ECE 3065

HOMEWORK 2

Due by Friday 10. September

Problems

1. The magnetic field of a remote sensing wave propagating through Si (nonmagnetic lossless material) is given by

\[ H = \hat{z}50 \cos(10^9 t - 5y) \, (\text{mA/m}) \]  \hspace{1cm} (1)

Find (a) the direction of wave propagation, (b) the phase velocity, (c) the wavelength in the material, (d) the relative permittivity of the material (Hint: think about the relationship between phase velocity, velocity of the light in the air and dielectric constant) and (e) the electric field in phasor form and in a form containing time-dependence.

2. The electric field phasor of a uniform plane wave used for mine detection is given by \( \hat{E} = \hat{y}10e^{0.2z} \, (V/m) \). If the phase velocity of the wave is \( 1.5 \times 10^8 \, (m/sec) \) and the relative permeability of the medium is \( \mu_r = 2.4 \), find (a) the wavelength, (b) the frequency \( f \) of the wave, (c) the relative permittivity of the medium (Hint: for a magnetic medium, the phase velocity is \( v_p = c_0/(\mu_r\varepsilon_r)^{0.5} \)) and (d) the magnetic field \( \mathbf{H}(z,t) \). BE CAREFUL WITH THE PROPAGATION DIRECTION OF THE WAVE!!

3. A wireless communication antenna is transmitting waves, described by the electric field:

\[ \mathbf{E}(z,t) = \hat{x}|E_{x0}|\cos(\omega t - kz) + \hat{y}|E_{y0}|\cos(\omega t - kx + \delta), \]  \hspace{1cm} (2)

Identify the polarization state (Linear, RHS/LHS Circular, ...) and sketch the locus of \( \mathbf{E}(0,t) \) for each of the following cases:

(a) \( |E_{x0}| = 3\,V/m, \ |E_{y0}| = 4\,V/m, \ \delta = 0^\circ \),
(b) \( |E_{x0}| = 3\,V/m, \ |E_{y0}| = 4\,V/m, \ \delta = 180^\circ \),
(c) \( |E_{x0}| = 3\,V/m, \ |E_{y0}| = 3\,V/m, \ \delta = 90^\circ \),
(d) \( |E_{x0}| = 3\,V/m, \ |E_{y0}| = 3\,V/m, \ \delta = -90^\circ \),

4. Repeat Question (3.) for waves of the form

\[ \mathbf{E}(y,t) = \hat{x}|E_{x0}|\cos(\omega t - ky) + \hat{z}|E_{z0}|\cos(\omega t - kx + \delta), \]  \hspace{1cm} (3)

and substituting \( |E_{z0}| \) for the \( |E_{y0}| \) in cases (a)-(d).

5. The electric field of a uniform plane wave propagating in free space is given by \( \hat{E} = (\hat{x} + j\hat{y})20e^{-j\pi z/6} \, (V/m) \) for a ground-penetrating radar. Specify the modulus, direction and polarization state of this wave. Is a receiving antenna measuring E-fields above 15 V/m going to be pick up the signal?

6. For each of the following combinations of parameters, used in RF earthquake survivors detection systems, determine if the material is a low-loss dielectric, a quasi-conductor, or a good conductor, and then calculate \( a, \beta, \lambda, \gamma \) and \( \eta \):

(a) glass with \( \mu_r = 1, \ \varepsilon_r = 5, \ \text{and} \ \sigma = 10^{-12} \, \text{S/m at 10 GHz} \),
(b) animal tissue with \( \mu_r = 1, \ \varepsilon_r = 12, \ \text{and} \ \sigma = 0.3 \, \text{S/m at 100 MHz} \),
(c) wood with \( \mu_r=1 \), \( \epsilon_r=3 \), and \( \sigma = 10^{-4} \text{ S/m} \) at 1 kHz.

7. Ignoring reflection at the air-soil boundary, if the amplitude of a 2-GHz incident wave, used in mine detection, is 10 V/m at the surface of a wet soil medium, at what depth will it be down to 1 mV/m? Wet soil is characterized by \( \mu_r=1 \), \( \epsilon_r=16 \) and \( \sigma = 5 \times 10^{-4} \text{ S/m} \).

8 Based on wave attenuation and reflection measurements conducted at 1 MHz, it was determined that the intrinsic impedance of a certain medium is 28.145\(^\circ\) (\( \Omega \)) and the skin depth is 5m. Determine: (a) the conductivity of the material, (b) the wavelength in the medium, and (c) the phase velocity. (HINT: think about the phase angle of the intrinsic impedance and the intrinsic impedance of a good conductor)

9 An FM wave traveling in a nonmagnetic medium with \( \epsilon_r=9 \) is characterized by an electric field given by

\[ E = [\hat{y}3\cos(\pi \times 10^7 t + kx) - \hat{z}2\cos(\pi \times 10^7 t + kx)] \text{ (V/m)} \]. Determine the direction of wave travel and the average power density carried by the wave.

10 The electric-field phasor of a uniform plane wave traveling downward in water is given by

\[ \hat{E} = \hat{x}10e^{-0.2z}e^{-j0.2z} \text{ (V/m)}, \]

where \( \hat{z} \) is the downward direction and \( z=0 \) is the water surface. If \( \sigma=4 \text{ S/m} \),

(a) obtain an expression for the average power density,

(b) determine the attenuation rate,

(c) determine the depth at which the power density has been reduced by 40 dB.