Amateur Extra License Class

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Amateur Extra Class

Chapter 10
Topics in Radio Propagation

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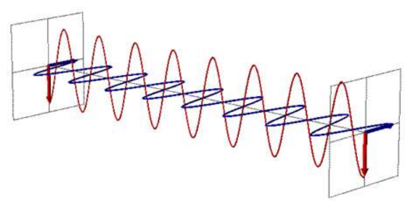
Electromagnetic Waves

An electromagnetic wave is a combination of an electric wave (E) & a magnetic wave (H) oriented at right angles to each other.

- Each wave varies with time in a sinusoidal pattern at the same frequency.



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Electromagnetic Waves

In free space, electromagnetic waves travel at the speed of light.

- 186,000 miles/second.
- 300,000.000 meters/second

Light is actually an extremely high frequency electromagnetic wave.

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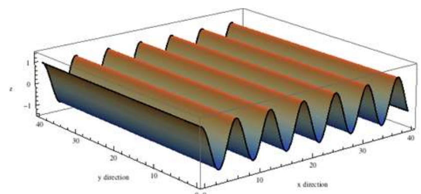
Electromagnetic Waves

Wavefronts.

- To a stationary observer, the E & H fields appear to vary with time at the frequency of the wave.
- To an observer moving at the same speed as and in the same direction as the wave, the E & H fields appear to be constant.
  - This is called a wavefront.



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Electromagnetic Waves

Polarization

- Polarization refers to the way the E-field is orientated with respect to the surface of the earth.
  - Horizontal polarization.
  - Vertical polarization.
  - Left-hand circular polarization.
  - Right-hand circular polarization.

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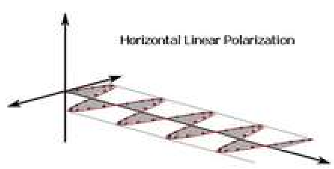
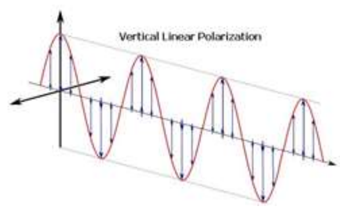
Electromagnetic Waves

Polarization

- If the E-field is parallel to the surface of the earth, the wave is said to be horizontally polarized.
- If the E-field is perpendicular to the surface of the earth, the wave is said to be vertically polarized.





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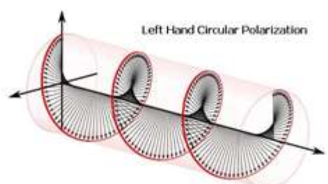
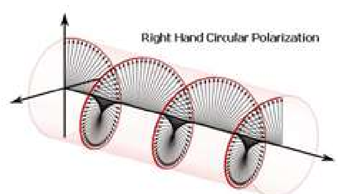
Electromagnetic Waves

Polarization

- The polarization of radio waves can also rotate 360° while propagating.





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E3A14 -- What is meant by circularly polarized electromagnetic waves?

A. Waves with an electric field bent into a circular shape

B. Waves with a rotating electric field

C. Waves that circle the Earth

D. Waves produced by a loop antenna

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Solar Effects

Flux and Flares.

- The energy from sun that most effects propagation is in the extreme ultra-violet (EUV) spectrum.
  - 100-1200 angstroms (10-120 nm).
  - EUV light is completely absorbed by the upper atmosphere creating the ionosphere.

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Solar Effects

Flux and Flares.

- Satellites photograph the light emitted by the sun at various wavelengths to determine solar activity.
  - The images are labeled by wavelength.
    - e.g. – 304A indicates 304 angstroms (30.4 nm).

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Solar Effects

Flux and Flares.

- The sudden emission of an extremely large amount of energy from the surface of the sun across a broad spectrum of frequencies is called a solar flare.
  - The UV & X-ray energy emitted by a solar flare can cause instabilities in the Earth's geomagnetic field.

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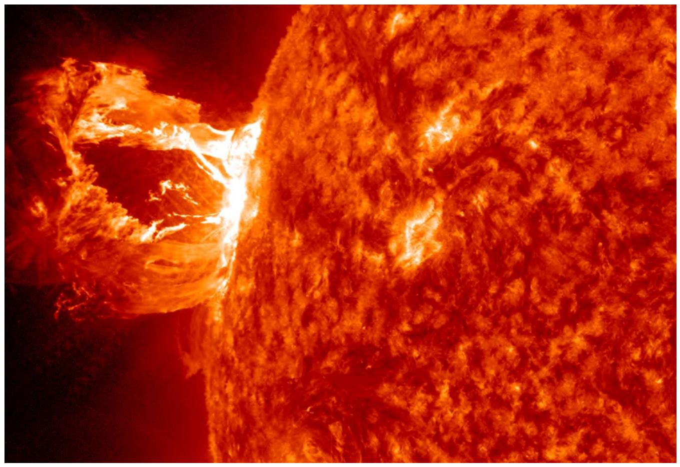
Solar Effects



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Solar Effects

Flux and Flares.

- Solar flares are classified according to the amount of x-ray radiation from the flare.
  - A-class = Barely discernable -- No impact on propagation.
  - B-class = Weak -- No impact on RF propagation.
  - C-class = Minor – Little impact on RF propagation.
  - M-class = Medium -- Brief radio blackouts, especially near polar regions.
  - X-class = Large -- Planet-wide radio blackouts

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Solar Effects

Flux and Flares.

- Increasing from one class to the next indicates a ten-fold increase in the solar flux.
- Each class is divided into 10 sub-classes numbered 0-9.
  - The strength of the flux increases linearly with the number.
    - e.g. -- an X3 flare 1.5 times as strong as a class X2 flare.

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E3C07 -- Which of the following descriptors indicates the greatest solar flare intensity?

A. Class A
B. Class B
C. Class M
D. Class X

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E3C09 -- How does the intensity of an X3 flare compare to that of an X2 flare?

A. 10 percent greater
B. 50 percent greater
C. Twice as great
D. Four times as great

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E3C10 -- What does the 304A solar parameter measure?

A. The ratio of X-Ray flux to radio flux, correlated to sunspot number
B. UV emissions at 304 angstroms, correlated to the solar flux index
C. The solar wind velocity at 304 degrees from the solar equator, correlated to solar activity
D. The solar emission at 304 GHz, correlated to x-ray flare levels

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Solar Effects

Geomagnetic Field.

