EE2011 Engineering Electromagnetics - Part CXD
Tutorial 7

Q1*

A team of scientists is designing a radar as a probe for measuring the depth of the ice layer over the Antarctic land mass. In order to measure a detectable echo due to the reflection by the ice-rock boundary, the thickness of the ice sheet should not exceed three skin depths. If $\varepsilon_r' = 3$, $\varepsilon_r'' = 10^{-2}$ and $\mu_r = 1$ for ice and if the maximum anticipated ice thickness in the area under exploration is 1.2 km, what frequency range is useable with the radar?

Q2*

The magnetic field of a linearly polarised uniform plane wave propagating in the +*y* direction in seawater ($\varepsilon_r = 80$, $\mu_r = 1$ and $\sigma = 4$ S/m) is

$$\mathbf{H}(y=0,t) = \hat{\mathbf{x}}\, 0.1 \sin\left(10^{10}\pi t - \pi/3\right).$$

(i) Determine the attenuation constant, phase constant, intrinsic impedance, phase velocity, wavelength and skin depth.

(ii) Find the location at which the amplitude of **H** is 0.01 A/m.

(iii) What are the phasor forms for E-field and H-field?

(iv) Write the expressions for $\mathbf{E}(y=0.5,t)$ and $\mathbf{H}(y=0.5,t)$.

Q3

A 1-MHz plane wave propagates in a conductive medium characterized by a permittivity $\varepsilon' = 8\varepsilon_0$, a permeability $\mu = \mu_0$, and a conductivity $\sigma = 4.8\times10^{-2}$ S/m. Determine:

(i) The ratio between the magnitudes of the conduction and displacement current densities. Comment on the conductive and insulating (dielectric) properties of this medium.

(ii) The skin depth.

Q4

A uniform plane wave propagates in seawater. The constitutive parameters of seawater are $\varepsilon_r = 72$, $\mu_r = 1$ and $\sigma = 4$ S/m. The frequency of the wave is at 5×10^6 Hz.

(i) Calculate the attenuation constant, intrinsic impedance, phase velocity, wavelength and skin depth;

(ii) Let the wave propagate in the +z direction and the average power density at z = 0 is equal to 1 W/m^2. Find the location (i.e., the value of z) at which the average power density is 10^{-4} W/m^2.

***** Questions to be discussed in the class.

For Q1 and Q2, which will be discussed in the tutorial class, the final solutions are given as follows. The full version of solutions will be distributed in due time.

Q1.

$f \le 41.6$ MHz

Q2.

(i)

$\alpha = 84,\ \beta = 300\pi$,

$\eta = 41.65 + j3.7136 = 41.8 e^{j0.0283\pi}\quad (\Omega)$,

$u_p = \omega/\beta = 33.3\times10^6\ \ \text{(m/s)},\ \ \lambda = 2\pi/\beta = 0.67\ \ \text{(cm)},\ \ \delta = 1/\alpha = 1.19\ \ \text{(cm)}$

(ii)

$y = 2.74\ \ \text{(cm)}$

(iii)

$\mathbf{E}(y) = \hat{\mathbf{z}} 4.18 e^{-\alpha y} e^{-j\beta y} e^{-j2.5291}$ V/m

$\mathbf{H}(y) = \hat{\mathbf{x}} 0.1 e^{-\alpha y} e^{-j\beta y} e^{-j5\pi/6}$ A/m

(iv)

$\mathbf{E}(0.5,t) = \hat{\mathbf{z}} 2.53\times10^{-18} \sin\left(10^{10}\pi t - 0.9583\right)$ V/m

$\mathbf{H}(0.5,t) = \hat{\mathbf{x}}\, 5.75\times10^{-20} \sin(10^{10}\pi t - \pi/3)\quad$ A/m

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