Near Vertical Indcidence Skywave Propagation (NVIS): What It Is and How to Use It

Alden Oyer, AG5S

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Based on the presentation

“NEAR VERTICAL INCIDENCE SKYWAVE (NVIS)”

by

Charles Rogers, NM5CR

Here is a good location for High Angle Skywave Propagation.

NVIS PRESENTATION OUTLINE

- How Radio Waves Refract Off The Ionosphere, What Goes Up Sometimes Comes Down

- How To Get The Signal To Go Up So It Comes Down Again. NVIS Antenna Designs and Builds Including Practical NVIS Antennas. Myth Busting Involved!

Frequencies between 1.8 and 30 MHz. have three propagation modes:

-Line of sight

-Ground wave

-**Sky wave**

- Signal **refracts** off the ionosphere.
- If used correctly, sky wave propagation enables us to provide continuous and dependable coverage that spans several hundred miles instead of several thousand miles.

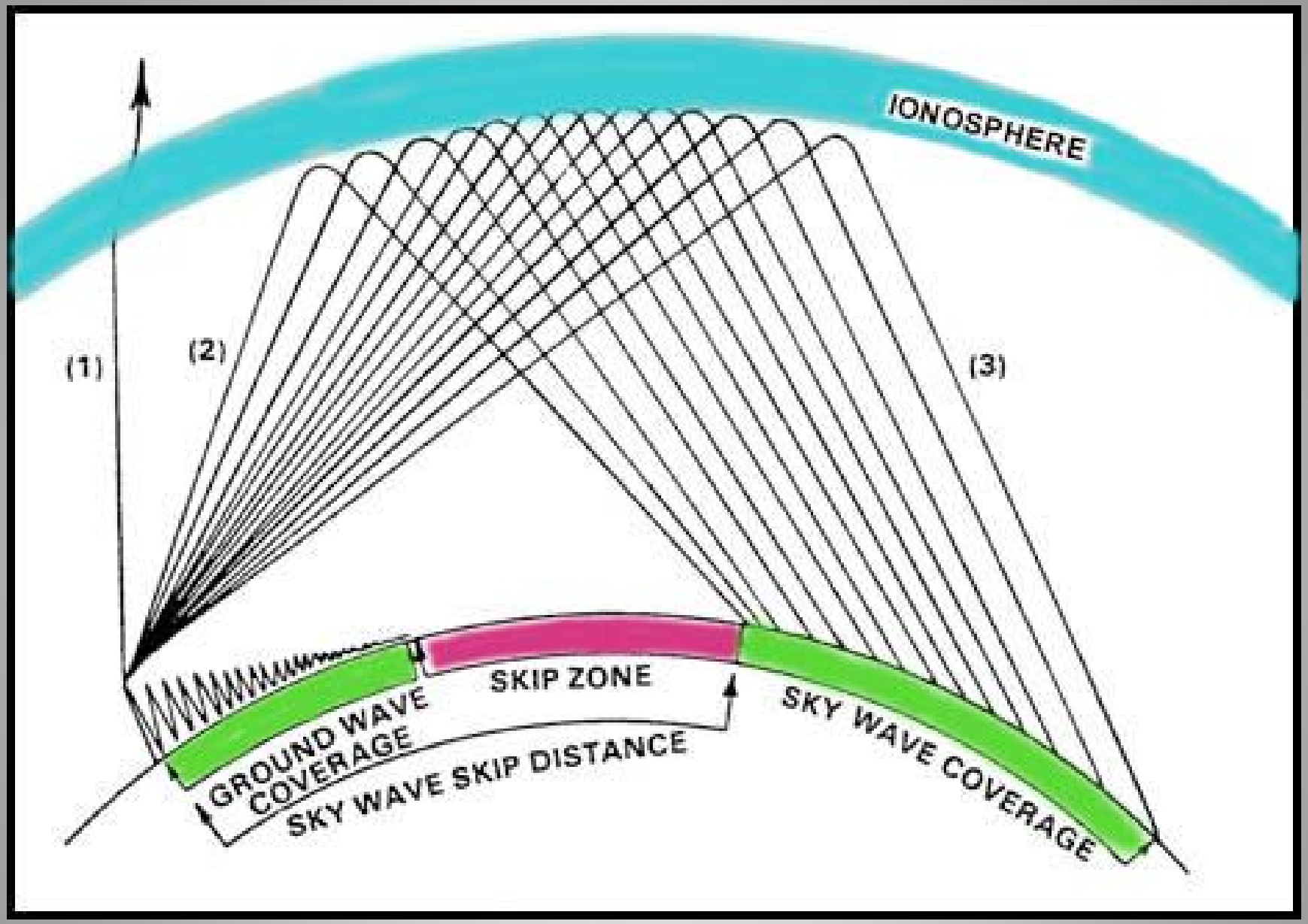
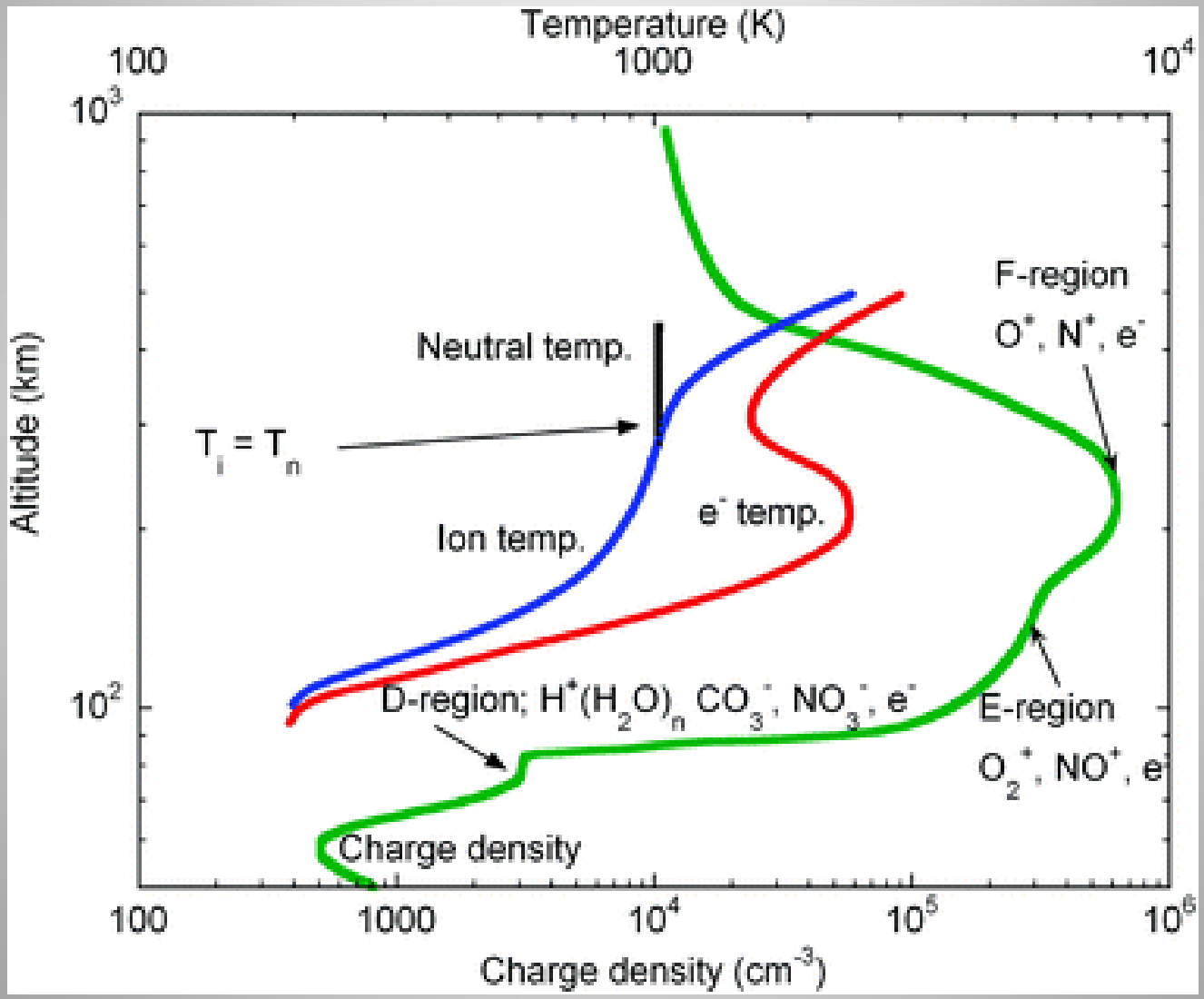


Illustration not to scale.

What is the Ionosphere?

