Halifax Amateur Radio Club

Basic Amateur Radio Licensing Course – Fall 2013

Thursday, 17 October 2013

Propagation

Objectives

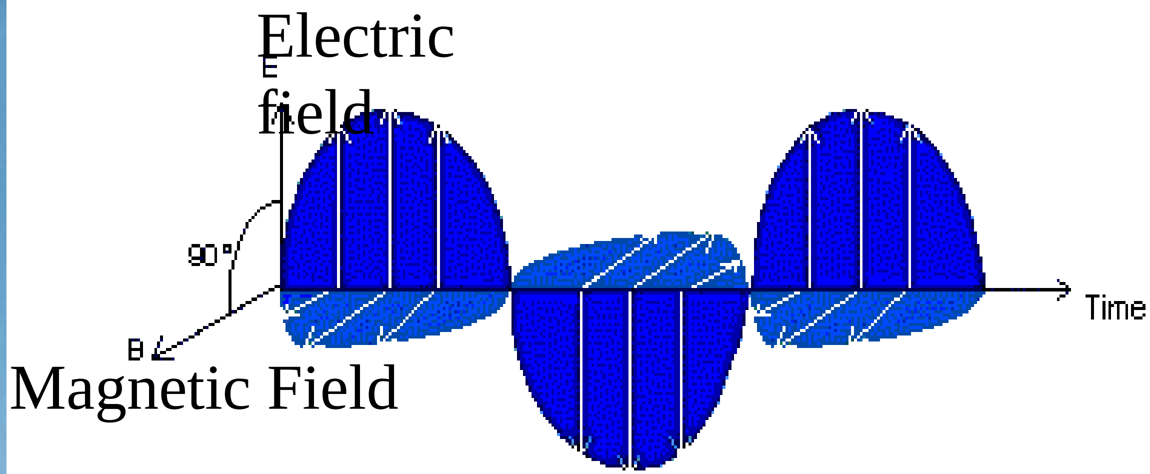
- When you finish this chapter your should:
  - – be familiar with the classification of RF waves
  - – be familiar with the factors affecting propagation of RF waves
  - – be familiar with the propagation characteristics of the different Amateur Radio bands.

Understanding RF Waves

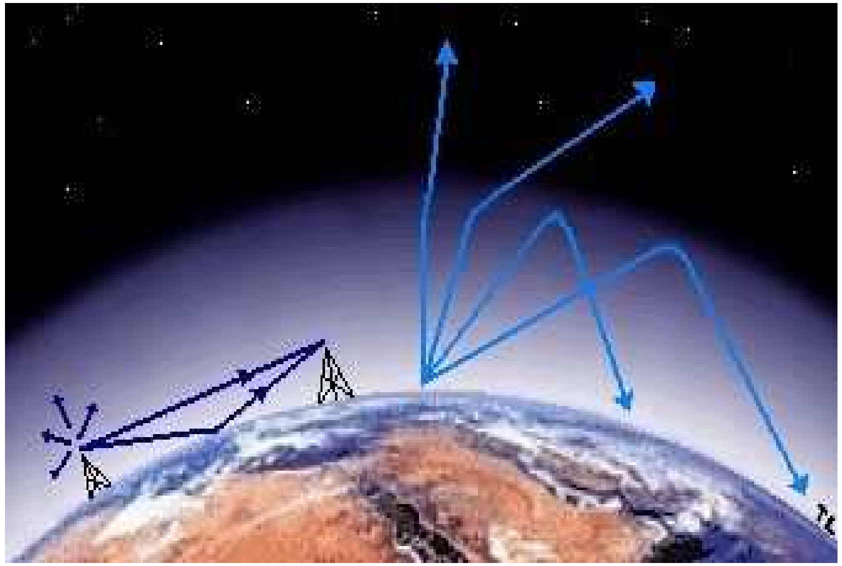
- RF waves are one type of EM radiation - they:
  - radiate from source at 300 million metres/sec
  - decrease in strength in an “inverse square relationship” as they spread out from the source
    - **Signal 2 km from source will be 1/4 as strong as when 1 km from source**
  - are transverse waves **(vibrate side to side)**
  - have both **electrical** and a **magnetic** components

