# Chapter 6

## Propagation

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

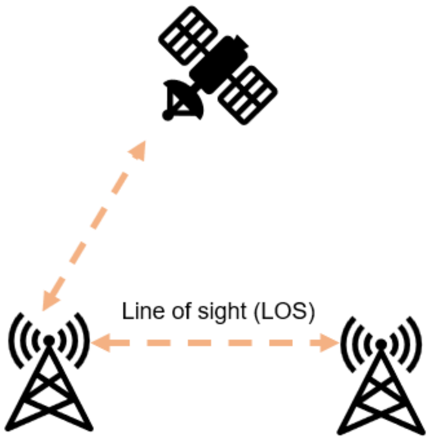
How wrong they were.

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.

### Line of sight

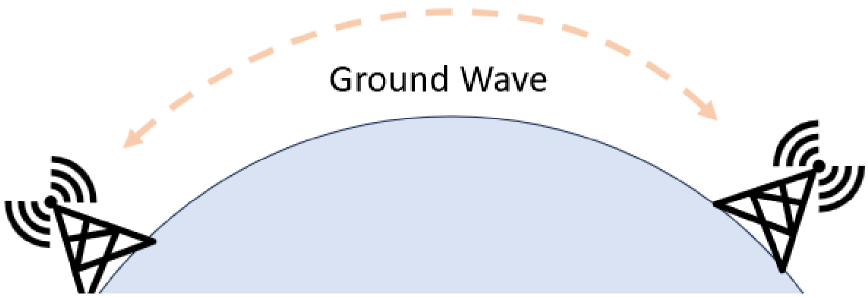
Radio waves travelling directly in a straight line from the transmitting antenna to the receiving antenna. This termed line of sight or direct wave which is around 64 km on earth. Satellite communications uses longer line-of-sight paths and ground stations can communicate with spacecraft billions of miles from Earth.




### 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.

At lower frequencies, in the VLF to ELF range, the ground wave enables even longer-range transmissions. These frequencies can submarines.



