11.1: Introduction

Consider a plane wave propagating along the z-direction in vacuum, and polarized with its electric vector along the x-axis: its magnetic field vector must be directed along the y-axis. Now introduce two infinitely conducting metal planes which block off all of space except the region between x= +a and x= -a, see Figure (11.1.1). The boundary conditions at x= ±a that must be satisfied by the electric and magnetic fields are

1. the tangential components of E must be zero;
2. the normal component of H must be zero.

This latter condition is a consequence of the Maxwell equation

$$\mathrm{div}(\overrightarrow{\mathrm{B}})=0$$

which requires the normal component of $\vec{B}$ to be continuous through an interface, coupled with the requirement that both the electric and magnetic fields are zero inside a perfect conductor: recall from Chapter(10) that in the limit of infinite conductivity the skin depth of a metal goes to zero. **Notice that the above two boundary conditions are satisfied by the plane wave.** The plane wave solutions of Maxwell's equations

$$\mathrm{E_x}=\mathrm{E_0}\exp(i[\mathrm{kz}-\omega \mathrm{t}]), \tag{11.1.1}$$

$$\mathrm{H_y}=\mathrm{H_0}\exp(i[\mathrm{kz}-\omega \mathrm{t}]), \tag{11.1.2}$$

can be used to describe the propagation of electromagnetic energy between two conducting planes. Energy is transported at the speed of light just as it is for a plane wave in free space. Notice that if it is attempted to close in the radiation with conducting planes at y= ±b the boundary conditions E_x = 0 and H_y = 0 cannot be satisfied on the planes y= ±b. Waves can be transmitted through such hollow pipes but the radiation bounces from wall to wall in a complex pattern that will be studied later. It will be shown that waves cannot be transmitted through a hollow pipe if the frequency is too low; there exists a lower frequency cut-off. However, a pair of parallel conducting planes unbounded in one transverse direction can transmit waves at all frequencies. In practice infinite planes are inconvenient, so one uses either strip-lines or co-axial cables, see Figures (11.1.2) and (11.2.3).

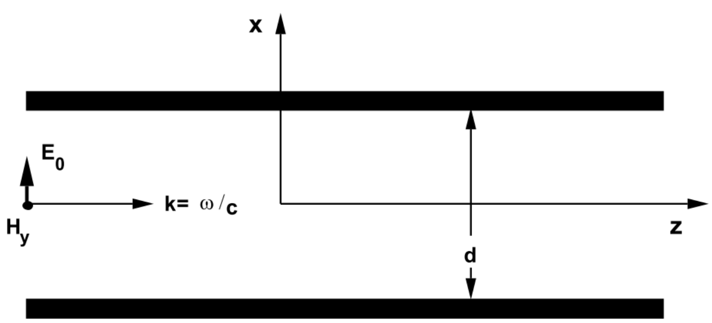

Figure 11.1.1: A plane wave propagating between two perfectly conducting planes. $\mathrm{E_x}=\mathrm{E_0}\exp(i[\mathrm{kz}-\omega\mathrm{t}]),\mathrm{H_y}=(\mathrm{E_0}/\mathrm{Z_0})\exp(i[\mathrm{kz}-\omega\mathrm{t}])$.

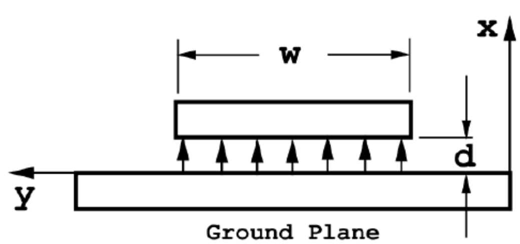

Figure 11.1.2: A strip-line. $\mathrm{E_x}=\mathrm{E_0},\mathrm{V}=\mathrm{E_0 d}.\mathrm{H_y}=\mathrm{E_0}/\mathrm{Z_0},\mathrm{I}=\mathrm{wJ_s}=\mathrm{w}\,(\mathrm{E_0}/\mathrm{Z_0})$