Lect2: EM Radio Waves and Antenna Operation

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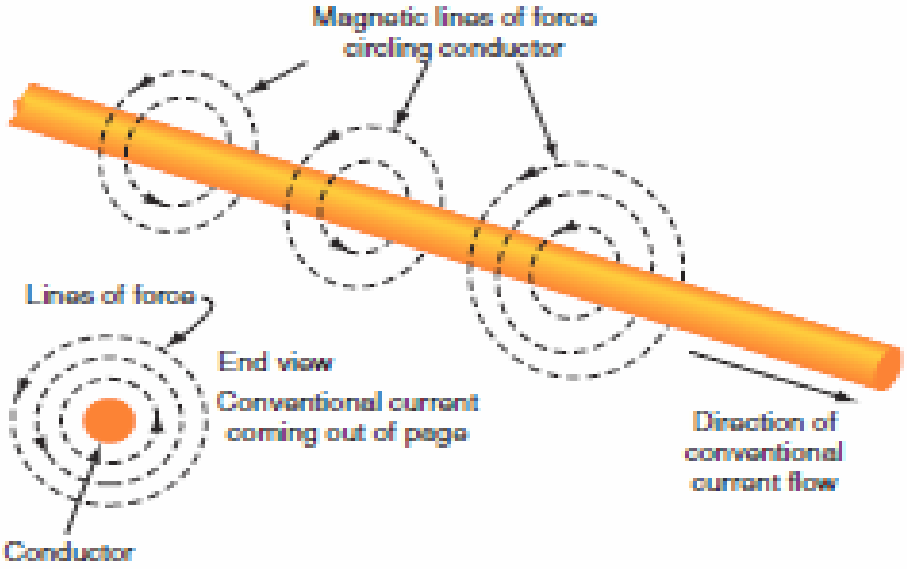
EM Radio Waves

- In wireless communications: a radio EM signal generated by a transmitter is sent into free space and eventually picked up by a receiver.
- *Antenna:* The interface between Tx and free-space and between free-space Rx.
- A radio signal is called an EM wave, why??

What is the Electromagnetic (EM) radio wave and how it is generated and radiated???

EM Radio Waves

- ***magnetic field:*** an invisible force field created by a magnet or an electromagnet (like antenna).
- How generated around a conductor??



- H-field field strength [A/m]

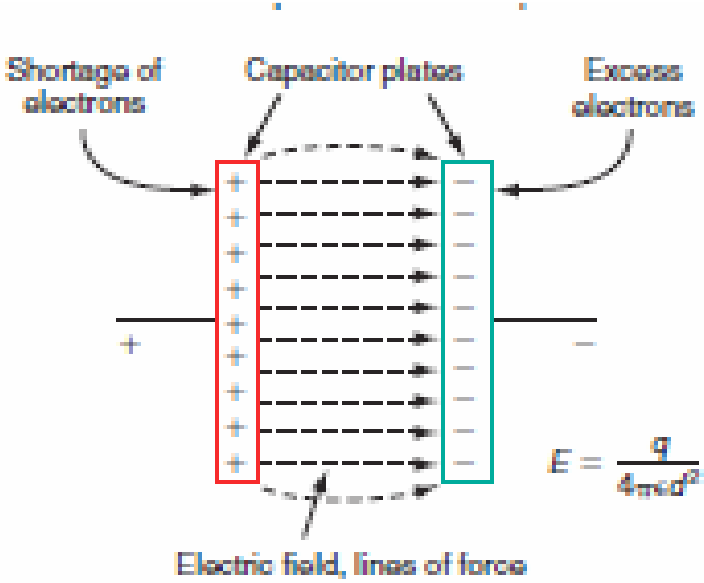
$$H = \frac{I}{2\pi d}$$

where I = current, A

d = distance from wire, m

EM Radio Waves

- ***electric field:*** an invisible force field produced by the presence of a potential difference between two conductors or points.
- Common example: electric field produced between the plates of a charged capacitor



- E-filed strength [V/m]

$$E = \frac{q}{4\pi\varepsilon d^2}$$

where q = charge between the two points, C
ε = permittivity
d = distance between conductors, m

EM Radio Waves

❑Maxwell's Equations.

