Jules' Workshop

Standard

Unit 17

PROPAGATION

ACMA Syllabus February 2024

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Propagation

Overview

Propagation is defined as the movement of radio waves from a transmitter to a receiver. As these waves travel (propagate) from one point to another, they are impacted by different phenomena such as reflection, refraction, diffraction, absorption, polarization, and scattering.

Understanding these effects on radio propagation allows an amateur to select reliable frequencies for operation.

History

In 1912, the U.S. Congress imposed the Radio Act of 1912 on amateur radio operators, limiting their operations to frequencies above 1.5 MHz (wavelength 200 meters or smaller). The government thought those frequencies were useless. This led to the discovery of HF radio propagation via the ionosphere in 1923.Wikipedia

Propagation Methods

The 1912 radio act prompted experimentation by amateur radio operators with these higher frequencies. The frequencies were found to propagate very well over vast distances. The results of these experiments evolved into the common propagation methods used today.

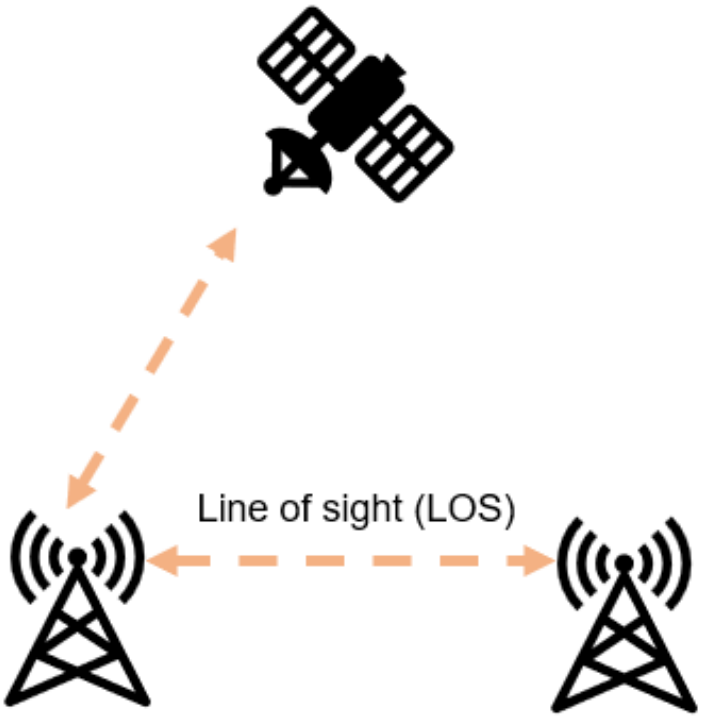
Line of sight

Radio waves travelling in a straight line from the transmitting antenna to the receiving antenna is called line of sight or direct wave propagation.

On the earth's surface, this distance is around 64 km.

Satellite communications use longer line-of-sight paths.

Ground stations can communicate with spacecraft billions of kilometres from Earth.



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Ground Wave

Signals between 30 and 3,000 kHz, vertically polarized radio waves can travel as surface waves following the contour of the Earth.

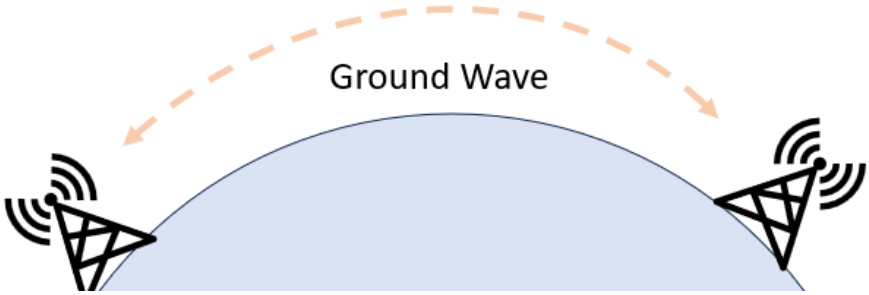
This is called ground wave propagation, and signals are attenuated as they follow the earth's surface.

3 – 30 kHz (VLF - Very Low Frequency): Used for navigation, time signals, and deep-sea submarine communications.

30 – 300 kHz (LF - Low Frequency): Used for maritime and aircraft navigation, with signals following the earth's curve (ground waves).

