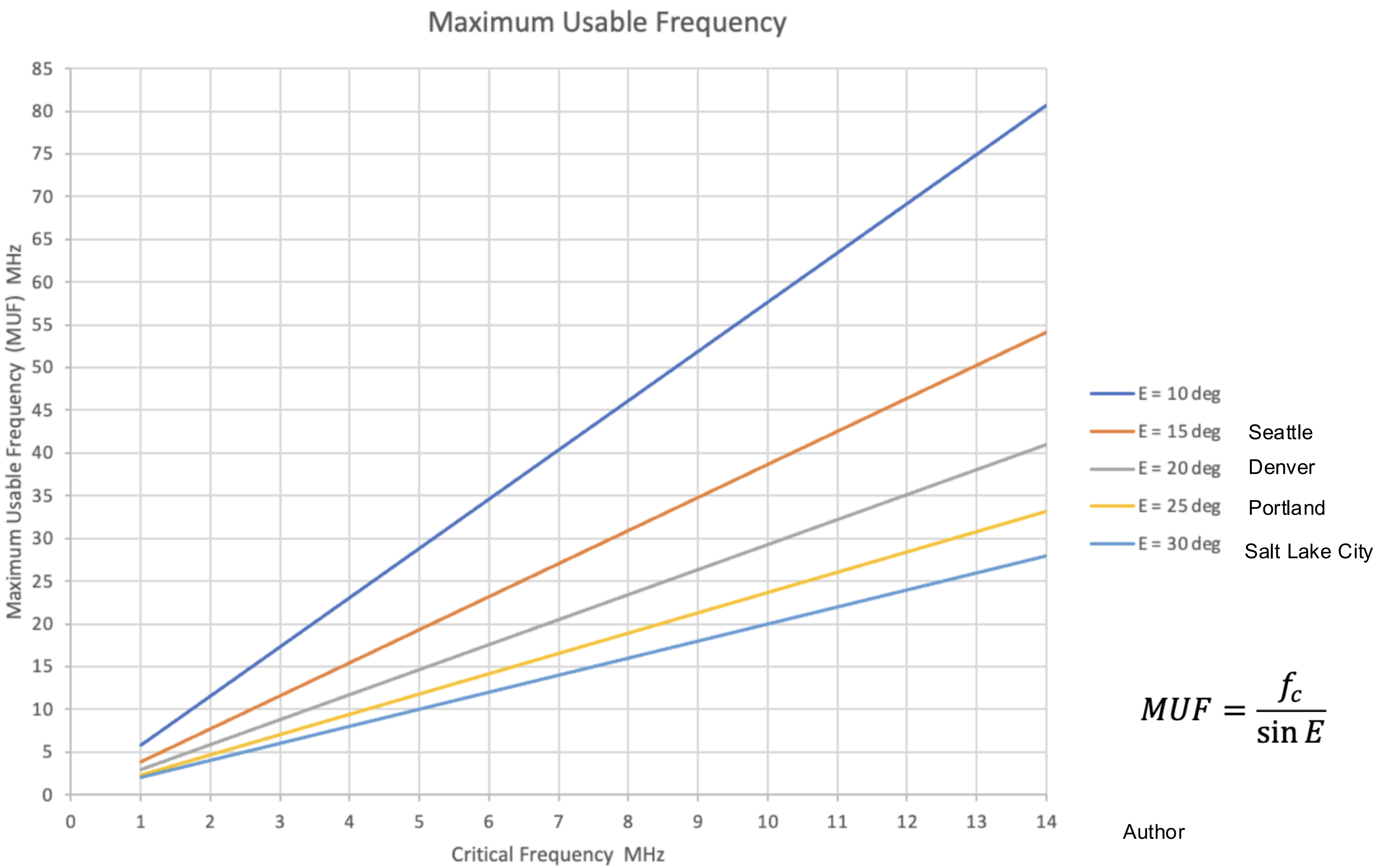
Author



Maximum Usable Frequency (MUF)

- Two important parameters in HF communications are Critical Frequency (f_c) and Maximum Usable Frequency (MUF)
- Transmitting vertically above the Critical Frequency or obliquely at frequencies above the MUF result in the transmitted signal being lost to outer space
- But, as can be seen in the above figures Critical Frequency and MUF are not the same thing
- MUF depends on the current critical frequency as well as the angle at which a signal must be transmitted to reach the receiving station, plus antenna and other factors
- For NVIS communications we ignore these complications and focus only on the ionosphere's critical frequency