- Can predict the existence of propagating EM waves [Maxwell, 1865].
- They specify the relationships between the variations of **E (**the electric field vector) and **H** (the magnetic field vector) in time and space within a medium.
- The **E** field strength: generated by either a time-varying magnetic field or a free charge.
- The **H** field: generated by either a time-varying electric field or a current.
- The first two Maxwell's equations (curl equations):

An electric field is produced by a time-varying magnetic field

A magnetic field is produced by a time-varying electric field or by a current

- With constants of proportionality: medium permeability & permittivity

$$\mu = \mu_0 \mu_r \qquad \mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$$

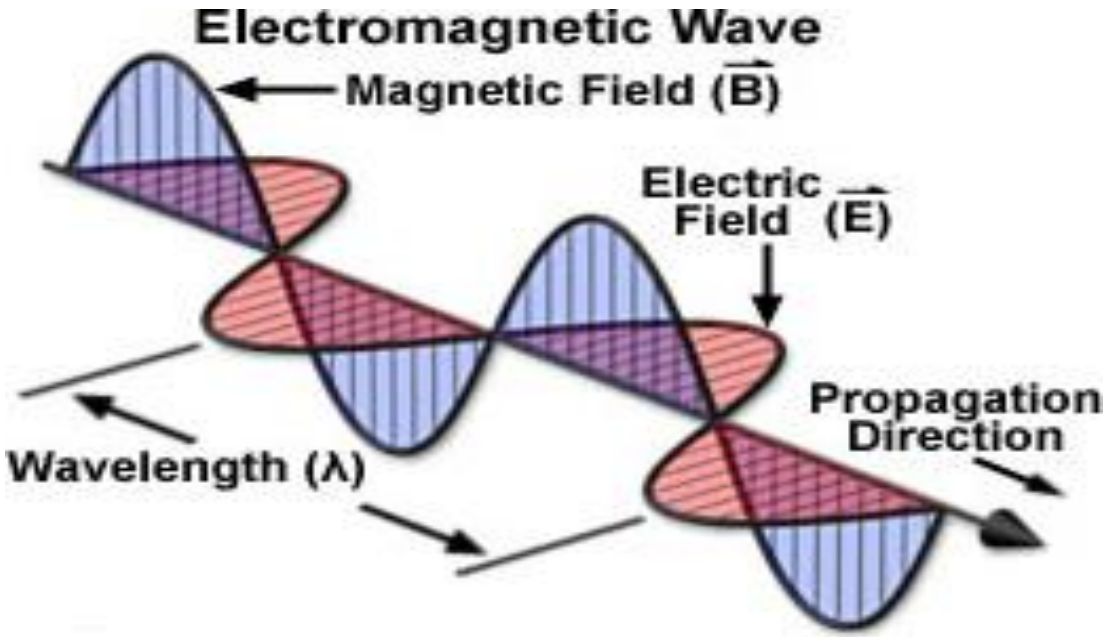
$$\varepsilon = \varepsilon_0 \varepsilon_r \qquad \varepsilon_0 = 8.854 \times 10^{-12} \approx \frac{10^{-9}}{36\pi}\mathrm{F\,m^{-1}}$$

- "*The simplest possible time varying solution to Maxwell's equations is the plane waves*". [1]

EM Radio Waves

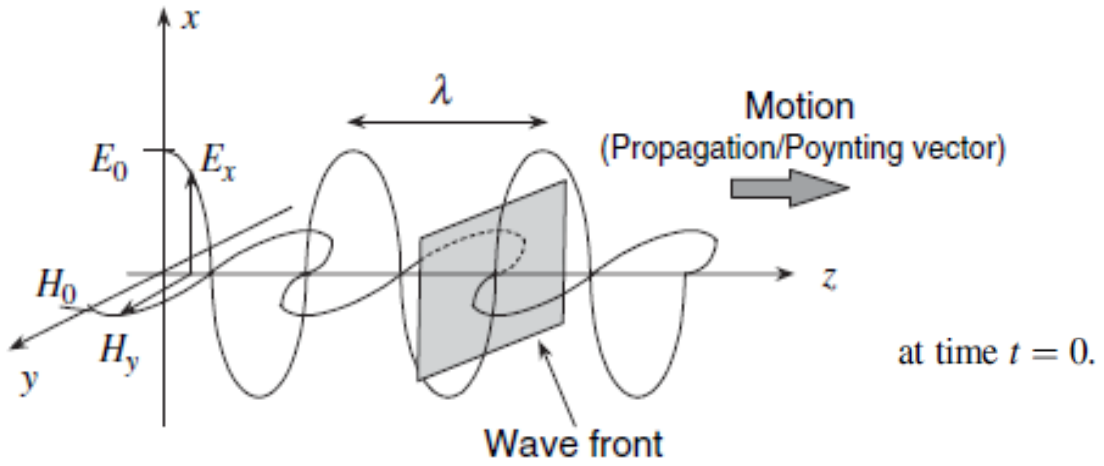
❑EM plane wave:

- Electromagnetic signals (or just radio waves) consist of in phase electric and magnetic fields.
- The electric and magnetic fields are at right angles to each other and to the direction of propagation.
- Radio-frequency (RF) waves: EM signals radiated (*by an antenna*) in the free space.
- EM Signals carried by cable are not radio signals.



EM Radio Waves

- *Maxwell's curl equations: The oscillating electric field produces a magnetic field, which itself oscillates to recreate an electric field.*
- *This interplay between the two fields stores energy and hence carries power along the Poynting vector.*

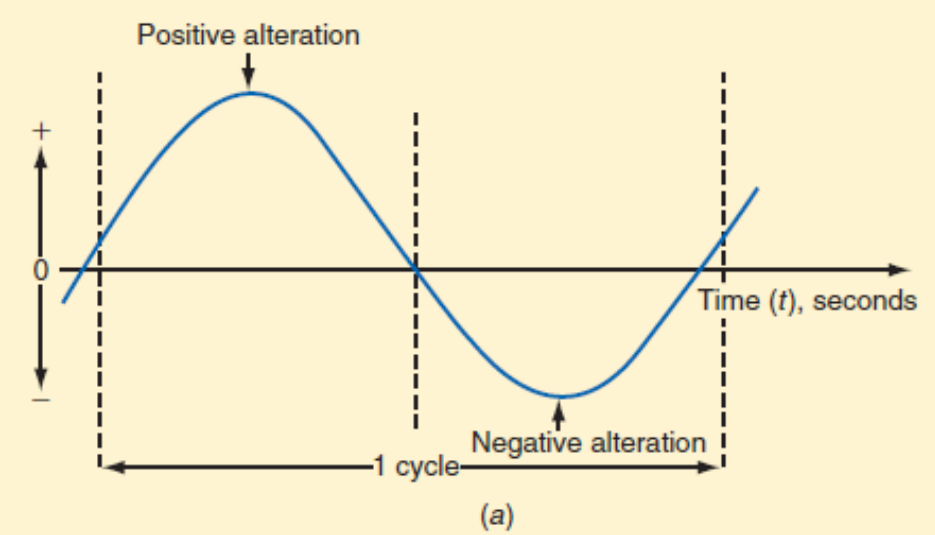


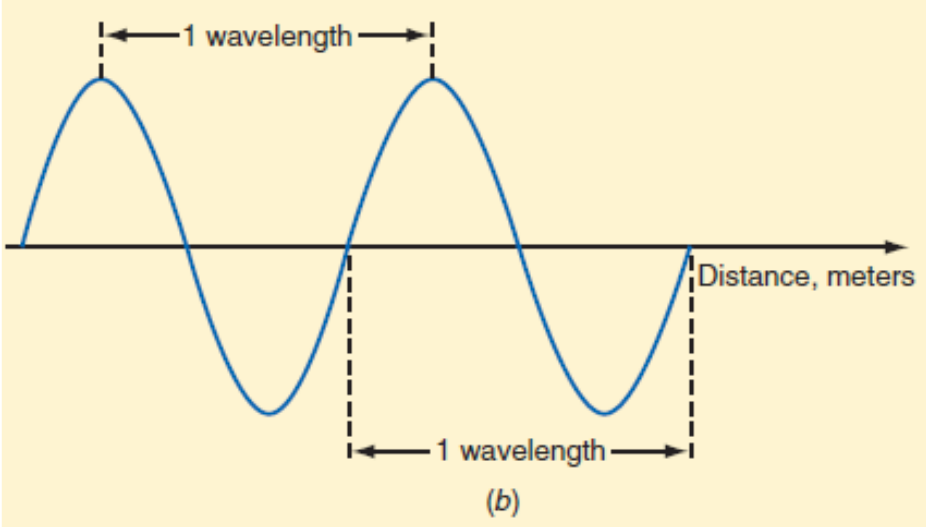
l: A plane wave propagating through space at a single moment in time

- *Now, how such a wave is generated and radiated into free space?? Ans: Antenna operation.*

