Propagation:

The science and study of radio wave reflection, refraction, diffraction, absorption, polarization, and scattering.

Hamvention®

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Measurement Convention:

- Meter
- Centimeter
- Millimeter
- Hertz - Hz
- Kilohertz – KHz
- Megahertz – MHz
- Gigahertz – GHz

Propagation

Radio Wave Propagation

- **Radio propagation** is the behavior of radio waves when they are transmitted, or propagated from one point on the Earth to another, or into various parts of the atmosphere.
- Like light waves, radio waves are affected by the phenomena of
- reflection

  refraction

  diffraction

  absorption

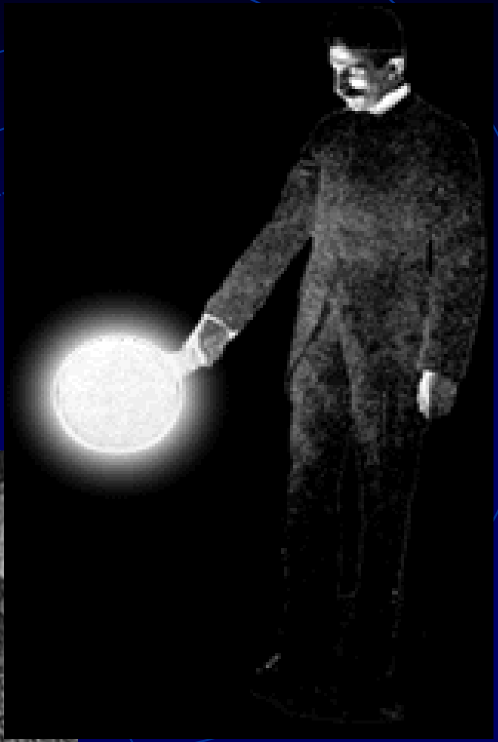
  polarization

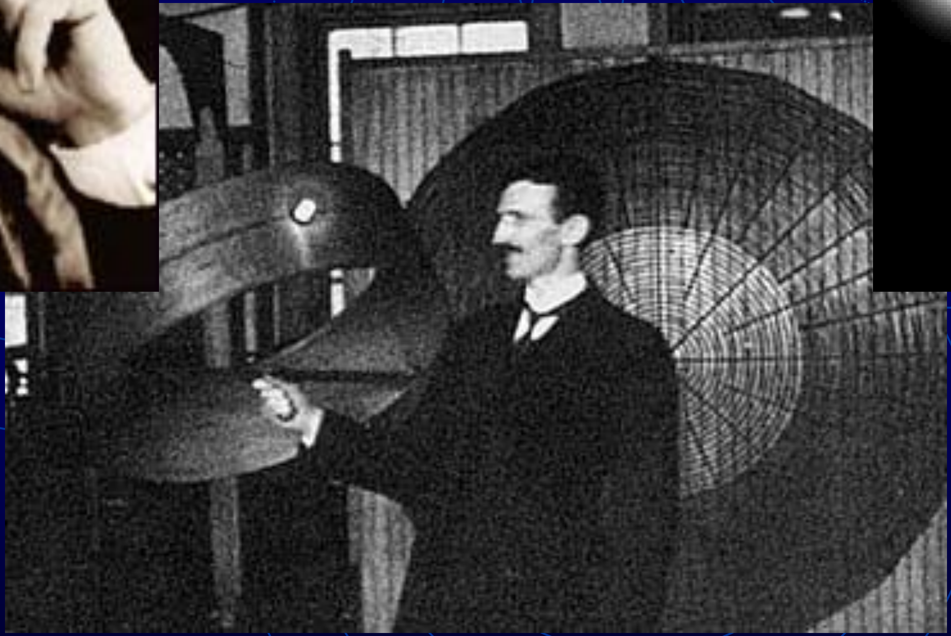
  scattering

Early History

- 1850 – Fazio & Foucalt – Speed of Light
- 1852 - Gustav Kirchoff – Speed of Electricity
- 1853 – James Maxwell – Light = Electricity
- 1896 – Aleksandr Popov – Wireless Experiments
- 1899 – Nikola Tesla – First Antenna Theory
- 1901 – G. Marconi First Transatlantic Signal

Nikola Tesla

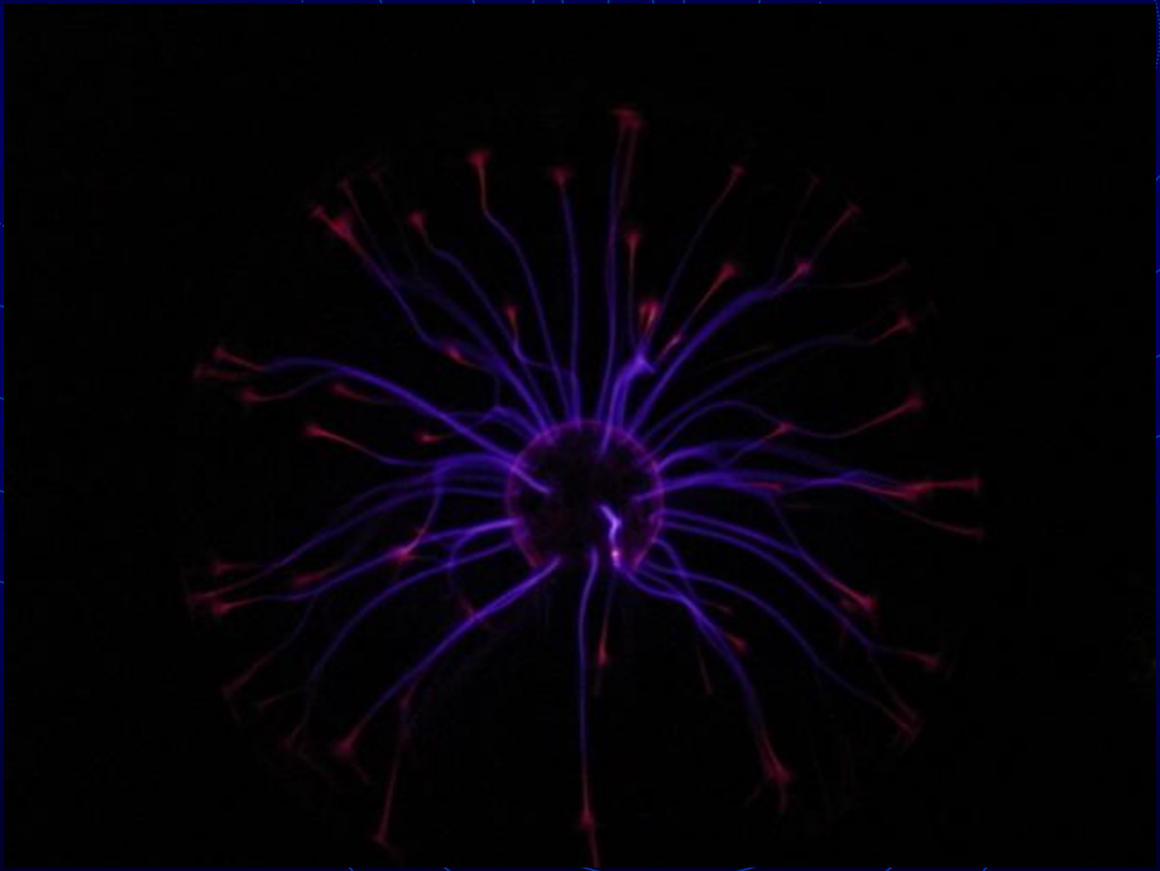




The Tesla Coil

Please don't try this at home.

Tesla Coil – Plasma Discharge



Marconi,
Father of Radio

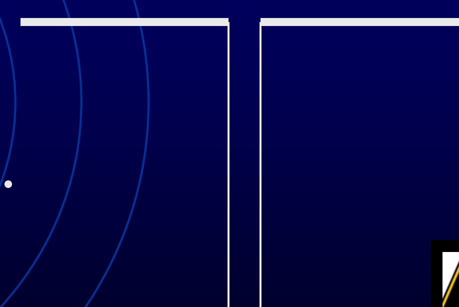
Antenna Definition

- "The antenna launches energy from a transmitter into space or pulls it in from a passing wave for a receiver. Without a suitable, properly installed antenna, the best transmitter and receiver are useless".

  Dr, John Kraus-W8JK, Professor Emeritus, Ohio State University, Columbus, Ohio.

The Dipole

- The dipole is the fundamental antenna. It is found freely in nature. Consisting of 2 equal length poles, the energy oscillates… it oscillates (moves back and fourth) in two directions. Natural examples are:
  - A rope or wire moving wave like between two movable anchors.
  - A banjo string, plucked.
  - A piano wire, struck.
  - A water molecule in a microwave oven.
  - Biomass in a magnetic field (MRI).

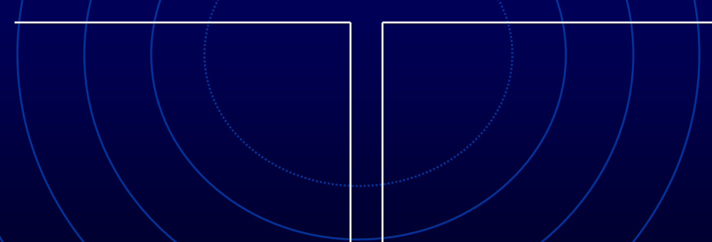


Wave formation

Waves are the result of energizing a “balanced” dipole system. This can be demonstrated by “waving” a rope, plucking a banjo string or striking a piano key.