MUF Example

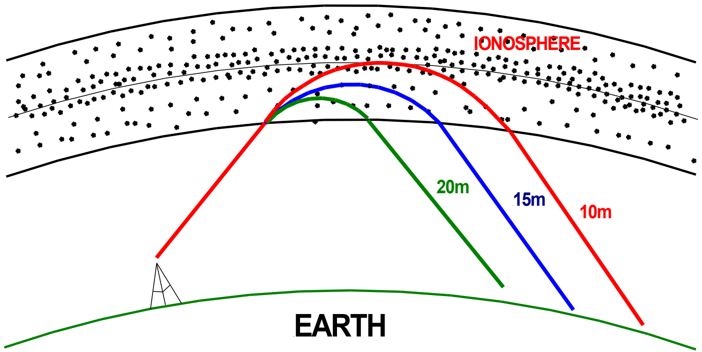


$$MUF = \frac{f_c}{\sin E}$$

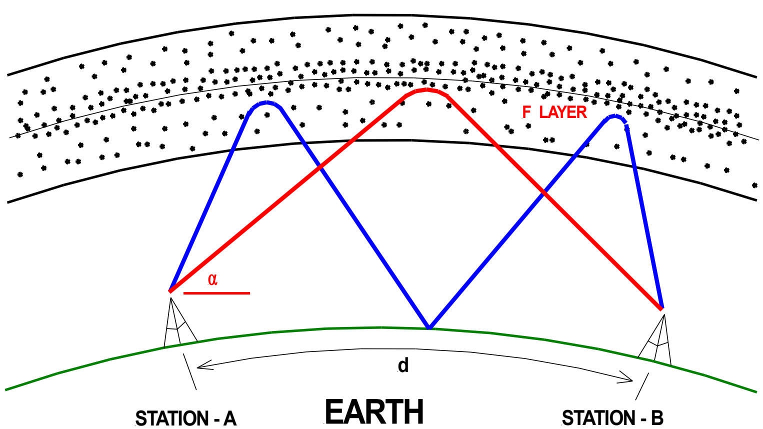
Author

- MUF depends on the Critical Frequency (f_c) and Angle (E) at which a signal is transmitted