300 – 3,000 kHz (MF - Medium Frequency): Includes the AM radio broadcast band (535–1705 kHz).

Amateur Bands in LF and MF but none in VLF.



Non-Line of Sight

Non-Line-of-Sight (NLOS) describes radio communications where there is no visual line of sight (LOS) between the transmitting antenna and the receiving antenna.

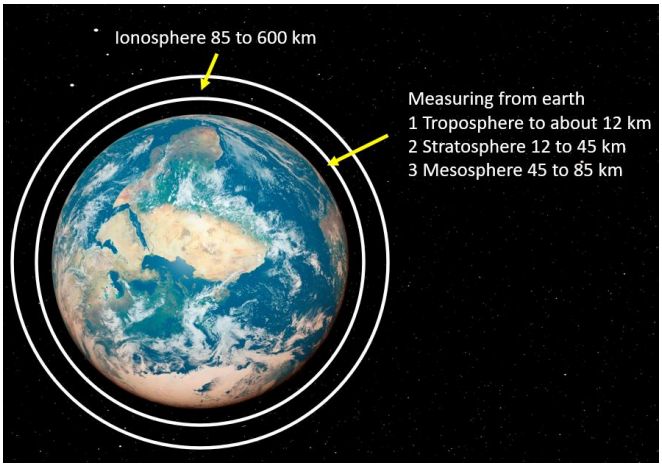
This propagation relies on reflections of the radio waves from the ionosphere.

Ionospheric Propagation

The ionosphere is the ionized upper atmosphere of Earth, from about 48 km to 965 km above sea level.

The ionosphere is essential for high frequency radio communications as it appears as a natural, non-maintained mirror in the sky that refracts (bends) radio waves back toward Earth.

This process allows signals to bypass the curvature of the Earth and travel over the horizon for long-distance.



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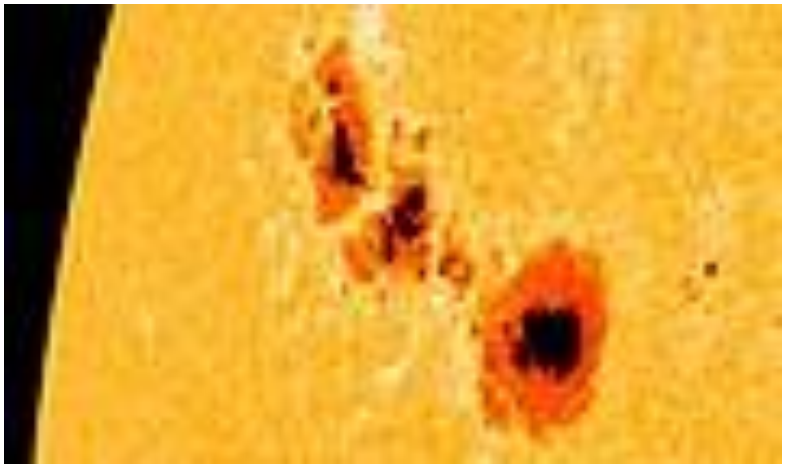
The Sun and the Ionosphere

The sun's electromagnetic radiation ionizes the earth's ionosphere.

The Sun also has intense areas called sunspots. These sunspots emit greater radiation than normal and occur naturally over an 11-year cycle.

Sunspots produce increased UV radiation that boosting the ionosphere which improves skip propagation.

Sunspots will increase during the "solar maximum" and decrease near the "solar minimum."

