Understanding NVIS

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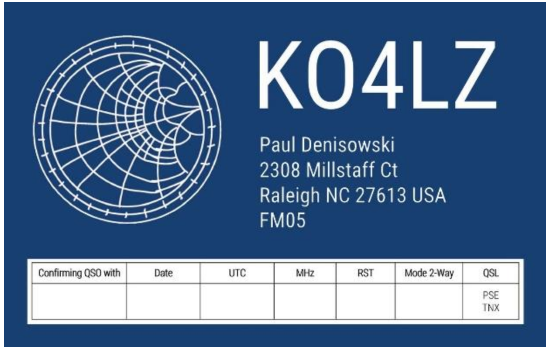
Make ideas real

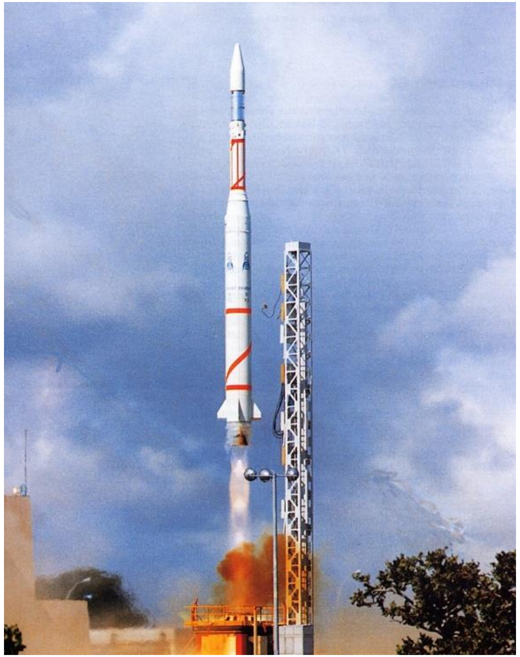
About the presenter

- ► Paul Denisowski, KO4LZ (ham for > 30 years)
  - – Active on HF and VHF/UHF (weak signal)
  - – Almost exclusively using indoor antennas
- ► MA from UNC-CH (1992), MSEE from NCSU (1996)
- ► Product Management Engineer at Rohde & Schwarz
  - – Spectrum analyzers, network analyzers, oscilloscopes, direction finding, interference hunting, etc. etc.
  - – Also cover propagation-related topics
    - – Primarily for mil / gov customers
  - – Hold a patent for a NVIS DF methodology
    - – US11550021B2



Decline of mil / gov interest in HF

- Satellites began to replace HF in the late 1960s
  - Much higher data rates
  - Relatively immune from variable propagation
  - Did not require trained operators
- Internet changed expectations on connectivity
  - Higher data rates / instant communications
  - Always available
  - Globally available
- Decline in HF use / funding / mindshare led to a decrease in development and knowledge of HF



Satellite vulnerabilities / weaknesses

- Anti-satellite (ASAT) technologies include:
  - Ground-based (e.g. lasers)
  - Air- or space-based “kill vehicles”
- Susceptible to jamming
  - Satellites not frequency-agile
- Solar storms or space weather
  - Flares and CMEs can disrupt / damage satellites
- Lack of polar coverage
  - Not all constellations cover the poles
- Terrain can block signals
  - Mountains, jungles, etc.

Renewed mil / gov interest in HF

- Global connectivity is mission-critical
  - Backup / redundancy is required
- Advantages of HF
  - Global coverage
  - Requires no “infrastructure”
  - Much, much cheaper than satellite
  - Robust against attacks
  - Robust against jamming
- Strong renewed mil / gov interest in HF over the last decade
  - Solutions from many providers

