General License Class

Chapter 8

Propagation

The Ionosphere

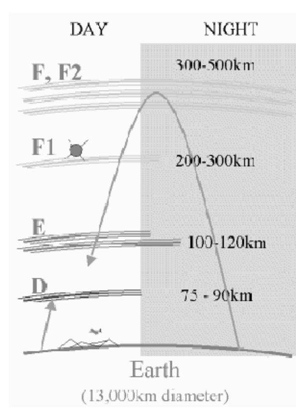
- Regions
  - Ionosphere.
    - A region of the atmosphere extending from 30 miles to 300 miles above the surface of the earth.
    - Solar radiation causes atoms in the ionosphere to become ionized.

The Ionosphere

- Regions
  - Ionosphere.
    - The ionosphere organizes itself into regions or "layers".
      - Varies with strength of ionization.
        - D-region disappears at night.
        - F-region splits into F_1 & F_2 regions during the day.

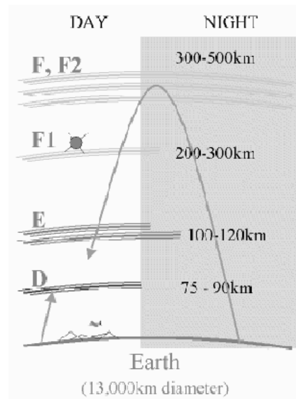
The Ionosphere

- Regions
  - D-Layer.
    - 30-60 miles altitude.
    - Rapidly disappears at sunset.
    - Rapidly re-forms at sunrise.
    - Absorbs long wavelength radio waves.
      - 160m, 80m, & 40m.



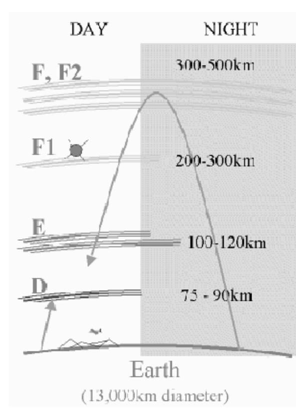
The Ionosphere

- Regions
  - E-Layer.
    - 60-70 miles altitude.
      - One hop up to 1200 miles.
    - Similar to D-layer.
      - Lasts longer into the night.
      - Less absorption.
    - Auroral propagation.
    - Sporadic-E skip.
      - 10m, 6m, & 2m.



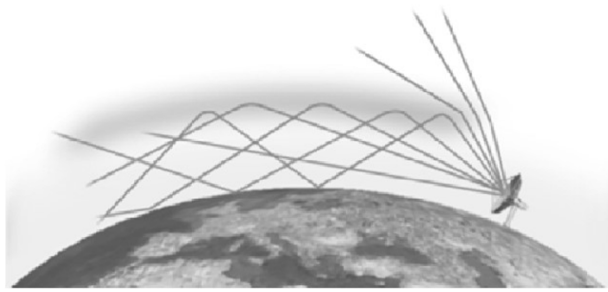
The Ionosphere

- Regions
  - F-Layer.
    - 100-300 miles altitude.
      - One-hop up to 2500 miles.
    - Can remain ionized all night.
    - Splits into F1-layer & F2-layer during the day.
      - F1-layer = 100-140 miles.
      - F2-layer = 200-300 miles.
    - Long-range HF propagation.



The Ionosphere

- Reflection & Absorption
  - Radio waves are refracted (bent) in the ionosphere.



The Ionosphere

- Reflection & Absorption
  - Radio waves are refracted (bent) in the ionosphere.
    - The stronger the ionization level, the more the waves will be bent.
    - The shorter the wavelength (higher frequency), the less the waves will be bent.
      - VHF & UHF are only slightly bent & almost never enough to return to earth.

The Ionosphere

- Reflection & Absorption
  - Radio waves are refracted (bent) in the ionosphere.
    - Critical angle.
      - Maximum angle at which radio waves are bent enough to return to earth.
      - Critical angle decreases with increasing frequency.
      - One reason why a low angle of radiation is important for working DX.

The Ionosphere

- Reflection & Absorption
  - Radio waves are refracted (bent) in the ionosphere.
    - Critical frequency.
      - Highest frequency at which radio waves sent straight up are bent enough to return to earth.
      - Important for NVIS operation.

