General License Class

1

General Class

Chapter 8

Propagation

2

The Ionosphere

Regions

- Ionosphere.
  - The ionosphere is a portion of the atmosphere that extends from about 30 miles to about 300 miles above the surface of the Earth.
    - The ionosphere reaches its highest altitude when the sun is directly overhead.
    - Solar radiation causes atoms in the ionosphere to become ionized.

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The Ionosphere

Regions

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

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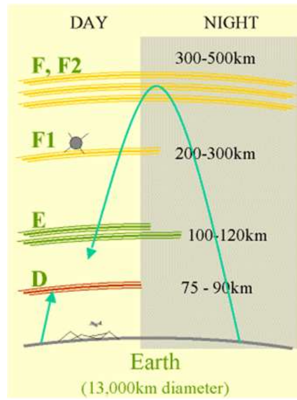
The Ionosphere

Regions

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



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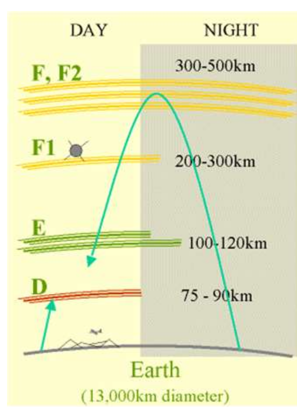
The Ionosphere

Regions

- E-Layer.
  - 60-70 miles altitude.
    - One hop up to 1200 miles.
  - Similar to the D-layer.
    - The E-layer lasts longer into the night than the D-layer.
    - The E-layer has less absorption than the D-layer.



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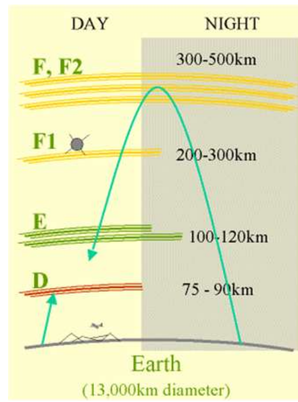
The Ionosphere

Regions

- E-Layer.
  - The E-layer is where the following types of propagation occur:
    - Auroral propagation.
    - Sporadic-E skip.
      - 10m, 6m, & 2m.
    - Meteor Scatter.



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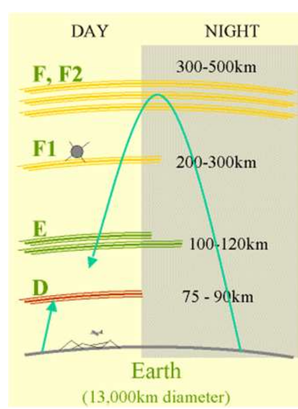
The Ionosphere

Regions

- F-Layer.
  - 100-300 miles altitude.
    - One-hop up to 2500 miles.
  - During periods of high sunspot activity, the F-layer can remain ionized all night.



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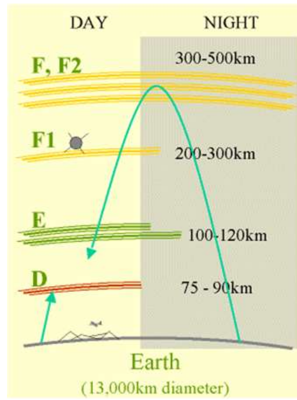
The Ionosphere

Regions

- F-Layer.
  - The F-layer splits into the F1-layer & the F2-layer during the day.
    - F1-layer = 100-140 miles.
    - F2-layer = 200-300 miles.
  - The F-layer is where long-range HF propagation occurs.



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The Ionosphere

Reflection

- 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 signals are only slightly bent & almost never enough to return to the surface of the Earth.

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The Ionosphere

Reflection

- Critical angle.
  - The maximum angle at which radio waves are bent enough to return to the surface of the Earth.
  - The critical angle decreases with increasing frequency.
  - The critical angle is one reason why a low angle of radiation is important for working DX.

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The Ionosphere

Reflection

- Critical frequency.
  - The critical frequency is the highest frequency at which radio waves sent straight up are bent enough to return to the surface of the Earth.
  - The critical frequency is important for NVIS operation.

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The Ionosphere

Absorption and Noise

- Aside from low levels of ionization in the ionosphere, the two main enemies of good propagation are absorption and noise.

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The Ionosphere

Absorption and Noise

- Absorption.
  - The 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.

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The Ionosphere

Absorption and Noise

- 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.