- Solar energy & charged particles from the sun deposit energy into the ionosphere and also into the Earth's geomagnetic field.
- For good propagation, the geomagnetic field needs to be stable.
  - Especially at higher latitudes (auroral zones).
- A geomagnetic storm is occurring when the geomagnetic field is disturbed (unstable).

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Solar Effects

Geomagnetic Field.

- The following parameters are used to evaluate propagation conditions:
  - B_Z
  - K-Index
  - A-Index
  - G-Index

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Solar Effects

Geomagnetic Field.

- B_Z is the intensity & orientation of the interplanetary magnetic field (IMF).
  - If B_Z is negative, then the IMF is aligned north-to-south (southward), making it easier for disruptions to occur.

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Solar Effects

Geomagnetic Field.

- The K-index is a measure of the short-term stability of the geomagnetic field.
  - The K-index measures the stability over a 3-hour period.
    - The K-index is calculated from how much the geomagnetic field intensity varies during that 3-hour period.
  - The measurements from 13 different locations around the world are averaged to arrive at the K-index value.

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Solar Effects

Geomagnetic Field.

- The A-index is a measure of the long-term stability of the geomagnetic field.
  - The A-index measures stability over a 24-hour period.
    - The A-index is calculated from the previous 8 K-index values.

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Solar Effects

K-Index Values	
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

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

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Solar Effects

Geomagnetic Field.

- The G-Index is a measure of geomagnetic "storminess" and is based on the A & K indices.

G-Index Values	
0	Quiet
1	Minor
2	Moderate
3	Strong
4	Severe
5	Extreme

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E3C02 -- What is indicated by a rising A or K index?

A. Increasing disruption of the geomagnetic field

B. Decreasing disruption of the geomagnetic field

C. Higher levels of solar UV radiation

D. An increase in the critical frequency

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E3C04 -- What does the value of Bz (B sub Z) represent?

A. Geomagnetic field stability
B. Critical frequency for vertical transmissions
➡ C. Direction and strength of the interplanetary magnetic field
D. Duration of long-delayed echoes

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E3C05 -- What orientation of Bz (B sub z) increases the likelihood that incoming particles from the sun will cause disturbed conditions?

➡ A. Southward
B. Northward
C. Eastward
D. Westward

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E3C08 -- What does the space weather term G5 mean?

A. An extreme geomagnetic storm
B. Very low solar activity
C. Moderate solar wind
D. Waning sunspot numbers

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HF Propagation

In nearly all cases, HF waves travel along the surface of the earth or they are returned to earth after encountering the upper layers of the ionosphere.

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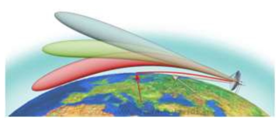
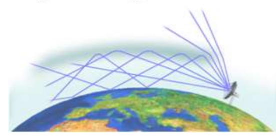
HF Propagation

All types of waves can change direction due to two different phenomena:

- Diffraction.
  - Encountering a reflecting surface's edge or corner.
- Refraction.
  - A change in velocity due to change in properties of the medium that the wave is traveling through.





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HF Propagation

Ground-Wave Propagation

- Ground wave propagation is not the same as line-of-sight but is a special type of diffraction.
  - The lower edge of a wave (closest to the earth) loses energy due to induced ground currents.
    - The lower edge slows, tilting the wave front forward.
    - Primarily effects vertically-polarized waves.
    - Most noticeable on longer wavelengths.
      - AM broadcast, 160m, & 80m.

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HF Propagation

Ground-Wave Propagation

- As a ground wave signal travels along the surface of the earth, it is absorbed, decreasing its strength.
  - Absorption is more pronounced at shorter wavelengths.
    - At 28 MHz, only useful up to a few miles.
- Most useful during daylight on 160m & 80m.
- Useful for communications between 50-100 miles.

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E3C12 -- How does the maximum distance of ground-wave propagation change when the signal frequency is increased?

A. It stays the same
B. It increases
→ C. It decreases
D. It peaks at roughly 14 MHz

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E3C13 -- What type of polarization is best for ground-wave propagation?

A. Vertical
B. Horizontal
C. Circular
D. Elliptical

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HF Propagation

Sky-Wave Propagation

- Sky-wave propagation (a.k.a. – skip) occurs when radio waves are refracted in the E & F layers of the ionosphere.
- The shorter the wavelength, the less refraction occurs.
  - Sky-wave propagation is usually possible only on the lower VHF frequencies (6m) and below.

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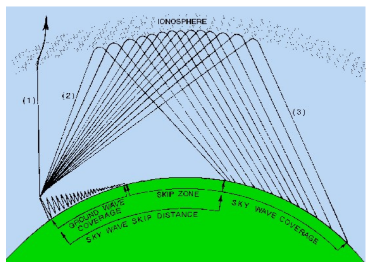
HF Propagation

Sky-Wave Propagation

- The maximum one-hop skip distance for sky-wave propagation is about 1500 miles in the E-layer and about 2500 miles in the F-layer.



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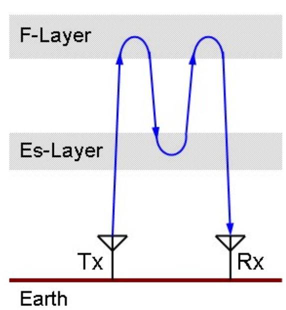
HF Propagation

Sky-Wave Propagation

- It is possible for a radio wave to be refracted between the E-layer and the F-layer or within the F-layer itself.
  - When this occurs, it is called a "chordal hop".
  - This provides long-distance skip without the losses imposed by reflecting off the Earth's surface.



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E3A06 -- What might help to restore contact when DX signals become too weak to copy across an entire HF band a few hours after sunset?

A. Switch to a higher frequency HF band
➡ B. Switch to a lower frequency HF band
C. Wait 90 minutes or so for the signal degradation to pass
D. Wait 24 hours before attempting another communication on the band

39

E3B10 -- Why is chordal hop propagation desirable?

