14-2: Common Antenna Types

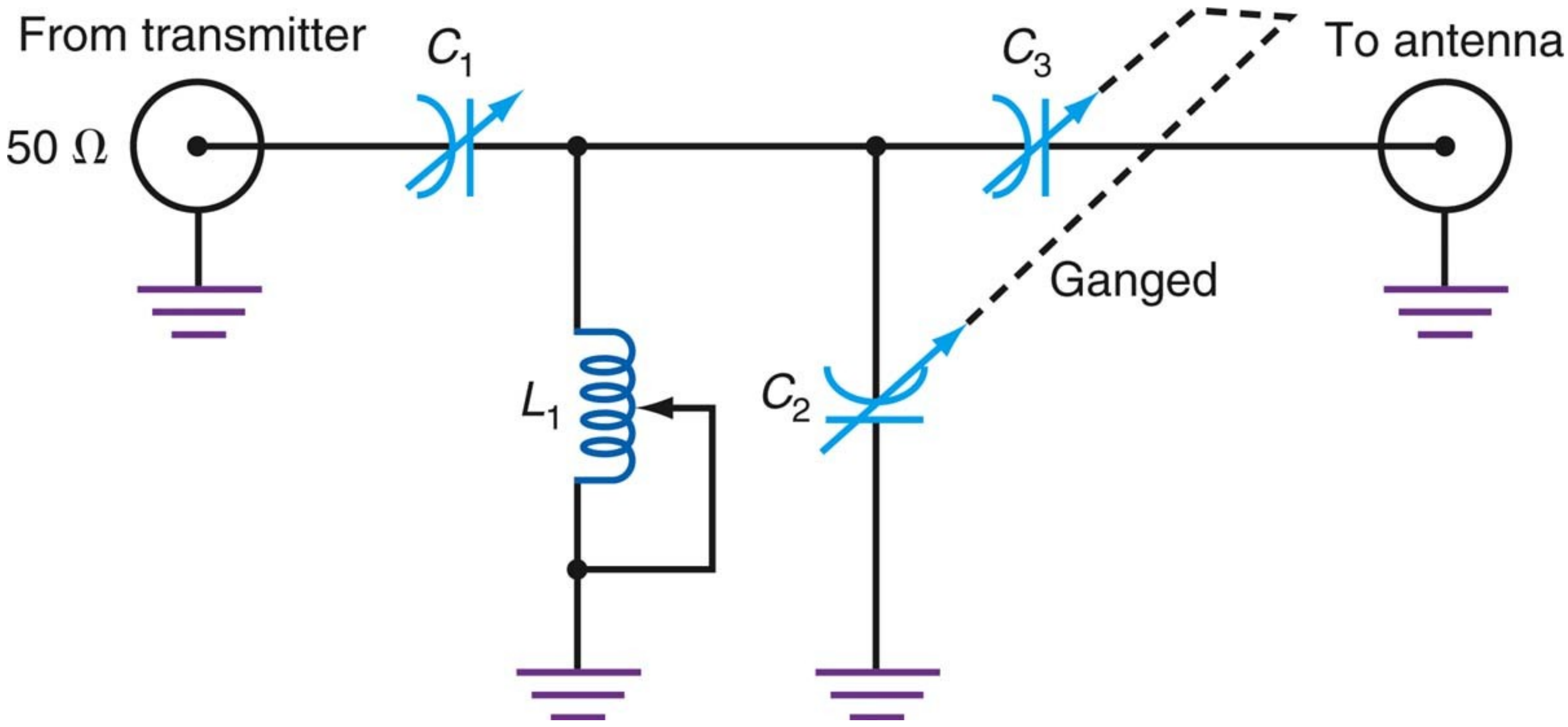

Figure 14-36: An antenna tuner.

14-3: Radio-Wave Propagation

- Once a radio signal has been radiated by an antenna, it travels or propagates through space and ultimately reaches the receiving antenna.
- The energy level of the signal decreases rapidly with distance from the transmitting antenna.
- The electromagnetic wave is affected by objects that it encounters along the way such as trees, buildings, and other large structures.
- The path that an electromagnetic signal takes to a receiving antenna depends upon many factors, including the frequency of the signal, atmospheric conditions, and time of day.

