Amateur Extra License Class

1

Amateur Extra Class

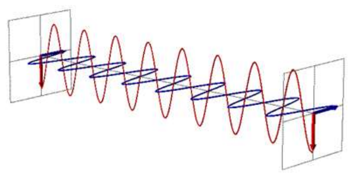
Chapter 10
Topics in Radio Propagation

2

Electromagnetic Waves

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

- Each field varies with time in a sinusoidal pattern at the same frequency.
- The wave travels at a right angle to both the E & H fields.



3

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.

In any other medium, electromagnetic waves travel at a fraction of the speed of light.

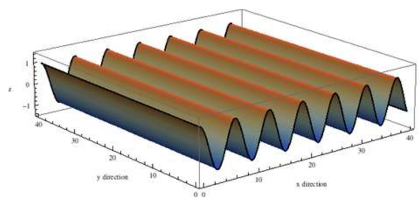
- The fraction is determined by the index of refraction of the medium.

4

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.



Electromagnetic Waves

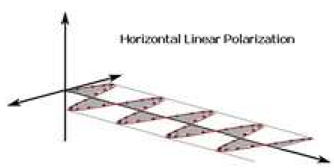
Polarization

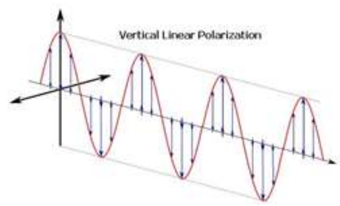
- Polarization refers to the way the E-field is orientated with respect to the surface of the earth.
  - Horizontal polarization.
  - Vertical polarization.
  - Left-hand circular polarization.
  - Right-hand circular polarization.
  - Left-hand elliptical polarization.
  - Right-hand elliptical polarization.

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.



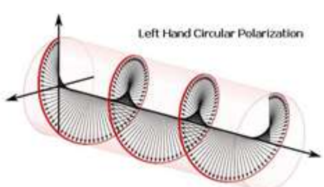


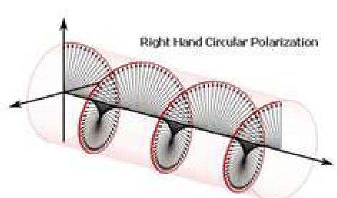
7

Electromagnetic Waves

Polarization

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



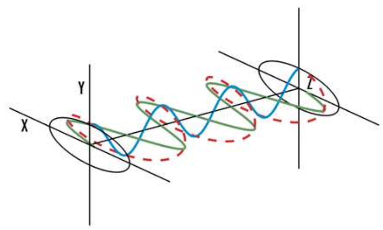


8

Electromagnetic Waves

Polarization

- Elliptical polarization.
  - If the E-field and the H-field are not the same amplitude, the rotating field forms an ellipse instead of a circle.



9

E3A04 -- In what direction does an electromagnetic wave travel?

A. It depends on the phase angle of the magnetic field
B. It travels parallel to the electric and magnetic fields
C. It depends on the phase angle of the electric field
→ D. It travels at a right angle to the electric and magnetic fields

10

E3A05 -- How are the component fields of an electromagnetic wave oriented?

A. They are parallel
B. They are tangential
➡ C. They are at right angles
D. They are 90 degrees out of phase

11

E3A10 -- What determines the speed of electromagnetic waves through a medium?

A. Resistance and reactance
B. Evanescence
C. Birefringence
➡ D. The index of refraction

12

E3A14 -- What are circularly polarized electromagnetic waves?

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

B. Waves with rotating electric and magnetic fields

C. Waves that circle Earth

D. Waves produced by a loop antenna

13

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.

14

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).

15

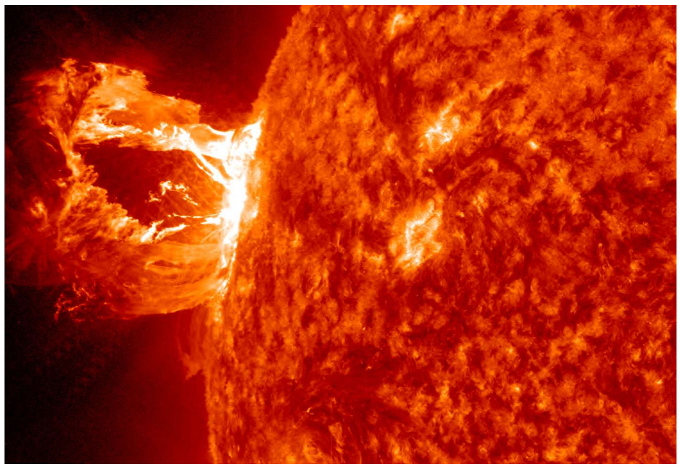
Solar Effects

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 resulting in short-term radio blackouts.

