5.3 Uniform Plane Wave in Lossy Dielectric

A lossy dielectric is a poor insulator, in which free charges conducts to some extent. It is an imperfect conductor and imperfect dielectric (which is a partial conducting medium) with $\sigma \neq 0$.

The propagation constant is given as

$$\gamma = \sqrt{[jw\mu (\sigma + jw \epsilon)]}$$

Rearranging the terms, we get

$$\gamma = \sqrt{[jw \epsilon (1 + (\sigma/ jw \epsilon)) jw\mu]}$$

$$\text{Therefore, } \gamma = \alpha + j \beta = jw \sqrt{\mu\epsilon} \sqrt{(1 - j (\sigma/ w \epsilon))}$$

The above equation gives the propagation constant for lossy dielectric medium which is different from lossless dielectric medium due to the presence of radical factor. The attenuation constant α and phase constant are calculated by substituting the values of w, μ, ϵ, and σ in the above equation.

The attenuation constant α indicates the certain loss of the wave signal in the medium and hence this type of medium is called as lossy dielectric.

And also due to $\sigma \neq 0$, the intrinsic impedance becomes a complex quantity and is given as

$$\eta = \sqrt{[(jw\mu) / (\sigma + jw \epsilon)]}$$

$$\eta = |\eta| \angle \Theta_n \text{ Ohms.}$$

Because of the complex quantity, η is represented in polar form as shown in the above equation where Θn is the phase angle difference between electric and magnetic fields. Thus, in lossy dielectric medium there exist a phase difference between the electric and magnetic fields.

The intrinsic impedance can be expressed as

$$\eta = \sqrt{[(jw\mu) / (\sigma + jw \epsilon)]}$$

$$= \sqrt{[(jw\mu) / jw \epsilon (1 + (\sigma / jw \epsilon)]}$$

$$\eta = (\sqrt{(\mu / \epsilon)}) (1 / \sqrt{(1 - j (\sigma / w \epsilon))} \text{ ohms}$$

And the angle Θ_n is given as

$$\Theta_n = ½ [(\pi/2) - \tan^{-1} (w \epsilon / \sigma)]$$

This angle depends on the frequency of the signal as well as properties of the lossy dielectric medium. Then, w becomes very small for a low frequency signal. Thus, the phase angle is given as

$$\Theta_n = (\pi/4)$$

For very high frequency signal, w becomes very large then,

$$\Theta_n = 0$$

So the range of Θn of a lossy dielectric for complete frequency range is $0\ \Theta_n\ (\pi/4)$.