Principles of Electronic Communication Systems

Third Edition

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Chapter 14

Antennas and Wave Propagation

Topics Covered in Chapter 14

- 14-1: Antenna Fundamentals
- 14-2: Common Antenna Types
- 14-3: Radio-Wave Propagation

14-1: Antenna Fundamentals

- The interface between the transmitter and free space and between free space and the receiver is the **antenna.**
- At the transmitting end the antenna converts the transmitter RF power into electromagnetic signals; at the receiving end the antenna picks up the electromagnetic signals and converts them into signals for the receiver.

14-1: Antenna Fundamentals

Radio Waves

- A radio signal is called an **electromagnetic wave** because it is made up of both electric and magnetic fields.
- Whenever voltage is applied to the antenna, an electric field is set up.
- This voltage causes current to flow in the antenna, producing a magnetic field.
- These fields are emitted from the antenna and propagate through space at the speed of light.

14-1: Antenna Fundamentals

Radio Waves: Magnetic Fields

- A magnetic field is an invisible force field created by a magnet.
- An antenna is a type of electromagnet.
- A magnetic field is generated around a conductor when current flows through it.
- The strength and direction of the magnetic field depend upon the magnitude and direction of the current flow.
- The SI unit for magnetic field strength is ampere-turns per meter.

14-1: Antenna Fundamentals

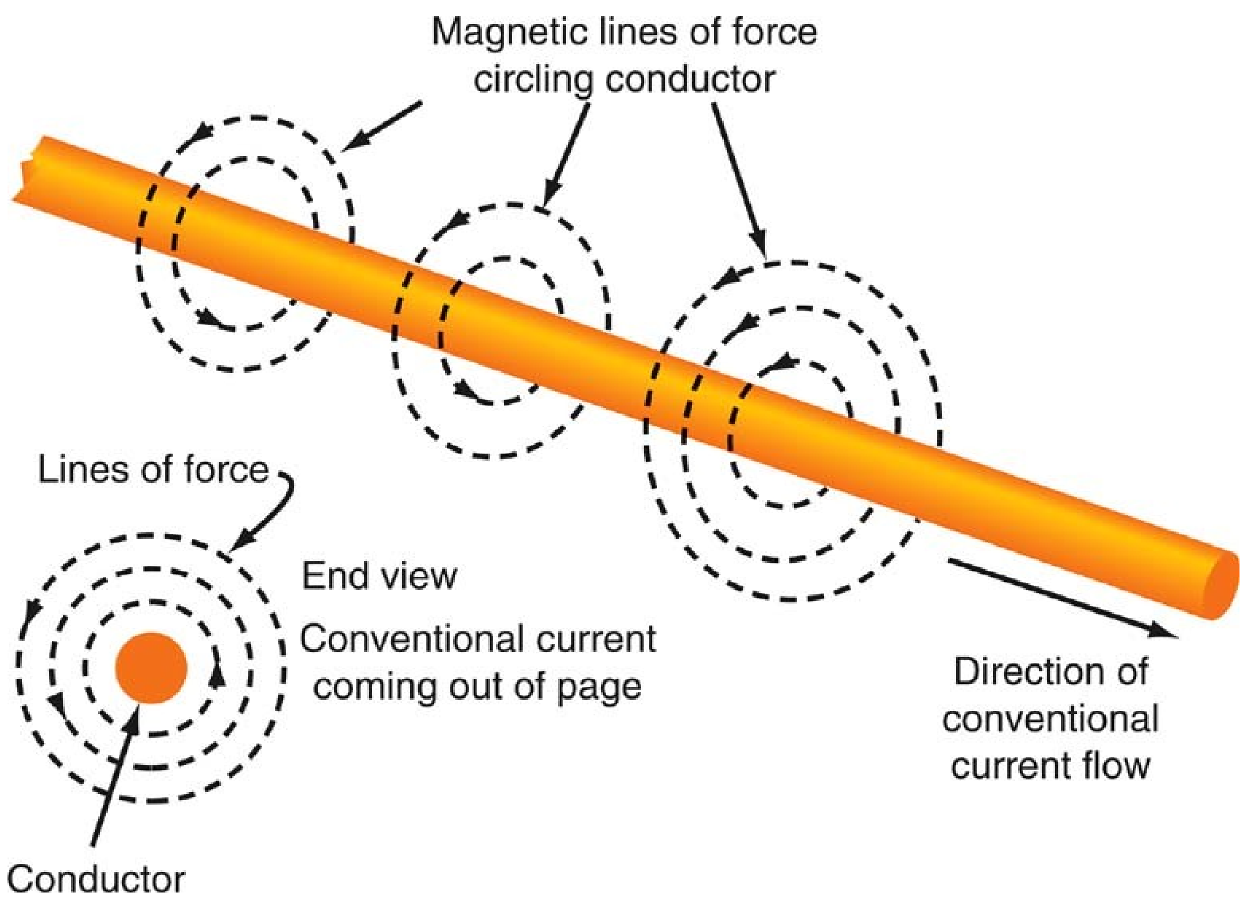

Figure 14-1: Magnetic field around a current-carrying conductor. Magnetic field strength *H* in ampere-turns per meter = $H = I\ I(2\ \pi d)$.

14-1: Antenna Fundamentals

Radio Waves: Electric Field

- An **electric field** is an invisible force field produced by the presence of a potential difference between two conductors.
- For example, an electric field is produced between the plates of a charged capacitor.
- An electric field exists between any two points across which a potential difference exists.
- The SI unit for electric field strength is volts per meter.
- **Permittivity** is the dielectric constant of the material between the two conductors.