16

Solar Effects



17

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

18

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.

19

Solar Effects

Flux and Flares.

- Geomagnetic storms are also classified by their strength on a scale of 0 to 5:
  - G0 = Quiet.
  - G1 = Minor.
  - G2 = Moderate.
  - G3 = Strong.
  - G4 = Severe.
  - G5 = Extreme.

20

E3C01 -- What is the cause of short-term radio blackouts?

A. Coronal mass ejections
B. Sunspots on the solar equator
C. North-oriented interplanetary magnetic field
D. Solar flares

21

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

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

22

E3C08 -- Which of the following is the space-weather term for an extreme geomagnetic storm?

A. B9
B. X5
C. M9
D. G5

23

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

24

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).

25

Solar Effects

Geomagnetic Field.

- The following parameters are used to evaluate propagation conditions:
  - B_Z – Intensity & orientation of the interplanetary magnetic field.
  - K-Index – Short-term geomagnetic stability.
  - A-Index – Long-term geomagnetic stability.
  - G-Index – Geomagnetic storm strength.

26

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.

27

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.

28

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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.

29

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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

30

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

31

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

32

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

33

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

34

HF Propagation

A couple of definitions:

- Lowest Useable Frequency (LUF) – The lowest frequency that will allow communications between 2 points on the Earth's surface.
- Maximum Useable Frequency (MUF) – The highest frequency that will allow communications between 2 points on the Earth's surface.

35

HF Propagation

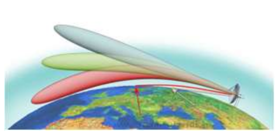
In nearly all cases, HF waves travel along the surface of the earth or they are returned to earth after encountering the upper layers of the ionosphere.

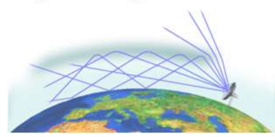
36

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.





37

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.

38

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.

39

E3B08 -- How does the maximum range 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 8 MHz

40

E3B13 -- What type of polarization is supported by ground-wave propagation?

➡ A. Vertical

B. Horizontal

C. Circular

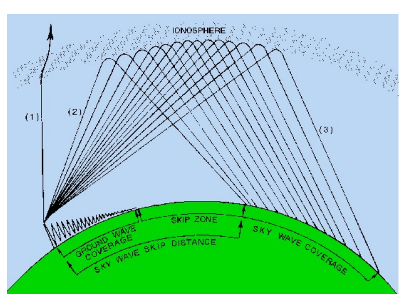
D. Elliptical

41

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.

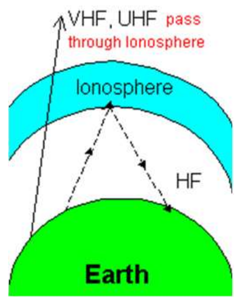


42

HF Propagation

Sky-Wave Propagation

- The shorter the wavelength, the less refraction occurs.
  - Sky-wave propagation is usually possible only on the lower VHF frequencies (6m) and below.

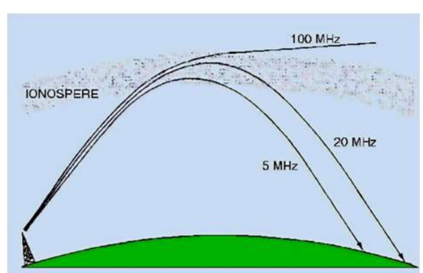


43

HF Propagation

Sky-Wave Propagation

- The lower the ionization level, the less refraction occurs.
  - It may be necessary to move to a lower-frequency band to maintain the desired communications.

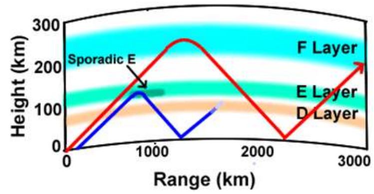


44

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.
- A lower take-off angle results in a greater single-hop distance.