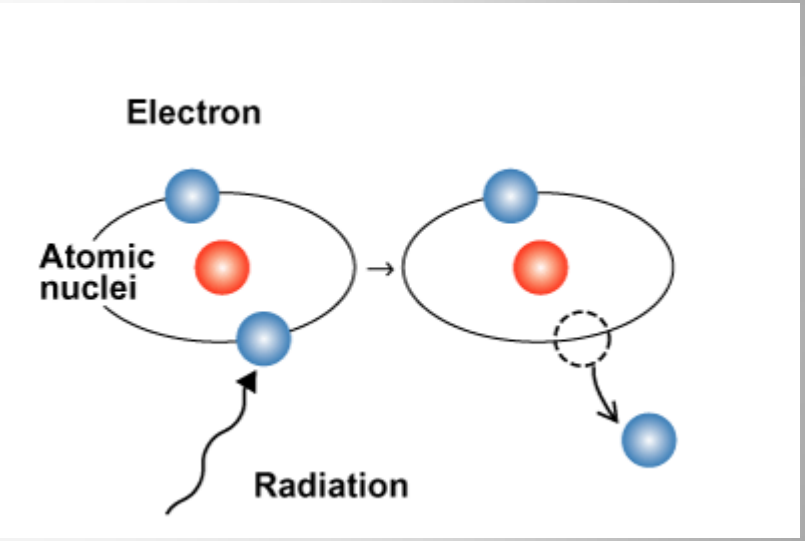
- The ionosphere is a region of Earth's upper atmosphere, from about 60 km (37 mi) to 1,000 km (620 mi) altitude, and includes the thermosphere and parts of the mesosphere and exosphere. It is ionized by solar radiation, plays an important part in atmospheric electricity and forms the inner edge of the magnetosphere. It has practical importance because, among other functions, it influences radio propagation to distant places on the Earth. [From Wikipedia, the free encyclopedia]

Ionospheric Chemistry

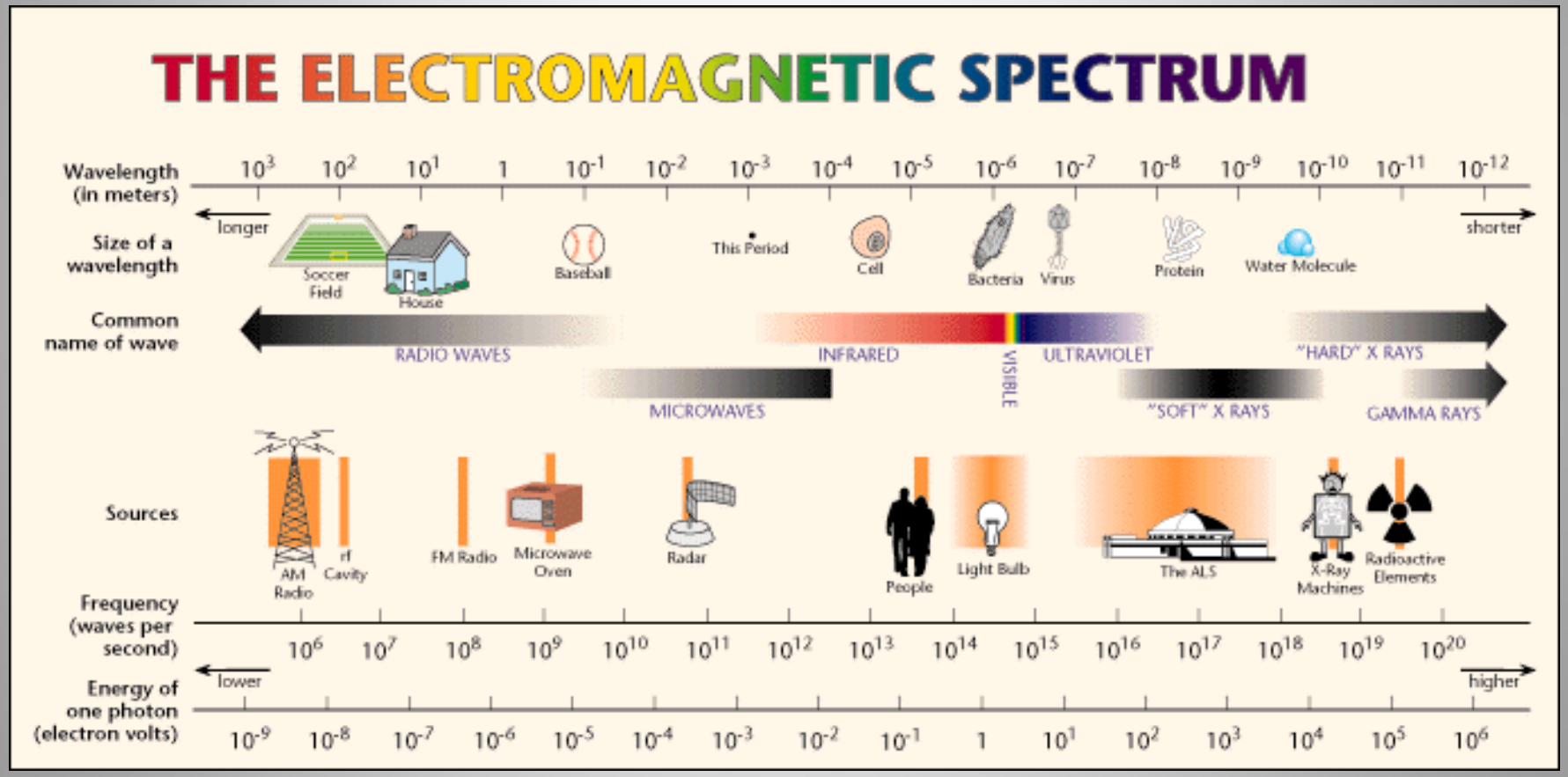


Ionization Process

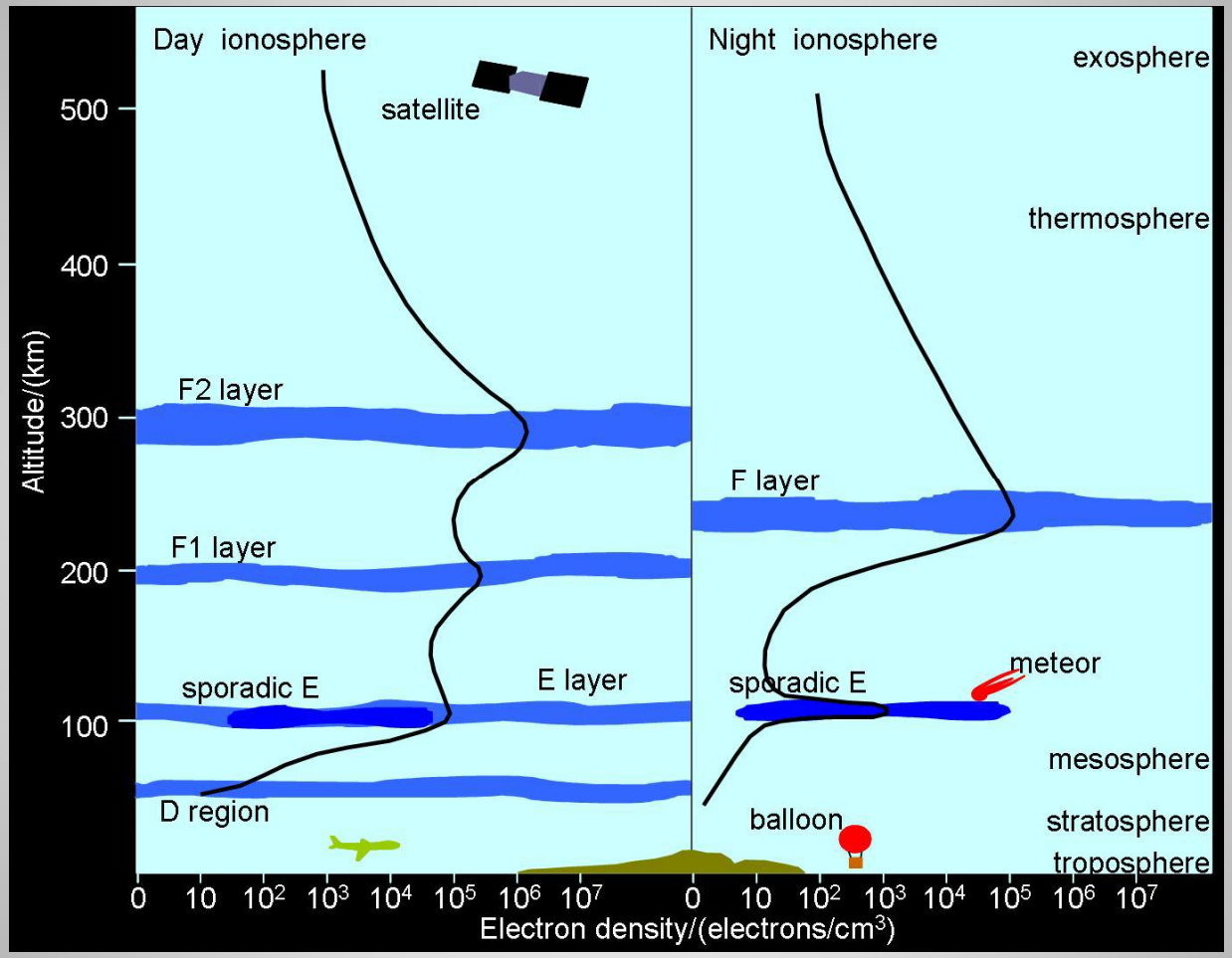
- Incoming electromagnetic radiation with enough energy can strip an electron from a neutral atom or molecule.
- The electrons and positive ions move freely constrained by the Earth's magnetic field.
- Solar soft x-rays and ultraviolet light are most responsible for the ionization.