The Ionosphere

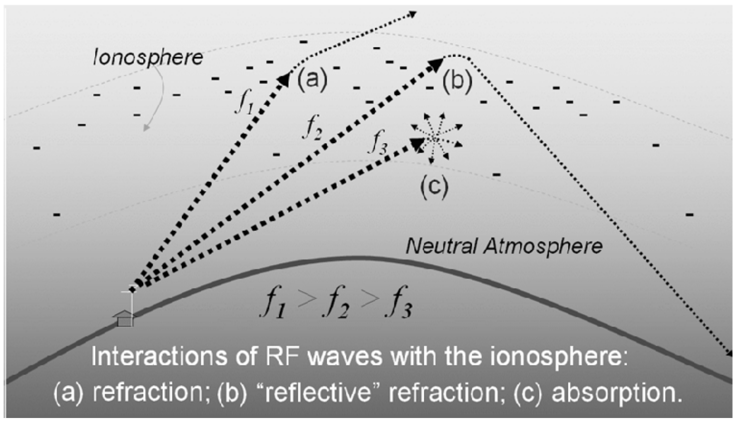
- Reflection & Absorption
  - Absorption.
    - Atmosphere is denser at lower altitudes, causing part of the RF energy to be absorbed.
      - The longer the wavelength (lower frequency), the higher the amount of absorption.

The Ionosphere

- Reflection & Absorption
  - Absorption.
    - D-region.
      - Almost no refraction (bending) of radio waves.
      - Almost completely absorbs radio waves below 10 MHz.
    - E-region.
      - More refraction than D-region.
      - Less absorption than D-region.

The Ionosphere

- Reflection & Absorption



The Ionosphere

- Sky-Wave & Ground-Wave Propagation.
  - Sky-Wave.
    - Refracting radio waves back to earth using the ionosphere (a.k.a. – skip).
    - Each trip from earth to ionosphere & back to earth is called a "hop".
    - Multiple hops are common.

The Ionosphere

- Sky-Wave & Ground-Wave Propagation.
  - Sky-Wave.
    - Maximum distance of a single hop depends on altitude of the region where refraction takes place.
      - E-region = Single hop can be up to 1200 miles.
      - F-region = Single hop can be up to 2500 miles.

The Ionosphere

- Sky-Wave & Ground-Wave Propagation.
  - Sky-Wave.
    - Hops considerably less than the maximum distance is called short skip.
      - Higher critical angle
    - Short skip is a good indicator that skip is possible on a higher frequency band.
    - Fluttery sound result of irregularities in ionization region causing multiple paths.

The Ionosphere

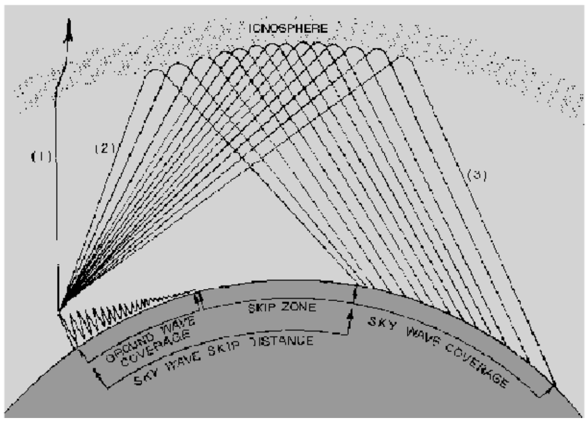
- Sky-Wave & Ground-Wave Propagation.
  - Ground-Wave.
    - Radio waves can follow along the surface of the earth.
      - Primarily vertically polarized.
      - Losses in earth cause rapid decrease of signal strength for increasing distance.
        - Higher frequency → higher loss.

The Ionosphere

- Sky-Wave & Ground-Wave Propagation.
  - Skip distance.
    - Distance from transmitter where radio wave first returns to earth.
  - Skip zone.
    - Too close for sky-wave propagation, but too far for ground-wave propagation.

The Ionosphere

- Sky-Wave & Ground-Wave Propagation.