EM Radio Waves

- $v = \lambda f$

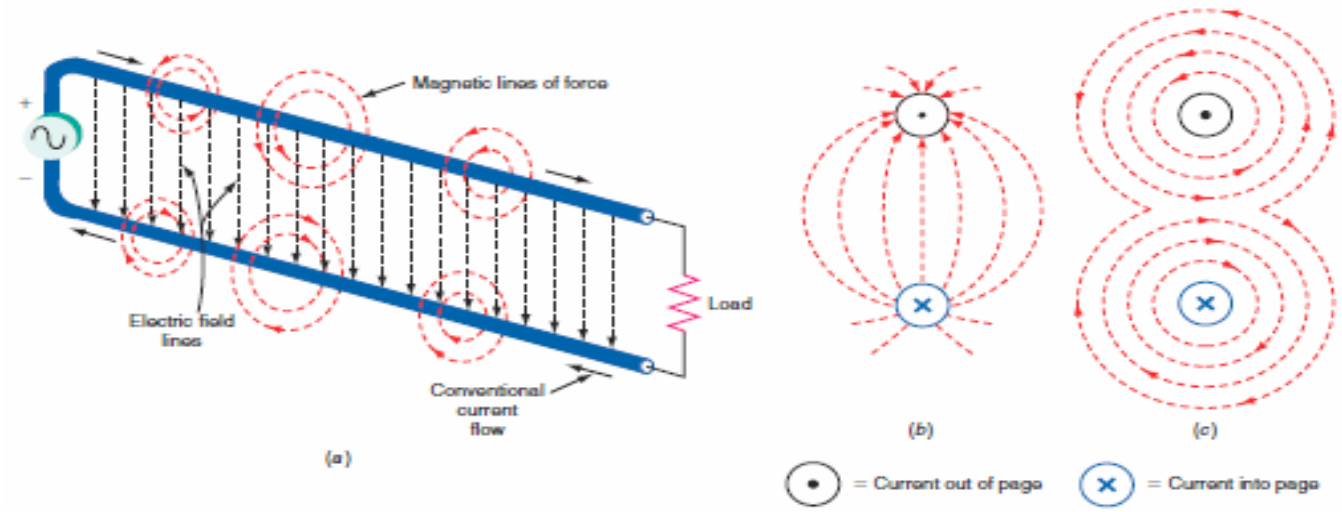




Antenna Operation

❑**Magnetic and Electric Fields in a <u>two-wire Transmission Line</u>.**

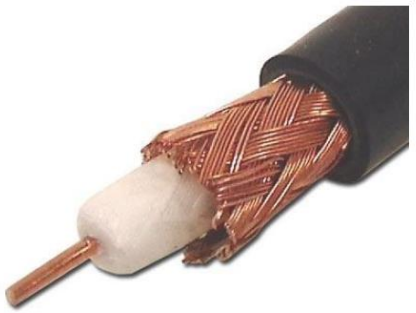
(a) Magnetic and electric fields around a transmission line. (b) Electric field. (c) Magnetic fields.



