NETCOM/9th Army Signal Command

HF Training Course
Lesson 01 – HF Radio Systems

311th Theater Signal Command, Ft. Meade MD
24-25 January 2004

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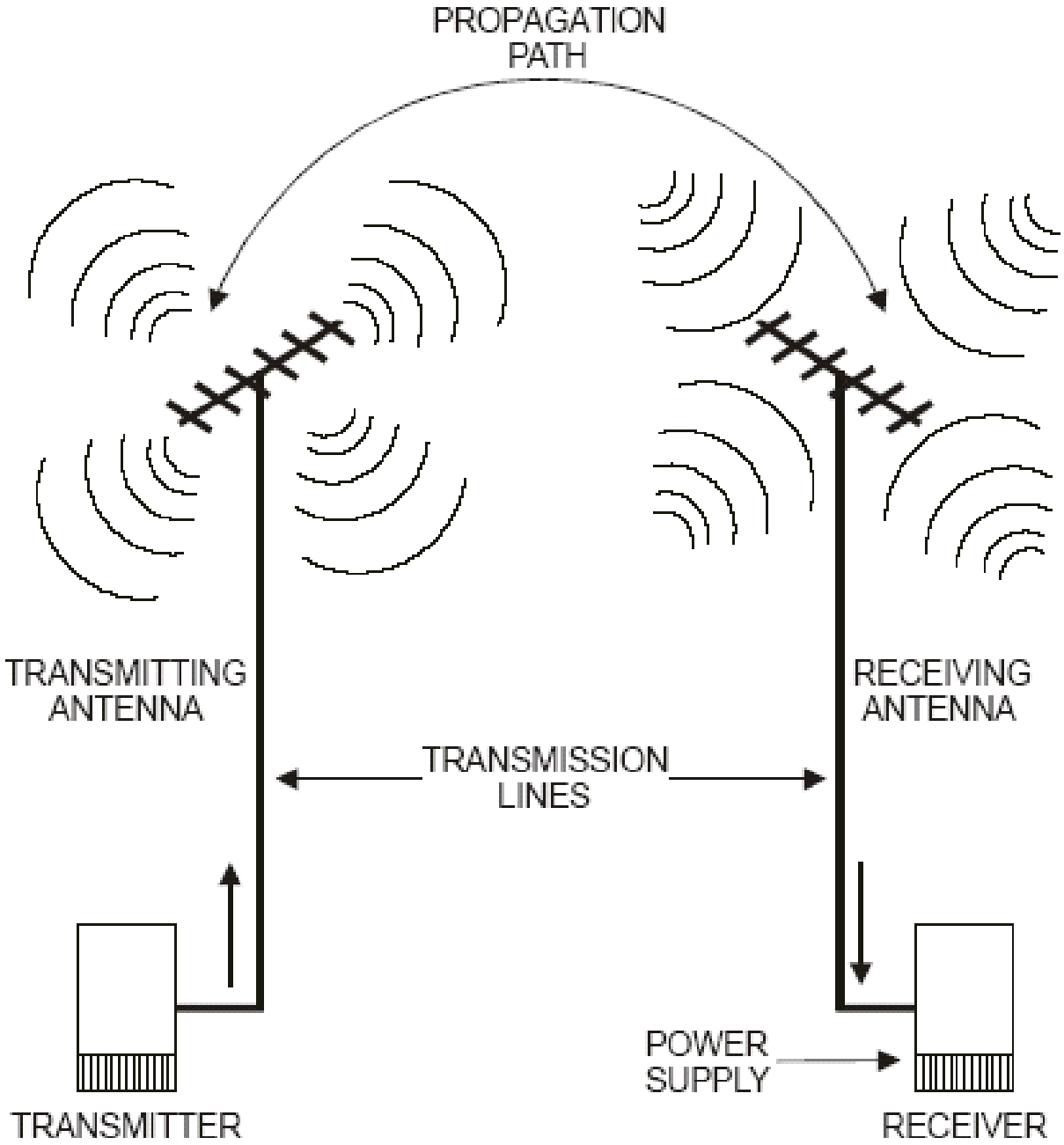
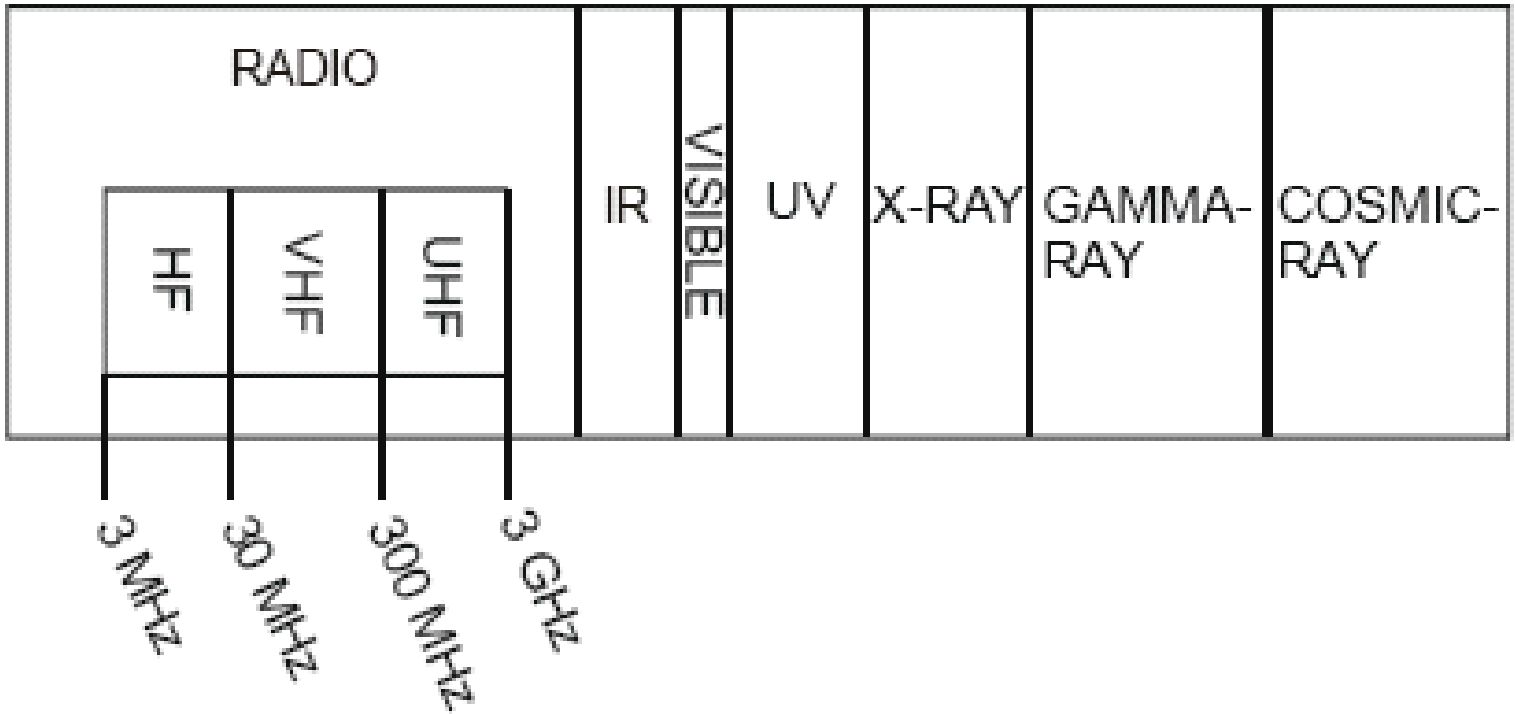
'Proud, Professional, & Ready'

HF Radio Systems



Electromagnetic Spectrum



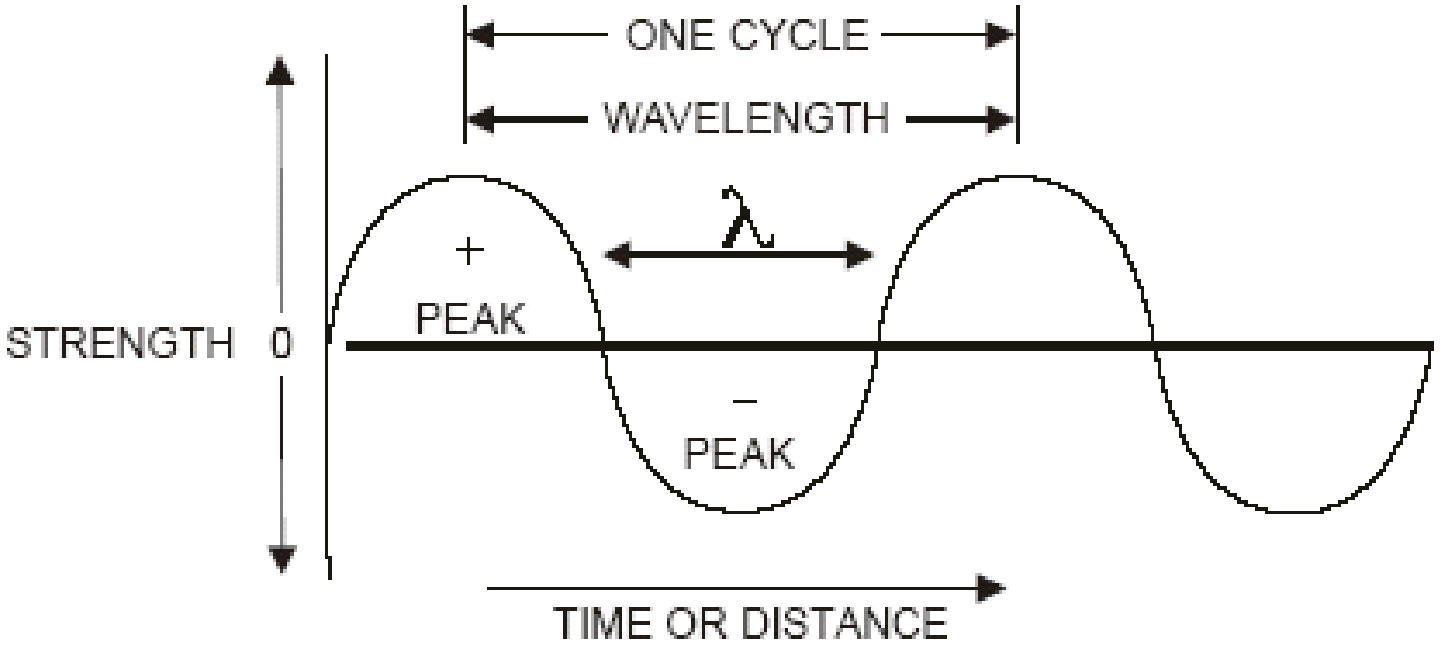
HF: 3 – 30 MHz

Table 1-1. Frequency Range Characteristics.

