Propagation Methods

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Outline I

Propagation Methods I

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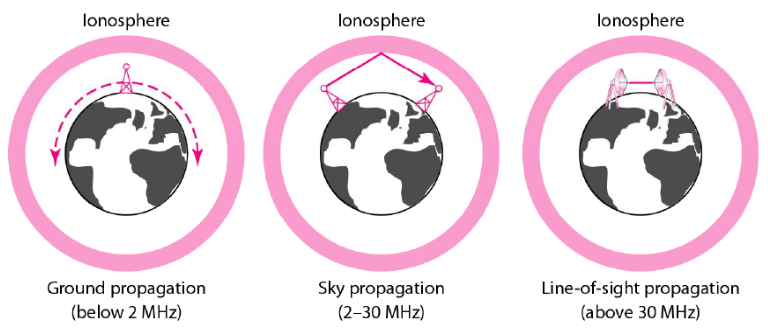


Ground Wave Propagation I

- Ground wave propagation more or less follows the contour of the earth and can propagate considerable distances, well over the visual horizon.
- This effect is found in frequencies up to about 2 *MHz*.
- Electromagnetic waves in this frequency range are scattered by the atmosphere in such a way that they do not penetrate the upper atmosphere.
- The best-known example of ground wave communication is *AM* radio.

Ground Wave Propagation II

- Several factors account for the tendency of electromagnetic wave in this frequency band to follow the earth's curvature.
  - The electromagnetic wave induces a current in the earth's surface, the result of which is to slow the wavefront near the earth, causing the wavefront to tilt downward and hence follow the earth's curvature.
  - Diffraction, which is a phenomenon having to do with the behavior of electromagnetic waves in the presence of obstacles.

Sky Wave Propagation I

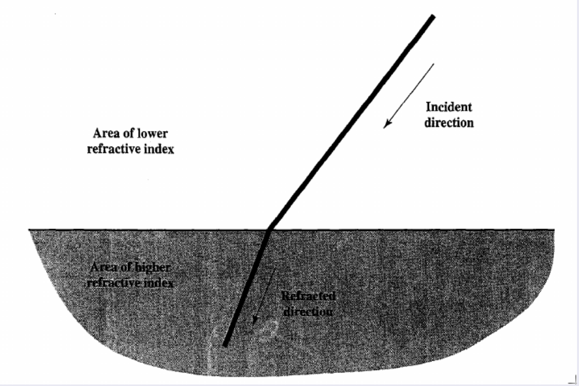
- Sky wave propagation is used for amateur radio, CB radio, and international broadcasts such as BBC and Voice of America.
- A signal from an earth-based antenna is reflected from the ionized layer of the upper atmosphere (ionosphere) back down to earth.
- Although it appears the wave is reflected from the ionosphere as if the ionosphere were a hard reflecting surface, the effect is in fact caused by refraction.
- A sky wave signal can travel through a number of hops, bouncing back and forth between the ionosphere and the earth's surface.
- With this propagation mode, a signal can be picked up thousands of kilometers from the transmitter.

Refraction I

- Refraction occurs because the velocity of an electromagnetic wave is a function of the density of the medium through which it travels.
- In a vacuum, an electromagnetic wave (such as light or a radio wave) travels at approximately 3×10^8 m/s.
- This is the constant, c, commonly referred to as the speed of light, but actually referring to the speed of light in a vacuum.
- In air, water, glass, and other transparent or partially transparent media, electromagnetic waves travel at speeds less than c.
- When an electromagnetic wave moves from a medium of one density to a medium of another density, its speed changes.
- The effect is to cause a one-time bending of the direction of the wave at the boundary between the two media.

Refraction II

Refraction of an Electromagnetic Wave



Refraction III

- If moving from a less dense to a more dense medium, the wave will bend toward the more dense medium.
- The index of refraction of one medium relative to another is the sine of the angle of incidence divided by the sine of the angle of refraction.
- The index of refraction is also equal to the ratio of the respective velocities in the two media.
- The absolute index of refraction of a medium is calculated in comparison with that of a vacuum.
- Refractive index varies with wavelength, so that refractive effects differ for signals with different wavelengths.

Refraction IV

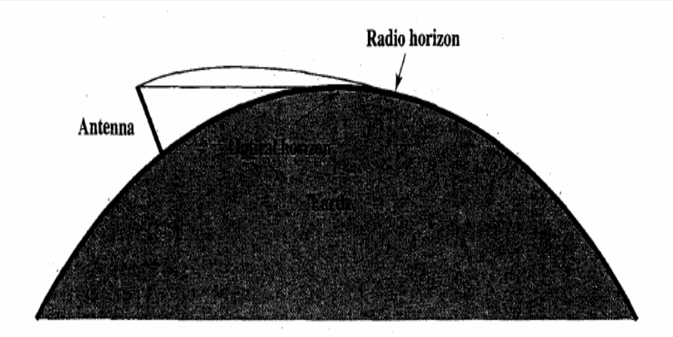
- Although figure shows an abrupt, one-time change in direction as a signal moves from one medium to another, a continuous, gradual bending of a signal will occur if it is moving through a medium in which the index of refraction gradually changes.
- Under normal propagation conditions, the refractive index of the atmosphere decreases with height so that radio waves travel more slowly near the ground than at higher altitudes.
- The result is a slight bending of the radio waves toward the earth.

Line-of-Sight Propagation I

- Above 30 *MHz* communication must be by line of sight.
- For satellite communication, a signal above 30 *MHz* is not reflected by the ionosphere and therefore can be transmitted between an earth station and a satellite overhead that is not beyond the horizon.
- For ground-based communication, the transmitting and receiving antennas must be within an effective line of sight of each other.
- The term effective is used because microwaves are bent or refracted by the atmosphere.
- The amount and even the direction of the bend depends on conditions, but generally microwaves are bent with the curvature of the earth and will therefore propagate farther than the optical line of sight.

Optical and Radio Line of Sight I

Optical and Radio Horizons



Optical and Radio Line of Sight II

- With no intervening obstacles, the optical line of sight can be expressed as :

$$d = 3.57\sqrt{h} \tag{1}$$

where d is the distance between an antenna and the horizon in kilometers and h is the antenna height in meters.

Optical and Radio Line of Sight III

- The effective (radio) line of sight to the horizon is expressed as :

$$d = 3.57\sqrt{Kh} \tag{2}$$

  where K is an adjustment factor to account for the refraction. A good rule of thumb is $K = 4/3$.

- Thus, the maximum distance between two antennas for *LOS* propagation is $3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$, where h_1 and h_2 are the heights of the two antennas.

Frequency Bands

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3-30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30-300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz-3 MHz	Sky	AM radio
HF (high frequency)	3-30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30-300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz-3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3-30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30-300 GHz	Line-of-sight	Radar, satellite