General License Course

Chapter 8
Propagation

Jim Andera
K0NK
2/2025

Review

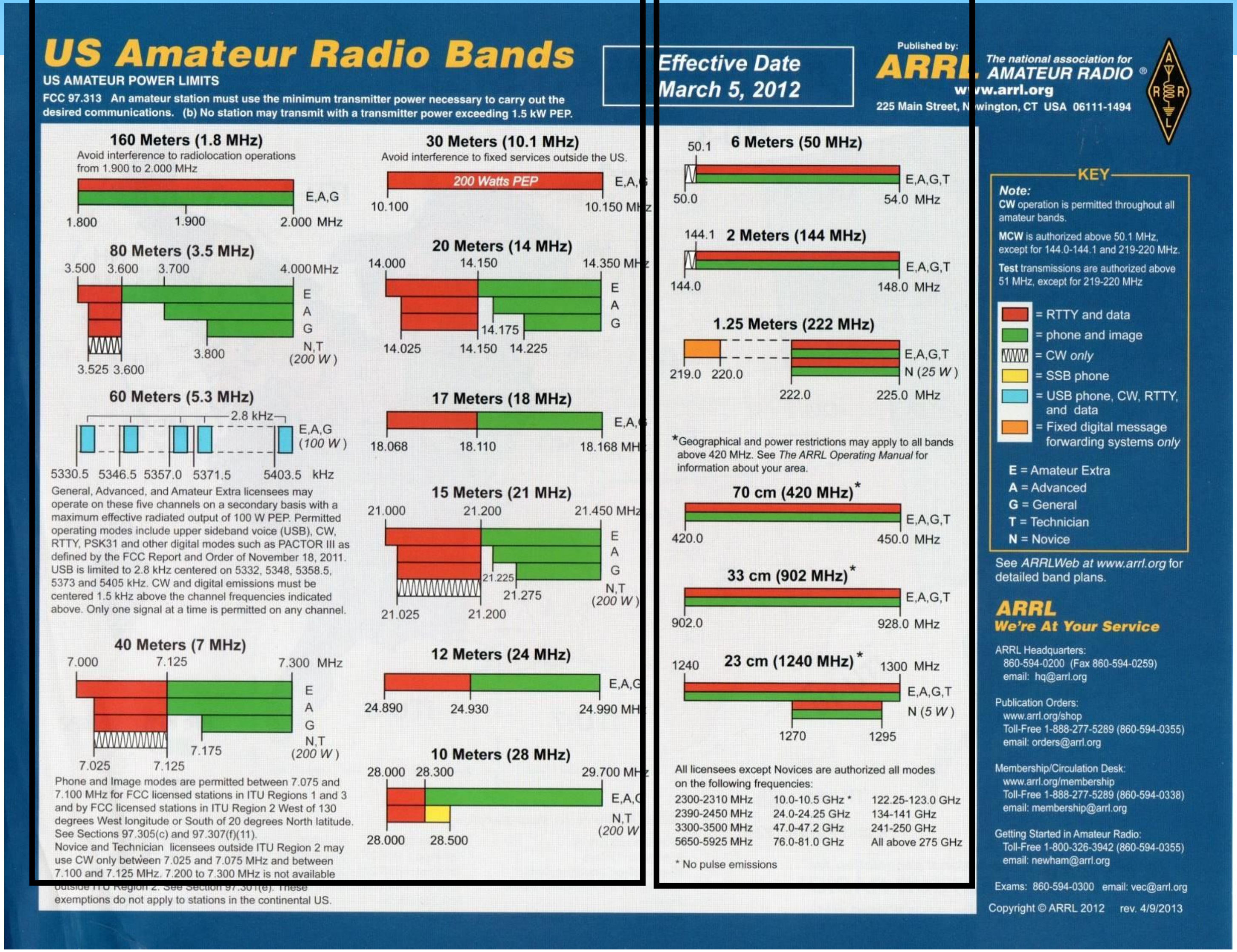
Ionospheric Skip

Line of-Sight

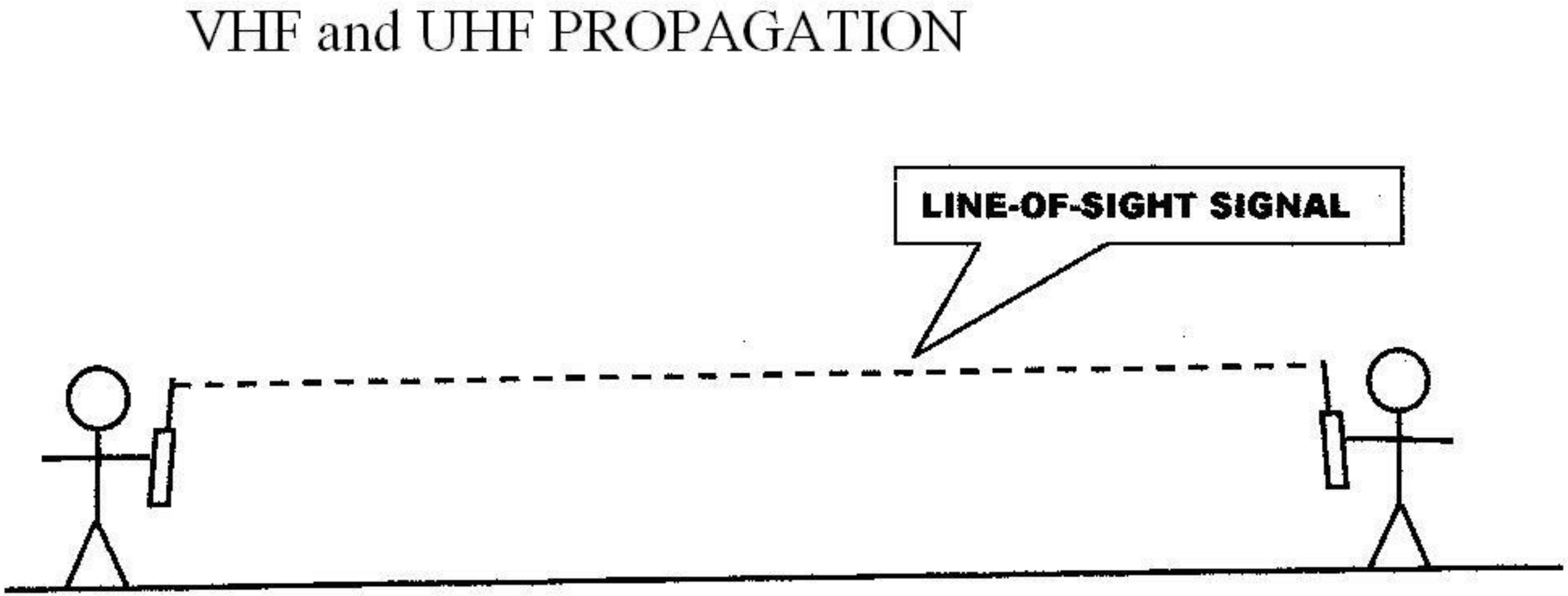
HF (High Frequency)

VHF / UHF

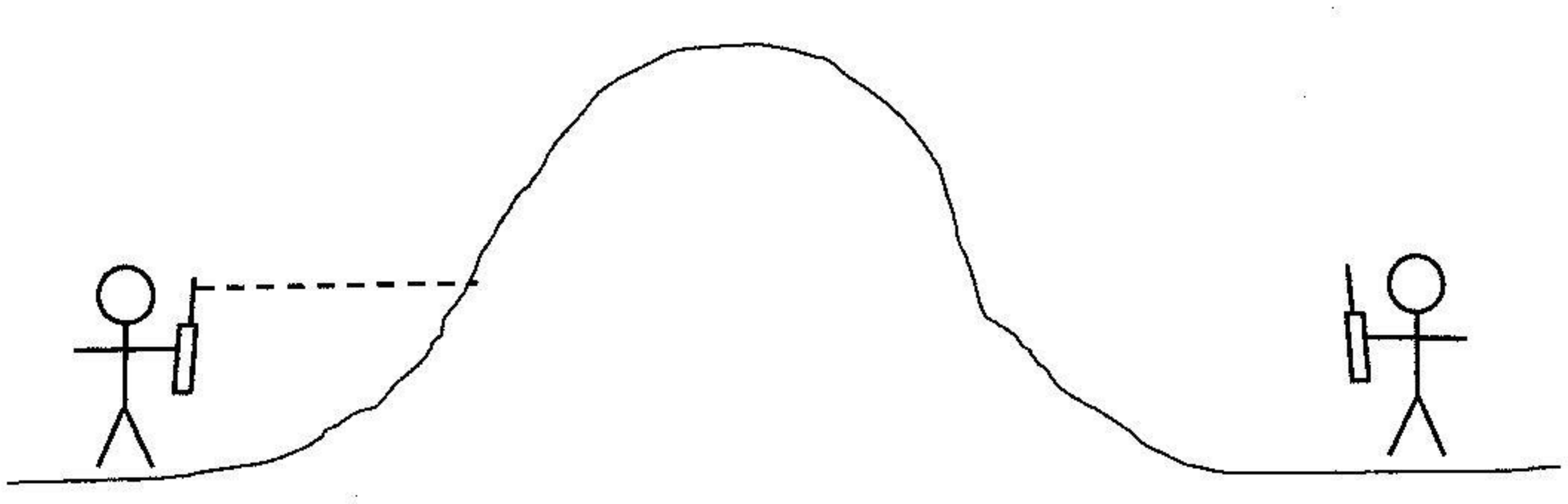
Gen Pg 3-9



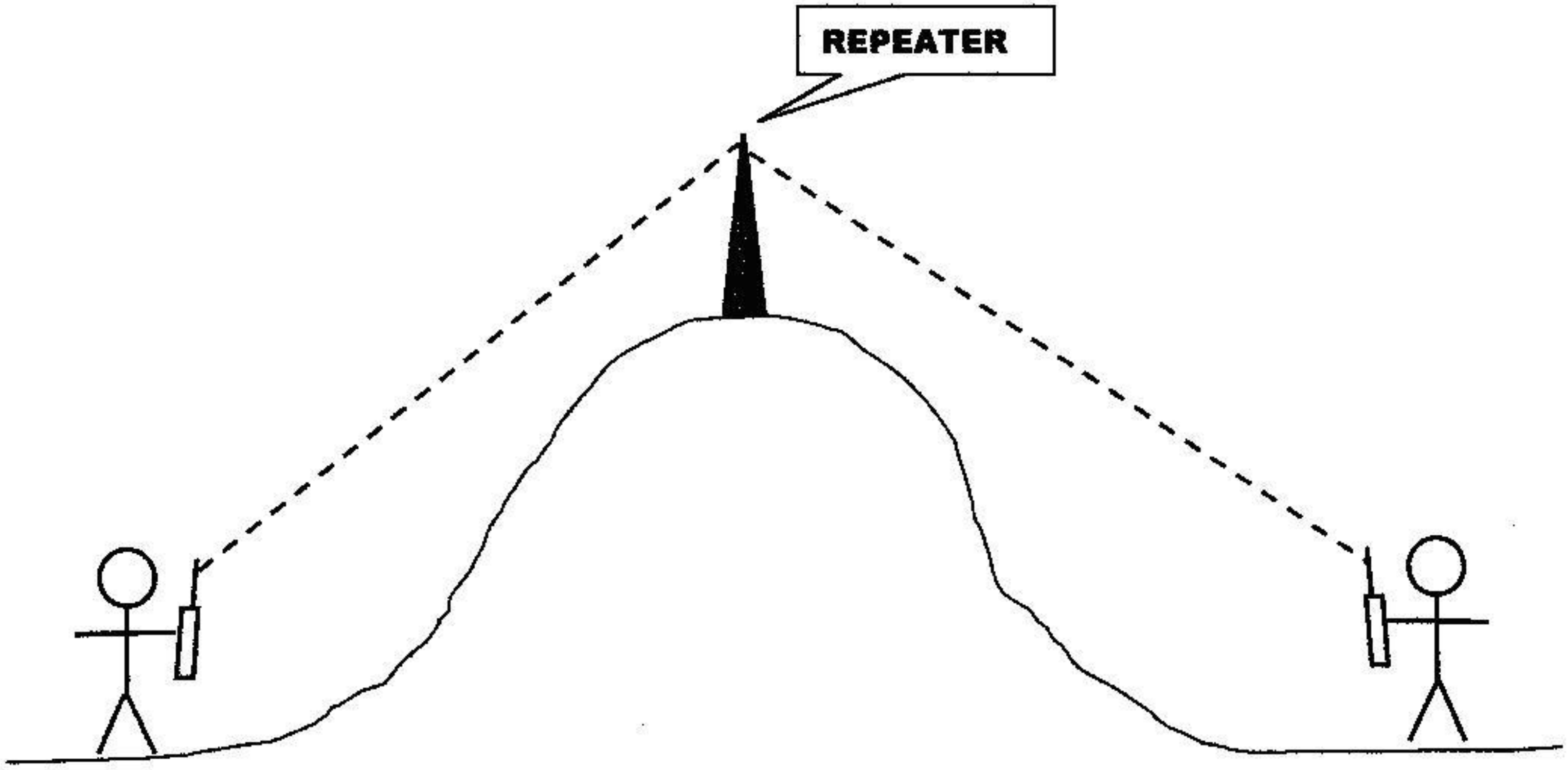
Review: Line of Sight Propagation



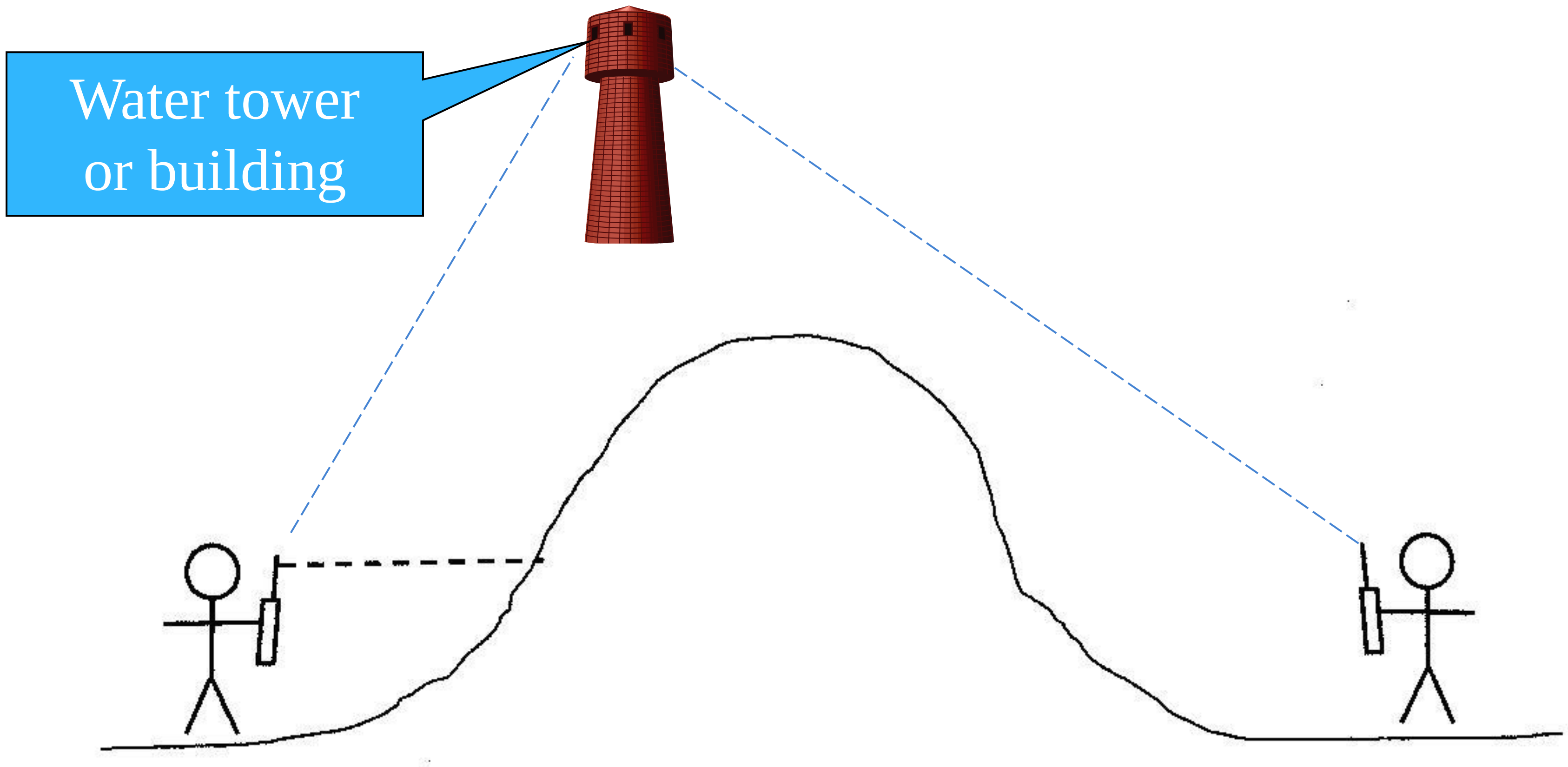
Review: Line-of-Site is Blocked



Review: Repeaters



Review: VHF – UHF Reflection



Review: Temperature Inversion

* Causes Troposphere Ducting
* VHF 2 meter (144 – 148 MHz)

