Module 5 : Plane Waves at Media Interface

Lecture 36 : Reflection & Refraction from Dielectric Interface (Contd.)

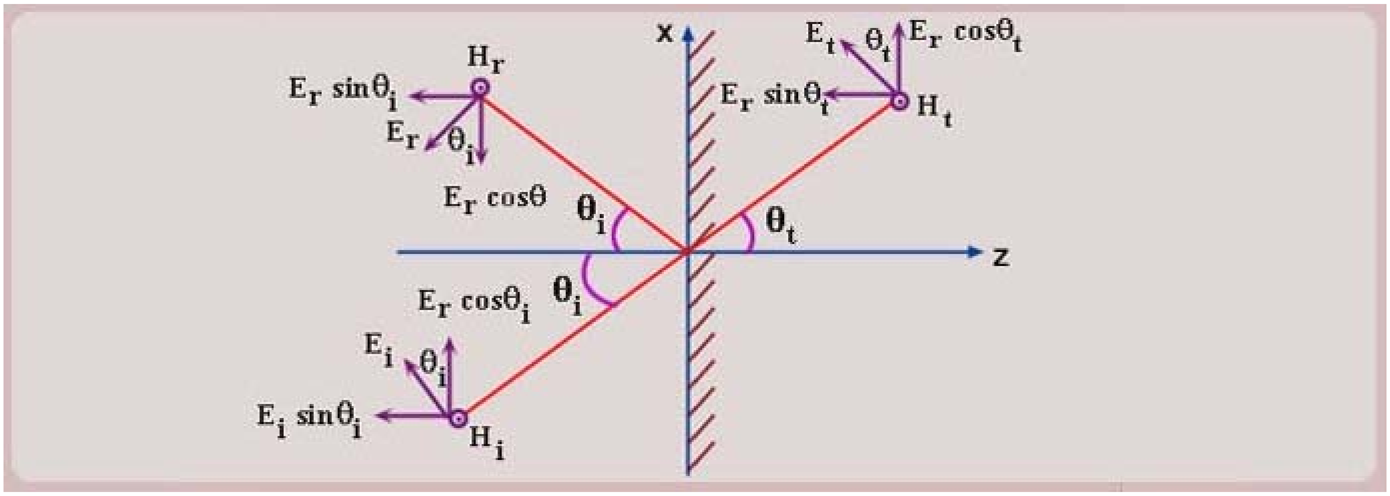
Objectives

In this course you will learn the following

- Reflection and Refraction with Parallel Polarization.
- Reflection and Refraction for Normal Incidence.
- Lossy Media Interface.

Reflection and Refraction with Parallel Polarization

- In this case the $\mathbf{E}$ - vector lies in the plane of incidence.
- Since the magnetic field is perpendicular to the wave direction the electric field it is now perpendicular to plane of the incidence. Let us therefore assume the magnetic field to be oriented in $+y$ direction.
- Using arguments similar to the previous case the magnetic fields or transmitted and reflected waves are also oriented in $+y$ direction.
- The direction of the electric fields can be obtained from the poynting vector as shown in the figure



- Applying continuity of tangential components of the electric and magentic fields at the interface, we get

$$|\mathbf{E_{i0}}|\cos\theta_i - |\mathbf{E_{r0}}|\cos\theta_i = |\mathbf{E_{t0}}|\cos\theta_t$$
$$|\mathbf{H_{i0}}| + |\mathbf{H_{r0}}| = |\mathbf{H_{t0}}|$$

- Solving the equations one can obtain the reflection and transmission coefficients for the parallel polarization as

Reflection coefficient :

$$\Gamma_{\parallel} = \frac{|\mathbf{E_{r0}}|}{|\mathbf{E_{i0}}|} = \frac{\eta_1\cos\theta_i - \eta_2\cos\theta_t}{\eta_1\cos\theta_i + \eta_2\cos\theta_t}$$

Transmission coefficient :

$$\tau_{\parallel} = \frac{|\mathbf{E_{t0}}|}{|\mathbf{E_{t0}}|} = \frac{2\eta_2\cos\theta_i}{\eta_2\cos\theta_t + \eta_1\cos\theta_i}$$