➡ A. The signal experiences less loss compared to multi-hop using Earth as a reflector
B. The MUF for chordal hop propagation is much lower than for normal skip propagation
C. Atmospheric noise is lower in the direction of chordal hop propagation
D. Signals travel faster along ionospheric chords

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E3B12 -- What is the primary characteristic of chordal hop propagation?

A. Propagation away from the great circle bearing between stations
B. Successive ionospheric reflections without an intermediate reflection from the ground
C. Propagation across the geomagnetic equator
D. Signals reflected back toward the transmitting station

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HF Propagation

Sky-Wave Propagation

- Ordinary and Extraordinary Waves.
  - When a radio wave enters the ionosphere, it splits into 2 waves that are polarized at right-angles to each other.
    - Ordinary wave (o-wave) – The E-field is parallel to the Earth's magnetic field.
    - Extraordinary wave (x-wave) – The E-field is perpendicular to Earth's magnetic field.
    - The o-wave & the x-wave recombine when they leave the ionosphere to form an elliptically polarized wave.

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HF Propagation

Sky-Wave Propagation

- Ordinary and Extraordinary Waves.
  - The fact that the wave returning to the Earth is elliptically-polarized is why antenna polarization has little effect on received field strength on HF.
    - Matching the polarization of the transmitting station & the receiving station antennas is not a concern like it is on VHF & UHF.

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E3B04 -- What is meant by the terms "extraordinary" and "ordinary" waves?

A. Extraordinary waves describe rare long-skip propagation compared to ordinary waves, which travel shorter distances

➡ B. Independent waves created in the ionosphere that are elliptically polarized

C. Long-path and short-path waves

D. Refracted rays and reflected waves

44

E3B07 -- What happens to linearly polarized radio waves that split into ordinary and extraordinary waves in the ionosphere?

A. They are bent toward the magnetic poles
B. They become depolarized
C. They become elliptically polarized
D. They become phase locked

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HF Propagation

Sky-Wave Propagation

- Predicting Propagation.
  - Computer modelling programs have been developed to predict the propagation between 2 points based on both the current solar data & the historical data.
    - Solar flux Index.
    - A-index.
    - K-index.
    - Number of sunspots.

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HF Propagation

Sky-Wave Propagation

- Predicting Propagation.
  - The primary program in use today is:
    - Voice of America Coverage Analysis Program (VOACAP).
    - VOACAP was designed by the VOA to predict HF propagation. between 2 points for the purposes of HF broadcasting.

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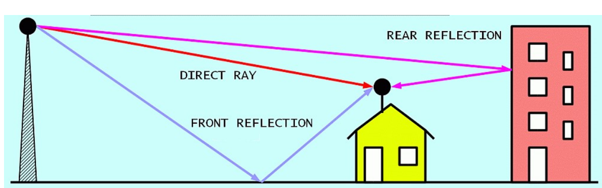
HF Propagation

Sky-Wave Propagation

- Predicting Propagation.
  - The modelling software can show that a radio wave can take more than one path between 2 points.
  - Following the various paths that the wave may take is called "ray tracing".



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E3C01 -- What does the radio communication term "ray tracing" describe?

A. The process in which an electronic display presents a pattern

➡ B. Modeling a radio wave's path through the ionosphere

C. Determining the radiation pattern from an array of antennas

D. Evaluating high voltage sources for X-Rays

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E3C11 -- What does VOACAP software model?

A. AC voltage and impedance

B. VHF radio propagation

➡ C. HF propagation

D. AC current and impedance

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HF Propagation

Sky-Wave Propagation

- Absorption.
  - The D layer is closer to the Earth where the atmosphere is more dense.
    - The ionized atoms & molecules are closer together and can recombine more rapidly.
      - The D layer is ionized only during daylight hours.
      - The D layer forms very rapidly at sunrise.
      - The D layer collapses very rapidly at sunset.

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HF Propagation

Sky-Wave Propagation

- Absorption.
  - Because the ionized particles are closer together, more collisions occur between the radio wave and the particles, causing much of the energy in the radio wave to be lost as heat.
    - The longer the wavelength, the greater the absorption.
      - Absorption in the D layer almost totally prevents sky-wave propagation on 160m & 80m during daylight hours.
      - There is a noticeable reduction in sky-wave propagation on 40m during daylight hours.
      - There is little effect on 20m & up.

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HF Propagation

Sky-Wave Propagation

- Absorption.
  - Geomagnetic disturbances & solar flares increase absorption.
    - As the A & K indices rise, the absorption increases.
    - The noise level increases as the signals decrease.
    - The absorption is more pronounced for paths over the polar regions.

53

E3C03 -- Which of the following signal paths is most likely to experience high levels of absorption when the A index or K index is elevated?

A. Transequatorial

B. Polar paths

C. Sporadic E

D. NVIS

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E3C15 -- What might be indicated by a sudden rise in radio background noise across a large portion of the HF spectrum?

A. A temperature inversion has occurred

➡ B. A solar flare has occurred

C. Increased transequatorial propagation is likely

D. Long-path propagation is likely

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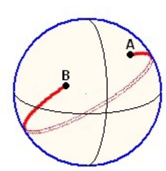
HF Propagation

Sky-Wave Propagation

- Long Path and Gray Line Propagation.
  - Radio waves travel a great-circle path between 2 stations.
  - The path is shorter in one direction & longer in the other.
    - Most contacts follow the shorter path.
    - Sometimes the signal strength is greater if the longer path is used. This is called "long path" propagation.
      - The long path is 180° from the short path.



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HF Propagation

Sky-Wave Propagation

- Long Path and Gray Line Propagation.
  - A slight echo on the received signal may indicate that long path propagation is occurring.
  - With long path propagation, the received signal may be stronger if antenna is pointed 180° away from the station.
  - Long path propagation can occur on all MF & HF bands.
    - 160m through 10m.
    - Most often on 20m.

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HF Propagation

Long Path vs. Short Path

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HF Propagation

Sky-Wave Propagation

- Long Path and Gray Line Propagation.
  - During daylight hours, absorption in the D layer prevents long-distance communications on the lower frequency bands.
  - During the nighttime hours, the ionization of the F layer is too low to support long-distance communications on the lower frequency bands.
  - Gray line propagation allows long-distance communications on the lower frequency bands.

