

Lecture-2

1.3 Radiation Mechanism:

When electric charges undergo acceleration or deceleration, electromagnetic radiation will be produced. Hence it is the motion of charges, that is currents, is the source of radiation. Here it may be highlighted that, not all current distributions will produce a strong enough radiation for communication.

To give a mathematical flavor to it, as we know (we will study the details later, in this course)

$$A = \frac{\sim Idl}{4\pi r}$$

and

$$dl \frac{dI}{dt} = dlq \frac{dv}{dt} = dlqa$$

So,

$$E = -\nabla V - \frac{\partial A}{\partial t} = -\nabla V - \frac{\sim dl \cdot \partial I}{4\pi r \cdot \partial t} = -\nabla V - \frac{\sim dl \cdot qa}{4\pi r}$$

- As shown in these equations, to create radiation (electric field), there must be a time-varying current dI/dt or an acceleration (or deceleration) a of a charge q .
- If the charge is not moving, a current is not created and there is no radiation.
- If a charge is moving with a uniform velocity,
 - there is no radiation if the wire is straight, and infinite in extent
 - there is radiation if the wire is curved, bent, discontinuous, terminated, or truncated
- If the charge is oscillating in a time-motion, it radiates even if the wire is straight.

These situations are shown in Fig. 10.

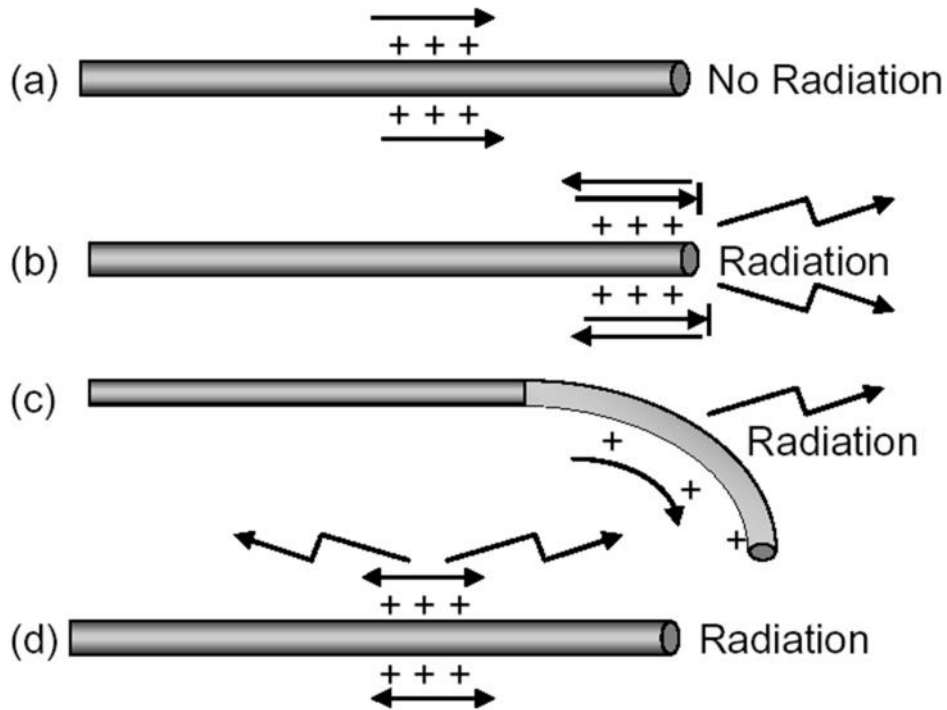


Fig. 10: Conditions for radiation

So, it is the current distribution on the antennas that produce the radiation. Usually these current distributions are excited by transmission lines and waveguides (Fig. 11)

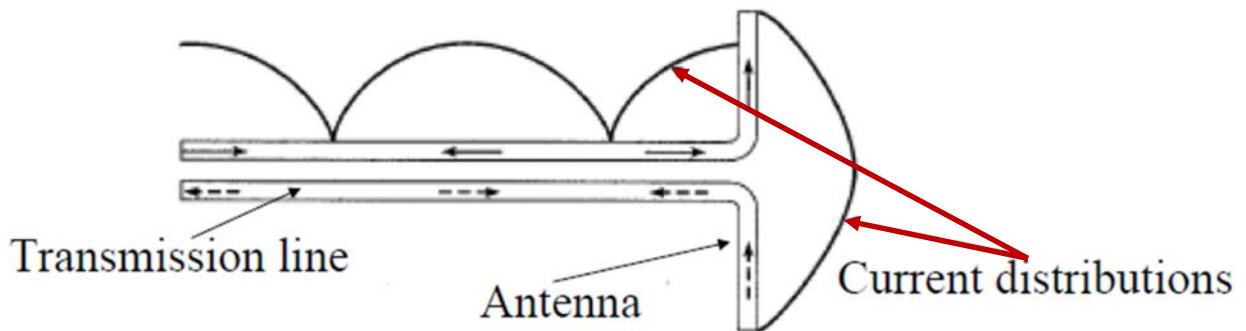


Fig. 11: Antenna radiation mechanism

1.4 Antenna Parameters:

Before discussing the different parameters of a typical antenna, let us recall the concept of **Poynting vector** and **steradian** (sr) [a unit for measuring solid angle] concept.

In most cases, it is easy to use the spherical polar co-ordinate system (Fig. 12) while dealing with antenna radiation properties.