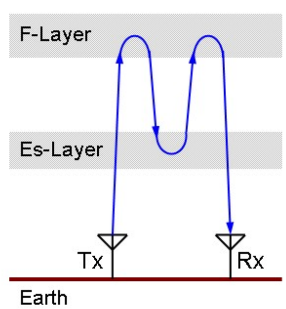


45

HF Propagation

Sky-Wave Propagation

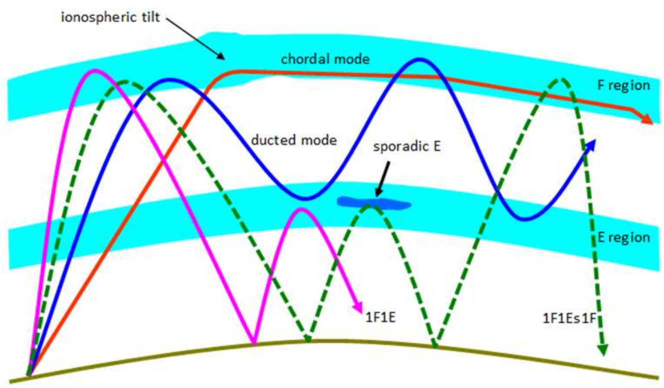
- It is possible for a radio wave to be refracted between the E-layer and the F-layer or within the F-layer itself.
  - When this occurs, it is called a "chordal hop".
  - This provides long-distance skip without the losses imposed by reflecting off the Earth's surface.



46

HF Propagation

Sky-Wave Propagation



47

HF Propagation

Sky-Wave Propagation

- During daylight hours, ionization of the D-layer absorbs signals at MF and lower-HF frequencies.
  - Signals are prevented from reaching the E- or F-layers.
  - Especially pronounced on 160m & 80m.
  - Long-distance communications only feasible on paths that are entirely in darkness.

48

E3A06 -- What should be done to continue a long-distance contact when the MUF for that path decreases due to darkness?

A. Switch to a higher frequency HF band
B. Switch to a lower frequency HF band
C. Change to an antenna with a higher takeoff angle
D. Change to an antenna with greater beam width

49

E3B05 -- Which of the following paths is most likely to support long-distance propagation on 160 meters?

A. A path entirely in sunlight
B. Paths at high latitudes
C. A direct north-south path
D. A path entirely in darkness

50

E3B07 -- What effect does lowering a signal s transmitted elevation angle have on ionospheric HF skip propagation?

A. Faraday rotation becomes stronger

B. The MUF decreases

➡ C. The distance covered by each hop increases

D. The critical frequency increases

51

E3B10 -- What is the effect of chordal-hop propagation?

➡ A. The signal experiences less loss compared to multi-hop propagation, which uses Earth as a reflector

B. The MUF for chordal-hop propagation is much lower than for normal skip propagation

C. Atmospheric noise is reduced in the direction of chordal-hop propagation

D. Signals travel faster along ionospheric chords

52

E3B12 -- What is 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

53

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.

54

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.

55

E3B04 -- What are extraordinary and ordinary waves?

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

➡ B. Independently propagating, elliptically polarized waves created in the ionosphere

C. Long-path and short-path waves

D. Refracted rays and reflected waves

56

HF Propagation

Sky-Wave Propagation

- Predicting and Observing 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.

57

HF Propagation

Sky-Wave Propagation

- Predicting and Observing 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.

58

HF Propagation

Sky-Wave Propagation

- Predicting and Observing Propagation.
  - A number of online reporting networks have been established that report call signs heard at various points on the Earth.
    - Allow real-time propagation conditions anywhere on the Earth.
    - Signals monitored include CW and various digital modes.

59

E3C09 -- What type of data is reported by amateur radio propagation reporting networks?

A. Solar flux

B. Electric field intensity

C. Magnetic declination

D. Digital-mode and CW signals

60

E3C11 -- What does VOACAP software model?

A. AC voltage and impedance

B. VHF radio propagation

C. HF propagation

D. AC current and impedance

61

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.

62

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.

63

HF Propagation

Sky-Wave Propagation

- Absorption.
  - Geomagnetic disturbances caused by coronal mass ejections (CMEs) & 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 where aurora occurs.

64

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. Through the auroral oval
C. Sporadic-E
D. NVIS

65

E3C12 -- Which of the following is indicated by a sudden rise in radio background noise across a large portion of the HF spectrum?