14-1: Antenna Fundamentals

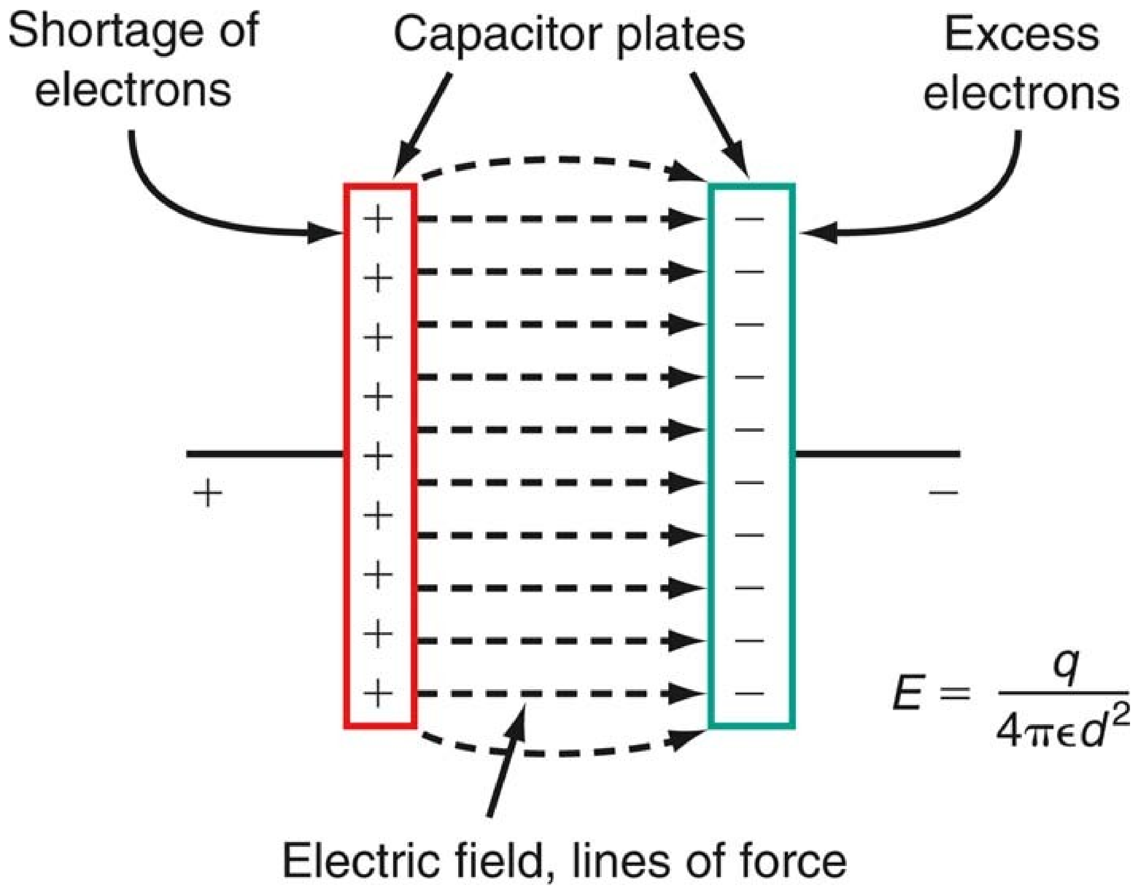

Figure 14-2: Electric field across the plates of a capacitor.

14-1: Antenna Fundamentals

Radio Waves: Magnetic and Electric Fields in a Transmission Line

- At any given time in a two-wire transmission line, the wires have opposite polarities.
- During one-half cycle of the ac input, one wire is positive and the other is negative.
- During the negative half-cycle, the polarity reverses.
- The direction of the electric field between the wires reverses once per cycle.
- The direction of current flow in one wire is always opposite that in the other wire. Therefore, the magnetic fields combine.

14-1: Antenna Fundamentals

Radio Waves: Magnetic and Electric Fields in a Transmission Line

- A transmission line is made up of a conductor or conductors.
- Transmission lines do not radiate signals efficiently.
- The closeness of the conductors keeps the electric field concentrated in the transmission line dielectric.
- The magnetic fields mostly cancel one another.
- The electric and magnetic fields do extend outward from the transmission line, but the small amount of radiation that does occur is extremely inefficient.