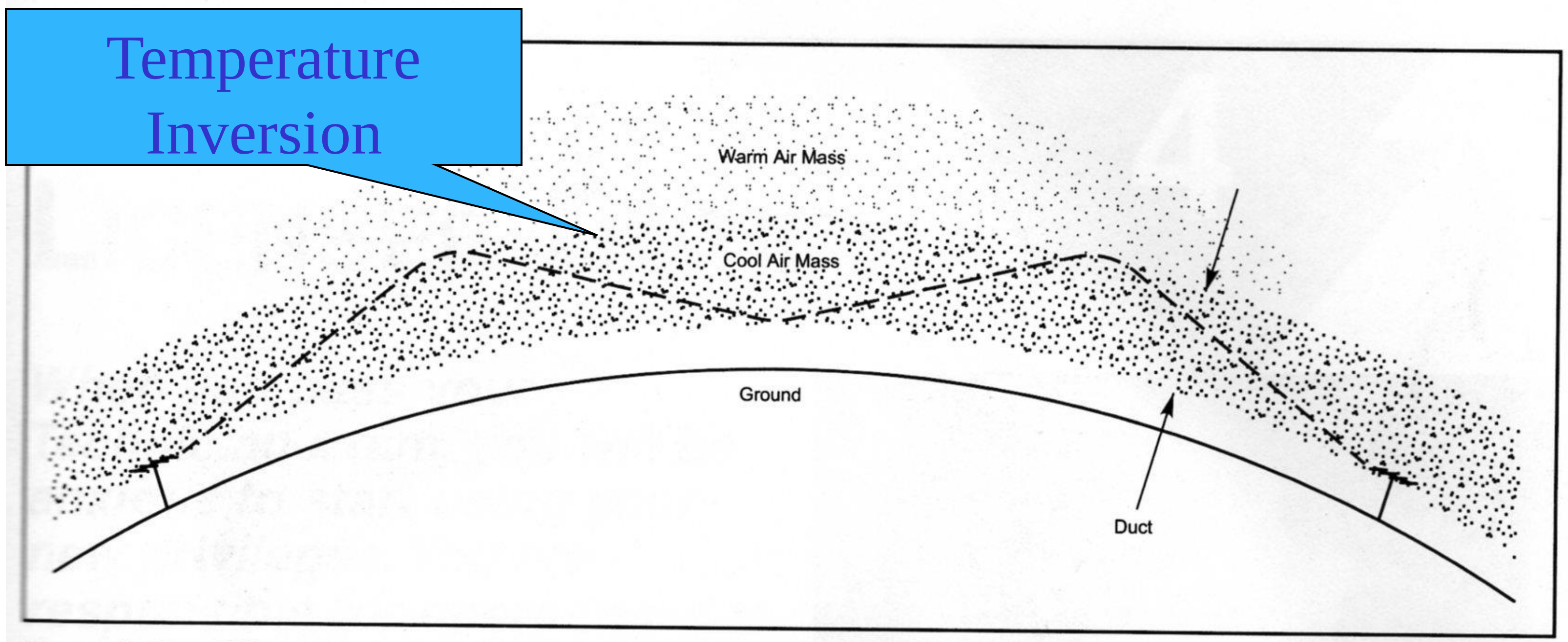
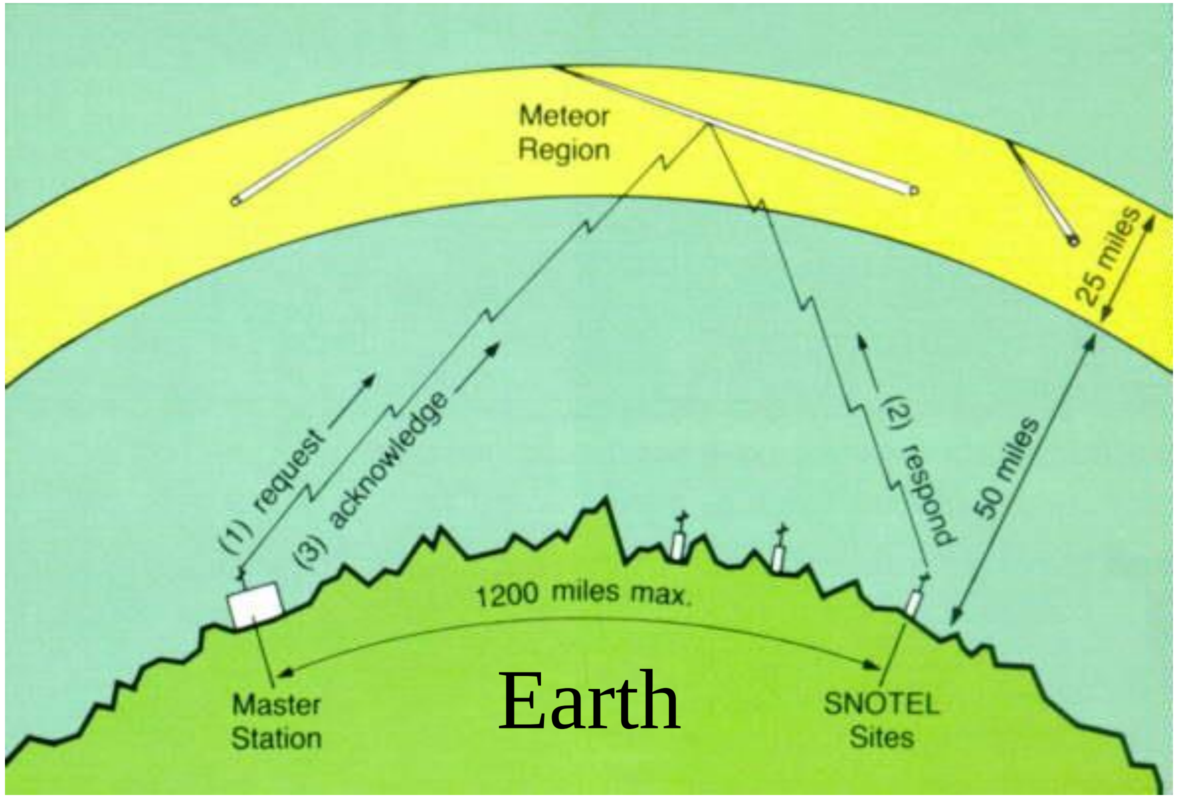


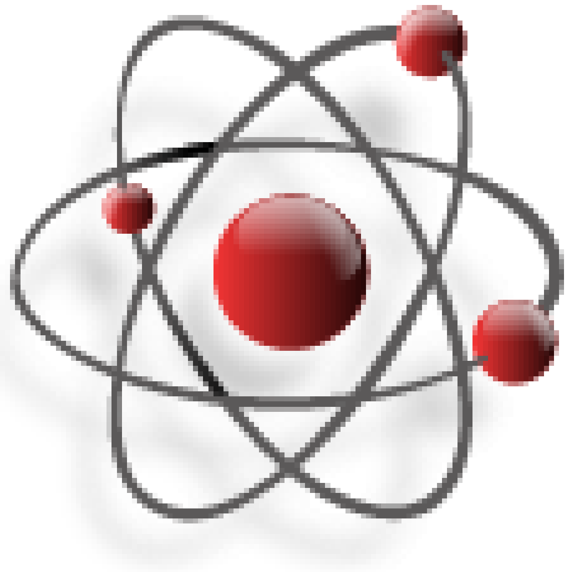
Figure 3.10 — When a cool air mass is overrun by a mass of warmer air, a "duct" may be formed, allowing VHF and UHF radio signals to travel great distances with little attenuation, or signal loss.

Review: Meteor Scatter

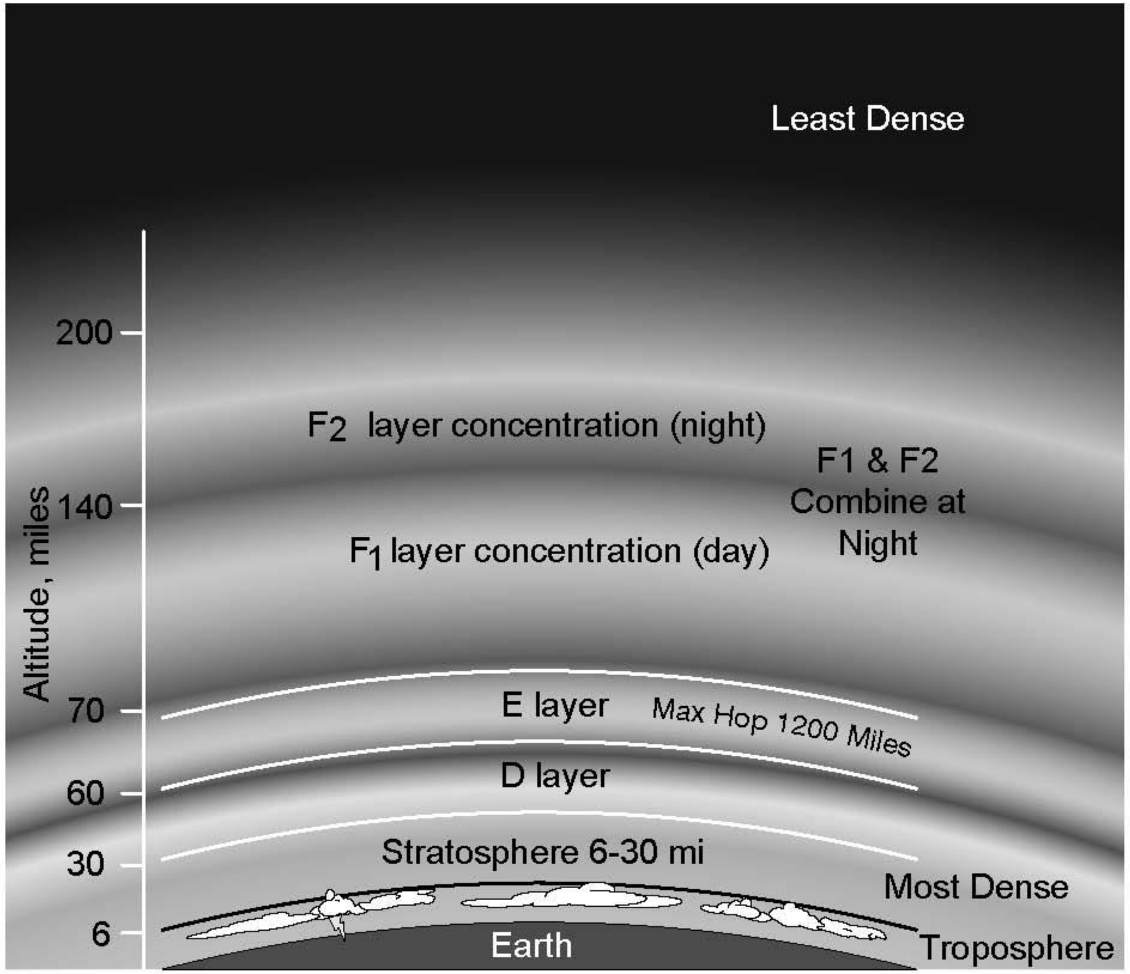
* 6 meter (50 -54 MHz)



Review: Skywave Propagation



Ultraviolet energy from the sun can knock electrons away from atoms, creating **ions.** This creates the **Ionosphere**