Band	Ground Wave Range	Sky Wave Range	Power Required
HF	0–50 miles	100–8000 miles	.5–5 kW
VHF	0–30 miles	50–150 miles	.5 or less kW
UHF	0–50 miles	N/A	.5 or less kW

Wavelength

- **Radio waves travel at the speed of light, approximately 300,000,000 meters/second**

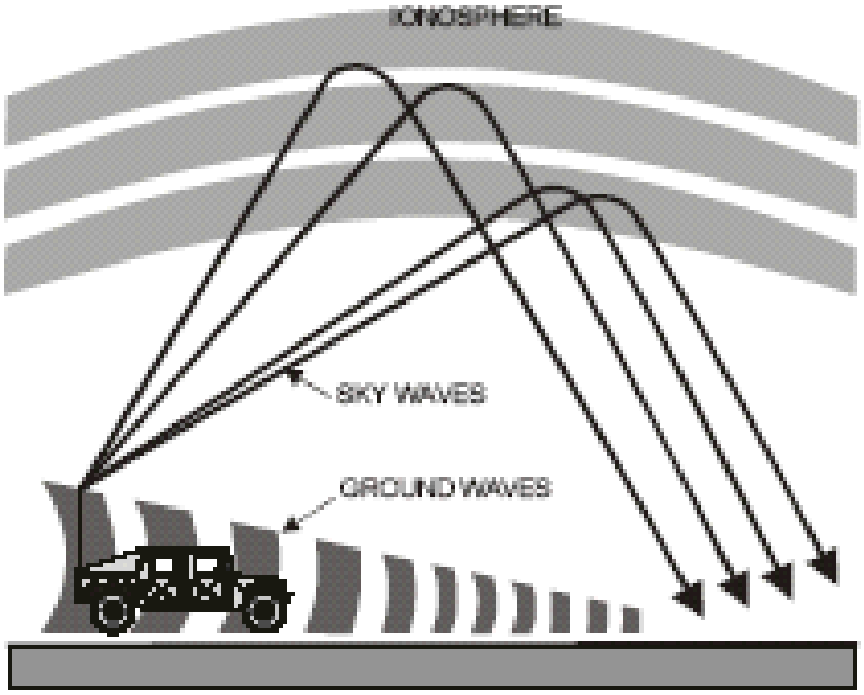


$$\text{Wavelength (meters)} = \frac{\text{300,000,000 (meters/second)}}{\text{Frequency (Hertz or cycles/second)}} = \frac{\text{300}}{\text{Frequency (MHz)}}$$

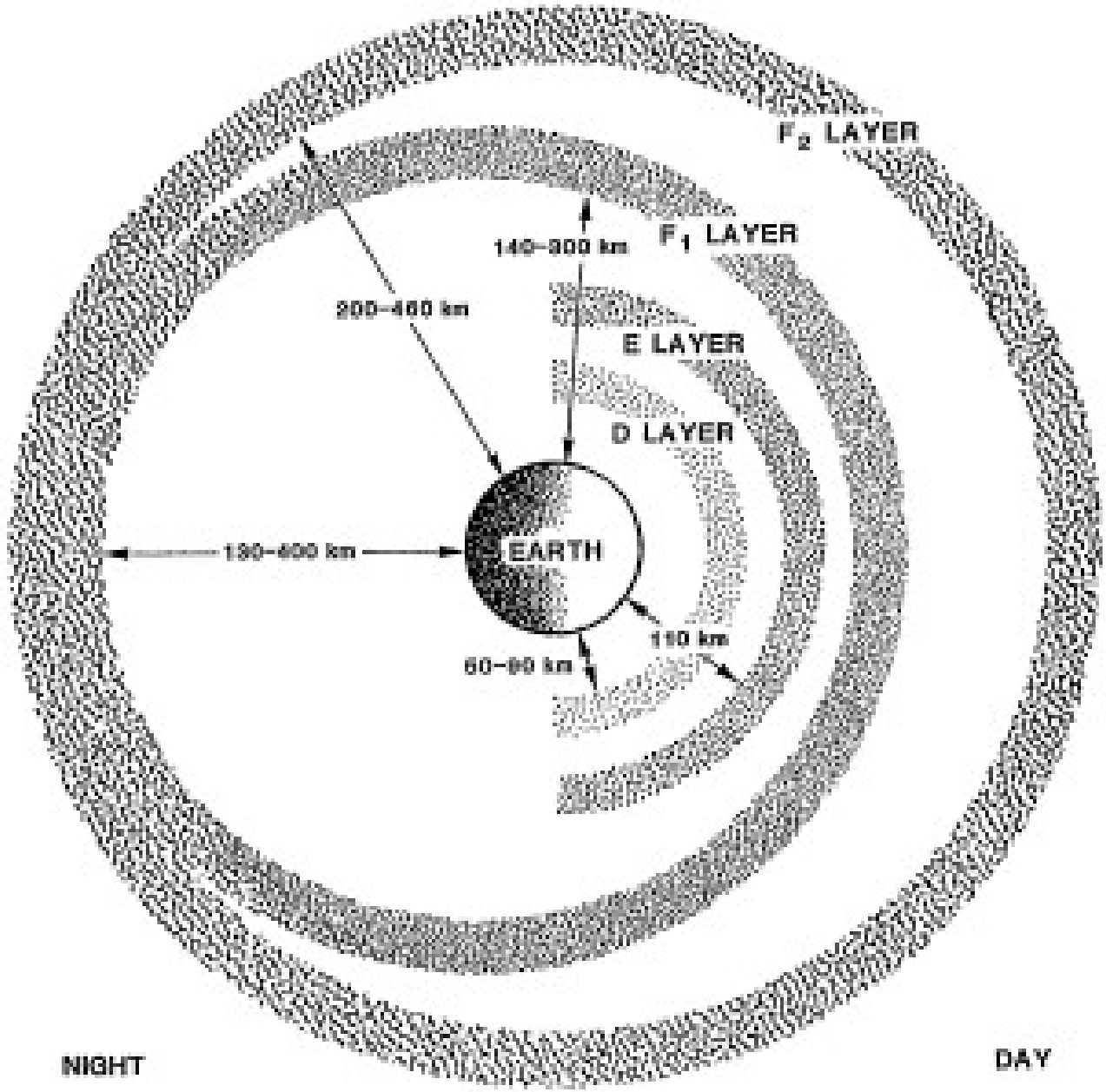
Principle Paths for Radio Wave Propagation

FACTORS AFFECTING PROPAGATION

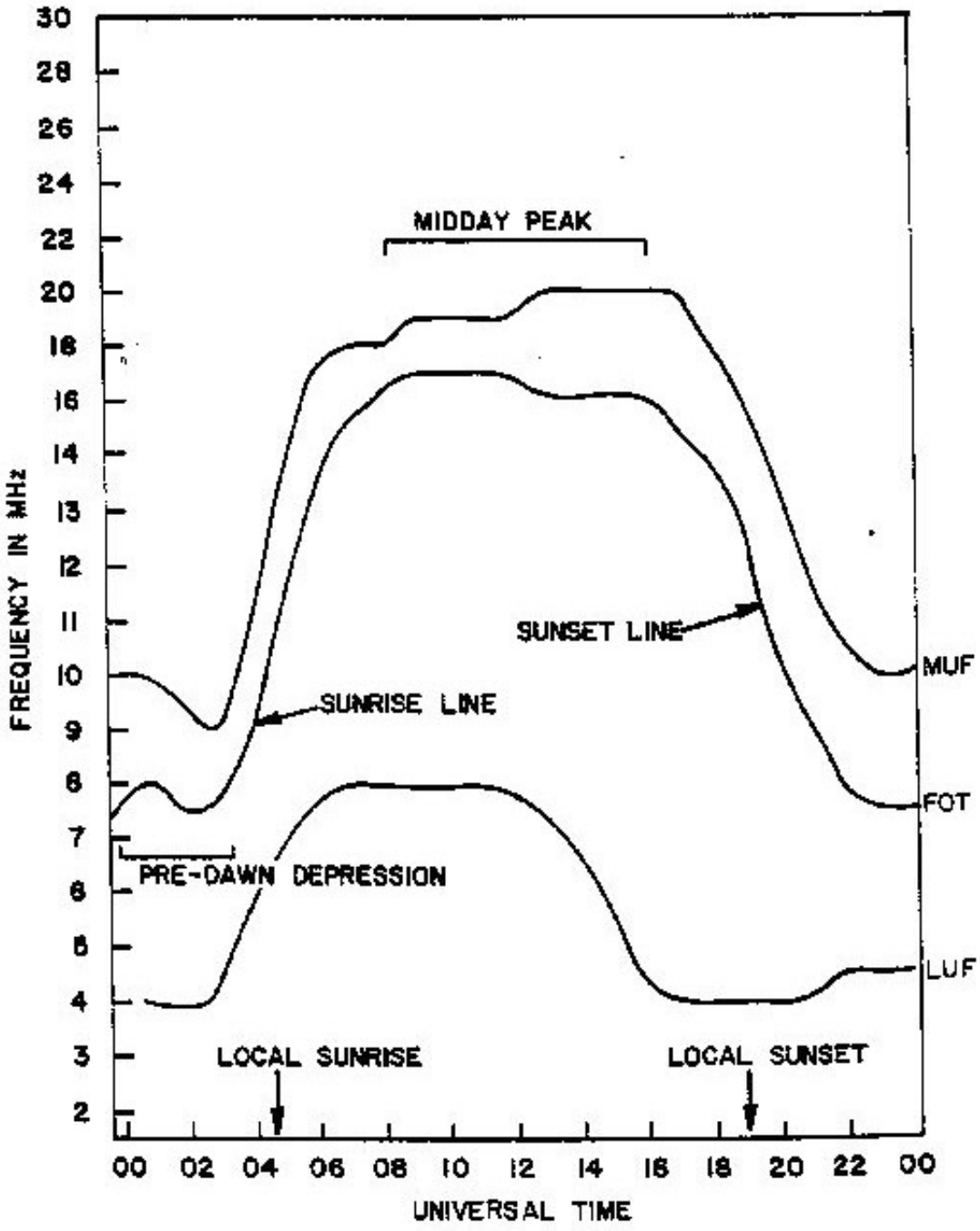
- Frequency
- Time of Day
- Season
- 11-year Sunspot Cycle
- Solar Storms
- Nuclear Effects
- Ground Conductivity



