Homework 4 Solution Set

Blake Chapter 7 Questions 1-10
10 points (1 per problem)

1. What are the similarities between radio waves and light waves?

   Radio and light waves are both forms of electromagnetic energy. They both contain perpendicular, in-phase electric and magnetic fields. Both radio and light waves tend to travel in straight lines.

2. What is meant by the characteristic impedance of a medium? What is the characteristic impedance of free space?

   The characteristic impedance of a medium is the ratio of electric to magnetic field within the medium ($Z_0 = \frac{E}{H}$). It is also the square root of the ratio of magnetic permeability to electric permittivity of the medium; ($Z_0 = \sqrt{\frac{\mu}{\varepsilon}}$).

3. State the difference between power and power density. Explain why power density decreases with the square of the distance from a source.

   Power is the rate at which work can be performed; power density is the amount of power available per unit area (typically in watts/m^2).

   Power density is calculated by allowing the transmitted energy to spread over the surface of a virtual sphere with a surface area $A = 4\pi r^2$ where *r* is the radius of the sphere, representing the distance from the RF source at the sphere's center to the observation point at its surface. Because the surface area of a sphere is proportional to the square of its radius, the power density falls inversely as the square of distance.

4. A radio wave propagates in such a way that its magnetic field is parallel with the horizon. What is its polarization?

   The polarization of a wave with a magnetic component parallel with the earth is vertical. This means that the electric field is vertically oriented with respect to the earth's surface.

5. What is an isotropic radiator? Could such a radiator be built? Explain.

   An isotropic radiator is a theoretical antenna that radiates equally well in all directions. It isn't possible to build such a device with our current technology, but that hasn't stopped people from trying to build new and unique "compact" antennas. Check the site http://www.eh-antenna.com/ for information about a unique line of very compact HF antennas!

6. State three factors that determine the amount of power extracted from a wave by a receiving antenna.

The three factors that determine the amount of power extracted by a receiving antenna are:

a) The incoming field strength (or field density), $\mathscr{P}$;
b) The effective aperture of the receiving antenna, A_R, in m^2;
c) The orientation of the receiving antenna with respect to the incoming RF wave; when the polarization of the receiver's antenna is the same as the transmitter's, maximum signal transfer occurs.

We can state this relationship mathematically:

$$P_R = A_R P \cos^2 \phi$$

where A_R is the aperture, P is the power density ($\mathscr{P}$), and ϕ is the difference angle between the incoming wave's polarization and the receiving antenna's polarization. Note that for small ϕ , $\cos^2 \phi$ is approximately 1.

7. The equation given for calculating path loss in decibels shows the loss increasing with frequency. Why is this?

Path loss increases with frequency because the effective aperture of receiving antennas decreases with increasing frequency. Equation (7.12) relates this: $A_{eff} = \dfrac{\lambda^2 G_R}{4\pi}$ (Note that wavelength *decreases* with increasing frequency).

8. State two undesirable effects that can be caused by reflections in line-of-sight communication and explain how they arise.

Two undesirable effects cause by reflections in LOS communications are multipath distortion and fading. Distortion can occur when there are significant time differences between direct and reflected versions of a signal; the receiver gets both the original and delayed signals simultaneously, leading to errors in demodulation. Fading is caused by constructive and destructive interference between the direct and reflected signals; fading is highly dependent on the receiver's location in space.

9. Why is the attenuation greater for mobile communication than for free space?

Free-space models for attenuation are only valid in empty ("free") space. Mobile communications occurs near the earth's surface where there are many obstructions to the signal such as trees, buildings, vehicles, and so on.

10. What is meant by space diversity? How can it be used to improve the reliability of a communication system?

Space diversity is a method of improving performance by locating receiving antennas at different physical locations. The antennas may be located only a few meters apart in mobile applications. When the signal at one antenna is degraded by multipath interference, the other antenna's signal may be usable. Dual receivers are required to make use of the antennas, plus circuitry to "vote" on the better of the two incoming signals (or in advance applications, DSP circuitry to combine the received signals into a useful output.)