Chapter 8

Propagation on the HF Frequencies

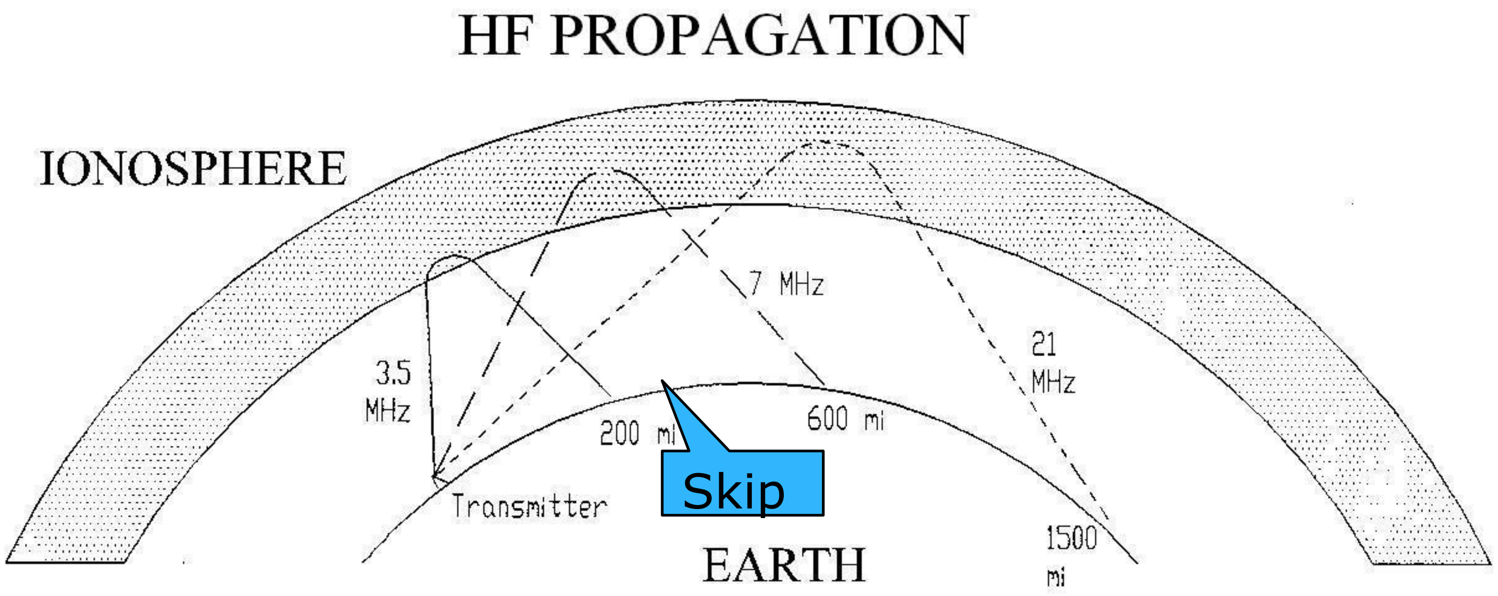
Black Text: Regular information

Blue Text: Information related to a Question-Pool question

Bold text: Key words

HF Propagation

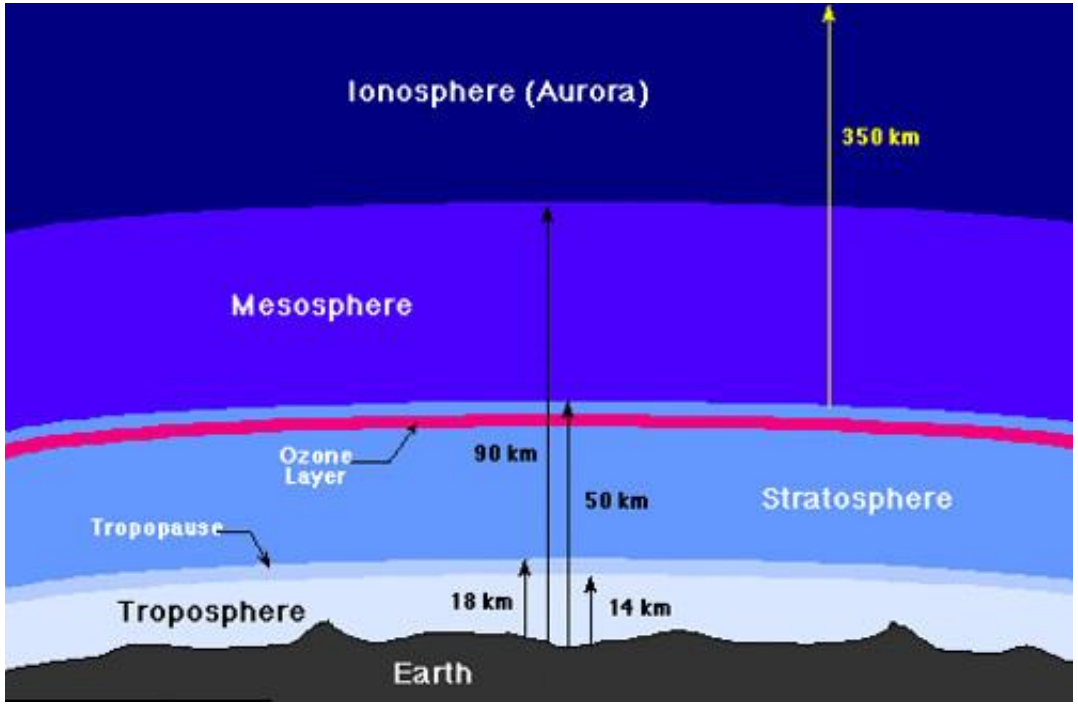
* The ionosphere reflects HF radio waves



Section 8:1 The Ionosphere

10 Questions

- Long-path vs. short-path
- Layers of the ionosphere
  - D-layer
  - E-layer
  - F1 and F2 layers
  - Absorption - reflection
- Critical Frequency
- Critical angle

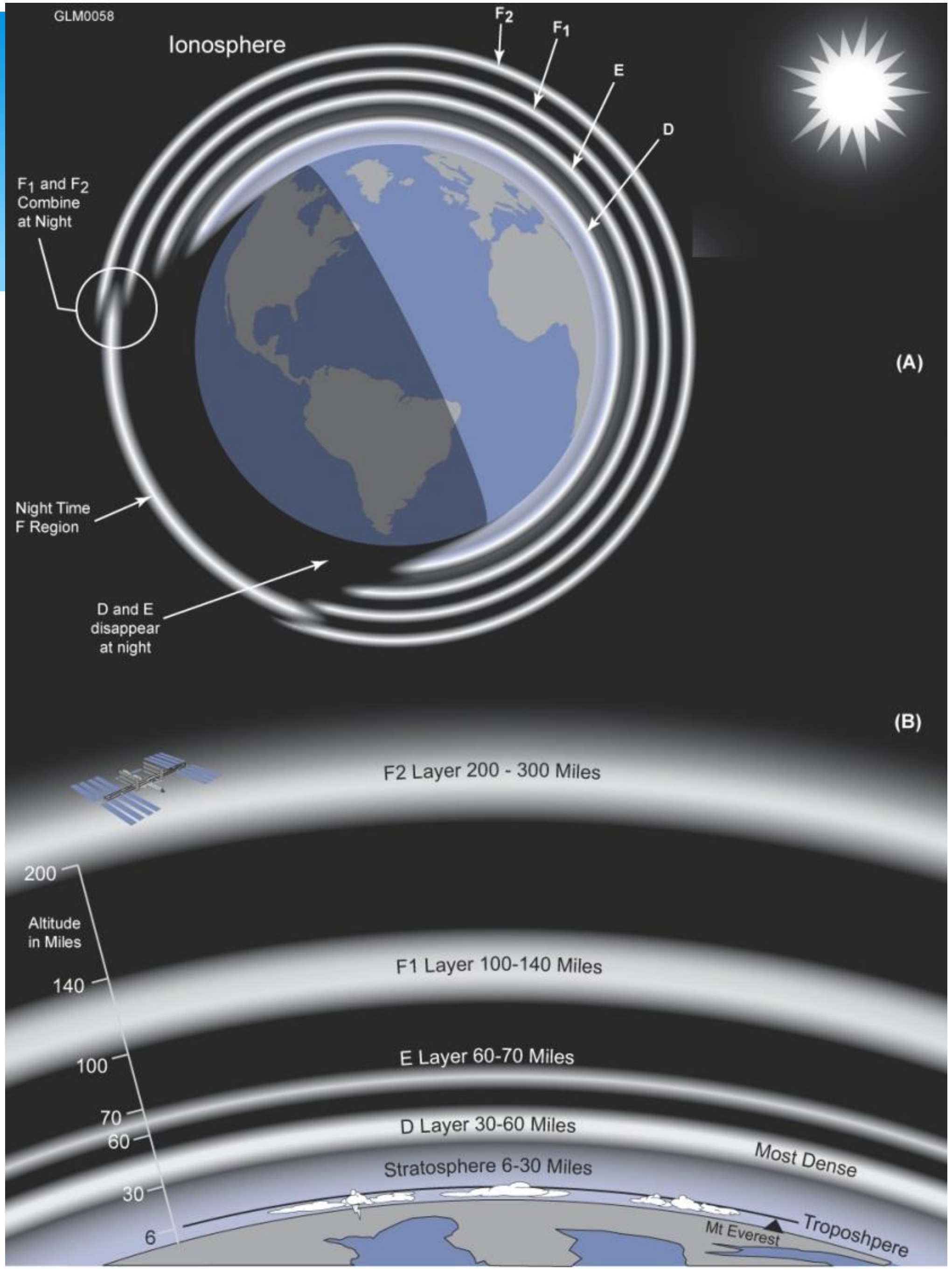


Ionospheric Regions (Layers)

8-3

- Located 30 to 300 miles above the surface of the Earth is the **ionosphere**

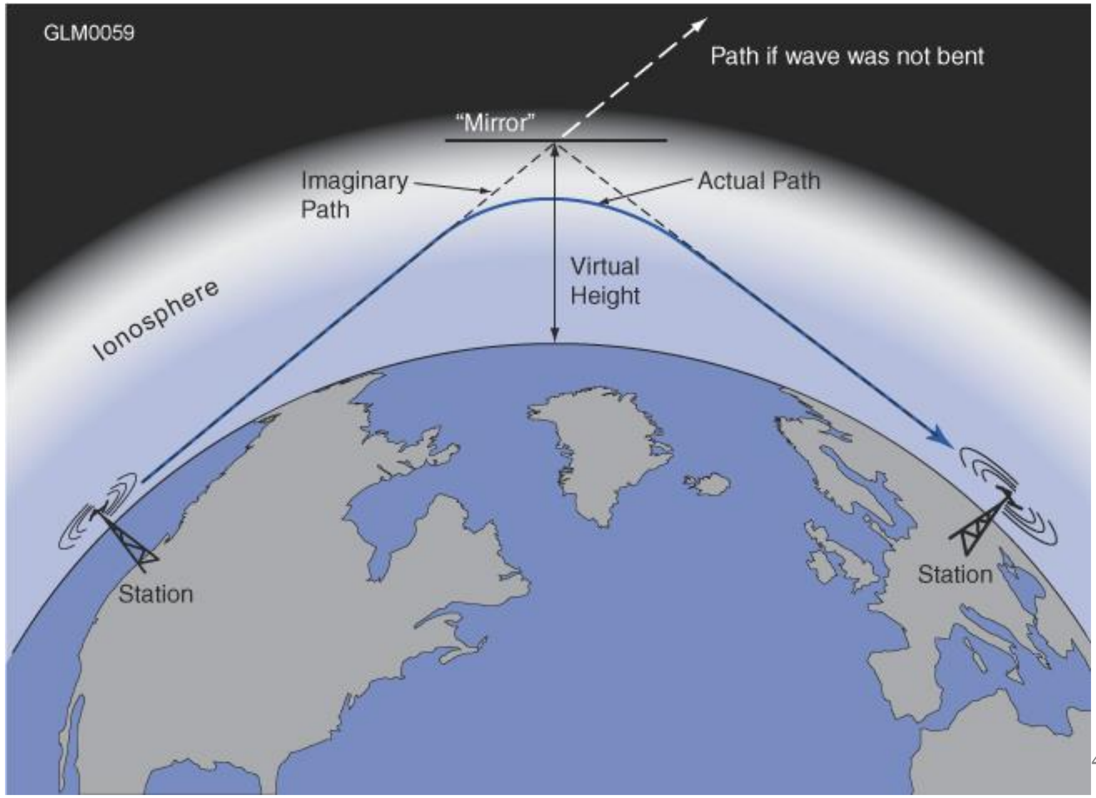
- The ionosphere is made up of multiple layers:
  - D
  - E
  - F
    - F1 and F2



Reflection & Absorption

8-2, 4 & 5

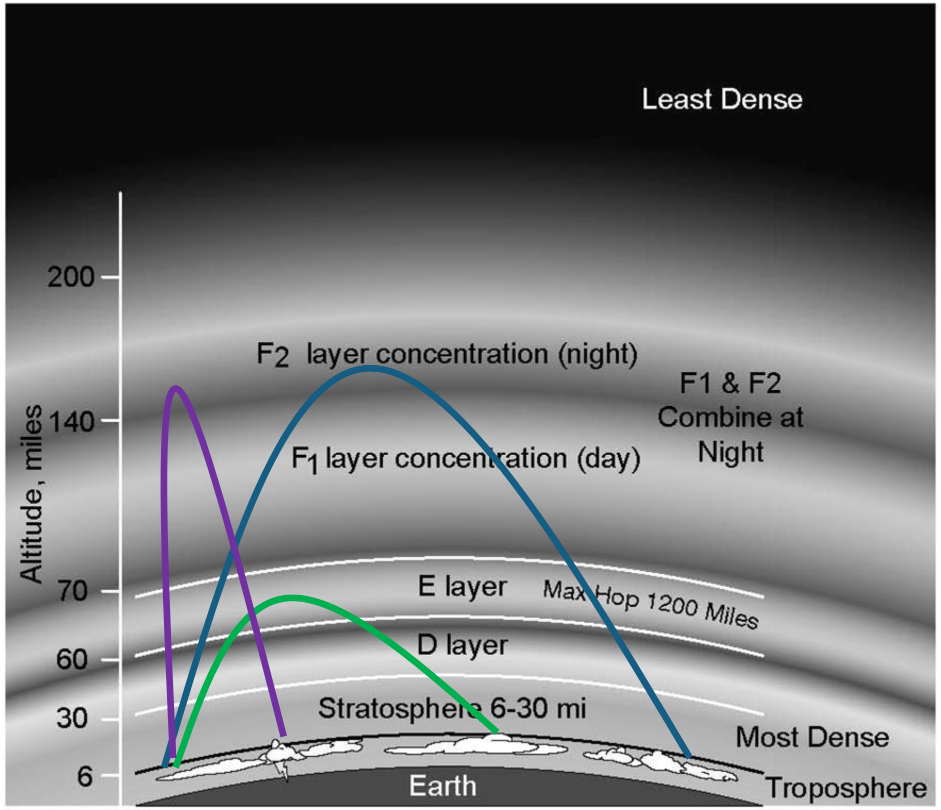
- The ability of the ionosphere to bend or refract radio waves depends on how strongly the regions gasses are ionized **and the frequency**
- The stronger the ionization, the more the wave will be bent
- The higher the frequency of the wave, the less it is bent (VHF & UHF are hardly bent)
- This bending is often loosely referred to as a **“reflection”** off the ionosphere



Sky-wave Propagation

8-2, 3 & 5

- *Hop* – one reflection from the ionosphere
- *Skip* (*sky-wave)* – propagation by ionospheric refraction. The higher the reflecting region, the longer the hop
    - F2 layer hops up to 2500 miles (G3B09)
    - E layer hops up to 1200 miles (G3B10)
- The Maximum height of the F2 layer occurs at noon, when the sun is overhead.

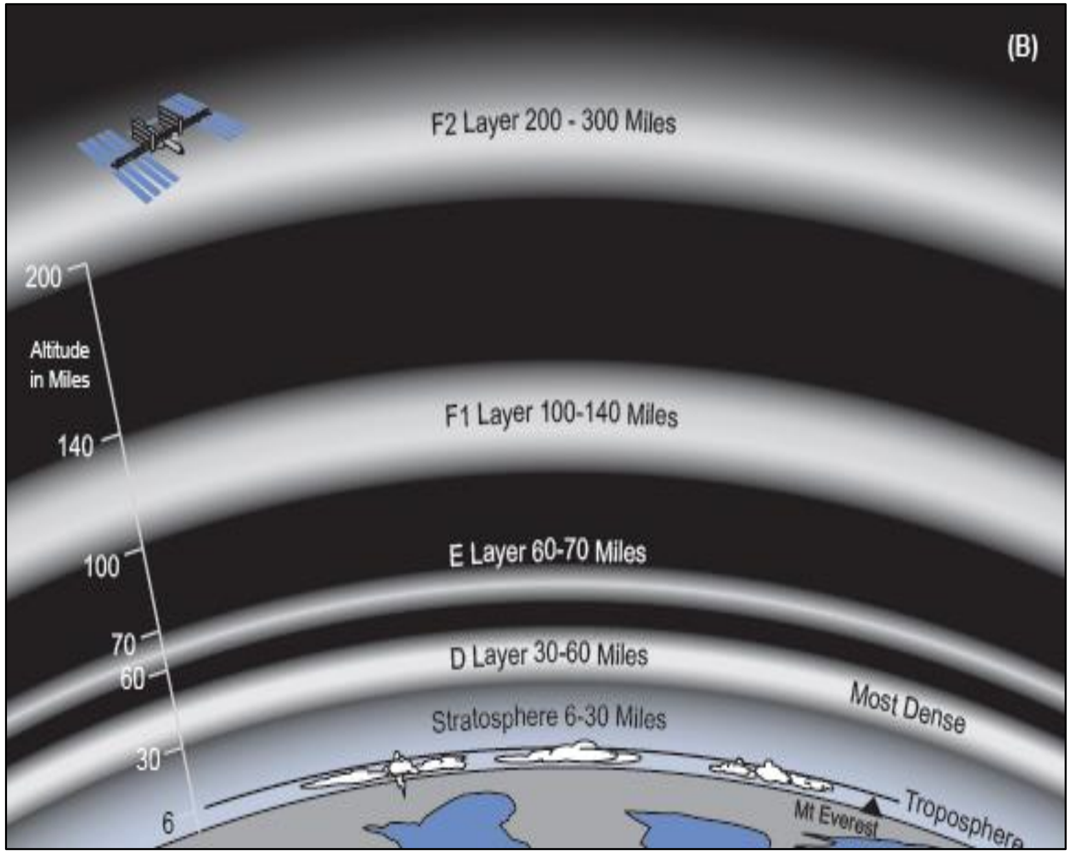


- FYI: Short skip on 10m is a good indication that sky-wave propagation may be available on 6m