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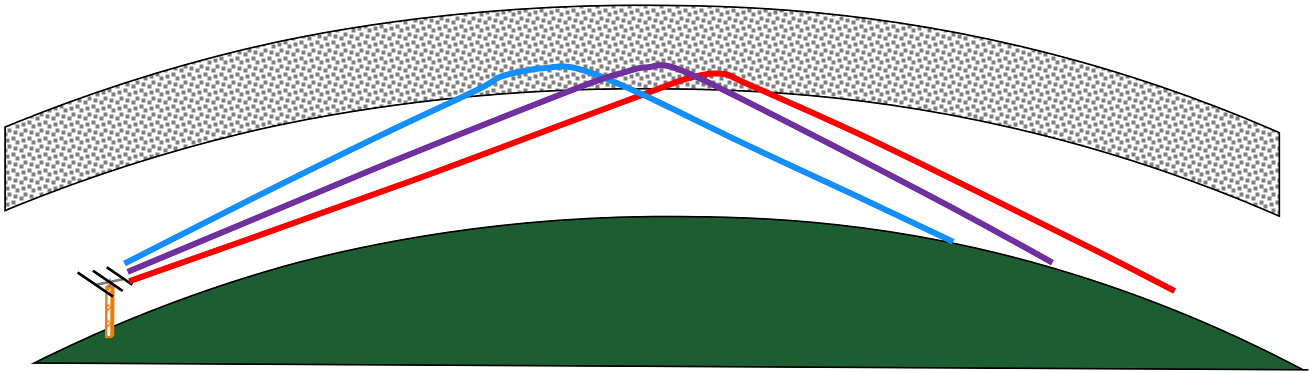
Review of HF skywave propagation

- Enables beyond line of sight (BLOS) and worldwide communications
- Signals are refracted by layers of ionized particles in the atmosphere (**ionosphere**)
  - The D-layer **absorbs** signals (helps determine minimum frequency)
  - The F-layer **refracts** signals (helps determine maximum frequency)



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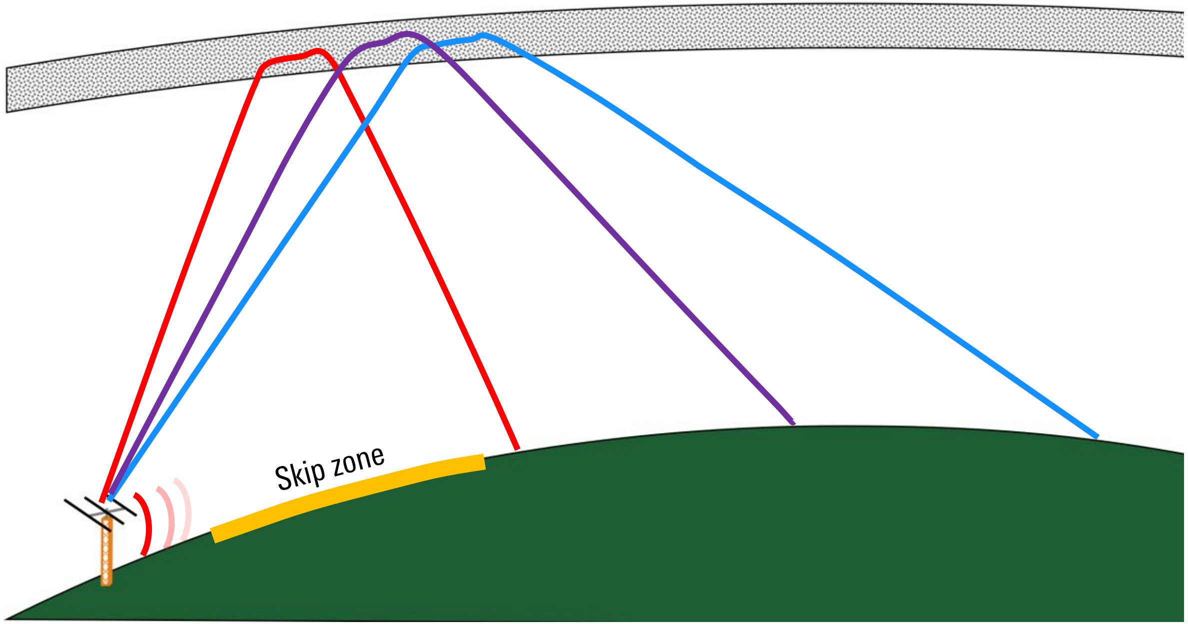
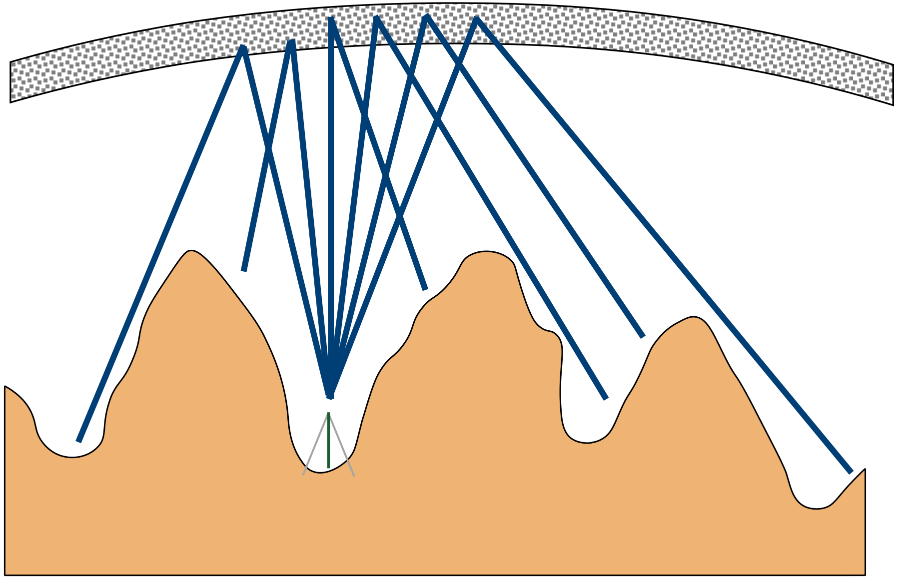
Skip zone