14-1: Antenna Fundamentals

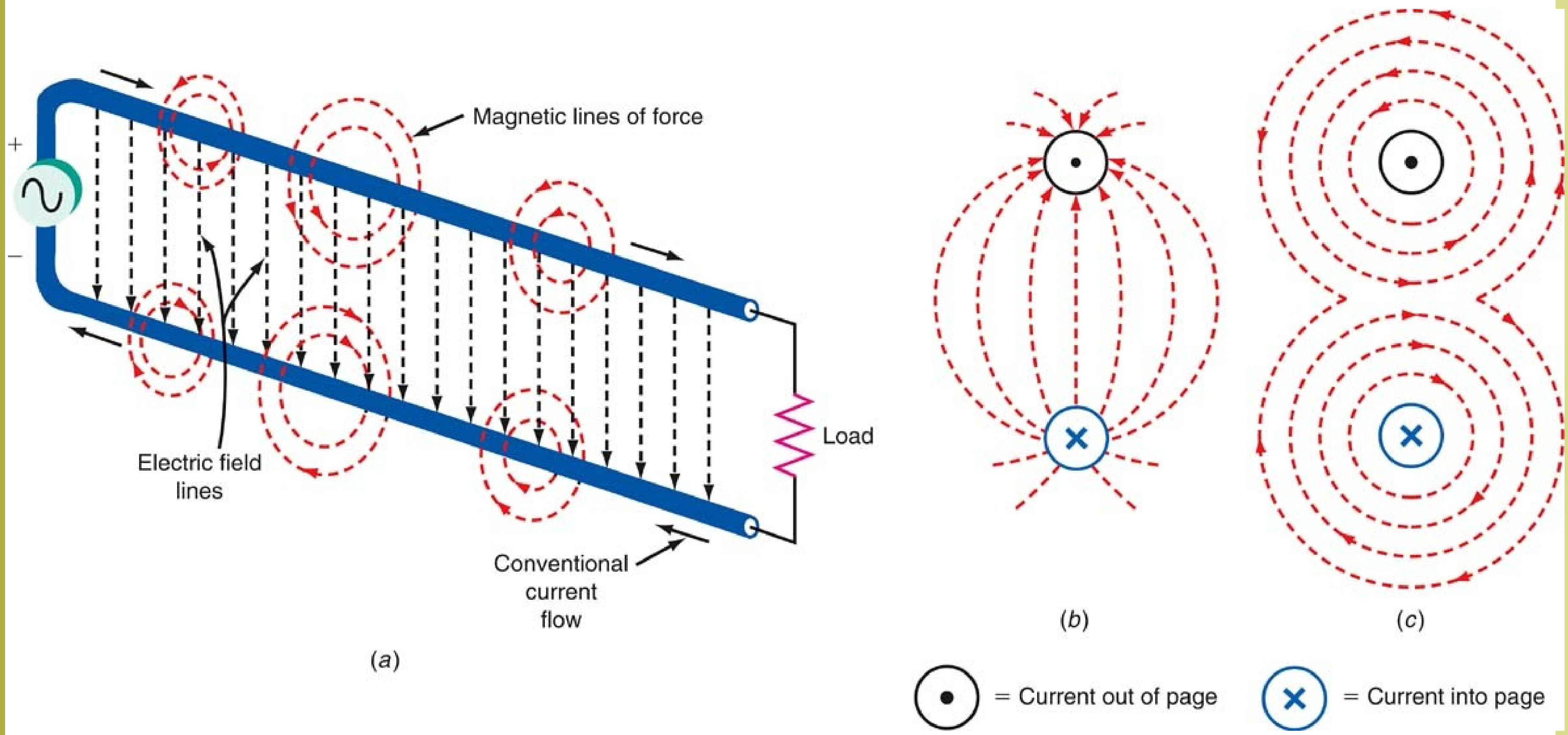

Figure 14-3: (*a*) Magnetic and electric fields around a transmission line. (*b*) Electric field. (*c*) Magnetic fields.

14-1: Antenna Fundamentals

Antenna Operation: The Nature of an Antenna

- If a parallel-wire transmission line is left open, the electric and magnetic fields escape from the end of the line and radiate into space.
- This radiation is inefficient and unsuitable for reliable transmission or reception.
- The radiation from a transmission line can be greatly improved by bending the transmission-line conductors so they are at a right angle to the transmission line.

14-1: Antenna Fundamentals

Antenna Operation: The Nature of an Antenna

- The magnetic fields no longer cancel; they now aid one another.
- The electric field spreads out from conductor to conductor.
- Optimum radiation occurs if the segment of transmission wire converted into an antenna is one quarter wavelength long at the operating frequency.
- This makes an antenna that is one-half wavelength long.