EM Waves

- EM waves are generally polarized
  - Vertical polarization (electric field perpendicular to ground) - vertical antenna
  - Horizontal polarization (electric field parallel to the ground - horizontal antenna



EM Waves



Radio Waves

- **Space**
  - **Sky** — **Ionospheric**
  - **Reflected**
- **Ground**
  - **Direct** — **Tropospheric**
  - **Surface** — **Ground**

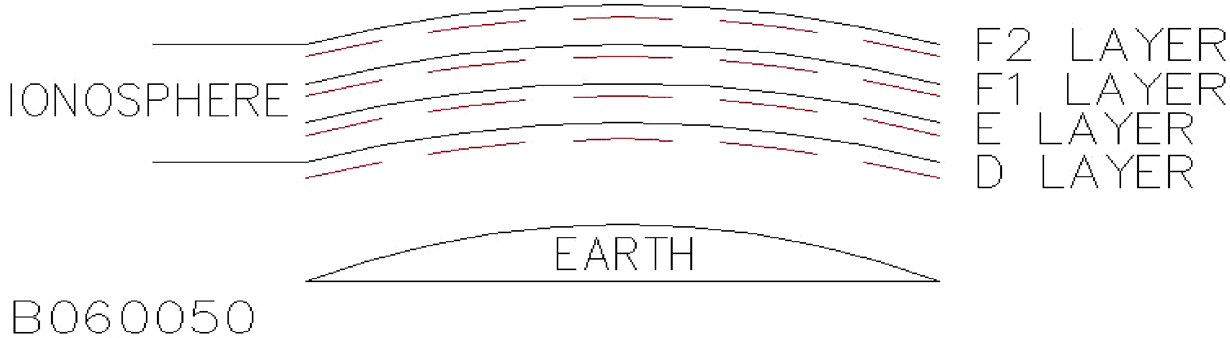
Troposphere - from surface of the earth up to ~ 20km

Ionosphere - from 50 to 400 km up

Atmospheric Ionization

- Effect of ionizing (UV & X-ray) radiation from the sun on the atmosphere
  - **Ionization** of gas molecules (valence electrons ejected) creating ions of gas
  - **Recombination** - ions & electrons recombine to form stable gas (non-ionized)
  - **Daylight hours -** ionization takes place at the same time as recombination
  - **Nighttime hours -** recombination predominates

Ionospheric Layers



D-layer - 70 - 90 km above earth - absorbs long-wave (160 & 80 metre band) RF energy in daytime & disappears at night

E-layer - 100 - 120 km above earth - most effective as a refracting layer in daytime; is diminished at night