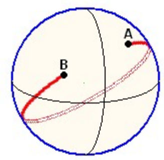
A. A temperature inversion has occurred
B. A coronal mass ejection impact or a solar flare has occurred
C. Transequatorial propagation on 6 meters is likely
D. Long-path propagation on the higher HF bands is likely

66

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.



67

HF Propagation

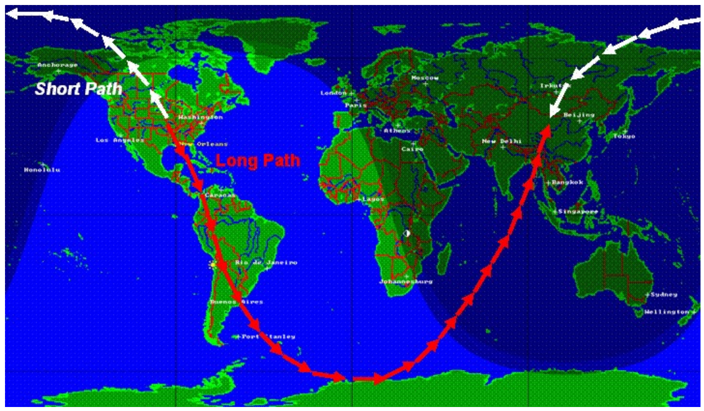
Sky-Wave Propagation

- 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 40m & 20m.

68

HF Propagation

Long Path vs. Short Path



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.

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.

71

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.

72

HF Propagation

Long Path and Gray Line

- Gray line propagation.

73

E3B06 -- On which of the following amateur bands is long-path propagation most frequent?

A. 160 meters and 80 meters

➡ B. 40 meters and 20 meters

C. 10 meters and 6 meters

D. 6 meters and 2 meters

74

VHF/UHF/Microwave Propagation

Above 50 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.

75

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%.

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

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

76

E3C06 -- How does the VHF/UHF radio horizon compare to the geographic horizon?

A. It is approximately 15 percent farther

B. It is approximately 20 percent nearer

C. It is approximately 50 percent farther

D. They are approximately the same

77

VHF/UHF/Microwave Propagation

Fresnel Zone

- Radio waves leaving an antenna spread out to form a cone of energy.
- Some of the energy can be reflected off the surface of the Earth near the transmitting antenna at the same angle as the direct signal & will arrive at the receiving antenna in phase.
- The area where this can occur is an elliptical area called a “Fresnel zone”.

78

VHF/UHF/Microwave Propagation

Fresnel Zone

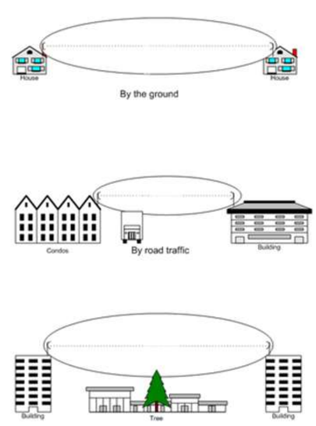
- The higher the frequency, the smaller the Fresnel zone.
- At HF & 6m, signals reflected off the ground in the Fresnel zone reinforce the direct signal causing an increase of the signal at the receiver.
  - This effect is known as “ground gain”.

79

VHF/UHF/Microwave Propagation

Fresnel Zone

- At VHF & up, obstructions in the path can cause decreased signal strength at the receiver.
  - Terrain.
  - Buildings.
  - Vegetation.
  - Other.

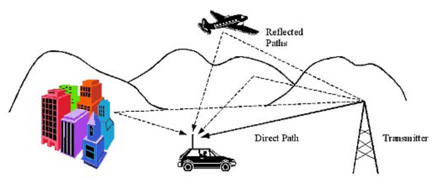


80

VHF/UHF/Microwave Propagation

Multipath

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



81

E3A05 -- What does the term ground gain mean?

A. The change in signal strength caused by grounding the antenna

B. The gain of the antenna with respect to a dipole at ground level

C. To force net gain to 0 dB by grounding part of the antenna

D. An increase in signal strength from ground reflections in the environment of the antenna

82

E3A08 -- Which frequency band has the smallest first Fresnel zone

A. 5.8 GHz
B. 3.4 GHz
C. 2.4 GHz
D. 900 MHz

83

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.