Radio Waves

Radio waves are formed by energizing a "dipole" (di meaning to cut or dissect and pole is a pole is a pole). The pole or antenna is a specific length relating to the energizing frequency.



Transmission and Reception

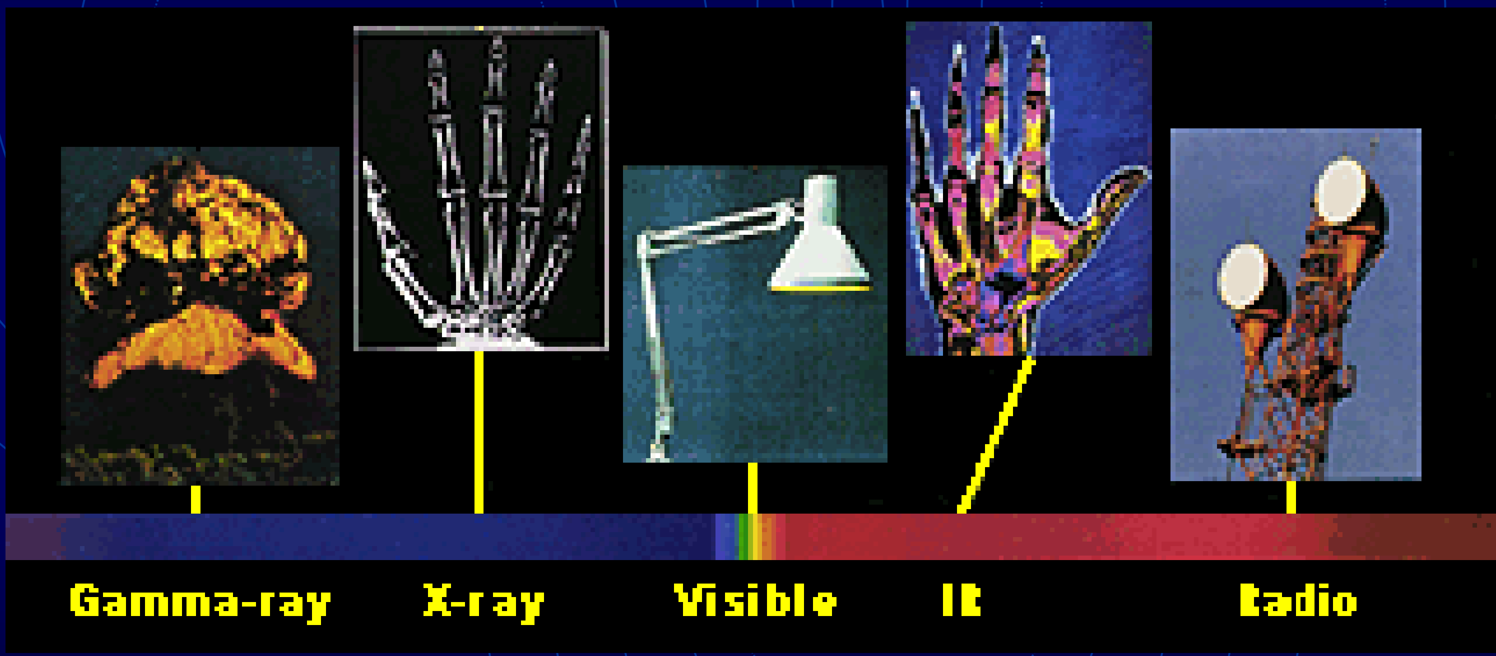
- Radio waves are emitted by an oscillating dipole and escape into electromagnetic space much like music from a piano that moves the air near it.
- The radio receiver detects the radio wave in a manner similar to the human ear detecting a note from a piano.

Transmission / Reception

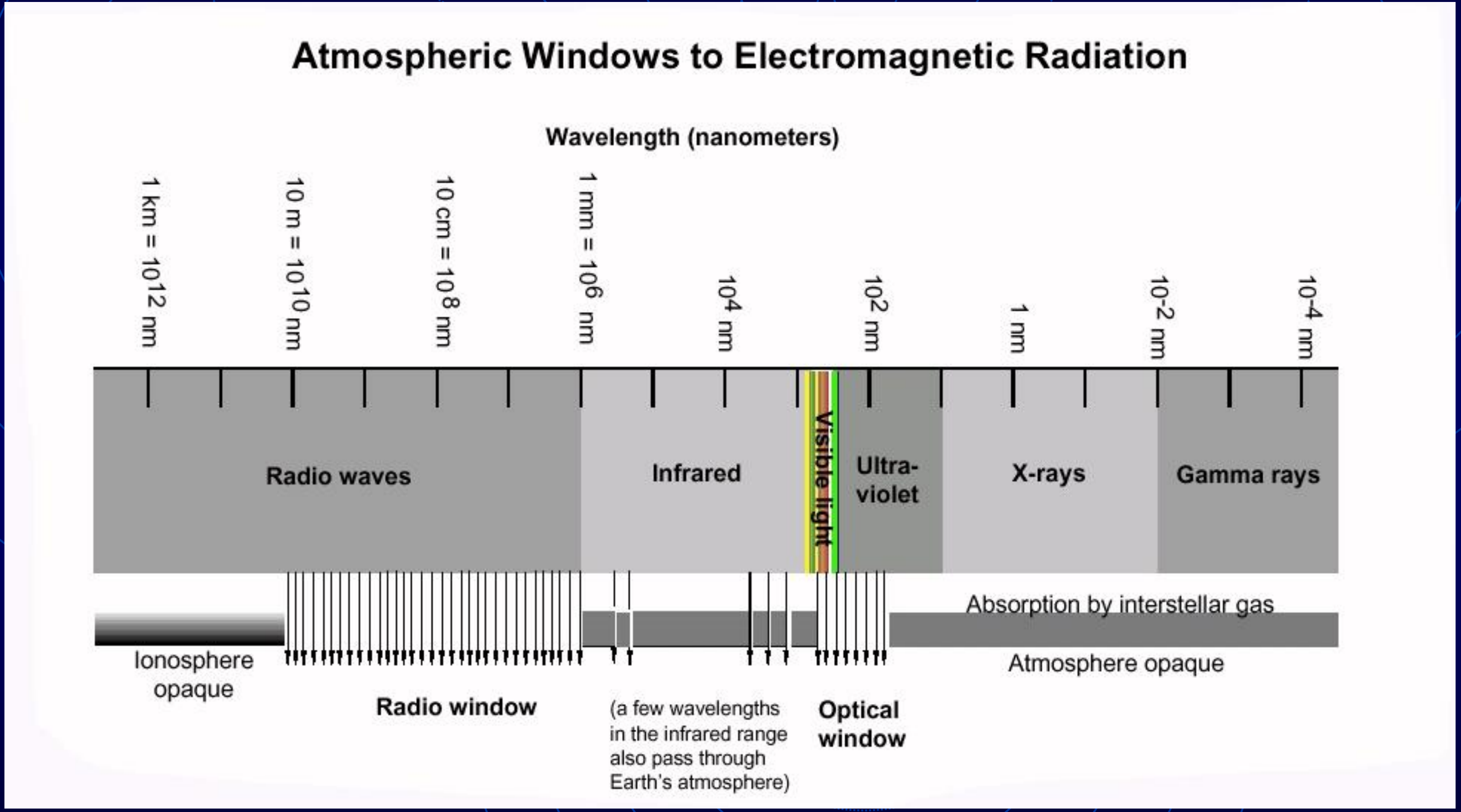
Radio Spectrum

- As we discuss propagation, we will refer to various radio frequencies.
- These frequencies are generated by oscillators that vary in time.
- The mathematical occurrence of these frequencies are represented in order on a continuum or what is commonly called a spectrum.
- A rainbow is a spectrum of light frequencies acting on water molecules after a rain.

Electromagnetic Radiation



The Electromagnetic Spectrum



The Electromagnetic Spectrum*

• VLF – Very Low Frequencies	3-30KHz
• LF – Low Frequencies	30-300 KHz
• MF – Medium Frequencies	300 - 3000 KHz.
• HF – High Frequencies	3MHz – 30 MHz
• VHF – Very High Frequencies	30 MHz – 300 MHz
• UHF – Ultra High Frequencies	300 MHz – 3 GHz
• SHF – Super High Frequencies	3 GHz – 30 GHz
• EHF – Extra High Frequencies	30 GHz – 300 GHz

- *IEEE, ANSI, and NTIA

Propagation

- Radio waves flow from the transmitter’s oscillating antenna to the receiver's oscillating antenna but not always directly

- Because radio waves travel in a Variety of ways to the receiver, a knowledge of propagation is very important in getting the most enjoyment of amateur radio.

Propagation: How Signals Travel

- When dealing with radio signals, Transmission – Reception takes 3 forms:

- Line of Sight
- Ground Wave
- Sky-Wave

Line of Sight Propagation

- The simplest form of propagation is line of site. All frequencies will function in this form.
- Distance between the transmitter and receiver is dependent on the frequency / wavelength of the signal.
- Line of site propagation is very useful at VHF and UHF Frequencies.

