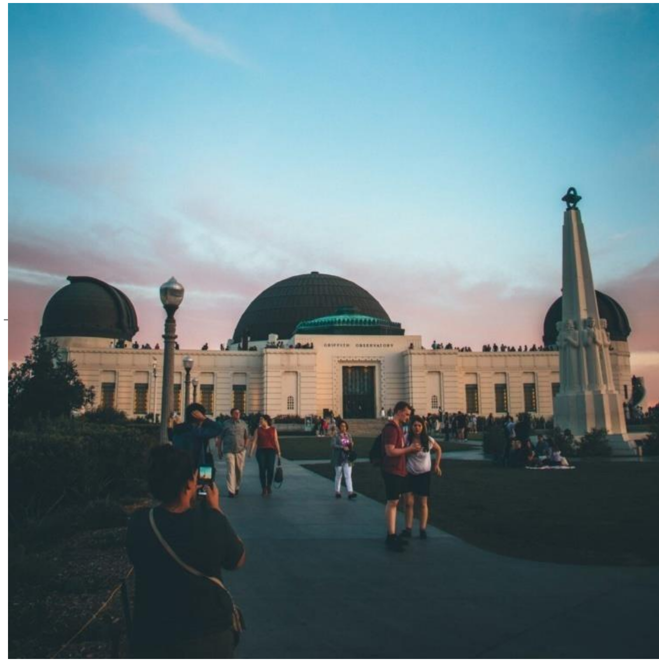
CHEROKEE AMATEUR RADIO SOCIETY
WX4CAR

Fundamentals of Ionospheric Propagation of Electromagnetic Energy in the 3 to 50 Mhz Frequency Range

OR

CQ DX!

Neal Sulmeyer – N4EA



Propagation is the study of the interaction between electromagnetic radiation and mater.

1672 Isaac Newton proposed the particle nature of light to explain the reflection and refraction of light

In 1678, Christian Huygens claimed to have disproved Newton's theory by showing that the laws of reflection and refraction can be derived from his wave theory of light.

In 1905 Albert Einstein 1905 explained the photo-electric affect proving the dual nature of light for which he received the Nobel prize.

Some interactions are best explained with the particle nature and others by the wave nature of electromagnetic radiation.

Radiation and Absorption

Radiation is the process of converting kinetic energy into electromagnetic energy.

Absorption is the process of converting electromagnetic energy into kinetic energy.

Reflection

A portion of the electromagnetic energy that encounters a boundary will be reflected (rejected or thrown back). The energy incident on the boundary either be reflected, transmitted through the boundary, or absorbed.

The ratio of energy reflected, transmitted, and absorbed is dependant on many factors and beyond the scope of this presentation.

Radio frequencies are reflected off the earth in varying degrees but the best medium is salt water. This is one reason why verticals on the beach can work exceptionally well.

Refraction

Refraction is the redirection of a wave as it passes from one medium to another. The redirection can be caused by the wave's change in speed or by a change in the medium.

Index of refraction is a measurable and calculable quantity that indicates the amount of redirection (bending) of the wave.