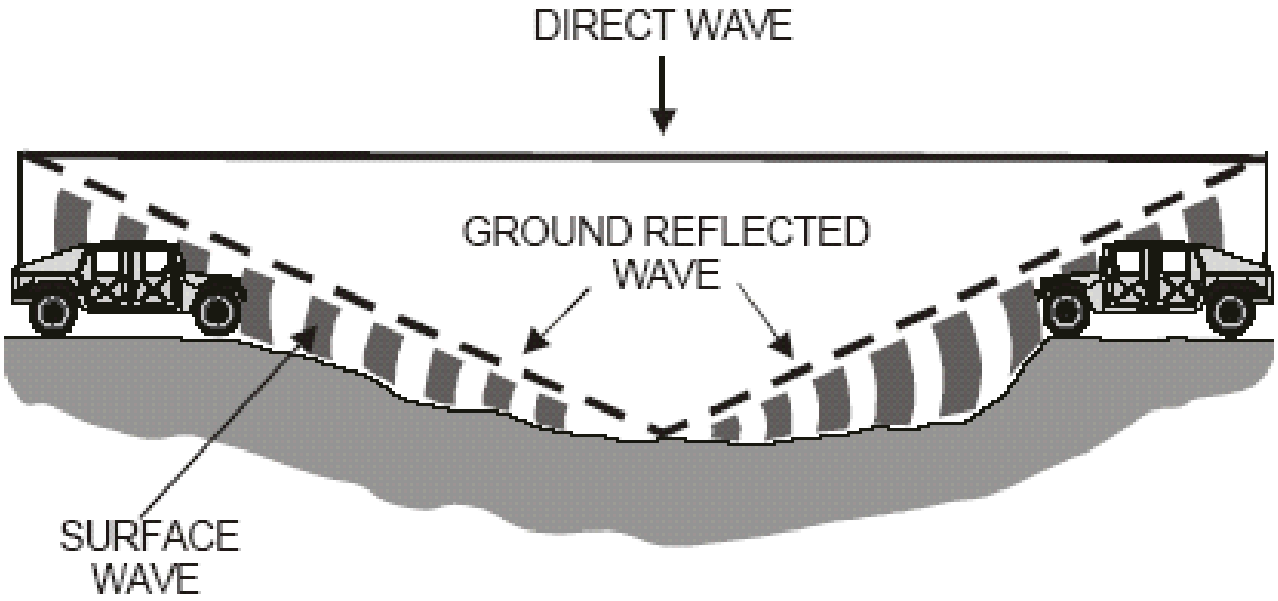
Impact of Time of Day



Daily Propagation (Typical)

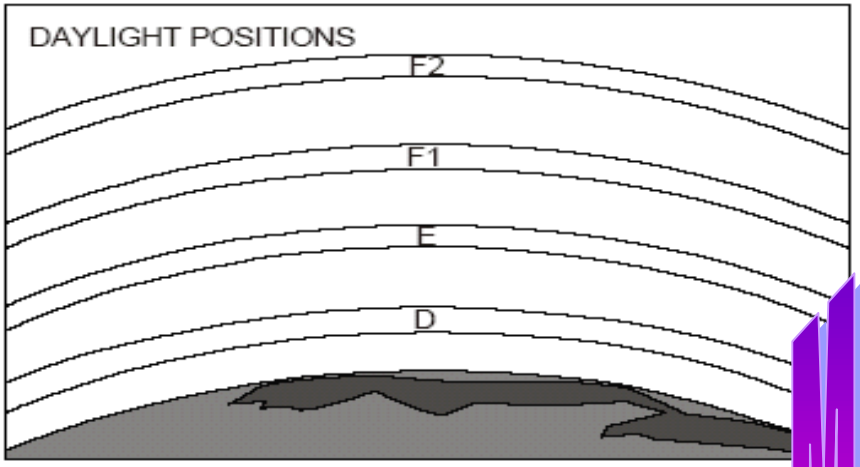


Ground Wave Propagation



Sky Wave Propagation

- **Most useful mode for medium to long-haul communications**
- **Totally dependent on ionospheric conditions**
- Sporadic E. When it is excessively ionized, the E layer often blocks out the reflections back from the higher layers. It can also cause unexpected propagation of signals hundreds of miles beyond the normal range. This effect can occur at any time.



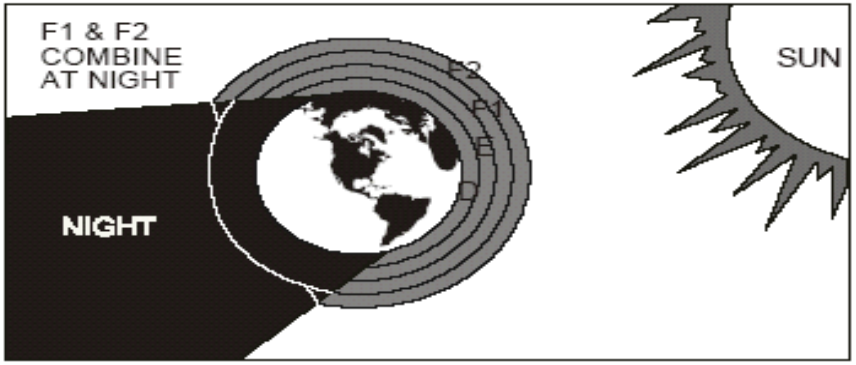
F2 250-500 km (250-420 km at night)
F1 200-250 km
E 90-130 km
D 75-90 km

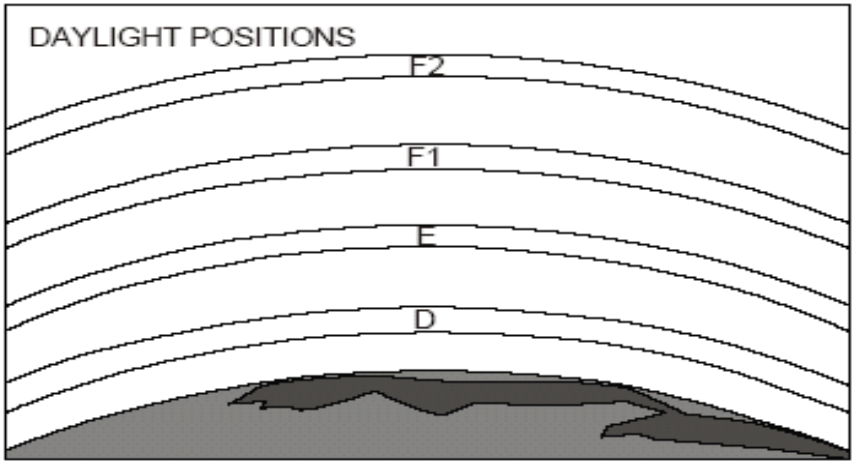
LUF

MUF

Sky Wave Propagation

- Sudden ionospheric disturbance (SID). A sudden ionospheric disturbance coincides with a bright solar eruption and causes abnormal ionization of the D layer. This effect causes total absorption of all frequencies above approximately 1 MHz. It can occur without warning during daylight hours and last from a few minutes to several hours. When SID occurs, receivers seem to go dead.
- Ionospheric storms. During these storms, sky wave reception above approximately 1.5 MHz shows low intensity and is subject to a type of rapid blasting and fading called "flutter fading." These storms may last from several hours to days and usually extend over the entire Earth