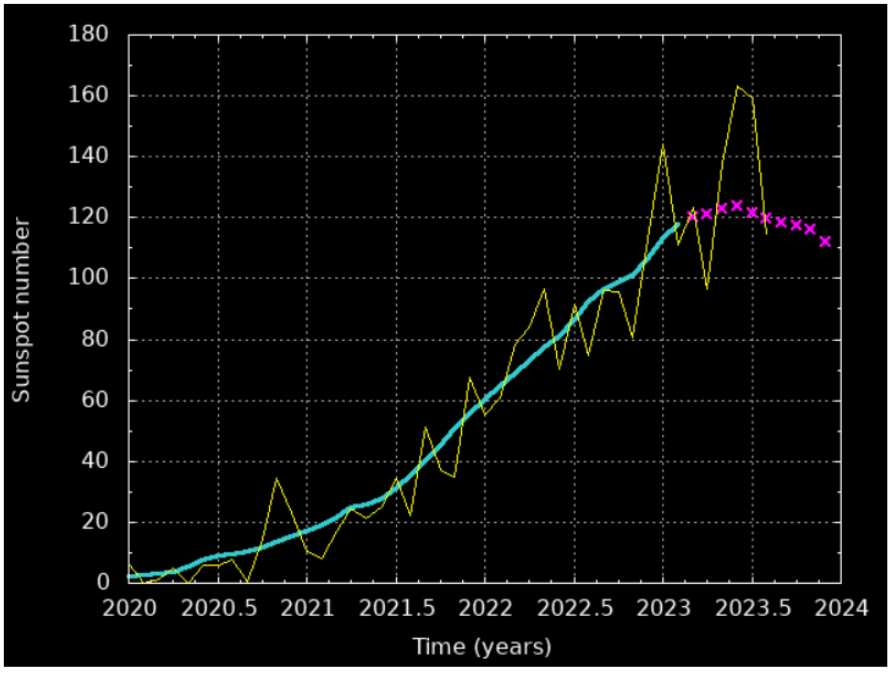


The higher HF bands will be more successful with skip propagation during the years near solar maximum. Some of these higher HF bands may not open during the lower activity portions of the solar cycle.

The sun's rotation also impacts on radio propagation. As the sun spins on its axis and rotates approximately every 28 days, prominent sunspots are rotated out of view of earth.

This rotation alters the intensity of sunspots over the 28 days which impacts radio propagation.

Solar flares and eruptions can also temporarily enhance the D-layer absorption of RF reducing HF skip propagation across the bands.



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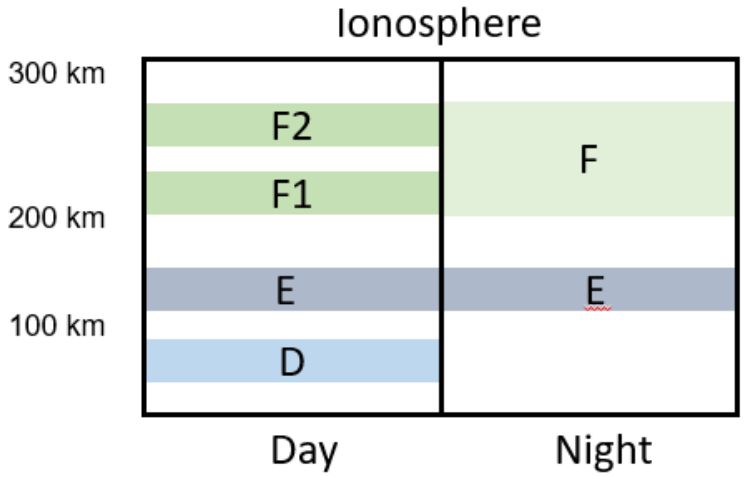
Ionospheric layers

The ionospheric layers change from hour to hour with a dramatic shift during nighttime.

During the day, there are four dominant layers: D, E, F1 and F2. During the night, the D layer disappears and the F layers combine.



D Layer

The D layer is the closest layer to earth at 48 km to 90 km. Here medium frequency (MF) and lower high frequency (HF) radio waves are significantly attenuated. This absorption peaks around noon and is reduced at night.

E Layer

The E layer is the middle layer at 90 km to 150 km. At night, the E layer weakens because the primary source of ionization, the sun, is no longer present. After sunset, a rise in the height of the E layer increases the range of the radio waves.

Sporadic E Layer

Sporadic E layer (Es) is an unpredictable occurrence where radio signals are reflected off relatively small "clouds" in the lower E region. The Es propagation often supports very high frequencies (VHF) long-distance communication during the summer solstice.

F layer.

The F layer from about 150 km to more than 500 km. The F layer has the highest electron density and any signals penetrating this layer will escape into space.

The F layer consists of one layer (F2) at night, but during the day, a secondary layer (F1) often forms.

Because the F2 layer remains by day and night, this is responsible for most skywave propagation of radio waves and long-distance high frequency radio communications.

Reflection and Refraction

RF Reflection is where the signal is reflected from the ionosphere like a mirror.

Waves can be reflected several times from earth to the ionosphere giving multiple skips.

RF refraction is where the radio wave bends as it passes through mediums of different densities in the ionosphere.