14-3: Radio-Wave Propagation

Optical Characteristics of Radio Waves

- Radio waves act much like light waves.
- Light waves can be reflected, refracted, diffracted, and focused by other objects.
- The focusing of waves by antennas to make them more concentrated in a desired direction is comparable to a lens focusing light waves into a narrower beam.

14-3: Radio-Wave Propagation

Optical Characteristics of Radio Waves: Reflection

- Any conducting surface looks like a mirror to a radio wave, and so radio waves are reflected by any conducting surface they encounter.
- Radio-wave reflection follows the principles of light-wave reflection.
- The angle of reflection is equal to the angle of incidence.
- The direction of the electric field approaching the reflecting surface is reversed from that leaving the surface. This is equivalent to a 180° phase shift.

14-3: Radio-Wave Propagation

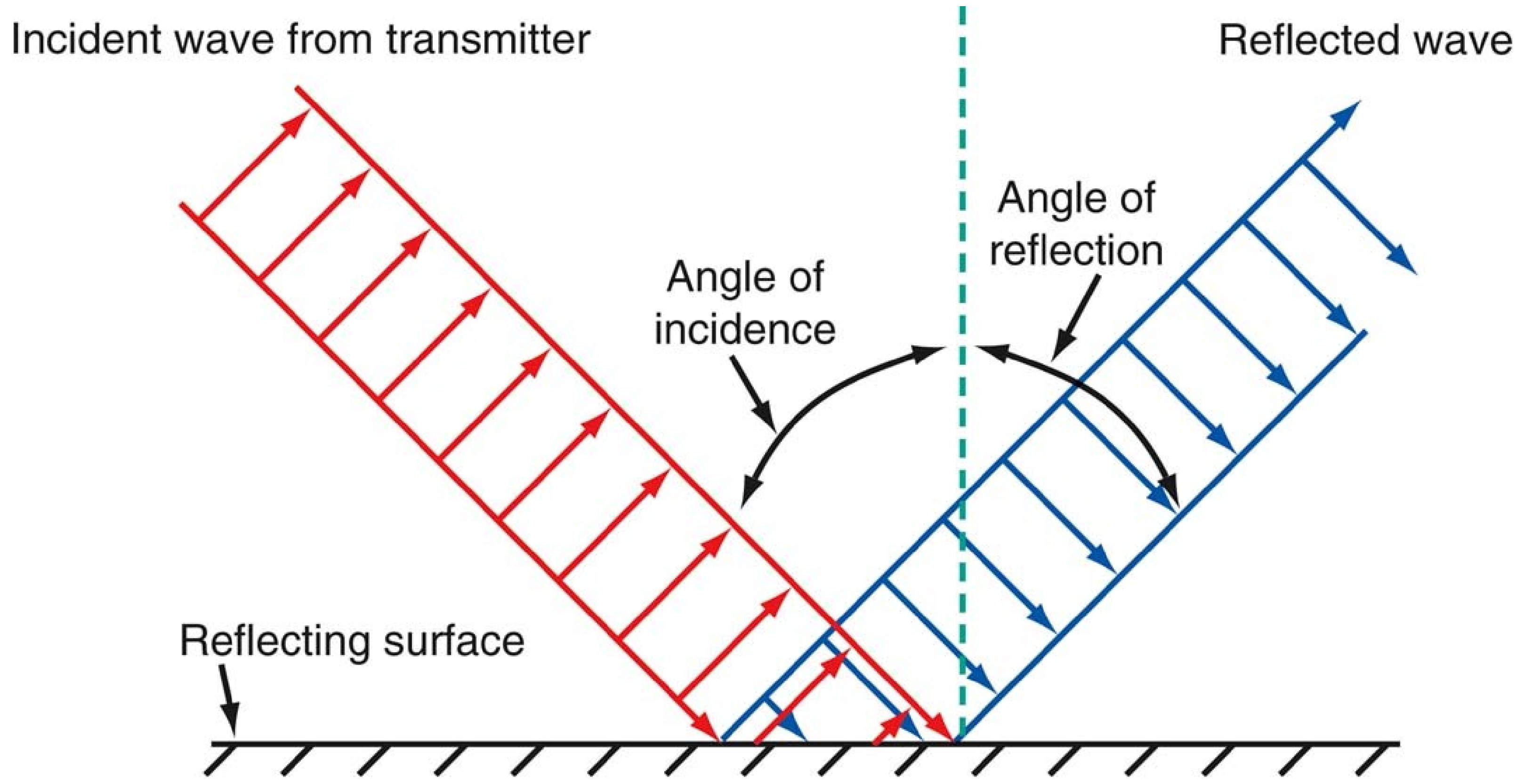

Figure 14-37: How a conductive surface reflects a radio wave.

14-3: Radio-Wave Propagation

Optical Characteristics of Radio Waves: Refraction

- **Refraction** is the bending of a wave due to the physical makeup of the medium through which the wave passes.
- Index of refraction is obtained by dividing the speed of a light (or radio) wave in a vacuum and the speed of a light (or radio) wave in the medium that causes the wave to be bent.

14-3: Radio-Wave Propagation

Optical Characteristics of Radio Waves: Refraction

- The relationship between the angles and the indices of refraction is given by a formula known as **Snell's law:**