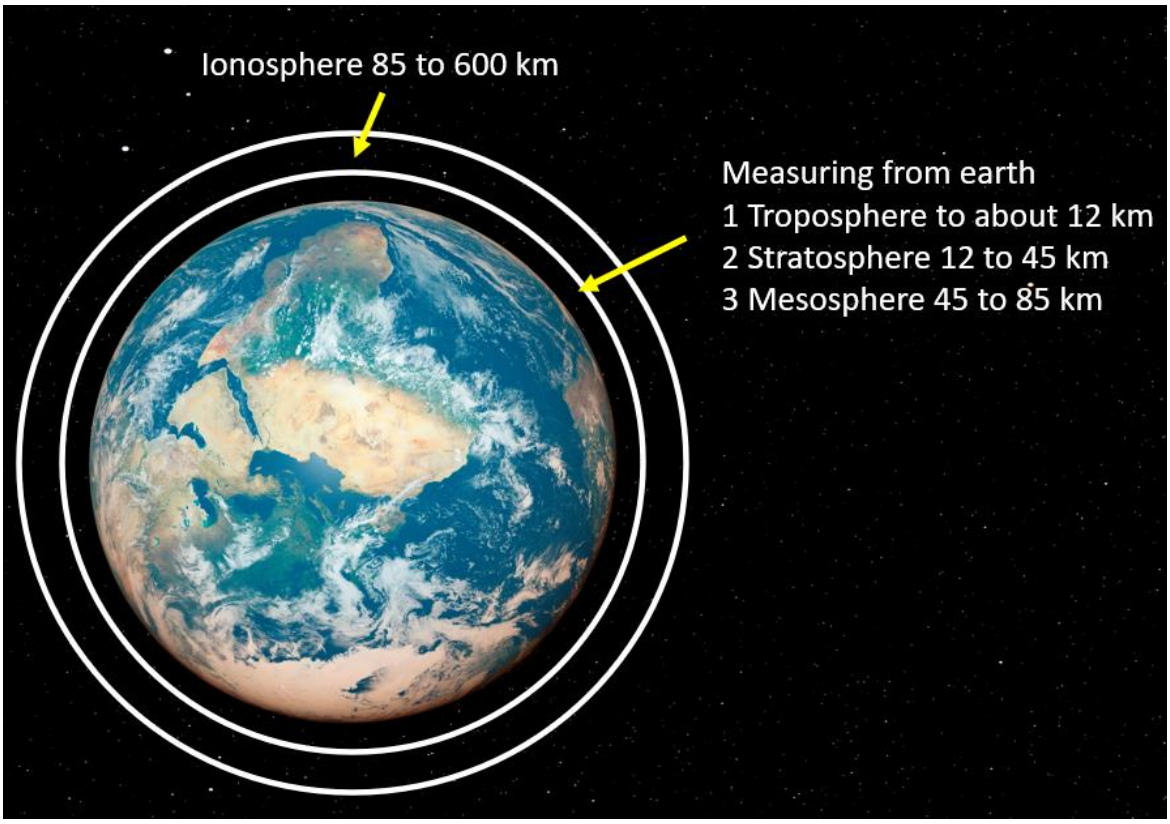
## Non-Line of Sight

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. Waves can be reflected several times from earth to the ionosphere give multiple skips. Here transmissions can travel great distances.

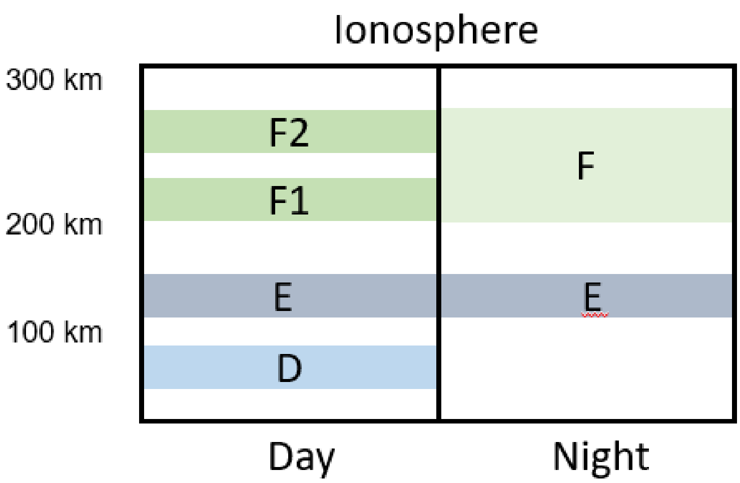
## Ionospheric Propagation

The ionosphere is the ionized upper atmosphere of Earth, from about 48 km to 965 km above sea level. The ionosphere has practical importance as it influences radio propagation to distant points on Earth.




## Ionospheric layers

Layers in the ionosphere change from day to nighttime as shown below.



## D Layer

The D layer is the closest layer 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, 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 an increase in the height of the E layer maximum increases the range to which radio waves can travel by reflection from the F

## Sporadic E Layer

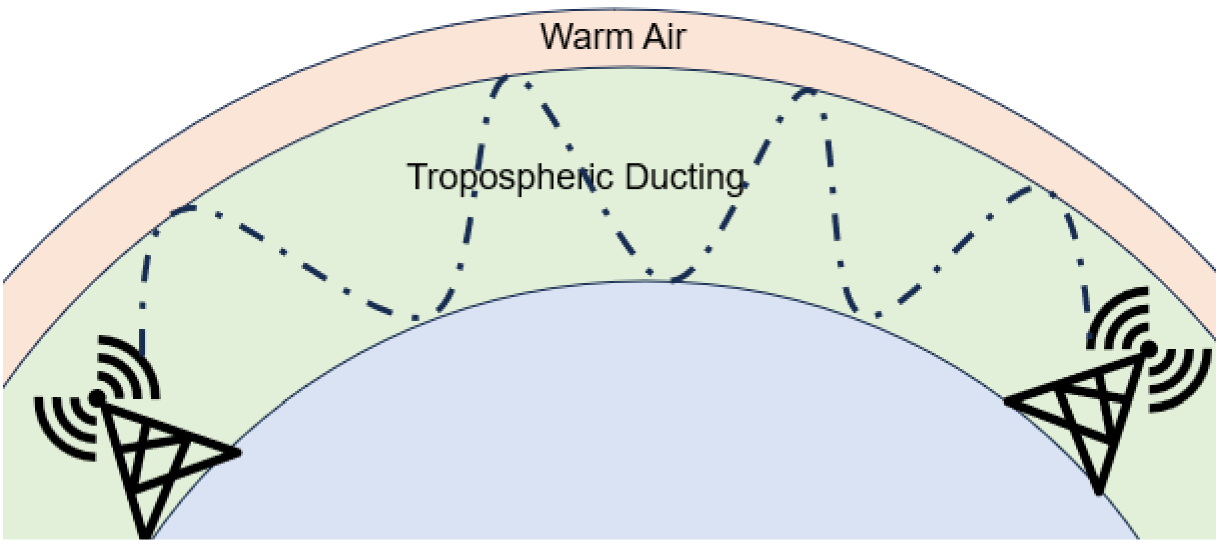
Sporadic E layer (Es) is an unpredictable occurrence where radio signals are reflected off relatively small "clouds" in the lower E region. The Es propagation often supports very high frequencies (VHF) long-distance communication during the summer solstice.