The Electromagnetic Spectrum

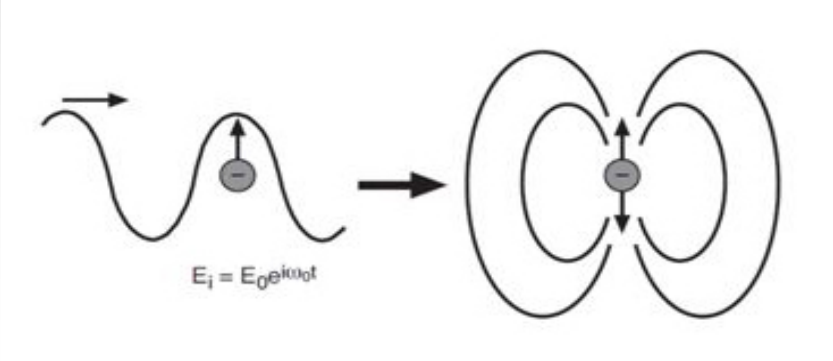


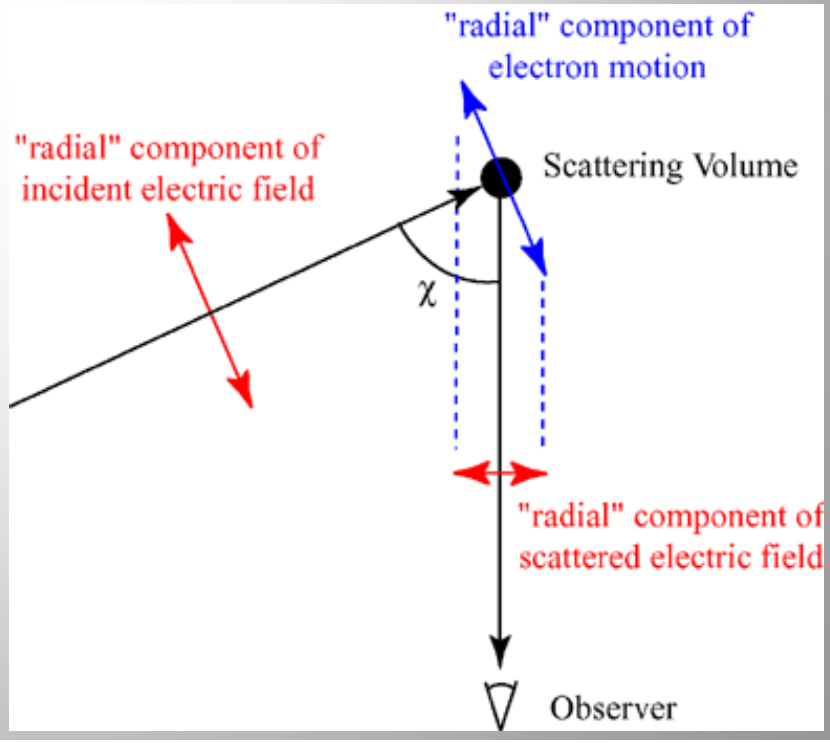
Day and Night Ionosphere

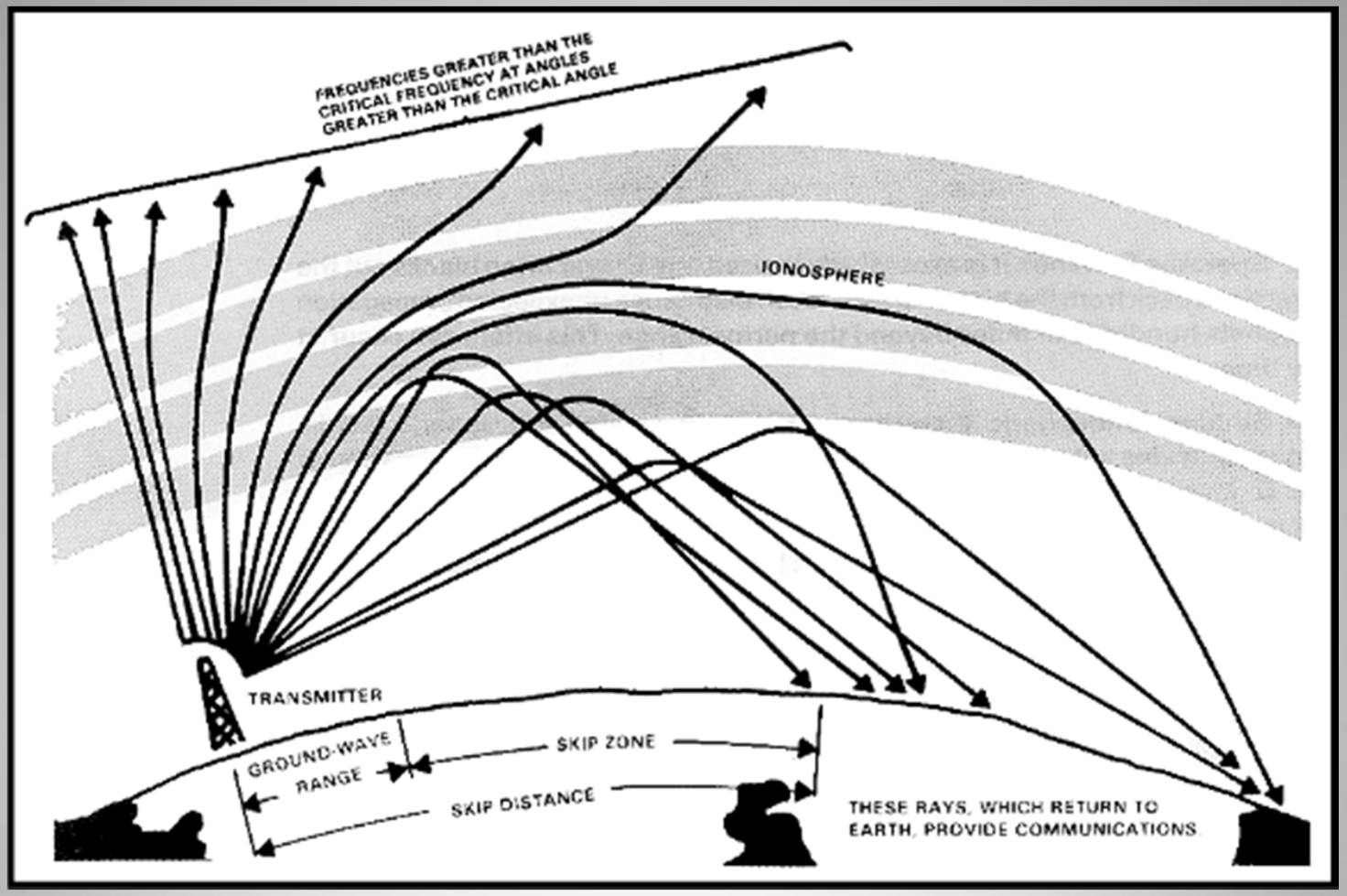


How Does the Radio Wave Refract in the Ionosphere?

- The radio wave causes charged particles to synchronously accelerate. (Think simpathetic vibration)
- The charged particles radiate a wave in other directions.
- Positive ions, being so heavy, don't scatter as well as the much lighter electrons (moving tons compared to an ounce).
- The net result from many scatterings is the radio wave bends away from regions higher electron density towards regions of lower electron density.

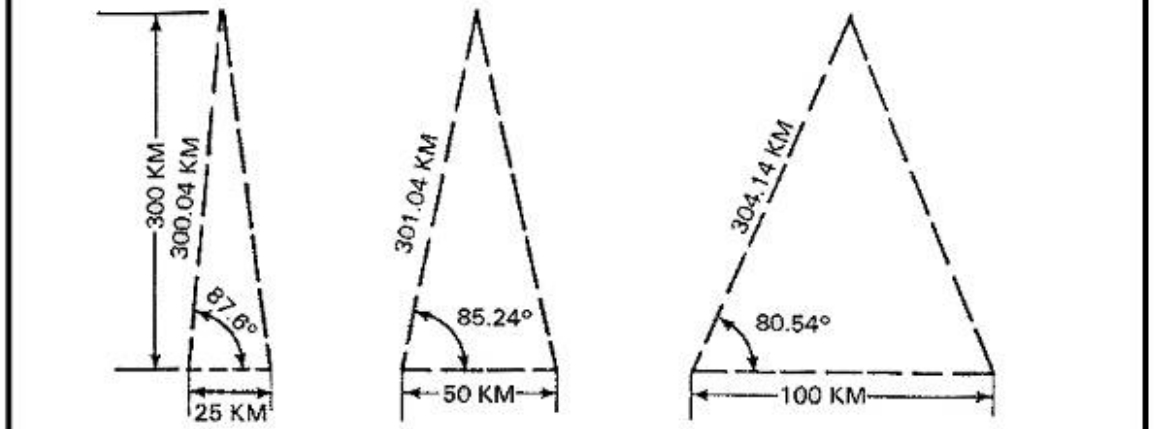






At a given frequency, the radio wave can refract back down to the Earth's surface at low to moderate angles to the horizontal. As the wave approaches the vertical, it will usually not be bent enough and will radiate into space. The lower the frequency, the higher the angle.

Takeoff angles are used to describe NVIS operation and path length. Signal strength stays fairly equal over the area of coverage. Here are three examples for 15, 30, and 60 miles.



GROUND RANGE Km	RADIO PATH LENGTH Km	RANGE VARIABLE 20 LOG d	V LOSS dB
25	600.5	55.57	0
50	600.08	55.59	0.02
100	608.28	55.68	0.11
NIGHT OR DAY ABSORPTION, TURN-AROUND, NORMAL ATMOSPHERICS. AVERAGE PATH LOSS (3 TO 5 MHz) = 110 dB + 10 dB.			

Figure M-3. Path length and incident angle (near-vertical incidence sky-wave mode).

MUF = Maximum Usable Frequency: The highest frequency at which ionospheric propagation between specific locations will be available 50% of the time.

LUF = Lowest Usable Frequency: The lowest frequency at which ionospheric propagation between specific locations and using specific power levels, receiving equipment and antennas will be available 50% of the time. The LUF can be improved (lowered) by increasing power, using higher gain antennas, or by substituting higher performance receiving equipment.

- Frequencies must be between the **LUF** and the **MUF**. A general rule of thumb is:
  - Nighttime 2-4 Mhz
  - Daytime 4-8 Mhz

- The best operating frequency is usually 20 to 25% below the **MUF**. Propagation data are always specific to the time of year, time of day and solar activity.

NVIS propagation occurs readily at the high end of the MF range and in the lower end of the HF frequency range.

160 m	1.8 – 2 MHz
80/75 m	3.5 – 4 MHz
40 m	7 – 7.3 MHz

Also, the newer 60 meter band can be a good candidate for high angled skywave propagation.

Big Myth

- NVIS is a mystical and esoteric mode that requires a “special” antenna.

FACTS

- There is nothing special about NVIS (or high angle skywave propagation)!
- The wavelength used must be long enough so it refracts back to earth.
- The optimum antenna is a horizontal dipole!

Antennas

- So, that’s how the signal comes down.
- How to get it to go up?
- Consider a horizontally polarized antenna (i.e. dipole) at various heights above the ground.