$$n_1 \sin \Theta_1 = n_2 \sin \Theta_2$$

where

n_1 = index of refraction of initial medium

n_2 = index of refraction of medium into which wave passes

Θ_1 = angle of incidence

Θ_2 = angle of refraction

14-3: Radio-Wave Propagation

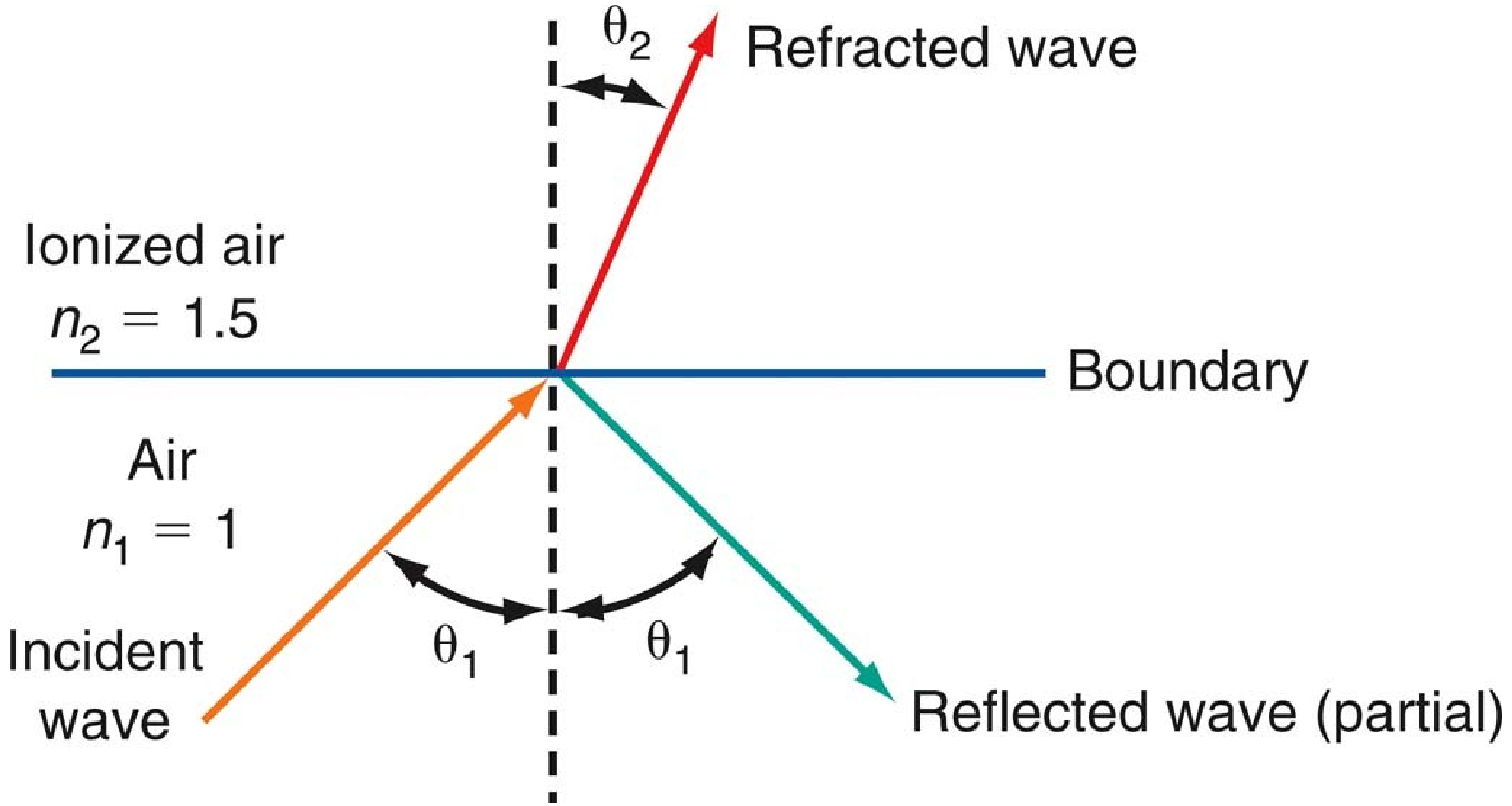

Figure 14-38: How a change in the index of refraction causes bending of a radio wave.

14-3: Radio-Wave Propagation

Optical Characteristics of Radio Waves: Diffraction

- **Diffraction** is the bending of waves around an object.
- Diffraction is explained by **Huygen's principle:**
  - Assuming that all electromagnetic waves radiate as spherical waveforms from a source, each point on a wave front can be considered as a point source for additional spherical waves.
  - When the waves encounter an obstacle, they pass around it, above it, and on either side.
  - As the wave front passes the object, the point sources of waves at the edge of the obstacle create additional spherical waves that penetrate and fill in the shadow zone.

