Chapter 4
Basic Electromagnetic Theory

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ABSTRACT

Electromagnetic theory covers the basic principles of electromagnetism. This chapter explores relationships between electric and magnetic fields. The chapter describes the behaviour of electromagnetic wave. The four sets of Maxwell's equations which underpin the principles of electromagnetism are briefly explained. An illustration on wave polarization and propagation is presented. The author describes the classification of waves according to their wavelengths (i.e. the electromagnetic spectrum).

THE ELECTROMAGNETIC WAVES

Light waves or visible lights are the most common electromagnetic (EM) waves. An EM wave does not need a medium to propagate, unlike mechanical waves (like sound waves or water waves) which need a medium to propagate. It can travel through air, solid materials or the vacuum of space. EM waves cannot exist in the absence of a magnetic waves. Vibration of electric charge must occur for an EM wave to form. This leads to the formation of the magnetic and the electric components in an EM wave. When the two get charged, they move together in the direction of the wave and are perpendicular to each other, but maintaining the direction of the formed EM wave. This can be illustrated in Figure 1.

WAVES IN GENERAL

Waves are disturbances that relate to any function that moves, be it the ocean waves, sound waves, or mechanical waves (like vibrations on a guitar string) and EM fields. The disturbances are called travelling waves if they are moving away from the source that created them. Standing waves are formed whenever two waves of identical frequency interfere with one another while traveling in the opposite directions along the same medium. There are two types of wave motions, namely the transverse wave and the longitudinal wave. A transverse wave is a travelling wave in which a disturbance is created in a

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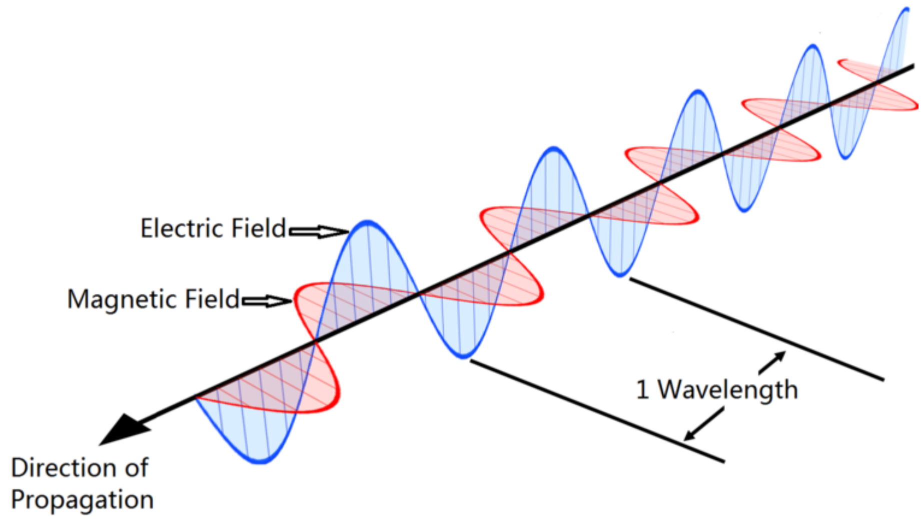
Figure 1. Electromagnetic wave propagation



direction perpendicular to the direction in which the wave is travelling. One example of a transverse wave is an EM wave travelling in free space. A longitudinal wave is a wave that vibrates back and forth along or parallel to the direction in which the wave is travelling. It is also sometimes referred to as compression wave. Sound wave is an example of longitudinal wave. The highest point of a wave is known as "peak", the lowest "trough", as illustrated in Figure 2. The distance between two consecutive "peaks" is called the wavelength while the distance between the "peak" and "trough" is called the amplitude. EM waves can be split into a range of frequencies. This is known as the electromagnetic spectrum. Some of the applications of EM waves include the transmission of long and short radio waves, frequency modulation (FM) and amplitude modulation (AM) waves, as well as, television (TV), telephone, and wireless signals or energies. They are also responsible for transmitting energy in the form of microwaves, infrared radiation (IR), visible lights (VIS), ultraviolet light (UV), X-rays, and gamma rays. EM waves travel in the speed of light, which is a constant velocity of $c = 3 \times 10^{8} ms^{-1}$ in vacuum. The speed will be slightly lower when they travel in a medium, where the speed will be determined by the type of medium, they are travelling in. They are neither deflected by the electric field, nor by the magnetic field. However, they are capable of showing interference or diffraction. As mentioned earlier, EM waves are 'transverse' waves. This means that they are measured by their amplitude and wavelength, as illustrated in Figure 2.

The frequency, wavelength and period of an EM wave travelling in free space can be calculated using the following formulas:

Let $u = f\lambda$, where u is the speed at which the EM wave is travelling, f is the frequency of the EM wave and λ is the wavelength. The wavelength of the EM wave would be (Sadiku, 2007):

$$\lambda = \frac{u}{f} \tag{1}$$

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