Ground Wave Propagation

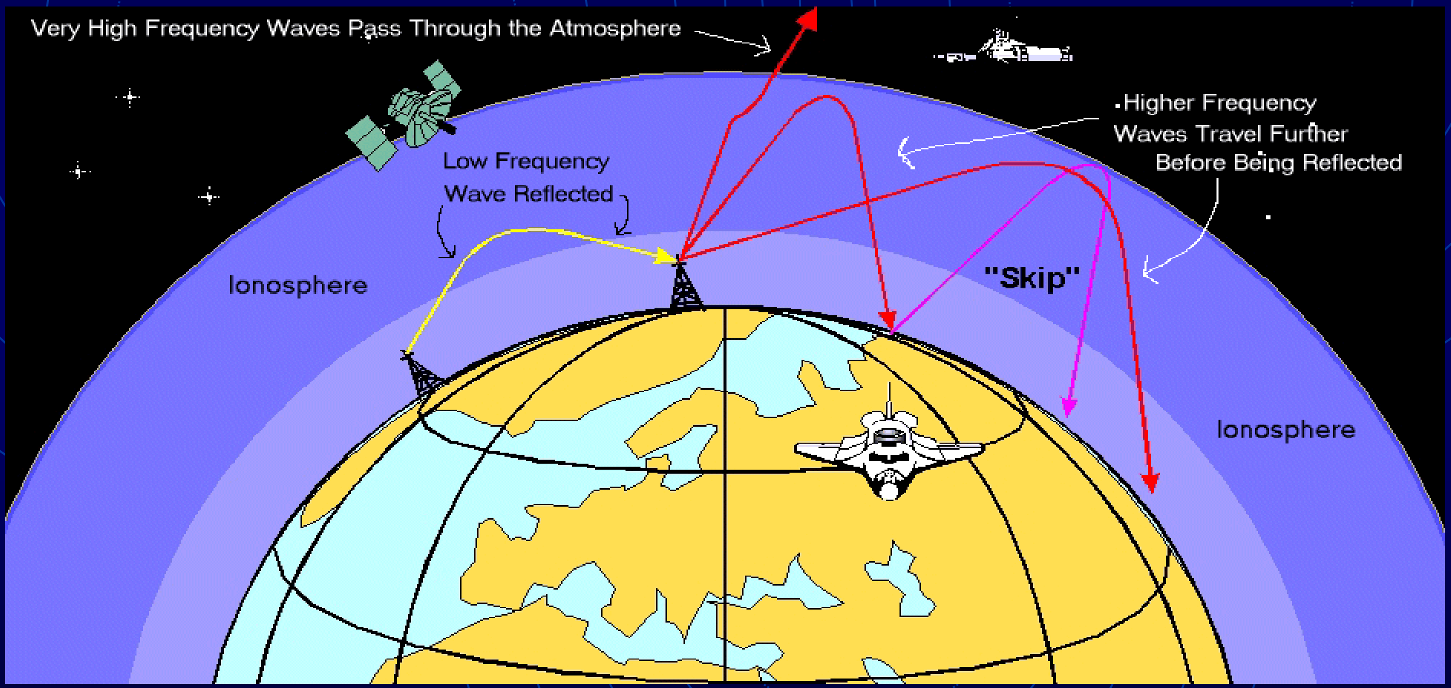
- This form of propagation fits most frequencies but the distance between the transmitter and receiver will vary with geography and composition of “ground”.

- A good example of very different “grounds” is the difference between the desert and the ocean.

Sky Wave Propagation

- This form of propagation is influenced by many chemical and physical phenomena.
- Sky wave propagation results in communications covering our entire globe.

Sky Wave Propagation



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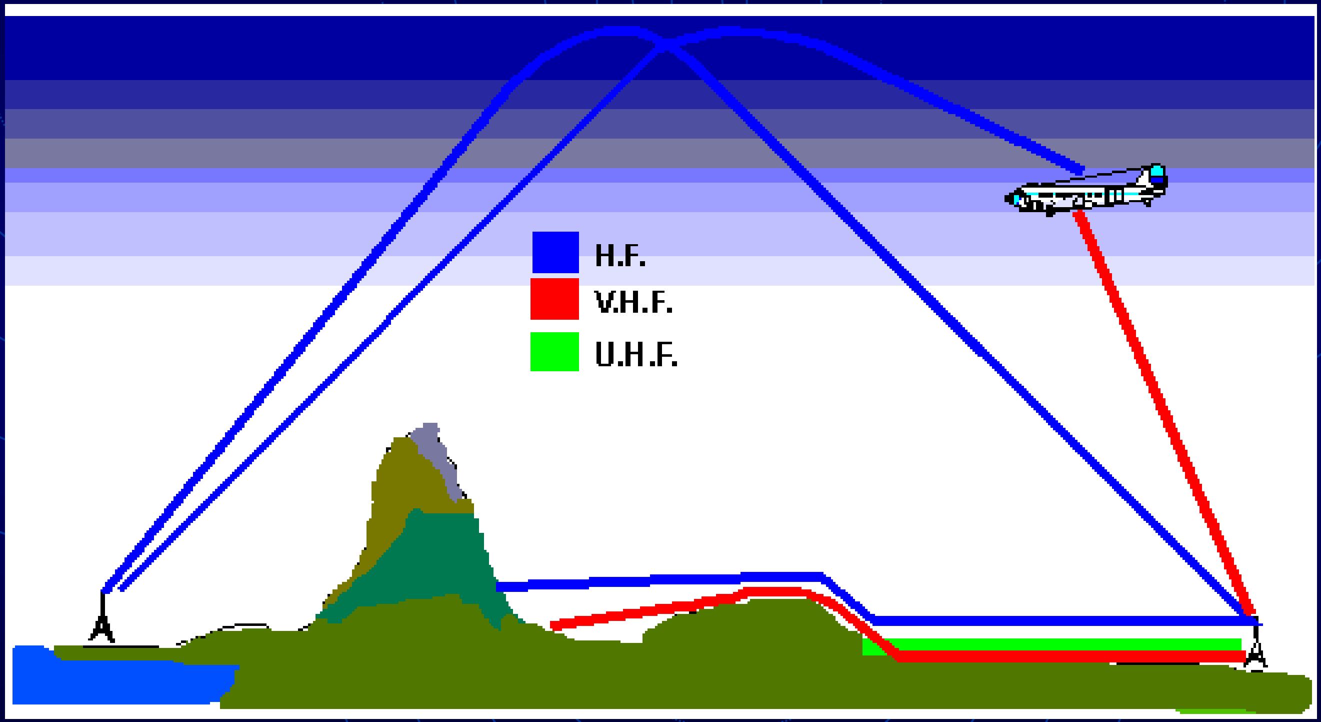
Comparison of Various Propagation Modes



Sky-Wave Propagation

- Otherwise known as “skip” is primarily due to the ionization of the earths upper atmosphere.
- This part of the atmosphere is known as: ionization + atmosphere = Ionosphere.

The Ionosphere - How is it Formed?

- High energy radiation (ultraviolet), from our sun (solar radiation) strikes atoms of various gasses and vapors in the earth's upper atmosphere.
- Electrons are knocked off the outer orbits of the atoms creating an ion. The process is called ionization.
- Because this event takes place in the upper atmosphere, we call the layer the ionosphere.

Solar Activity

- Solar activity has the most effect on sky-wave propagation.
- Solar activity is a function of sunspot occurrence.
- With increased activity, long-distance communication in the HF and VHF range is enhanced.

Ionosphere Regions

- The part of the ionosphere that is primarily responsible for "sky-wave" exists in 3 to 4 layers depending on the time of day. These layers exist at differing altitudes.
  - D Region / 30 to 60 miles
  - E Region / 60 to 70 miles
  - F1 Region / 70 t0 140 miles
  - F2 Region / 140 to 200 miles