- The incident angle affects the range achievable using skywave propagation
  - Angle depends on antenna type and installation
- Lower incident angles yield greater distances
- In a “skip zone” signals cannot be received via skywave or groundwave



Near vertical incidence skywave (NVIS)

- Special case of skywave that enables
  - Skip zone coverage
  - Coverage in rough terrain
- Implemented using antennas with very high (> 75°) radiation angles and low HF frequencies
- Typical coverage range is several hundred kilometers
- Common applications include:
  - Military
  - Disaster relief
  - Amateur radio



Advantages of NVIS - technical

- Resistant to fading / more constant received signal level
  - Shorter path through D-layer
  - Shorter overall path length
  - Terrain does not attenuate signal
  - Fading due to multipath reduced
- Works well with low power
  - Important for portable operation
- Omnidirectional coverage
  - Does not require knowledge of receiver location
  - Antenna orientation is unimportant
  - Flexibility in setup and siting

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Advantages of NVIS – operational (for mil / gov applications)

- Lower probability of intercept
  - Low power
  - Vertical radiation pattern
- Difficult (but not impossible) to DF
  - Vertical pattern
  - Energy returns with roughly equal strength
  - No strong groundwave to locate
- Difficult to jam via groundwave
- Antennas are low / discrete
  - Can be easily erected, often by one person
  - Does not require controlling the “high ground”

