Module 5 : Plane Waves at Media Interface

Lecture 39 : Electro Magnetic Waves at Conducting Boundaries

Objectives

In this course you will learn the following

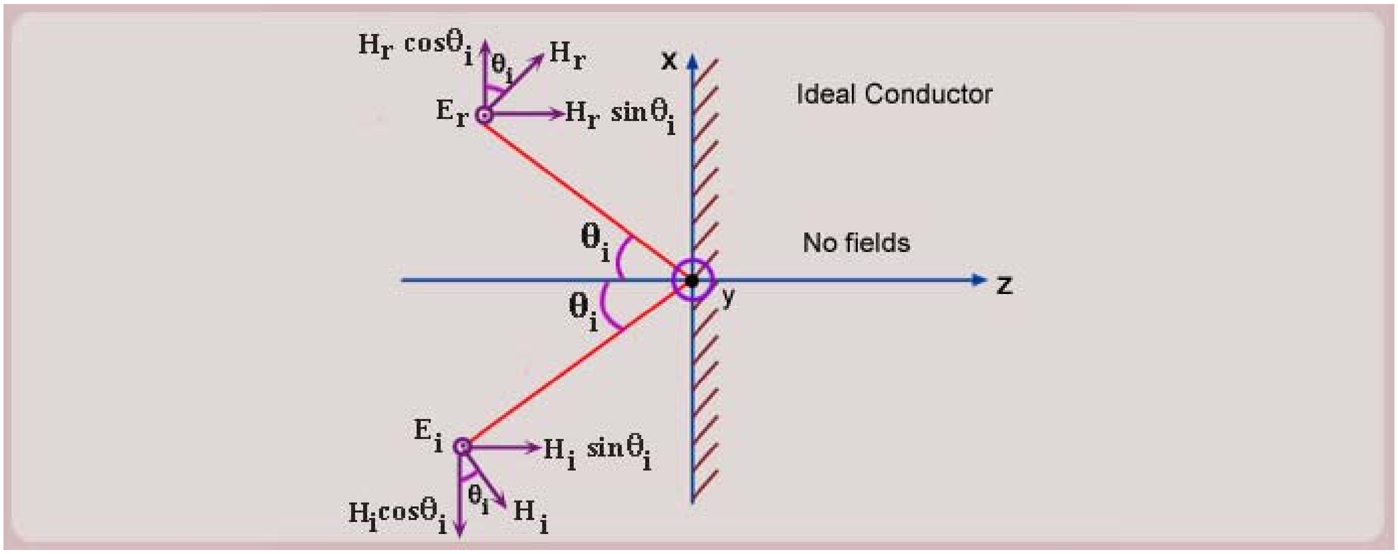
- Reflection from a Conducting Boundary.
- Normal Incidence at Conducting Boundary.

Reflection from a Conducting Boundary

- Let us consider a dielectric conductor-interface with a wave incident from a dielectric side. Since no time varying fields exists inside an ideal conductor there is no question of transmitted wave in this case. The wave is therefore completely reflected from a conducting boundary.

- Again we can investigate two polarization namely Perpendicular and Parallel.

Perpendicular Polarization



- The electric and magnetic fields for incident wave for the geometry given in the figure can be written as

$$\mathbf{E_i} = E_{i0} e^{-j\beta_1 (x \sin\theta_i + z\cos\theta_i)} \hat{\mathbf{y}}$$
$$\mathbf{H_i} = \frac{E_{i0}}{\eta_1} e^{-j\beta_1 (x \sin\theta_i + z\cos\theta_i)} (-\cos\theta_i \hat{\mathbf{x}} + \sin\theta_i \hat{\mathbf{z}})$$

- The reflected fields on the similar lines can be written as

$$\mathbf{E_r} = E_{r0} e^{-j\beta_1 (x \sin\theta_i - z\cos\theta_i)} \hat{\mathbf{y}}$$
$$\mathbf{H_r} = \frac{E_{r0}}{\eta_1} e^{-j\beta_1 (x \sin\theta_i - z\cos\theta_i)} (\cos\theta_i \hat{\mathbf{x}} + \sin\theta_i \hat{\mathbf{z}})$$