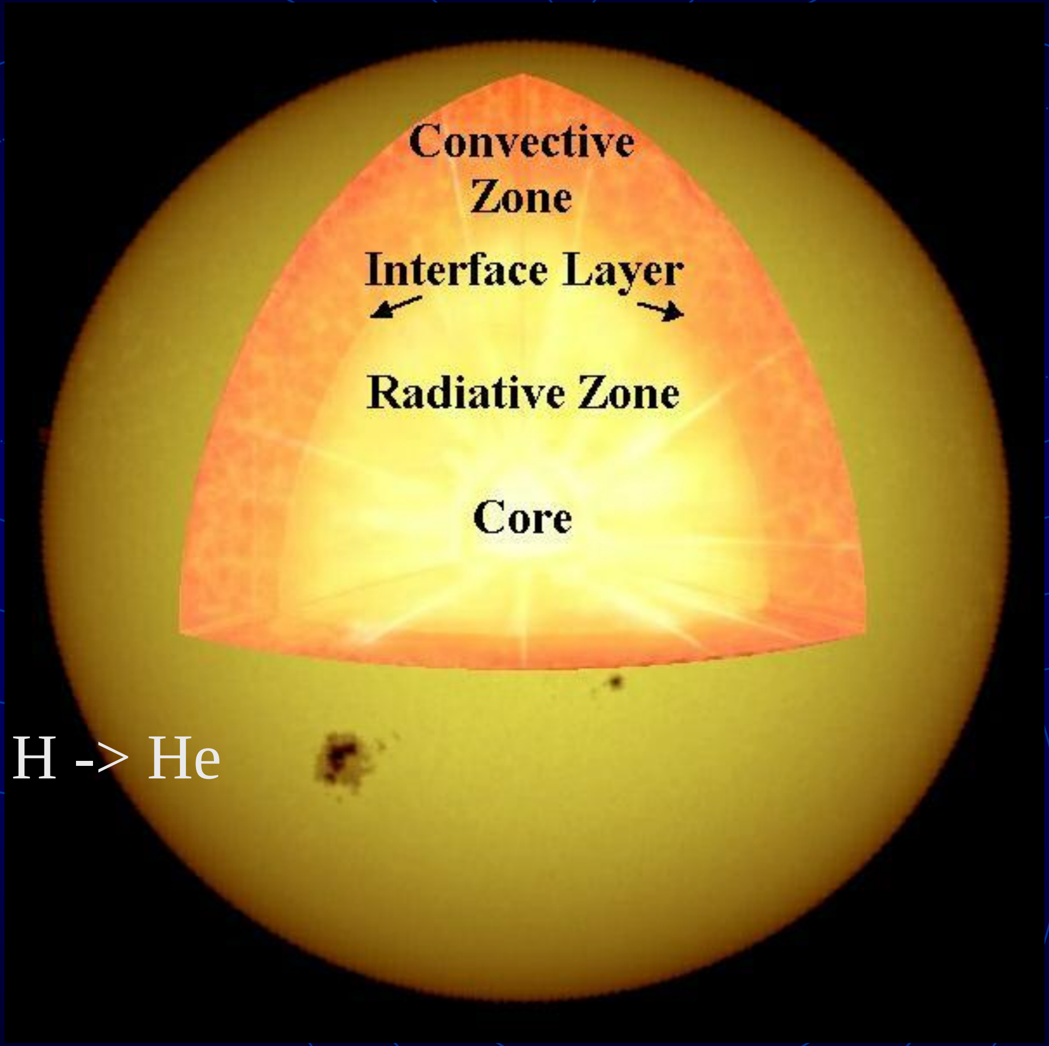
Propagation at Selected Layers

- D Region: Closest to the earth and least ionized and is responsible for short hop HF communication.
- E Region: Daylight absorption of MF and HF. Can be useful for single hop HF out to 1200 miles. VHF skip can exist with "sporadic E" (more later).
- F Region: Most responsible for DX. In the daytime, this layer splits into two parts: F1 and F2. After sunset, this layer combines into one. The F2 Region is primarily responsible for long hops or skip to 2500 miles. F2 reaches its maximum height at noon during the summer.

Ionosphere Variation

- Day – Night
  - Because of variation in the temperature of the earth's surface, the distances between the ionospheric layers will change and combine.
- Seasonal
  - The hot temperatures of the summer season will energize the atmosphere and warm-up the layers creating static and pushing the layers to higher altitudes.
- Geographical
  - The location of the land mass and the height above sea level will greatly effect propagation both positively and negatively.
- Cyclic
  - Because of the effects of the sunspot cycle, propagation will vary every 11 years.

The Sun's Core – An Infinite Source of Energy



He -> H -> He

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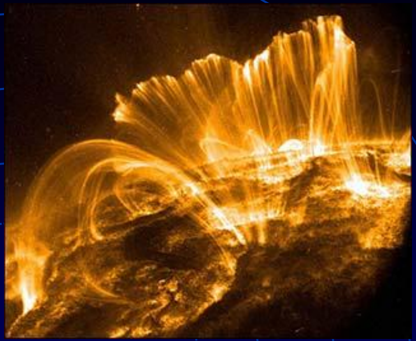
Solar Flux

- Because of the tremendous amount of energy produced by the sun, the sun emits radio waves on all frequencies.
- The radio wave emission is called Solar Flux.
- The solar flux is measured at specific frequencies and reported as the Solar-Flux Index.

Ionosphere Disturbances

- Sunspot Cycle
- Solar Flare's
- SID's – Sudden Ionosphere Disturbances
- Ionosphere Storms
- Polar Blackout

Solar Flare



- A solar flare is a burst of energy emitted from the sun's surface going out into space thousands of miles.

- A solar flare can emit intense UV radiation hitting the earth within 8 minutes after the event. Particles from the flare arrive in the earth's upper atmosphere from an hour to about 2 days later.

Solar Flare / Eclipse of the Sun

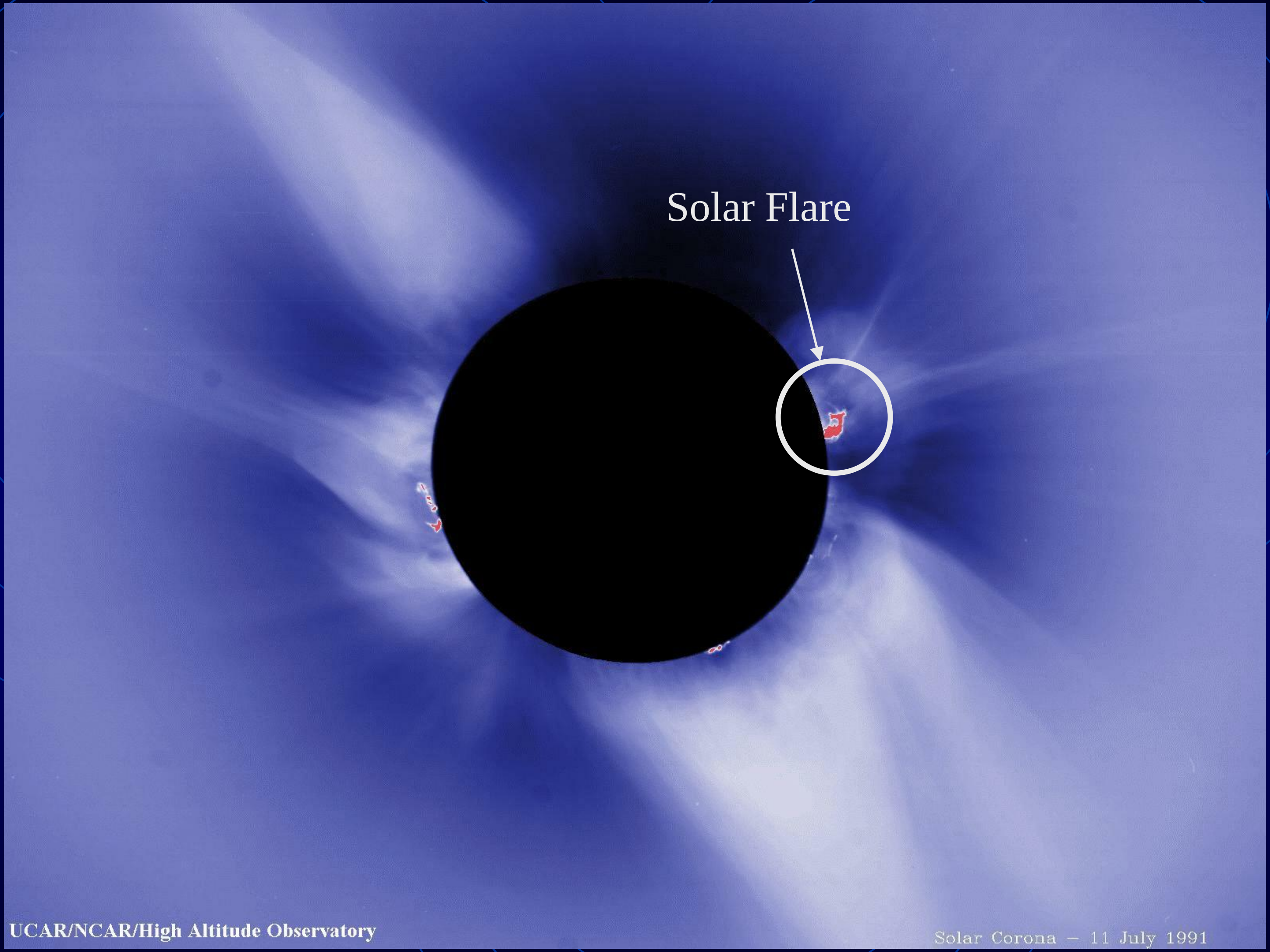
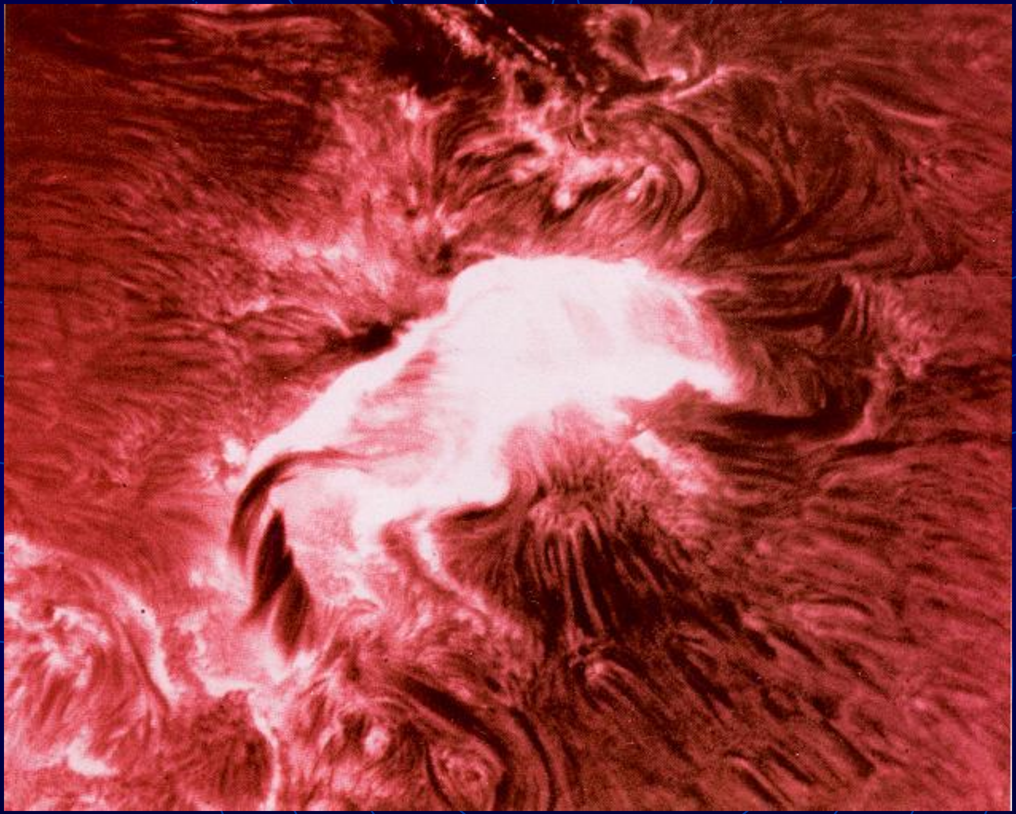