F-layer - At nighttime F1 & F2 layers merge into a single layer

F1-layer - 140 - 190 km above earth -

F2-layer - 300 + km above earth -

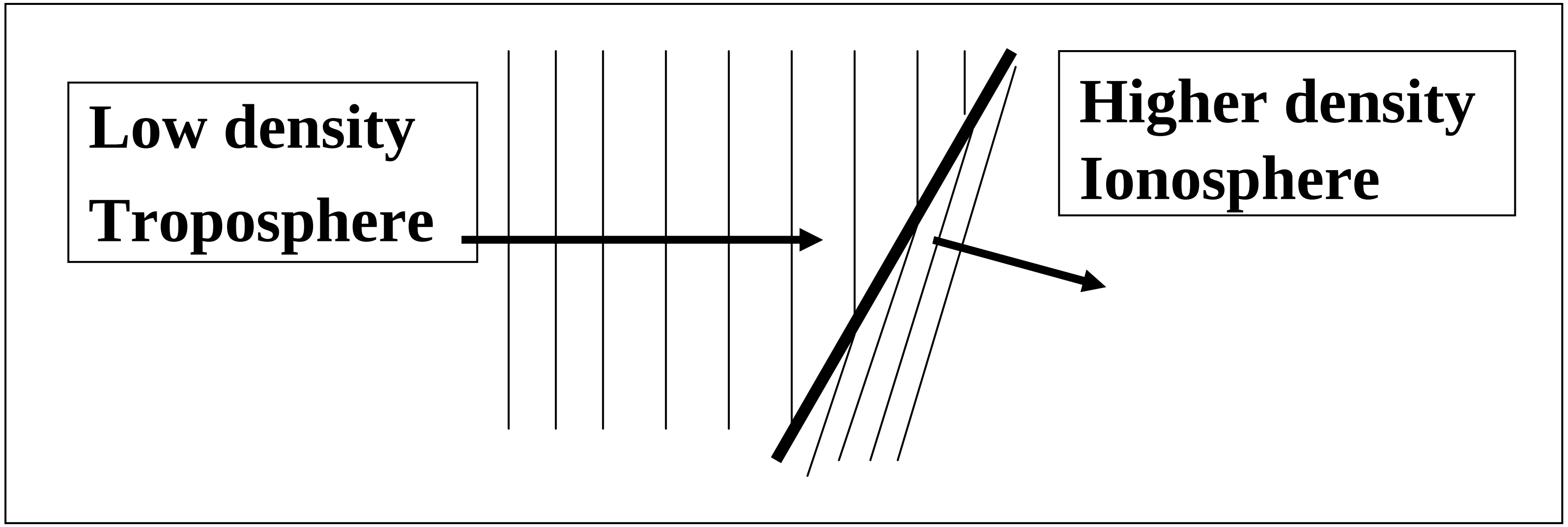
All layers vary in density with amount of ionization - i.e. time of day; time of year, and solar activity.

Altering Radio Wave

- Radio waves generally travel in straight lines, BUT…..
  - **Attenuation -** "inverse square law" applies and energy dissipates as waves spread out from source.
  - **Reflection -** short (VHF/UHF) radio waves can be reflected by solid dense objects; but not longer HF and MF waves
  - **Refraction & Diffraction** >>>>>>