Disadvantages of NVIS

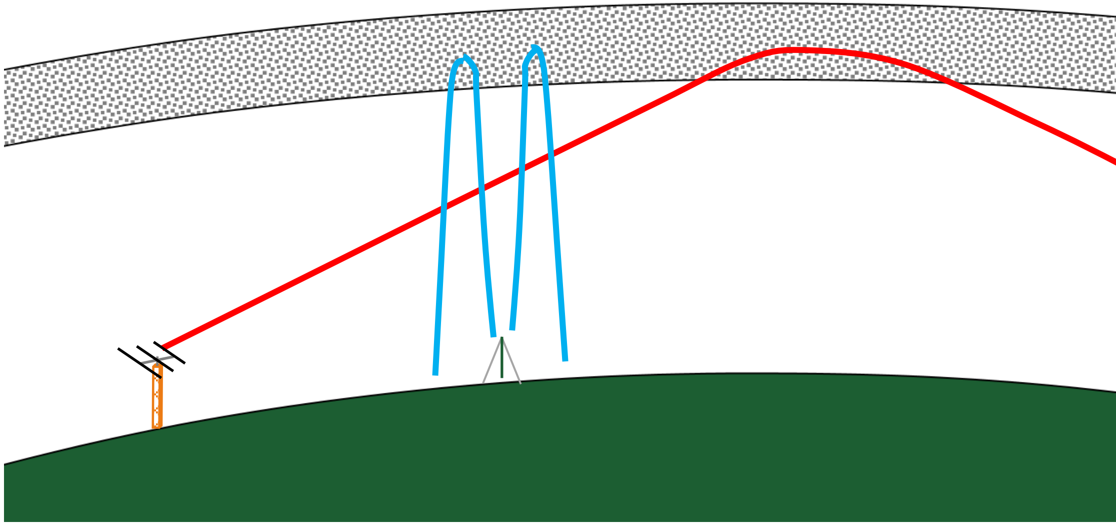
- ► Only works at lower frequencies
- ► Limited range (hundred of km vs. thousands of km)
- ► Both stations need NVIS antennas for good results
- ► Both atmospheric and man-made noise tends to be higher at the lower frequencies used for NVIS

Frequencies

- NVIS frequencies must be:
  - low enough to be refracted by the F layer
  - high enough to not be excessively attenuated by the D layer
- NVIS frequencies usually between 2 and 10 MHz
  - Depends on ionization (solar cycle, time of day, season, etc.)
  - Depends on antenna
  - 4 to 8 MHz during the day
  - 2 to 4 MHz at night
- May be manually chosen by the operator or automatically using ALE

About NVIS antennas

- NVIS is essentially an “antenna” technology
- Most HF skywave antennas are designed for a **low** radiation angle
  - Longer skywave distances
- NVIS antennas are designed for a **high** radiation angle (> 75°)
  - Usually implemented using antennas that are low to the ground
- An antenna tuning unit (ATU) may be needed



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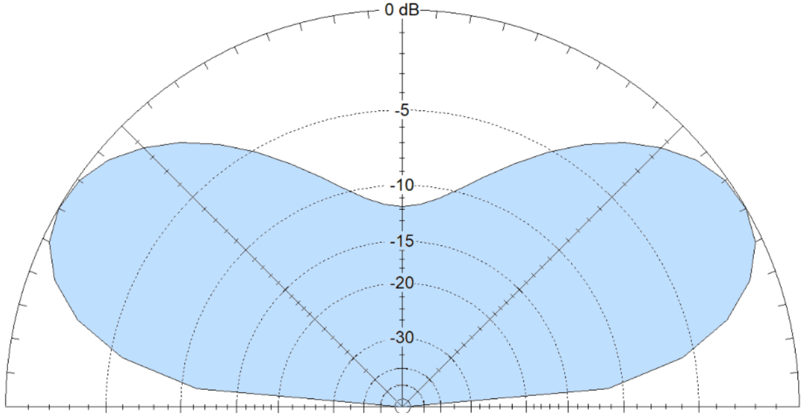
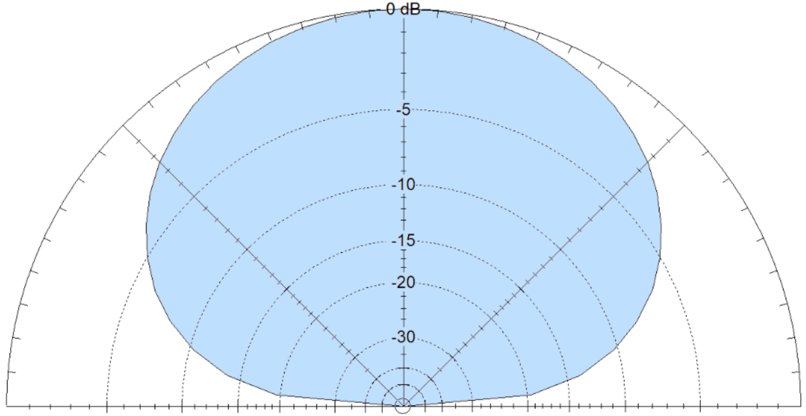
Elevation (vertical) pattern