Regions
D, E, F Layers

8-2, 3 & 5

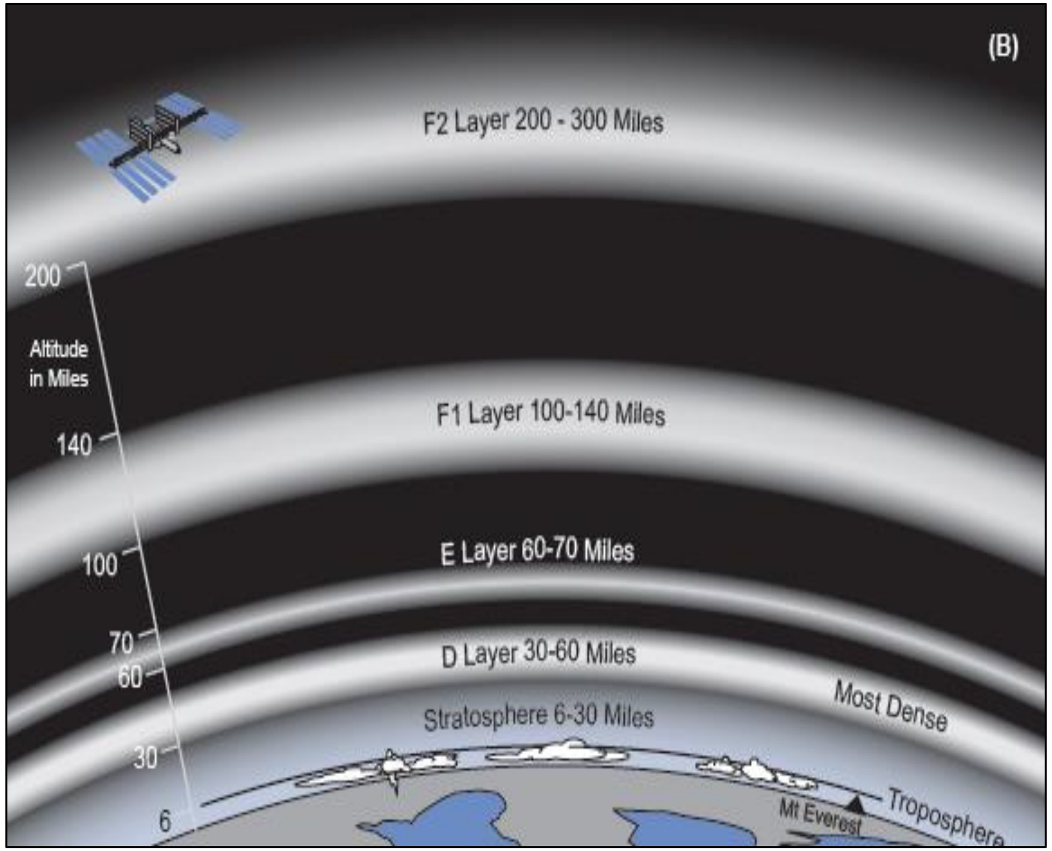
- **D Layer**: Closest to the earth (G3C01)
  - 30 – 60 miles in altitude
  - Only present when illuminated by the Sun
    - Disappears at night
  - The D layer absorbs HF signals during the day, especially below 10 MHz (G3C05 & 11)
- **E Layer**: 60 – 70 miles in altitude
  - Disappears later at night
  - Acts similarly to the D layer, often absorbing HF signals, however it may also reflect some HF signals at distance up to 1200 miles (G3B10)



Regions

8-2, 3

- **F Layer** – is 100 – 300 miles above Earth
  - During the day it breaks into F1 and F2 layers
  - At night it returns to a single F layer
  - The F1 and F2 layers vary with the local time, season, latitude and solar activity
  - The stronger the Sun's illumination, the higher the F2 layer will be (when the Sun is overhead)
  - **F2 layer is the highest layer and responsible longest distance communications-- hops up to 2500 miles** (G3B09, G3C03)

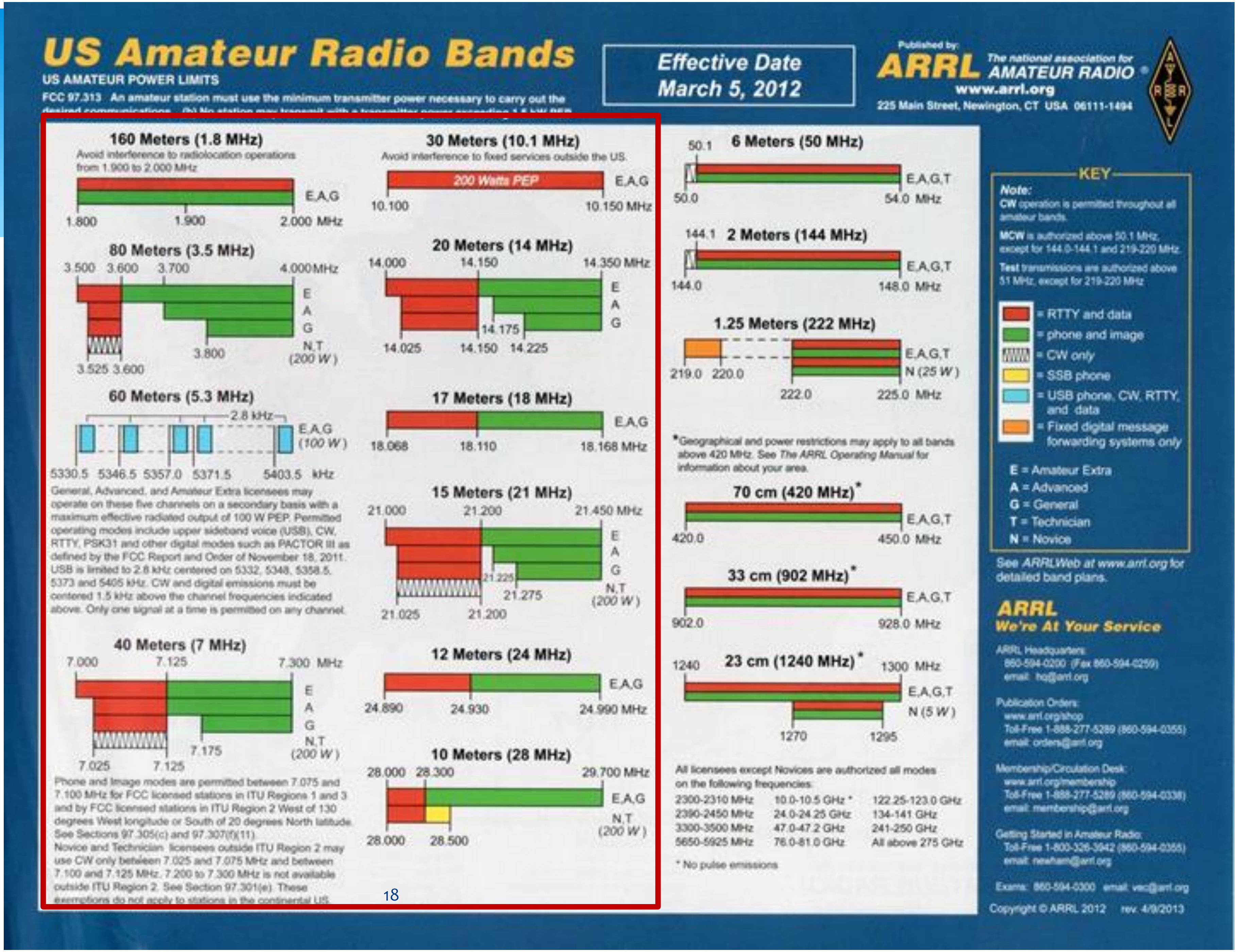


Ten HF Bands Pg 3-9

Side notes:

Technically speaking, 160m is in the MF range rather than the HF range

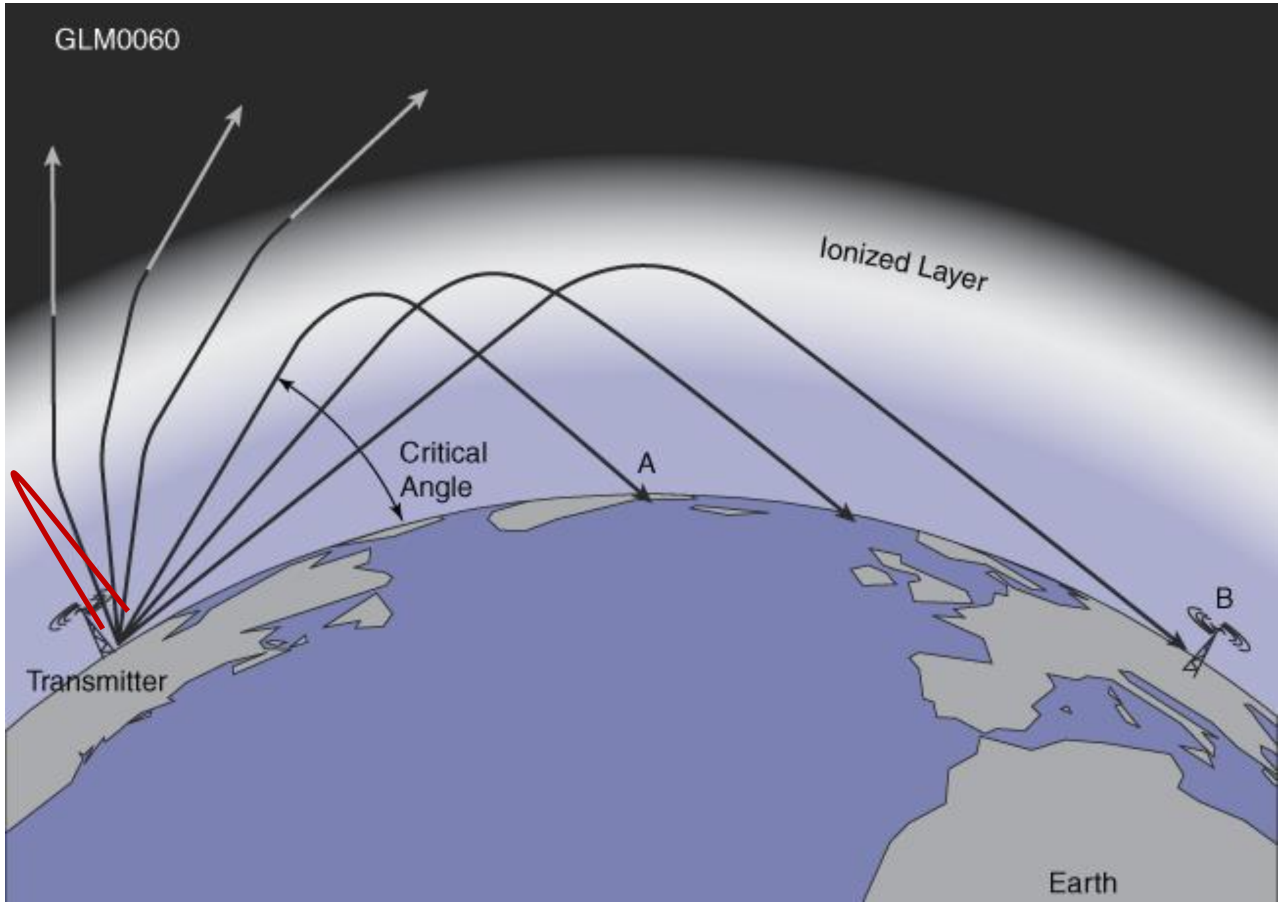
6m may at times exhibit characteristics similar to the upper HF bands



Reflection, Absorption & Sky-wave Propagation 8-5

- ***Critical Angle*** – the highest angle at which the radio wave will be refracted back to Earth (G3C04)

•***Critical Frequency*** – the highest frequency that a signal transmitted straight up will be returned to Earth (G3C04)



Absorption and Noise

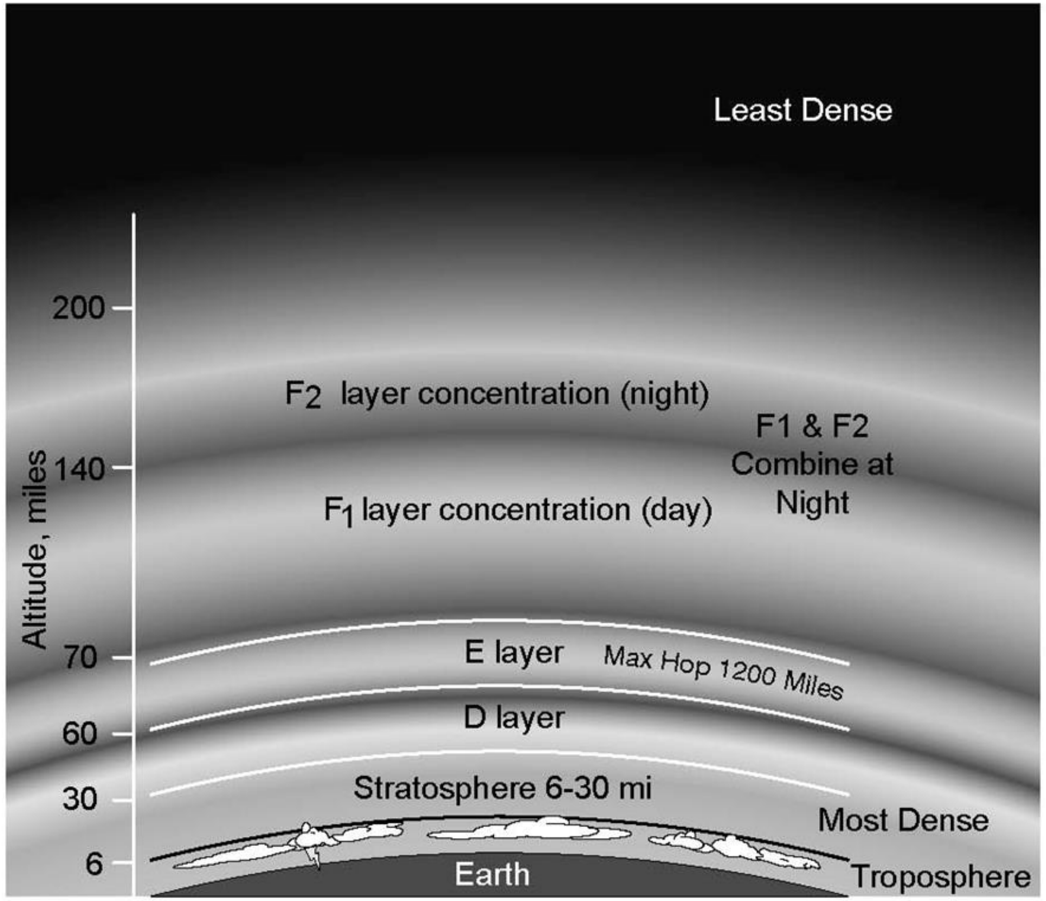
8-5

- **D Layer**: **The D layer absorbs HF signals**

•*Absorption* increases in the daytime when the UV is more intense

•Signals below 10 MHz can be completely **absorbed by the D region** during the day light hours, making long-range communications difficult or impossible (160m, 80m, 60 and 40m) (G3C05, G3C11)