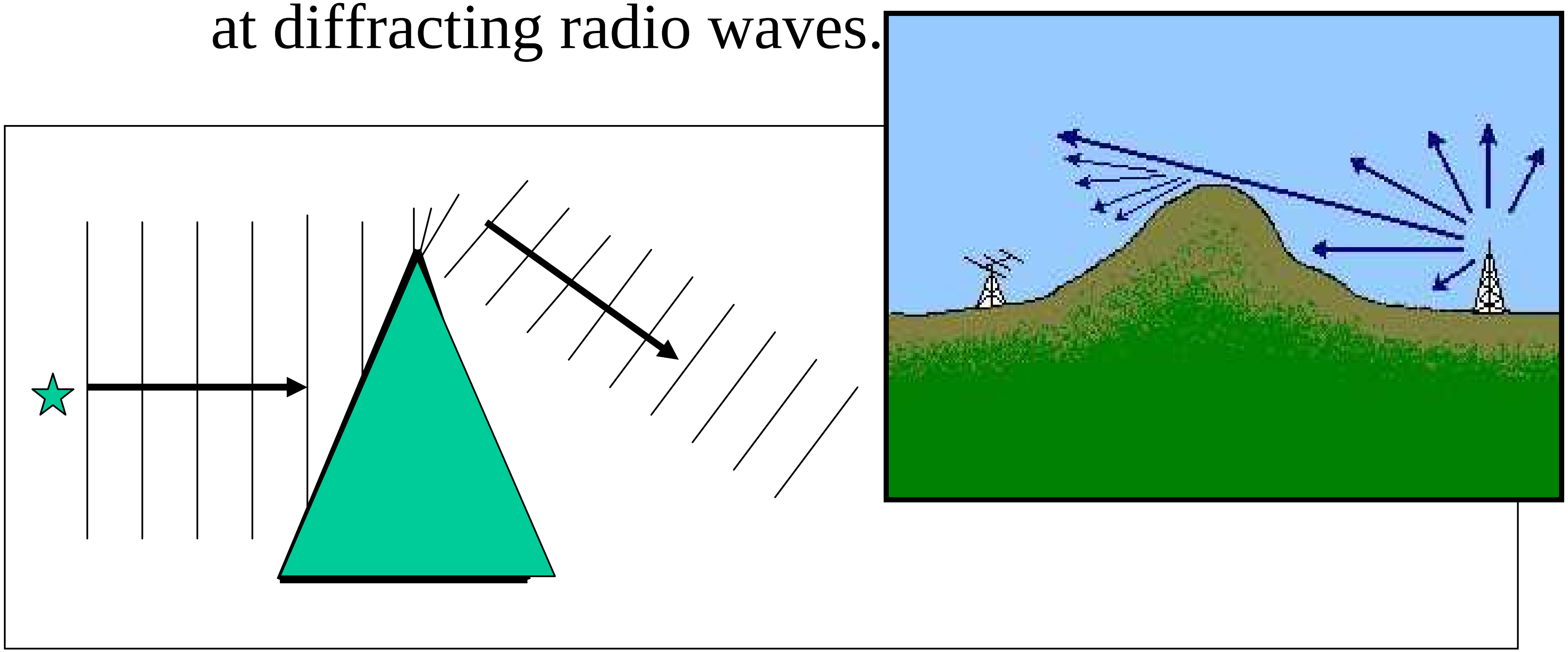
Refraction of Radio Waves

– **Refraction -** or bending occurs when radio waves pass through atmospheric layers with different densities or refractive indices, thus changing the velocity of the wave.