The Ionosphere

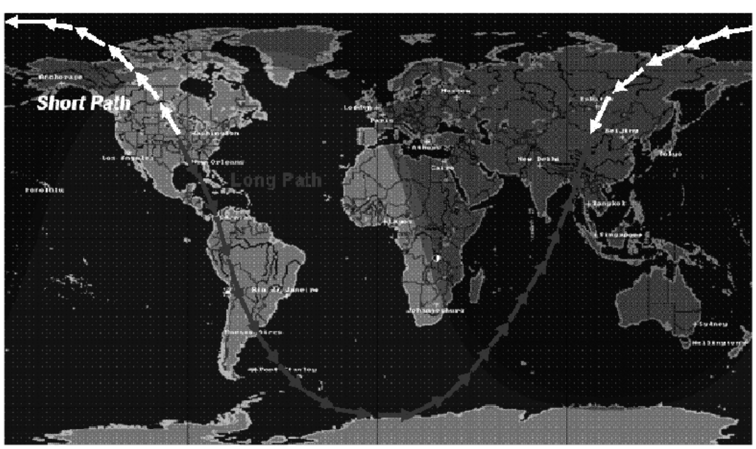
- Long Path & Short Path
  - Short path.
    - Direct route between stations
    - Shortest distance.
  - Long path.
    - 180° from short path.
    - Longest distance.

The Ionosphere

- Long Path & Short Path
  - Conditions may not support short path, but long path may be possible.
  - Echo indicates both short & long paths are open.

The Ionosphere

- Long Path & Short Path



G2D06 -- How is a directional antenna pointed when making a "long-path" contact with another station?

A. Toward the rising Sun

B. Along the gray line

C. 180 degrees from its short-path heading

D. Toward the north

G3B01 -- How might a sky-wave signal sound if it arrives at your receiver 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 well-defined echo might be heard

G3B02 -- Which of the following is a good indicator of the possibility of sky-wave propagation on the 6 meter band?

A. Short skip sky-wave propagation on the 10 meter band
B. Long skip sky-wave propagation on the 10 meter band
C. Severe attenuation of signals on the 10 meter band
D. Long delayed echoes on the 10 meter band

G3B09 -- What is the approximate maximum distance along the Earth's surface that is normally covered in one hop using the F2 region?

A. 180 miles
B. 1,200 miles
C. 2,500 miles
D. 12,000 miles

G3B10 -- What is the approximate maximum distance along the Earth's surface that is normally covered in one hop using the E region?

A. 180 miles
B. 1,200 miles
C. 2,500 miles
D. 12,000 miles

G3C01 -- Which of the following ionospheric layers is closest to the surface of the Earth?

A. The D layer
B. The E layer
C. The F1 layer
D. The F2 layer

G3C02 -- Where on the Earth do ionospheric layers reach their maximum height?

A. Where the Sun is overhead
B. Where the Sun is on the opposite side of the Earth
C. Where the Sun is rising
D. Where the Sun has just set

G3C03 -- Why is the F2 region mainly responsible for the longest distance radio wave propagation?

A. Because it is the densest ionospheric layer
B. Because it does not absorb radio waves as much as other ionospheric regions
C. Because it is the highest ionospheric region
D. All of these choices are correct

G3C04 -- What does the term “critical angle” mean as used in radio wave propagation?

A. The long path azimuth of a distant station
B. The short path azimuth of a distant station
C. The lowest takeoff angle that will return a radio wave to the Earth under specific ionospheric conditions
D. The highest takeoff angle that will return a radio wave to the Earth under specific ionospheric conditions

G3C05 -- Why is long distance communication on the 40, 60, 80 and 160 meter bands more difficult during the day?

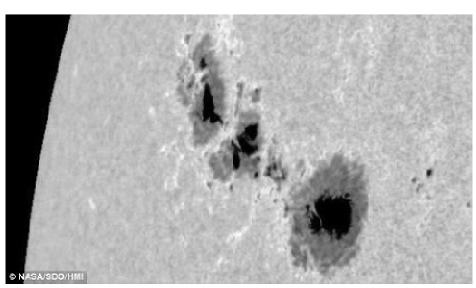
A. The F layer absorbs signals at these frequencies during daylight hours
B. The F layer is unstable during daylight hours
C. The D layer absorbs signals at these frequencies during daylight hours
D. The E layer is unstable during daylight hours

G3C12 -- Which ionospheric layer is the most absorbent of long skip signals during daylight hours on frequencies below 10 MHz?