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HF Propagation

Sky-Wave Propagation

- Long Path and Gray Line Propagation.
  - At sunset:
    - The D layer collapses rapidly, reducing adsorption.
    - The F layer collapses more slowly.
  - At sunrise:
    - The D layer doesn't start forming until the sun is well above the horizon.
    - The F layer starts ionizing at first light.

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HF Propagation

Sky-Wave Propagation

- Long Path and Gray Line Propagation.
  - The result is that long distance communications are often possible during twilight hours on the lower frequency bands.
    - 8,000 to 10,000 miles.
    - 160m, 80m, 40m, & possibly 30m.

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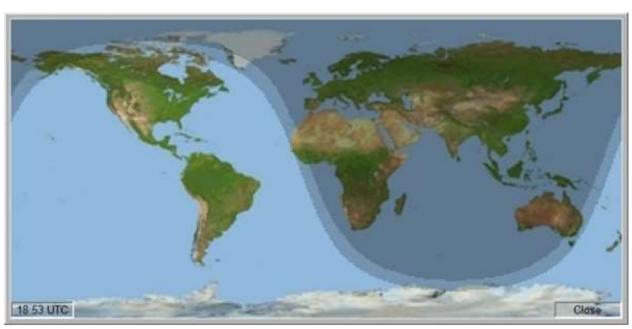
HF Propagation

Long Path and Gray Line

- Gray line propagation.



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E3B05 -- Which amateur bands typically support long-path propagation?

A. 160 meters to 40 meters
B. 30 meters to 10 meters
➡ C. 160 meters to 10 meters
D. 6 meters to 2 meters

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E3B06 -- Which of the following amateur bands most frequently provides long-path propagation?

A. 80 meters
➡ B. 20 meters
C. 10 meters
D. 6 meters

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VHF/UHF/Microwave Propagation

Above 30 MHz, radio waves are rarely refracted back to earth by the ionosphere.

- Must use other techniques for long-distance communications.
- A low-angle of radiation from the antenna is more important than on HF.
- It is more important for the polarization of the transmitting & receiving antennas to match than on HF.

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VHF/UHF/Microwave Propagation

Radio Horizon

- The radio horizon not the same as the visual horizon.
  - Variations in the density of the atmosphere cause refraction that bends radio waves & increases the “line-of-sight” distance by about 15%.

Visual Horizon (miles) $\approx 1.32\sqrt{H_{ft}}$

Radio Horizon (miles) $\approx 1.415\sqrt{H_{ft}}$

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E3C06 -- By how much does the VHF/UHF radio-path horizon distance exceed the geometric horizon?

A. By approximately 15 percent of the distance
B. By approximately twice the distance
C. By approximately 50 percent of the distance
D. By approximately four times the distance

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E3C14 -- Why does the radio-path horizon distance exceed the geometric horizon?

A. E-region skip
B. D-region skip
C. Due to the Doppler effect
D. Downward bending due to density variations in the atmosphere

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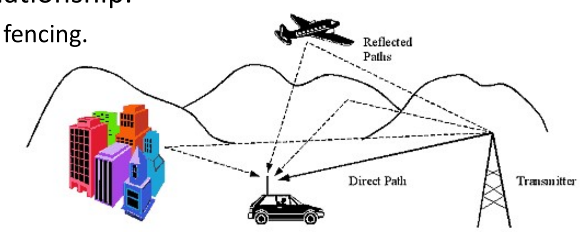
VHF/UHF/Microwave Propagation

Multipath

- Radio waves reflected off of many objects arrive at the receive antenna at different times.
  - The waves reinforce or cancel each other depending on phase relationship.
    - Picket fencing.



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VHF/UHF/Microwave Propagation

Tropospheric Propagation

- VHF/UHF/microwave propagation is normally limited to about 50 miles.
- Temperature inversions can create a “duct” where radio waves can travel for long distances.
  - 100-300 miles.

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VHF/UHF/Microwave Propagation

Tropospheric Propagation

- Ducting is more common over water.
- Ducting is rare on 6m.
- Ducting can occur on 2m.
- Ducting is most common on UHF & microwave frequencies.
- Hepburn maps show where conditions exist to support tropospheric ducting.

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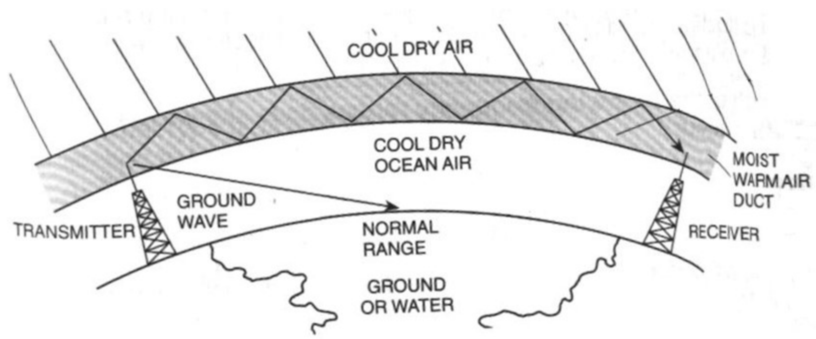
VHF/UHF/Microwave Propagation

Tropospheric Propagation



Tropospheric Ducting

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VHF/UHF/Microwave Propagation

Tropospheric Propagation

- Other types of “tropo” include scattering off of precipitation.
  - Precipitation must be within line-of-sight range of both stations.

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E3A04 -- What do Hepburn maps predict?

A. Sporadic E propagation
B. Locations of auroral reflecting zones
C. Likelihood of rain scatter along cold or warm fronts
D. Probability of tropospheric propagation

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E3A05 -- Tropospheric propagation of microwave signals often occurs in association with what phenomenon?

A. Grayline
B. Lightning discharges
C. Warm and cold fronts
D. Sprites and jets

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E3A07 -- Atmospheric ducts capable of propagating microwave signals often form over what geographic feature?

A. Mountain ranges
B. Forests
C. Bodies of water
D. Urban areas

76

E3A10 -- Which type of atmospheric structure can create a path for microwave propagation?

A. The jet stream
B. Temperature inversion
C. Wind shear
D. Dust devil

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E3A11 -- What is a typical range for tropospheric propagation of microwave signals?