“Standard” Dipole



Lower take-off angle works well for long-distance skywave

“NVIS” Dipole



High take-off angle works well for NVIS (but poorly for long-distance skywave)

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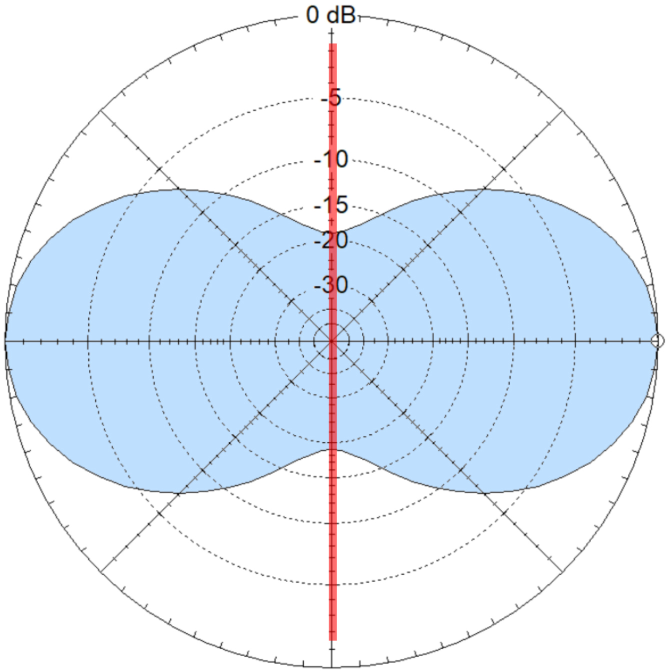
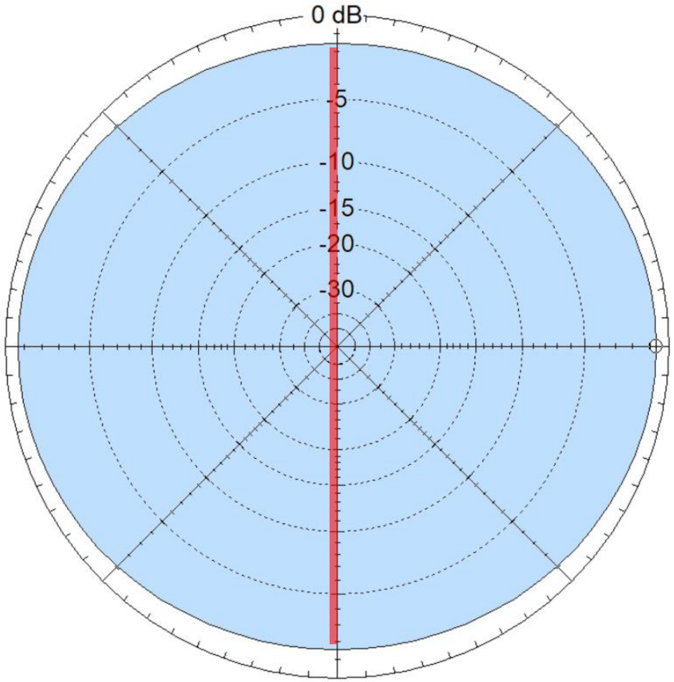
Azimuth (horizontal) pattern