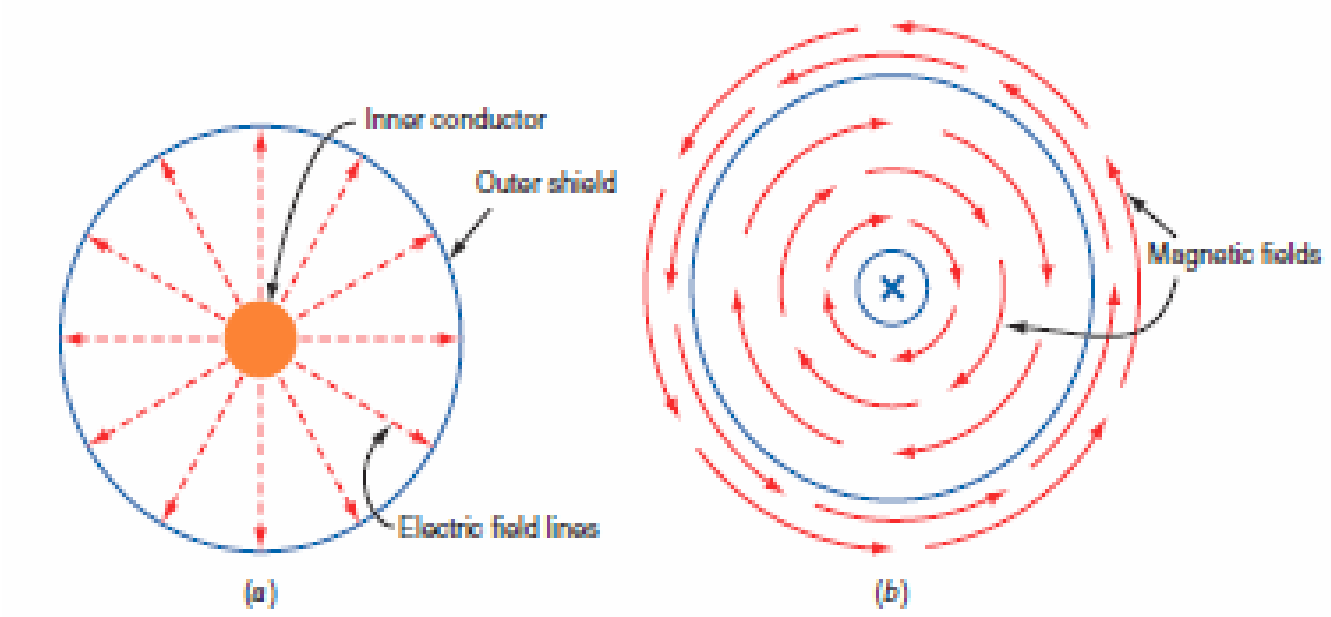
- Two-wire transmission lines causes small amount of radiation, which is extremely inefficient to act like antenna, why??

Antenna Operation

❑Magnetic and Electric Fields in coaxial cables:



Electric and magnetic fields in a coaxial cable (cross-sectional end view). (*a*) Electric field. (*b*) Magnetic fields.



- Coaxial cable does not radiate any electromagnetic energy, why??. So, they are the preferred transmission line for most applications. Cannot act like antennas.

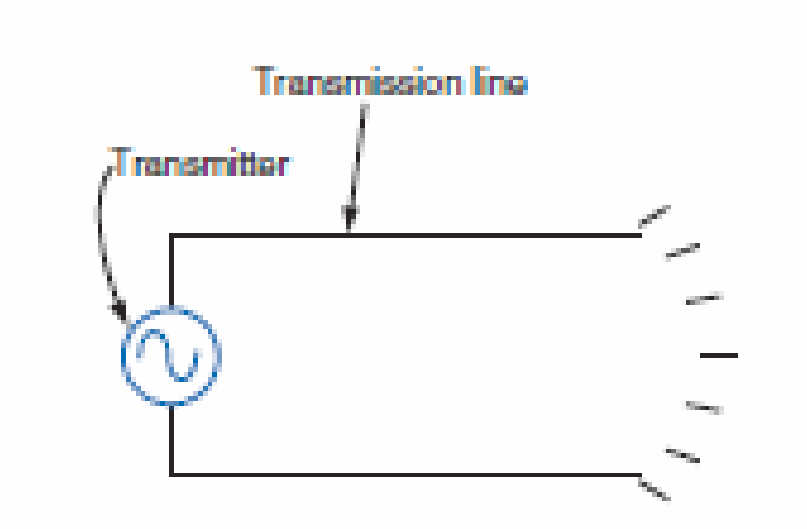
Antenna Operation

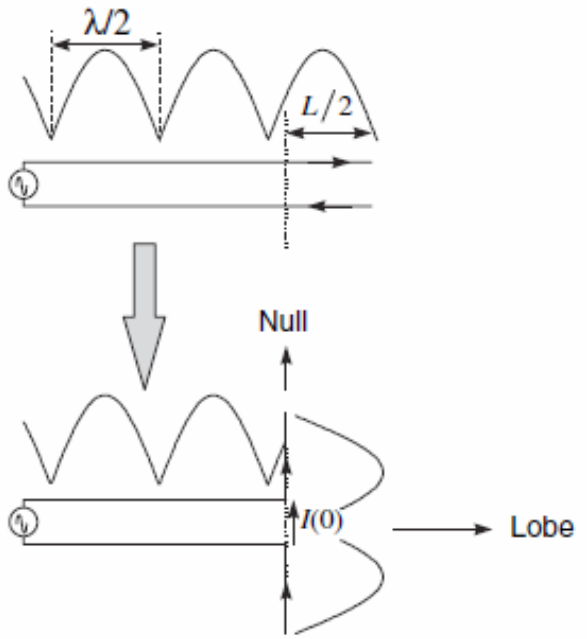
- *So, what exactly is an antenna, and what is the relationship between an antenna and a transmission line? How are the electric and magnetic fields radiated?*

Antenna Operation

❑The Nature of an Antenna

- A parallel-wire transmission line is left open (standing wave): the radiation from the end of the line is inefficient and unsuitable for reliable transmission or reception (no far field radiation).