14-3: Radio-Wave Propagation

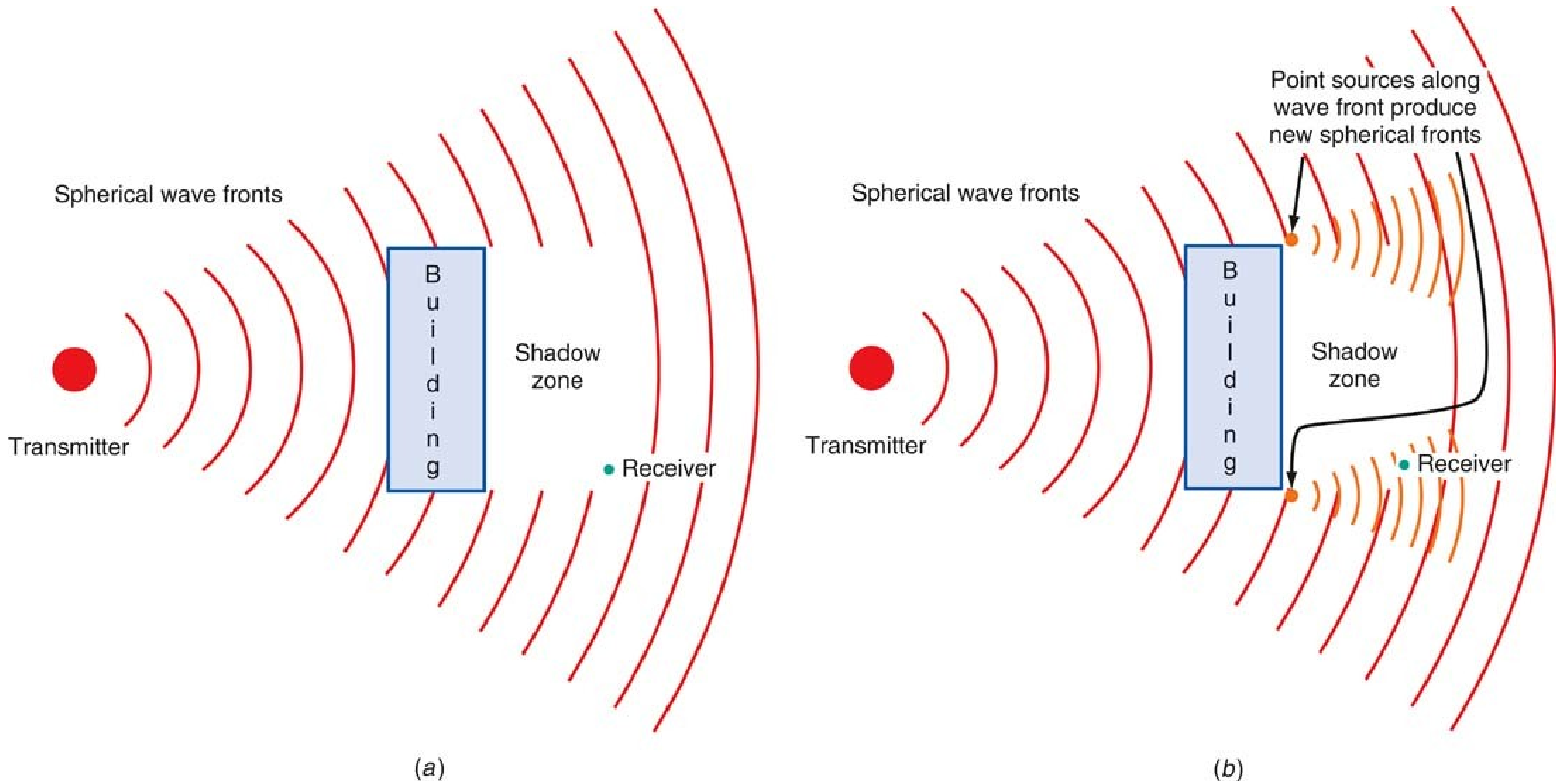

Figure 14-39: Diffraction causes waves to bend around obstacles.

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space

- The three basic paths that a radio signal can take through space are:
  - Ground wave
  - Sky wave
  - Space wave

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space: Ground Waves

- **Ground** or **surface waves** leave an antenna and remain close to the earth.
- Ground waves actually follow the curvature of the earth and can travel at distances beyond the horizon.
- Ground waves must have vertical polarization to be propagated from an antenna.
- Ground-wave propagation is strongest at the low- and medium-frequency ranges.
- AM broadcast signals are propagated primarily by ground waves during the day and by sky waves at night.