A. The F2 layer
B. The F1 layer
C. The E layer
D. The D layer

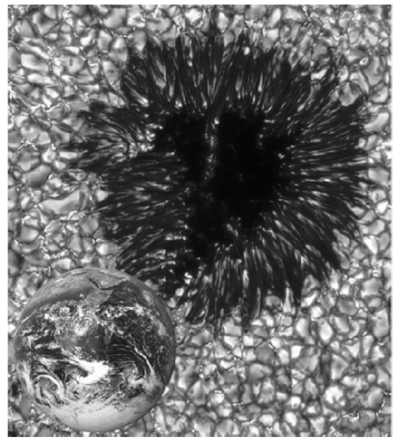
The Sun

- Sunspots & Cycles
  - Sunspots.
    - Areas of intense magnetic activity on the surface (photosphere) of the sun.



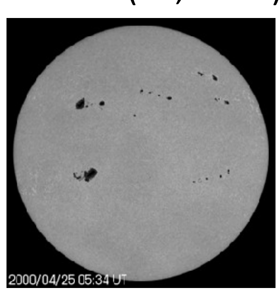
The Sun

- Sunspots & Cycles
  - Sunspots.
    - Up to 50,000 miles in diameter.
    - Emit UV radiation which ionizes earth's atmosphere.
    - Earliest observation dates from 354 BC.



The Sun

- Sunspots & Cycles
  - Sunspots.
    - Cooler in temperature (4,900°F to 7,600°F) than surrounding surface (10,000°F) so they appear darker.



The Sun

- Sunspots & Cycles
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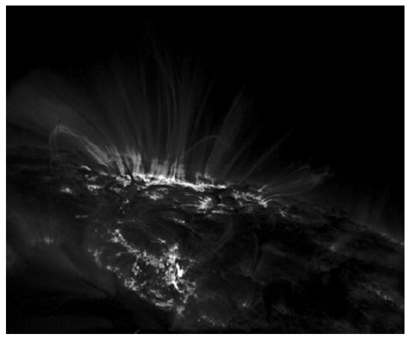
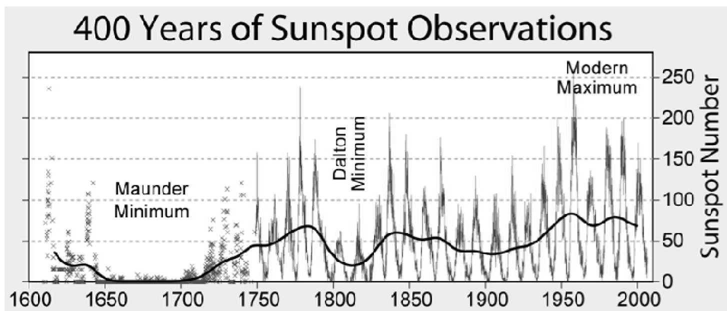


The Sun

- Sunspots & Cycles
  - Sunspots.
    - Life span of less than a day to a few weeks.
    - Stationary on sun’s surface.
    - Appear to move because of sun’s rotation.
      - Sunspots rotate back into view every 28 days.

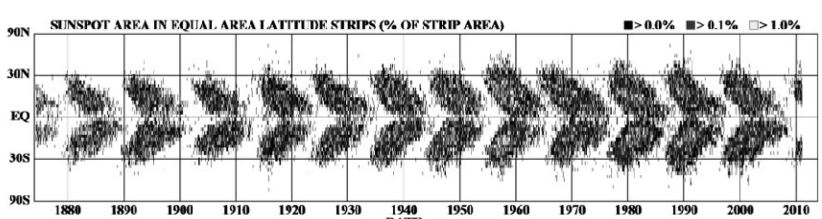
The Sun

- Sunspots & Cycles
  - Solar Cycles.
    - Number of sunspots varies in 11-year cycles.



