Lesson 12: Signal Propagation

Preparation for
Amateur Radio
Technician Class
Exam

Topics

- HF Propagation
- Ground-wave
- Sky-wave
- Ionospheric regions
- VHF/UHF Propagation
- Line-of-sight
- Tropospheric Bending and Ducting
- VHF/UHF Signals through the Ionosphere
- Exam Questions for this section

Reading

- Chapter 3

Propagation

- Propagation – how radio waves travel
- The 4 basic ways radio waves travel (propagate) are:
  - Directly from one point to another (line-of-sight)
  - Travel along the ground (ground-wave)
  - Refract off the atmosphere (sky-wave)
  - Travel inside the atmosphere (ducting)

HF Propagation

- Radio waves in the HF band can travel fairly long distances due to their relatively long wavelength
- The two major kinds of HF Propagation are:
  - Ground-wave
  - Sky-wave

Ground-wave Propagation

- HF signals travel along the Earth's surface, even over hills
- They follow the curvature of the Earth for distances up to 100 miles, depending on the actual frequency and the terrain

Sky-wave Propagation

- HF signals can be refracted or bent off the ionosphere
- Transmission distance is very long, depending on ionospheric conditions and frequency
  - Contacts of up to 2500 miles are possible with one skip (refraction)
  - Worldwide communication is possible with several skips (multi-hops) when conditions are right

Ionization

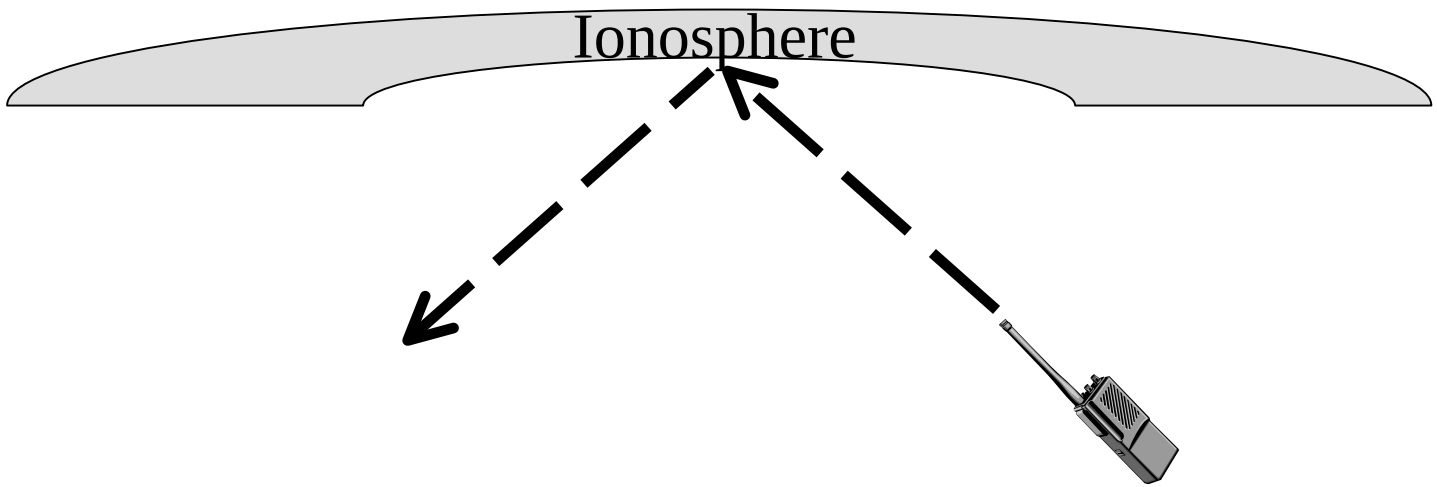
- The Earth's upper atmosphere (from 25 to 200 miles high) is made up of many neutral gas atoms (neither positive nor negative)
  - It is called the ionosphere
- This part of the atmosphere is affected by Ultraviolet Radiation (UV) from the sun
- The UV causes the atmosphere to become ionized (gas atoms take on a positive or negative charge)
- When the ionosphere is ionized, it refracts radio waves

Ionization

- Ionization is affected by:
  - Time of day – mid-day is best, just before sunrise is worst
  - Time of year – summer is best
  - Sunspot cycle – the more sunspots, the more ionization; sunspot activity varies on an 11 year cycle

Bounce, Skip or Hop

- A radio wave will bounce (skip, hop) off the ionosphere at roughly the same angle that it strikes the ionosphere
  - A lower angle of entry generally means your signal will travel farther



Refraction

- The level of refraction depends on the amount of ionization
  - Higher ionization means a larger range of frequencies are refracted
- The ionosphere does not refract all frequencies the same
  - Lower frequencies refract better