14-3: Radio-Wave Propagation

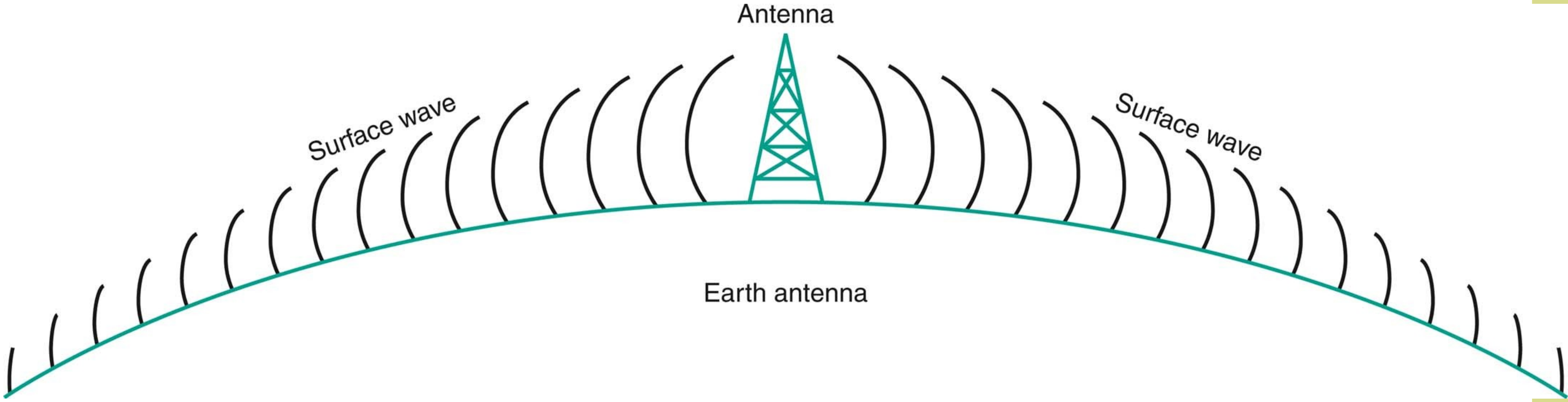

Figure 14-40: Ground or surface wave radiation from an antenna.

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space: Sky Waves

- Sky-wave signals are radiated by the antenna into the upper atmosphere, where they are bent back to earth.
- When a radio signal goes into the ionosphere, the different levels of ionization cause the radio waves to be gradually bent.
