PROBLEM SET 1
ECE 713 Spring Quarter 2008

Assigned: March 24th
Quiz: April 4th Instructor: Joel Johnson

Problem 1

For each of the following scenarios, describe which propagation mechanism would usually be the dominant mechanism, and briefly discuss which secondary effects (if any) may be important in some cases. Dominant mechanism possibilities are direct transmission, direct + Earth reflections, groundwave, terrain diffraction, and ionospheric reflection. Secondary effects are the dominant mechanisms plus tropospheric refraction, atmospheric attenuation, and ducting.

(a) A GPS receiver (which operates at L-Band, 1.575 GHz) receives signals from a satellite directly overhead.

(b) A car-based cellular phone (operating at 900 MHz) communicates with a cellular tower that is within the line of sight.

(c) A listener uses his AM radio to receive WTVN (610 KHz) during the day.

(d) An FM radio station transmits at 100 MHz to users located outside the line of sight (perhaps in a valley beyond a mountain separating the users and the station's antenna).

(e) The Voice of America transmits to Europe at 15 MHz.

Problem 2

A dispersive, but otherwise simple, material has its polarization characterized by the polarization function

$$f(t-t_1) = A\exp\left(-\frac{(t-t_1)}{\tau_1}\right)$$

The relaxation constant τ_1 is characteristic of a molecular orientation process and is 10^{-10} seconds, while $A = 3 \times 10^{10}$.

(a) Find an algebraic expression for the complex susceptibility, $\chi(\omega)$.

(b) Show that for "low" frequencies ($\omega \ll 10^{10}$ rads/m) the complex susceptibility becomes real and approximately equal to $A\tau_1$.

(c) Plot the real and imaginary parts of the dielectric constant that results for this medium versus frequency. A qualitiative sketch is sufficient, but include peak and minimum values and their locations for both the real and imaginary parts.

(d) For a 1 GHz electric field of the form given by equation (3.59) in the notes with M and N both zero, calculate the phase change and attenuation incurred after propagation through 1 meter of this medium in the +x direction.

Problem 3

The electric field of a 900 MHz plane wave propagating in free space can be written as

$$\underline{\bar{E}} = (\sqrt{2}\hat{x} + j(\hat{y} - \hat{z}))e^{-jk(y+z)/\sqrt{2}} \text{ V/m.}$$

(a) Find k and λ.

(b) Write a unit vector in the direction of propagation.

(c) Find the magnetic field vector, $\underline{\bar{H}}$.

(d) What is the polarization of this electric field - linear, circular (rh or lh), or elliptical?

Problem 4

A Hertzian dipole antenna of length d is located in free space at the origin of a spherical coordinate system (r, θ, ϕ), and carries peak-to-peak current $\underline{I}$ flowing in the $\hat{z}$ direction. Electric and magnetic fields produced by this antenna are $\underline{\bar{E}} = \hat{\theta}\frac{j\eta_0 k\underline{I}d}{4\pi r}e^{-jkr}\sin\theta$ V/m, $\underline{\bar{H}} = \hat{\phi}\frac{jk\underline{I}d}{4\pi r}e^{-jkr}\sin\theta$ A/m in the far field of the antenna, where k is the propagation constant in free space and η_0 is the impedance of free space.

(a) Calculate the time average Poynting vector $\bar{S} = \frac{1}{2}Re\{\underline{\bar{E}} \times \underline{\bar{H}}^*\}$ in the far field of the antenna.

(b) Integrate the normal component of this Poynting vector over the surface of a sphere for a large value of r to obtain the total power radiated by the Hertzian dipole, P_r.

(c) Find the radiation resistance of the Hertzian dipole, R_{rad}, by equating $P_r = \frac{1}{2}|\underline{I}|^2 R_{rad}$.

(d) Noting that the $\hat{\phi}$ component of the electric field for this antenna is zero, find the directivity of the Hertzian dipole using equation (4.13) from the notes by calculating $P_\theta(\theta, \phi) = \frac{1}{2\eta_0}|\underline{\bar{E}}|^2$ (note this would be an absolute calculation in units of Watts/m^2).

(e) Find the effective area of the (lossless) Hertzian dipole.

Problem 5

Using the world wide web, find and visit 3 sites which provide information on electromagnetic propagation. Write a brief summary (one paragraph) of the information available at each site, and whether you believe this site would be of use for propagation engineers or researchers.