Propagation of Radio Waves

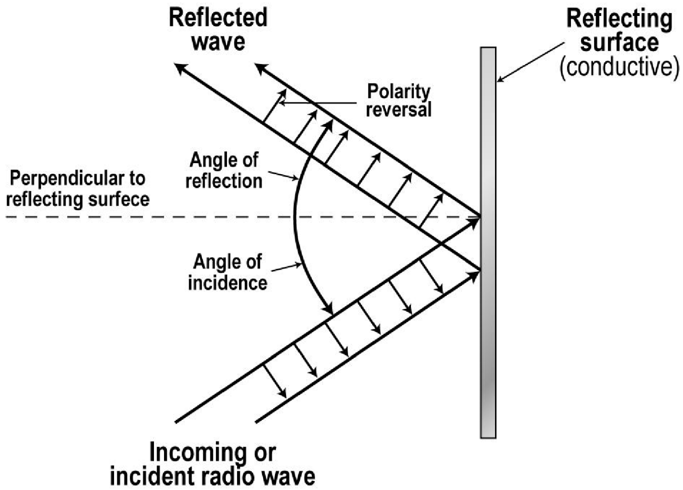
Radio Wave Propagation

Propagation refers to how radio waves travel through space and how they are affected by the environment in which they travel.

Radio waves are similar to light waves in that they can be reflected, refracted, diffracted, and focused.

Reflection refers to how a radio wave can be redirected by some physical element or device. Radio waves tend to pass right through objects that are not good conductors. This causes its speed to be slowed depending upon the type of material. The better the conductor the object is the better it will reflect the wave. This reflection is like the reflection of light by a mirror. Radio waves are reflected best by a good conductor, the larger the better. Large metal buildings, water towers, and airplanes are good reflectors of radio energy.

Reflection



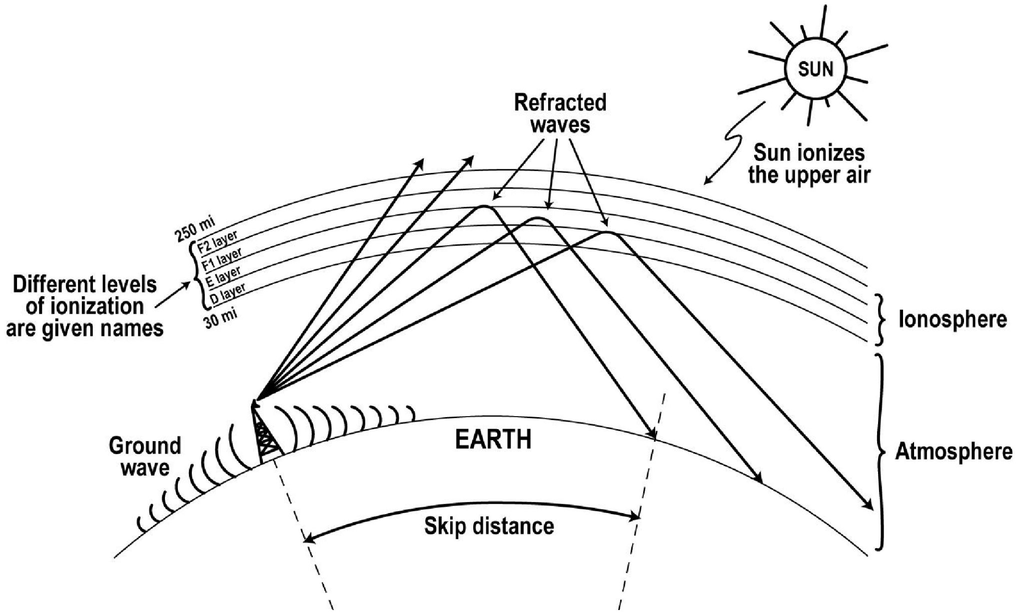
A single conductor, like a wire or pipe placed near an antenna, will reflect much of the signal. As with light, radio signals are reflected according to the rule that says the angle of incidence is equal to the angle of reflection. Reflection produces a 180° phase shift in the signal. Reflection of radio waves is what makes radar possible. Ships, planes and other large objects readily reflect radio waves making them “visible” to a radar receiver.

Refraction and Diffraction

Radio signals are also refracted. Refraction is the bending of a light or radio wave caused by a change in the density of the medium through which it passes. When light passes through the air then into glass, the speed of transmission in the glass is slower so the waves are bent or deflected from a straight line path. Radio waves are also refracted as they pass through the air with different densities caused by different levels of ionization.

Radio waves also under go diffraction. When a light wave or radio wave encounters an object it cannot penetrate, the wave is blocked. Some of the waves that are not blocked pass by on the sides. A shadow zone is produced on the other side of the object where no signal exits. However, because of diffraction some of the waves get through into the shadow zone because the waves are bent around the edges of the object.

