CHAPTER 2

Physical Concept of Radiation

All truths are easy to understand once they are discovered;
The point is to discover them

—Galileo Galilei

2.1 INTRODUCTION

For wireless communication systems, the antenna is one of the most critical components. A good design of the antenna can relax system requirements and improve overall system performance. A typical example is TV for which the overall broadcast reception can be improved by utilizing a high performance antenna. An antenna is the system component that is designed to radiate or receive electromagnetic waves. In other words, the antenna is the electromagnetic transducer which is used to convert, in the transmitting mode, guided waves within a transmission line to radiate free-space waves or to convert, in the receiving mode, free-space waves to guided waves. In a modern wireless system, the antenna must also act as a directional device to optimize or accentuate the transmitted or received energy in some directions while suppressing it in others. The antenna serves to a communication system the same purpose that eyes and eyeglasses serve to a human. The history of antennas dates back to James Clerk Maxwell who unified the theories of electricity and magnetism, and eloquently represented their relations through a set of profound equations best known as *Maxwell's Equations.* His work was first published in 1873. He also showed that light was electromagnetic and that both light and electromagnetic waves travel by wave disturbances of the same speed. In 1886, Professor Heinrich Rudolph Hertz demonstrated the first wireless electromagnetic system. He was able to produce in his laboratory at a wavelength of 4 m a spark in the gap of a transmitting $\lambda/2$ dipole which was then detected as a spark in the gap of a nearby loop. It was not until 1901 that Guglielmo Marconi was able to send signals over large distances. He performed, in 1901, the first transatlantic transmission from Poldhu in Cornwall, England, to St. John's, Newfoundland. His transmitting antenna consisted of 50

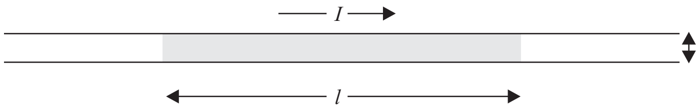


Fig. 2.1

movement. The acceleration due to change in direction is called centripetal acceleration. Since a current is the rate of change of charge, and a time varying current corresponds to acceleration or deceleration of charges, which is the required condition to radiate electromagnetic waves.

Consider a current '*I*' be flowing in an extremely thin wire. From the fundamental equation of current

$$I = \frac{q}{t}$$

where q is the charge moved through the length l of the wire in time t

$$I = \frac{q}{t} \times \frac{l}{l} = \frac{q}{l} \times \frac{l}{t}$$

$I = \rho_l v$ where ρ_l is the linear charge density and v is the drift velocity of charge

Differentiating the above equation with respect to time

$$\frac{dI}{dt} = \rho_l \frac{dv}{dt} = \rho_l a ,$$

here a is the acceleration of charge

or
$$l \frac{dI}{dt} = l\rho_l a \tag{2.1}$$

This equation is the basic relation between current and charge and is known as fundamental equation of electromagnetic radiation.

2.2.2 Radiation From Single Wire

The conducting wire can radiate electromagnetic energy if there is:

- oscillating current in wire
- steady current in curved, bent, discontinuous, terminated, or truncated wire as shown in figure 2.2

Consider a pulse source is applied to the end of the wire and the other end is connected to the ground via load as shown in figure 2.3.

The free electrons are accelerated from the source end and are retarded at the load end due to the build-up of the electrons there. The electromagnetic radiations are produced at the ends and along the length of the wire. Since the magnitude of acceleration or retardation is not uniform throughout, as a result there is a broad frequency spectrum (frequency is proportional to acceleration or retardation of electric charge). The band width depends upon the pulse width.

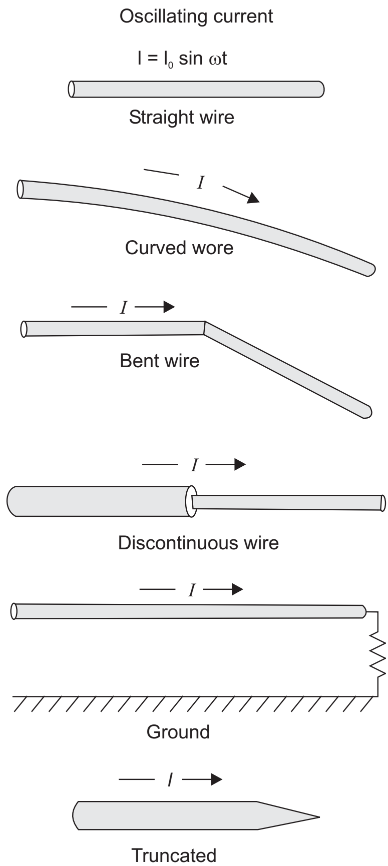


Fig. 2.2

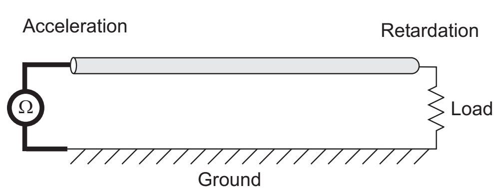
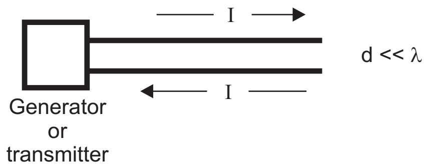


Fig. 2.3

For AC current, ideally there is single frequency of radiation. The moving charge through curved or bent wire experiences centripetal acceleration, which also produces radiation. For discontinuous wire impedances change rapidly at the point of discontinuity which is also responsible for radiation.