## F layer.

The F layer from about 150 km to more than 500 km. The F layer has the highest electron density and 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.

## Tropospheric Ducting and Temperature Inversion

The atmosphere is normally 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.

### 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

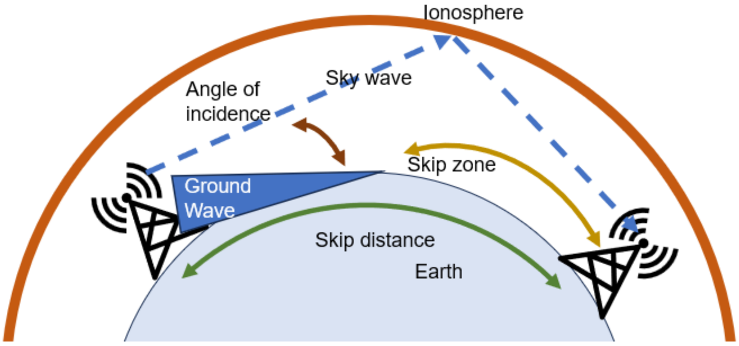
Auroras at or near the poles are a sign of an atmospheric disturbance. The auroras can cause significant changes to radio propagation conditions. HF radio propagation via the ionosphere can be blacked out. VHF can be used for communications around the poles during auroras.

### 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.

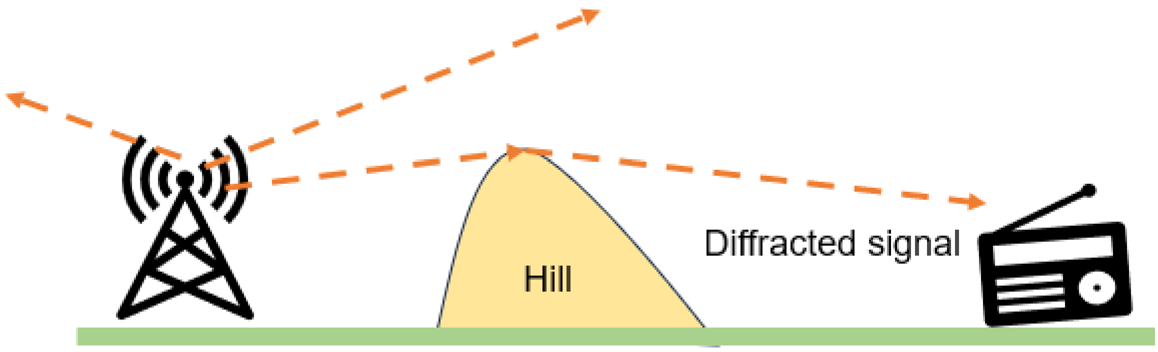
### Radio Communications

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, allowing greater ranges to be achieved with multiple hops. This skipping can be unreliable.