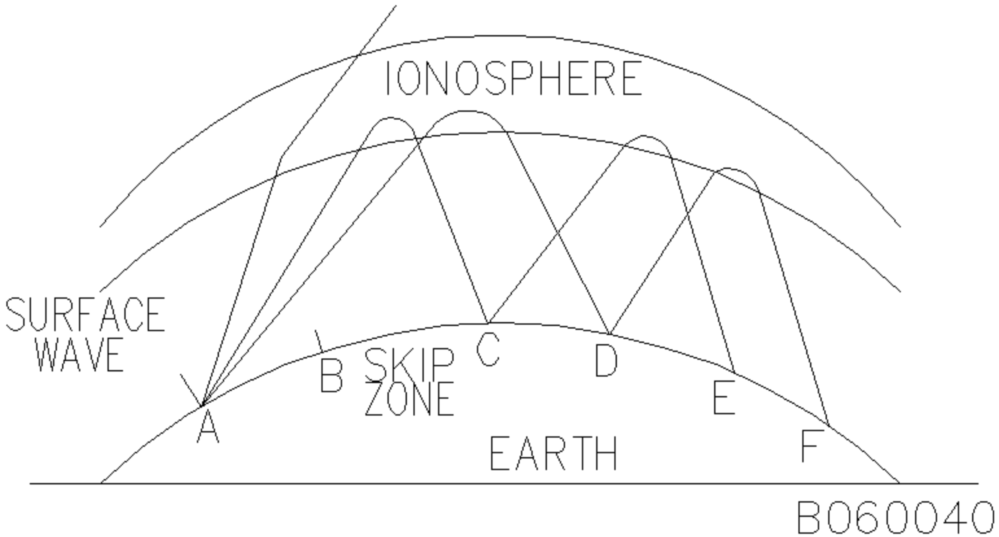
Diffraction of Radio Waves

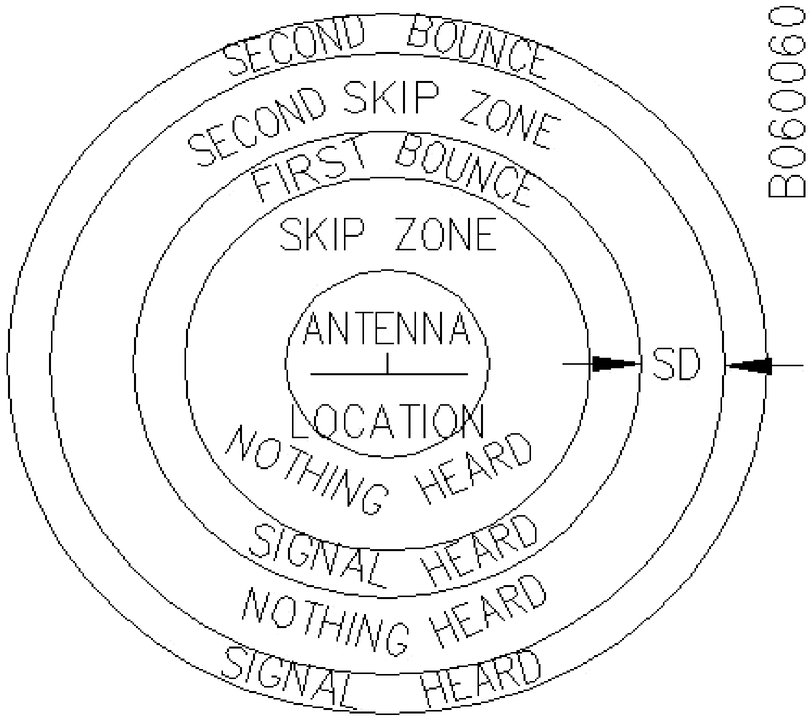
– **Diffraction -** or bending or radio waves around a solid object; sharp edges are most effective at diffracting radio waves.



Radio Wave “Skip”