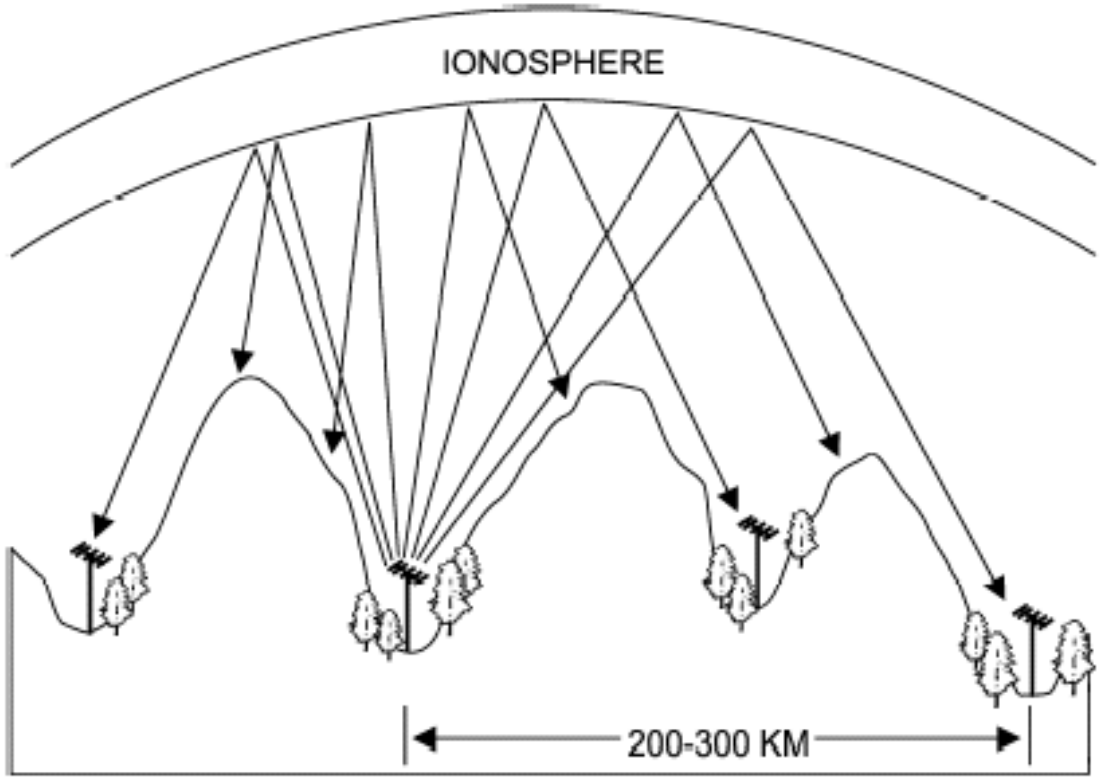




F2 250-500 km (250-420 km at night)
F1 200-250 km
E 90-130 km
D 75-90 km

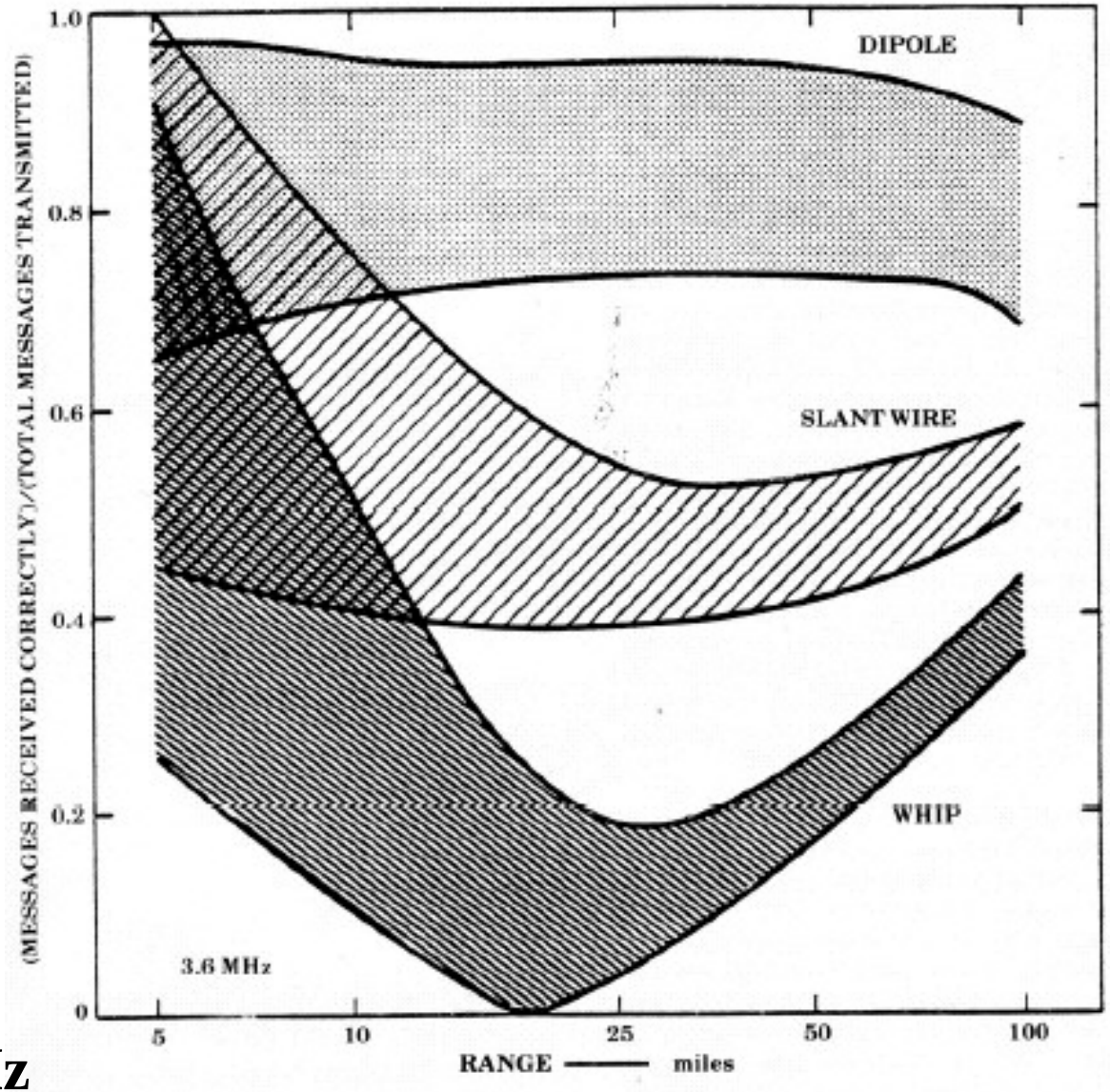
http://www.spaceweather.com

Near Vertical Incidence Skywave
NVIS



- Provides communications in the "Skip Zone", 30-300 km.
- 2-8 MHz, dependent on time-of-day (lower at night)
- Requires HIGH launch angle from antenna (Near Vertical!)