### Diffraction

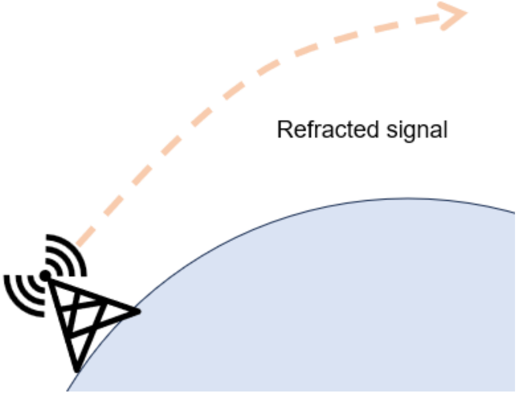
Diffraction is the bending of signals around edges of geometric objects.



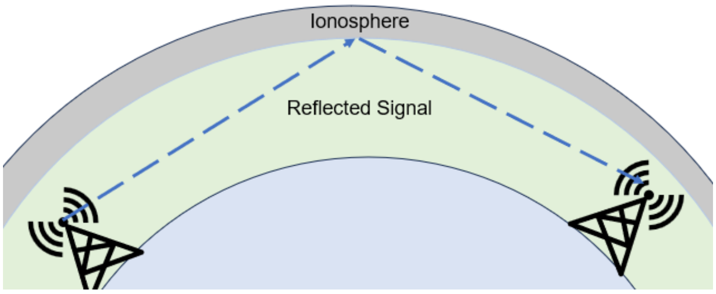
## Refraction

Radio waves can be refracted (bent) in the ionosphere.




## Reflection

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




## The Sun and the Ionosphere

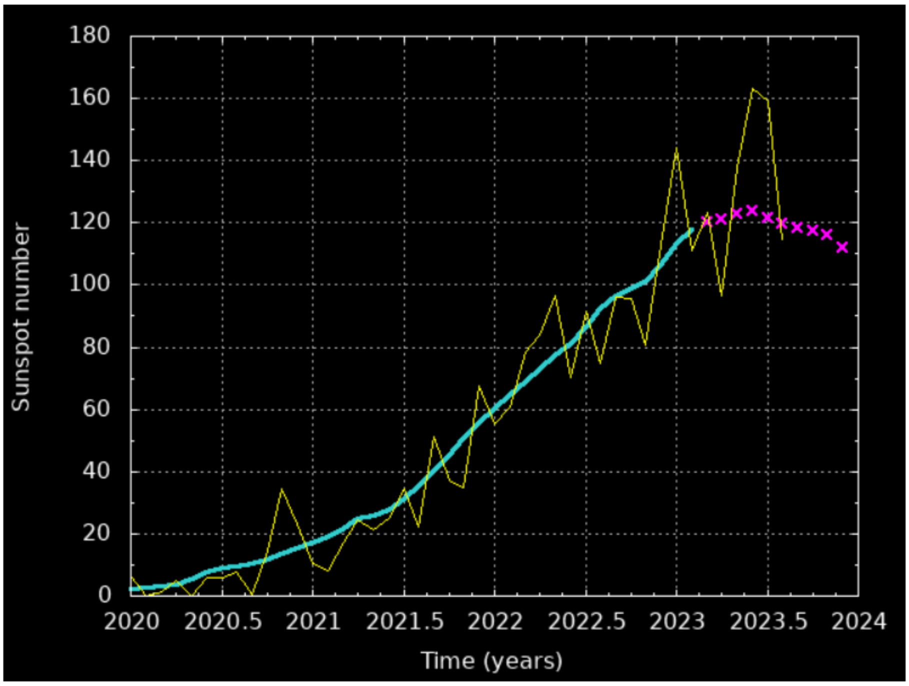
The sun's electromagnetic radiation ionizes the earth's ionosphere. The Sun also has intense areas called sunspots. These sunspots emit greater radiation than normal. radiation and naturally over an 11-year cycle. Sunspots produce increased UV radiation that boosting the ionosphere which improves skip propagation.

Sunspots will increase during the "solar maximum" and decrease near the "solar minimum." Below is a chart copied from the Bureau of Meteorology site and shows the sunspot activity is approaching a peak.