Theoretical Antenna Considerations

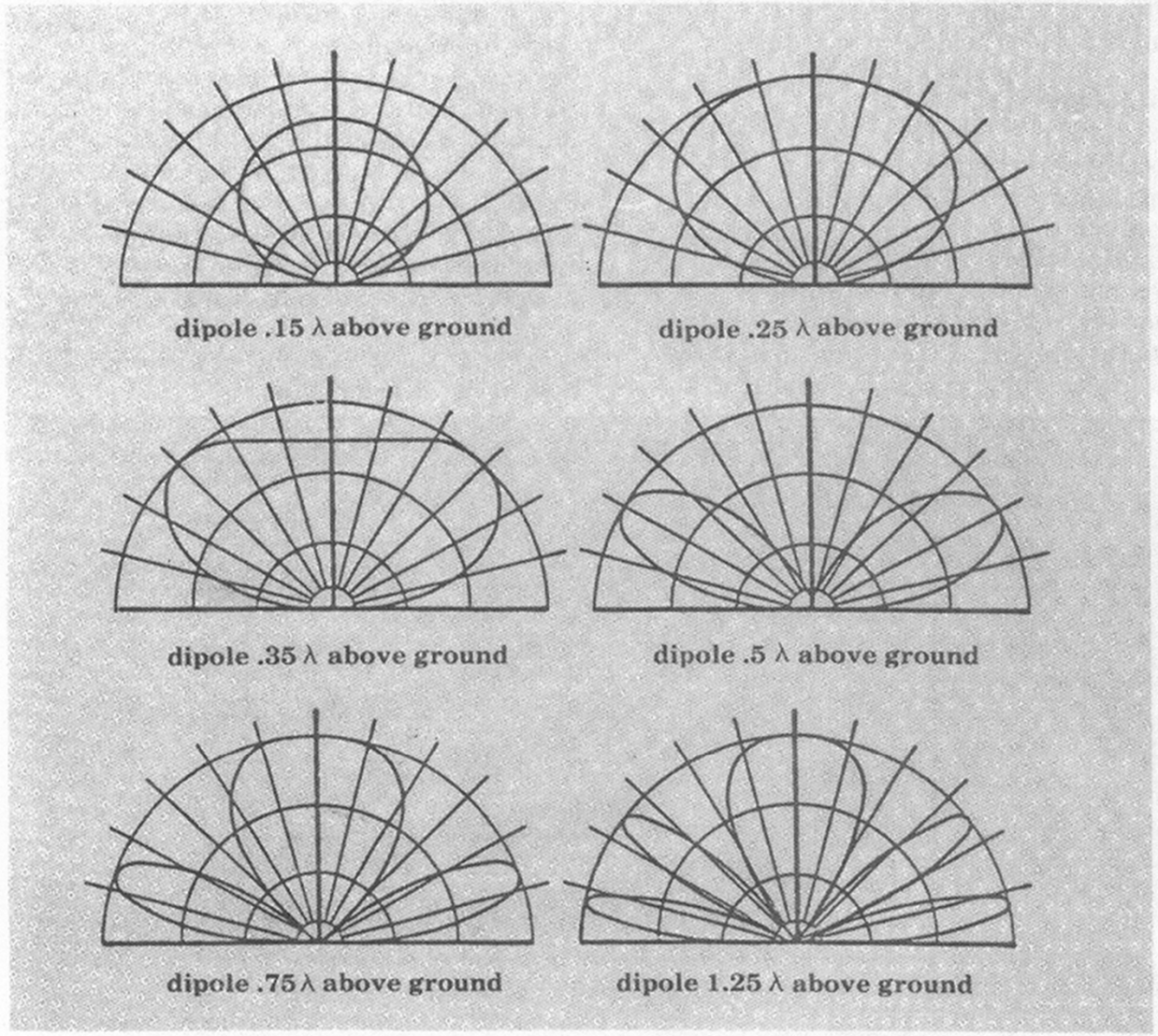
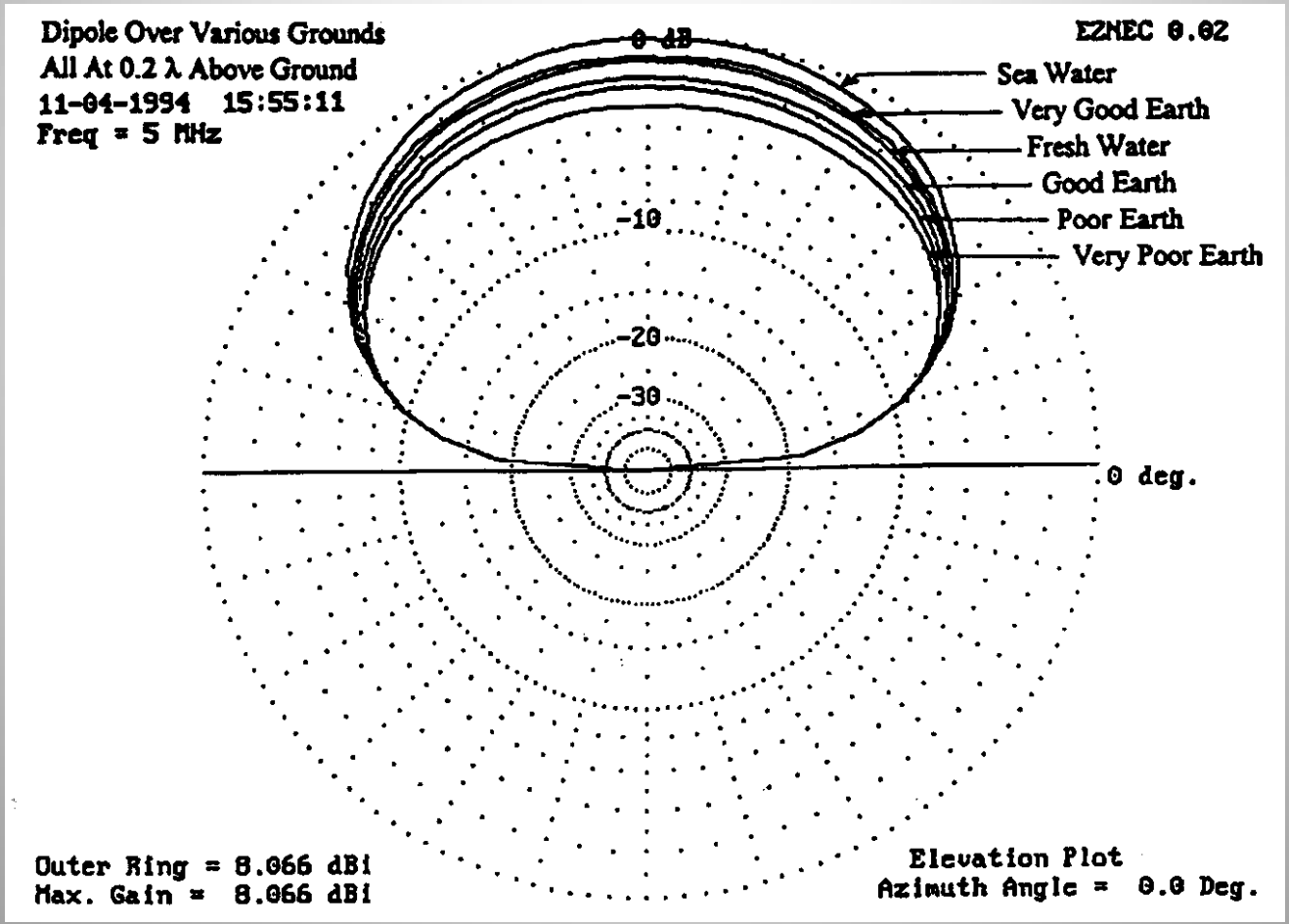


Figure 3. Horizontal dipole radiation patterns at various heights (in wavelengths) above the ground (from Air Force Comm. Pam. 100-16).

The type of ground has some effect on the overall theoretical gain of the antenna, about 3db.



Vertical Gain of Dipole at 0.2 Wavelength Over Various Types of Ground (dBi)