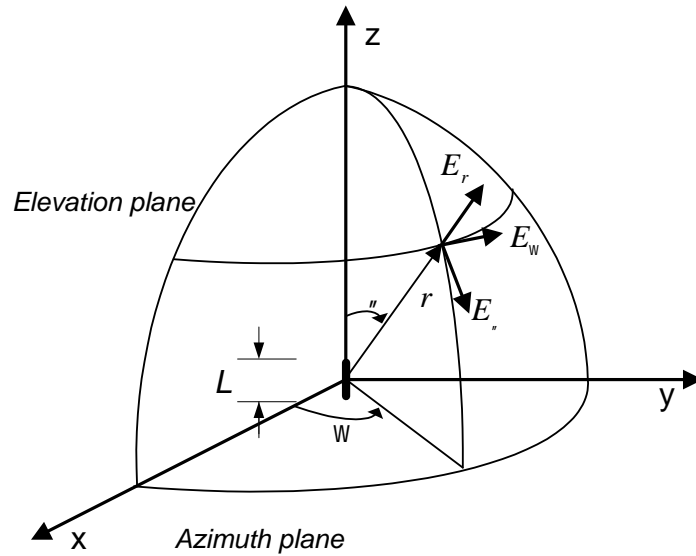


Fig. 12: Spherical polar coordinate system

The below figure, Fig. 13 shows the calculation of a small surface area ($r^2 \sin\theta \, d\theta \, d\phi$) in spherical polar coordinate system.

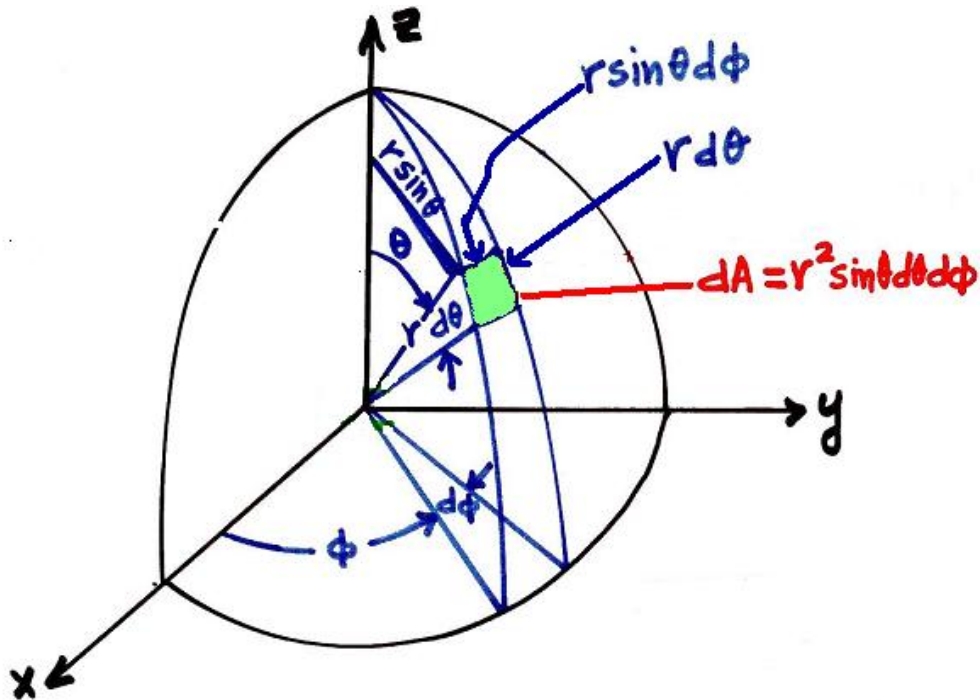


Fig. 13: Calculation of infinitesimally small surface area in spherical polar coordinate system

1.4.1 Poynting Vector

Mathematically the Instantaneous Poynting Vector is given by

$$\begin{aligned}\mathbf{p} &= \mathbf{E}(x, y, z, t) \times \mathbf{H}(x, y, z, t) \\ &= \text{Re}\{\mathbf{E}(x, y, z)e^{j\omega t}\} \times \text{Re}\{\mathbf{H}(x, y, z)e^{j\omega t}\} \quad (\text{W/m}^2)\end{aligned}$$

And the Average Poynting Vector as:

$$\mathbf{P}_{\text{av}} = \frac{1}{2} \text{Re}\{\mathbf{E}(x, y, z) \times \mathbf{H}(x, y, z)^*\} \quad (\text{W/m}^2)$$

The magnitude of the Poynting vector gives the instantaneous or average **power density** of the electromagnetic wave. Its direction gives the direction of the power flow at that particular point.

1.4.2 Power Intensity

It is the power radiated in a given direction per unit solid angle and has units of Watts per steradian (W/sr). Mathematically it is given by:

$$U = r^2 |\mathbf{P}_{\text{av}}| \quad (\text{W/sr})$$

Note: U is a function of direction (θ, ϕ) only and not distance (r).

Steradian (sr): a measure of solid angle.

Solid angle Ω is the ratio of that part of a spherical surface area S subtended at the center of a sphere to the square of the radius of the sphere.

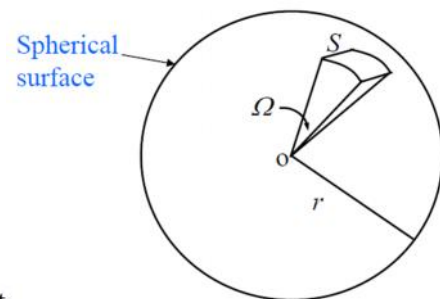


Fig. 14: Solid angle concept

$$= \frac{S}{r^2} \text{ (sr)}$$

- The solid angle subtended by a whole spherical surface is $= \frac{4\pi r^2}{r^2} = 4\pi$ (sr)
- In Fig. 13, a small surface is in spherical polar coordinate system is shown as $dA = r^2 \sin\theta \, d\theta \, d\phi$ (m^2). Hence $d\Omega = \sin\theta \, d\theta \, d\phi$ (sr). This information will be used later for calculation of radiated power of antennas.