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The Ionosphere

Absorption and Noise

- Noise.
  - Storms generate noise (static) which covers up weak signals, making them difficult to hear.
    - The strength of the noise decreases with increasing frequency.
    - Atmospheric noise is stronger during the summer.
      - More storms.

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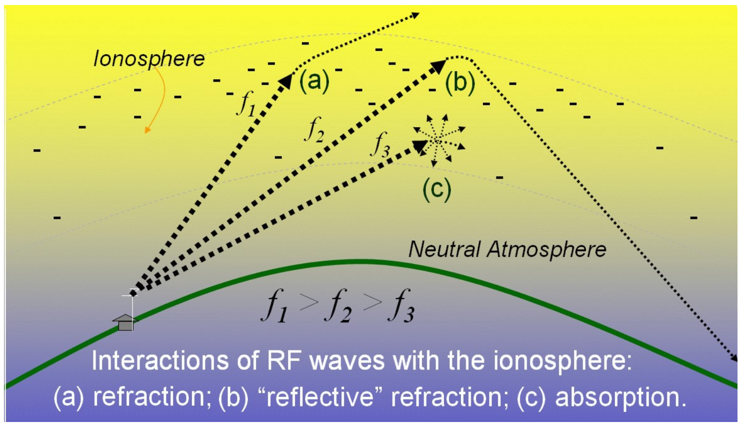
The Ionosphere



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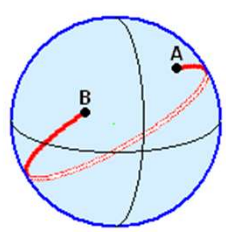
The Ionosphere

Long Path & Short Path

- Short path.
  - The short path is the direct route (shortest distance) between stations.
- Long path.
  - The long path is 180° from the short path and is the longest distance between stations.



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The Ionosphere

Long Path & Short Path

- Conditions may not support communications using the short path, but long path communications may be possible.
- A pronounced echo indicates that both short & long paths are open.

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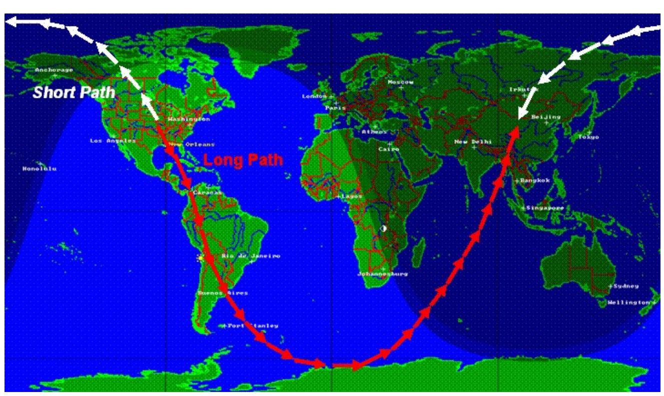
The Ionosphere

Long Path & Short Path



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The Ionosphere

Sky-Wave & Ground-Wave Propagation.

- Sky-Wave.
  - Sky-wave propagation is refracting radio waves back to the surface of the Earth using the ionosphere (a.k.a. – skip).
  - Each trip from the Earth to the ionosphere & back to the Earth is called a “hop”.
  - Multiple hops are common.

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The Ionosphere

Sky-Wave & Ground-Wave Propagation.

- Sky-Wave.
  - The maximum distance of a single hop depends on the altitude of the region where the refraction takes place.
    - In the E-region, a single hop can be up to 1200 miles.
    - In the F-region, a single hop can be up to 2500 miles.

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The Ionosphere

Sky-Wave & Ground-Wave Propagation.

- Sky-Wave.
  - Hops that are considerably less than the maximum distance is called short skip.
    - The critical angle is higher.
  - The existence of short skip is a good indicator that skip is possible on a higher frequency band.

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The Ionosphere

Sky-Wave & Ground-Wave Propagation.

- Ground-Wave.
  - Radio waves can follow along the surface of the Earth.
    - Ground waves are primarily vertically polarized.
    - Losses in the ground cause a rapid decrease of signal strength with increasing distance.
      - Higher frequency → higher loss.

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The Ionosphere

Sky-Wave & Ground-Wave Propagation.

- Skip distance.
  - The distance from the transmitter where a radio wave first returns to the surface of the Earth.
- Skip zone.
  - Too close for sky-wave propagation, but too far for ground-wave propagation.