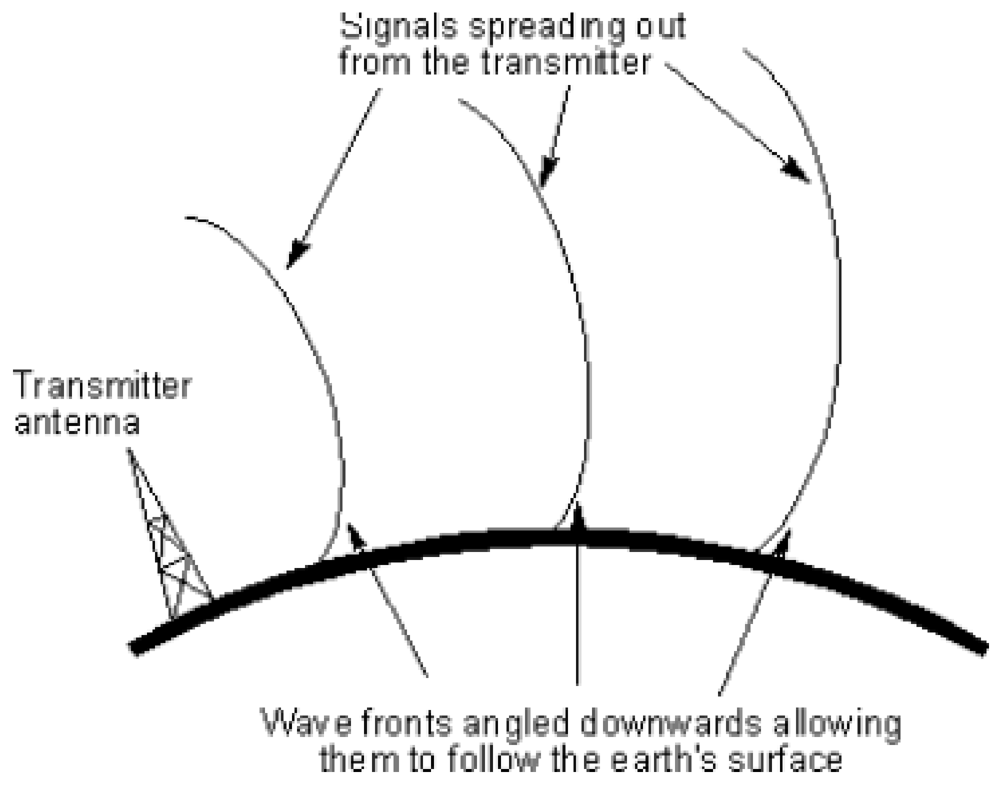
- **Noise**: Worse on HF than VHF/UHF
  - Covers up weak signals
  - Atmospheric storms (QRN)
  - Worse on the lower bands (160 – 40m)
  - Man-made noise is also a problem (QRM)



Ground-wave Propagation

FYI

- *Ground wave* – propagation along the Earth's surface
- More effective at the lower frequencies (160m, 80m)

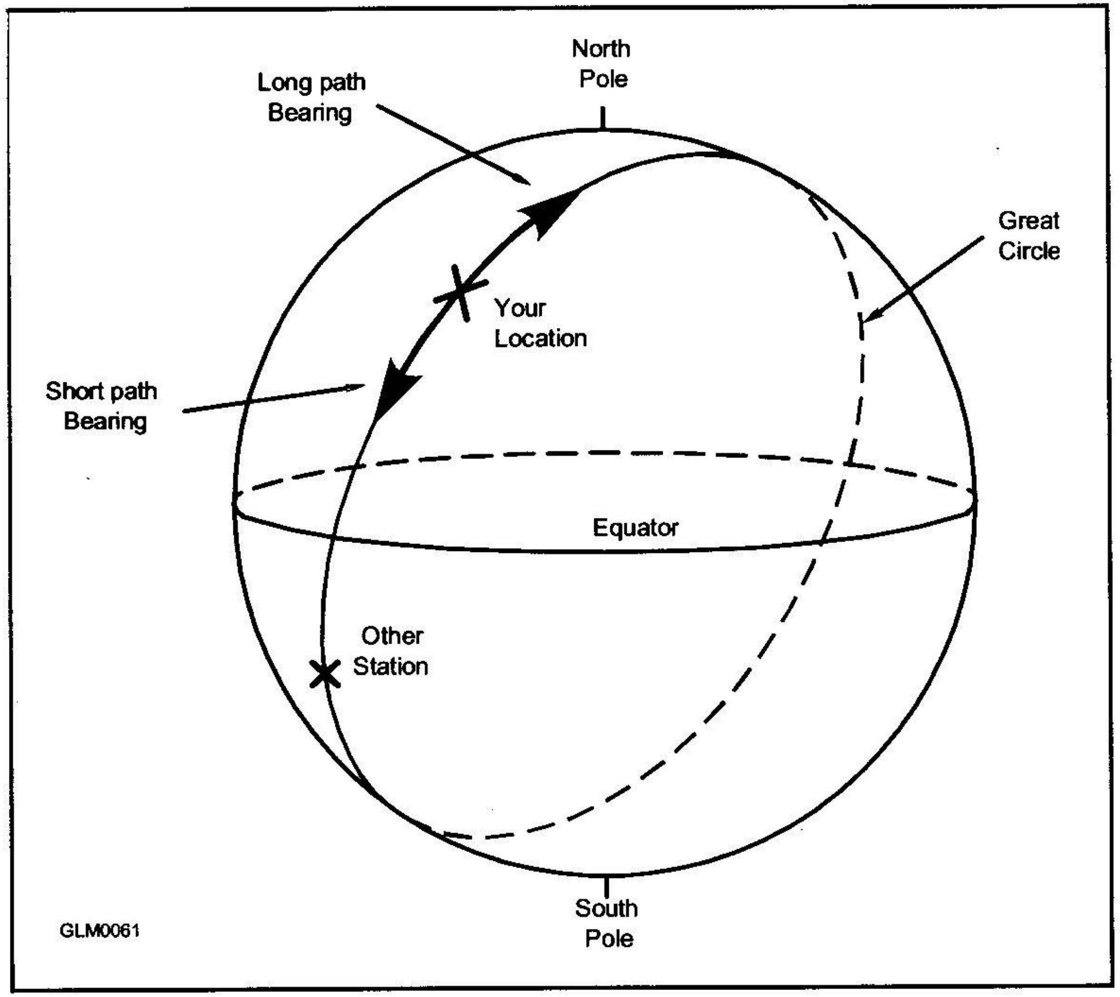


Ground wave radio propagation

Long Path & Short Path

8-5 & 6

- *Short path* – most HF contacts are made via short path or the most direct route
- *Long path* – signals take the long way around the world to complete the contact (**180˚ from short path**)
- A signal that is arriving via both long path and short path will have a slightly delayed echo (G3B01) (1/7second delay echo)
- For Long-path, a directional antenna would be pointed 180 degrees from the station's short path (G2D06)



Practice Questions

What is a characteristic of skywave signals arriving at your location by both short-path and long-path propagation?

A. Periodic fading approximately every 10 seconds
B. Signal strength increased by 3 dB
C. The signal might be cancelled causing severe attenuation
D. A slightly delayed echo might be heard

G3B01

What is a characteristic of skywave signals arriving at your location by both short-path and long-path propagation?

A. Periodic fading approximately every 10 seconds
B. Signal strength increased by 3 dB
C. The signal might be cancelled causing severe attenuation
D. A slightly delayed echo might be heard

G3B01

What is meant by the term “critical frequency” at a given incidence angle?

A. The highest frequency which is refracted back to Earth
B. The lowest frequency which is refracted back to Earth
C. The frequency at which the signal-to-noise ratio approaches unity
D. The frequency at which the signal-to-noise ratio is 6 dB

G3C02 (A) Page 8-5

What is meant by the term “critical frequency” at a given incidence angle?

A. **The highest frequency which is refracted back to Earth**
B. The lowest frequency which is refracted back to Earth
C. The frequency at which the signal-to-noise ratio approaches unity
D. The frequency at which the signal-to-noise ratio is 6 dB

G3C02 (A) Page 8-5

Why is skip propagation via the F2 region longer than that via the other ionospheric regions?

A. Because it is the densest
B. Because of the Doppler effect
C. Because it is the highest
D. Because of temperature inversions

G3C03 (C) Page 8-5

Why is skip propagation via the F2 region longer than that via the other ionospheric regions?

A. Because it is the densest
B. Because of the Doppler effect
C. **Because it is the highest**
D. Because of temperature inversions

Section 8:2 The Sun

23 Questions

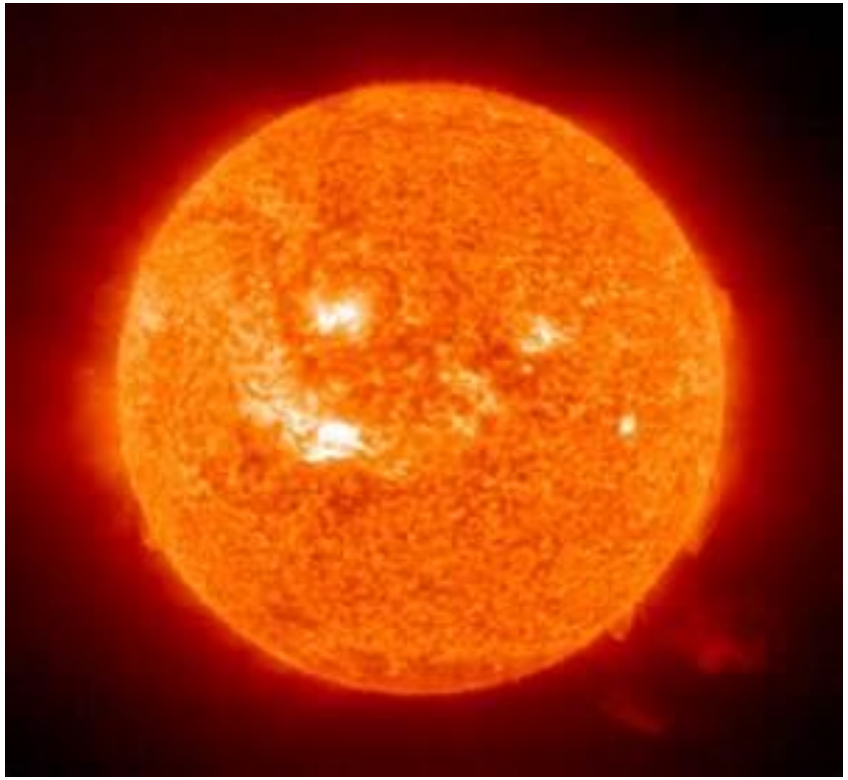
8-7 & 9

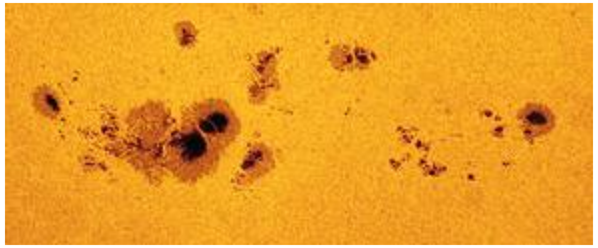
- The sun's characteristics
  - Sunspots and cycle
  - Solar Flux
  - A-Index and K Index
- Most & least reliable frequency bands
- Solar storms and flares
  - Geomagnetic storms/activity
  - Effects on propagation
  - **MUF and LUF**

The Sun

8-5

- Sunspots
  - The Sunspot number represents the number of sunspots and groups present at a given time
  - Sunspot numbers are useful in assessing the overall solar activity
  - **The more sunspots**, the more UV is generated, creating more ionization and **improving propagation conditions on the higher HF bands (10 MHz and up)** and possibly into the lower VHF range