Photo of a Solar Flare



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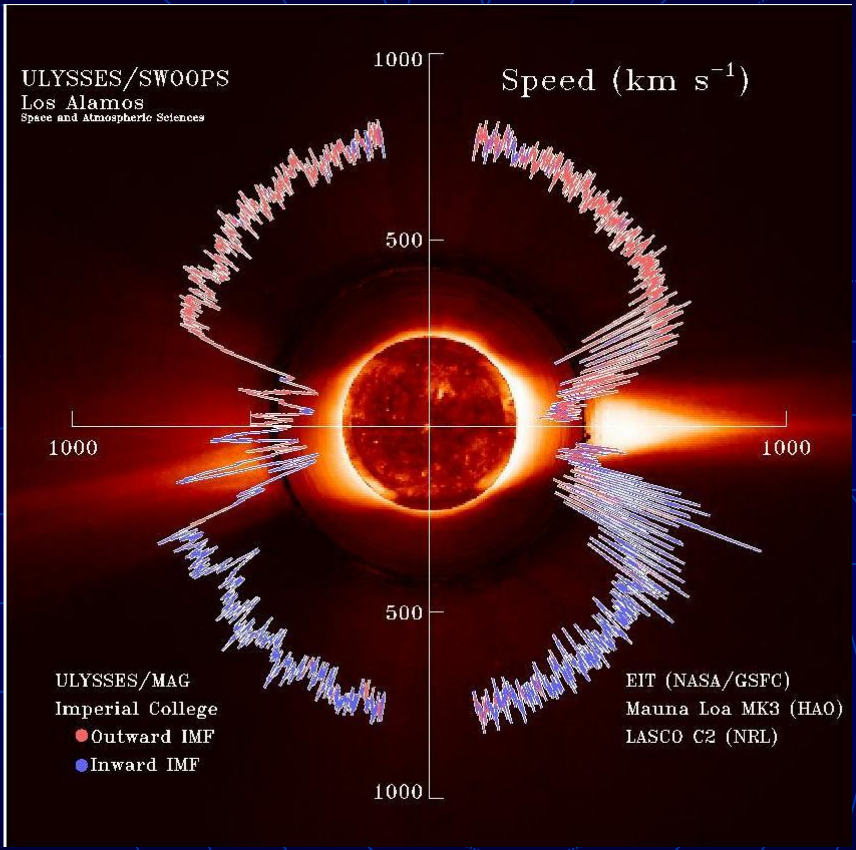
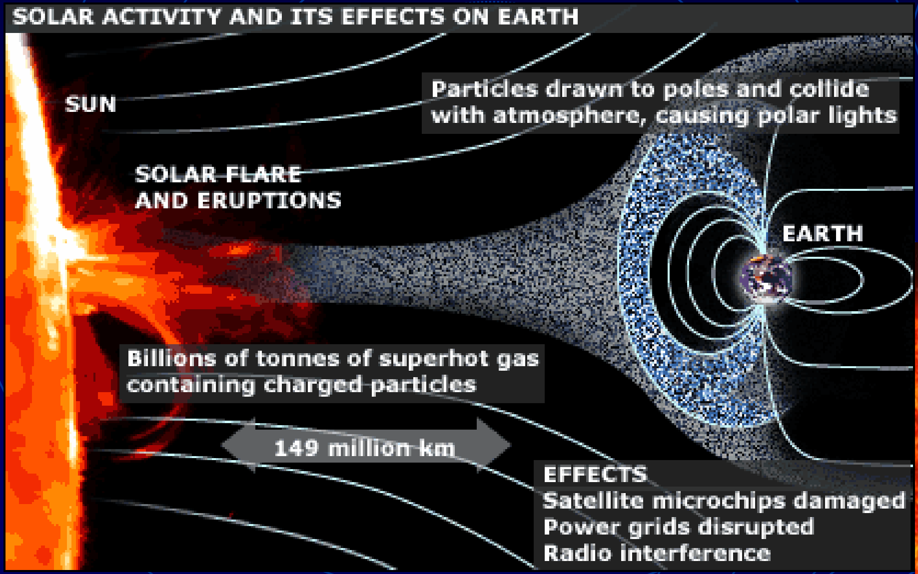
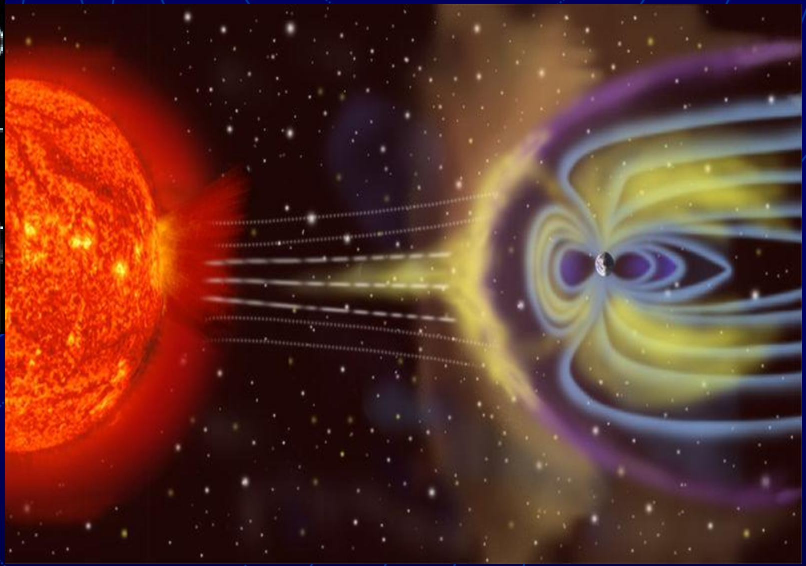
Measurement of a Solar Flare