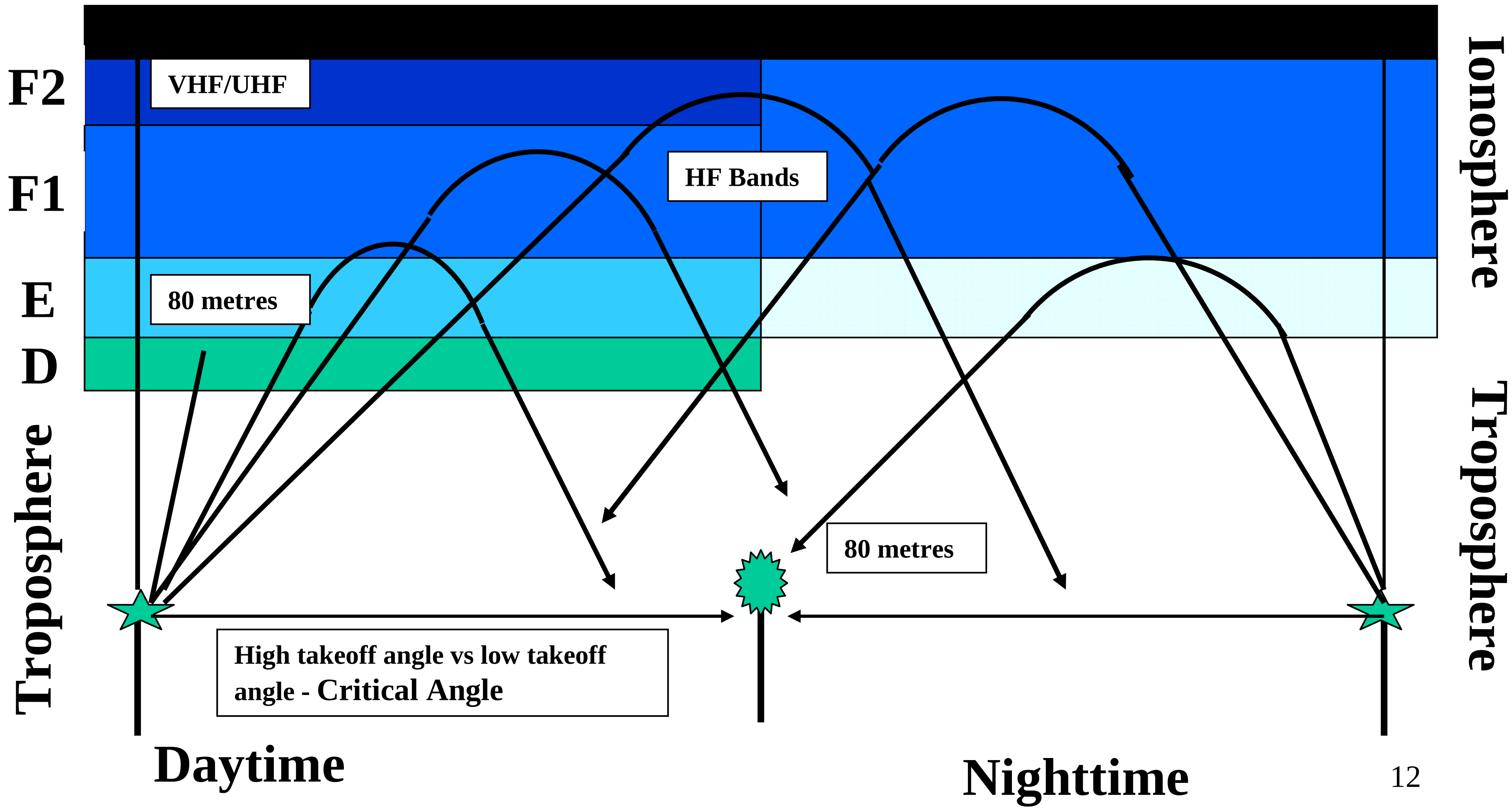
- **Ground wave zone -** Zone A - B
- **Skip zone or zone of silence -** Zone B - C
- **Skip distance -** minimum distance between refractions and reflections
- **Multi-hop propagation**
- **Fading -** when ionospheric conditions are changing





SD = SKIP DISTANCE

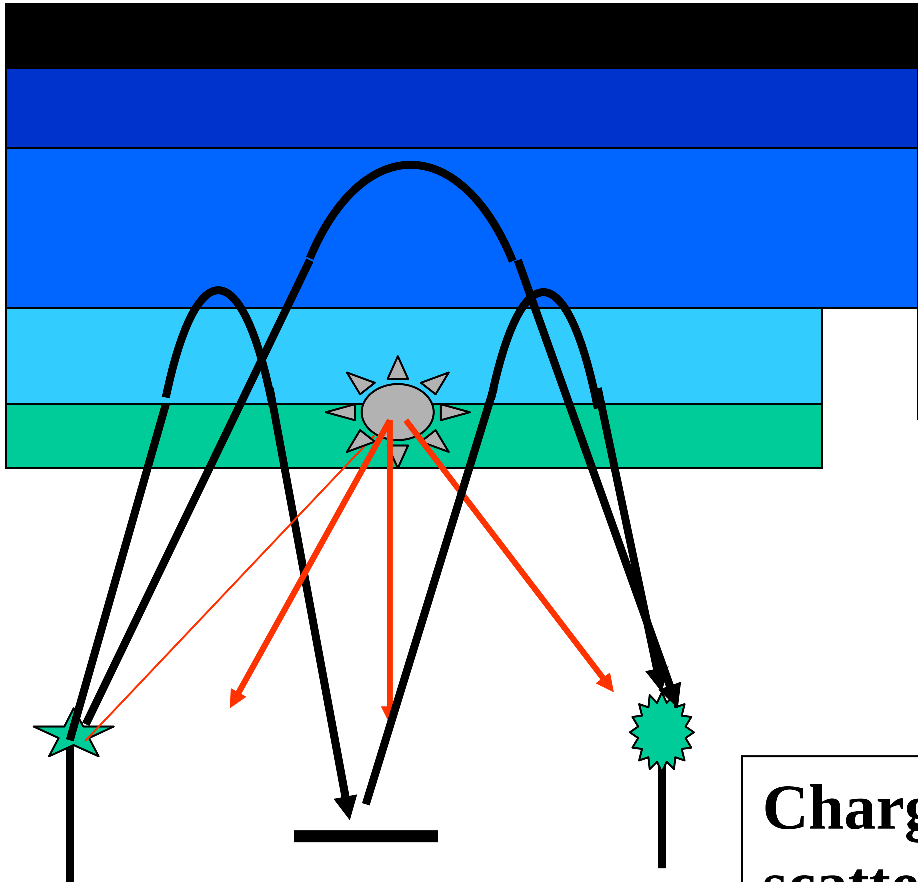
What happens to RF Radiation?