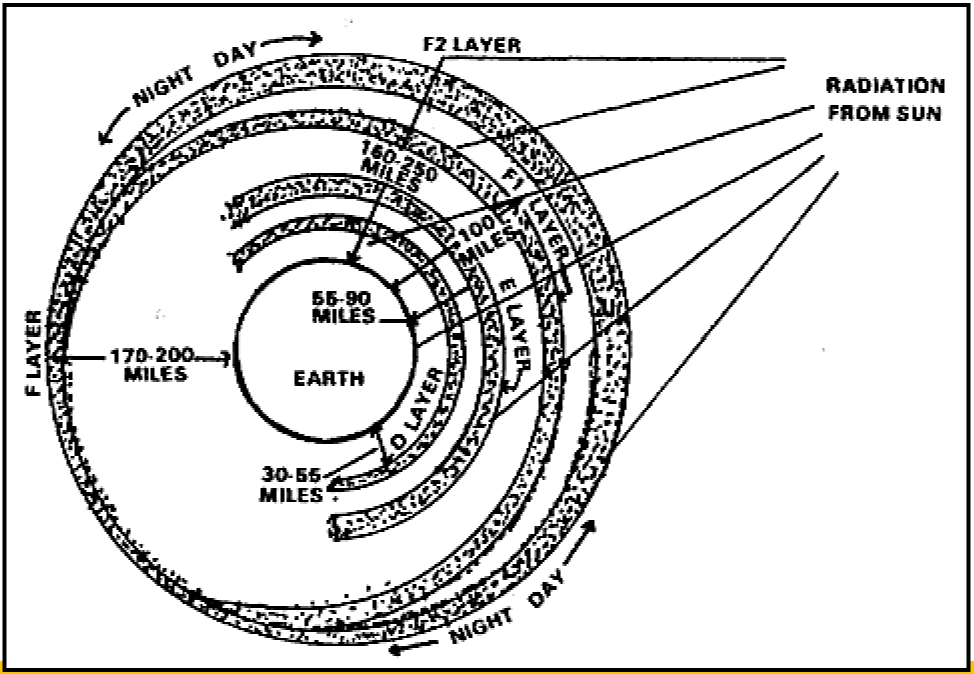
Ionosphere

The layer of the earth's atmosphere that contains a high concentration of ions and free electrons. It extends from about 50 to 600 miles (80 to 1,000 km) above the earth's surface.

The ionosphere is divided into several layers that vary in composition, electron density, thickness, height, and temperature.

Ionosphere

The layers of the ionosphere are non-homogeneous so the index of refraction is changes with height. This results in a continuing “bend” in the direction of the wave.



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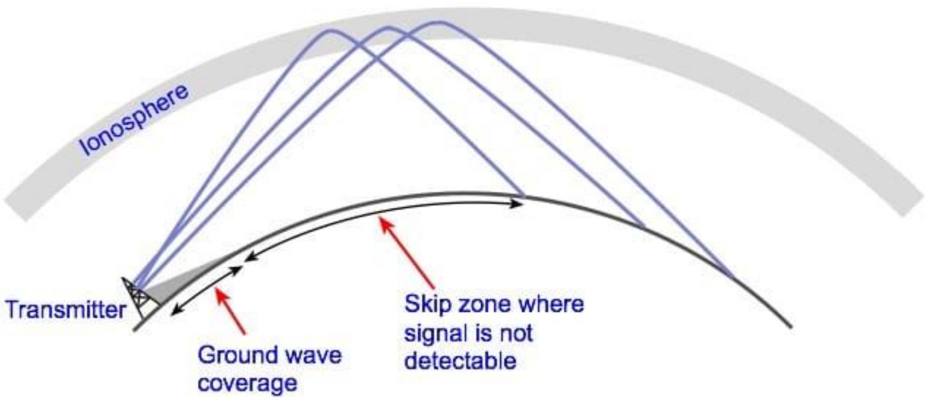
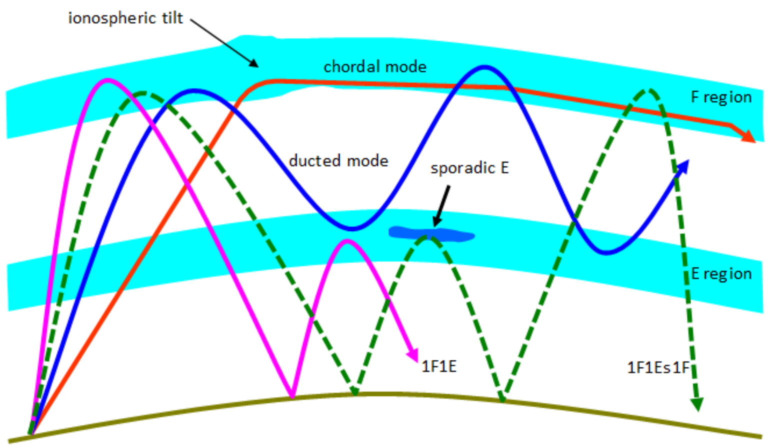
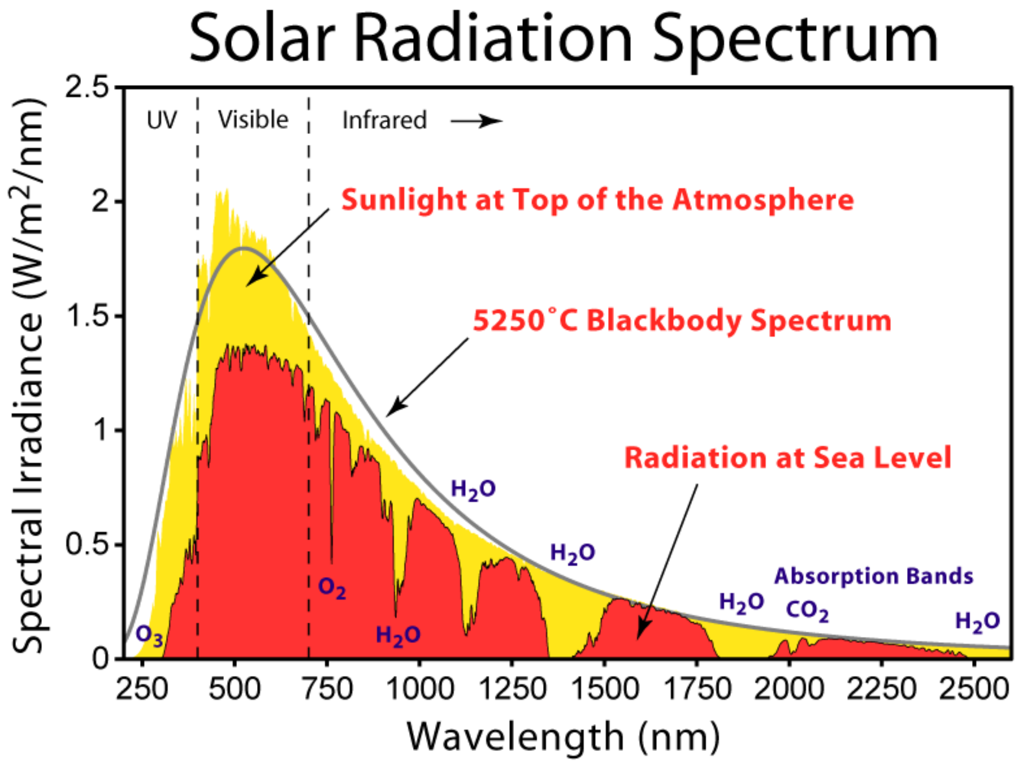
Modes of Propagation