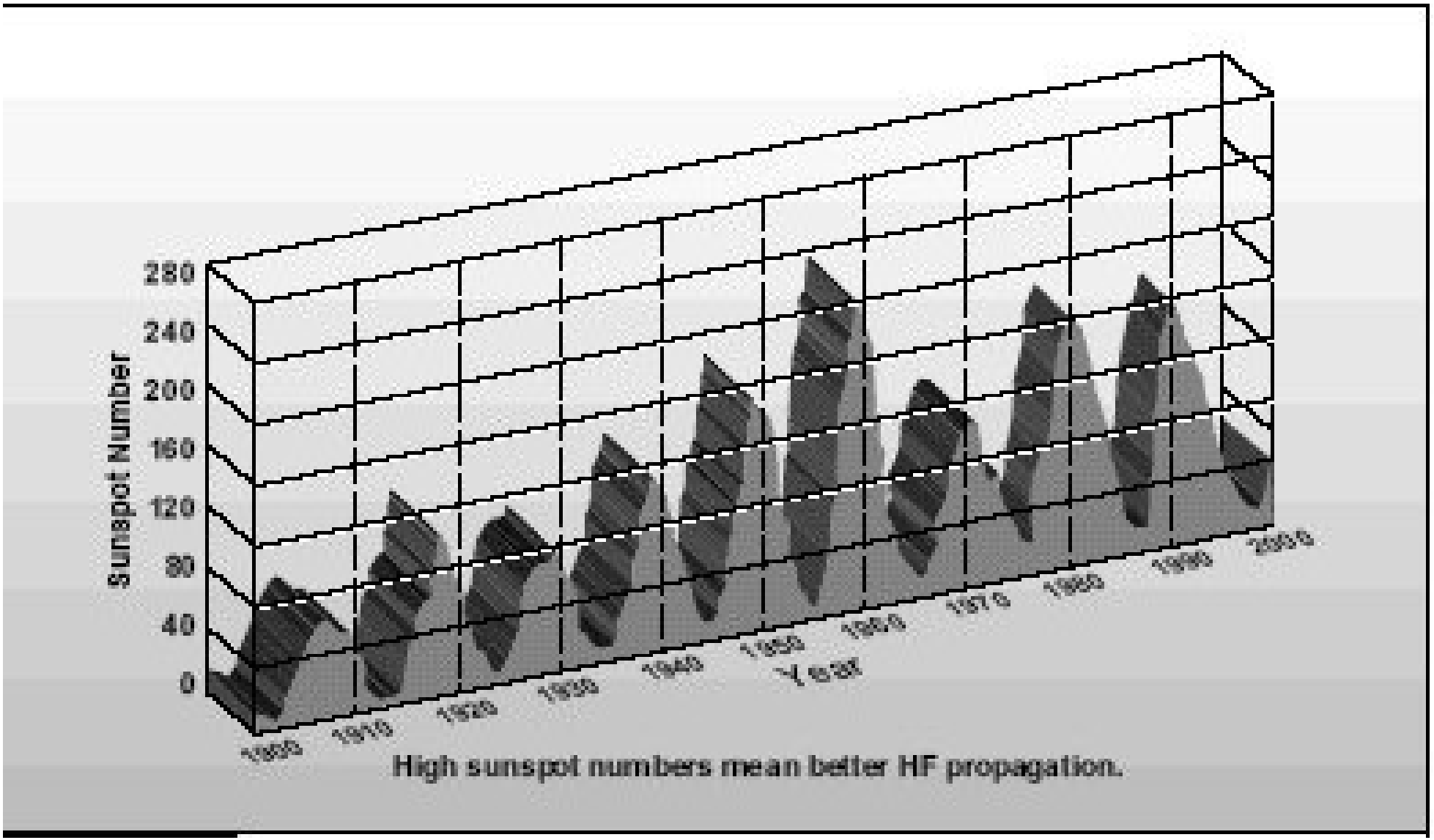
NVIS Skip-Zone Reliability



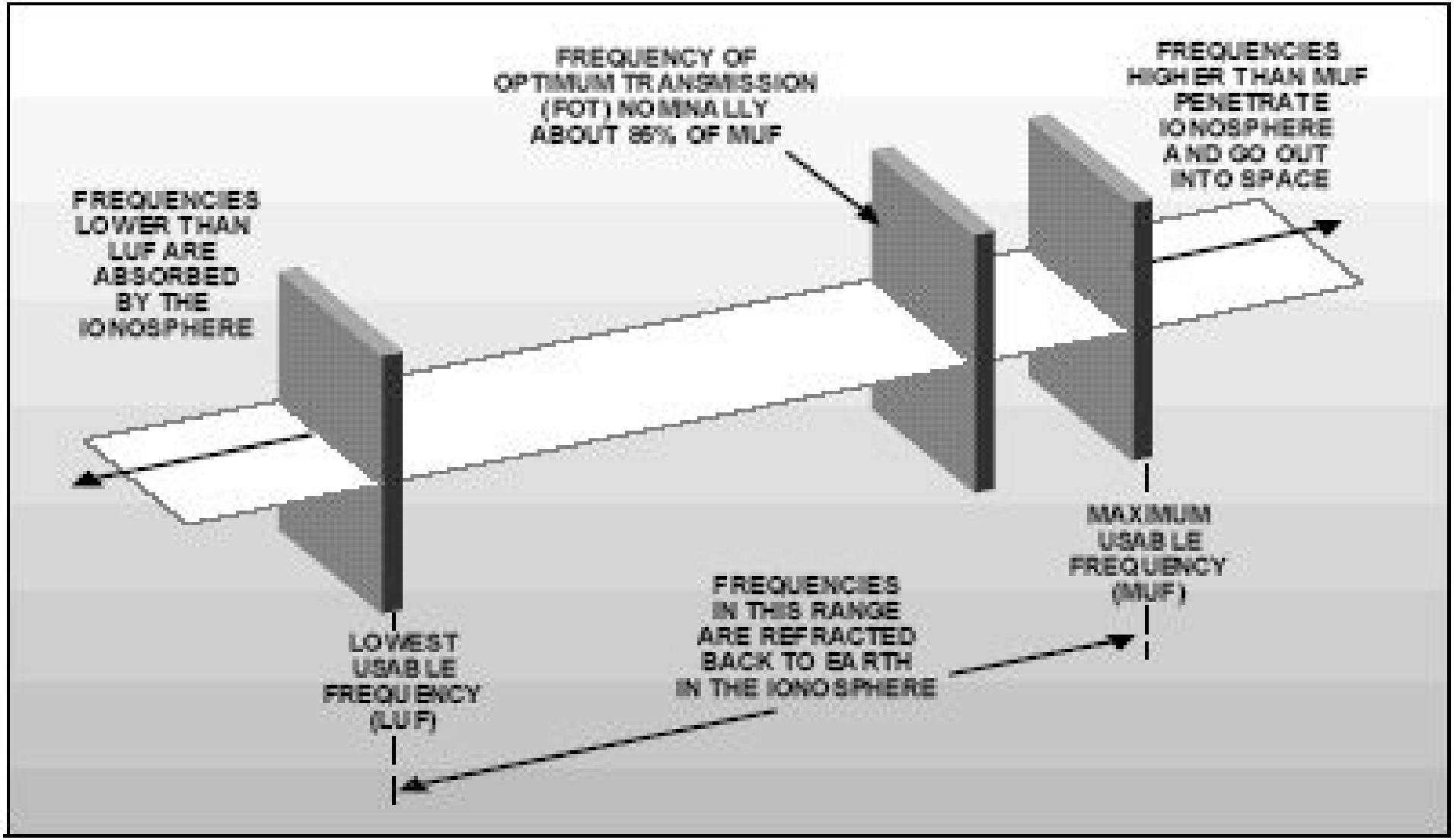
3.6 MHz

Figure 9. Communication success as a func of range for AN/PRC-74 in mountainous and varied terrain - incl jungle - in Thailand