The Sun

- Sunspots & Cycles
  - Solar Cycles.
    - At beginning of cycle, sunspots appear at mid latitudes & appear closer to equator as cycles progresses.



The Sun

- Sunspots & Cycles
  - Solar Cycles.
    - At peak of solar cycle, ionization level can be high enough that 10m stays open all night.
    - At minimum of solar cycle, bands above 20m may not be open at all.

The Sun

- Sunspots & Cycles
  - Solar Cycles.
    - Strong seasonal & daily variations in propagation.
      - Seasonal variations due to different levels of ionization between summer & winter.
      - Seasonal variations on lower bands due to lower atmospheric noise during winter months.
      - Daily variations due to different levels of ionization between day & night.

The Sun

- Measuring Solar Activity
  - Sunspot number (SSN).
    - SSN = 10 x Nr of groups + Nr of sunspots.
    - Average of observations from many different locations.
  - Solar flux index (SFI).
    - Measure of 10.7 cm (2.8 GHz) solar radiation.
      - Indicator of UV radiation.
    - Minimum value = 65, no maximum.

The Sun

- Measuring Solar Activity
  - K-index (K_P).
    - Measure of short-term stability of earth's magnetic field.
    - Minimum value = 0
    - Maximum value = 9.
    - Updated every 3 hours.
    - Higher values → Poorer HF propagation.

K-Index	Meaning
0	Inactive
1	Very quiet
2	Quiet
3	Unsettled
4	Active
5	Minor storm
6	Major storm
7	Severe storm
8	Very severe storm
9	Extremely severe storm

The Sun

- Measuring Solar Activity
  - A-index (A_P).
    - Measure of long-term stability of earth's magnetic field.
    - Minimum value = 0, maximum value = 400.
    - Calculated from previous 8 K-index values.
    - Higher values → Poorer HF propagation.

A-Index	Meaning
0-7	Quiet
8-15	Unsettled
16-29	Active
30-49	Minor storm
50-99	Major storm
100-400	Severe storm

The Sun

- Assessing Propagation
  - Maximum useable frequency (MUF).
    - Highest frequency that will allow communications between 2 points.
      - Radio waves on frequencies below the MUF will be refracted back to earth.
      - Radio waves on frequencies above the MUF will be lost into space.
      - Use a frequency just below the MUF for the best results.

The Sun

- Assessing Propagation
  - Lowest useable frequency (LUF).
    - Lowest frequency that will allow communications between 2 points.
      - Radio waves on frequencies below the LUF will be absorbed by the D-region.
      - If the MUF drops below the LUF, then sky-wave communications are not possible between those 2 points.

The Sun

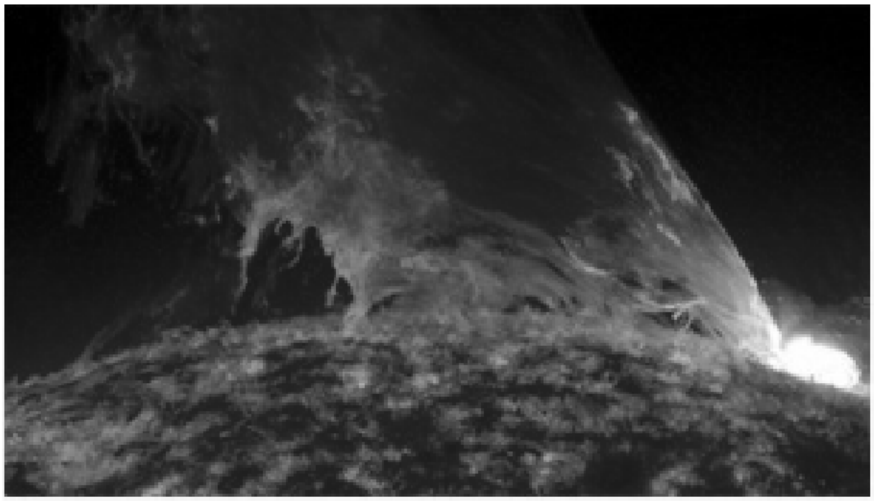
- Assessing Propagation
  - International beacons.
    - Transmitters placed at 18 locations around the world.
      - Sponsored by the NCDXF & the IARU.
    - 14.100 MHz, 18.110 MHz, 21.150 MHz, 24.930 MHz, & 28.200 MHz.
    - Sends callsign (22 wpm) followed by 4 1-second dashes.
      - Callsign & 1st dash = 100 Watts.
      - 2nd dash = 10 Watts.
      - 3rd dash = 1 Watt.
      - 4th dash = 0.1 Watt.

