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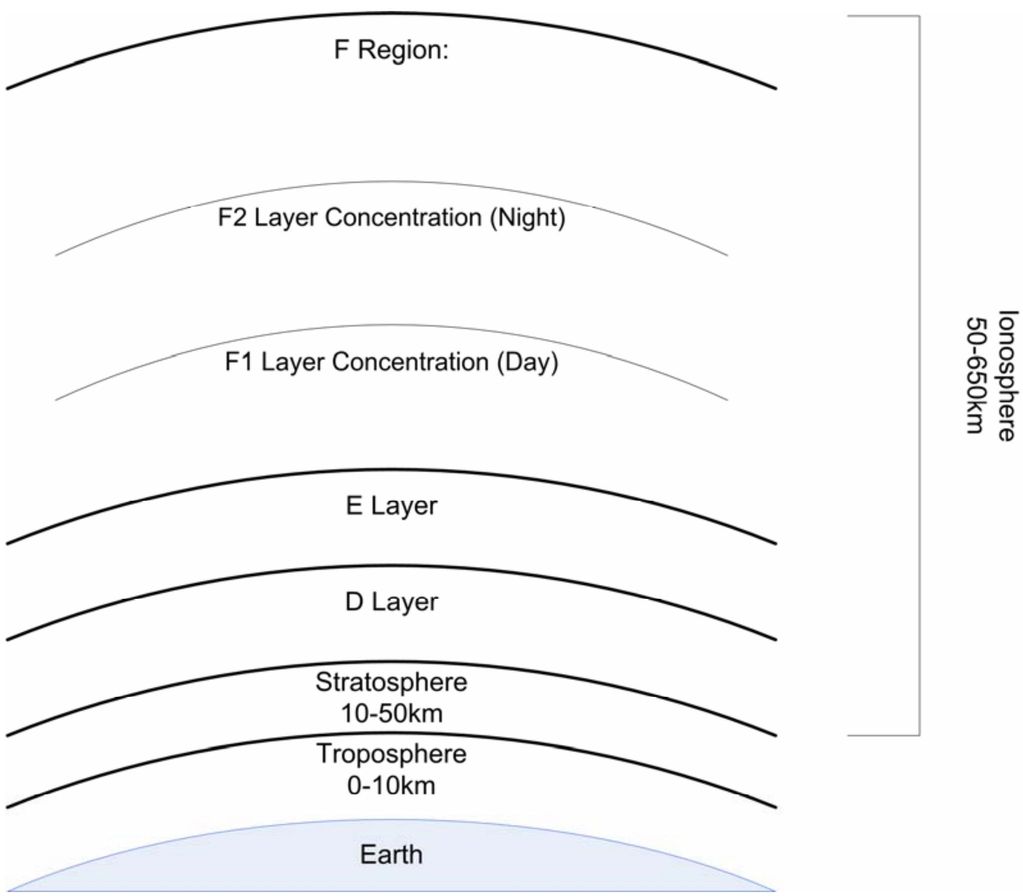
Amateur Radio Signal Propagation

Signal propagation is simply how a radio signal travels. There are a number of environmental factors that affect propagation, but for the amateur radio operator the primary considerations are the state of the ionosphere, the transmission frequency, altitude, and the angle of transmission.

What is the Ionosphere?

The ionosphere is the part of the atmosphere that is electrically charged, the amount of charge determines the density of each part of the ionosphere. These different densities are referred to as layers, and are identified as D, E, and F. If an RF signal enters the ionosphere at a favorable frequency and angle, the signal will be refracted, returning to the earth where it can be received by another radio or hop back up to the ionosphere. The peak times for signal propagation are early morning or early evening. During the course of the day as UV penetrates farther into the atmosphere, the D layer becomes ionized and causes attenuation or absorption of RF signals.



How Do the Layers Affect Signals?

Each layer reacts differently to RF signals. At the higher levels of the ionosphere (E and F) the air density decreases, which reduces the number of collisions between electrons. This has the effect of refracting the signal instead of causing attenuation or absorption, as in the D layer. In practical terms, this refraction is often referred to as hop, skip, or reflection.

The Troposphere

The troposphere is just another term for the familiar atmosphere that we all see when we look up at the sky to check the weather. RF signals cannot bounce off the troposphere; however, the weather conditions in the troposphere can propagate signals from elements created by the weather. This propagation includes signals that are scattered to the earth from rain, hail, or also from a phenomenon known as tropospheric ducting. When a cool air mass is covered by a mass of warmer air, a "duct" can be formed through the cold air mass, allowing some radio signals to travel great distances through this duct.

The D Layer

Like the troposphere, the D layer does not refract signals and adds considerable loss to a signal, called absorption. Absorption loss is when some of the energy of the signal is turned to heat. Absorption is greatest at the MF and HF frequencies. The D layer is primarily an obstacle, requiring the signal to have the proper frequency and angle so that it can pass through to the denser layers.

The E Layer

Some signal bounce can occur in the E layer. However, there is considerable absorption as the signal passes through the D layer. This layer exists mostly during the day when the effects of the sun create the ionization. Signal propagation from this layer can occur in a number of different ways, but is rather uncommon.