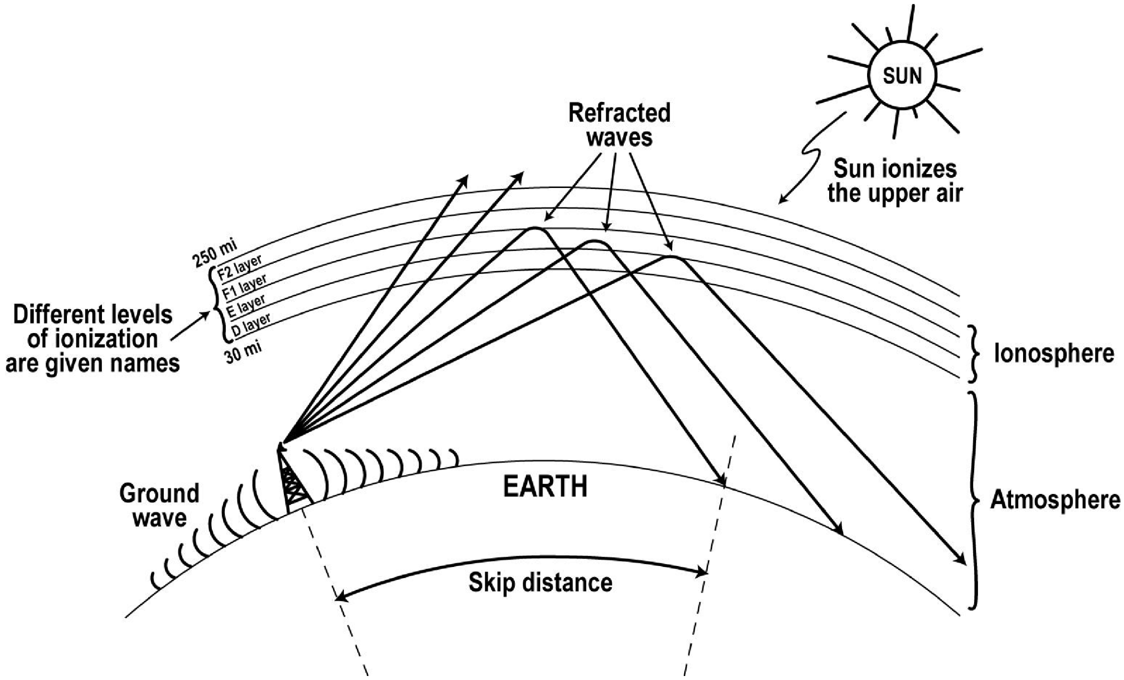
Radio Wave Travel



Radio waves travel through space in three basic ways: ground waves, sky waves, and space waves.

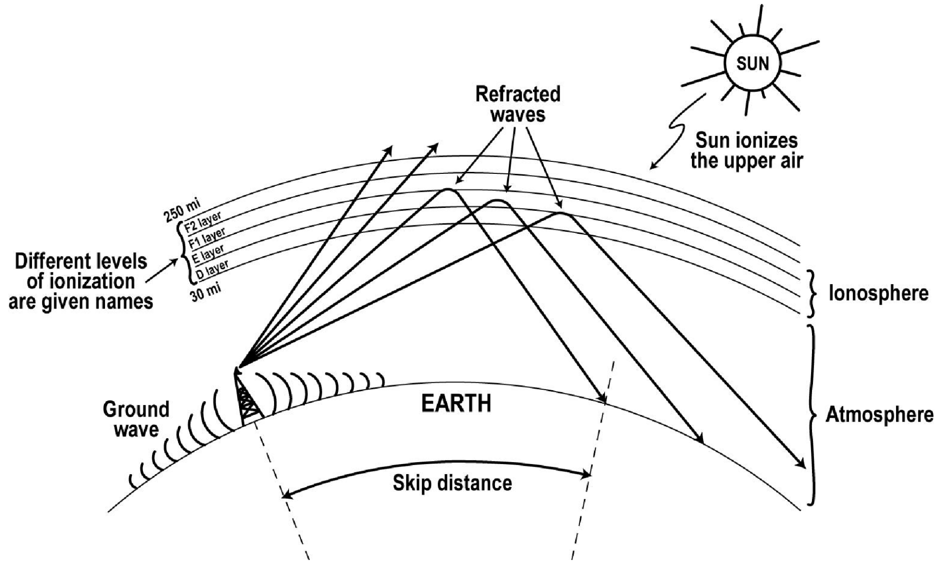
Ground waves are radio waves that essentially hug the earth as they are emitted from the antenna. They follow the curvature of the earth. Only radio signals below about 3 MHz produce ground waves. AM radio waves are an example.

Sky Waves



When emitted by the antenna, sky waves travel up into the atmosphere and then into the ionosphere around the earth and are refracted back to earth. The ionosphere consists of layers of air with different levels of ionization.

Skip Distance



The closer to the sun, the greater the ionization and the better conductor the air becomes. Different levels of ionization cause the radio waves to undergo refraction which bends them back to earth at a distance far away from the antenna. This is called the skip distance. This makes world wide communications possible. Sky waves are effective only for radio signals in the 3 to 30 MHz range. These are known as short waves.

Space Waves

Space waves, also referred to as direct waves, apply to signals at frequencies above about 50 MHz. The direct waves travel in a straight line and are not refracted by the ionosphere. They pass right through.

Propagation of space waves is what is called line-of-sight (LOS) transmission. In order for a wave to reach the receiving antenna, there must be a clear unobstructed path between the two antennas. The transmitting antenna must “see” the receiving antenna. LOS transmission greatly restricts the distance over which such waves can travel.

LOS Transmission

Since the earth curves, the maximum theoretical transmission distance is to the horizon which is related to the height of the antenna.

$D = \sqrt{2h}$ where D is the distance to the horizon in miles and h is the antenna height in feet. An antenna 50 feet high can transmit to the horizon $\sqrt{2(50)} = \sqrt{100} = 10$ miles away.

Increasing the height of the antennas increases the distance of transmission.

Most modern wireless applications like cell phones, wireless LANs, and other services use UHF and microwave frequencies and all use LOS transmission.

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