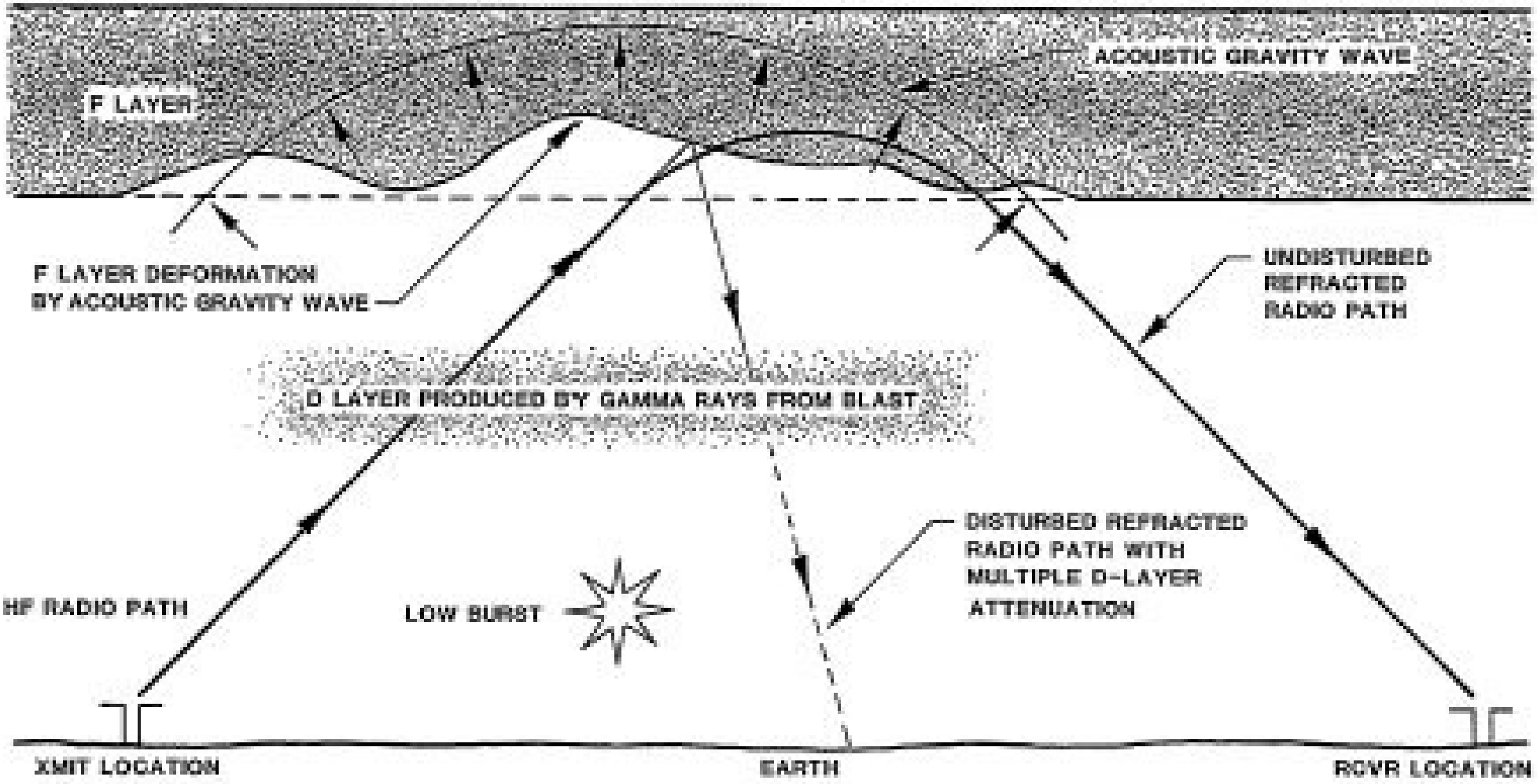
Propagation Cycles



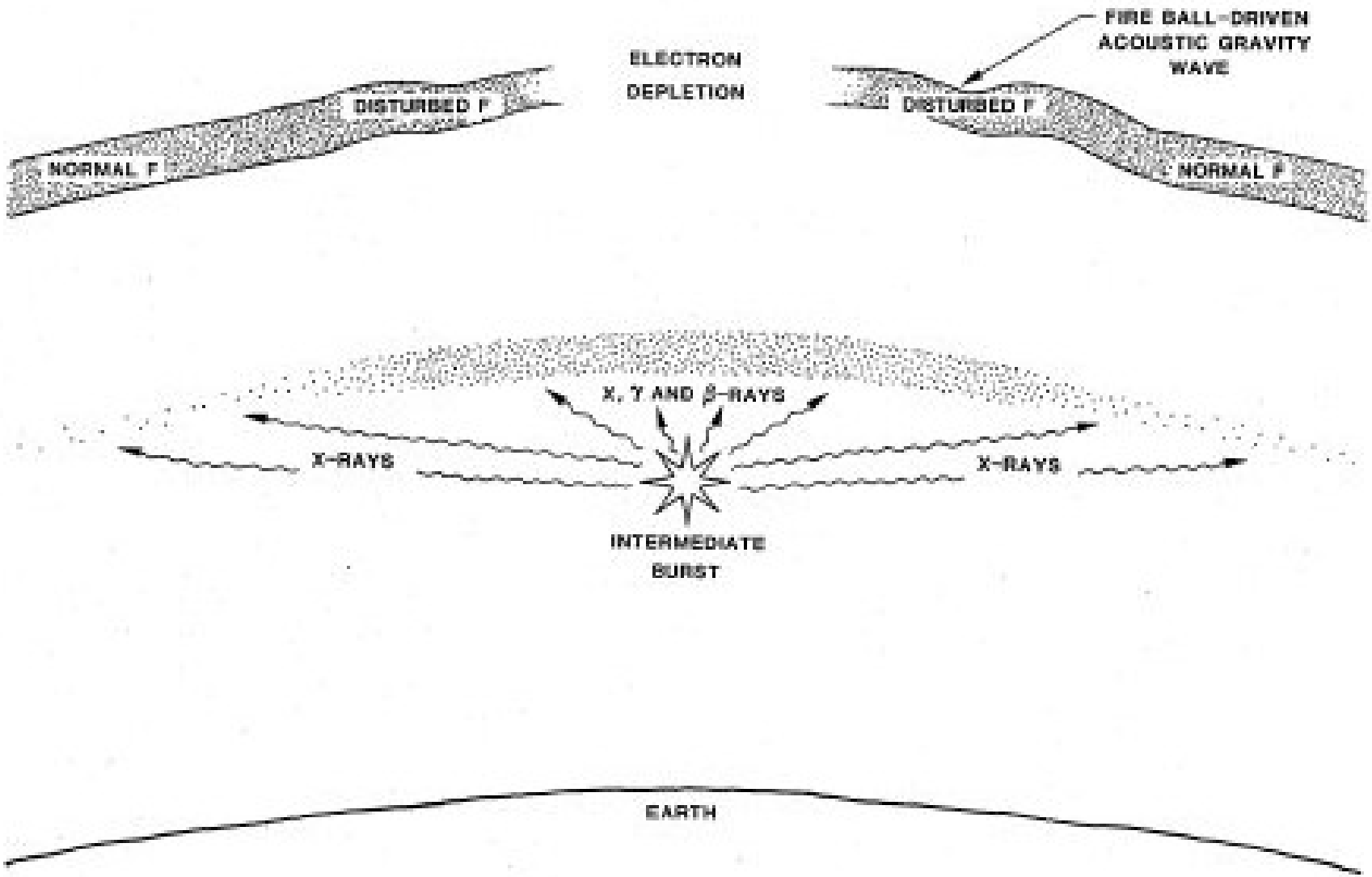
MUF - LUF


FREQUENCY OF OPTIMUM TRANSMISSION (FOT) NOMINALLY ABOUT 85% OF MUF
FREQUENCIES HIGHER THAN MUF PENETRATE IONOSPHERE AND GO OUT INTO SPACE
FREQUENCIES LOWER THAN LUF ARE ABSORBED BY THE IONOSPHERE
MAXIMUM USABLE FREQUENCY (MUF)
FREQUENCIES IN THIS RANGE ARE REFRACTED BACK TO EARTH IN THE IONOSPHERE
LOWEST USABLE FREQUENCY (LUF)

Nuclear Effects on Propagation
Low Altitude

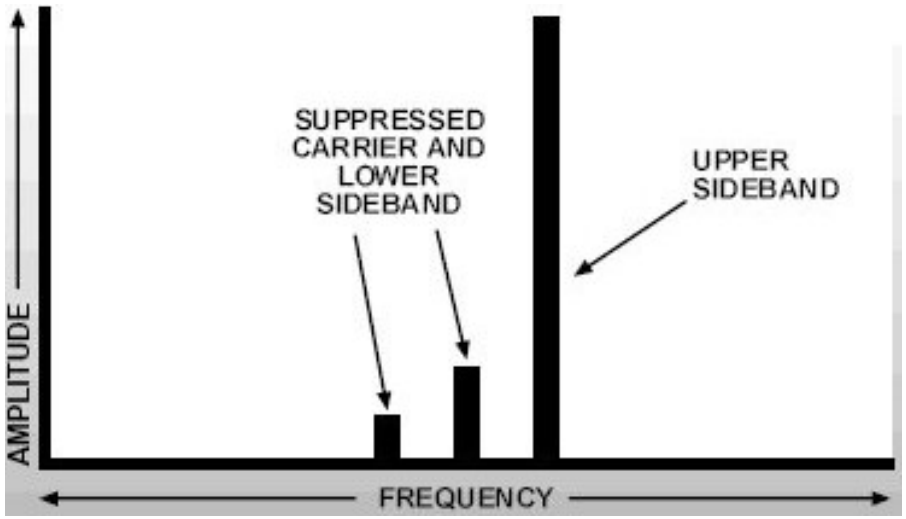


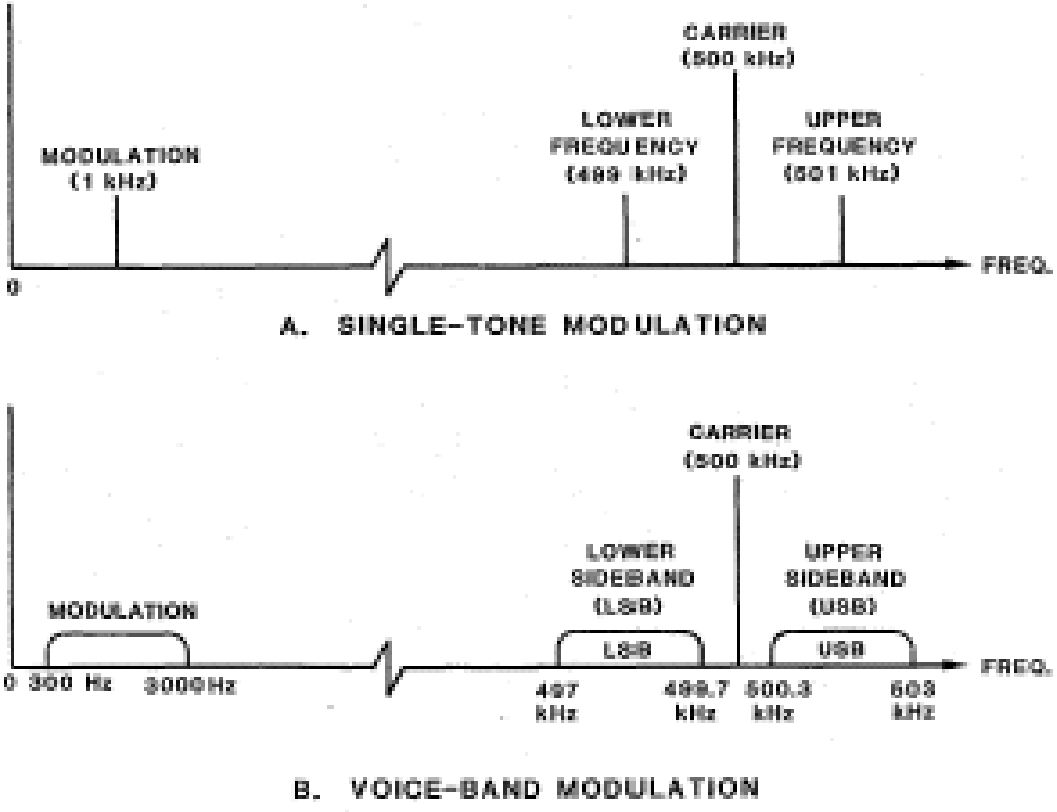
Nuclear Effects on Propagation Medium Altitude



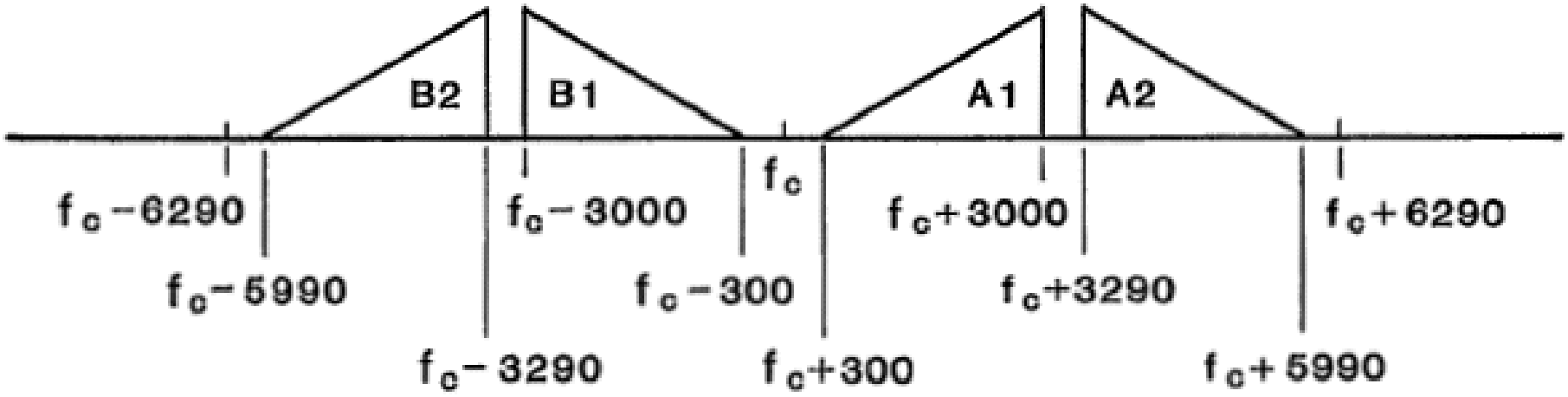
Amplitude Modulation Types

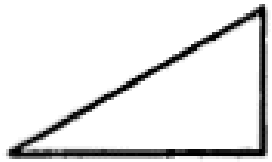
- **Amplitude Modulation**
  - **Full carrier (AM)**
  - **Reduced Carrier (DSB)**
  - **Single Sideband (SSB)**
  - **Independent Sideband (ISB)**