A. 10 miles to 50 miles
B. 100 miles to 300 miles
C. 1200 miles
D. 2500 miles

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VHF/UHF/Microwave Propagation

Sporadic E Propagation

- Temporary, highly-ionized areas can form in the E layer.
  - Refraction occurring in these areas is called "sporadic E propagation".
  - These areas can last for a few minutes or for several hours.
  - Sporadic E propagation can occur on:
    - 10m.
    - 6m.
    - 2m.
  - Sporadic E propagation allows contacts of 300 to 1200 miles.

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VHF/UHF/Microwave Propagation

Sporadic E Propagation

- Sporadic E propagation can occur at any time of the day or night.
- Sporadic E propagation can occur any time of the year, but is most common near the summer & winter solstices.
  - Sporadic E propagation is best near the summer solstice during May, June, & July.

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E3B09 -- At what time of year is Sporadic E propagation most likely to occur?

A. Around the solstices, especially the summer solstice
B. Around the solstices, especially the winter solstice
C. Around the equinoxes, especially the spring equinox
D. Around the equinoxes, especially the fall equinox

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E3B11 -- At what time of day can sporadic E propagation occur?

A. Only around sunset
B. Only around sunset and sunrise
C. Only in hours of darkness
D. Any time

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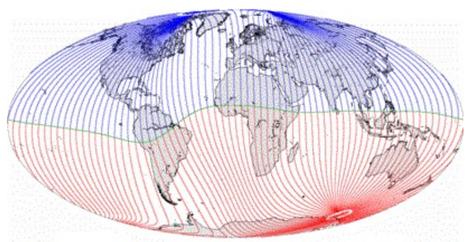
VHF/UHF/Microwave Propagation

Transequatorial Propagation

- Communications between stations located an equal distance north & south of the magnetic equator is called "transequatorial propagation".



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VHF/UHF/Microwave Propagation

Transequatorial Propagation

- Is most prevalent around the spring & autumn equinoxes.
- Is best during the afternoon & early evening.
- Allows contacts up to about 5,000 miles.
- Useable up to 2m & somewhat on 70cm.
  - As the frequency increases, the paths are more restricted to being exactly equidistant from and perpendicular to the magnetic equator.

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E3B01 -- What is transequatorial propagation?

A. Propagation between two mid-latitude points at approximately the same distance north and south of the magnetic equator
B. Propagation between points located on the magnetic equator
C. Propagation between a point on the equator and its antipodal point
D. Propagation between points at the same latitude

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E3B02 -- What is the approximate maximum range for signals using transequatorial propagation?

A. 1000 miles
B. 2500 miles
C. 5000 miles
D. 7500 miles

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E3B03 -- What is the best time of day for transequatorial propagation?

A. Morning
B. Noon
C. Afternoon or early evening
D. Late at night

87

VHF/UHF/Microwave Propagation

Auroral Propagation

88

VHF/UHF/Microwave Propagation

Auroral Propagation

- Charged particles from the sun (solar wind) are concentrated over the magnetic poles by the earth's magnetic field & ionize the E-layer.
  - This ionization is visible as the aurora borealis (northern lights) in the northern hemisphere or as the aurora australis (southern lights) in the southern hemisphere.
  - The refraction of VHF & UHF signals in this ionized layer is called "auroral propagation" & can support contacts up to about 1,400 miles.

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VHF/UHF/Microwave Propagation

Auroral Propagation

- Using Auroral Propagation.
  - The reflections off the aurora change rapidly.
    - All signals sound fluttery.
    - SSB signals sound raspy.
    - CW signals sound like they are modulated with white noise.
  - CW is the most effective mode.
  - SSB contacts can be made on 6m if the signals are strong.
    - Operator should speak slowly & distinctly.

90

VHF/UHF/Microwave Propagation

Auroral Propagation

- Using Auroral Propagation.
  - The antenna should be pointed towards the aurora, **NOT** towards the station being worked.
    - In the US, point the antenna north.
    - The exact antenna direction may need to be adjusted as the location of the aurora changes.
  - An increasing K-index of 3 or more may indicate that auroral propagation is possible.

91

E3A12 -- What is the cause of auroral activity?

A. The interaction in the F2 layer between the solar wind and the Van Allen belt

B. An extreme low-pressure area in the polar regions

C. The interaction in the E layer of charged particles from the Sun with the Earth's magnetic field

D. Meteor showers concentrated in the extreme northern and southern latitudes

92

E3A13 -- Which of these emission modes is best for auroral propagation?

A. CW

B. SSB

C. FM

D. RTTY

93

VHF/UHF/Microwave Propagation

Meteor Scatter Communications

- Meteors passing through the ionosphere collide with air molecules & strip off electrons leaving a trail of ionized particles in their wake.
  - This ionization occurs at or near the E-region.
    - 50-75 miles above the earth.
  - Reflecting signals off these ionized trails is called "meteor scatter" propagation.

94

VHF/UHF/Microwave Propagation

Meteor Scatter Communications

- The best bands for meteor scatter propagation are 10m, 6m, & 2m.
  - 20 MHz to 432 MHz is possible.
  - Most activity is on 6m.

95

VHF/UHF/Microwave Propagation

Meteor Scatter Communications

- Major meteor showers:
  - Quadrantids – January 3-5.
  - Lyrids – April 19-23.
  - Arietids – June 8.
  - Aquarids – July 26-31.
  - Perseids – July 27 to August 14.
  - Orionids – October 18-234.
  - Taurids – October 26 to November 16.
  - Leonids – November 14-16.
  - Geminids – December 10-14.
  - Ursids – December 22.

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VHF/UHF/Microwave Propagation

Meteor Scatter Communications

- Operating techniques.
  - Keep transmissions **SHORT** with repeated call signs & signal reports.
  - Divide each minute into four 15-second segments.
    - Stations at the west end of the path transmit during the 1st & 3rd segments.
    - Stations at the east end of the path transmit during the 2nd & 4th segments.

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VHF/UHF/Microwave Propagation

Meteor Scatter Communications

- Operating techniques.
  - Modes:
    - High speed CW (HSCW).
      - 800-2,000 wpm.
      - Computer generated & decoded.
    - MSK144, part of the WSJT-X software suite, was designed for meteor scatter communications.
      - MSK144 sends repeated short bursts of data.

98

E2D01 -- Which of the following digital modes is designed for meteor scatter communications?