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 in that the sun spins on its axis and rotates approximately every 28 days. As the sun rotates, prominent sunspots are rotated out of view of earth. Altering intensity of sunspots over the 28 days also impacts radio propagation.




(last updated 01 Sep 2023 10:18 UT)

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

## 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. 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.

## Maximum Usable Frequency (MUF)

The Critical Frequency is tested vertically. Signals transmitted around the world are not aimed vertically but at an angle to the earth or at low angles of incidence. These sky waves can propagate over great distances. 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 is lost.
The MUF is generally three times greater than the CF (for the F region) and up to five times (for the E region).

## Power

> "In free space the intensity of electromagnetic radiation decreases with distance by the inverse square law, because the same amount of power spreads over an area proportional to the square of distance from the source."

Put simply, the radio wave diminishes in power rapidly with distance from the transmitter.

## Minimum Detectable Signal- Sensitivity

A minimum detectable signal is a signal at the input of a system that can be detected over the background noise. The signal can be defined as a signal that produces a signal-to-noise ratio of a given value at the output. See Signal to Noise Ratio

## 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.

## 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.

## Noise

### Galactic Noise

Galactic or Cosmic noise are RF signals at frequencies above about 15 MHz. These signals are detected if the antennas are directed to the sun or other regions of the sky. Celestial objects like quasars, which are super dense objects far from Earth, emit electromagnetic waves in their full spectrum, including radio waves.

### Atmospheric Noise

Atmospheric noise is radio noise caused by natural atmospheric processes, primarily lightning discharges in thunderstorms. On a worldwide scale, there are about 40 lightning flashes per second – ≈3.5 million lightning discharges per day. Wikipedia

### Noise Floor

If there were no manmade signals present, the RF spectrum has a natural noise level called the thermal noise floor. The noise floor is the measure of the signals created from all the noise sources where noise is defined as any signal other than the one being monitored.

### Band Noise

Band noise is a combination of natural electromagnetic atmospheric noise and manmade radio frequency interference (RFI) from other electrical devices.

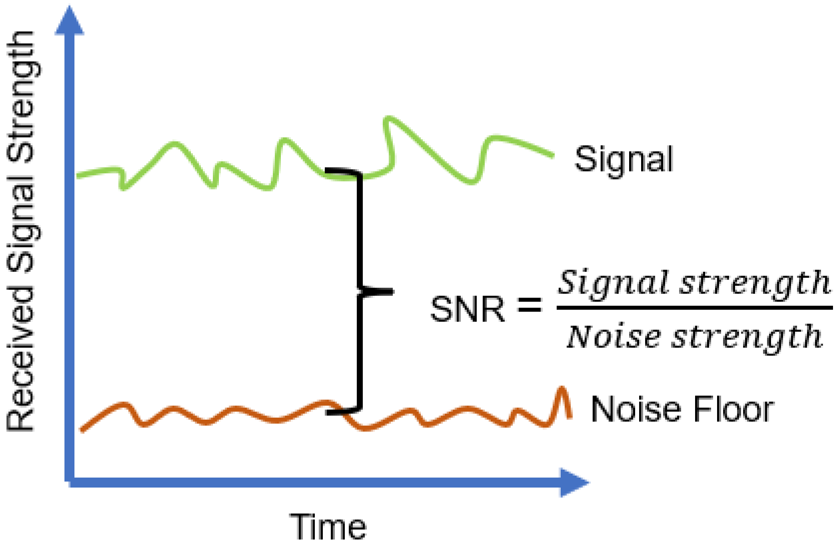
### Receiver Noise

Receiver noise is the noise present in the receiver input circuits caused by the random thermal motion of molecules (Thermal Noise). See lesson 10.

### Signal to Noise Ratio

Signal-to-noise ratio (SNR) compares the level of a desired signal to the level of background noise. SNR is the ratio of signal power to noise power in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. A suggested minimum SNR is 20dB.




- Up to 30MHz manmade, galactic and atmospheric noise predominate.
- 50 MHz External noise still greater than internal noise
- 100 MHz and upward, external noise minimal and component thermal noise needs consideration.

Go to Chapter 6 Questions.

*Have fun and stay safe.*