Amplitude Modulation
ISB





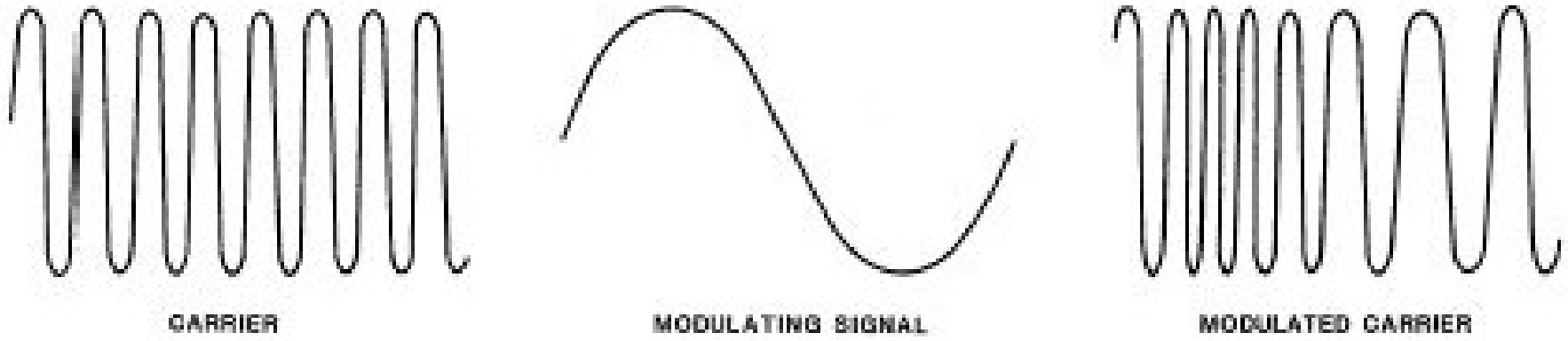
NORMAL SIDEBAND

INVERTED SIDEBAND

f_c CARRIER FREQUENCY

Frequently used for multi-channel, Full-duplex commo (fixed site)

Frequency Modulation



Advantages:

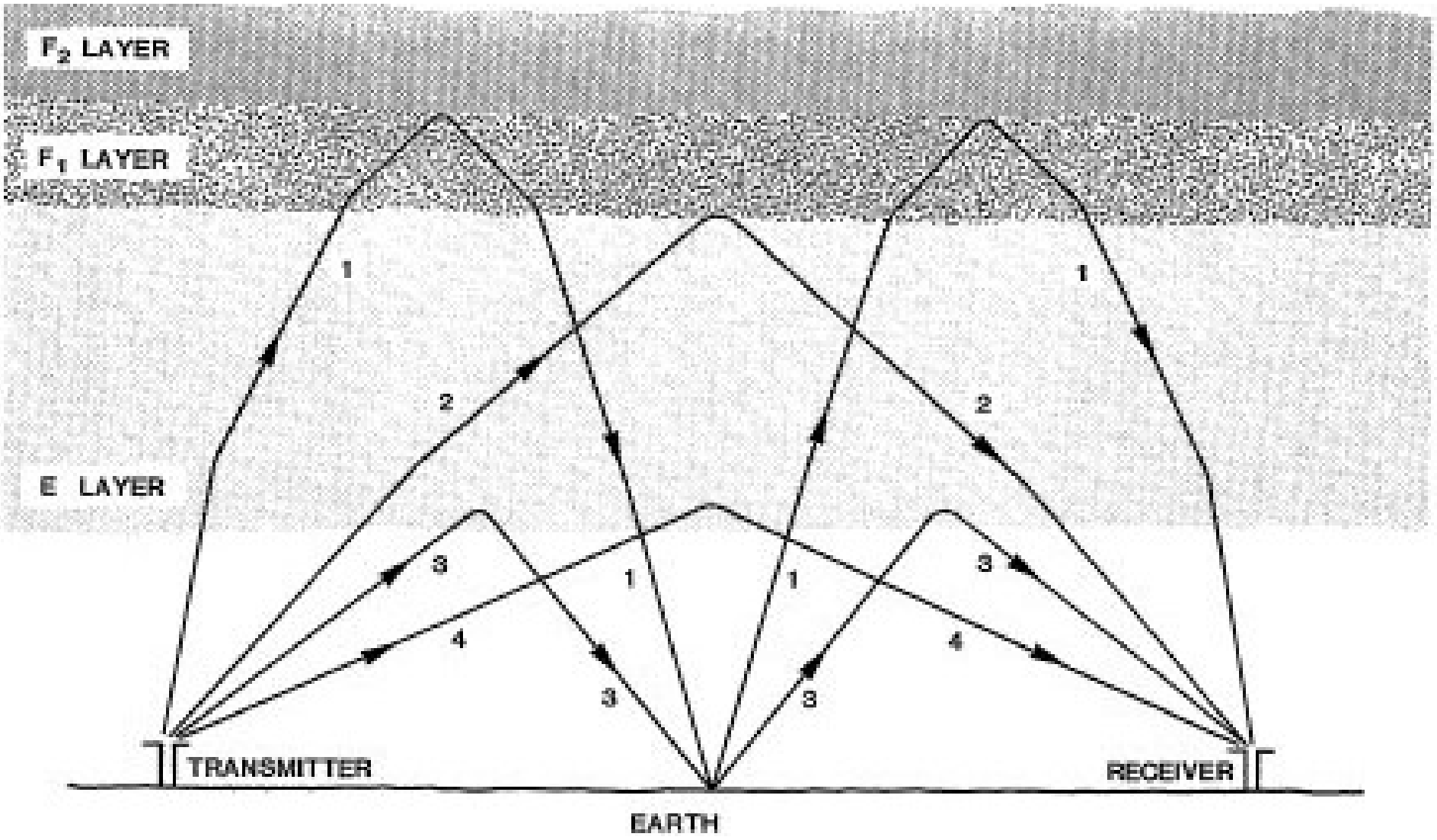
- **Low noise, high fidelity**

Disadvantages:

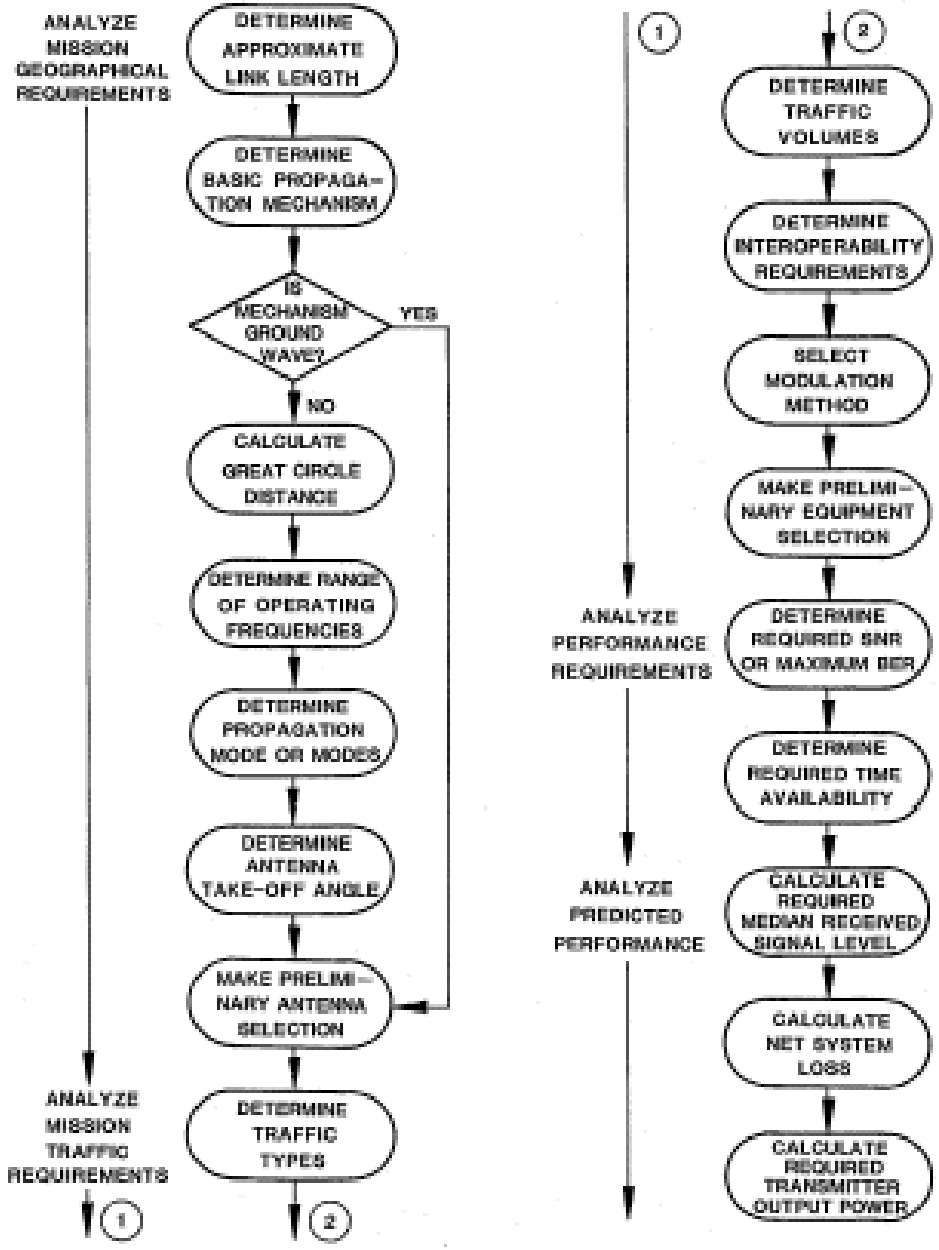
- **Takes more bandwidth**
- **Less efficient (more power for same distance, S/N ratio)**
- **High duty cycle**