A. WSPR

➡ B. MSK144

C. Hellschreiber

D. APRS

E2D02 -- Which of the following is a good technique for making meteor scatter contacts?

A. 15-second timed transmission sequences with stations alternating based on location

B. Use of special digital modes

C. Short transmissions with rapidly repeated call signs and signal reports

➡ D. All these choices are correct

E3A08 -- When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at what layer of the ionosphere?

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

101

E3A09 -- Which of the following frequency ranges is well suited for meteor-scatter communications?

A. 1.8 MHz - 1.9 MHz
B. 10 MHz - 14 MHz
➡ C. 28 MHz - 148 MHz
D. 220 MHz - 450 MHz

102

VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- A technique for making extremely long distance contacts on VHF & UHF is to reflect a radio wave off the surface of the moon.
  - This technique is referred to as “moon bounce” or EME.
  - If both stations can “see” the moon, they can communicate.
    - Contacts up to nearly 12,000 miles are possible.

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VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- Since the round-trip distance to the moon and back is nearly a half million miles, the path loss is extreme.
  - Extremely high gain antenna systems are used.
  - Very low noise figure pre-amplifiers are required on receivers.
  - To minimize path loss, most contacts are made when the moon is at perigee.
    - About 2 dB less path loss.

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VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

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VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- The higher the moon is in the sky, the shorter the distance through the Earth's atmosphere resulting in less path loss.
- Because of increased noise from the sun in the background, EME is not useable near a new moon.

106

VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- An effect known as "libration fading" is caused by the multipath effects of the rough moon surface in combination with the relative motion between the earth and the moon.
  - Libration fading is a rapid, deep, irregular fading.
    - Up to 20 dB or more.
    - Up to 10 Hz.
    - Can cause slow-speed CW to sound like high-speed CW.

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VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- JT65, a part of the WSJT-X software family, was specifically designed for EME communications.
  - JT65 uses alternating time-synchronized transmissions.
  - Special encoding techniques allow copying signals with extremely low signal-to-noise ratios.

108

E2D03 -- Which of the following digital modes is especially useful for EME communications?

A. MSK144
B. PACTOR III
C. Olivia
D. JT65

109

E2D05 -- What is one advantage of the JT65 mode?

A. Uses only a 65 Hz bandwidth
B. The ability to decode signals which have a very low signal-to-noise ratio
C. Easily copied by ear if necessary
D. Permits fast-scan TV transmissions over narrow bandwidth

110

E2D06 -- Which of the following describes a method of establishing EME contacts?

A. Time synchronous transmissions alternately from each station
B. Storing and forwarding digital messages
C. Judging optimum transmission times by monitoring beacons reflected from the Moon
D. High speed CW identification to avoid fading

111

E3A01 -- What is the approximate maximum separation measured along the surface of the Earth between two stations communicating by Moon bounce?

A. 500 miles, if the moon is at perigee
B. 2000 miles, if the moon is at apogee
C. 5000 miles, if the moon is at perigee
D. 12,000 miles, if the moon is visible by both stations

112

E3A02 -- What characterizes libration fading of an EME signal?

A. A slow change in the pitch of the CW signal
B. A fluttery irregular fading
C. A gradual loss of signal as the sun rises
D. The returning echo is several hertz lower in frequency than the transmitted signal

113

E3A03 -- When scheduling EME contacts, which of these conditions will generally result in the least path loss?

A. When the moon is at perigee
B. When the moon is full
C. When the moon is at apogee
D. When the MUF is above 30 MHz

114

Questions?

115

Amateur Extra Class

Chapter 11
Safety

116

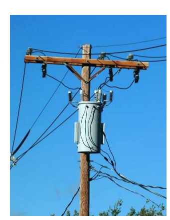
Break

117

Hazardous Materials

PCBs

- Polychlorinated Biphenyls (not printed circuit boards).
- PCBs are an additive to the oils used as an insulator in older electrical components.
  - Large transformers.
  - High-voltage capacitors.
- PCBs are a known carcinogen.



118

Hazardous Materials

PCBs

- Avoid skin contact with PCBs.
  - Wear rubber gloves
  - Wipe down the case with a paper towel.
- Properly dispose of the component & the materials used to handle it.

119

Hazardous Materials

Beryllium and Beryllium Oxide

- Beryllium (Be) is a metal that alloyed with copper to stiffen it & to improve conductivity.
  - Beryllium is commonly used in spring contacts.
- Beryllium Oxide (BeO) is a ceramic used asan insulator inside vacuum tubes & semiconductors.
  - Beryllium oxide is not dangerous in its solid form.
  - Beryllium oxide is a known carcinogen if it is crushed & the dust is inhaled.

120

Hazardous Materials

Lead and Soldering

- Standard solder is an alloy of lead and tin.
- The dangers from soldering **do not** include the inhaling of lead vapors.
    - The temperatures involved in soldering are not not high enough to create lead vapor. The fumes/vapors created during soldering are caused by burning flux.
- The danger of using solder containing lead is the accidental ingestion of lead after handling the solder.
    - Wash hands thoroughly before handling food.

121

Hazardous Materials

Carbon Monoxide

- Carbon monoxide (CO) is a colorless, odorless, tasteless gas that is generated by the incomplete combustion of fossil fuels.
- Carbon monoxide can **ONLY** be detected by a carbon monoxide detector.
    - Ordinary smoke detectors will **NOT** detect CO gas.

122

Hazardous Materials

Carbon Monoxide

- Generators & fossil fuel heaters must only be used in open, well-ventilated areas.
- Install carbon monoxide detectors in any area occupied by people where CO gas may accumulate.
- Fuel must not be stored by the generator or heater.

123

E0A07 -- How may dangerous levels of carbon monoxide from an emergency generator be detected?

A. By the odor
B. Only with a carbon monoxide detector
C. Any ordinary smoke detector can be used
D. By the yellowish appearance of the gas

124

E0A09 -- Which insulating material commonly used as a thermal conductor for some types of electronic devices is extremely toxic if broken or crushed and the particles are accidentally inhaled?

A. Mica
B. Zinc oxide
➡ C. Beryllium Oxide
D. Uranium Hexaflouride

125

E0A10 -- What toxic material may be present in some electronic components such as high voltage capacitors and transformers?