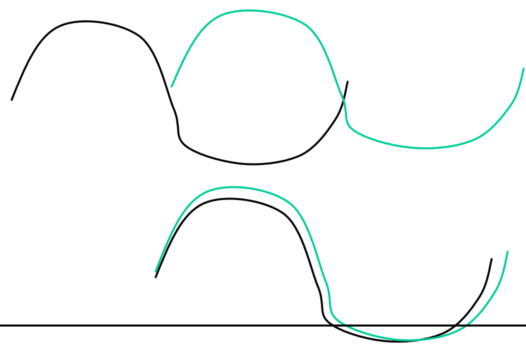
Attenuation & Fading

- **S-meter -** gives a relative indication of received signal (field) strength
- **Field Strength -** intensity or strength of signal (radio wave)
  - remember the "inverse-square relationship"
- **Signal Fading results from:**
  - rapid reduction in ionization at sunset
  - increased absorption by D-layer at dawn
  - disappearance of E-layer
  - multi-path propagation (in and out of phase)

Multi-path Fading & Scatter



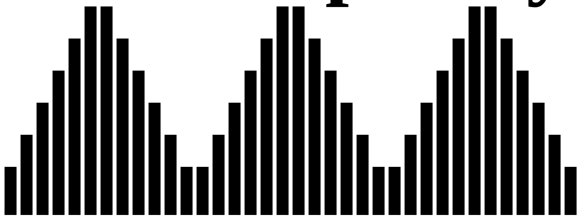
Waves arrive either in phase - so as to complement, or out of phase - so as to cancel.



Charged particles can cause scattering of signals - forward & backward reflection

Sun Effects on RF Propagation

- **Sunspots (s) -** responsible for ionizing radiation
- **Sunspot Cycle -** 11 years from maximum #s to minimum #s and back - presently heading to the peak of cycle 24.



  – With high sunspot numbers the shorter wavelength or higher frequency bands (10 & 6 metres) become active for long-distance communication - i.e. increase in the MUF occurs with increased ionization of the atmosphere..

Sun Effects on RF Propagation

- **Solar Storms** or SIDs (Sudden Ionospheric Disturbances) caused by ejection of X-rays, protons and electrons from sun -

Result in:

> rapid buildup of D-layer absorbing almost all HF waves

> disrupting the magnetic fields of the earth - **Geomagnetic Storms** produce radio background noise & allow ionizing radiation to penetrate at poles of earth causing Aurora (Northern Lights)

Propagation Reports

- **Solar Flux Index -** is a measurement of the intensity of solar radio emissions measured at a frequency of 2800 MHz - correlates well with levels of ionizing radiation from sun
- **K-Index -** scale from 0 to 9 indicating geomagnetic disturbances in the previous three hours.
- **A-Index -** scale from 0 to 400 express a summary of the K-index over the previous day.