Solar and Geomagnetic Affects on the Ionosphere

- The sun emits both electromagnetic (EM) radiation and particles.
- The EM radiation is essentially that of a “black body” at 5250˚ C.
- Particles emitted are protons, neutrons, electrons, and alpha particles (helium nuclei).



Space Weather

Solar Flux

Flux: the amount of a substance flowing through an aperture per unit time.

Solar flux unit: 1 sfu = 10^{-22} $W \cdot m^{-2} \cdot Hz^{-1}$

The solar flux is measured at 10.7 cm (2800 MHz).

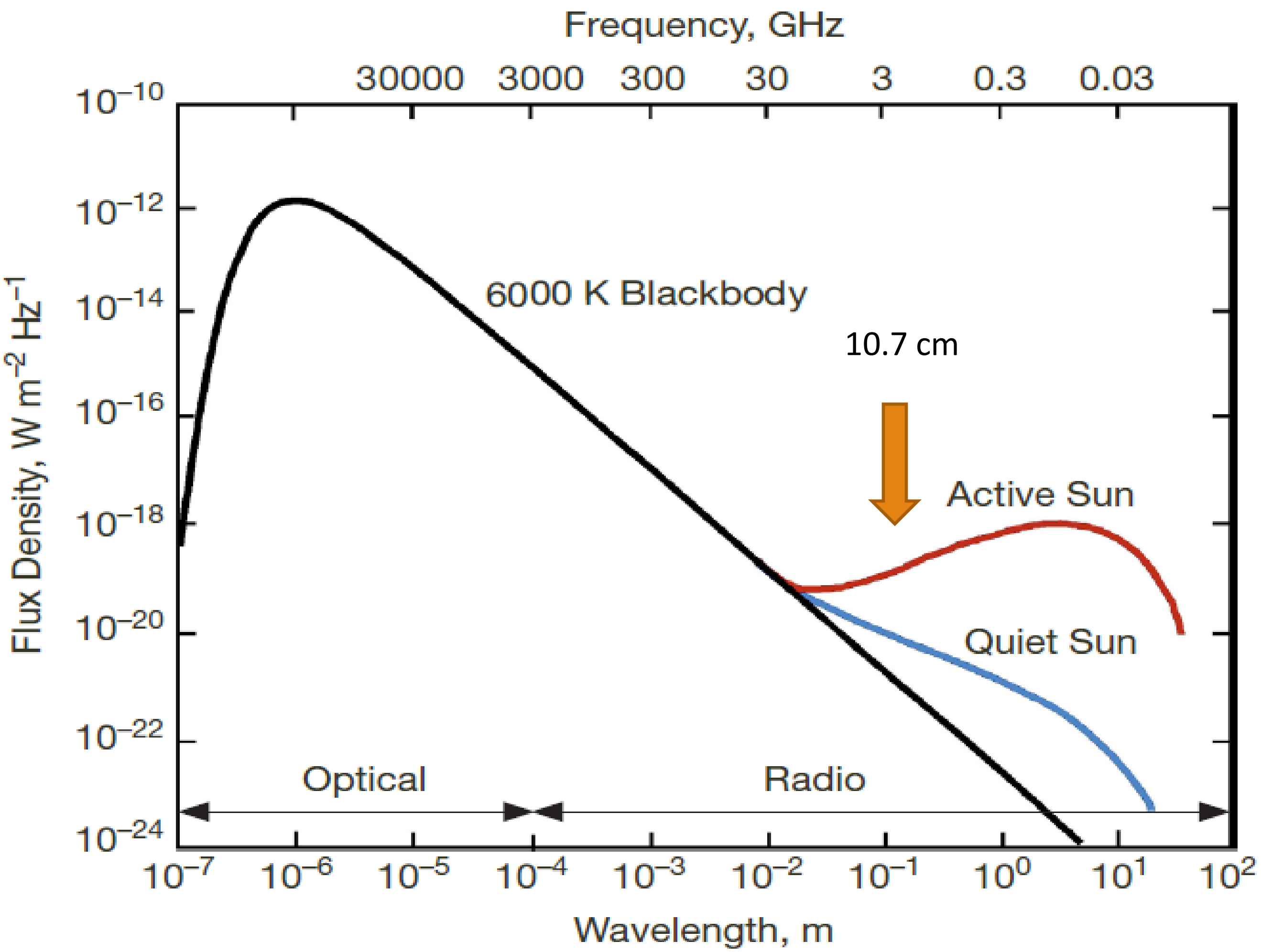
The wavelengths around 10.7 cm (frequencies around 2800 MHz) are ideal for monitoring the solar activity, as they are very sensitive to conditions in the upper chromosphere and at the base of the corona.