➡ A. Polychlorinated biphenyls
B. Polyethylene
C. Polytetrafluroethylene
D. Polymorphic silicon

126

RF Exposure

Radiation can be divided into 2 categories:

- Ionizing Radiation.
- Non-ionizing radiation.

127

RF Exposure

Ionizing Radiation.

- Ionizing radiations is radiation where the energy is high enough to strip electrons from atoms or to break atoms apart.
  - Ultra-violet light.
  - X-rays.
  - Radioactive sources.

128

RF Exposure

Non-ionizing radiation

- Non-ionizing radiation is radiation where the energy is sufficient to strip electrons from atoms or to break atoms apart.
  - All radio frequency energy is non-ionizing.

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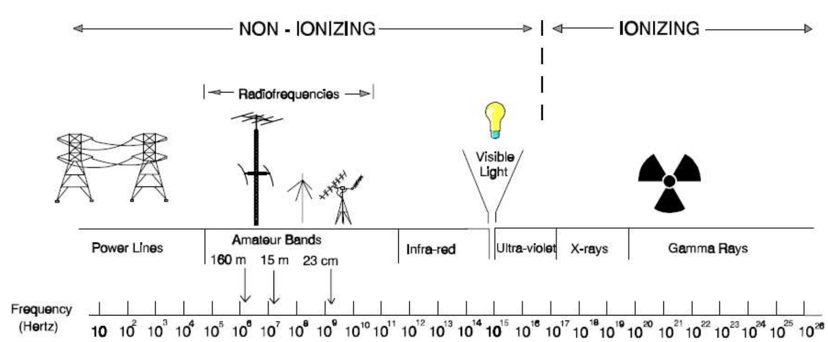
RF Exposure



130

RF Exposure

Power Density

- RF energy at low levels is not dangerous.
  - RF energy is only dangerous when the level is high enough to cause the heating of body tissue.
  - Heating is caused by the body absorbing RF energy.
  - The intensity of RF energy is called the power density.
    - Measured in mW/cm^2.

131

RF Exposure

Power Density.

- The intensity of the electric (E) field & the magnetic (H) field can be measured separately.
  - The E field is measured in V/m.
  - The H field is measured in A/m.
  - The E field & The H field can peak at different locations.
  - The field impedance varies due to ground reflections, scattering, & antenna proximity.
    - $Z = E / H$.

132

RF Exposure

Absorption and Limits

- The rate at which the body absorbs RF energy is called the “specific absorption rate” or SAR.
  - The SAR varies with frequency & with the size of the body part.
    - The range of the highest SAR is from 30 MHz to 1.3 GHz.
    - For the torso & limbs, the SAR is highest at VHF (30 MHz to 300 MHz).
    - For the head, the SAR is highest at UHF (300 MHz to 3 GHz).
    - For the eyes, the SAR is highest at microwave frequencies below 1 GHz.

133

RF Exposure

Absorption and Limits

- The FCC rules specify the highest level of exposure allowed from radio transmitters called the “maximum permissible exposure” or MPE.
  - The MPEs vary with frequency.
  - The MPEs vary according to the “environment”.

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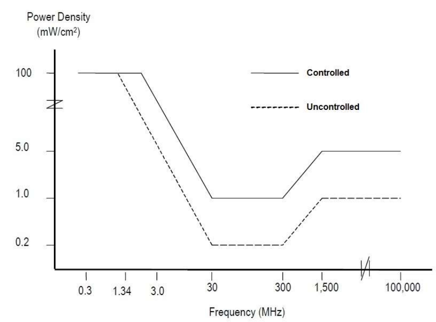
RF Exposure

Absorption and Limits

- Maximum permissible exposure (MPE).



135

RF Exposure

Averaging and Duty Cycle

- The exposure to RF energy is averaged over specified time periods to determine whether the exposure is below the MPE.
  - The body responds differently to long duration and short duration exposure.
  - Two different "environments" are averaged over different time periods.

136

RF Exposure

Averaging and Duty Cycle

- Controlled and Uncontrolled Environments.
  - There are 2 different types of locations in which different values of MPEs are specified.
    - The controlled environment.
    - The uncontrolled environment.

137

RF Exposure

Averaging and Duty Cycle

- Controlled and Uncontrolled Environments.
  - In a controlled environment:
    - Individuals are aware of the presence of RF energy.
    - Individuals are knowledgeable about the precautions to be taken.
    - Exposure is averaged over a 6-minute time period.
    - Higher levels of exposure are allowed.

138

RF Exposure

Averaging and Duty Cycle

- Controlled and Uncontrolled Environments.
  - In an uncontrolled environment:
    - Individuals are not aware of the presence of RF energy or,
    - Individuals are not knowledgeable about the precautions to be taken.
    - Exposure is averaged over a 30-minute time period.
    - Lower levels of exposure are imposed.

139

RF Exposure

Averaging and Duty Cycle.

- There are 2 different types of duty cycle that are taken into account when determining the exposure level.
  - Operational duty cycle.
  - Mode duty cycle.

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RF Exposure

Averaging and Duty Cycle.

- Operational duty cycle.
  - The ratio of the transmitter on time to the total time during the averaging period.

141

RF Exposure

Averaging and Duty Cycle.

- Mode duty cycle.
  - Depending on the mode being used, the transmitter may not be at full output power all of the time during the transmission.
  - Typical mode duty cycles are:
    - SSB (unprocessed) = 20% to 25%.
    - SSB (processed) = 40%.
    - FM = 100%.
    - CW = 40%.
    - SSTV & most digital modes = 100%.

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RF Exposure

Antenna System.

- When determining the exposure, the antenna gain the must be taken into account if in the far field of the antenna.
  - The far field of an antenna is where the antenna pattern does not change with distance.
    - Approximately 10λ from the antenna.

143

E0A02 -- When evaluating RF exposure levels from your station at a neighbor's home, what must you do?

A. Ensure signals from your station are less than the controlled Maximum Permitted Exposure (MPE) limits

B. Ensure signals from your station are less than the uncontrolled Maximum Permitted Exposure (MPE) limits

C. Ensure signals from your station are less than the controlled Maximum Permitted Emission (MPE) limits

D. Ensure signals from your station are less than the uncontrolled Maximum Permitted Emission (MPE) limits

144

E0A03 -- Over what range of frequencies are the FCC human body RF exposure limits most restrictive?