Geomagnetic Indices

Description	Typical K	Typical A
Quiet	0 - 1	0 - 7
Unsettled	2	8 - 15
Active	3	16 - 29
Minor Storm	4	30 - 49
Major Storm	5	50 - 99
Severe Storm	6 - 9	100 +

Propagation Prediction

- Critical Frequency (penetrating frequency)
  - highest frequency at which radio waves, if directed vertically upward, will be reflected back to earth by the ionosphere
  - above the critical frequency they pass through and so produce the "Skip Zone" or dead zone around the station..
- Maximum Usable Frequency (MUF)
  - highest frequency that will be refracted back by the ionosphere **assuming that the path is NOT vertical**
  - the greater the angle of ionosphere entry the higher the MUF that will be supported.
- Optimum Working Frequency (OWF)
  - frequency slightly lower that MUF - won't be affected by sudden perturbations in the ionosphere

MF & HF Amateur Band Propagation

- 160 metres (1.8 - 2.0 MHz)
  - Daytime - generally only local communication < 100km
    - at low angle of incidence get D-layer absorption
    - at high angle of incidence may get E-layer refraction
  - Nighttime - E & F-layer refraction - 3000 + km
- 80 metres (3.5 - 4.0 MHz)
  - Daytime - short-range communication < 400km
    - similar to 160 in D absorption and E refraction
  - Nighttime - E & F-layer refraction - 5000 + km

- Both bands are susceptible to man-made noise!

MF & HF Amateur Band Propagation

- 40 metres (7.0 - 7.3 MHz)
  - Daytime - communication up to 800km
    - similar to 160 in D absorption and E refraction
  - Nighttime - F-layer refraction with communication possible around the earth - especially in summer
    - Band suffers from atmospheric and man-made noise
    - Currently shares band with foreign commercial "shortwave" stations causing problems in evening.
    - 30 metres (10.1 - 10.15MHz) CW/digital only
  - Daytime - communication up to 1500km
  - Nighttime - F-layer refraction with communication possible around the earth

MF & HF Amateur Band Propagation

- 20 metres (14.0 - 14.350MHz) - DX band
  - Daytime - always open at some period of the day for world-wide communication - improves with the solar cycle and open around the clock
  - Nighttime - communication of 5000km or more.
  - Atmospheric and man-made noise not a problem
- 17 metres (18.068 - 18.168 MHz) - DX band
  - similar to 20 metres - good 24hr when solar activity is high.

MF & HF Amateur Band Propagation

- 15 metres (21.0 - 21.450MHz) - DX band
  - Similar to 20 metres, but much more affected by low solar flux when sometimes band fails to open during the daylight hours.
- 12 metres (24.89 - 24.99MHz) - DX band
  - similar to 15 and 10 metres - great DX when solar flux is high
  - benefits from Sporadic-E in mid-winder, spring and early summer
- 10 metres (28.0 - 29.7 MHz) - DX band
  - fantastic band when solar flux is high, but DEAD when solar flux is low.

VHF & UHF Propagation

- 2 metres and down
  - generally direct wave and satellite (penetrates ionosphere)
- 6 metres
  - can have characteristics of 10 metres when solar flux is high
- VHF generally thought of as “line-of-sight” but bending at interface of troposphere and ionosphere result in over-the-horizon communication

VHF & UHF Propagation

- Sporadic-E
  - ionized clouds in E-layer refract VHF extending communications to 2000km in spring & fall of the year
- Meteor Scatter
  - ionization trail that acts as with Sporadic-E but for short duration of time
- Auroral Effects
  - ionization of E-layer in northern northern hemisphere caused by solar storms
- Tropospheric Ducting
  - temperature inversions cause a duct that channels VHF & UHF waves over thousands of kms.

End