2.2.3 Radiation from Two Wires

Consider two straight conducting wires connected through generator or transmitter as shown in figure 2.4. The AC current in the two wires is same but their directions



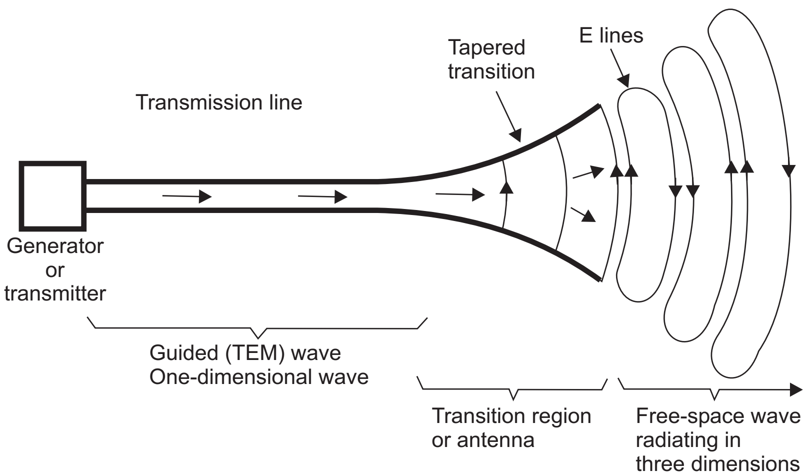


Fig. 2.4

are opposite. If the separation between the conductors is very small as compared to the wavelength, then the electromagnetic fields of both the wires cancel each other and as a result there is no net radiation. However when the open end of the wires are tapered which results in the increased separation between the wires, secondly the directions of currents in the two wires now are not exactly opposite which results in no net cancelling of electromagnetic fields and the structure starts radiating.

2.2.4 Radiation from Dipole

If the transition region of the two conductor wires is bent through 90° as shown below in figure 2.5, the two currents become exactly parallel to each other. This

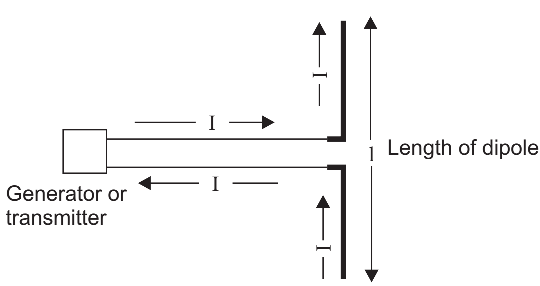


Fig. 2.5

the next quarter period, the original field line travels additional distance of $\lambda/4$ and the total distance becomes $\lambda/2$, simultaneously the charge on the dipole becomes zero. This can be thought of as being neutralized by the appearance of opposite charges. The field lines by this opposite charges are shown dashed (anti-clockwise sense). Since there is no net charge on the dipole and the existence of such-line is only possible when they form closed loops. These closed loops propagate away resulting in electromagnetic radiation.

2.3 CURRENT DISTRIBUTION ON THIN WIRE ANTENNA

Consider two wire transmission line which is open at load side. The source sends traveling current wave in the wires. The current at the each end reflects back with phase change of 180°. The incident and reflected current combine to produce a standing wave pattern of sinusoidal form as shown in figure 2.7. If the separation between the lines is very small as compared to wavelength, there will not be any radiation. If the open end region is bent to 90°, the currents in the two vertical sections become in the same direction as shown in figure 2.8, so corresponding

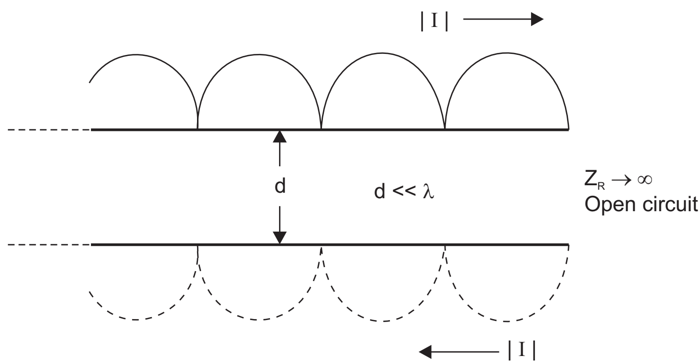


Fig. 1.7

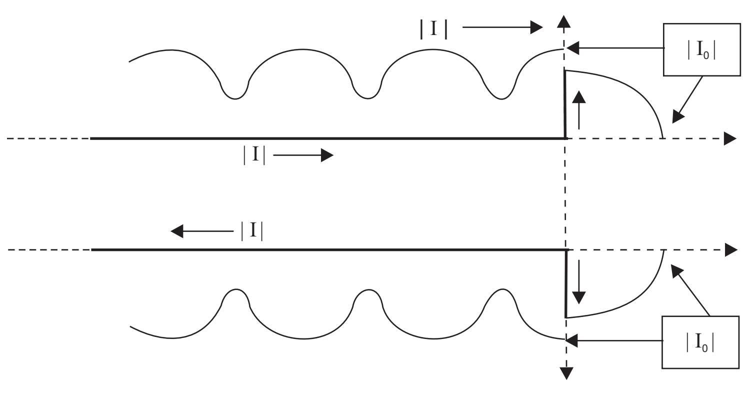


Fig. 2.8