- The smaller the angle with respect to the earth, the more likely it is that the waves will be refracted and sent back to earth.
- The higher the frequency, the smaller the radiation angle required for refraction to occur.

14-3: Radio-Wave Propagation

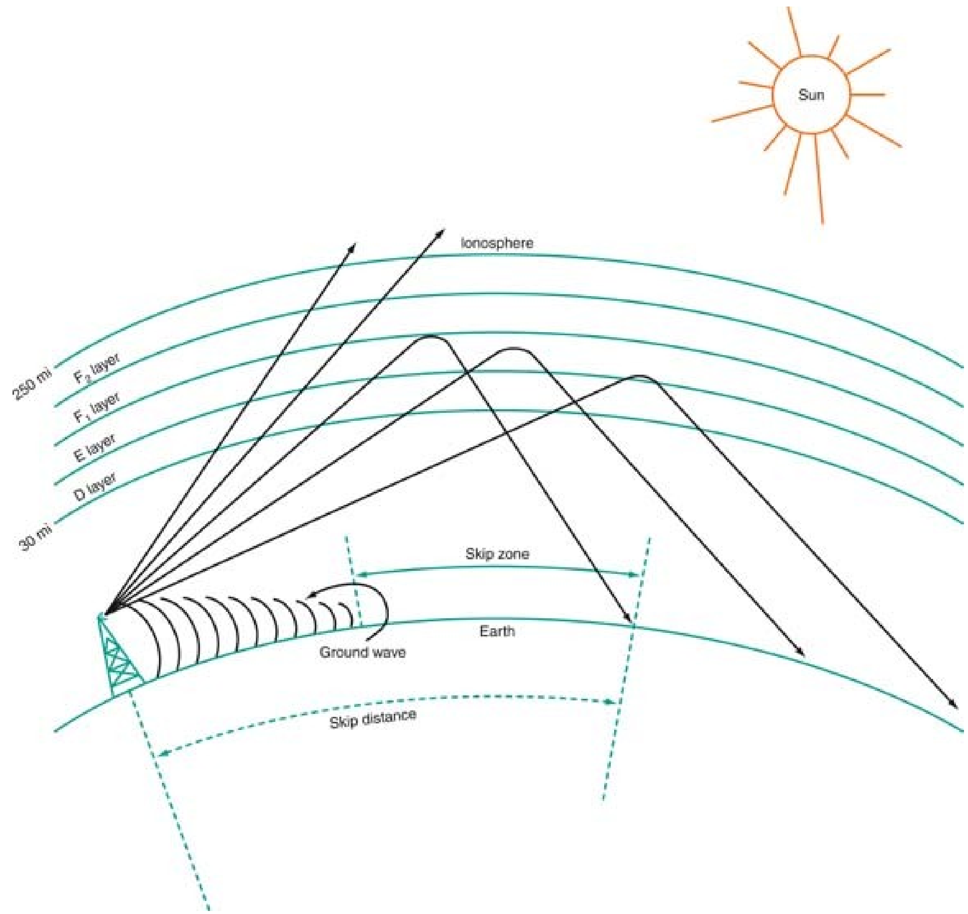

Figure 14-41: Sky wave propagation.