The Sun

- Assessing Propagation
  - Software.
    - VOACAP
      - Voice of America Coverage Analysis Program
      - Online predictions.
        - http://www.voacap.com/prediction.html
        - http://www.voacap.com/coverage.html
  - **Ignore the predictions – just listen!**

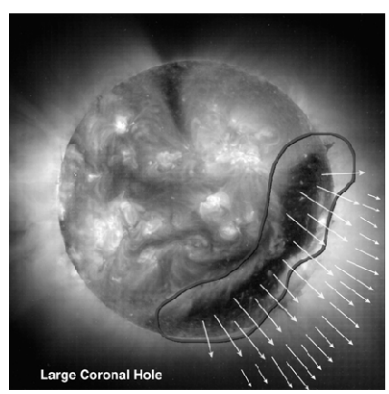
The Sun

- Solar Disturbances
  - Solar flare.
    - A large eruption of energy & particles from surface of the sun.
      - Caused by disruptions of the sun’s magnetic field.
      - Takes about 8 minutes for energy to reach earth.



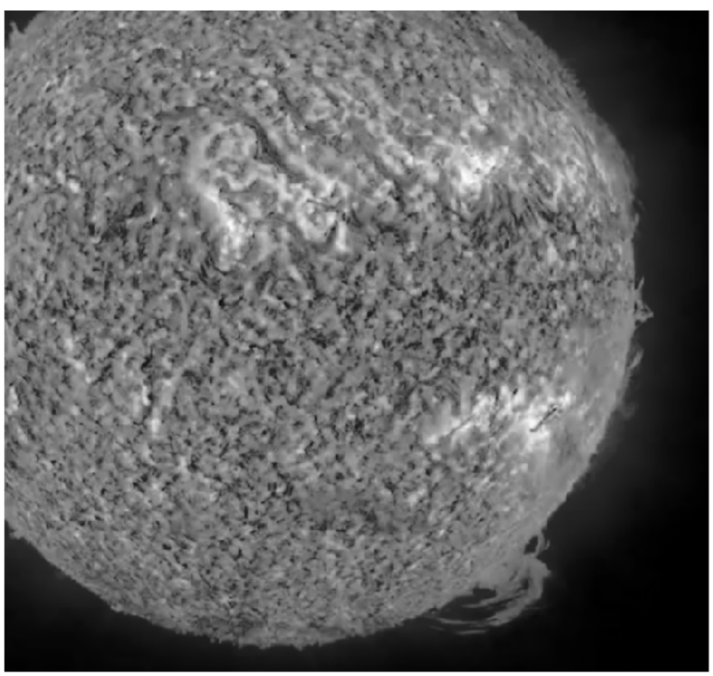
The Sun

- Solar Disturbances
  - Coronal hole.
    - A weak area in the corona through which plasma can escape the sun's magnetic field & stream through space at high velocity.



The Sun

- Solar Disturbances
  - Coronal mass ejection (CME).
    - Ejection of a large amount of material from the corona.
    - Narrow beam or wide area.
    - Often associated with a large solar flare.
    - Takes about 20-40 hours for particles to reach earth.



The Sun

- Solar Disturbances
  - Sudden ionospheric disturbance (SID).
    - UV-rays & X-rays from a solar flare travel to earth at the speed of light (186,000 mi/sec).
      - Reach earth in about 8 minutes.
    - Greatly increases ionization level of D-region.
      - Lower frequencies more greatly affected.
    - Can last from a few seconds to several hours.
    - Only affects sunlit side of earth.

The Sun

- Solar Disturbances
  - Geomagnetic disturbances.
    - CME's greatly increase strength of solar wind.
      - A continuous stream of charged particles.
      - Reaches earth in about 20-40 hours.
    - Particles become trapped in the magnetosphere near both poles increasing ionization of E-region & creating a geomagnetic storm.