Note

(1) **Magnitude of reflection coefficient is always less than unity and reflection coefficient is real.**

(2) **The transmission coefficient is real but it could be greater or less than unity.**

Reflection and Refraction for Normal Incidence

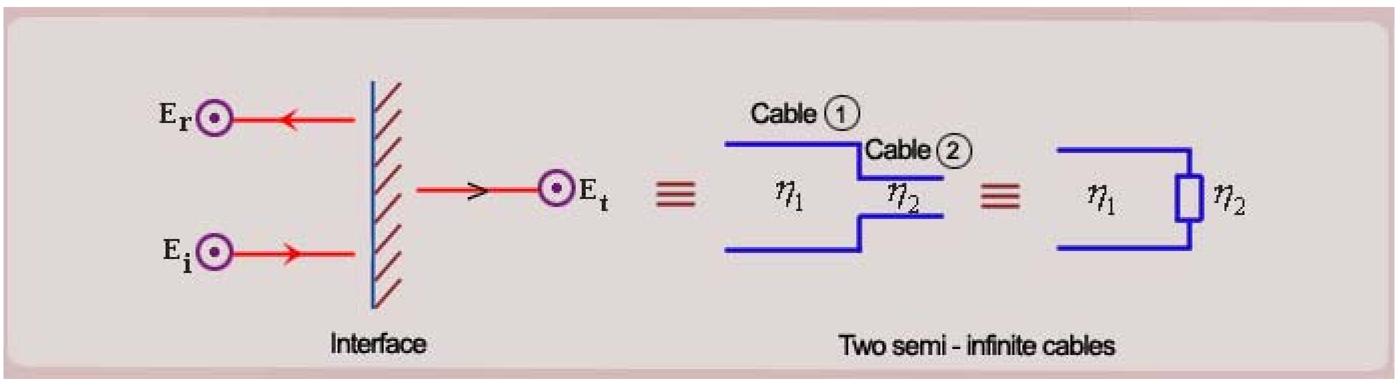
- We can investigate the case for normal incidence by substituting $\theta_i = 0$ in any of the two cases (perpendicular and parallel polarization) discussed earlier.
- By Snell's law when $\theta_i = 0$, θ_t is also zero
- Substituting $\theta_i = \theta_t = 0$ in the expressions for perpendicular polarization, we get the reflection and transmission coefficients for the normal incidence as

$$\text{Reflection coefficient} \quad : \quad \Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\text{Transmission coefficient} : \quad \tau = \frac{2\eta_2}{\eta_2 + \eta_1}$$

Analogy with Transmission Line

- The normal incidence case is indential to that of the transmission line with $\mathbf{E}$ replaced by $\mathbf{V}$, $\mathbf{H}$ replaced by $\mathbf{I}$ and η_1 and η_2 replaced by the characteristic impedances respectively.
- The normal incidence at a dielectric interface is equivalent to an infinity long transmission lines of characteristics impedances η_1 and η_2 respectively.



Lossy Media Interface

- The analysis of the lossy media interface can be carried out on the lines similar to that of loss less interface with appropriate changes needed for the propogation constant and intrinsic impedance of the lossy media.

- For a lossy medium the conductivity is not zero and propogation constant and interinsic impedance are given as

$$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \alpha + j\beta$$

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$$

- It should be noted that for lossy media the wave amplitude does not remain constant over the distance and therefore the transmitted and reflected wave decay exponentially as they travel away from the interface.

- The expressions for reflection and transmission coefficients given above can be used for any media with arbitraries high conductivity but not infinite conductivity. For any arbitrary high value of conductivity there is no true surface current and hence we can use the continuity of tangential components of magnetic fields as has been done uptil now.

- When the conductivity becomes infinite there is surface current and the skin depth is zero giving no propagation of an electro magnetic wave inside an ideal conductor.

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Recap

In this course you have learnt the following

- Reflection and Refraction with Parallel Polarization.
- Reflection and Refraction for Normal Incidence.
- Lossy Media Interface.