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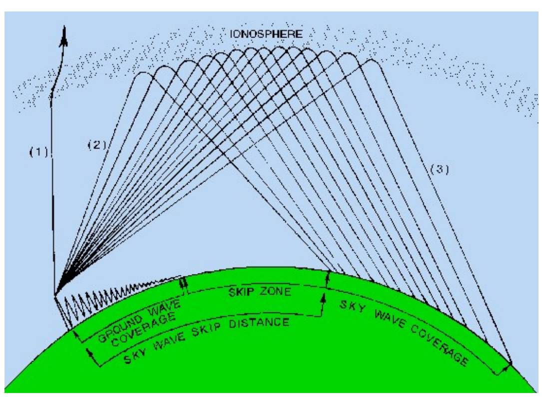
The Ionosphere

Sky-Wave & Ground-Wave Propagation.



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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 the station's short-path heading
D. Toward the north

27

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

28

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

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

29

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

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

30

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

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

31

G3C02 -- 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

32

G3C03 -- 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

33

G3C04 -- What does the term “critical angle” mean, as applied to 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 Earth under specific ionospheric conditions
D. The highest takeoff angle that will return a radio wave to Earth under specific ionospheric conditions

34

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

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

35

G3C11 -- Which ionospheric region is the most absorbent of signals below 10 MHz during daylight hours?

A. The F2 region
B. The F1 region
C. The E region
➡ D. The D region

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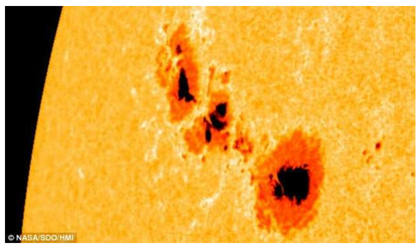
The Sun

Sunspots and Cycles

- Sunspots.
  - Sunspots are areas of intense magnetic activity on the surface (photosphere) of the sun.



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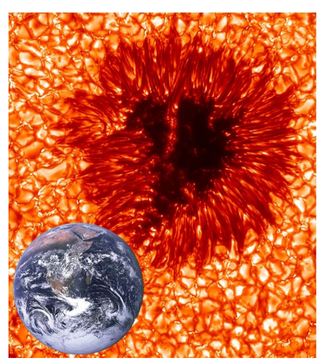
The Sun

Sunspots and Cycles

- Sunspots.
  - Sunspots can be up to 50,000 miles in diameter.
  - Sunspots were first observed by the Chinese in about 800 BC.
  - Sunspots were first mentioned in Western literature in about 300 BC.



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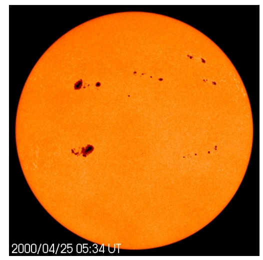
The Sun

Sunspots and Cycles

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



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The Sun

Sunspots and Cycles

- Sunspots.
  - Sunspots have a life span of less than a day to a few weeks.
  - Sunspots are stationary on the sun’s surface.
  - Sunspots appear to move because of the sun’s rotation.
    - Sunspots rotate back into view every 26-28 days.

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The Sun

Sunspots and Cycles

- Sunspots.
  - Sunspots emit UV radiation which ionizes the Earth's atmosphere.
    - More sunspots → higher levels of ionization.
    - Stronger sunspots → higher levels of ionization.
    - Higher levels of ionization cause greater refraction of radio waves in the ionosphere.
      - Better HF propagation.

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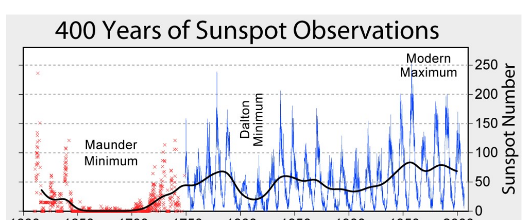
The Sun

Sunspots and Cycles

- Solar Cycles.
  - The number of sunspots varies in 11-year cycles.