The F Layer

This is the layer where most signal propagation occurs. During the day it has two layers: F1 and F2; at night, layer F1 disappears. This layer allows the signal to hop more than once, or multi-hop. Signals hopping in the F layer can hop to the ground or between the F layer and E layer. Unlike the other layers, propagation through the F layer is actually greater during the winter months through a phenomenon called *winter anomaly.*

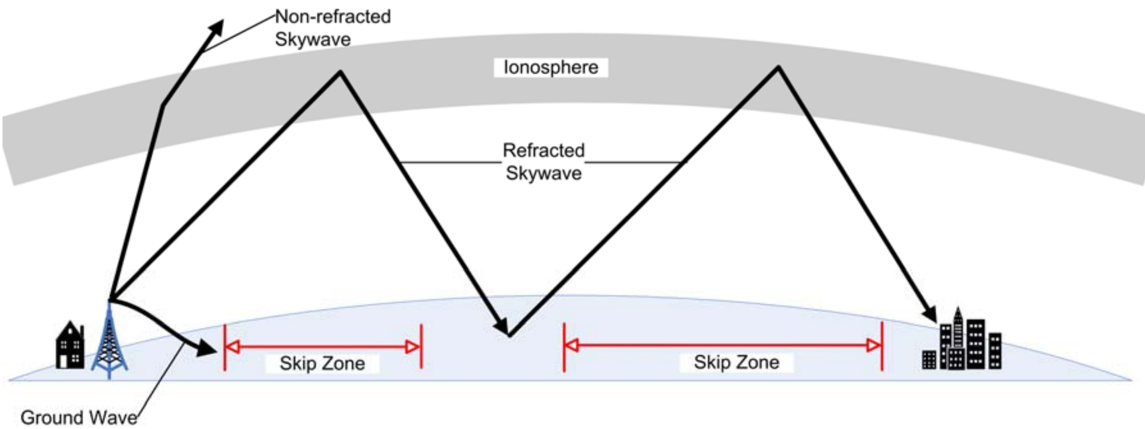
The following table shows the general frequency ranges that can be used for propagation through the ionosphere.

Layer (daylight only)	Useful Operating Frequencies
F_2	1-60MHz
F_1	10-20MHz
E	5-160MHz

How Do RF Signals Hop Using the Ionosphere?

Components of Radio Signals

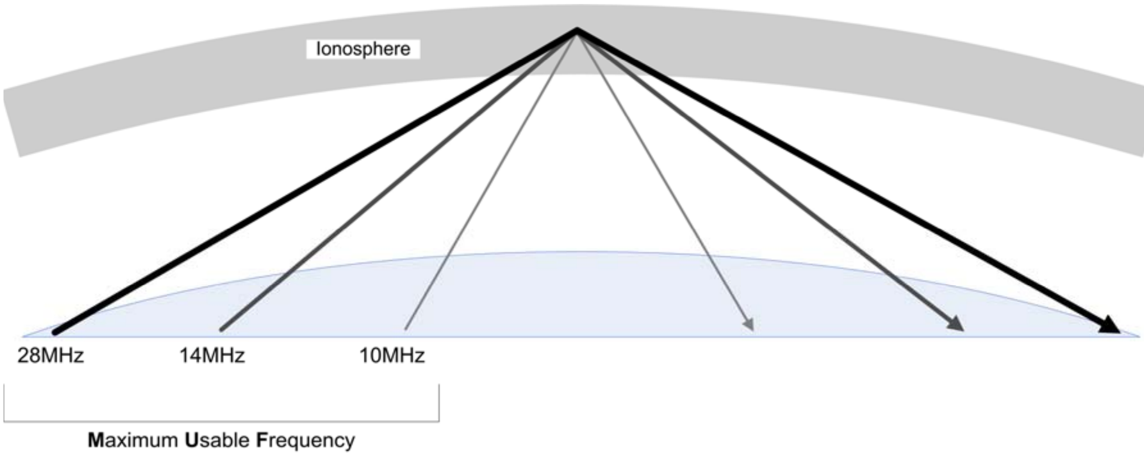
The two principal parts of a typical radio signal are the sky wave and the ground wave. The Skyway travels up to the sky and is the portion of the signal that hops off the ionosphere. This gives the signal the capability of traveling great distances. The ground wave literally travels on the ground, following the contours of the earth, often beyond line of sight. At best, a ground wave may go approximately 100 miles and then either be obstructed or simply dissipate.



Frequency, Altitude, and Angle

In addition to the proper density in the ionosphere, to be able to skip a wave off the ionosphere requires the right combination of frequency, altitude, and transmission angle. You need to select a favorable frequency for the atmospheric conditions and have your antenna properly tuned. When hopping from the ionosphere, you should consider what is called the Maximum Usable Frequency (MUF). This is the highest frequency that can be refracted from the ionosphere. Depending on frequency used, altitude, and atmospheric conditions, the MUF could be refracted from the ionosphere from absolute vertical to an angle greater than 45°. The earth's surface also plays a part in creating multi-hops. You have a much greater chance of the signal being re-propagated off water than you do with desert sand.

In general, the higher frequencies refract at shallower angles (see the following diagram). Higher frequencies also work better at higher altitudes. If the frequency is too high, it won't be refracted back to earth. If the angle of the wave is too steep, it will continue into space. The steepest angle that reflects back to earth is called the "critical angle". The skip zone (dead zone) is an area that cannot receive the signal because it is between hops.



Other Methods of Signal Propagation

Reflection from Obstacles

Signals can sometimes be reflected from buildings, planes, mountains, or other such impediments to line of sight transmission. Under the right conditions, signals can be extended several hundred kilometers. You can attain more distance if the reflecting object is closer to the signal origin.

Knife-edge Diffraction

A signal striking an object can sometimes progress behind an object in a phenomenon called knife-edge diffraction. When this happens, the bottom portion of the signal is blocked by the object, but the top portion of the signal is propagated behind the object. Instead of being blocked or reflected, the top portion of the signal will pass over the top of the object and curl around behind it. This enables a receiver to pick up the signal directly behind the object.

For knife-edge diffraction to occur, the object must have a somewhat sharp upper edge. This means that mountains, or even rolling hills, will propagate in this way. If the top of the mountain (or other such object) is forested or otherwise cluttered, the signal will be blocked and diffraction cannot occur.