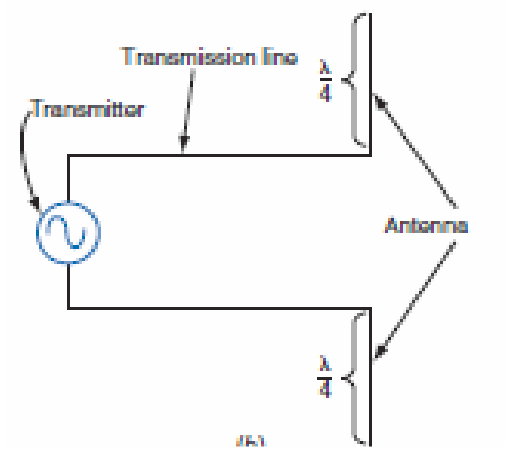


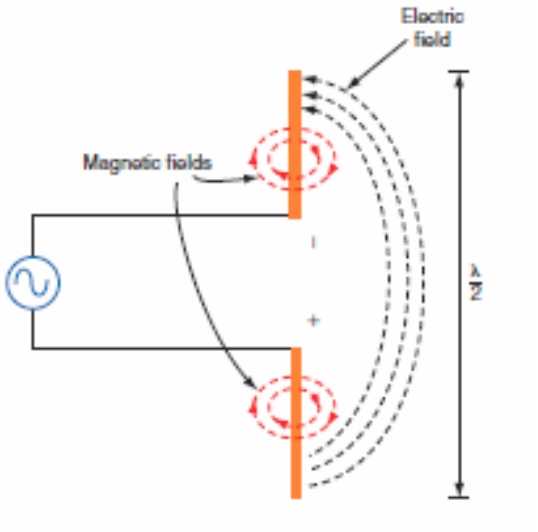


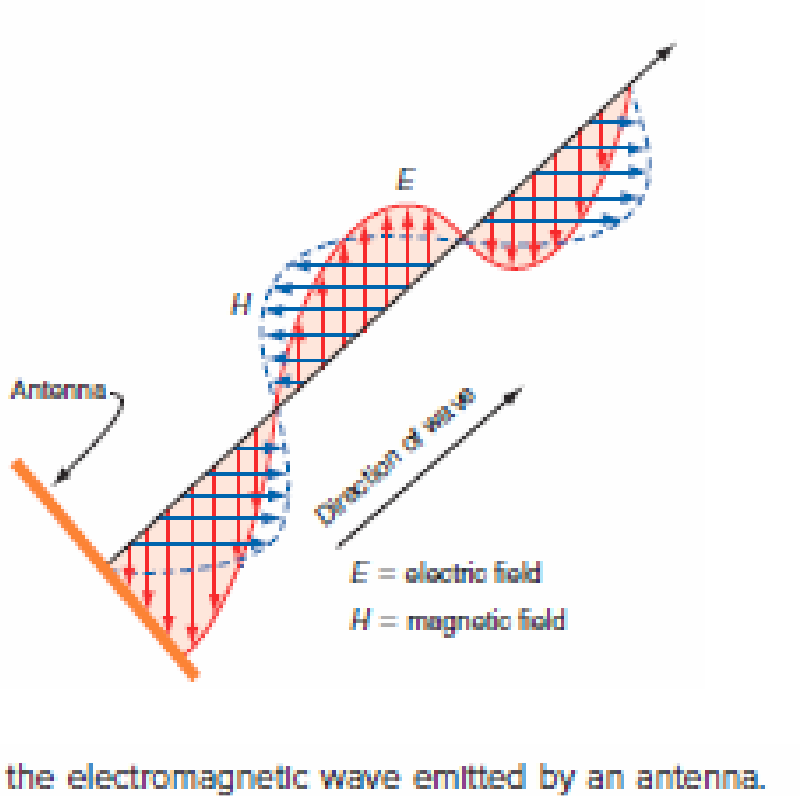
Antenna Operation

❑The Nature of an Antenna

- Bend the transmission line conductors as shown.