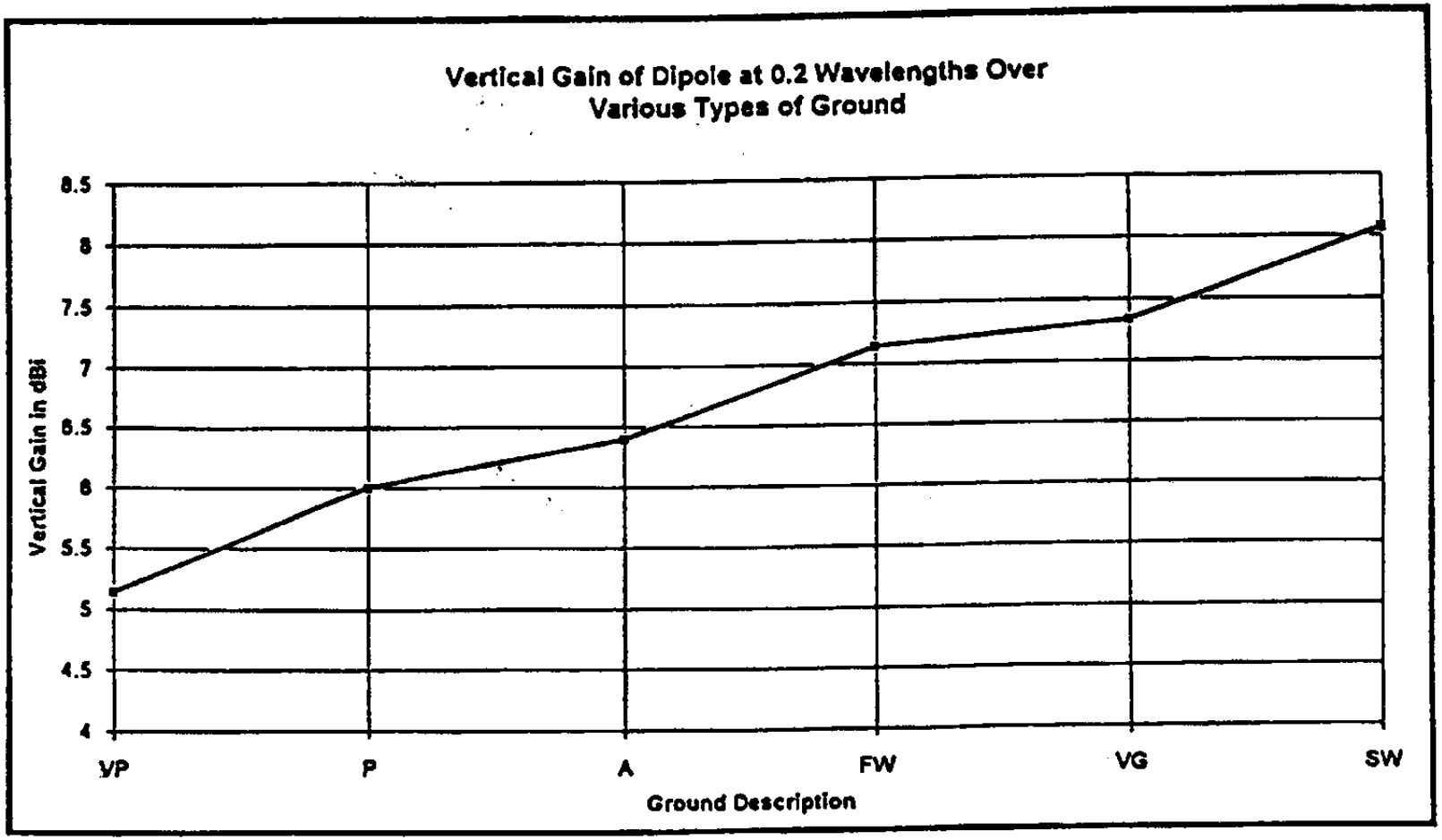
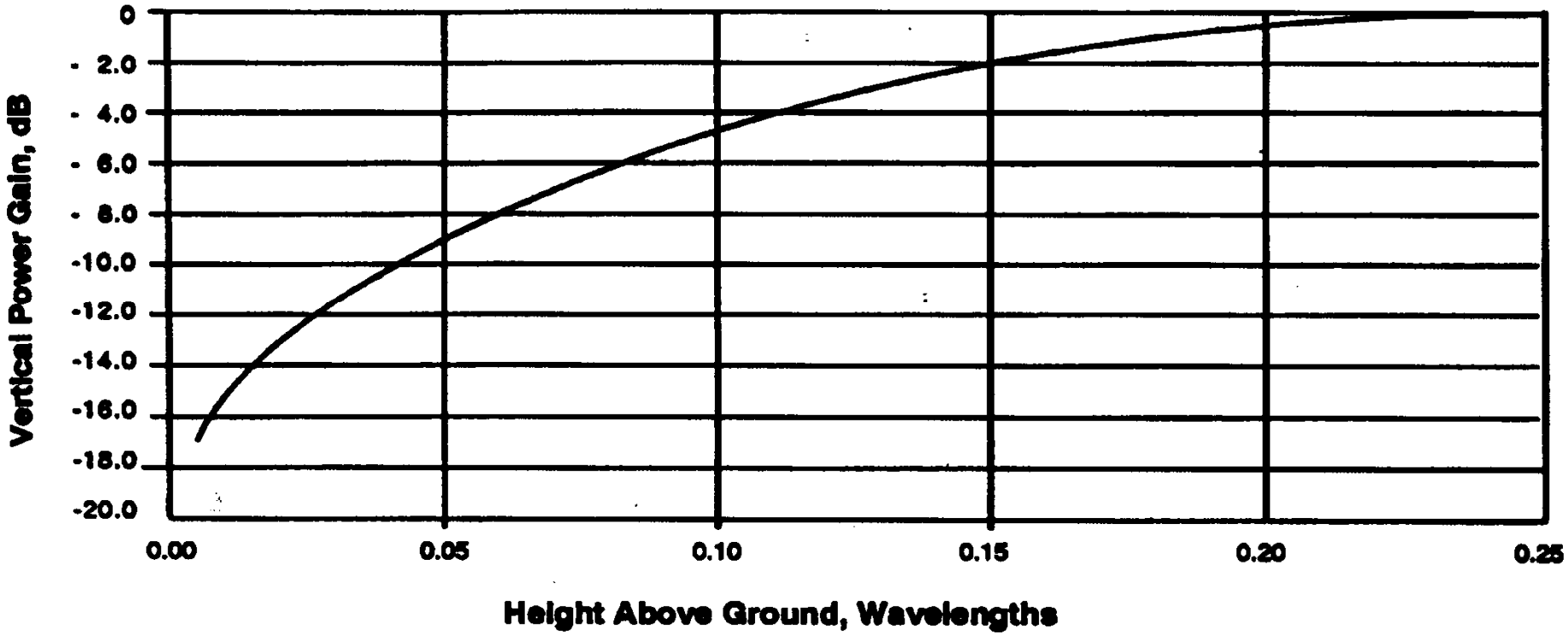


Figure 2. Half-wave dipole at 0.2 wavelengths over various grounds. While not much can be done to change the characteristics of the ground that is encountered, it is comforting to see that from the best to the worst the impact on radiated signal is only about 3 dB.

Gain of dipole at various wavelengths above ground (dBd).



Orientation of a horizontal antenna is generally not important at high angles, since the azimuth pattern of horizontal antennas is somewhat circular.

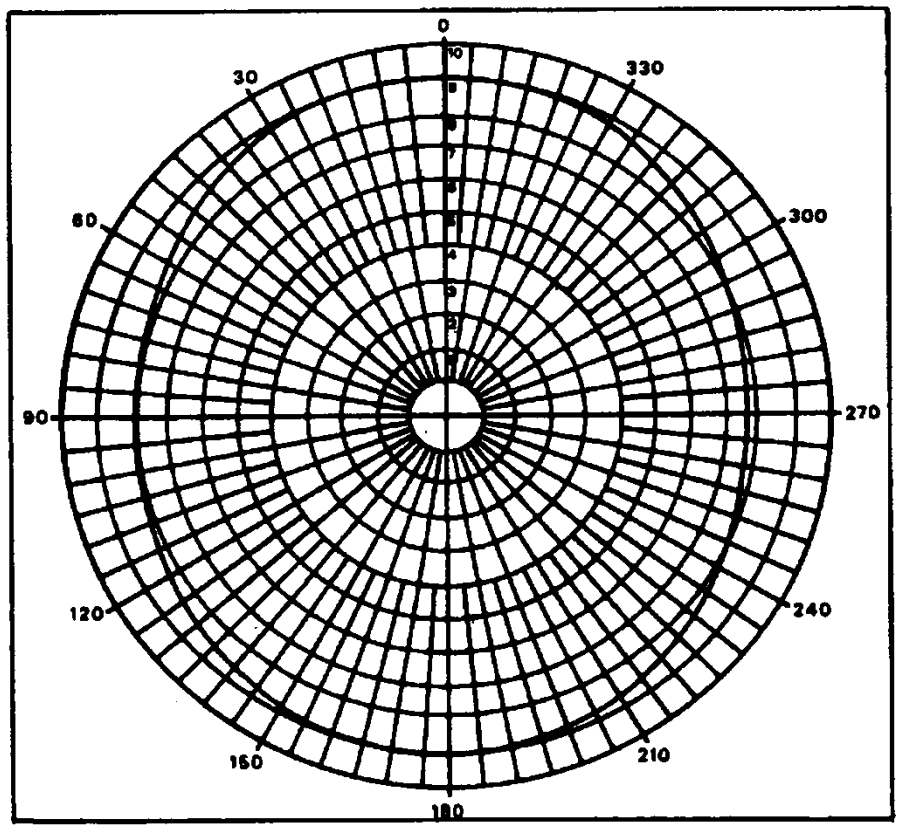


Figure M-2. Near-vertical incidence sky-wave antenna typical azimuth plane pattern.

Big Myth

- A proper NVIS antenna should be as low to the ground as possible to maximize vertical radiation.

FACTS

- A proper NVIS antenna should be as high as practical.
- A proper NVIS antenna should be as horizontal as practical.
- The azimuthal orientation (N/S, E/W, etc.) dosen’t matter.

General Antenna Criteria

- On Receive, you **must be able** to hear the other station.
- On Transmit, the other station **must be able** to hear you.
- On Transmit, you **shall not** make neither smoke nor sparks!
- **Perfection is the enemy of good enough!** We are aiming for **good enough**. Do not over engineer the design!
- **Keep It Simple, Student (KISS)!**

Engineering Considerations

- Long term (fixed location) or Short term (Portable or Moble) Installation?
  - A Long term installation should last a long time.
  - A Short term installation should be quick to assemble and quick to dismantle.
- Try to have a resonate antenna, but expect to use an antenna tuner (especially in the field).
- Design for multiband (80/60/40 meters) resonance. 160 meters is an option.