Solar Activity and Earth



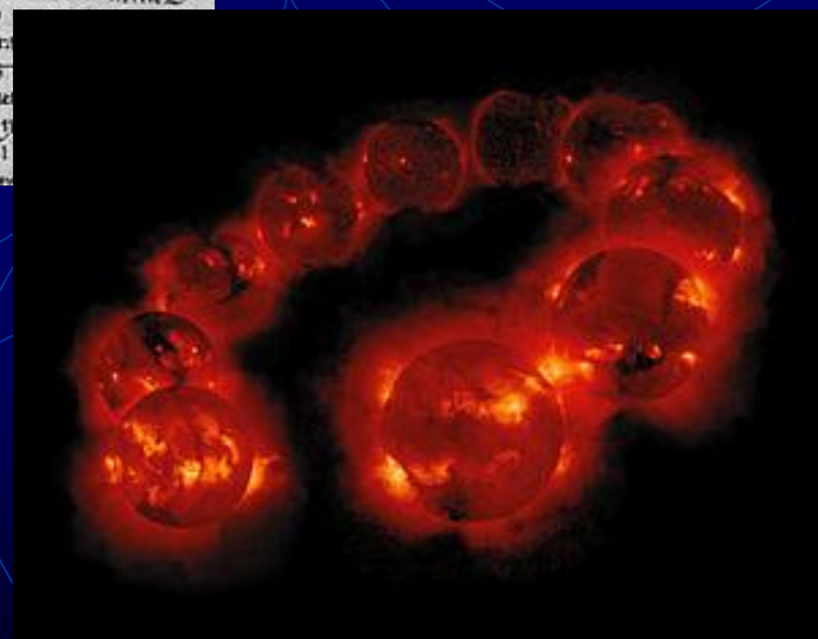


Sunspots

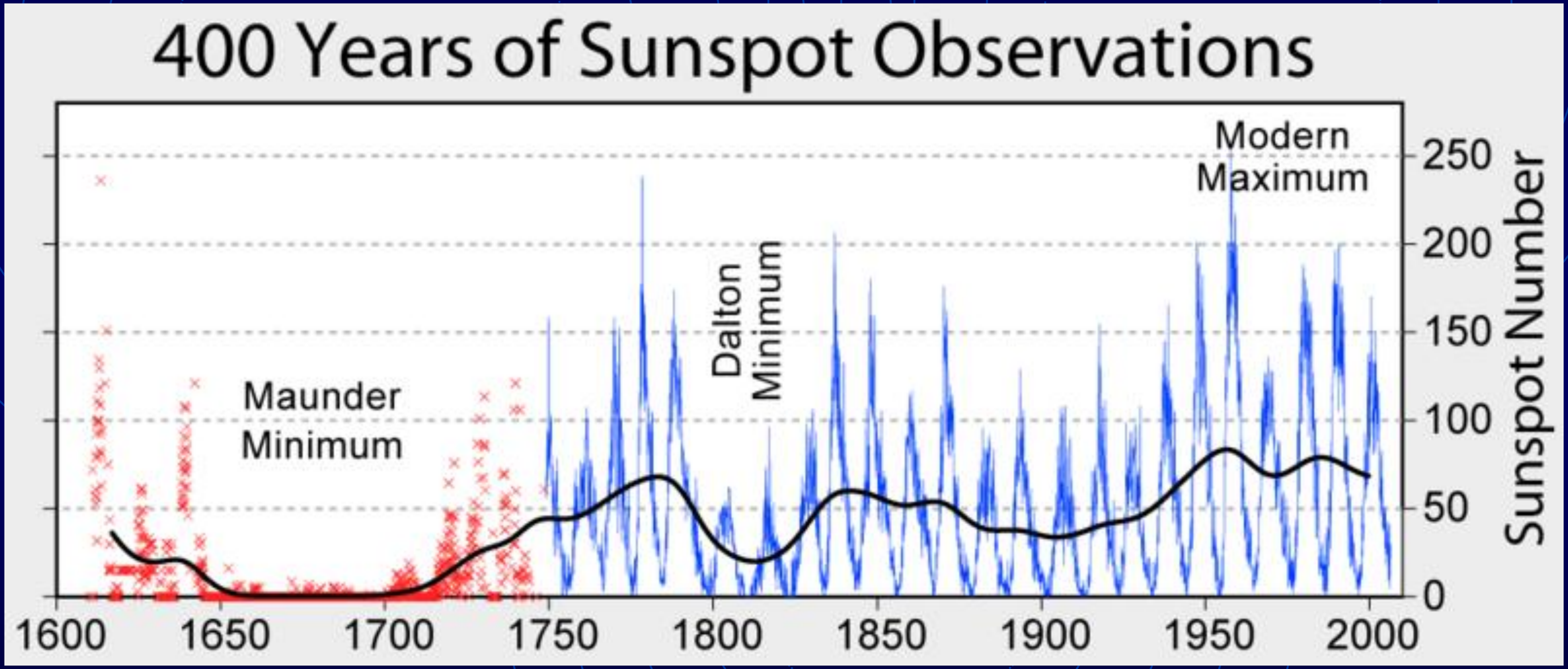
Sunspots Occurrence

- Sunspot maxima occurs on an average of every 11 years.
- Even though data has been recorded on sunspot activity for over 250 years, the cause for the phenomena is not yet known.

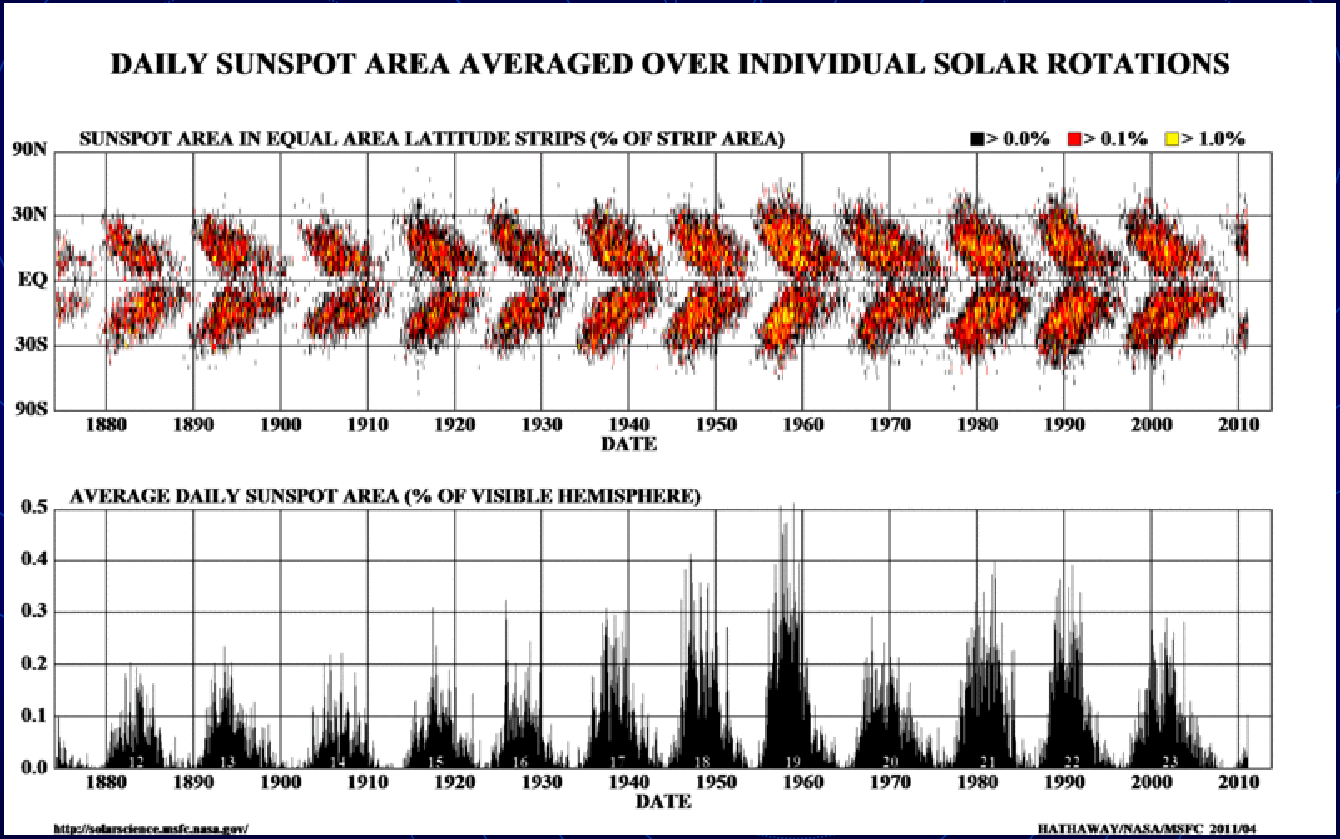
Observations Over The Years



Long Term Observation



Sunspot Average History



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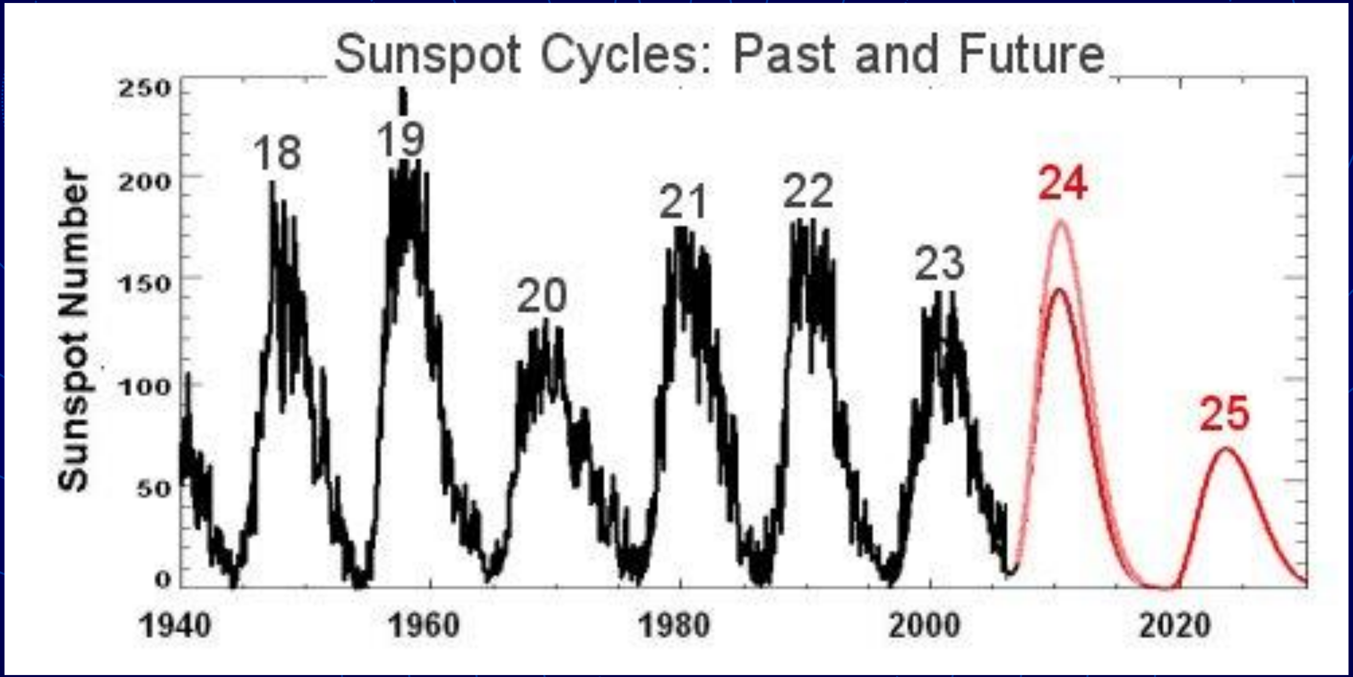
History of Sunspots