“Standard” Dipole



“NVIS” Dipole

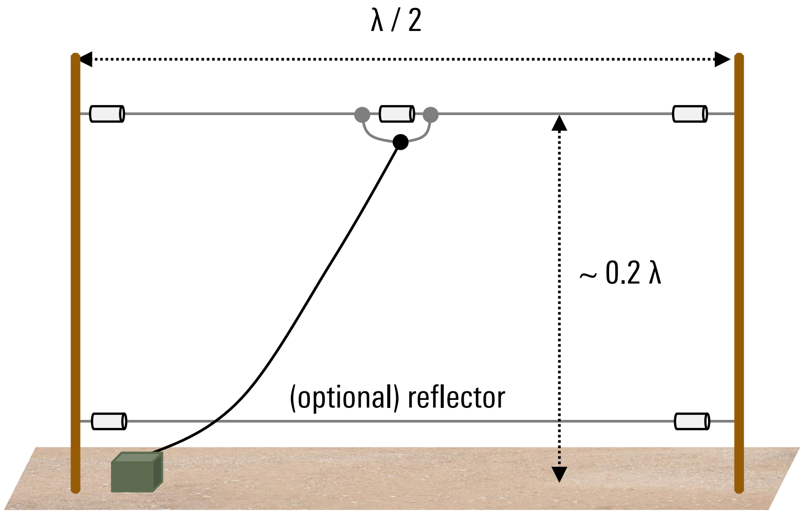


Common NVIS antenna types

- Many antenna types can be used / adapted for NVIS
- Portability / ease of setup (“field expedient”) often determines specific form factor
- Most common NVIS types:
  - Dipole
  - Inverted Vee
  - Unbalanced wire
  - Vehicle-mounted
- Others (usually fixed site):
  - Conical spiral
  - Vertical log periodic

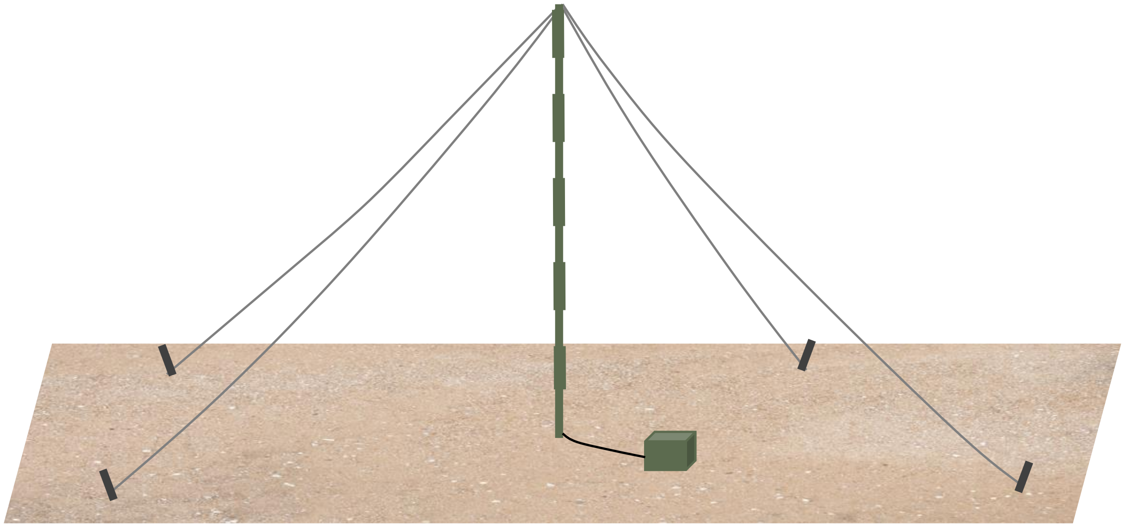
NVIS antenna example - dipole

- Low-angle skywave usually ~ 0.5 λ above ground
- NVIS dipoles usually ~ 0.2 λ above ground
  - Ex: ~ 8 meters at 7 MHz (40 meters)
  - Radiation angle increases as active element is lowered
- Optimum antenna height is also partly a function of the ground conductivity
  - Higher conductivity = lower optimal height
- Reflector element can be used in cases of low soil conductivity (sand, rock) or if dipole is high above the ground.



