EE2025 Engineering Electromagnetics: July-Nov 2019

Tutorial 3: Plane Waves in Lossy Dielectrics and Media Interface

1. A rectangular copper block is 30 cm in height (along z). In response to a wave incident on the block from above, a current is induced in the block in the positive x direction. Find the ratio of ac resistance of the block to its dc resistance at 1 kHz. Consider $\sigma = 5.8 \times 10^7$ S/m, $\mu_r = 1$.

2. At 2 GHz, the conductivity of the meat is of the order of 1 S/m. When meat is placed in a microwave oven, the EM field in the conducting material causes energy dissipation in the material in the form of heat. Derive the expression for average power density in the meat, if the peak electric field inside is E_0. Evaluate the average power density (in W/mm^2), for $E_0 = 4 \times 10^4$ V/m.

3. At microwave frequencies,the power density considered for human exposure is $1mW/cm^2$. A RADAR radiates a wave described as

$$E(r) = \frac{3000}{r} V/m$$

where r is the radial co-ordinate, which is the distance from the source. What is the radius of unsafe region?

4. For copper, $\mu = 4\pi \times 10^{-7} H/m$, $\epsilon = \epsilon_0 = \frac{1}{36\pi} \times 10^{-9} F/m$, $\sigma = 5.8 \times 10^7 S/m$. Assuming these are frequency independent, find the range of electromagnetic spectrum for which copper is a good conductor. Is it a good conductor for visible, UV, IR ranges ?

5. A laptop manufacturer wants to shield her laptop such that the energy from its high frequency clock doesn't radiate to the outside world. Assuming a clock rate of 2.45 GHz, what should be the thickness of the metal cladding on the laptop cover and weight of metal required, given standard laptop dimension of 15"x11" if she uses
   (a) silver ($\sigma = 6.2 * 10^7 S/m$,density=$10.49 g/cm^3$)
   (b) gold ($\sigma = 4.1 * 10^7 S/m$,density=$19.32 g/cm^3$)
   (c) copper ($\sigma = 5.8 * 10^7 S/m$,density=$8.96 g/cm^3$)

6. In a dielectric medium, a wave has electric and magnetic fields given as,

$$E = (j\hat{x} + 2\hat{y} - j\hat{z}) \exp\left[-j\pi(x+z)\right] V/m$$

$$H = \frac{1}{60\pi}(-\hat{x} + j\hat{y} + \hat{z}) \exp\left[-j\pi(x+z)\right] A/m$$

   Show that the wave is a uniform plane wave. Find
   (a) phase constant of the wave
   (b) velocity of the wave
   (c) frequency of the wave

7. A plane wave travels in yz-plane at an angle of 30° from the +y direction. The electric field of the wave is oriented in the x-direction with an amplitude 50 V/m. If the medium has the dielectric constant of 2.5. Find the vector magnetic field, the wave vector and the phase constant of the wave. Frequency of the wave is 1GHz.

8. A non magnetic medium has an intrinsic impedance of $240\angle 30$ Ω. Find its
   (a) loss tangent
   (b) Dielectric constant
   (c) Complex permittivity
   (d) Attenuation constant at 1 MHz.

9. The electric field component of an EM wave propagating in air is

$$\mathbf{E} = 50\cos(\omega t - \beta_1 x \sin 45^\circ - \beta_1 z \cos 45^\circ)\ \mathbf{a_y} V/m$$

If the wave is incident on a lossless medium ($\epsilon = 2.25\epsilon_0, \mu = \mu_0$) in $z \geq 0$, determine the magnetic field component, the transmission coefficient and Brewster angle.

10. A plane wave from free space to a lossless dielectric with $\mu = \mu_0, \epsilon = 4\epsilon_0$ is totally transmitted. Find θ_i and θ_t. What is the state of polarization of the wave ?

11. A parallel polarized wave in air with, $\mathbf{E} = (6\mathbf{a_y} - 8\mathbf{a_z})\sin(\omega t - 4y - 3z)$ V/m impinges a dielectric half space as shown in Figure 1. Find

    (a) Incidence angle θ_i.

    (b) Time average power in air ($\epsilon_0 = 8.85 * 10^{-12} F/m, \mu_0 = 4\pi * 10^{-7} H/m$).

    (c) The Reflected and Transmitted Electric fields (E_r, E_t).

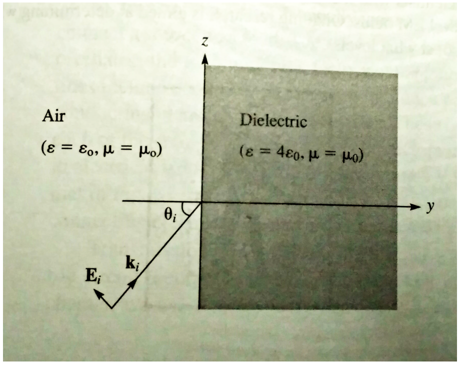

Figure 1: Air and Dielectric half spaces

12. A 1 GHz electromagnetic wave is normally incident on a 3 cm thick plastic slab of dielectric constant 5. What percent of the incident power is:

    (a) transmitted out through the slab ?

    (b) reflected back out off the slab ?