MUF Is Very Important for Oblique Communications



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

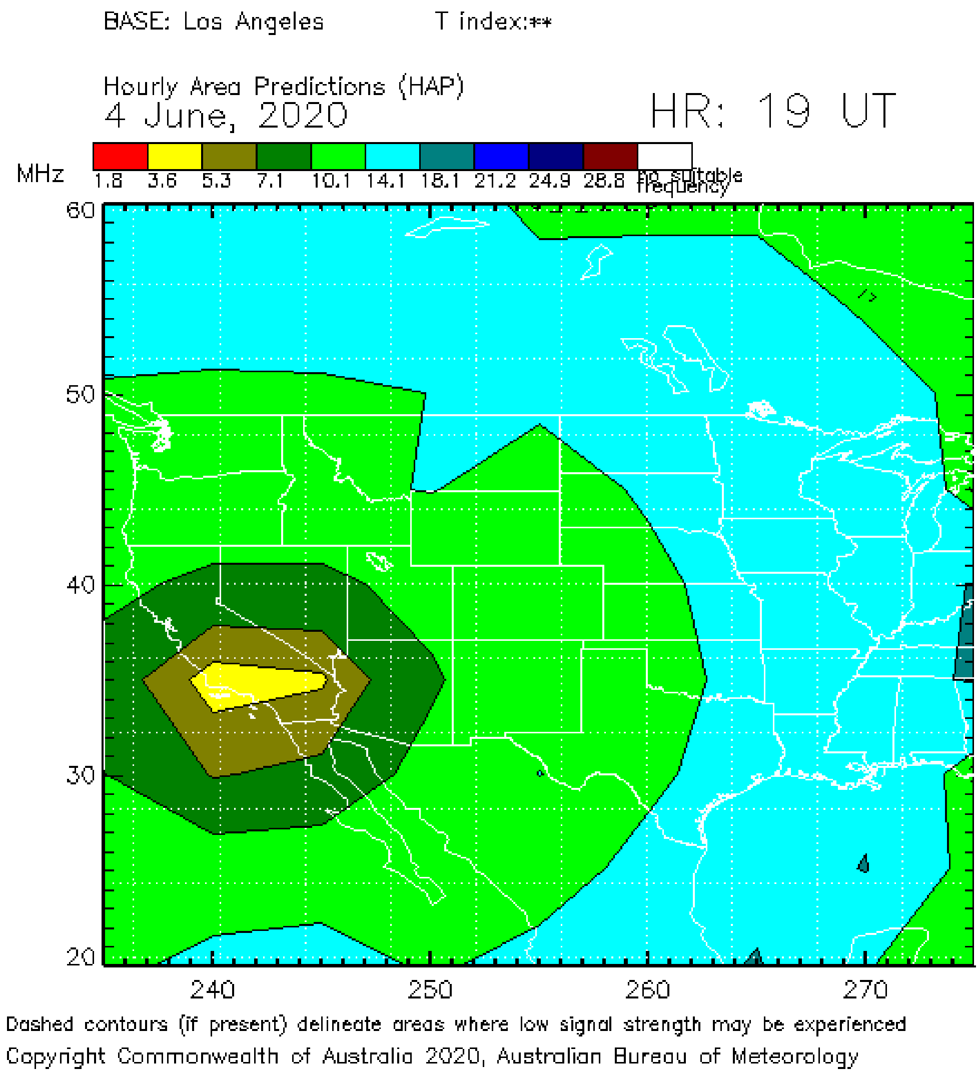


Author

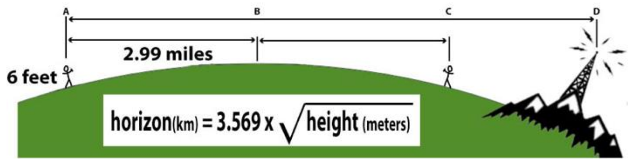
- The longest hops, best DX occurs at or near the MUF
  - DX on 15m is better than on 20m
  - DX is best on 10m
- Operating at the MUF minimizes D Layer absorption
  - D Layer absorption is inversely proportional to frequency squared
  - To avoid absorption, you want to operate at the highest frequency possible
- Operating at the MUF often reduces long distance multi-path interference

Determining MUF

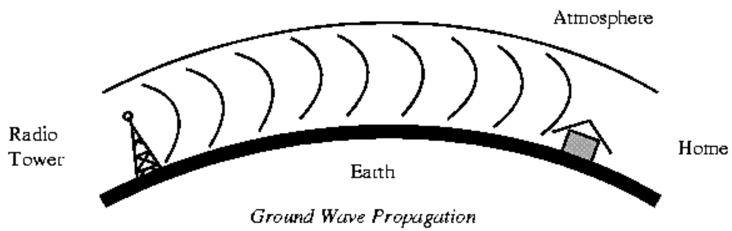
- MUF can be directly read from Hourly Area Prediction (HAP) charts provided by the Australian Government
- HAP Charts predict the optimum freq for communications between a specified city (the Base City) and a selected distant location
- Los Angeles, CA is the base city for this map
- For example, 20 meters (14.1 MHz) is the MUF for communications between Los Angeles and Chicago at 1900 UT (noon local time) on 6/4/2020
- 40 meters (7.1 MHz) is the MUF for communication with San Francisco
- HAP charts are found under the Tools tab of the www.skywave-radio.org website



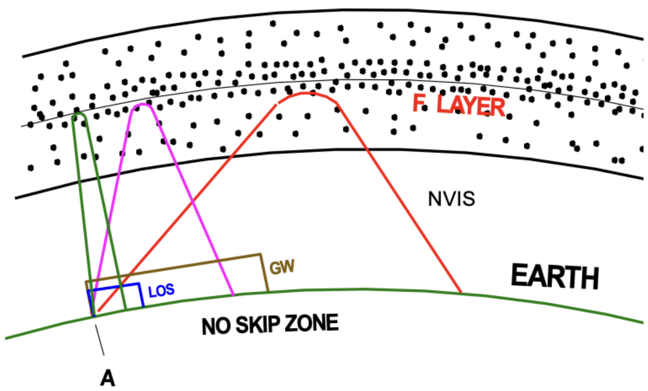
Historical Significances of LOS, GW and NVIS