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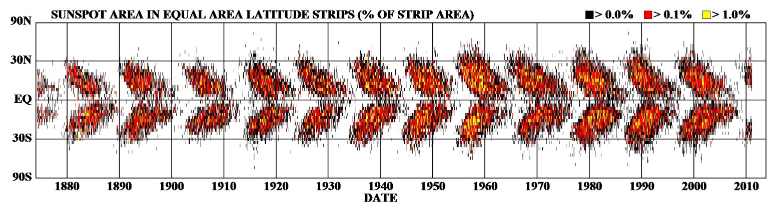
The Sun

Sunspots & Cycles

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



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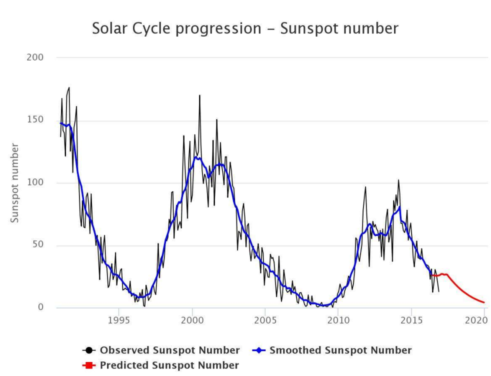
The Sun

Sunspots and Cycles



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The Sun

Sunspots and Cycles

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

45

The Sun

Sunspots and Cycles

- Solar Cycles.
  - There are strong seasonal & daily variations in propagation.
    - Seasonal variations due to the different levels of ionization between summer & winter.
      - Ionization levels are higher during the summer.
        - Sun is more directly overhead.
        - More hours of sunlight.

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The Sun

Sunspots and Cycles

- Solar Cycles.
  - There are strong seasonal & daily variations in propagation.
    - Seasonal variations on the lower bands due to lower atmospheric noise during the winter months.
      - Fewer thunderstorms → lower noise levels.

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The Sun

Sunspots and Cycles

- Solar Cycles.
  - There are strong seasonal & daily variations in propagation.
    - Daily variations due to:
      - Different levels of ionization between day & night.
      - Different amounts of absorption in the D- & E-regions between day & night.

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The Sun

Measuring Solar Activity

- The most familiar measurement of solar activity is the Smoothed Sunspot Number (SSN).
  - SSN = 10 x Nr of groups + Nr of sunspots.
  - The SSN is the result of observations from many different locations around the world.

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The Sun

Measuring Solar Activity

- A better measurement of solar activity is the Solar Flux Index (SFI).
  - SFI is a measurement of solar radiation reaching the surface of the Earth at a wavelength of 10.7 cm (2.8 GHz).
    - The SFI indicates the amount of UV radiation impacting the ionosphere.
    - The SFI takes into account both the number of the sunspots and their combined strength.

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The Sun

Measuring Solar Activity

- K-index (K_P).
  - A measure of the short-term stability of the Earth's magnetic field.
  - 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

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The Sun

Measuring Solar Activity

- A-index (A_P).
  - A measure of the long-term stability of the Earth's magnetic field.
  - Calculated from the 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

52

G3A01 -- How does a higher sunspot number affect 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 indicates that radio propagation is not possible on any band
- D. A zero sunspot number indicates undisturbed conditions

53

G3A04 -- Which of the following are the least reliable bands 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

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G3A05 -- What is the solar flux index?

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

55

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
C. Only at the minimum point
D. At any point in the solar cycle

56

G3A10 -- What causes HF propagation conditions to vary periodically in a 26- to 28-day cycle?

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

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G3A12 -- What does the K-index measure?

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

58

G3A13 -- What does the A-index measure?

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 Earth's geomagnetic field
D. The solar radio flux at Boulder, Colorado

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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

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The Sun

Assessing Propagation

- If you know the SSN, SFI, A-index, & K-index values, it is possible to do a fairly good job of predicting propagation between any 2 points on the Earth.

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The Sun

Assessing Propagation

- Maximum useable frequency (MUF).
  - The highest frequency that will allow communications between 2 points.
    - Radio waves on frequencies below the MUF will be refracted back to the surface of the Earth.
    - Radio waves on frequencies above the MUF will be lost into space.
    - Use a frequency just below the MUF for the best results.

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The Sun

Assessing Propagation

- Lowest useable frequency (LUF).
  - The 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 communication is not possible between those 2 points.

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The Sun

Assessing Propagation

- International beacons.
  - There is a network of beacon transmitters at 18 different 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.
    - Beacons transmit sequentially 24/7 on a 3-minute cycle.

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The Sun

Assessing Propagation

- International beacons.
  - Each beacon sends its callsign in Morse code at 22 wpm followed by four 1-second long dashes.
    - Callsign & 1st dash = 100 Watts.
    - 2nd dash = 10 Watts.
    - 3rd dash = 1 Watt.
    - 4th dash = 0.1 Watt.