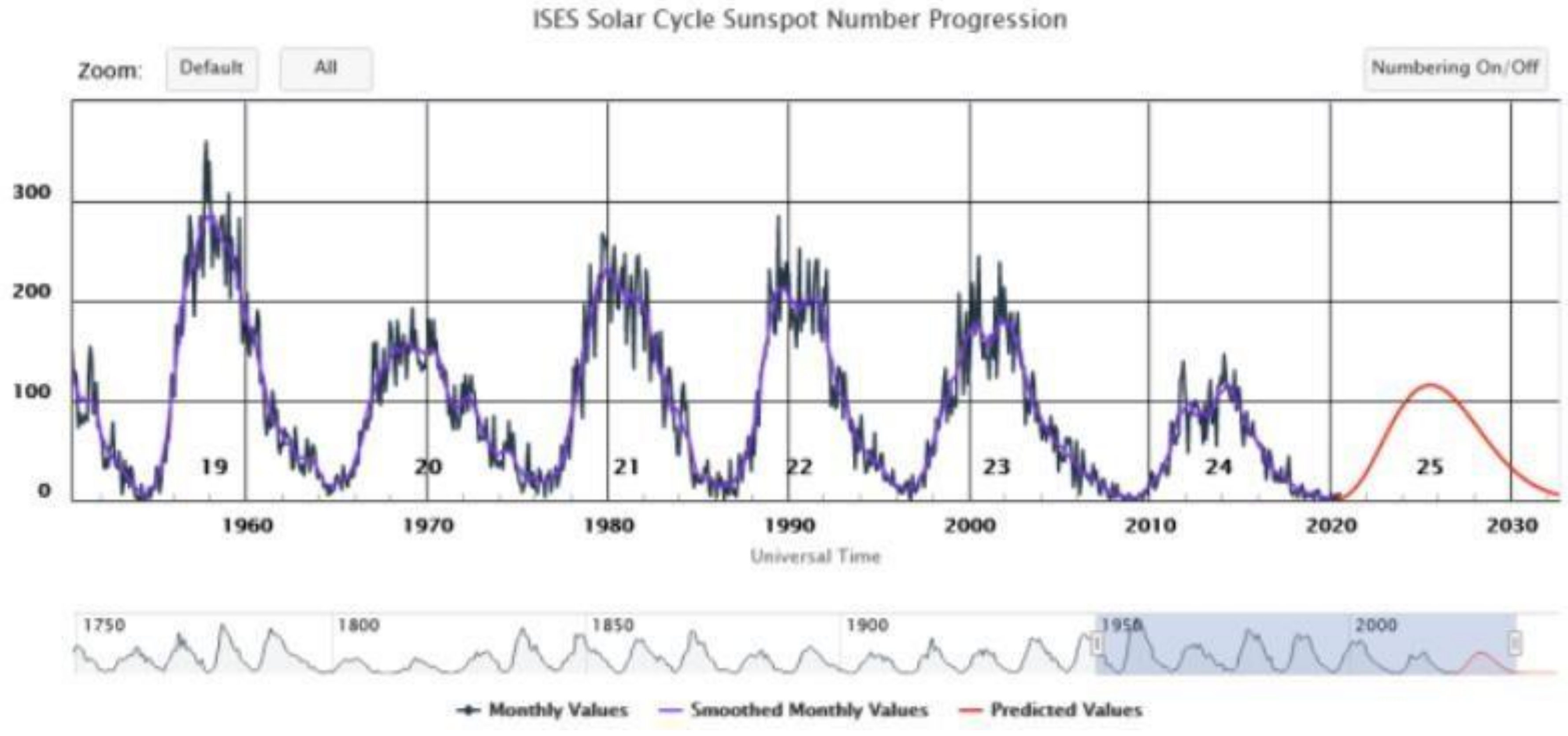




The 11-Year Solar Cycle

8-7

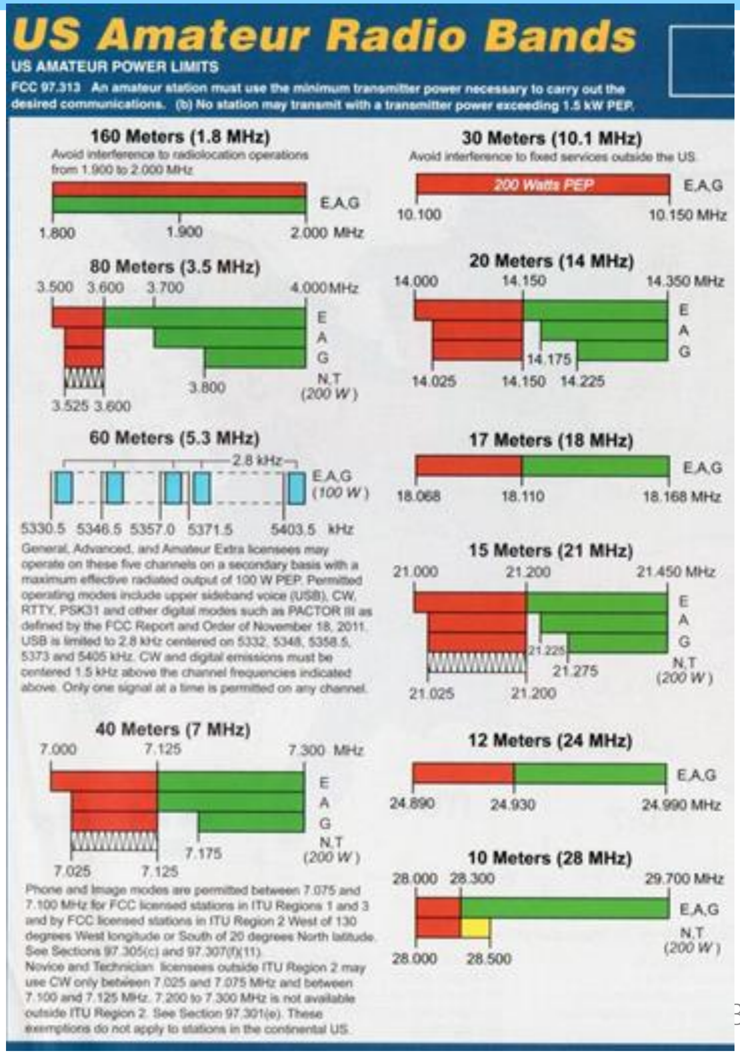
The number of sunspots varies on an approximately 11-year cycle,
Sunspot numbers are useful in assessing the overall solar activity



Solar Activity

8-7, 8

- High sunspot numbers generally mean good propagation at higher frequencies (i.e: 15, 12, & 10 meter bands) (G3A01)
  - 15, 12 and 10m bands are least reliable with low solar activity (G3A04)
- High sunspot numbers means increased absorption below 10 MHz
- 20 meter band is usually good during the daytime, regardless of sunspot number (G3A07)
- Sun rotates every 26-28 days, causing sunspots to reappear if still present. HF propagation tends to repeat as well (G3A10)



Daytime / Nighttime Propagation

8-8

Table 8-1

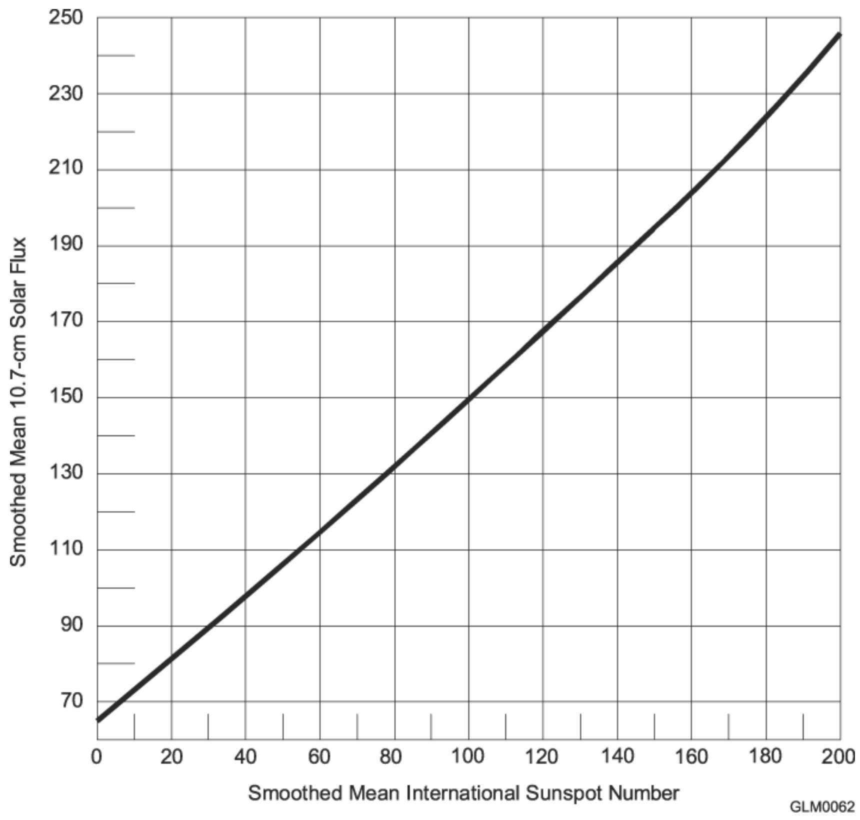
HF BAND (m)	DAYTIME	NIGHTTIME
160, 80, 60	Local and regional to 100 – 200 miles	Local to long distance with DX best near sunset or sunrise at one or both ends of the contact
40, 30	Local and regional to 300 – 400 miles	Short-range (20 or 30 miles) and medium distances (150 miles) to worldwide
20, 17	Regional to long distance, opening at or near sunrise and closing at night	20 meters is often open to the west at night and may be open 24 hours a day
15, 12, 10	Primarily long distance (1000 miles and more), opening to the east after sunrise and to the west in the afternoon	10 meters is often used for local communications 24 hours a day

- **Higher levels of atmospheric noise and static** are experienced on the lower HF frequencies, particularly **in summer** (G3B12)

Measuring Solar Activity

8-8

- **Solar-Flux Index (SFI)** – amount of 10.7 cm wavelength (2800 MHz) energy from the Sun (G3A05)
  - Values of 65 up to 250
- **K index (0-9)** – the short term stability of the Earth's *magnetic field* (G3A12)
  - 0 is quiet, 9 is extreme storm
- **A index (0-400)** – long-term geomagnetic field stability around the world (G3A13)
  - Values 0 (stable) to 400 (greatly disturbed)

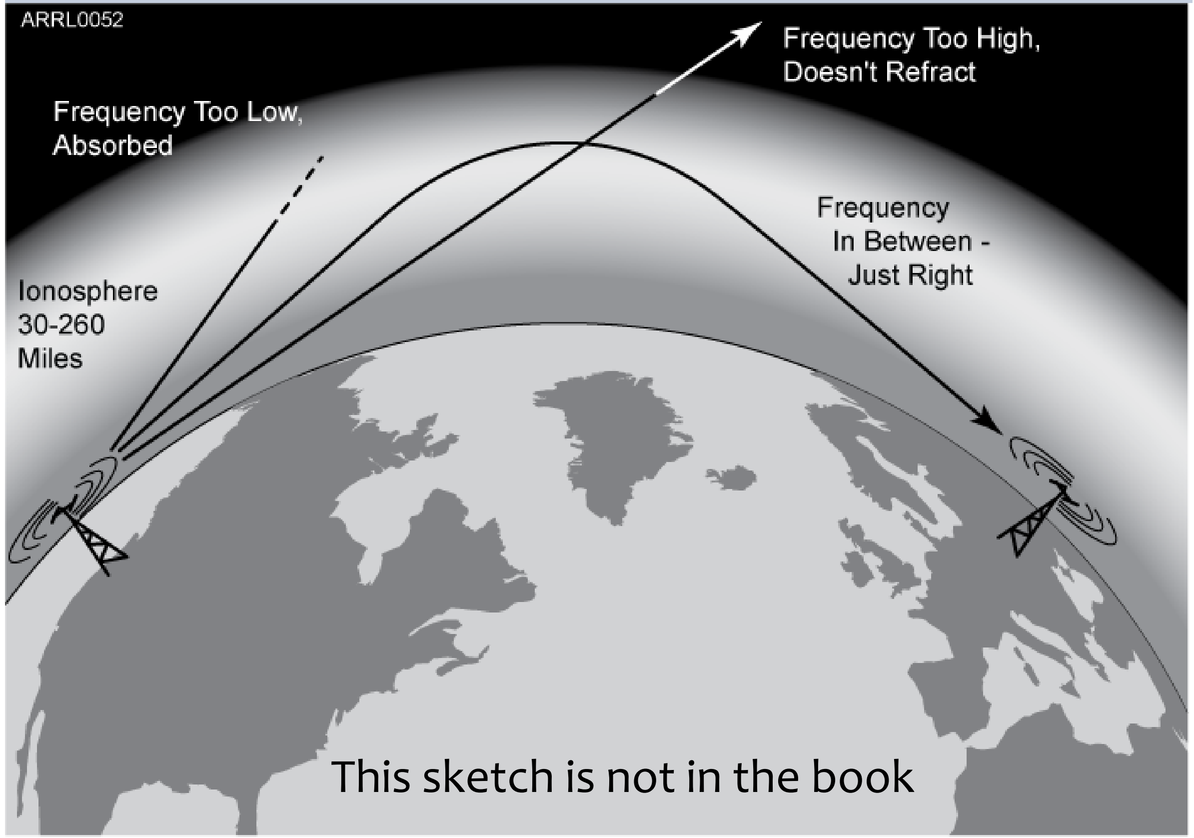


Approximate correlation between solar flux and sunspot number

Maximum Usable Frequency (MUF) Lowest Usable Frequency (LUF)

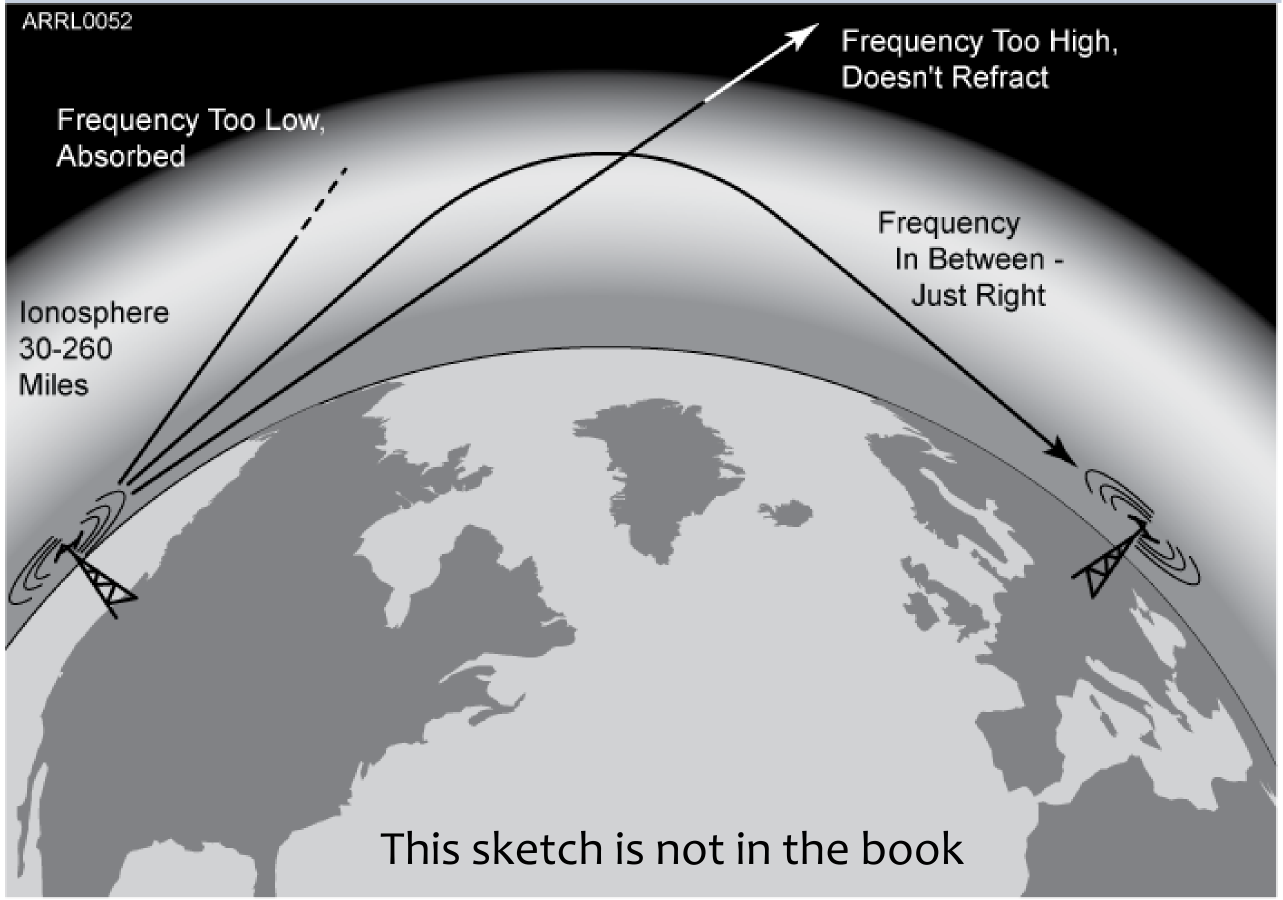
8-10

- **LUF (Lowest Useable Frequency)** – frequency below which there is too much absorption (attenuation) for communication between the two given points. (G3B06 & 07)
- **MUF (Max Useable Frequency)** – highest frequency at which sky-wave will support communications between the two given points. (G3B08)
- Sky-wave communications occur at frequencies **between the MUF and the LUF** because these frequencies **are refracted back to earth**. (G3B08)



Maximum Usable Frequency (MUF) Lowest Usable Frequency (LUF) 8-10

- Signals between the MUF and the LUF are reflected back to earth (G3B05)
- **If the LUF exceeds the MUF**, no ordinary sky-wave propagation will support communication over the path (G3B11)
- MUF/LUF vary with the **time, season, amount of solar radiation, geomagnetic stability, location and distance** (G3B02)
- Operating just below the MUF will often provide the best results (G3B03)



MUF & LUF Example

FYI

Goal: Communicate between two given points: Olathe, KS and Zenia, Ohio

1:00 pm EDT
Noon CDT

Definitions:

LUF Lowest Usable Freq

MUF Maximum Usable Freq

Frequency MHz	Band m	Signal Quality	Comment
3.850	75/80	Not heard	
5.373	60	Too weak to be readable	
7.250	40	Readable but weak and noisy	LUF
10.118	30	Strong and clear	
14.250	20	Very strong and clear	MUF
18.140	17	Not heard	
21.370	15	Not heard	
24.950	12	Not Heard	
28.650	10	Not Heard	

Calling CQ (i.e.: Calling anyone)

FYI

Goal: Talk to anyone anyplace

- You will most likely end up talking to wherever propagation may be favorable for that frequency at that time of the day. **See Table 8-1,** Pg 8-8
- Estimate or *determine what bands are open*, then put out a call on one of those bands, saying:

➢ "Is this frequency in use, this is K0NK?"

➢ "CQ, CQ, CQ, this is K0NK, K0NK, kilo zero November kilo calling CQ and listening"

But, how did we determine what bands are open?