84

VHF/UHF/Microwave Propagation

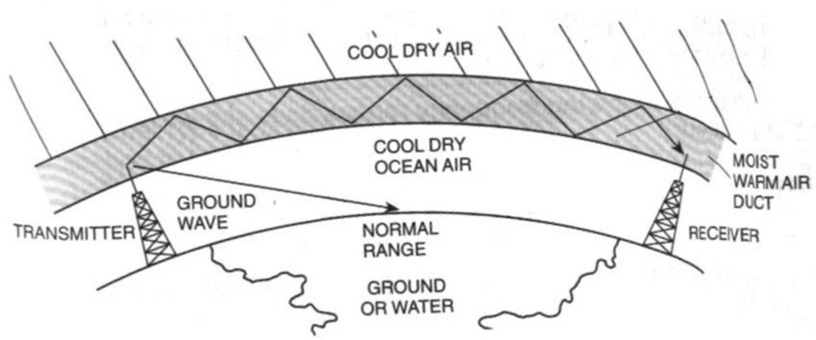
Tropospheric Propagation

- 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.

85

VHF/UHF/Microwave Propagation

Tropospheric Propagation



Tropospheric Ducting

86

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.

87

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

A. Mountain ranges

B. Stratocumulus clouds

➡ C. Large bodies of water

D. Nimbus clouds

88

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

A. 10 miles to 50 miles

B. 100 miles to 300 miles

C. 1,200 miles

D. 2,500 miles

89

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.

90

VHF/UHF/Microwave Propagation

Sporadic E Propagation

- Sporadic-E propagation can occur at any time of the day or night, but most commonly during daylight hours.
- 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.

91

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

92

E3B11 -- At what time of day is sporadic-E propagation most likely to occur?

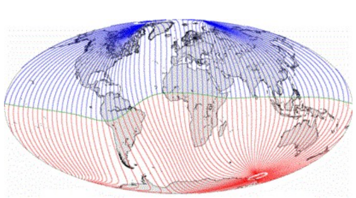
A. Between midnight and sunrise
B. Between sunset and midnight
C. Between sunset and sunrise
D. Between sunrise and sunset

93

VHF/UHF/Microwave Propagation

Transequatorial Propagation

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



94

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 5,000 miles.
  - Most commonly in the range of 2,000 to 3,000 miles.

95

VHF/UHF/Microwave Propagation

Transequatorial Propagation

- 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.

96

E3B01 -- Where is transequatorial propagation (TEP) most likely to occur?

- A. Between points separated by 2,000 miles to 3,000 miles over a path perpendicular to the geomagnetic equator
- B. Between points located 1,500 miles to 2,000 miles apart on the geomagnetic equator
- C. Between points located at each other s antipode
- D. Through the region where the terminator crosses the geographic equator

97

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

- A. 1,000 miles
- B. 2,500 miles
- C. 5,000 miles
- D. 7,500 miles

98

E3B03 -- At what time of day is transequatorial propagation most likely to occur?

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

99

VHF/UHF/Microwave Propagation

Auroral Propagation

100

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.
- Strong geomagnetic storms increase the intensity of the ionization.

101

VHF/UHF/Microwave Propagation

Auroral Propagation

- 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.

102

VHF/UHF/Microwave Propagation

Auroral Propagation

- The refraction of VHF & UHF signals in this ionized layer is called "auroral propagation" & can support contacts up to about 1,400 miles.
  - An increasing K-index of 3 or more may indicate that auroral propagation is possible.

103

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.

104

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.

105

E3A12 -- What is most likely to result in auroral propagation?

A. Meteor showers

B. Quiet geomagnetic conditions

C. Severe geomagnetic storms

D. Extreme low-pressure areas in polar regions

106

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

A. CW

B. SSB

C. FM

D. RTTY

107

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.

108

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.

109

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.

110

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.

111

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.

112

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

A. WSPR
B. MSK144
C. Hellschreiber
D. APRS

113

E3A08 -- When a meteor strikes the Earth's atmosphere, a linear ionized region is formed at what region of the ionosphere?

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

114

E3A09 -- Which of the following frequency ranges is most 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

115

VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

116

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.

117

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.

118

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.

119

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.

120

VHF/UHF/Microwave Propagation

Earth-Moon-Earth Communications

- The WSJT-X family of software contains 2 modes that were specifically designed for EME communications.
  - JT65 & Q65.
  - Both modes use alternating, time-synchronized transmissions.
  - Special encoding techniques allow copying signals with extremely low signal-to-noise ratios.