Some Suggested Designs Found in the Literature

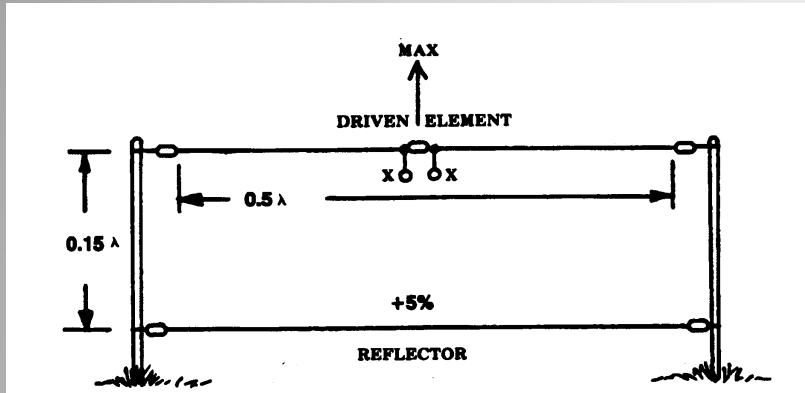
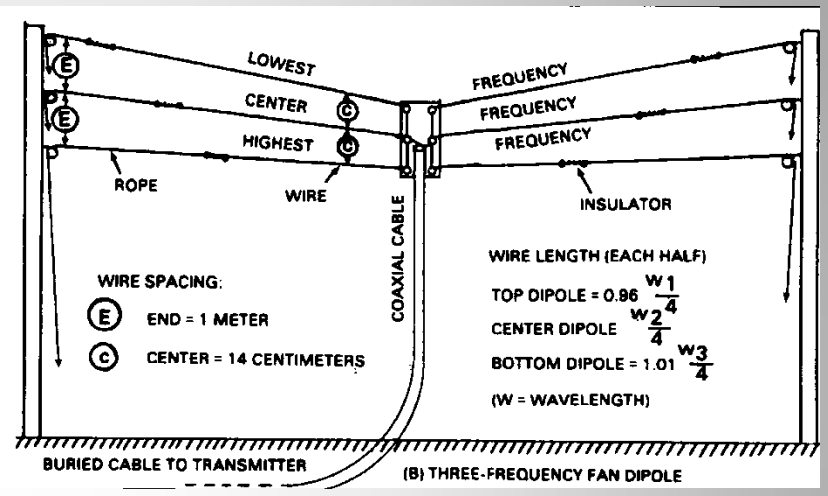
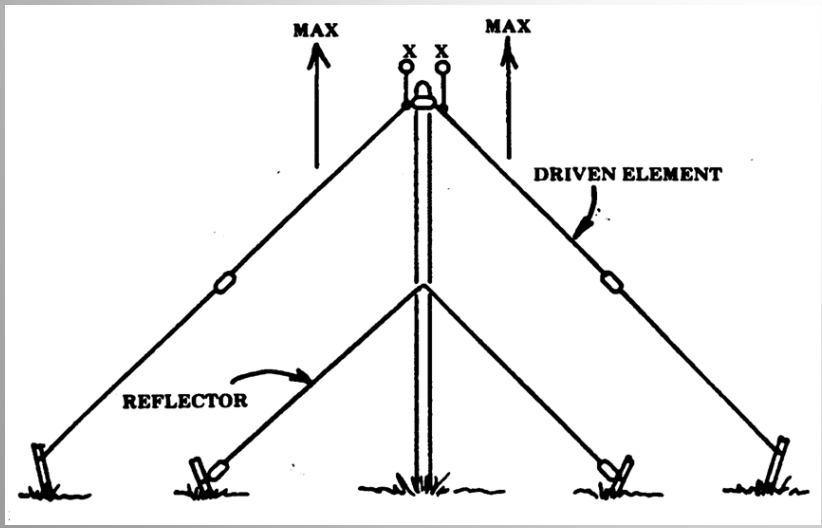
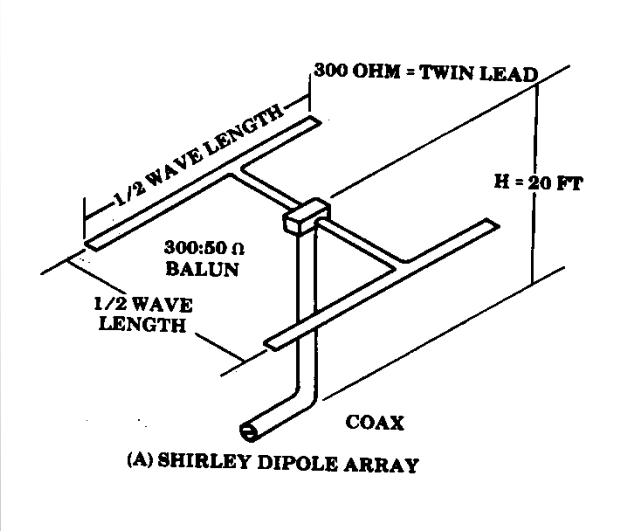


Figure 4. Half wavelength dipole with reflector



(B) THREE-FREQUENCY FAN DIPOLE





(A) SHIRLEY DIPOLE ARRAY

More Suggested Designs Found in the Literature

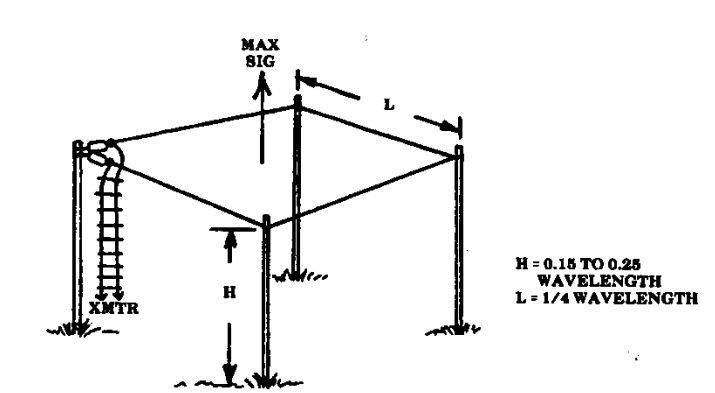


Figure 7. Full wave loop antenna. Note if coaxial cable is used a 4:1 BALUN transformer is required.

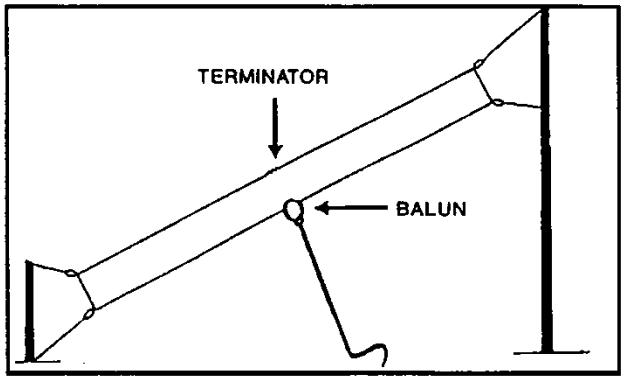
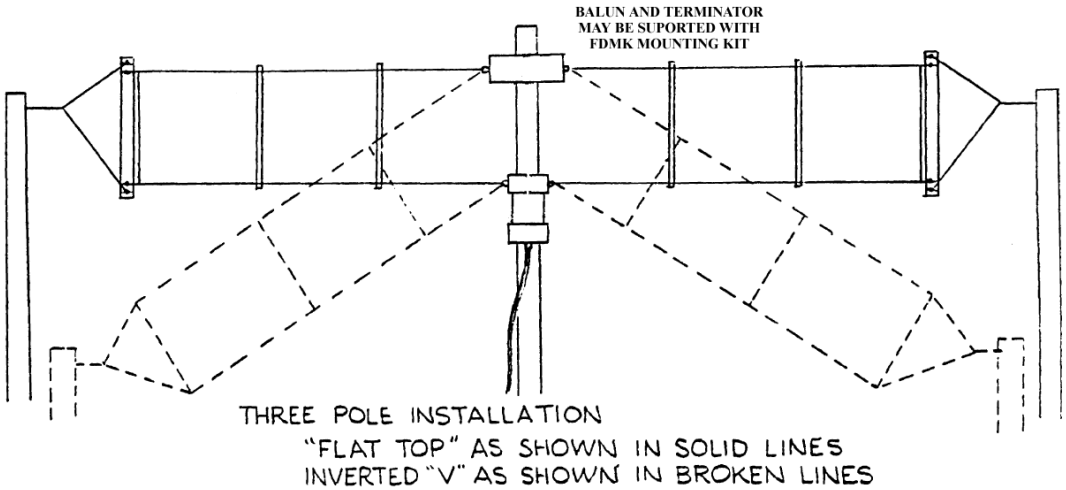
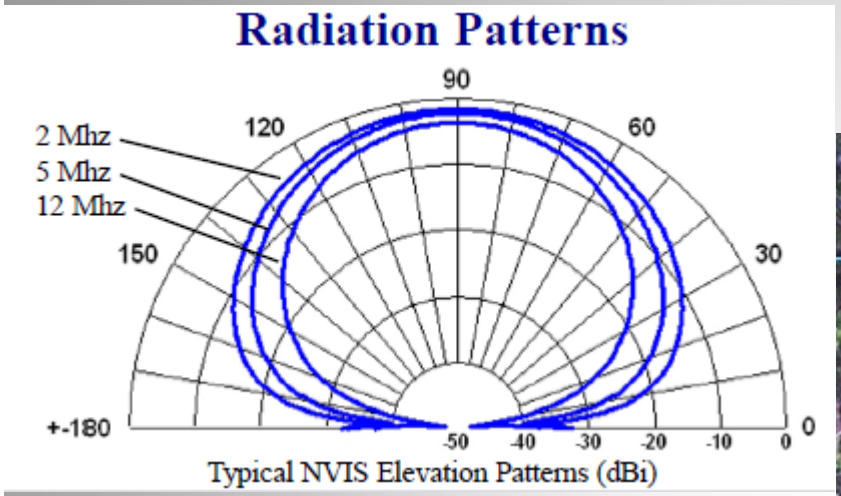


Figure 9. The T2FD (Terminated 2-Wire Folded Dipole) Antenna Configured as an Inclined Version