The Sun

- Solar Disturbances
  - Geomagnetic disturbances.
    - High-latitude HF propagation greatly decreased.
      - Can last several hours to a few days.
    - Auroral activity greatly increased.
      - Reflection possible on 15m & up.
        - Strongest on 6m & 2m.
      - Signals modulated with hiss or buzz.
        - CW.

The Sun

- Solar Disturbances

Break

G3A01 -- What is the significance of the sunspot number with regard to HF propagation?

A. Higher sunspot numbers generally indicate a greater probability of good propagation at higher frequencies

B. Lower sunspot numbers generally indicate greater probability of sporadic E propagation

C. A zero sunspot number indicate radio propagation is not possible on any band

D. All of these choices are correct.

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

G3A03 -- Approximately how long does it take the increased ultraviolet and X-ray radiation from solar flares to affect radio-wave propagation on the Earth?

A. 28 days
B. 1 to 2 hours
C. 8 minutes
D. 20 to 40 hours

G3A04 -- Which of the following amateur radio HF frequencies are least reliable for long distance communications during periods of low solar activity?

A. 80 meters and 160 meters
B. 60 meters and 40 meters
C. 30 meters and 20 meters
D. 15 meters, 12 meters and 10 meters

G3A05 -- What is the solar-flux index?

A. A measure of the highest frequency that is useful for ionospheric propagation between two points on the Earth
B. A count of sunspots which is adjusted for solar emissions
C. Another name for the American sunspot number
D. A measure of solar radiation at 10.7 centimeters wavelength

G3A06 -- What is a geomagnetic storm?

A. A sudden drop in the solar-flux index
B. A thunderstorm which affects radio propagation
C. Ripples in the ionosphere
D. A temporary disturbance in the Earth's magnetosphere

G3A07 -- At what point in the solar cycle does the 20 meter band usually support worldwide propagation during daylight hours?

A. At the summer solstice
B. Only at the maximum point of the solar cycle
C. Only at the minimum point of the solar cycle
D. At any point in the solar cycle

G3A08 -- Which of the following effects can a geomagnetic storm have on radio-wave propagation?

A. Improved high-latitude HF propagation
B. Degraded high-latitude HF propagation
C. Improved ground-wave propagation
D. Improved chances of UHF ducting

G3A09 -- What effect does a high sunspot number have on radio communications?

A. High-frequency radio signals become weak and distorted
B. Frequencies above 300 MHz become usable for long-distance communication
C. Long-distance communication in the upper HF and lower VHF range is enhanced
D. Microwave communications become unstable

G3A10 -- What causes HF propagation conditions to vary periodically in a 28-day cycle?

A. Long term oscillations in the upper atmosphere
B. Cyclic variation in the Earth's radiation belts
C. The Sun's rotation on its axis
D. The position of the Moon in its orbit

G3A11 -- Approximately how long is the typical sunspot cycle?

A. 8 minutes
B. 40 hours
C. 28 days
D. 11 years

G3A12 -- What does the K-index indicate?

A. The relative position of sunspots on the surface of the Sun
B. The short term stability of the Earth’s magnetic field
C. The stability of the Sun's magnetic field
D. The solar radio flux at Boulder, Colorado

G3A13 -- What does the A-index indicate?

A. The relative position of sunspots on the surface of the Sun
B. The amount of polarization of the Sun's electric field
C. The long term stability of the Earth’s geomagnetic field
D. The solar radio flux at Boulder, Colorado

G3A14 -- How are radio communications usually affected by the charged particles that reach the Earth from solar coronal holes?

A. HF communications are improved
B. HF communications are disturbed
C. VHF/UHF ducting is improved
D. VHF/UHF ducting is disturbed

G3A15 -- How long does it take charged particles from coronal mass ejections to affect radio propagation on the Earth?

A. 28 days
B. 14 days
C. 4 to 8 minutes
D. 20 to 40 hours

G3A16 -- 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

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

G3B04 -- What is a reliable way to determine if the MUF is high enough to support skip propagation between your station and a distant location on frequencies between 14 and 30 MHz?