The quite sun (no sun spots) typically around 65 sfu but has been measured down to the mid 50's sfu.

During high solar activity the index can reach values into the 300 sfu. The record burst occurred on June 5, 1991. It was estimated to be 55,000 sfu!

EM radiation is what ionizes the molecules in the ionosphere. Higher solar flux yields more intense ionization. And this yields increased refraction and reflection at the higher end on the HF spectrum.

Space Weather



Space Weather

Particle Flux

Particle flux does not penetrate the ionosphere. So there are no earth based measurements.

In January 1959, the Soviet spacecraft Luna 1 first directly observed the solar wind and measured its strength, using hemispherical ion traps.

Today, space weather satellites provides us with data on the solar wind.

The solar wind travels at about 1200 mph. It takes about three days to reach the earth.

The source of solar winds is primarily flares and coronal mass ejection (CME) events. Such events are infrequent and mostly not aimed at the earth. But when the do hit….

Particle the enter the ionosphere cause recombination of ions (i.e. decrease in ionization levels) and can absorb EM at HF and VHF+ frequencies. Intense storms cause total radio blackouts!

Space Weather

Geomagnetic Field

Earth’s magnetic field traps and then funnels charged particles towards the magnetic poles.

The result is a reduction in ionization and increased absorption, especially at the poles.

Geomagnetic activity is a consequence of the charged particles in the solar wind.

The Kp-index gives us a quick indication of the strongest observed geomagnetic activity over a 3-hour period. A magnetometer measures the maximum deviation of the horizontal component of the magnetic field at its location and reports this. The global Kp-index is then determined with an algorithm that puts the reported K-values of every station together. The Kp-index ranges from 0 to 9 where a value of 0 means that there is very little geomagnetic activity and a value of 9 means extreme geomagnetic storming.

The Ap Index provides a daily average level for geomagnetic activity. Uses a moving average of eight 3 hour K-Index values. When used with K-Index: Both high indicates geomagnetic field is unstable, and HF signals are prone to sudden fades, and some paths may close while others open up abruptly and with little warning. High K index/Low A indicates a sudden, abrupt disturbance in the geomagnetic field.

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More Numbers!

Sunspot number: The relative sunspot number is defined as SSN = K (10g + s), where g is the number of sunspot groups and s is the total number of distinct spots. The scale factor K (usually less than unity) depends on the observer.

The following three indicators are calculated by NOAA and range from 0 to 5. 0 = none, 1 = minor, 2 = moderate, 3 = strong, 4 = severe, and 5 = Extreme.

Geomagnetic storm: based on Kp index. G5 (Kp = 9) is extreme.

Solar radiation (particles) storm: S3 is strong with degraded HF propagation, and S5 is Extreme with complete HF blackout.

Radio blackouts: R1 is weak or minor degradation at HF on sunlit side. R3 is wide area blackout at HF, loss of radio contact for about an hour on sunlit side of Earth. R5 is extreme, complete HF blackout on the entire sunlit side of the Earth lasting for a number of hours.

X-Ray, UV, and proton flux is measured with the GOES satellites.

Space Weather

Resources

Spaceweather.gov

Spaceweather.com

NOAA Space weather prediction center: swpc.noaa.gov

Spaceweatherlive.com

European space agency: swe.ssa.esa.in

www.space.com/topics/space-weather

And many more….

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Q&A