Layers of air with varying temperature, pressure, or humidity will cause the RF wave to bend.

This phenomenon changes the signal's direction and can enable long-distance communications.

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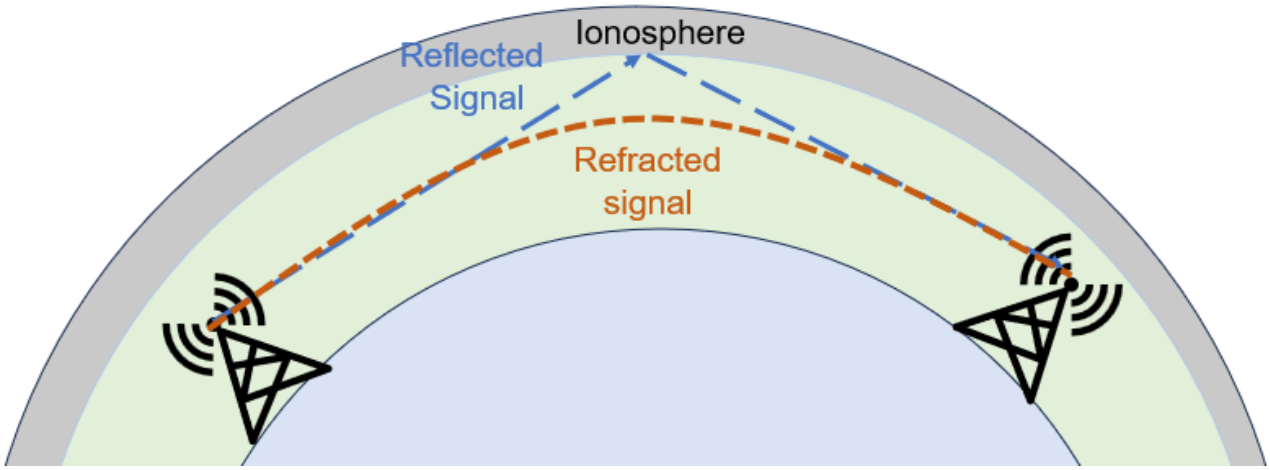
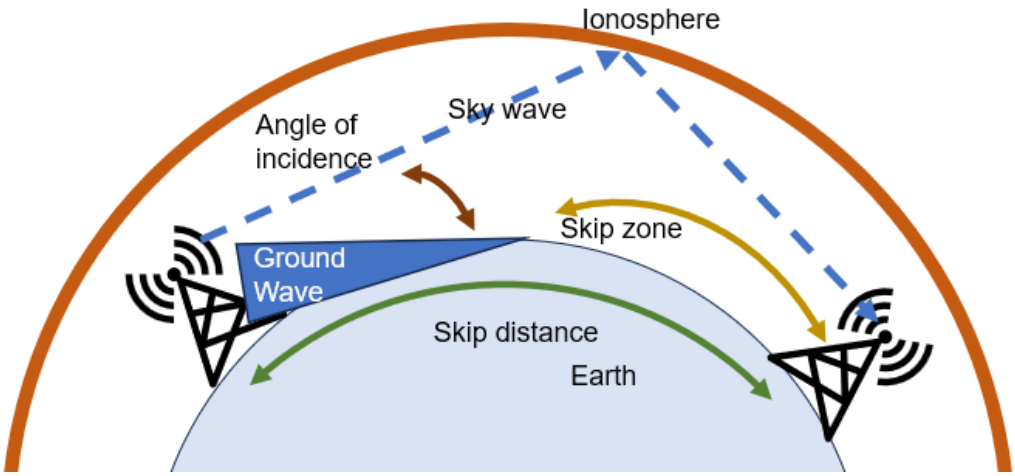
RF reflection is generally more common in everyday over the horizon communications than RF refraction.



Radio Communications

The ionosphere can reflect radio waves back toward the Earth beyond the horizon. This technique, called "skip" or "skywave" propagation. The returning radio waves can reflect off the Earth's surface into the sky again, called skips, allowing greater ranges to be achieved with multiple hops. Issues impacting the skip distance are the angle of incidence of the antenna and the height of the ionosphere.



HF Ground wave

HF ground wave propagation involves radio signals (3–30 MHz) traveling along the Earth's surface. This method is highly effective for short-to-medium range communication (up to ~100 km over land, 300+ km over sea), particularly when using vertical antennas.