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space: Space Waves

- A **direct wave,** or **space wave,** travels in a straight line directly from the transmitting antenna to the receiving antenna.
- Direct-wave radio signaling is often referred to as **line-of-sight communication.**
- Direct or space waves are not refracted, nor do they follow the curvature of the earth.
- Line-of-sight communication is characteristic of most radio signals with a frequency above 30 MHz, particularly VHF, UHF, and microwave signals.

14-3: Radio-Wave Propagation

$d = \sqrt{2h_t}$

$D = \sqrt{2h_t} + \sqrt{2h_r}$

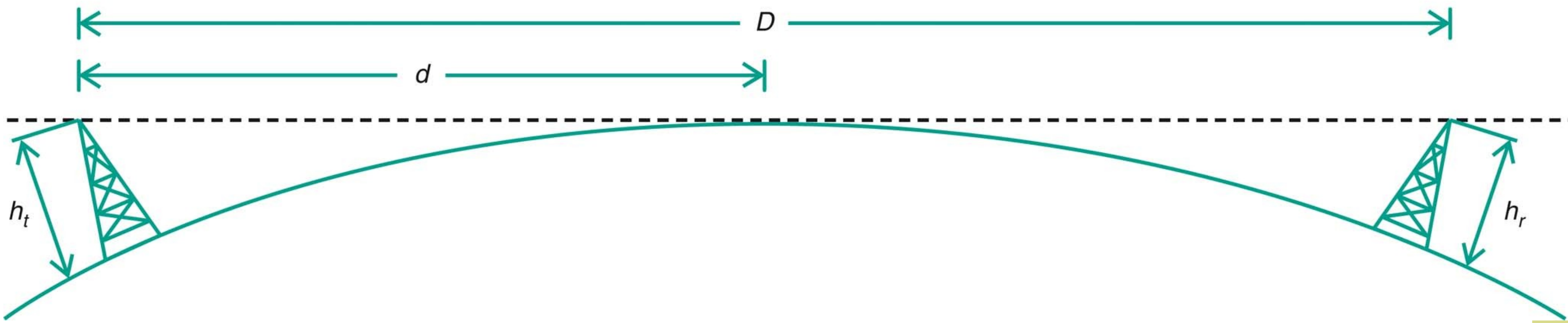

Figure 14-42: Line-of-sight communication by direct or space waves.

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space: Space Waves

- **Repeater stations** extend the communication distance at VHF, UHF, and microwave frequencies.
- A **repeater** is a combination of a receiver and a transmitter operating on separate frequencies.
- The receiver picks up a signal from a remote transmitter, amplifies it, and retransmits it (on another frequency) to a remote receiver.
- Repeaters are widely used to increase the communication range for mobile and handheld radio units.

14-3: Radio-Wave Propagation

Radio-Wave Propagation Through Space: Space Waves

- In a **trunked repeater system**, multiple repeaters are under the control of a computer system that can transfer a user from an assigned but busy repeater to another, available repeater, thus spreading the communication load.
- **Communication satellites** act as fixed repeater stations.
- The receiver-transmitter combination within the satellite is known as a **transponder.**

14-3: Radio-Wave Propagation

Common Propagation Problems: Fading

- **Fading** is the variation in signal amplitude at the receiver caused by the characteristics of the signal path and changes in it.
- Fading typically makes the received signal smaller.
- Fading is caused by four factors:
  1. Variation in distance between transmitter and receiver.
  2. Changes in the environmental characteristics of the signal path.
  3. The presence of multiple signal paths.
  4. Relative motion between the transmitter and receiver.

14-3: Radio-Wave Propagation

Common Propagation Problems: Diversity System

- A **diversity system** uses multiple transmitters, receivers, or antennas to mitigate the problems caused by multipath signals.
- With **frequency diversity**, two separate sets of transmitters and receivers operating on different frequencies are used to transmit the same information simultaneously.
- Space or **spatial diversity** uses two receive antennas spaced as far apart as possible to receive the signals.