B&W Manpack MP-45 or MP-90 One Man Setup 15-min. **$1990.00**



Difficult tuning with gain down about 5 db from a dipole

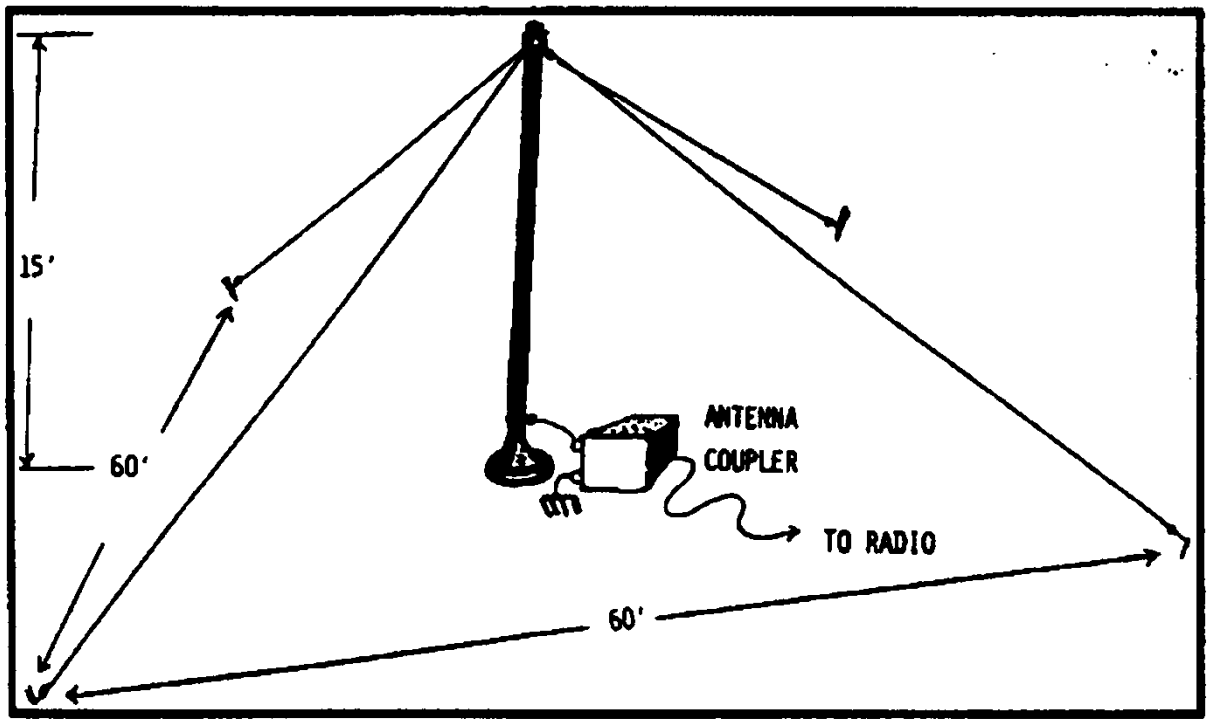
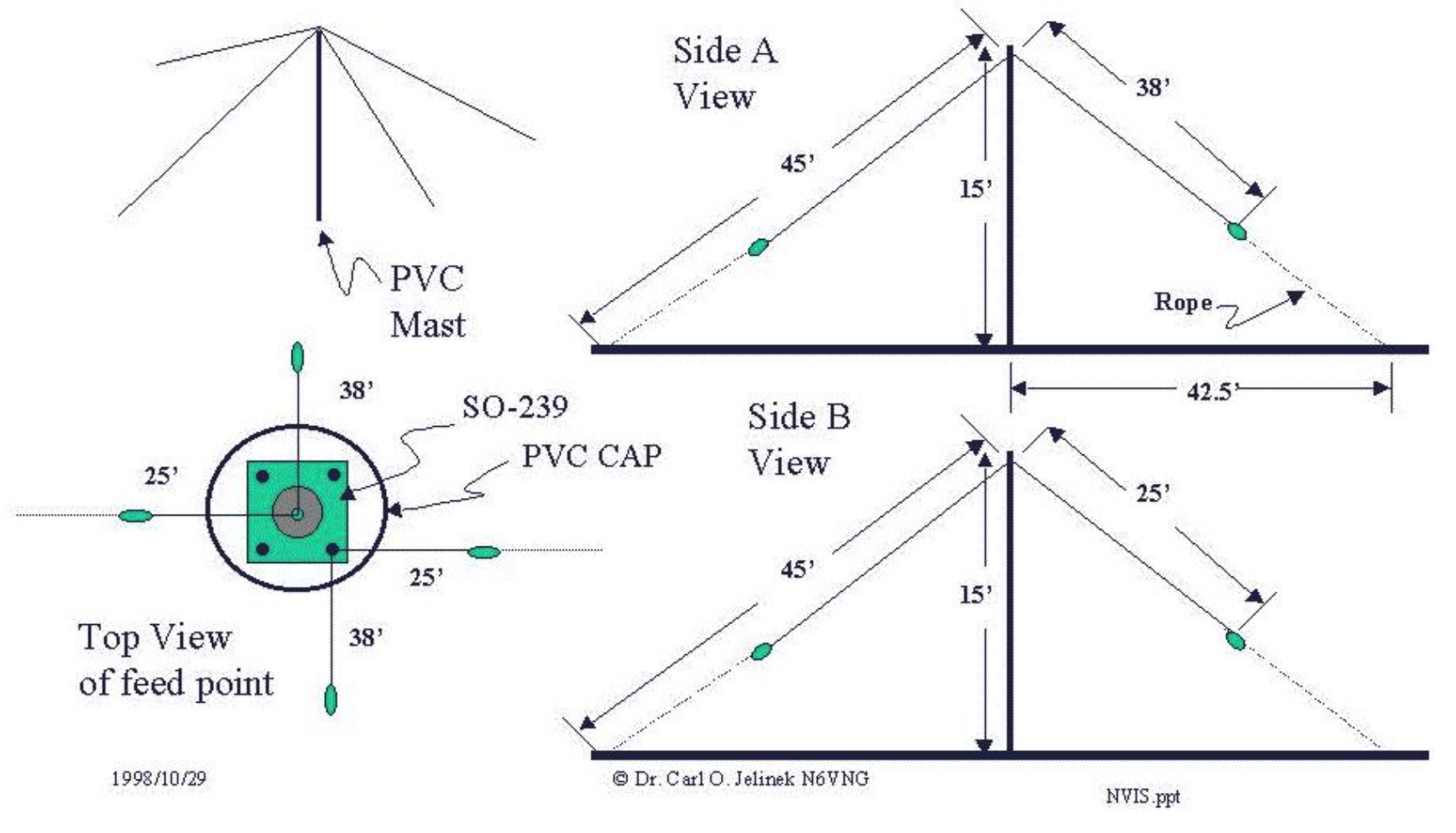


Figure 8. The AS-2259/2268 (also known as the Collins 637K)

Dual Band Portable NVIS

Two Inverted “V”s Placed 90 deg to minimize coupling. One central support and four stakes.



MilitaryMobile NVIS Antenna

- Antenna must be oriented in the horizontal position towards the back or front of vehicle
- The longer the antenna the better
  - Consider whip antenna
- Whip antenna configuration
  - 45 Degrees tilt
  - Tie down end with rope
- Tilted pattern when tied towards back of vehicle
- Vertical loop pattern when tied to front of vehicle

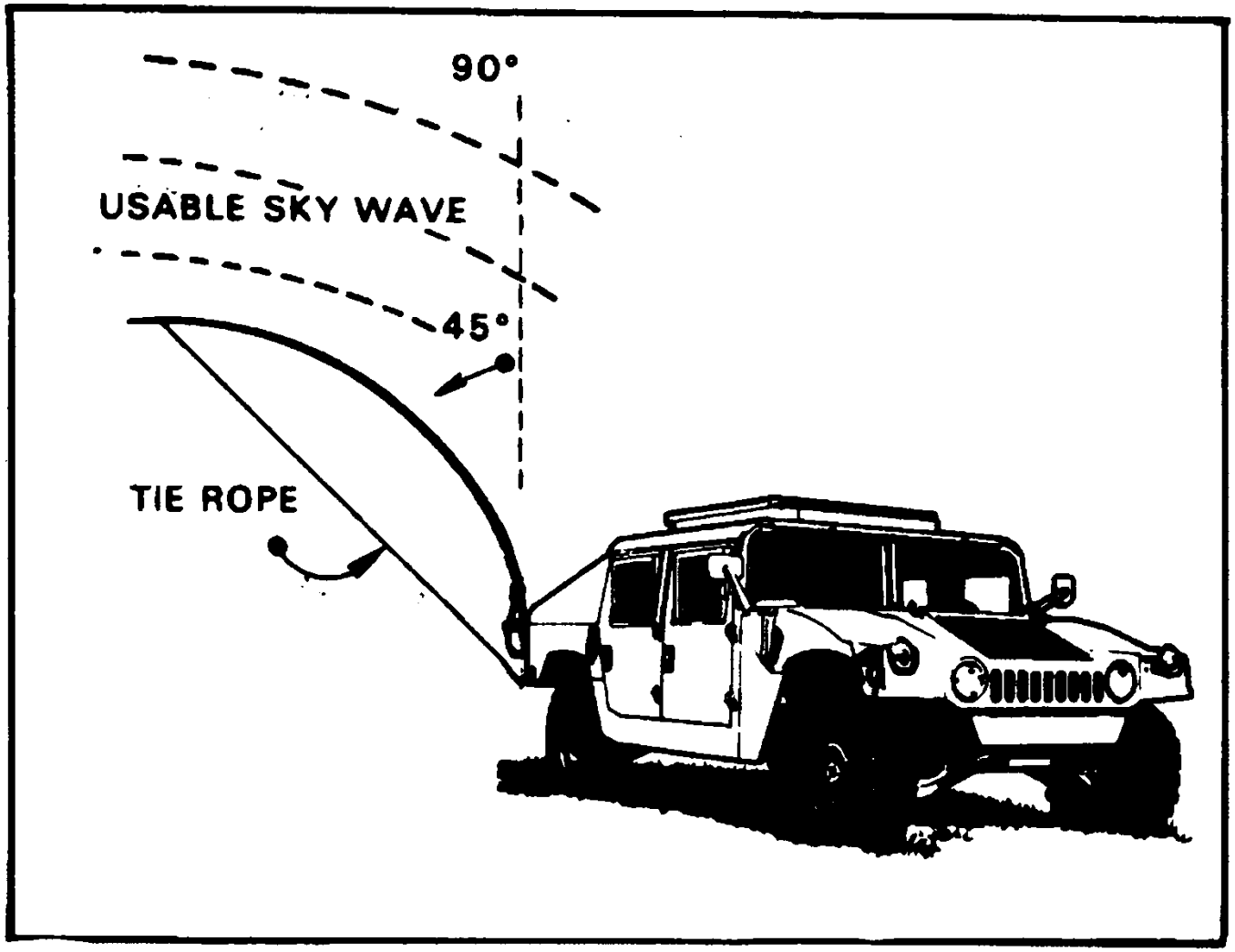


Figure M-9. Tying the whip antenna down.