121

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

A. MSK144

B. PACTOR III

C. WSPR

D. Q65

122

E2D05 -- What is the characteristic of the JT65 mode?

A. Uses only a 65 Hz bandwidth
➡ B. Decodes signals with a very low signal-to-noise ratio
C. Symbol rate is 65 baud
D. Permits fast-scan TV transmissions over narrow bandwidth

123

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

➡ A. Time-synchronous transmissions alternating between stations
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

124

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

A. 2,000 miles, if the moon is at perigee
B. 2,000 miles, if the moon is at apogee
C. 5,000 miles, if the moon is at perigee
➡ D. 12,000 miles, if the moon is visible by both stations

125

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

126

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

127

WABASH VALLEY AMATEUR RADIO ASSOCIATION W9UUU.org

Questions?

128

Break

129

Amateur Extra Class

Chapter 11
Safety

130

Climbing Safety

Before You Begin: Preparation

- Make certain that you have all necessary safety equipment, tools, and supplies.
  - Don't forget the sunscreen.
- Carefully inspect all safety equipment.
  - Climbing belt.
  - Hard hats for both climber and ground personnel.
  - Gloves.

131

Climbing Safety

Pre-Climb Safety Inspection

- Carefully inspect all aspects of the antenna system being worked on:
  - Tower.
  - Tower base.
  - Guy wires.
  - Guy wire anchors.
  - etc.

132

Climbing Safety

100% Tie-Off: A rule to Live By.

- OSHA regulations require that a worker's climbing belt/harness be provided with at least 2 lanyards to ensure that the worker is secured to the tower by at least one lanyard at all times.
  - Lanyards should be attached to a leg of the tower.
  - A shock-absorbing lanyard should be attached above the worker's head.

133

E0A07 -- What is meant by 100% tie-off regarding tower safety?

A. All loose ropes and guys secured to a fixed structure

B. At least one lanyard attached to the tower at all times

C. All tools secured to the climber s harness

D. All circuit breakers feeding power to the tower must be tied closed with tape, cable, or ties

134

E0A11 -- To what should lanyards be attached while climbing?

A. Antenna mast
B. Guy brackets
C. Tower rungs
➡ D. Tower legs

135

E0A12 -- Where should a shock-absorbing lanyard be attached to a tower when working above ground?

➡ A. Above the climber’s head level
B. To the belt of the fall-arrest harness
C. Even with the climber's waist
D. To the next lowest set of guys

136

RF Exposure

Radiation can be divided into 2 categories:

- Ionizing Radiation.
- Non-ionizing radiation.

137

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.

138

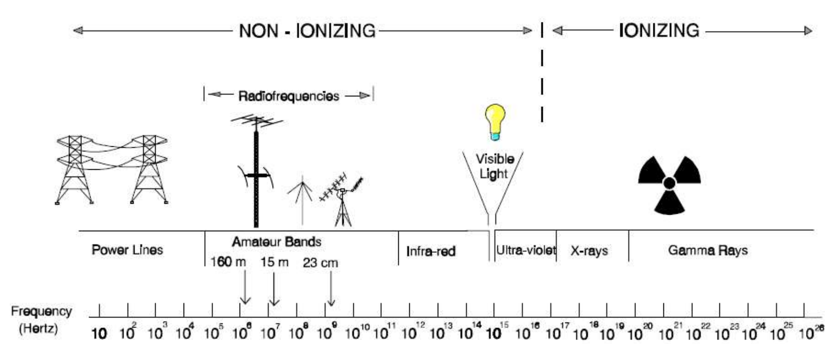
RF Exposure

Non-ionizing radiation

- Non-ionizing radiation is radiation where the energy is not sufficient to strip electrons from atoms or to break atoms apart.
  - All radio frequency energy is non-ionizing.

139

RF Exposure



140

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.

141

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.
    - $Z = E / H$.

142

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.

143

RF Exposure

Absorption and Limits

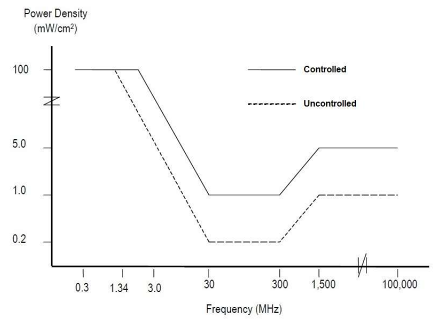
- The FCC rules specify the highest level of exposure allowed from radio transmitters called the “maximum permissible exposure” or MPE.
  - The MPEs vary with frequency.
  - The MPEs vary according to the “environment”.

