Physical Concept of Radiation (Radiation Mechanism)

One of the first questions that may be asked concerning antennas would be "how is radiation accomplished?"

In other words, how are the electromagnetic fields generated by the source, contained and guided within the transmission line and antenna, and finally "detached" from the antenna to form a free-space wave?

Let us first examine some basic sources of radiation

Radiation from Single Wire

Conducting wires are material whose prominent characteristic is the motion of electric charges and the creation of current flow.

The total charge Q Within volume V is moving in the z direction with a uniform velocity v_z (meters/sec). It can be shown that the current density J_z (amperes/m2) over the cross section of the wire is given by

$$J_z = q_v v_z$$

If the wire is made of an ideal electric conductor, the current density J_s (amperes/m) resides on the surface of the wire and it is given by

$$J_s = q_s v_z$$

q_s – surface charge density

If the wire is very thin (ideally zero radius), then the current in the wire can be represented by

$$I_z = q_l v_z$$

q_l – charge per unit length

Instead of examining all three current densities, we will primarily concentrate on the very thin wire. The conclusions apply to all three. If the current is time varying, then the derivative of the current of can be written as

$$dI_z/dt = q_l\,(dv_z/dt) = q_l a_z$$

If the wire is of length l, then can be written as

$$l\,(dI_z/dt) = l\,q_l\,(dvz/dt) = l\,q_l a_z$$

It simply states that to create radiation, there must be a time-varying current or an acceleration (or deceleration) of charge.

Periodic charge acceleration (or deceleration) or time-varying current is also created when charge is oscillating in a time-harmonic motion, for a λ/2 dipole. Therefore,

1. If a charge is not moving, current is not created and there is no radiation.

2. If charge is moving with a uniform velocity

    a. There is no radiation if the wire is straight, and infinite in extent.

    b. There is radiation if the wire is curved, bent, discontinuous, terminated, or truncated.

3. If charge is oscillating in a time-motion, it radiates even if the wire is straight.

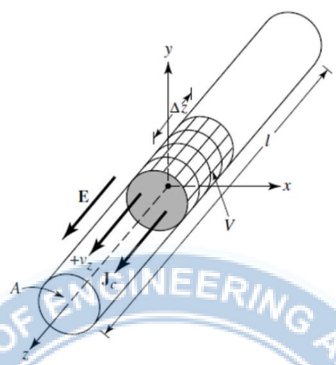


Figure 1.9 Charge uniformly distributed in a circular cross section cylinder wire.

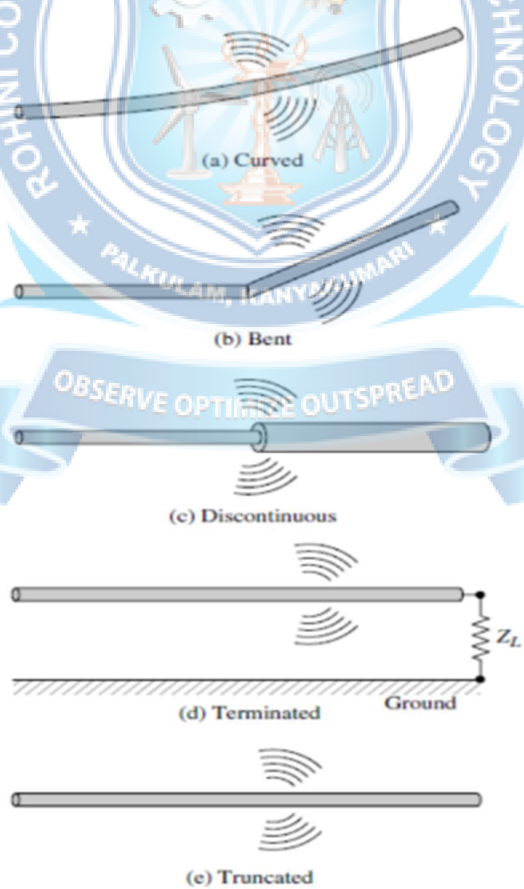
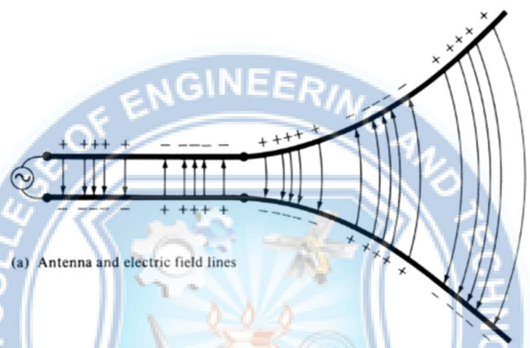


Figure 1.10 Wire configurations for radiation.