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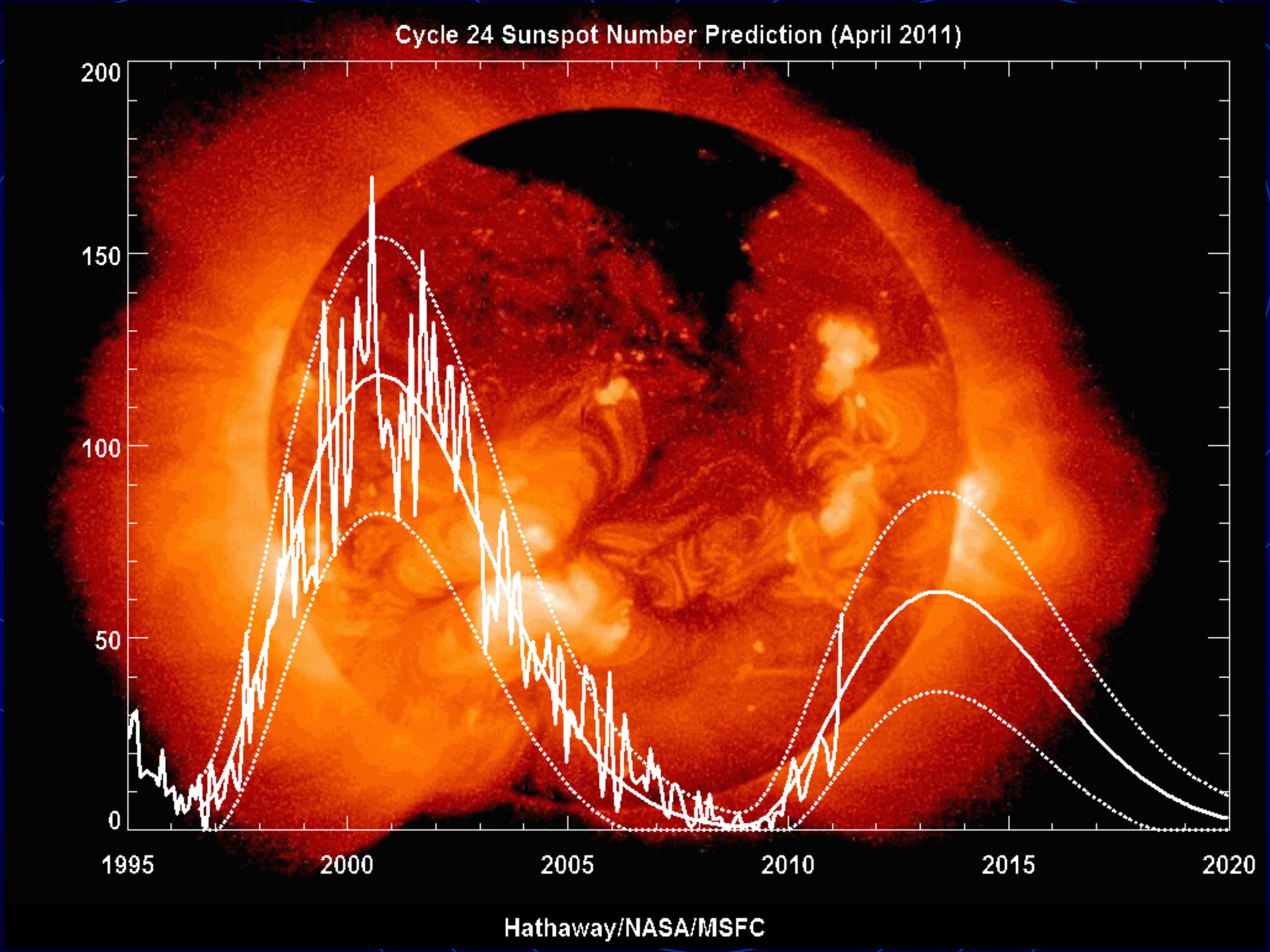
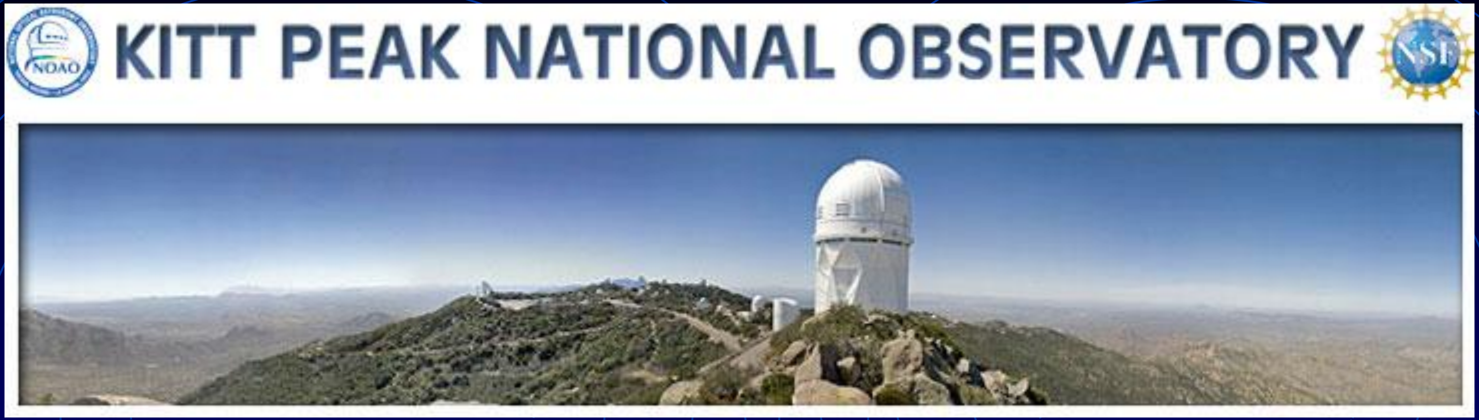
Cycle 23 - NOW


Cycle 24 Sunspot Number Prediction (April 2011)
200
150
100
50
0
1995
2000
2005
2010
2015
2020
Hathaway/NASA/MSFC


KITT PEAK NATIONAL OBSERVATORY

Relative Sunspot Number

- A measure of sunspot activity, computed from the formula:
- $R = k(10g + f)$,
- where R is the relative sunspot number,
- f the number of individual spots,
- g the number of groups of spots,
- and k a factor that varies with the observer (his or her personal equation),
- the seeing, and the observatory (location and instrumentation). Also known as sunspot number; sunspot relative number; Wolf number; Wolf-Wolfer number; Zurich number.

Read more: http://www.answers.com/topic/relative-sunspot-number#ixzz1LrgBvA10

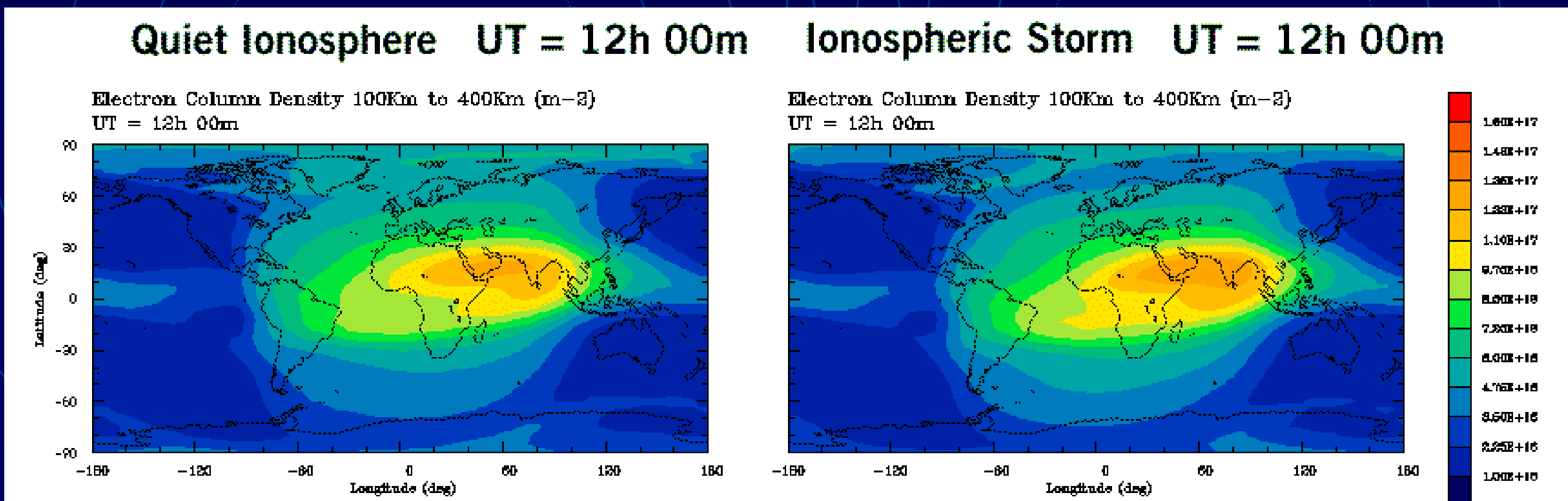
Sudden Ionosphere Disturbance (SID)

- A SID is a blackout of HF sky wave communications that occurs after a solar flair.
- A large amount of UV radiation leaves the sun at the speed of light and arrives 8 minutes later.
- The D-Layer rapidly becomes a radio wave absorber. Depending on the “attack” angle, a SID could last from a few minutes to a few hours.