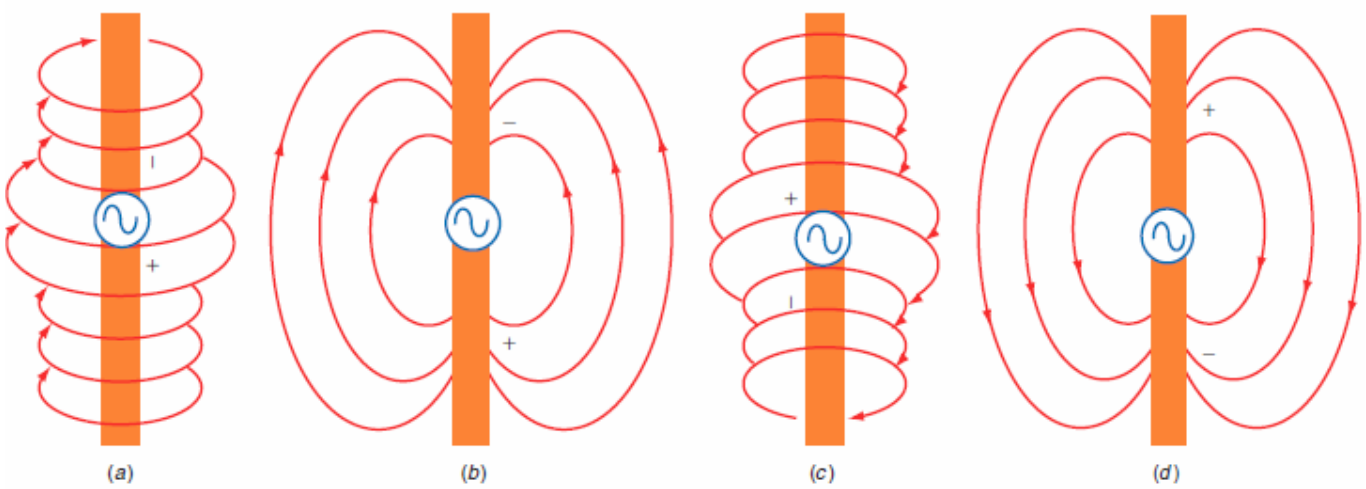
Viewing the electromagnetic wave emitted by an antenna.

- The magnetic fields no longer cancel each others. The electric field spreads out from conductor to conductor. The result is an *antenna*.
- Optimum radiation: one-half wavelength long antenna.

Antenna Operation

❑The Nature of an Antenna

- An antenna as if one conductor is connected directly to the generator or transmitter.



- What is the generator signal??
- If antenna is away from the generator??

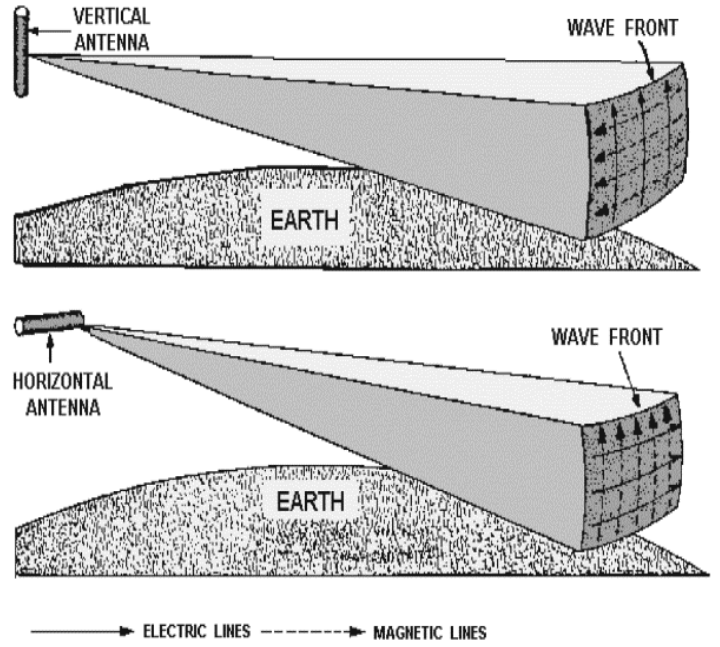
Antenna Operation

- Near Field and Far Field?

- Polarization?
  - Vertical Polarization.
  - Horizontal Polarization.
  - Circular Polarization.

VERTICAL POLARIZATION

HORIZONTAL POLARIZATION



Thank you