Angle of incidence

Angle of incidence, or Antenna take-off angle, is the vertical angle from the horizon at which an antenna radiates the maximum amount of energy.

Lower angles, less than 15 degrees, are optimal for long-distance (DX) communication, requiring fewer ionospheric hops.

Sky Wave

Skywave is the radio waves reflected to Earth by the ionosphere, enabling over-the-horizon communications.

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Skip Zone

The skip zone, or silent zone, occurs in high-frequency (HF) radio communication, between the end of ground wave coverage and the first return of the skywave.

Skip Distance

Skip distance is the minimum distance between a radio transmitter and the point where a skywave signal first returns to Earth. It represents the shortest distance for refracted signals, forming the outer boundary of the "skip zone".

Other Non-Line of Sight Communications.

Tropospheric Ducting and Temperature Inversion

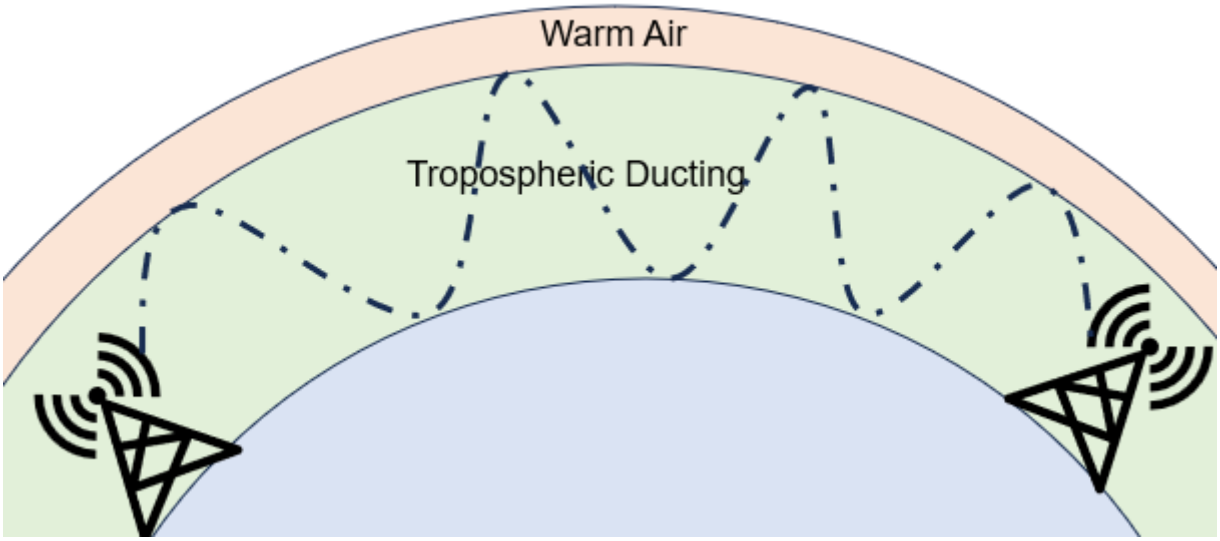
The atmosphere is colder the higher you go.

Occasionally a layer of air in the troposphere will be at a higher temperature than the layers of air above and below.

This temperature inversion layer creates a duct which radio waves can travel along.

A temperature inversion may extend for 1,500 km or more along a stationary weather front.

Tropospheric ducting of radio signals is relatively common during the summer and autumn months.



Tropospheric Scatter

Also known as troposcatter, is a method of communicating with microwave radio signals over considerable distances – often up to 500 kilometres.

This method of propagation uses the tropospheric scatter phenomenon, where radio waves at UHF and SHF frequencies are randomly scattered as they pass through the upper layers of the troposphere.

Radio signals are transmitted in a narrow beam aimed just above the horizon in the direction of the receiver station. As the signals pass through the troposphere, some of the energy is scattered back toward the Earth, allowing the receiver station to pick up the signal.