Rarely used in HF communications

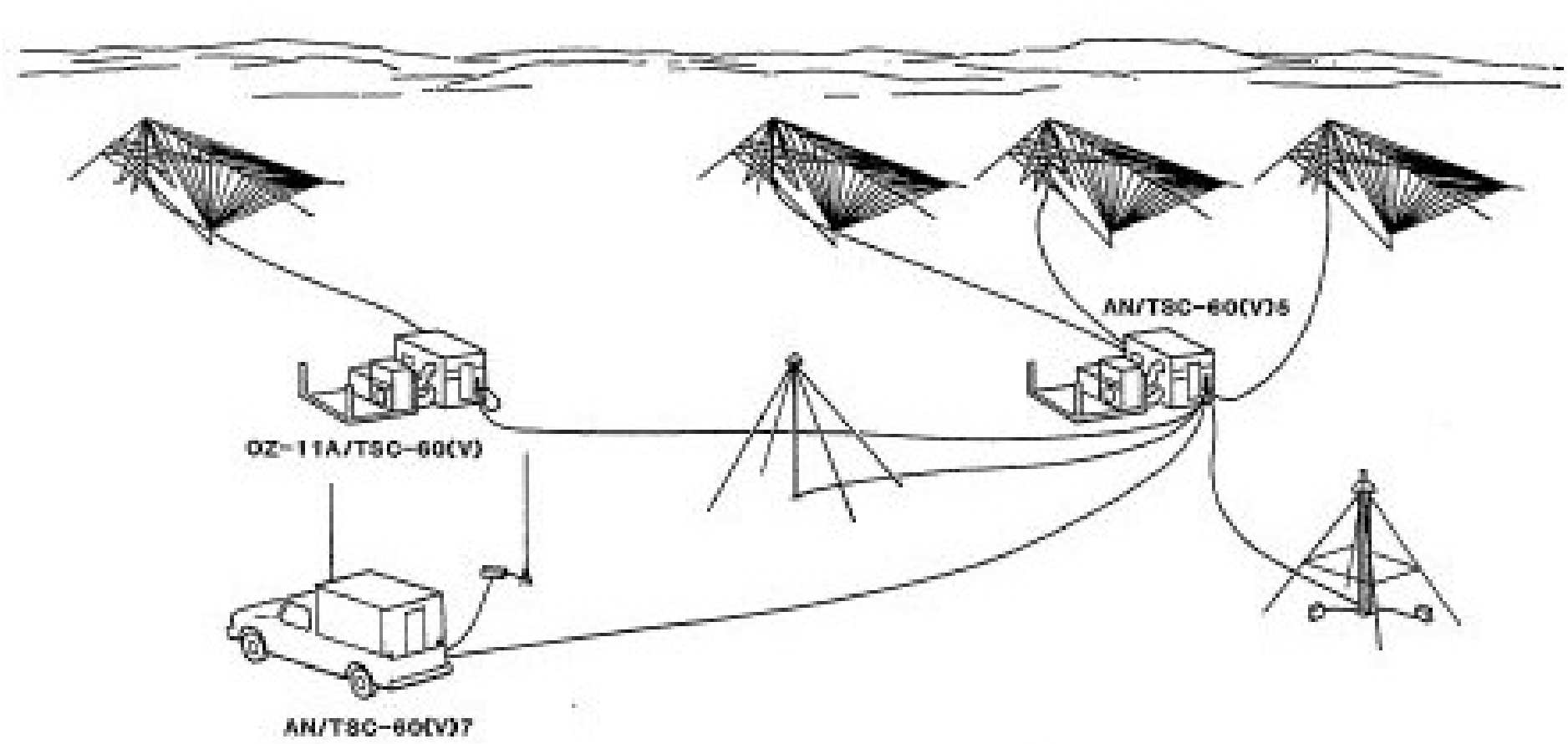
Multi-Path Distortion



HF System Planning



Siting Considerations

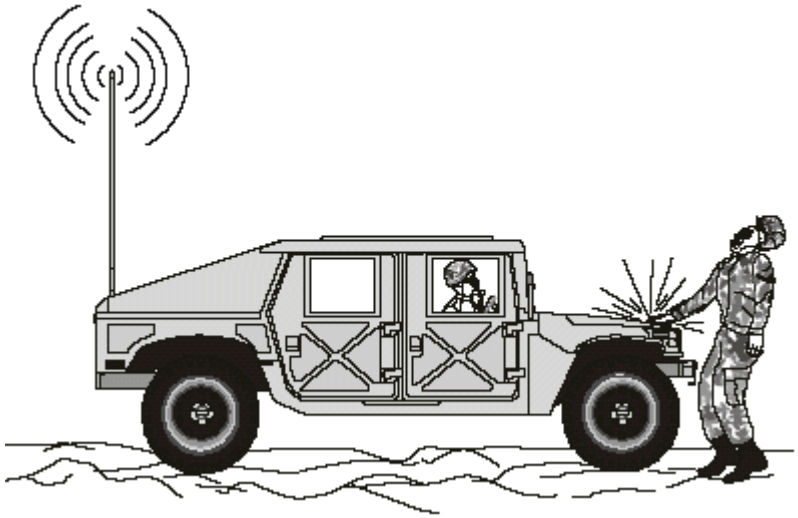


Noise Sources

- Place HF antennas as distant from CPs as possible to reduce mutual interference
- Ensure that generators are grounded
- Beware new plasma monitors – they are generally prolific HF noise sources
- Ensure that all computer equipment cases are closed and grounded to reduce noise level
- Do not allow high-powered tropo and satcomm system transmissions across your antenna field

Grounding Considerations

- **Utilize ground rod(s) and/or MK-2551 Surface Wire Grounding Kits , EVEN ON PORTABLE UNITS**
- **Bond radio transceiver(s), antennas and ancillary equipment (remember power systems!)**
- **Use baluns or coaxial chokes to reduce "RF in the shack"**
- **RF burns are preventable!**
- **Recommend at least 30 radials on vertical antennas (50 ft on a 32 ft vertical)**
- **Consider installation of lightning/EMP protection**



Grounding Techniques

Table 1 Soil Quality and Grounding

Type of Soil	Quality of Ground	Suggested Earth Grounding Electrode
Wet, organic soil	Very good	Ground rod, SWGK
Clay, loam, or shale	Good	Ground rod, SWGK or plate
Clay, loam, or shale mixed with gravel or sand	Poor	Buried pipes, building frame, or other metal object or a ground plate or several ground rods electrically connected together
Gravel, sand, or stone	Very Poor	Same as above *

RF Exposure Guidelines

- **FCC Maximum permissible exposure (MPE) 3 – 30 MHz**
  - **Controlled/Occupational Exposure ($900/f^2$) mW/cm^2**
  - **General Population Exposure ($180/f^2$) mW/cm^2**
- **Guidelines based upon whole-body absorption rates causing heating**

NETCOM/9th Army Signal Command

HF Exposure Guideline
100/400 watt Systems

AN/GRC-193A HF Radio Set *(used in AN/TRC-189)*

SYSTEM DESCRIPTION

The AN/GRC-193 is a HF Single Side Band (SSB) vehicular radio that utilizes a 4.88 m whip (for mobile operation) or AN/GRA-50 doublet antenna (for fixed operation).

SYSTEM PARAMETERS

Frequency: 2 – 30 MHz Power: 100 W ; 400 W

SYSTEM HAZARDS	*HAZARD CONTROLS (to reduce or eliminate risk)*
Power Density Levels (PDL)	This system is able to produce potentially hazardous PDLs in excess of the safety standard. Establish a Nonionizing Radiation Protection Program (IAW guidelines provided in this TB) .
Hazard distance from antenna	Exclude personnel to distances of 1.1 m (100 W) and 2.5 m (400 W) from the antenna.
RF shock/burn	Observe standard RF shock precautions. Do not touch the antenna when energized.
Other.....	Consult the equipment Technical Manual for other operator and/or maintenance hazards. Do not operate the system in a free space radiating mode inside of buildings.

REFERENCES: TM 11-5820-924-10-HR

TB43-0133

FCC Guidelines (Dipole)

TABLE 7. Horizontal half-wave dipole wire antenna (estimated gain 2 dBi) assuming surface (ground) reflection

Distance (meters) from any part of the antenna for compliance with either occupational/controlled or general population/uncontrolled exposure limits										
	3.5 MHz		7 MHz		14 MHz		21 MHz		28 MHz	
Transmitter power (watts)	con.	unc.	con.	unc.	con.	unc,	con.	unc.	con.	unc,
100	0.2	0.5	0.4	0.9	0.9	1.9	1.3	2.8	1.7	3.7
500	0.5	1.0	0.9	2.1	1.9	4.2	2.8	6.3	3.8	8.4
1000	0.7	1.5	1.3	2.9	2.6	5.9	4	8.9	5.3	11.8
1500	0.8	1.8	1.6	3.6	3.3	7.2	4.9	10.9	6.5	14.5

FCC Guidelines
Quarter-Wave Vertical Antenna

TABLE 6. Omnidirectional HF quarter-wave vertical or ground plane antenna (estimated gain 1 dBi) assumes surface (ground) reflection

Distance (meters) from any part of the antenna for compliance with either occupational/controlled or general population/uncontrolled exposure limits										
	3.5 MHz		7 MHz		14 MHz		21 MHz		28 MHz	
Transmitter power (watts)	con.	unc.	con.	unc.	con.	unc.	con.	unc.	con.	unc.
100	0.2	0.4	0.4	0.8	0.8	1.7	1.1	2.5	1.5	3.3
500	0.4	0.9	0.8	1.9	1.7	3.7	2.5	5.6	3.3	7.5
1000	0.6	1.3	1.2	2.7	2.4	5.3	3.5	7.9	4.7	10.6
1500	0.7	1.6	1.4	3.2	2.9	6.5	4.3	9.7	5.8	12.9