Line of Sight



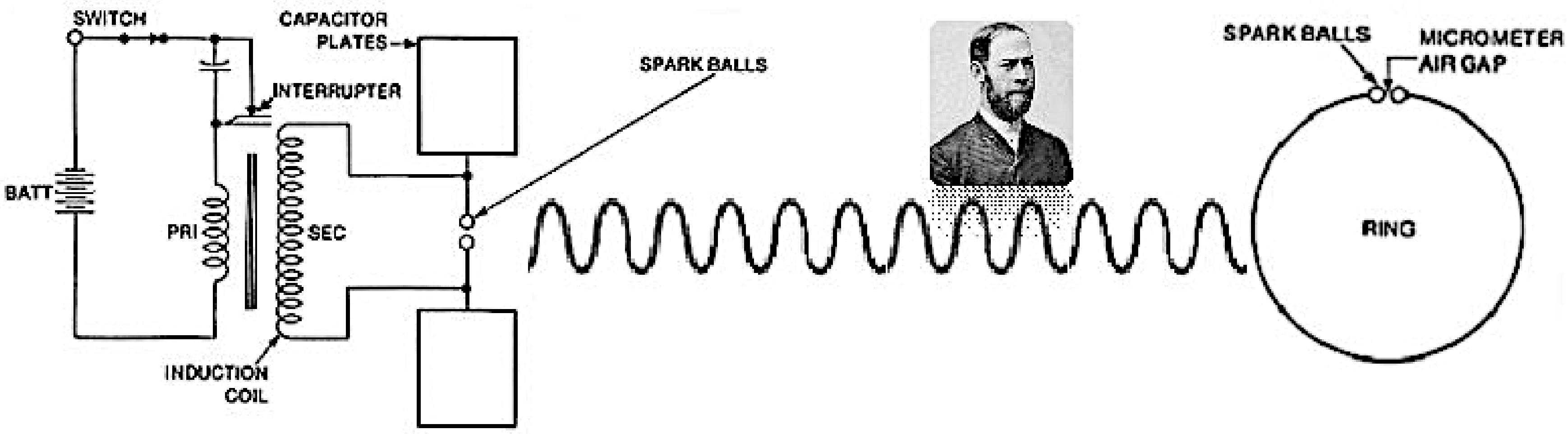
Ground Wave



Near Vertical Incident Skywave

- Historically line of sight, ground wave, and NVIS were the original three modes of radio wave propagation
- The early wireless pioneers had little knowledge of these propagation modes
- In fact, they had no idea that an ionosphere even existed

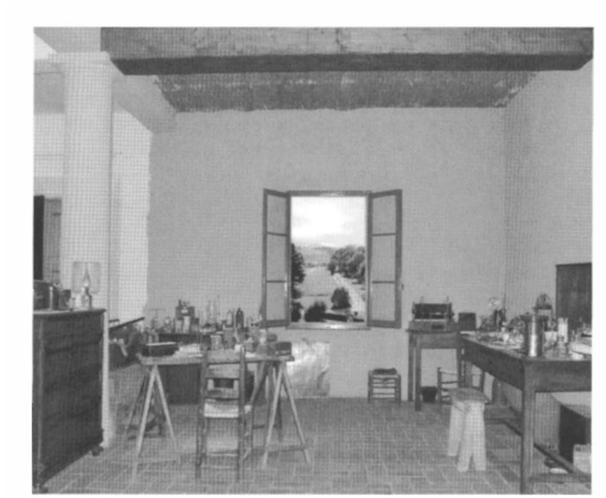
Line of Sight Propagation



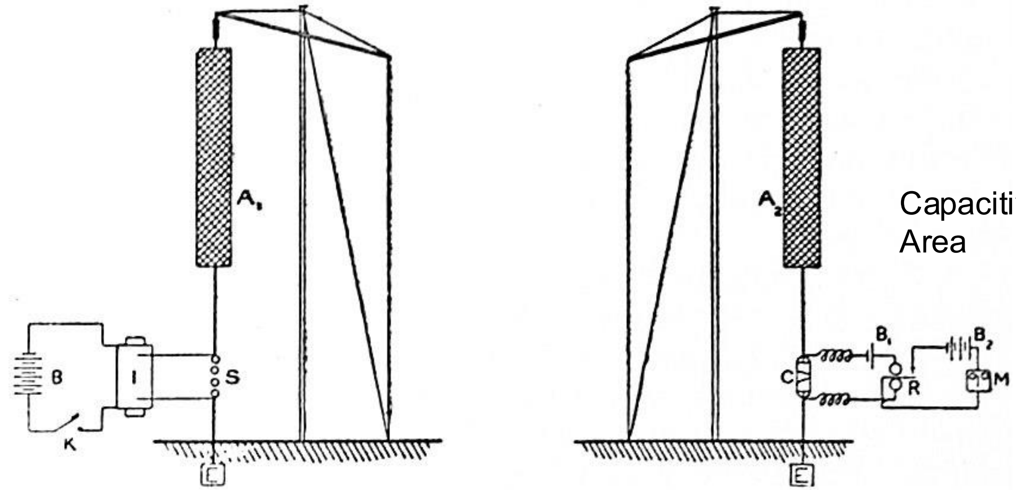
Wikipedia

- In 1888 physicist Heinrich Hertz working in his laboratory used line of sight propagation between his crude spark gap transmitter and receiving loop to prove that electromagnetic waves predicted by Maxwell 20 years earlier really existed
- Hertz performed extensive experiments in what we consider the 6 meter to 70 cm frequency bands proving conclusively that electromagnetic waves did in fact exist
- It is unlikely that the commercial ramifications of his experiments ever occurred to him