14-1: Antenna Fundamentals

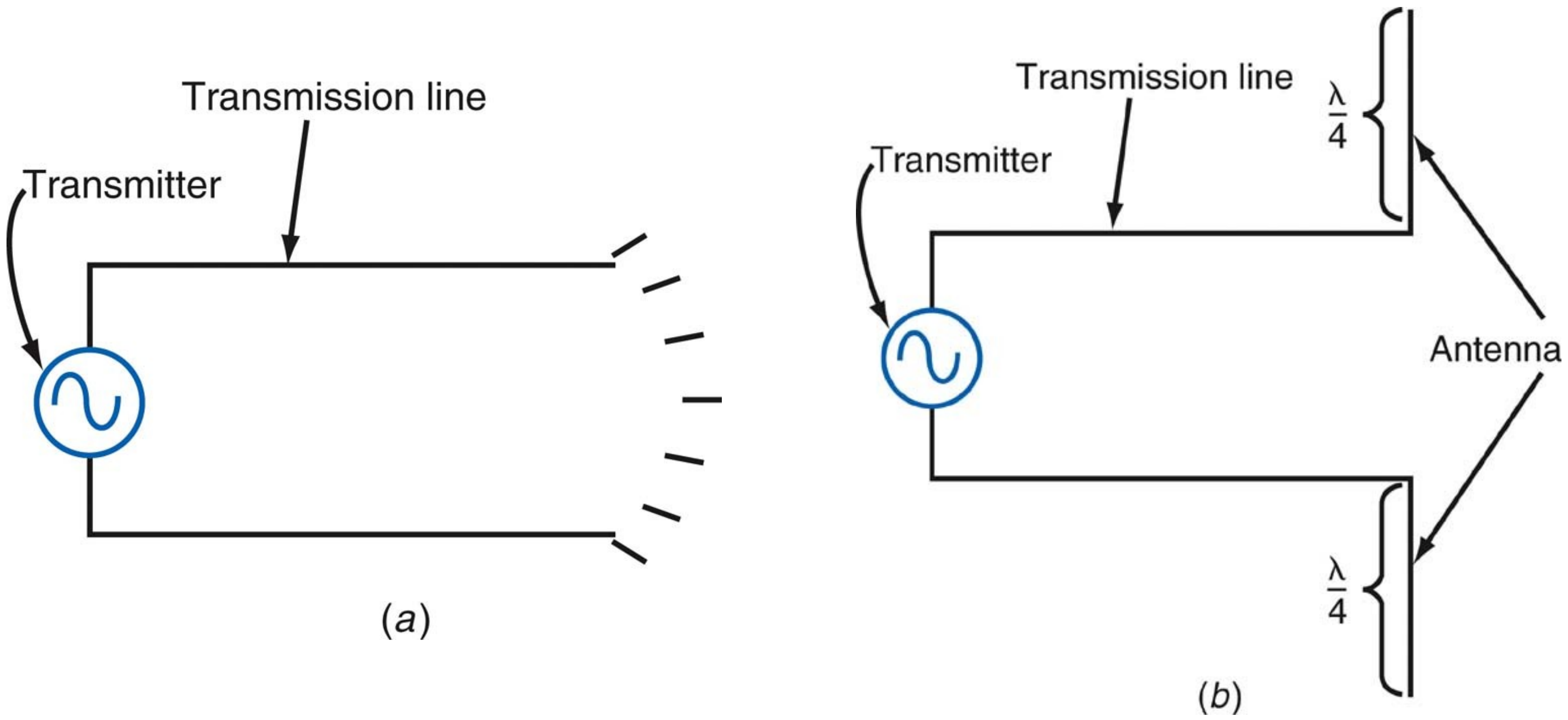

Figure 14-5: Converting a transmission line into an antenna. (*a*) An open transmission line radiates a little. (*b*) Bending the open transmission line at right angles creates an efficient radiation pattern.

14-1: Antenna Fundamentals

Antenna Operation

- The ratio of the electric field strength of a radiated wave to the magnetic field strength is a constant and is called the **impedance of space**, or the **wave impedance**.
- The electric and magnetic fields produced by the antenna are at right angles to one another, and are both perpendicular to the direction of propagation of the wave.

14-1: Antenna Fundamentals

Antenna Operation

- Antennas produce two sets of fields, the **near field** and the **far field**.
  - The **near field** describes the region directly around the antenna where the electric and magnetic fields are distinct.
  - The **far field** is approximately 10 wavelengths from the antenna. It is the radio wave with the composite electric and magnetic fields.
- **Polarization** refers to the orientation of magnetic and electric fields with respect to the earth.

14-1: Antenna Fundamentals

Antenna Reciprocity

- **Antenna reciprocity** means that the characteristics and performance of an antenna are the same whether the antenna is radiating or intercepting an electromagnetic signal.
- A transmitting antenna takes a voltage from the transmitter and converts it into an electromagnetic signal.
- A receiving antenna has a voltage induced into it by the electromagnetic signal that passes across it.

14-1: Antenna Fundamentals

The Basic Antenna

- An antenna can be a length of wire, a metal rod, or a piece of tubing.
- Antennas radiate most effectively when their length is directly related to the wavelength of the transmitted signal.
- Most antennas have a length that is some fraction of a wavelength.
- One-half and one-quarter wavelengths are most common.