Mandatory Problems on Uniform Plane Waves (Lossy Media, Transmission and Reflection from Dielectric/Metal Interfaces under Normal Incidence)

(30 pts) 1. An airplane flies over the surface of an ocean that has the electrical properties: \( \varepsilon = 81 \varepsilon_0, \mu = \mu_0, \) and \( \sigma = 887.66 \omega \varepsilon \) at a frequency of \( 1.0 \, \text{MHz} \). The airplane transmits a signal of the form of a \( 1.0 \, \text{MHz} \) plane wave that is propagating straight downward and that delivers an electric field amplitude of 0.1 V/m immediately under the surface of the water. A submarine requires a minimum signal level of \( 10.0 \, \mu \text{V/m} \) to communicate with the airplane.

   (10 pts) a. Determine the wavelength of the wave propagating in the water.

   (20 pts) b. Determine how deep the submarine can be submerged and still communicate with the airplane.

(60 pts) 2. A uniform electromagnetic plane wave of frequency 100.0 kHz propagates inside a copper alloy. The magnetic permeability of the alloy is that of free space. It is also known that the wavelength in the alloy is 0.5 mm.

   (10 pts) a. Determine the conductivity of the alloy

   (10 pts) b. Determine the value of the attenuation constant in dB/mm

   (20 pts) c. Assuming that the direction of propagation is in the +x-direction and that at \( x=0 \) the electric field phasor

   \[ \vec{E_0}(0, y, z) = 0.1 \hat{y} \, (V/m) \]

   determine the magnetic field phasor at \( x=0.25 \text{mm} \).

   (20 pts) d. Determine the time-average power density at \( x=0.25 \text{mm} \).

(50 pts) 3. The starship Enterprise needs to communicate with an away team that is trapped in a cave 2.0km below the surface of the red planet Mars. The tunnel leading to this cave has
collapsed during their explorations. The planet’s surface is known to have the electrical properties \( \varepsilon = 9\varepsilon_0 \), \( \mu = \mu_0 \), and \( \sigma = 5.0 \times 10^{-4} \text{ mho/m} \). The away team’s transmitter has been damaged and now only radiates 100 W of power at 10 GHz. The Enterprise is testing a new ultra-sensitive receiver that can detect signals at very, very low powers. Assume plane waves for all of your analysis.

(30 pts) a. Taking into account the presence of the interface, determine the minimum power level required for the Enterprise’s new receiver so that it can hear the away team’s distress call.

(20 pts) b. If the Enterprise is parked in a low orbit 10km above the surface of the planet, determine how long in time it will take for a rescue team to beam down to the cave (assume that the teleport beam propagates in a medium at the same speed that a plane wave would)

(40 pts) 4. Consider a plane wave propagating in air. It’s electric field phasor has the form:

\[
E_o(x, y, z) = (3.0 \hat{x} + 4.0 \hat{y}) e^{-j2\omega x}
\]

It is normally incident on a lossless material whose interface with the air is located at \( z=0.0 \). The dielectric constants of this material have the values: \( \varepsilon = 8.0\varepsilon_0 \) and \( \mu = 2.0\mu_0 \).

(20 pts) a. Determine the power carried away by the reflected field.

(20 pts) b. Determine the power carried away by the transmitted field.

(20 pts) 5. Ulaby Problem 7.19

(40 pts) 6. Ulaby Problem 8.4

Optional problems on 1D Plane Waves in Lossy Media, Normal Incidence Scattering

Ulaby: Problems 7.16, 7.17, 7.18, 8.1, 8.2, 8.3, 8.5

Homework Solutions provided: ONLINE