The signal must be transmitted at a high power and in a specific frequency range (1- 10 GHz). The signal must be transmitted at a specific angle, typically between 2 and 5 degrees above the horizon, to ensure effective scattering

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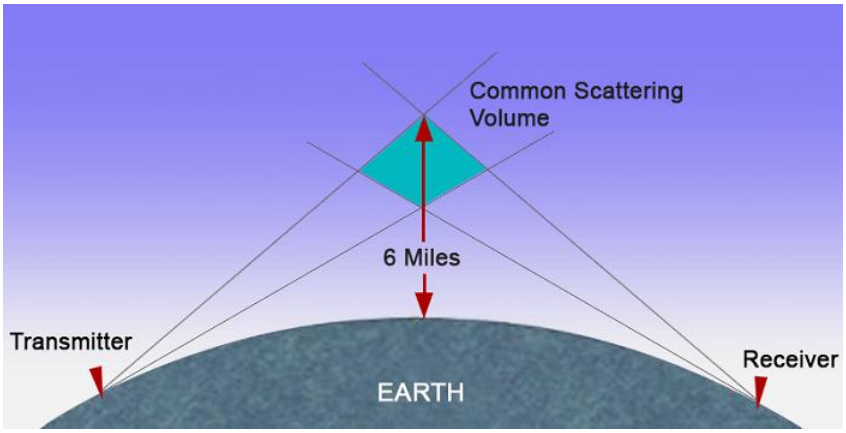
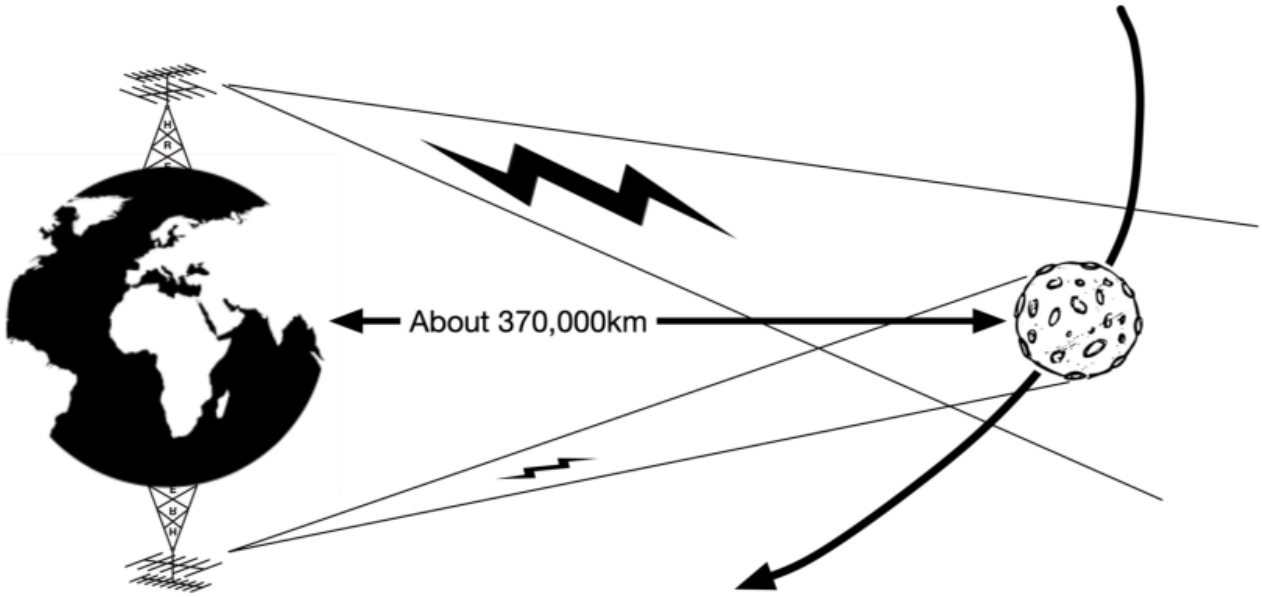


Moon Bounce

Earth–Moon–Earth communication (EME), Moon bounce, is a radio communications technique that uses the moon to bounce radio signals back to earth. This path the longest communications path any two stations on Earth can use.

Amateur frequency bands from 50 MHz to 47 GHz have been used successfully, but most EME communications are on the 2 meter, 70-centimeter, or 23-centimeter bands.



Auroral Scatter

Auroras at or near the poles are a sign of an atmospheric disturbance. The auroras can cause significant changes to radio propagation conditions. HF radio propagation via the ionosphere can be blacked out. VHF can be used for communications around the poles during auroras.