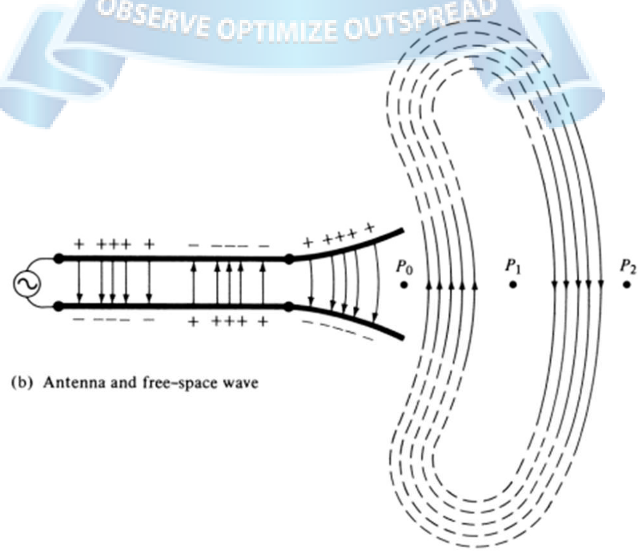
4.2 Two Wire

Let us consider a voltage source connected to a two-conductor transmission line which is connected to an antenna. Applying a voltage across the two-conductor transmission line creates an electric field between the conductors. The electric field has associated with it electric lines of force which are tangent to the electric field at each point and their strength is proportional to the electric field intensity. The electric lines of force have a tendency to act on the free electrons (easily detachable from the atoms) associated with each conductor and force them to be displaced. The movement of the charges creates a current that in turn creates a magnetic field intensity. Associated with the magnetic field intensity are magnetic lines of force which are tangent to the magnetic field.



(a) Antenna and electric field lines

Electric field lines start on positive charges and end on negative charges. They also can start on a positive charge and end at infinity, start at infinity and end on a negative charge, or form closed loops neither starting or ending on any charge. Magnetic field lines always form closed loops encircling current-carrying conductors because physically there are no magnetic charges. In some mathematical formulations, it is often convenient to introduce equivalent magnetic charges and magnetic currents to draw a parallel between solutions involving electric and magnetic sources.



(b) Antenna and free-space wave

Figure 1.11 Source, transmission line, antenna, and detachment of electric field lines.

4.3 Dipole

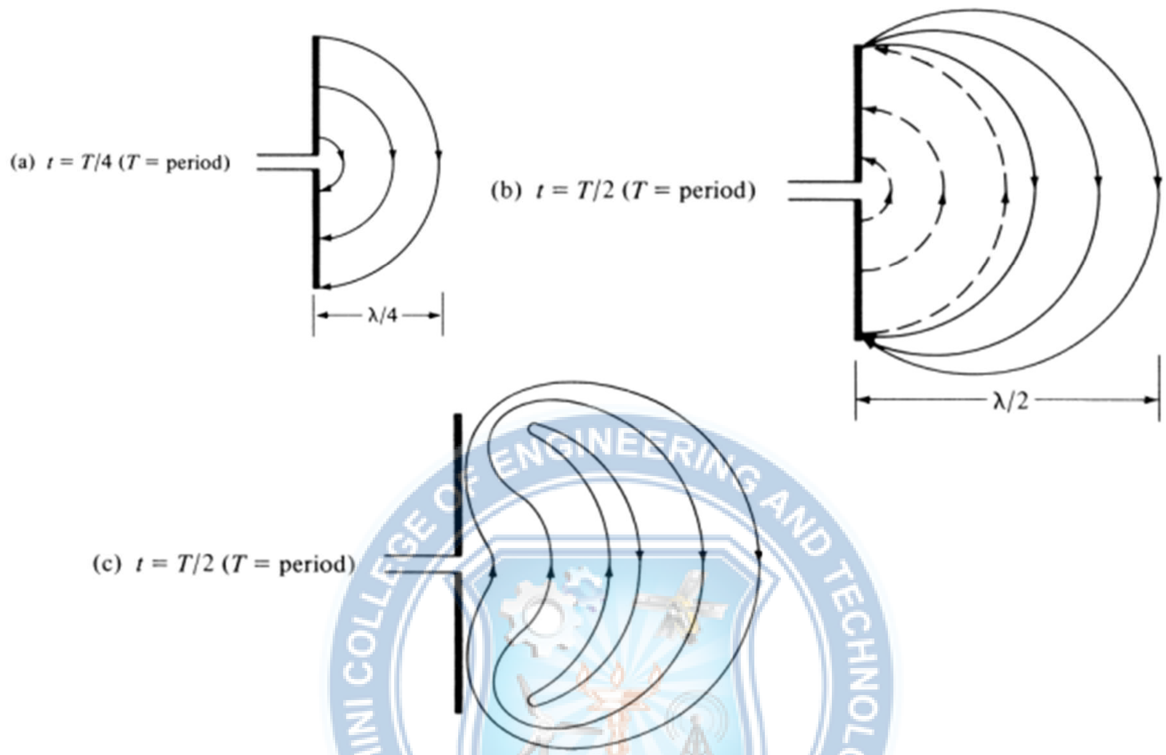


Figure 1.12 Formation and detachment of electric field lines for short dipole