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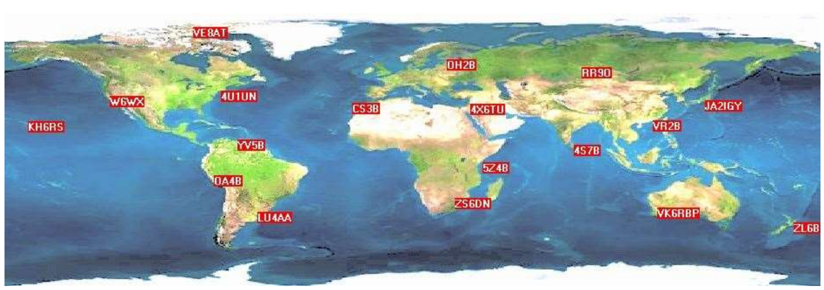
The Sun

Assessing Propagation

- International beacons.



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The Sun

Assessing Propagation

- Reverse Beacon Network (RBN).
  - The Reverse Beacon Network consists of a series of receiving stations located around the world which gather the call signs of stations heard at their location. You can access the RBN via the internet & look up your own call sign to see where you are being heard.

    https://www.reversebeacon.net

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The Sun

Assessing Propagation

- Propagation can be predicted by 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!**

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Break

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The Sun

Solar Disturbances

- There are occasional disturbances in the Earth’s atmosphere.
  - Hurricanes, typhoons, tornados, etc.
- Similarly, there are occasional disturbances in the surface of the sun.
  - Solar flares, coronal holes, & coronal mass ejections (CMEs).

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The Sun

Solar Disturbances

- Solar flare.
  - A large eruption of energy & particles from the surface of the sun.
    - Solar flares are caused by disruptions of the sun's magnetic field.
    - It takes about 8 minutes for the energy from a solar flare to reach the Earth.

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The Sun

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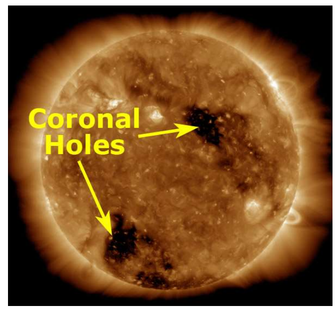
The Sun

Solar Disturbances

- Coronal hole.
  - A coronal hole is a weak (thin) area in the sun's corona through which plasma can escape the sun's magnetic field & stream through space at high velocity.



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The Sun

Solar Disturbances

- Coronal mass ejection (CME).
  - A coronal mass ejection is the violent expulsion of a large amount of material from the corona.
  - A CME can be either a narrow beam of material or it can be spread over a wide area.
  - CMEs are often associated with large solar flares.

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The Sun

Solar Disturbances

- Coronal mass ejection (CME).
  - Normally, it takes about 20-40 hours for the particles to reach the Earth. However, it can be up to several days.

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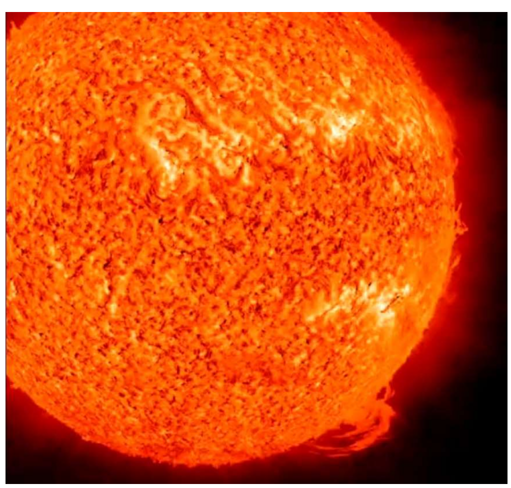
The Sun



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The Sun

Solar Disturbances

- Sudden ionospheric disturbance (SID).
  - A sudden ionospheric disturbance (SID) occurs when the UV-rays & X-rays from a solar flare impact the ionosphere.
    - The rays will reach the Earth in about 8 minutes.
    - There is a sudden increase in the ionization level which is especially noticeable in the D-region.
      - The lower frequency bands will be more greatly affected.

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The Sun

Solar Disturbances

- Sudden ionospheric disturbance (SID).
  - An SID can last from a few seconds to several hours.
  - An SID only affects the sunlit side of the Earth.
    - Nighttime communications are relatively unaffected.

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The Sun

Solar Disturbances

- Geomagnetic disturbances.
  - CME's result in a continuous stream of charged particles.
    - These particles greatly increase the strength of the solar wind.
    - The particles reach the Earth in about 20-40 hours.