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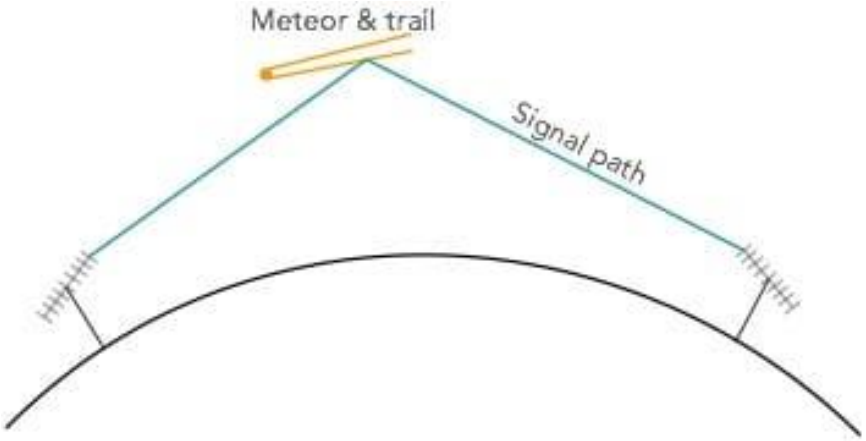
Meteor Scatter

Meteor scatter, or meteor burst communications, uses the dense trails of ionisation left by meteors as they enter the upper layers of the Earth's atmosphere.

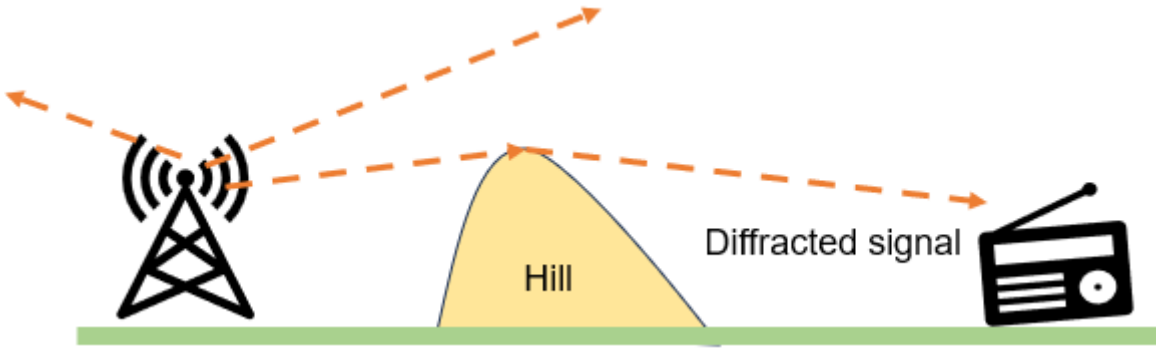
Meteors of all sizes enter the earth's atmosphere regularly, but they are very short lived.

This propagation method is best suited to signals in the VHF and sometimes the UHF band.



RF Diffraction

RF Diffraction is the bending of signals around edges of geometric objects allowing signals to reach non-line-of-sight (NLOS) areas. Signals can curve over hills and around buildings, extending the RF coverage.



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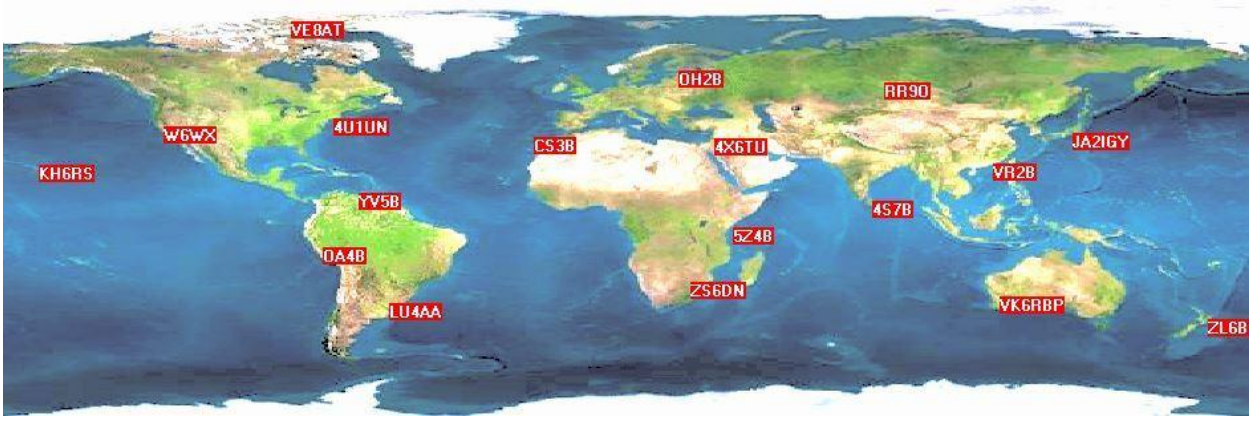
Propagation Terms.