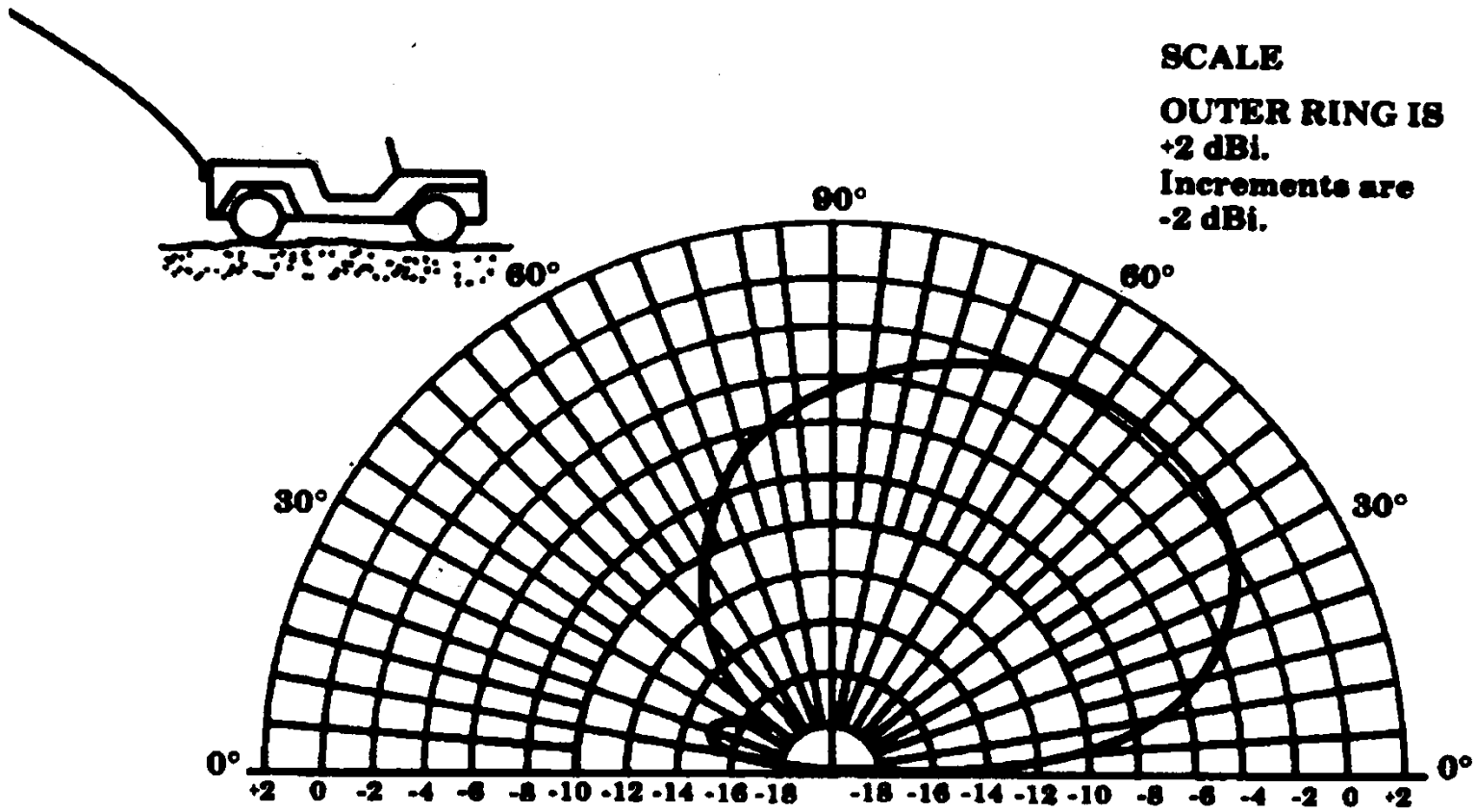


Figure 10. Far-field elevation pattern of vehicular 15 ft. whip bent backwards at 45° at 10 MHz.

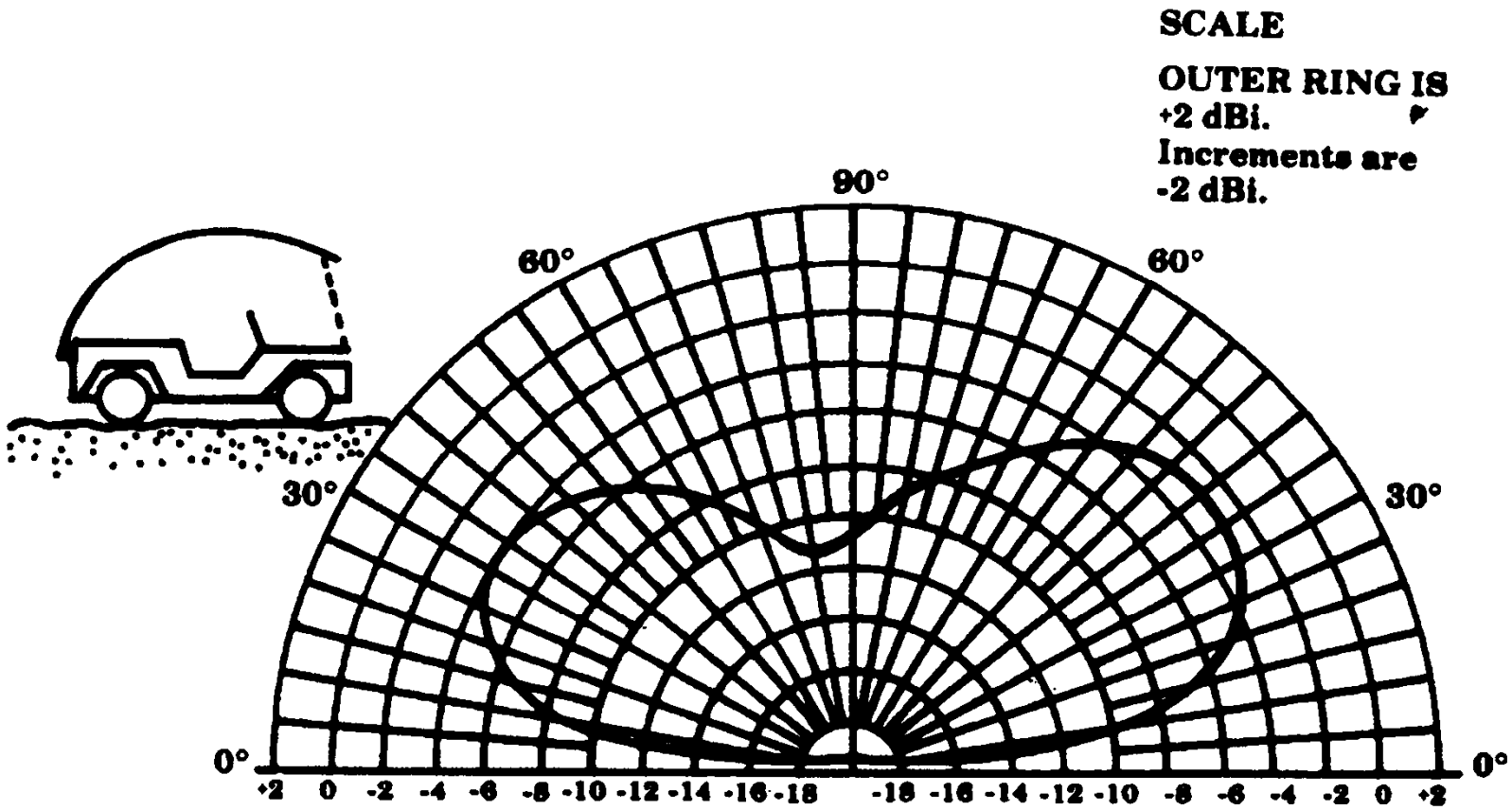


Figure 9. Far-field elevation pattern of vehicular 15 ft. whip tied to front of vehicle at 10 MHz.

NVIS Take Away Page

- There is nothing mystical about NVIS or NVIS antennas!
- Any antenna with significant high angle radiation can be used for reliable communications out to several hundred miles.
- The antenna does NOT need to be elaborate.
- Use a horizontal antenna.
- Mount it as high as practical.
- Azimuthal angle is not critical. There is little difference between a north/south or an east/west orientiented dipole.
- Design for resonance on the 80/60/40 meter bands. The 40 meter band is the shortest wavelength that will support NVIS propagation. Generally use longer wavelengths. 160 meters is an option.
- Depending on circumstances, the feedpoint impedance will not be optimum. Use an antenna tuner.
- Go with what you got. KISS!

References and Acknowledgments

- "**Near Vertical Incidence Skywave (NVIS)**", Charles P. Rogers, KJ5KU, DCHF Presentation, August 7-9, 2015

- "**Ionospheric Radio Propagation**", Kenneth Davies, Dover Publications, Inc., 1966 (This Dover edition is an unabridged and corrected publication republication of the work originally published in 1965 as National Bureau of Standards Monograph 80. It is available as a free PDF download on the internet.)

- **Wikipedia** (Various)

- "**Near Vertical Incidence Skywave Communications, Theory, Techniques and Validation**", Fiedler and Farmer, 1996, World Radio Books. (Out of Print)