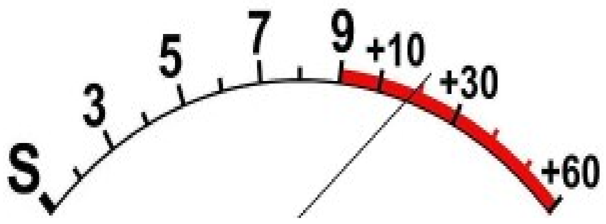
- We could just tune around the band and see how may signals you hear

Assessing Propagation – Digital Channels

FYI

- Listening to FT8 frequencies is a good way to quickly learn if a band is “Open”

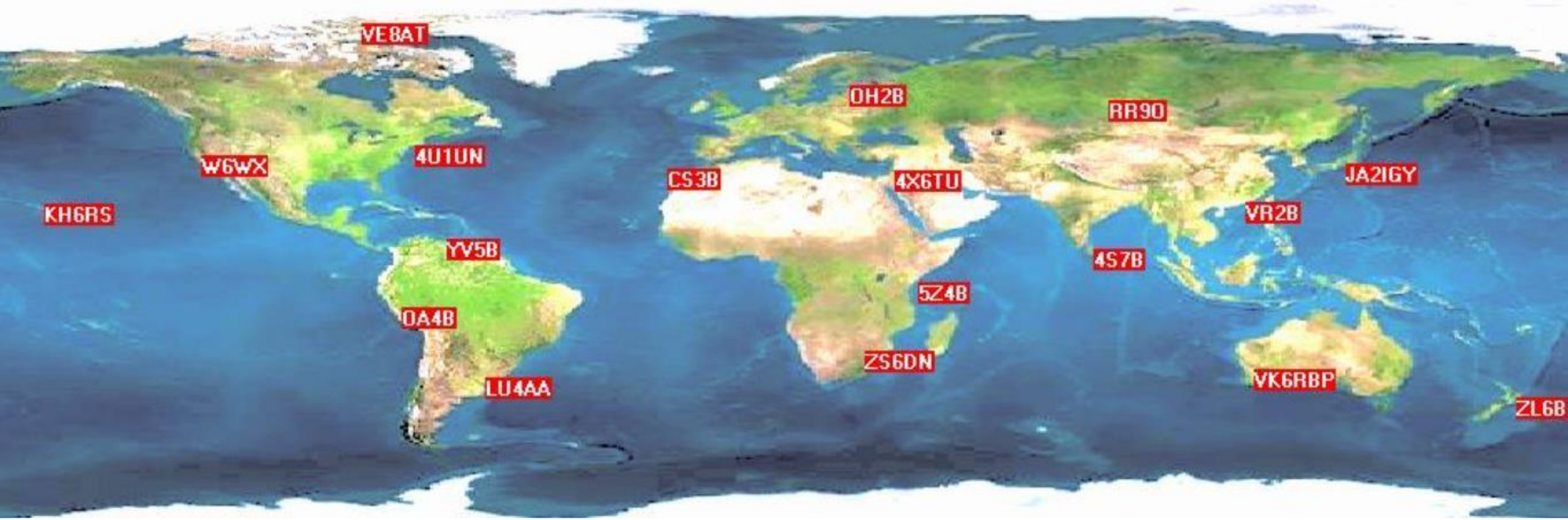
- **160m** – 1.840 MHz
- **80m** – 3.573 MHz
- **40m** – 7.074 MHz
- **30m** – 10.136 MHz
- **20m** – 14.074 MHz
- **17m** – 18.100 MHz
- **15m** – 21.074 MHz
- **12m** – 24.915 MHz
- **10m** – 28.074 MHz
- **6m** – 50.313 MHz
- **2m** – 144.174 MHz



Receiver S-Meter

18 Worldwide Beacons

8-10



- The NCDXF supports an international network of beacon stations that transmit continuously on 20-10 meters

Assessing Propagation - Beacons

http://www.ncdxf.org/beacon/index.html 8-10

- Check actual band conditions between two points by listening for beacon stations
- Each beacon transmits once on each band once every three minutes, 24 hours a day.
- A transmission consists of the callsign of the beacon sent at 22 words per minute CW followed by four one-second dashes.
- The callsign and the first dash are sent at 100 watts. The remaining dashes are sent at 10 watts, 1 watt and 100 milliwatts.

Frequency	Beacon	Location
14.100	VK6RBP	Australia
18.110	ZL6B	New Zealand
21.150	KH6RS	Hawaii
24.930	W6WX	California
28.200	VE8AT	Nunavut

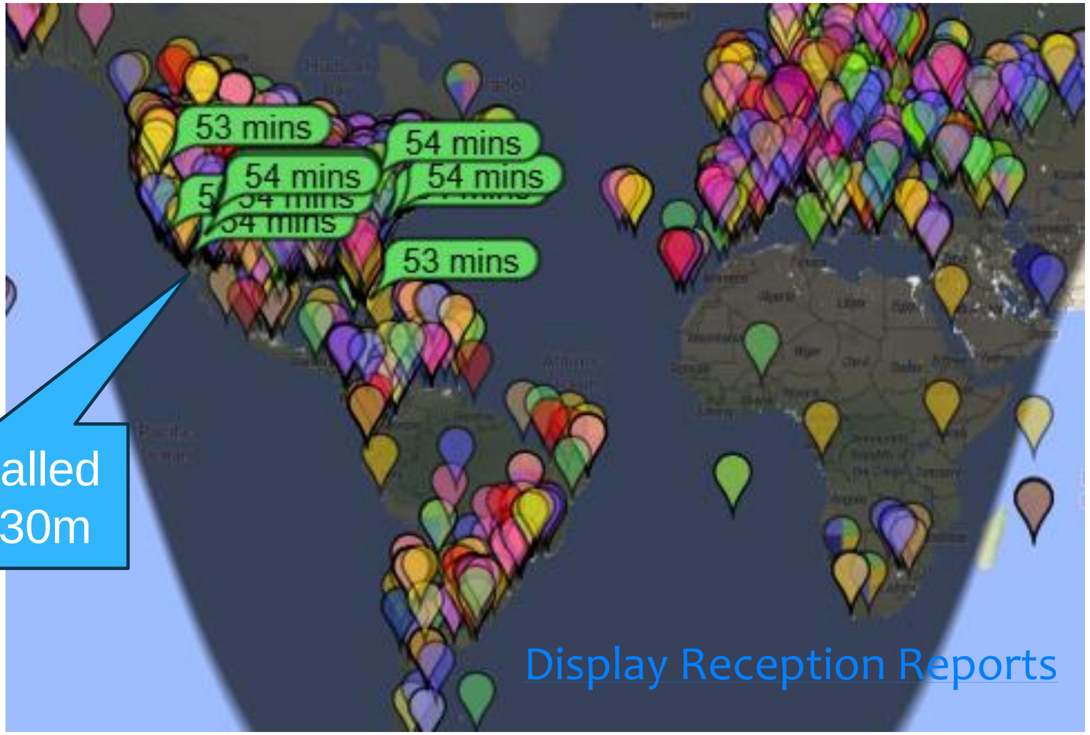
•At the end of each 10 second transmission, the beacon steps to the next higher band and the next beacon in the sequence begins transmitting

•HF Beacon stations transmit continuously on 20-10 meters

Reverse Beacon Network

https://www.pskreporter.info/pskmap.html 8-10

Listens for CQ on CW or RTTY



Check for propagation using a network of automated receiving stations (G3B04)

- Over 5000 receivers around the world automatically listen for stations calling CQ
- When a particular station is heard calling CQ on CW or RTTY, each automated station hearing the CQ decodes the callsign and posts a flag on a map

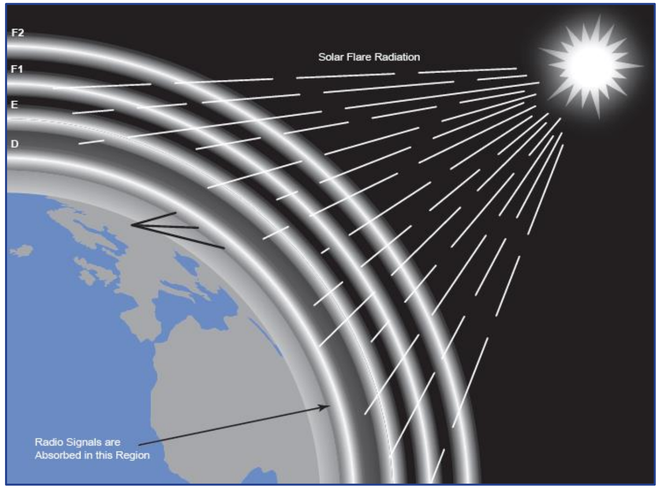
Solar Disturbances

8-10

- Solar flare – a large eruption of energy and solar material on the surface of the Sun
- Coronal hole – a weak area in the Sun's outer layer where ionized gas and charged particles escape the Sun's magnetic field
- Coronal mass ejection (CME) – an ejection of large amounts of material from the corona

• CME may be directed in a narrow stream or wide spray (disruptive to radio communications)

Solar Disturbances
Sudden Ionospheric Disturbance (SID) 8-11, 12



- UV & X-ray radiation from solar flares travels at the speed of light and reaches the Earth's ionosphere in about 8 minutes (G3A03)
  - Increases D layer ionization and absorption dramatically, causing a radio blackout (Sudden Ionospheric Disturbance or SID) that can last from seconds to several hours
  - Affects lower bands more than higher bands; higher bands may still be useful (G3A02)
  - SID only impacts the sunny side of the Earth so dark side may be relatively unaffected

Solar Disturbances
Geomagnetic Disturbances

8-12

- Geomagnetic Disturbances
  - The sun gives off a stream of particles called *solar wind*
  - Charged particles from coronal holes and CMEs take 15 hours to several days to reach the Earth (G3A11)
  - Particles increase ionization in the E region
  - **Causes geomagnetic storms** which cause **degraded HF propagation**, especially at high-latitude propagation (G3A08)

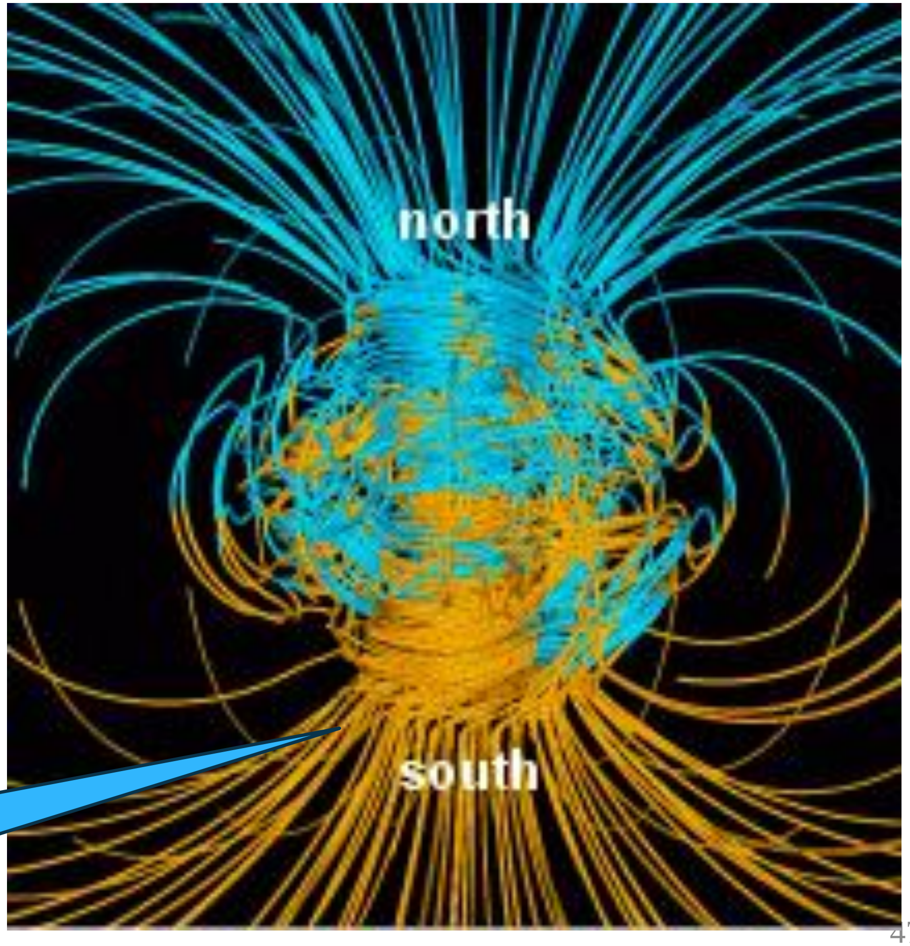
The Northern Lights

Auroras are actually a glow of gases ionized by the incoming charged particles as they flow vertically down into the atmosphere, guided by the magnetic field

Geomagnetic Disturbances

8-12

- Charged particles from solar coronal holes disrupt the upper ionosphere, disturbing HF propagation for a period of hours or days (G3A14)
- A geomagnetic storm is a disturbance in the Earth's geomagnetic field (G3A06)
- Auroras created by this geomagnetic activity can improve VHF propagation on 6 and 2 meters (hiss or buzz) (G3A09)



The magnetic lines of force are more concentrated at the poles

Practice Questions

What effect does a Sudden Ionospheric Disturbance have on the daytime ionospheric propagation of HF radio waves?

A. It enhances propagation on all HF frequencies

B. It disrupts signals on lower frequencies more than those on higher frequencies

C. It disrupts communications via satellite more than direct communications

D. None, because only areas on the night side of the Earth are affected

G3A02

What effect does a Sudden Ionospheric Disturbance have on the daytime ionospheric propagation of HF radio waves?

A. It enhances propagation on all HF frequencies

B. It disrupts signals on lower frequencies more than those on higher frequencies

C. It disrupts communications via satellite more than direct communications

D. None, because only areas on the night side of the Earth are affected

G3A02

Which of the following is typical of the lower HF frequencies during the summer?

A. Poor propagation at any time of day

B. World-wide propagation during daylight hours

C. Heavy distortion on signals due to photon absorption

D. High levels of atmospheric noise or static G3B12

Which of the following is typical of the lower HF frequencies during the summer?

A. Poor propagation at any time of day

B. World-wide propagation during daylight hours

C. Heavy distortion on signals due to photon absorption

D. High levels of atmospheric noise or static G3B12

Which of the following effects can a geomagnetic storm have on radio propagation?

A. Improved high-latitude HF propagation

B. Degraded high-latitude HF propagation

C. Improved ground-wave propagation

D. Improved chances of UHF ducting

G3A08

Which of the following effects can a geomagnetic storm have on radio propagation?

A. Improved high-latitude HF propagation

B. Degraded high-latitude HF propagation

C. Improved ground-wave propagation

D. Improved chances of UHF ducting

G3A08

What is a possible benefit to radio communications resulting from periods of high geomagnetic activity?

A. Auroras that can reflect VHF signals

B. Higher signal strength for HF signals passing through the polar regions

C. Improved HF long path propagation

D. Reduced long delayed echoes

G3A09

What is a possible benefit to radio communications resulting from periods of high geomagnetic activity?

A. Auroras that can reflect VHF signals

B. Higher signal strength for HF signals passing through the polar regions

C. Improved HF long path propagation

D. Reduced long delayed echoes

G3A09

Which of the following applies when selecting a frequency for lowest attenuation when transmitting on HF?

A. Select a frequency just below the MUF

B. Select a frequency just above the LUF

C. Select a frequency just below the critical frequency

D. Select a frequency just above the critical frequency

G3B03

Which of the following applies when selecting a frequency for lowest attenuation when transmitting on HF?