Ground Wave Propagation



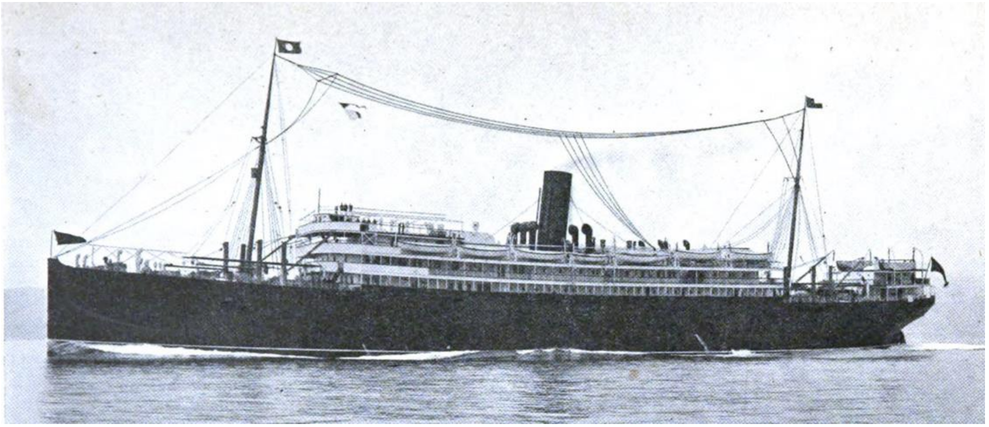
Wikipedia

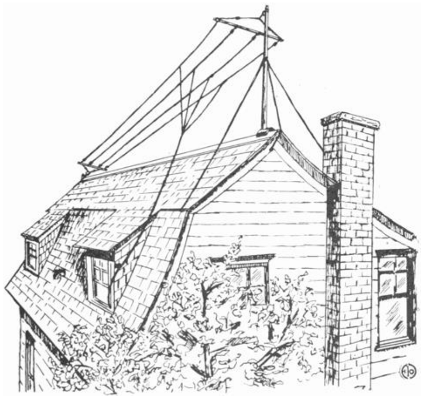


Attken

- 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

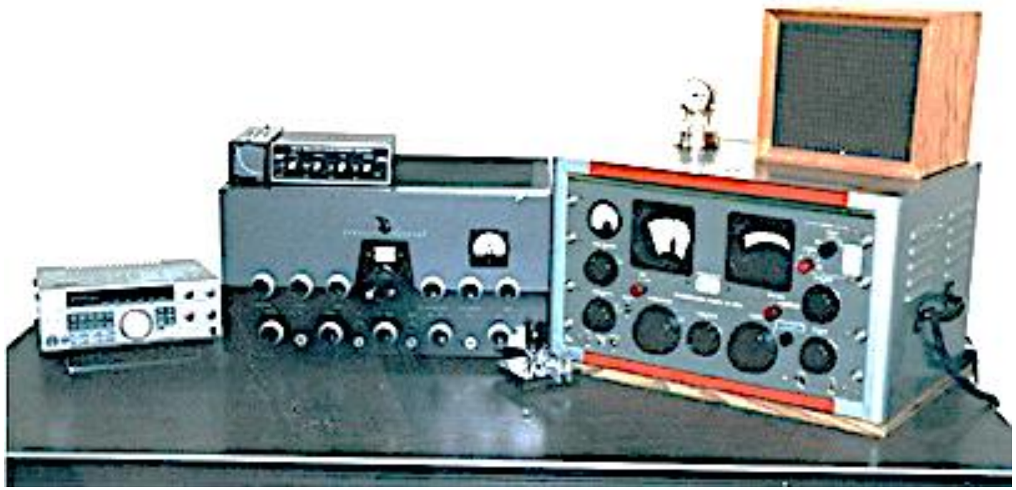




Wikipedia

- 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 ¼ wavelength above ground (or water) given the very low frequencies that they were using
- 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

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 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

That’s It Folks

HF Radio is fun

Plus

It provides communications when all else fails !