MUF

- The Maximum Usable Frequency (MUF) is the highest frequency at which the ionosphere bends radio waves back to a desired location on Earth
  - There are different MUF depending on where you want to send a signal
  - The MUF is determined by time of day, ionospheric conditions, and source and target of communication
    - New York to Germany is a different MUF than Ashland to Germany
    - MUF from Ashland to Germany in a low sunspot cycle is lower than the MUF from Ashland to Germany in a high sunspot cycle

Critical Frequency

- The Critical Frequency is the highest frequency where radio waves transmitted straight up into the ionosphere will be reflected back down to Earth
  - Above the critical frequency, radio waves pass through the ionosphere and go out into space
- The Critical Frequency depends on ionospheric conditions

Ionospheric Regions

- The ionosphere is actually made of several regions:
  - D – the lowest region affecting propagation
    - 35 to 60 miles above the earth
    - Ionization dissipates quickly
    - Maximum ionization at noon
    - Gone by sunset
    - Ineffective at refraction
    - Absorbs RF energy
- Bottom line – this region closest to the Earth mostly interferes (rather than helps) with radio transmissions

Ionospheric Regions

- E – the middle region affecting propagation
  - 60-70 miles above the earth
  - Ionization dissipates quickly
  - Maximum ionization at noon
  - Gone by sunset
  - Does some refraction, about 1250 miles for one hop

➢ Bottom line – this region is mostly used for relatively short range hops in the daytime

Ionospheric Regions

- F – the highest region affecting propagation
  - About 100-310 miles above the earth
  - Splits in 2 parts in the daytime
    - F1 – 140 miles
    - F2 – 200 miles
  - Ionization lingers through the night
  - Maximum ionization at noon
  - The most used region for skipping radio signals

➢ Bottom line – The F2 region is the most used region for propagation, responsible for almost all long-distance HF communication

VHF/UHF Propagation

- VHF and UHF bands are typically used for relatively short-range communication
  - They are not as good at ground wave propagation
  - UHF radio waves do not travel by sky-wave propagation
  - It avoids interference with people doing long-distance communication on the HF bands

Line-of-sight Propagation

- Line-of-sight propagation – when radio signals travel in a straight line from the transmitting antenna to the receiving antenna
  - This is the most common propagation when using repeaters or when communicating in simplex directly with another ham
  - Typically in distances much shorter than 100 miles
  - Subject to reflection off buildings, hills, and airplanes

Tropospheric Bending

- The troposphere is the region near Earth where all our weather occurs, reaching to a height of about 7 miles
- Slight refraction of VHF/UHF radio waves occurs in this region
  - It is most useful at 144 Mhz and above

Tropospheric Bending

- There is some signal loss as radio waves travel a path through the troposphere
  - The path loss increases as the frequency increases
- For DX (long distance) work in VHF and UHF bands, hams typically use the weak-signal modes such as CW or SSB

Tropospheric Ducting

- This is where radio waves get trapped in the troposphere, traveling a longer distance than normal before coming back to Earth
- In the case of a temperature inversion (warm air above cold) a “duct” can form between the temperature layers
  - Radio waves travel quite a ways in the duct before returning to Earth
  - This is most commonly seen over large bodies of water, such as oceans

Tropospheric Ducting

- VHF and UHF signals can travel quite far using tropospheric ducting
  - 950 miles or more over land
  - 2500 miles or more over ocean

VHF/UHF Signals through Ionosphere

- Sporadic-E or E-skip propagation is a summer time phenomenon
- When it happens, it allows propagation of the 6 meter band off the E region of the ionosphere

Exam Questions

- The following slides contain questions from the exam pool that are covered in this section of the notes

T3A01

- T3A01 What is the name of the area of the atmosphere that makes long-distance radio communications possible by bending radio waves?
  - A. Troposphere
  - B. Stratosphere
  - C. Magnetosphere
  - D. Ionosphere

T3A02

- T3A02 Which ionospheric region is closest to the Earth?
  - A. The A region
  - B. The D region
  - C. The E region
  - D. The F region

T3A03

- T3A03 Which region of the ionosphere is mainly responsible for absorbing MF/HF radio signals during the daytime?
  - A. The F2 region
  - B. The F1 region
  - C. The E region
  - D. The D region

T3A04

- T3A04 Which region of the ionosphere is mainly responsible for long-distance sky-wave radio communications?
  - A. D region
  - B. E region
  - C. F1 region
  - D. F2 region

T3A05

- T3A05 When a signal travels along the surface of the Earth, what is this called?
  - A. Sky-wave propagation
  - B. Knife-edge diffraction
  - C. E-region propagation
  - D. Ground-wave propagation

T3A06

- T3A06 What type of solar radiation is most responsible for ionization in the outer atmosphere?
  - A. Thermal
  - B. Non-ionized particle
  - C. Ultraviolet
  - D. Microwave