A. Listen for signals from an international beacon
B. Send a series of dots on the band and listen for echoes from your signal
C. Check the strength of TV signals from Western Europe
D. Check the strength of signals in the MF AM broadcast band

G3B05 -- What usually happens to radio waves with frequencies below the MUF and above the LUF when they are sent into the ionosphere?

A. They are bent back to the Earth
B. They pass through the ionosphere
C. They are amplified by interaction with the ionosphere
D. They are bent and trapped in the ionosphere to circle the Earth

G3B06 -- What usually happens to radio waves with frequencies below the LUF?

A. They are bent back to the Earth
B. They pass through the ionosphere
C. They are completely absorbed by the ionosphere
D. They are bent and trapped in the ionosphere to circle the Earth

G3B07 -- What does LUF stand for?

A. The Lowest Usable Frequency for communications between two points
B. The Longest Universal Function for communications between two points
C. The Lowest Usable Frequency during a 24 hour period
D. The Longest Universal Function during a 24 hour period

G3B08 -- What does MUF stand for?

A. The Minimum Usable Frequency for communications between two points
B. The Maximum Usable Frequency for communications between two points
C. The Minimum Usable Frequency during a 24 hour period
D. The Maximum Usable Frequency during a 24 hour period

G3B11 -- What happens to HF propagation when the Lowest Usable Frequency (LUF) exceeds the Maximum Usable Frequency (MUF)?

A. No HF radio frequency will support ordinary sky-wave communications over the 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

G3B12 -- What factor or factors affect the MUF?

A. Path distance and location
B. Time of day and season
C. Solar radiation and ionospheric disturbances
D. All of these choices are correct

Scatter Modes

- Scatter Characteristics
  - Localized areas in the ionosphere can reflect radio waves as well as refract them.
    - Direction of reflection is unpredictable.
    - Reflected signals are **MUCH** weaker than refracted signals & have a wavering sound.
    - Allows propagation above the MUF.

Scatter Modes

- Scatter Characteristics
  - Backscatter.
    - Signals can be reflected from uneven terrain at the far end of the path back towards the source.

Scatter Modes

- Near Vertical Incidence Sky-wave (NVIS)
  - At frequencies below the critical frequency, signals arriving at any angle are reflected.
  - Allows communications up to 200-300 hundred miles.
  - Eliminates the “skip zone”.

Scatter Modes

- Near Vertical Incidence Sky-wave (NVIS)
  - Select a frequency below the critical frequency but high enough that absorption in the D-region is not excessive.
  - Use a horizontally-polarized antenna mounted 1/8λ to 1/4λ above the ground.
    - 10' to 12' above the ground is best.
    - A grounded wire on the ground directly beneath the antenna improves signal by up to 6 dB.

G3C06 -- What is a characteristic of HF scatter signals?

A. They have high intelligibility
B. They have a wavering sound
C. They have very large swings in signal strength
D. All of these choices are correct

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

G3C08 -- Why are HF scatter signals in the skip zone usually weak?

A. Only a small part of the signal energy is scattered into the skip zone
B. Signals are scattered from the magnetosphere which is not a good reflector
C. Propagation is through ground waves which absorb most of the signal energy
D. Propagations is through ducts in F region which absorb most of the energy

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

G3C10 -- Which of the following might be an indication that signals heard on the HF bands are being received via scatter propagation?

A. The communication is during a sunspot maximum
B. The communication is during a sudden ionospheric disturbance
C. The signal is heard on a frequency below the Maximum Usable Frequency
D. The signal is heard on a frequency above the Maximum Usable Frequency

G3C11 -- Which of the following antenna types will be most effective for skip communications on 40 meters during the day?

A. Vertical antennas
B. Horizontal dipoles placed between 1/8 and 1/4 wavelength above the ground
C. Left-hand circularly polarized antennas
D. Right-hand circularly polarized antenna

G3C13 -- What is Near Vertical Incidence Sky-wave (NVIS) propagation?

A. Propagation near the MUF
B. Short distance HF propagation using high elevation angles
C. Long path HF propagation at sunrise and sunset
D. Double hop propagation near the LUF

Questions?

Next Week

Chapter 9

Safety