Note

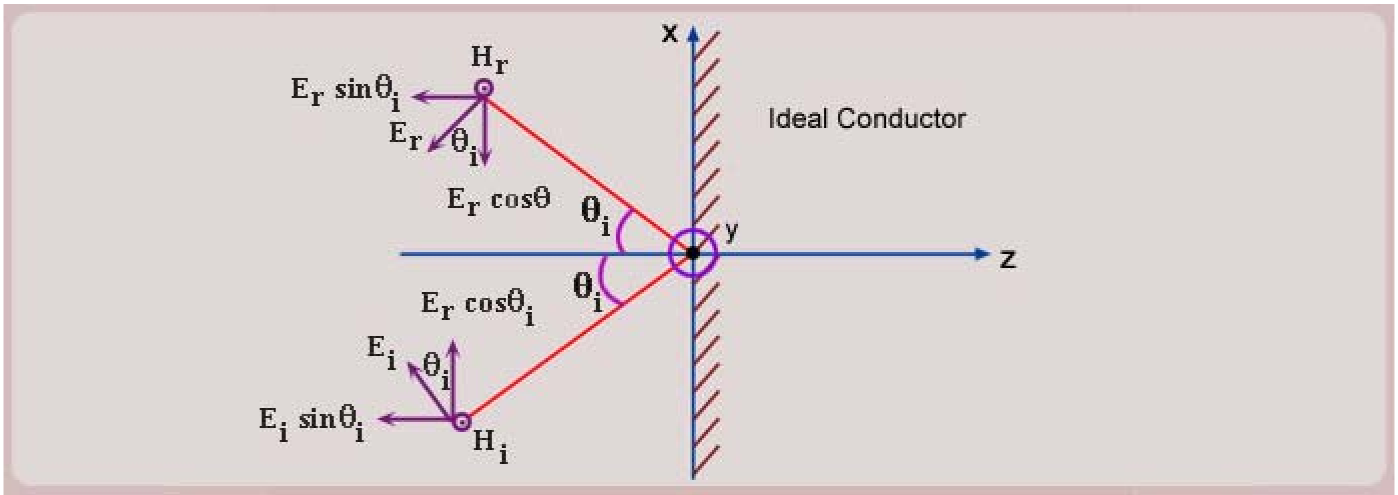
- **The direction of the magnetic fields are chosen so as to get correct direction of Poynting vectors for the two aves.**

- Making the tangential component of total electric field(incident and reflected) at the interface zero, we get the reflection coefficient as

$$\Gamma_\perp = \frac{E_{r0}}{E_{i0}} = -1$$

- We may recall that on a Transmission Line the voltage reflection coefficient is -1 for a short circuit load. The ideal conducting boundary therefore is analogous to a short circuit impedance on a Transmission Line.

Parallel Polarization



- For Parallel polarization the fields for the incident and relfected waves can be written as

Incident Wave :

$$\mathbf{H_i} = \frac{E_{i0}}{\eta_1} e^{-j\beta_1 (x \sin\theta_i + z\cos\theta_i)} \hat{\mathbf{y}}$$

$$\mathbf{E_i} = E_{i0} e^{-j\beta_1 (x \sin\theta_i + z\cos\theta_i)} \{\cos\theta_i \hat{\mathbf{x}} - \sin\theta_i \hat{\mathbf{z}}\}$$

Reflected Wave :

$$\mathbf{H_r} = \frac{E_{r0}}{\eta_1} e^{-j\beta_1 (x \sin\theta_i - z\cos\theta_i)} \hat{\mathbf{y}}$$

$$\mathbf{E_i} = E_{r0} e^{-j\beta_1 (x \sin\theta_i - z\cos\theta_i)} \{-\cos\theta_i \hat{\mathbf{x}} - \sin\theta_i \hat{\mathbf{z}}\}$$

- Making tangential component of the electric field at the interface zero we get the relfection coefficient as

$$\Gamma_{\parallel} = \frac{E_{r0}}{E_{i0}} = 1$$

Note

- **Since the reflection coefficient is +1 in this case one should not conclude that for Parallel polarization the conducting boundaries behaves like the open circuit impedance. The reflection coefficient becomes +1 because the electric field directions have already been taken such that the tangential components for the incident and reflected waves cancel each other at the interface. Hence irrespective of the polarization conducting boundary is always equivalent to the Short Circuit Impedance.**

Normal Incidence at Conducting Boundary

- For Normal Incidence $\theta_i = 0$ the incident and reflected fields can be written as

  Incident Wave :

$$\mathbf{E_i} = E_{i0} e^{-j\beta_1 z} \hat{\mathbf{x}}$$
$$\mathbf{H_i} = \frac{E_{i0}}{\eta_1} e^{-j\beta_1 z} \hat{\mathbf{y}}$$

  Reflected Wave :

$$\mathbf{E_r} = E_{r0} e^{j\beta_1 z} \hat{\mathbf{x}}$$
$$\mathbf{H_r} = \frac{E_{r0}}{\eta_1} e^{j\beta_1 z} \hat{\mathbf{y}}$$

- The reflection coefficient therefore is

$$\Gamma = \frac{E_{r0}}{E_{i0}} = -1$$

- This case is exactly identical to the Transmission Line with the short circuit load.

- Since magnitude of reflection coefficient is equal to one, the entire power is reflected from the conducting boundary.

- We therefore have two waves with equal amplitude travelling in opposite directions. Therefore in dielectric medium, we get Standing waves. The electric field becomes zero in the planes which are parallel to the conducting boundary and are located at distances which are multiple of $\lambda / 2$.

- In these planes the magnetic fields is maximum and it is zero in the planes which are straggled by a distance of $\lambda / 4$

- The planes over which the electric field is zero we can introduce a conducting sheet without affecting the field distribution. However, now we have created a dielectric region which is not semi infinite but is confined between two Parallel Conducting Boundaries.

- This structure is called the Parallel Plane Wave Guide which can be used to transport Electro Magnetic Energy.

Recap

In this course you have learnt the following

- Reflection from a Conducting Boundary.
- Normal Incidence at Conducting Boundary.

Congratulations! You have finished Module 5. To view the next Module select it from left hand side of the page.