T3A07

- T3A07 What is the usual cause of sky-wave propagation?
  - A. Signals are reflected by a mountain
  - B. Signals are reflected by the Moon
  - C. Signals are bent back to Earth by the ionosphere
  - D. Signals are retransmitted by a repeater

T3A08

- T3A08 What type of propagation has radio signals bounce several times between Earth and the ionosphere as they travel around the Earth?
  - A. Multiple bounce
  - B. Multi-hop
  - C. Skip
  - D. Pedersen propagation

T3A09

- T3A09 What effect does the D region of the ionosphere have on lower-frequency HF signals in the daytime?
  - A. It absorbs the signals
  - B. It bends the radio waves out into space
  - C. It refracts the radio waves back to earth
  - D. It has little or no effect on 80-meter radio waves

T3A11

- T3A11 When a signal is returned to Earth by the ionosphere, what is this called?
  - A. Sky-wave propagation
  - B. Earth-Moon-Earth propagation
  - C. Ground-wave propagation
  - D. Tropospheric propagation

T3A12

- T3A12 How does the range of sky-wave propagation compare to ground-wave propagation?
  - A. It is much shorter
  - B. It is much longer
  - C. It is about the same
  - D. It depends on the weather

T3B07

- T3B07 How does the number of sunspots relate to the amount of ionization in the ionosphere?
  - A. The more sunspots there are, the greater the ionization
  - B. The more sunspots there are, the less the ionization
  - C. Unless there are sunspots, the ionization is zero
  - D. Sunspots do not affect the ionosphere

T3B08

- T3B08 How long is an average sunspot cycle?
  - A. 2 years
  - B. 5 years
  - C. 11 years
  - D. 17 years

T3B11

- T3B11 What is the condition of the ionosphere above a particular area of the Earth just before local sunrise?
  - A. Atmospheric attenuation is at a maximum
  - B. The D region is above the E region
  - C. The E region is above the F region
  - D. Ionization is at a minimum

T3B12

- T3B12 What happens to signals that take off vertically from the antenna and are higher in frequency than the critical frequency?
  - A. They pass through the ionosphere
  - B. They are absorbed by the ionosphere
  - C. Their frequency is changed by the ionosphere to be below the maximum usable frequency
  - D. They are reflected back to their source

T3B13

- T3B13 In relation to sky-wave propagation, what does the term "maximum usable frequency" (MUF) mean?
  - A. The highest frequency signal that will reach its intended destination
  - B. The lowest frequency signal that will reach its intended destination
  - C. The highest frequency signal that is most absorbed by the ionosphere
  - D. The lowest frequency signal that is most absorbed by the ionosphere

T3A10

- T3A10 How does the signal loss for a given path through the troposphere vary with frequency?
  - A. There is no relationship
  - B. The path loss decreases as the frequency increases
  - C. The path loss increases as the frequency increases
  - D. There is no path loss at all

T3B01

- T3B01 When a signal travels in a straight line from one antenna to another, what is this called?
  - A. Line-of-sight propagation
  - B. Straight line propagation
  - C. Knife-edge diffraction
  - D. Tunnel ducting

T3B02

- T3B02 What can happen to VHF or UHF signals going towards a metal-framed building?
  - A. They will go around the building
  - B. They can be bent by the ionosphere
  - C. They can be reflected by the building
  - D. They can be polarized by the building's mass

T3B03

- T3B03 Ducting occurs in which region of the atmosphere?
  - A. F2
  - B. Ecosphere
  - C. Troposphere
  - D. Stratosphere

T3B04

- T3B04 What causes VHF radio waves to be propagated several hundred miles over oceans?
  - A. A polar air mass
  - B. A widespread temperature inversion
  - C. An overcast of cirriform clouds
  - D. A high-pressure zone

T3B05

- T3B05 In which of the following frequency ranges does sky-wave propagation least often occur?
  - A. LF
  - B. UHF
  - C. HF
  - D. VHF

T3B06

- T3B06 Why should local amateur communications use VHF and UHF frequencies instead of HF frequencies?
  - A. To minimize interference on HF bands capable of long-distance communication
  - B. Because greater output power is permitted on VHF and UHF
  - C. Because HF transmissions are not propagated locally
  - D. Because signals are louder on VHF and UHF frequencies

T3B09

- T3B09 Which of the following frequency bands is most likely to experience summertime sporadic-E propagation?
  - A. 23 centimeters
  - B. 6 meters
  - C. 70 centimeters
  - D. 1.25 meters

T3B10

- T3B10 Which of the following emission modes are considered to be weak-signal modes and have the greatest potential for DX contacts?
  - A. Single sideband and CW
  - B. Packet radio and RTTY
  - C. Frequency modulation
  - D. Amateur television