Amateur Beacon:

An amateur beacon is a fixed-frequency transmitter that sends out continuous wave (CW) signals (usually Morse code identifying the station).

Amateur operators listen to these beacons to test whether specific bands are "open" for long-distance communication (propagation).

The primary global network for amateur beacons is the International Beacon Project (IBP), which uses 18 synchronized, high-frequency beacons to cover worldwide DX paths



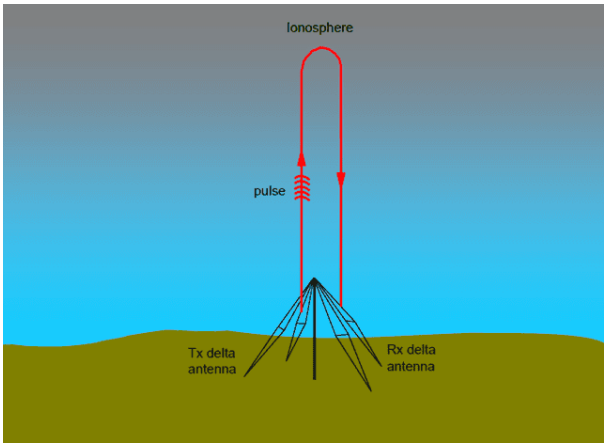
Critical Frequency (CF)

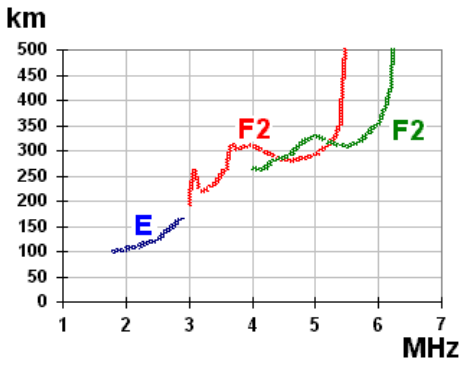
The critical frequency is an indication of the ionosphere and HF propagation.

CF is obtained by sending a signal pulse directly upwards (vertically) and received back at the same site. This device is called an ionosonde. In amateur

The time taken for the signal gives an indication of the height of the layer.

As the frequency is increased a point is reached where the signal will pass right through the layer. The frequency at which this occurs is called the critical frequency. A plot of the reflections against frequency can be generated and indicates of the state of the ionosphere for that part of the world.





Fading

Fading is a common feature of ionospheric propagation. The signal variations may be slight, or signals can completely disappear. As the ionosphere changes, the signals will fall in and out of phase with one another, resulting in the strength varying by a considerable degree.

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Maximum Usable Frequency (MUF)

The maximum usable frequency (MUF) is the maximum frequency you can use at that time to achieve the skip. Frequencies above the MUF will go through the ionosphere and are lost.

Communications may or may not succeed when using the MUF. Commonly, the optimal operating frequency for a given path is estimated at 80 to 90% of the MUF. The MUF is approximately 3 times the critical frequency.

Optimum Working Frequency

The optimum working frequency (OWF) estimates the maximum frequency that must be used for a given critical frequency and incident angle.

Path Loss

Path loss, or path attenuation, is the reduction in signal intensity as it propagates through space.

Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas.

Selective fading or frequency selective fading

This is a radio propagation anomaly caused by cancellation of a radio signal by itself. That is the signal arrives at the receiver by two different paths, and at least one of the paths is changing (lengthening or shortening). This typically happens in the early evening or early morning as the various layers in the ionosphere move, separate, and combine. The two paths can both be skywave or one be groundwave.

More excellent material at [SWS - Other Topics - Introduction to HF Radio Propagation (bom.gov.au)]

Go to Unit 17 questions.

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