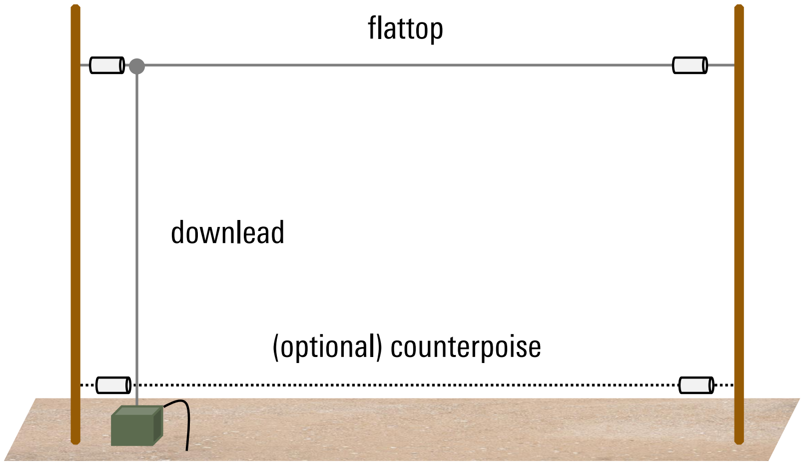
NVIS antenna example – inverted Vee

- ► Dipole supported by a center mast
- ► Pair of dipoles (“turnstile”) often used
  - – Reduces polarization sensitivity
- ► Easy to erect: only one support
  - – Can be raised by one person
- ► Mast only slightly higher than dipole
  - – Apex angle should be kept low



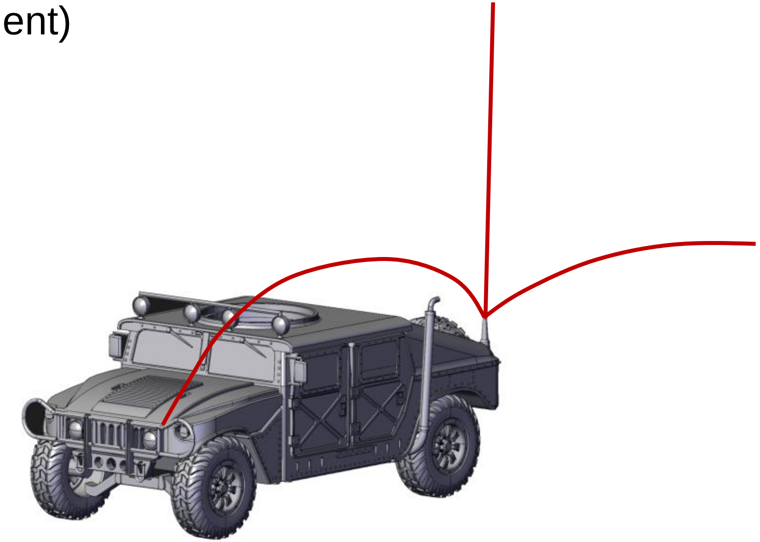
NVIS antenna example – unbalanced wire

- An inverted L is an example of an unbalanced antenna used in NVIS
  - Horizontal flattop
  - Vertical download
- Works against ground (or counterpoise if necessary)
- Antenna radiates along entire length if connection is made at the end of the wire
- Also can be mounted on vehicles



Mobile NVIS antennas

- Loop antennas popular because they can used in motion
- Standard vertical whip antennas can be bent/tied into horizontal position for use in NVIS
  - Best performance when tied backwards
  - Can be tied forward for use in motion (less efficient)



Additional mobile NVIS antennas

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Skywave vs. groundwave

- In addition to maximizing high-angle skywave signals, a NVIS antenna should also minimize low-angle groundwave signals
  – Distortion / fading may occur if a station receives a signal via skywave and groundwave
- Additional advantages of minimizing groundwave:
  – Reduces the impact of noise sources
  – Reduces effectiveness of groundwave-based jamming
  – Makes traditional ground-based radiolocation (direction finding) more difficult
    – But NVIS emitters can still be accurately DF’ed using multiple DF stations and elevation angle

Summary

- NVIS uses very high (> 75°) elevation angles to refract signals back from the ionosphere
- Main characteristics:
  - Coverage of “skip zones”
  - Coverage in terrain-challenged areas
  - Omnidirectional coverage
  - Lower POI, harder to DF, greater jamming immunity
  - Uses low HF frequencies (~ 2 to 10 MHz)
- Common NVIS antennas
  - Dipoles (mounted low) / inverted Vee
  - Unbalanced antennas (inverted L)
  - Loop-style antennas