Geomagnetic Disturbance

- A dramatic change in the earth's magnetic field over a short period of time results in a geomagnetic disturbance.
- These usually occur in areas greater than 45 degrees latitude.

Ionosphere Storms



Propagation in the HF Bands

- Without ionization of the atmosphere due to the sun’s energy, HF propagation would be limited to line of site.

Propagation on the VHF Bands

- VHF propagation is principally line of site but much longer paths are possible with e-layer phenomena.
- Ionization of the atmosphere due to re-entry of meteors will also create a condition for VHF long distance propagation.
- One new method of long distance VHF communication results from bouncing VHF signals off high altitude commercial airliners.

Propagation on the UHF Bands

- UHF propagation is basically line of site. Some long range propagation is possible with E-Layer phenomena.
- UHF is used mainly for local communication. Sometimes UHF can be part of a wide area repeater system allowing for interstate communication.

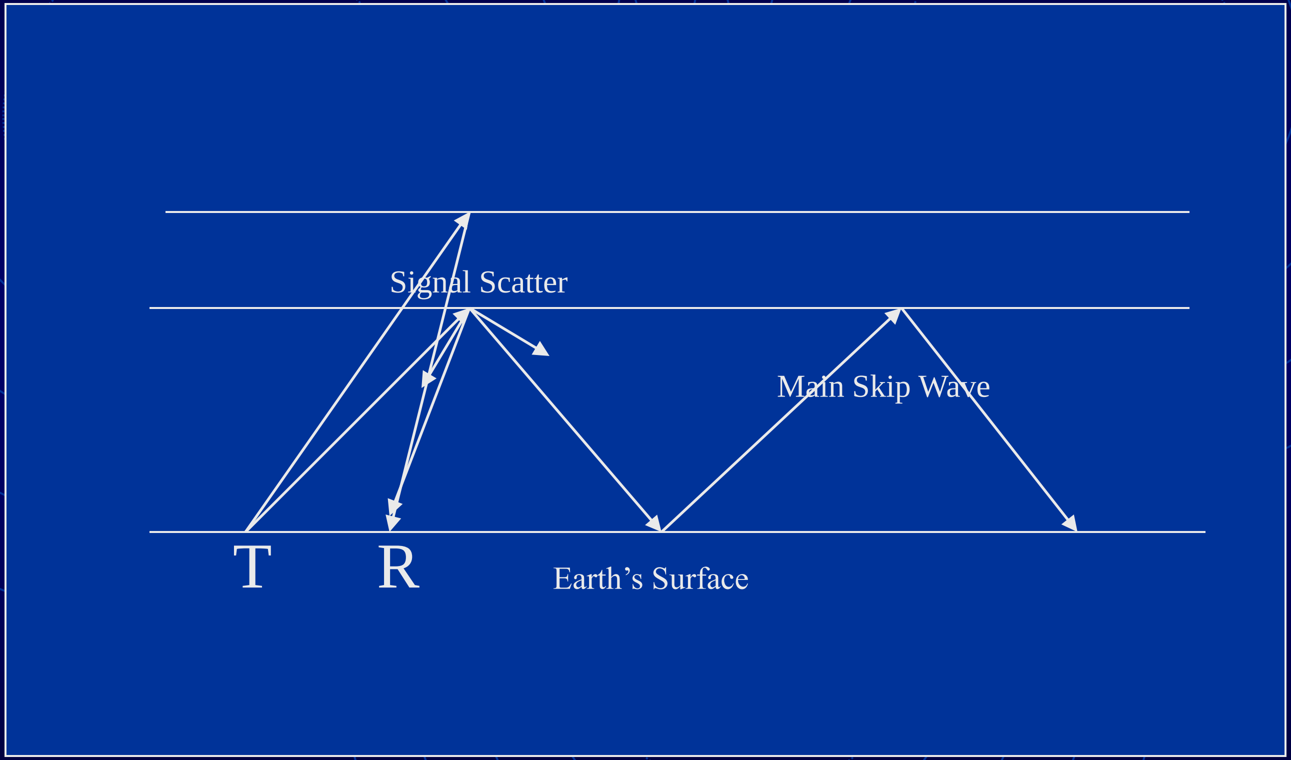
MUF – Maximum Usable Frequency

- Maximum Usable Frequency (MUF) is defined as the upper limit of available frequencies for a given atmospheric situation.
- MUF can be approximately measured by monitoring bacon stations at or near the frequency in question.
- In the U.S., 4 beacons are available from the National Bureau of Standards. Three are also available from the Canadian Government. Many private beacons are available (see internet).

Government Beacon Frequencies Available:

- 3.330Mhz - CHU
- 4.670MHz - CHU
- 5 MHz – NBS (WWVH)
- 7.850MHz - CHU
- 10MHz – NBS
- 15MHz – NBS
- 20MHz – NBS

The Scatter Modes



Characteristics of Scattered Signals

- Too Far for Ground Wave – Too Near for Sky Wave
- A Wavering Sound Due to Multiple Arrivals of the Signal
- The Sound Is Distorted Due to Multiple Path Signals
- Usually, Received Signals Are Weak

Aurora Propagation (Northern Lights)

Aurora Propagation

- A beautiful display of ionized clouds in the northern hemisphere called the Aurora Borealis is also propagation enhancing.
- The Aurora is formed by ionized gasses in the upper atmosphere being concentrated by the earth's magnetic poles.
- This mode supports great propagation on 50 and 144 MHz.

Sporadic "E"

- Sporadic E is the ionization of the E layer of the ionosphere.
- It occurs most predominately during June and July in the North American Hemisphere.
- It concentrates in the frequency range of 50 MHz but is responsible for improved propagation on 28MHz and 144MHz.

Sporadic “E” (Cont.)

- The cause of sporadic E is not completely known, but the most popular theory relates to wind shear at 100km altitude.
- When this occurs, E reflections are almost “mirror-like” and can result on spectacular DX on QRP – especially on VHF and UHF.
- Monitoring distant NOAA weather stations is a good way to measure it’s occurrence.

Troposphere Bending and Ducting

- The troposphere is the part of the atmosphere that is closest to the earth.
- VHF / UHF radio waves are known to travel beyond the horizon while following the troposphere.
- The troposphere can be “radio enhanced” with thermal inversions forming “ducts” in which VHF / UHF waves pass through moving signals up to 2500 miles.

Path Loss Trough The Troposphere

- The path loss increases with higher frequencies.
  - Low VHF = Lowest Loss
  - Medium VHF = Medium Loss
  - UHF = Highest Loss

Effects Of The Weather

- The Seasons
- The Clouds
- Lightning
- Rain
- Snow
- Fog

The Seasons

- Summer, Fall, Winter and Spring have an effect on propagation.
- This is emphasized with the length of daylight (amount of ionizing sunlight).
- Also, the hot air of the summer and the cold air of winter changes the air density as well as the heights of the ionosphere regions (D, E, F1 and F2).

The Clouds

- Obviously, clouds can be massive. They contain large amounts of water and can either be your friend of foe w/r to radio propagation.

- In some cases the cloud blocks signals from reaching destination. In other cases, cloud formations "rub" while going in opposite directions causing ionization between them creating a reflecting zone.

Lightning

- Lightning is a byproduct of differentiated charges between objects – cloud to cloud, cloud to ground, cloud to conducting objects.
- Lightning can cause significant electrical noise thus determining signal effeteness.

Rain

- Rain, being predominately made of water is also a dipole molecule. If you get enough rain within the radio wave path, it will greatly reduce the signal.

- On the other hand, rain being a dipole can be used as a reflector thus enhancing the signal.

Snow

- Snow provides interesting propagation phenomena. Because of it's water make-up, snow also exhibits some of the same characteristics of rain and fog.

- Depending on temperature, snow can be very dry and under the correct conditions, create a tremendous amount of static electricity.

Fog

- Fog is water vapor. It is usually formed close to the ground due to differentiated atmospheric temperatures.

- Fog properties are much like clouds, however nearby fog can be very debilitating in the UHF/VHF frequency range

Summary

- Radio communication has 4 basic building blocks – The transmitter, The receiver the antenna and the medium in which the radio wave travels.

- Understanding these 4 building blocks is important in achieving communication beyond line of site.

- The causes and effects of radio propagation continues to remain a mystery.

- Understanding the make-up of the phenomena of propagation will greatly enhance the excitement of Radio Communication.

Questions and Dialog

- Open for questions
- Hearing none will provoke a quiz!!!
- Not passing, will cause you to drop down one license level!!!!

Thank You

de:W8GUC and WS8B