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The Sun

Solar Disturbances

- Geomagnetic disturbances.
  - The particles become trapped in the Earth's magnetosphere near both poles.
  - The particles greatly increase the ionization of the E-region which creates a geomagnetic storm.

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The Sun

Solar Disturbances

- Geomagnetic disturbances.
  - High-latitude HF propagation is greatly decreased.
    - The effects can last several hours to a few days.

81

The Sun

Solar Disturbances

- Geomagnetic disturbances.
  - Auroral activity is greatly increased.
    - Reflection is possible on 15m & up.
      - Strongest on 6m & 2m.
    - Signals are modulated with a hiss or buzz.
      - CW is the best mode for auroral communications.

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The Sun

Solar Disturbances

83

G3A02 -- What effect does a sudden ionospheric disturbance have on the daytime ionospheric propagation?

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

84

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

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

85

G3A06 -- What is a geomagnetic storm?

A. A sudden drop in the solar flux index
B. A thunderstorm that affects radio propagation
C. Ripples in the geomagnetic force
D. A temporary disturbance in Earth's geomagnetic field

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G3A08 -- How can a geomagnetic storm affect HF propagation?

A. Improve high-latitude HF propagation
B. Degrade ground wave propagation
C. Improve ground wave propagation
D. Degrade high-latitude HF propagation

87

G3A09 -- How can high geomagnetic activity benefit radio communications?

A. Creates auroras that can reflect VHF signals
B. Increases signal strength for HF signals passing through the polar regions
C. Improve HF long path propagation
D. Reduce long delayed echoes

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G3A11 -- How long does it take a coronal mass ejection to affect radio propagation on Earth?

A. 28 days
B. 14 days
C. 4 to 8 minutes
➡ D. 15 hours to several day

89

G3A14 -- How is long distance radio communication usually affected by the charged particles that reach Earth from solar coronal holes?

A. HF communication is improved
➡ B. HF communication is disturbed
C. VHF/UHF ducting is improved
D. VHF/UHF ducting is disturbed

90

G3B02 -- What factors affect the MUF?

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

91

G3B03 -- Which frequency will have the least attenuation for long-distance skip propagation?

➡ A. Just below the MUF
B. Just above the LUF
C. Just below the critical frequency
D. Just above the critical frequency

92

G3B04 -- Which of the following is a way to determine current propagation on a desired band from your station?

A. Use a network of automated receiving stations on the internet to see where your transmissions are being received
B. Check the A-index
C. Send a series of dots and listen for echoes
D. All these choices are correct

93

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

94

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

A. They are refracted back to Earth
B. They pass through the ionosphere
➡ C. They are attenuated before reaching the destination
D. They are refracted and trapped in the ionosphere to circle Earth

95

G3B07 -- What does LUF stand for?

➡ A. The Lowest Usable Frequency for communications between two specific points
B. Lowest Usable Frequency for communications to any point outside a 100-mile radius
C. The Lowest Usable Frequency during a 24-hour period
D. Lowest Usable Frequency during the past 60 minutes

96

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

97

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

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Scatter Modes

Scatter Characteristics

- Localized areas in the ionosphere can reflect radio waves as well as refract them.
  - The directions of any reflections are unpredictable.

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Scatter Modes

Scatter Characteristics

- Scatter allows propagation above the MUF.
- Signals received via scatter are **MUCH** weaker than refracted signals.
- Signals received via scatter are often distorted or have a wavering sound due to multi-path.

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Scatter Modes

Scatter Characteristics

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

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Scatter Modes

Near Vertical Incidence Sky-wave (NVIS)

- At frequencies below the critical frequency, signals arriving at any angle are refracted back to the Earth.
- NVIS allows communications up to 200-300 hundred miles.
- NVIS eliminates the “skip zone”.

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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 strength by up to 6 dB.

103

G3C06 -- What is a characteristic of HF scatter?

A. Phone signals have high intelligibility
B. Signals have a fluttering sound
C. There are very large, sudden swings in signal strength
D. Scatter propagation occurs only at night

104

G3C07 -- What makes HF scatter signals often sound distorted?

A. The ionospheric region 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 paths

105

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 via ground waves, which absorb most of the signal energy
D. Propagation is via ducts in the F region, which absorb most of the energy

106

G3C09 -- What type of propagation allows signals to be heard in the transmitting station's skip zone?

A. Faraday rotation
B. Scatter
C. Chordal hop
D. Short-path

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G3C10 -- What is near vertical incidence skywave (NVIS) propagation?

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

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Questions?

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General License Class

Next Week

Chapter 9

Safety

110