A. 300 kHz to 3 MHz

B. 3 to 30 MHz

➡ C. 30 to 300 MHz

D. 300 to 3000 MHz

145

E0A06 -- Why are there separate electric (E) and magnetic (H) field MPE limits?

A. The body reacts to electromagnetic radiation from both the E and H fields

B. Ground reflections and scattering make the field impedance vary with location

C. E field and H field radiation intensity peaks can occur at different locations

➡ D. All of these choices are correct

146

E0A08 -- What does SAR measure?

A. Synthetic Aperture Ratio of the human body
B. Signal Amplification Rating
C. The rate at which RF energy is absorbed by the body
D. The rate of RF energy reflected from stationary terrain

147

E0A11 -- Which of the following injuries can result from using high-power UHF or microwave transmitters?

A. Hearing loss caused by high voltage corona discharge
B. Blood clotting from the intense magnetic field
C. Localized heating of the body from RF exposure in excess of the MPE limits
D. Ingestion of ozone gas from the cooling system

148

RF Exposure

Estimating Exposure and Station Evaluation

- All fixed amateur stations must evaluate the RF exposure potential from each transmitter.
  - Mobile & portable stations are exempt.
  - A transmitter is exempt if the output power is below specified limits.
    - The power limits vary by frequency.
    - Only the transmitters that exceed the specified power output limits need to be evaluated.

149

RF Exposure

Estimating Exposure and Station Evaluation

- Power thresholds for RF Exposure Evaluation.

HF	
160m, 80m, 40m	500W
30m	425W
20m	225W
17m	125W
15m	100W
12m	75W
10m	50W

VHF/UHF/Microwave	
6m	50W
2m	50W
1.25m	50W
70cm	70W
33cm	150W
23cm	200W
13cm & up	250W

150

RF Exposure

Estimating Exposure and Station Evaluation

- Methods of Evaluating RF Exposure.
  - Precision measurements at specific frequencies using a calibrated field strength meter and a calibrated antenna.
    - **VERY** expensive.
      - ≈ $15,000.
  - Less precise measurements using a broad-band electromagnetic exposure meter.
    - Heliogenesis Model EM2
      - ≈ $140

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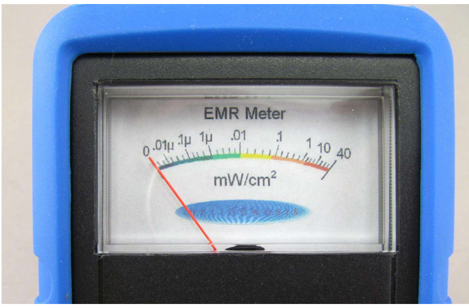
RF Exposure

Estimating Exposure and Station Evaluation

Heliogenesis Model EM2 Electromagnetic Exposure Meter

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RF Exposure

Estimating Exposure and Station Evaluation

- Methods of Evaluating RF Exposure.
  - Calculate using formulas.
    - Use charts based on formulas.
    - Use software based on formulas.
    - Need to know:
      - Transmitter output power.
      - Feedline loss.
      - Antenna gain.
      - Antenna height above ground.
      - Frequency.

153

RF Exposure

Estimating Exposure and Station Evaluation

- If there are multiple transmitters at the same location:
  - All transmitter operators are jointly responsible for seeing that MPEs are not exceeded.
  - A transmitter must be included in the site evaluation if it produces more than 5% of the MPE for that frequency.

154

RF Exposure

Exposure Safety Measures

- Locate antennas where people cannot get near them.
- Do not point antennas at occupied locations.
- Carefully evaluate the exposure potential of “stealth” antennas.
- Use a dummy load when testing transmitters.

155

RF Exposure

Exposure Safety Measures.

- Locate VHF/UHF mobile antennas on the roof of the vehicle or on the trunk lid.
- Use extra care when using high-gain antennas for VHF/UHF/microwave frequencies.

156

E0A04 -- When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of which transmitters are responsible for mitigating over-exposure situations?

A. Only the most powerful transmitter
B. Only commercial transmitters
➡ C. Each transmitter that produces 5 percent or more of its MPE exposure limit at accessible locations
D. Each transmitter operating with a duty-cycle greater than 50 percent

157

E0A05 -- What is one of the potential hazards of using microwaves in the amateur radio bands?

A. Microwaves are ionizing radiation
➡ B. The high gain antennas commonly used can result in high exposure levels
C. Microwaves often travel long distances by ionospheric reflection
D. The extremely high frequency energy can damage the joints of antenna structures

158

Grounding and Bonding

An amateur radio station needs to deal with several types of "grounds".

- Electrical safety ground.
- Lightning dissipation ground.
- Common reference potential.
  - a.k.a. – RF ground.
- All 3 ground systems should be bonded together at a common point.

159

Grounding and Bonding

Electrical Safety Ground.

- The electrical safety ground is intended to prevent electrical shock.
- An electrical safety ground is required by the National Electrical Code (NEC).
- a.k.a. -- "3rd-wire" or "green wire" ground.

160

Grounding and Bonding

Lightning Dissipation Ground

- A lightning dissipation ground is intended to prevent damage to your station from lightning striking the antenna system.
  - Lightning is a high energy, short duration pulse:
    - The current in a lightning strike can be up to tens of thousands of Amperes.
    - The current in a lightning strike has RF components up to about 1 MHz.
    - Low resistance & low inductance ground connections are required.

161

Grounding and Bonding

Lightning Dissipation Ground

- The primary purpose of ground rods is to provide lightning protection for both AC power systems and antenna systems.

162

Grounding and Bonding

Common Reference Potential

- A common reference potential, more commonly called an RF ground, is intended to prevent stray RF voltages from interfering with the proper operation of station equipment.
  - Prevents RF feedback.
  - All equipment should be connected directly to a common ground.
    - Do **NOT** “daisy-chain” the equipment together.

163

E0A01 -- What is the primary function of an external earth connection or ground rod?

A. Reduce received noise

B. Lightning protection

C. Reduce RF current flow between pieces of equipment

D. Reduce RFI to telephones and home entertainment systems

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Questions?

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Amateur Extra Class

Next Week

Exam

166