144

RF Exposure

Absorption and Limits

- Maximum permissible exposure (MPE).



145

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.

146

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.

147

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.

148

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.

149

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 -- The ratio of the transmitter on time to the total time during the averaging period.
  - Mode duty cycle – The ration of the average output power to the peak output power.

150

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%.

151

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.

152

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 permissible exposure (MPE) limits
B. Ensure signals from your station are less than the uncontrolled maximum permissible exposure (MPE) limits
C. Ensure signals from your station are less than the controlled maximum permissible emission (MPE) limits
D. Ensure signals from your station are less than the uncontrolled maximum permissible emission (MPE) limits

153

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

154

E0A06 -- Why are there separate electric (E) and magnetic (H) MPE limits at frequencies below 300 MHz?

A. The body reacts to electromagnetic radiation from both the E and H fields
B. Ground reflections and scattering cause the field strength to vary with location
C. E field and H field radiation intensity peaks can occur at different locations
D. All these choices are correct

155

E0A08 -- What does SAR measure?

A. Signal attenuation ratio
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

156

RF Exposure

Estimating Exposure and Station Evaluation

- **ALL** amateur stations must evaluate the RF exposure potential from each transmitter.
  - **Exception**: Handheld radios purchased before May 3, 2021, are exempt from the evaluation requirement.
- **ANY** changes to your station requires that the station to be re-evaluated.
  - Changes to equipment.
  - Changes to antenna system.

157

RF Exposure

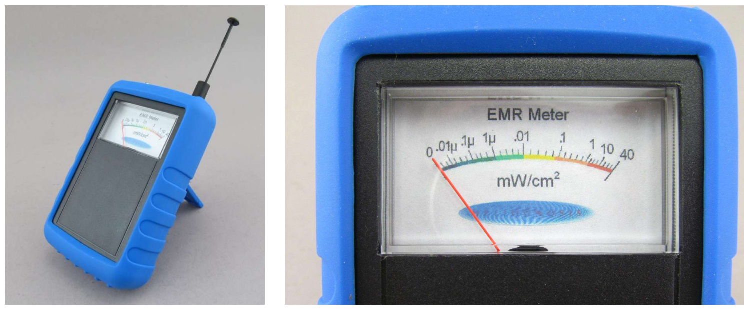
Estimating Exposure and Station Evaluation

- 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

158

RF Exposure

Estimating Exposure and Station Evaluation



Heliogenesis Model EM2 Electromagnetic Exposure Meter

159

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.

160

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.

161

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.

162

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.

163

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. Each transmitter that produces 20 percent or more of its MPE limit in areas where the total MPE limit is exceeded
B. Each transmitter operating with a duty cycle greater than 25 percent
C. Each transmitter that produces 5 percent or more of its MPE limit in areas where the total MPE limit is exceeded
D. Each transmitter operating with a duty cycle greater than 50 percent

164

E0A05 -- What hazard is created by operating at microwave frequencies?

A. Microwaves are ionizing radiation
B. The high gain antennas commonly used can result in high exposure levels
C. Microwaves are in the frequency range where wave velocity is higher
D. The extremely high frequency energy can damage the joints of antenna structures

165

E0A09 -- Which of the following types of equipment are exempt from RF exposure evaluations?

A. Transceivers with less than 7 watts of RF output
B. Antennas that radiate only in the near field
C. Hand-held transceivers sold before May 3, 2021
D. Dish antennas less than one meter in diameter

166

E0A10 -- When must an RF exposure evaluation be performed on an amateur station operating on 80 meters?

A. An evaluation must always be performed

B. When the ERP of the station is less than 10 watts

C. When the station s operating mode is CW

D. When the output power from the transmitter is less than 100 watts

167

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.

168

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.

169

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.

170

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.

171

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.

172

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

A. Prevent static build up on power lines
B. Lightning charge dissipation
C. Reduce RF current flow between pieces of equipment
D. Protect breaker panel from power surges

173

Questions?

174

Amateur Extra Class

Next Week

Exam

175