A. Select a frequency just below the MUF

B. Select a frequency just above the LUF

C. Select a frequency just below the critical frequency

D. Select a frequency just above the critical frequency

G3B03

What happens to HF propagation when the LUF exceeds the MUF?

A. Propagation via ordinary skywave communications is not possible over that path

B. HF communications over the path are enhanced

C. Double-hop propagation along the path is more common

D. Propagation over the path on all HF frequencies is enhanced G3B11

What happens to HF propagation when the LUF exceeds the MUF?

A. **Propagation via ordinary skywave communications is not possible over that path**

B. HF communications over the path are enhanced

C. Double-hop propagation along the path is more common

D. Propagation over the path on all HF frequencies is enhanced G3B11

How does the ionosphere affect radio waves with frequencies below the MUF and above the LUF?

A. They are refracted back to Earth

B. They pass through the ionosphere

C. They are amplified by interaction with the ionosphere

D. They are refracted and trapped in the ionosphere to circle Earth G3B05

How does the ionosphere affect radio waves with frequencies below the MUF and above the LUF?

A. They are refracted back to Earth

B. They pass through the ionosphere

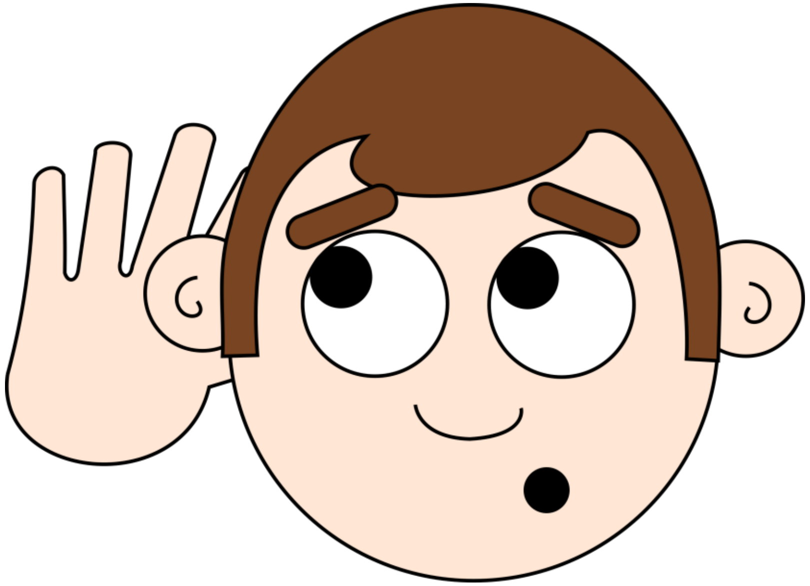
C. They are amplified by interaction with the ionosphere

D. They are refracted and trapped in the ionosphere to circle Earth G3B05

Section 8:3 Scatter Modes

5 Questions

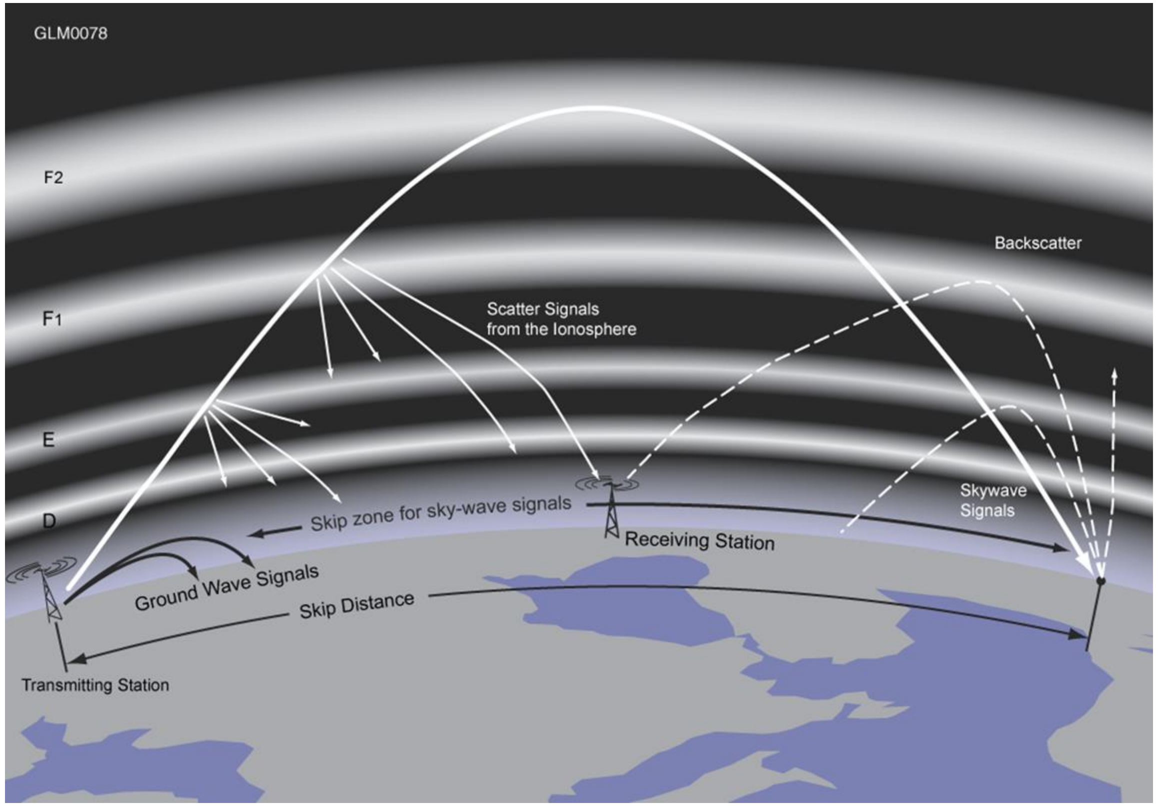
- Characteristics of HF scatter
  - Flutter
  - Distorted
  - Weak
- Allows HF signals to be heard in the skip zone
- Near vertical incidence skywave (NVIS)
  - Short distance communications



Scatter Modes

8-12 to 14

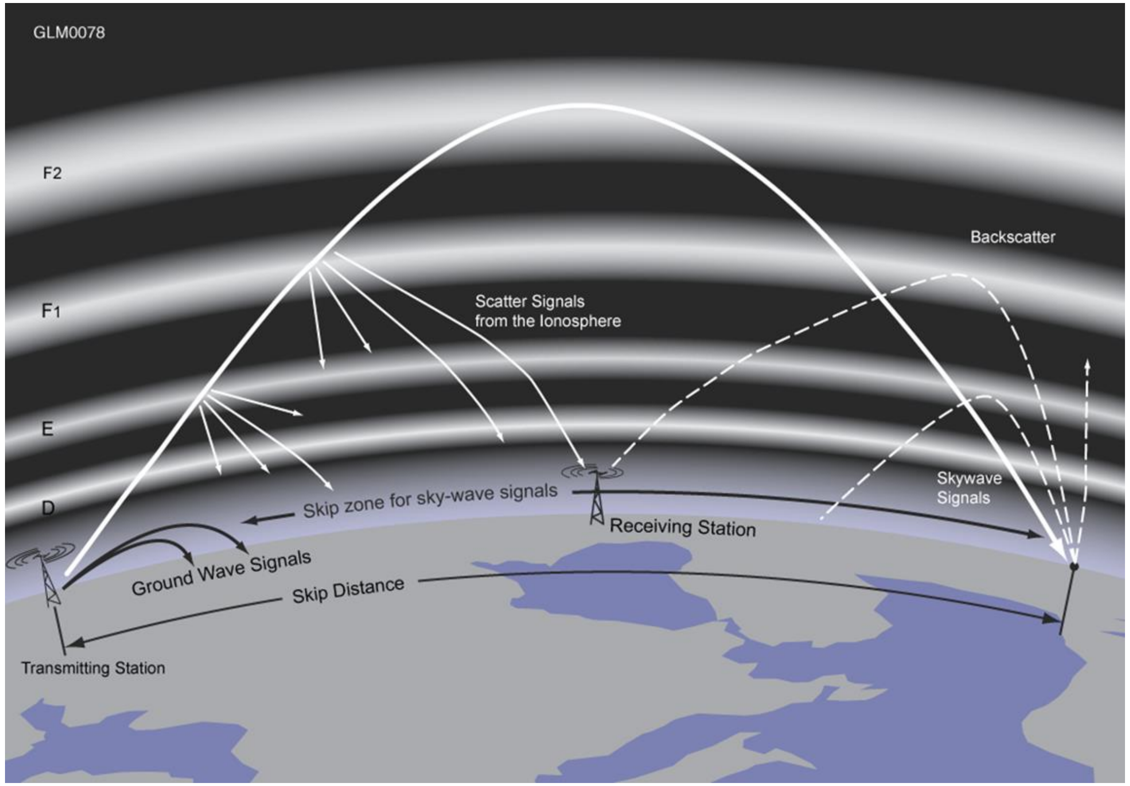
- Scatter Characteristics
  - Reflections are not very efficient and tend to spread out, providing only weak signal to the receiving station (G3C08)
  - Signals typically have a fluttering or **wavering** sound (G3C06)
  - Received signals may arrive from several different paths resulting in distortion (G3C07)



Scatter Modes

8-12 to 14

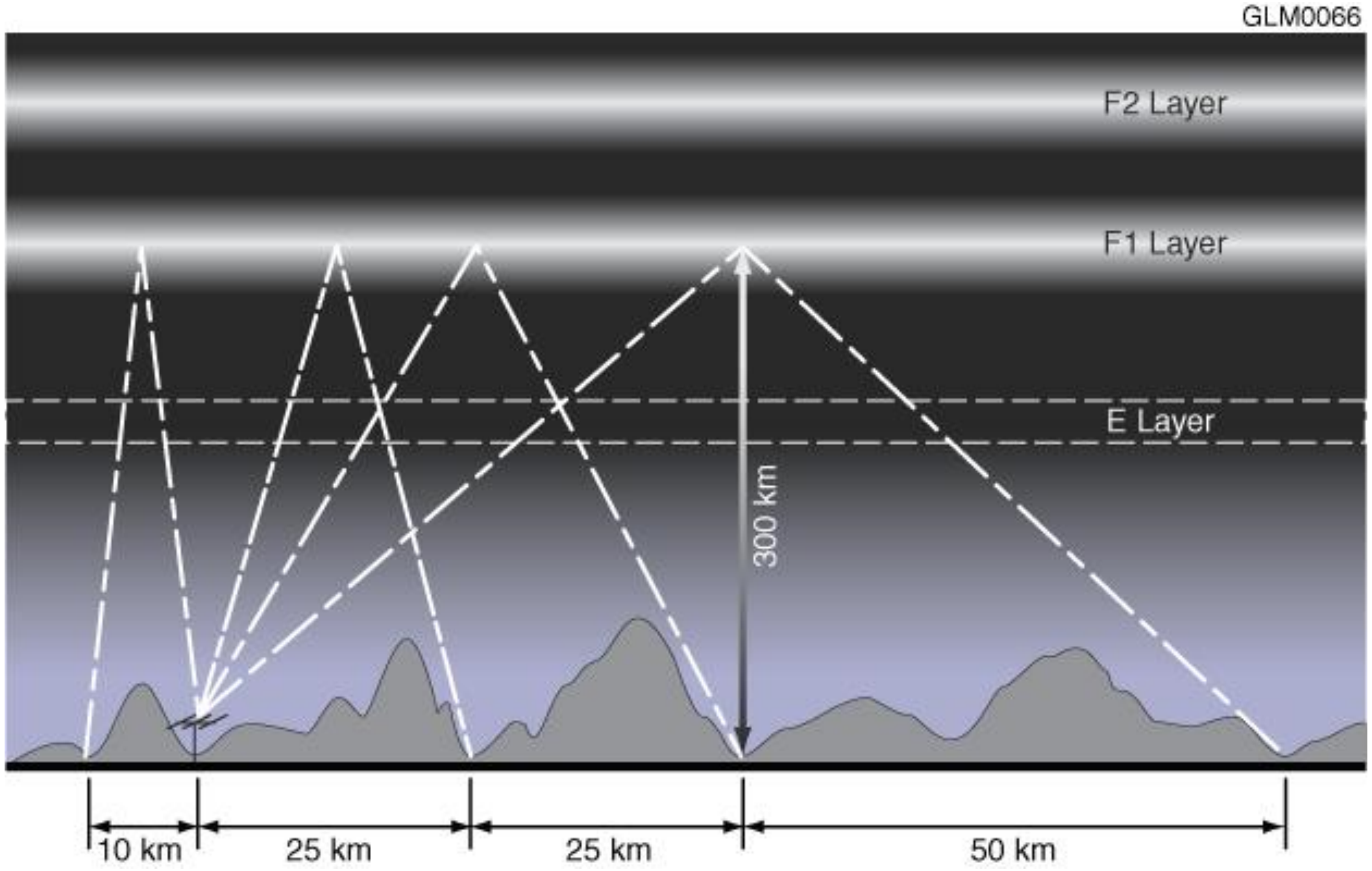
- Scatter Characteristics
  - Back scatter helps fill in the skip zone between groundwave and normal sky-wave (G3C09)
  - Back scatter signal may be weak and have a wavering sound (due to multiple signals being received) (G3C06 and G3C08)



NVIS Reflections (Near Vertical Incidence Sky-wave) 8-13 & 14

NVIS is short-distance MF or HF communications using high elevation angles. (G3C10)

- MF: 160m
- HF: 80, 60, 40m



Scatter Modes - NVIS

8-13 & 14

- Provides for short-distance MF or HF propagation using high angles of radiation.
  - Reflections from a signal radiating vertically are scattered back to Earth within a 200-300 mile range around the transmitting station
- Horizontal dipoles placed close to the ground (⅛ to ¼ wavelength high) have an omnidirectional pattern at **very high angles**
- NVIS works best at 40 meters and lower-frequency bands
- Two local NVIS nets:
  - Tuesdays, 8:30 pm, 3.820 MHz SSB – KS & Western MO, SATERN
  - Wednesdays, 6:45 pm, 3.540 CW – Johnson Co ARES

Practical Propagation Considerations

- Most HF QSO are conducted to wherever the band happens to be open to.
  - i.e. When calling CQ, the response will likely come from a station that is hearing you well.
- Under good propagation conditions, a QRP rig and good antenna will work DX
- Under poor propagation conditions, it can be difficult to communicate with 100W or even 1000 W, particularly between a given point A and a point B.
- In your first few months of HF operation, you will learn a lot about propagation
- Vertical antennas work poorly for NVIS communications
- Some digital modes (FT8) can take a “dead” band and yield many contacts

Practice Questions

What makes HF scatter signals often sound distorted?

A. The ionospheric layer involved is unstable

B. Ground waves are absorbing much of the signal

C. The E-region is not present

D. Energy is scattered into the skip zone through several different radio wave paths

G3C07

What makes HF scatter signals often sound distorted?

A. The ionospheric layer involved is unstable

B. Ground waves are absorbing much of the signal

C. The E-region is not present

D. Energy is scattered into the skip zone through several different radio wave paths

G3C07

What type of radio wave propagation allows a signal to be detected at a distance too far for ground wave propagation but too near for normal sky-wave propagation?

A. Faraday rotation

B. Scatter

C. Sporadic-E skip

D. Short-path skip

G3C09

What type of radio wave propagation allows a signal to be detected at a distance too far for ground wave propagation but too near for normal sky-wave propagation?

A. Faraday rotation

B. Scatter

C. Sporadic-E skip

D. Short-path skip

G3C09