Recommended Web Site:

- About Antennas: Good source of information and links.

5.6 KEY TERMS, REVIEW QUESTIONS, AND PROBLEMS

Key Terms

<table>
<thead>
<tr>
<th>adaptive equalization</th>
<th>flat fading</th>
<th>parabolic reflective antenna</th>
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</thead>
<tbody>
<tr>
<td>antenna</td>
<td>forward error correction (FEC)</td>
<td>radiation pattern</td>
</tr>
<tr>
<td>antenna gain</td>
<td>free space loss</td>
<td>radio LOS</td>
</tr>
<tr>
<td>atmospheric absorption</td>
<td>ground wave propagation</td>
<td>reception pattern</td>
</tr>
<tr>
<td>attenuation</td>
<td>Hertz antenna</td>
<td>reflection</td>
</tr>
<tr>
<td>beam width</td>
<td>impulse noise</td>
<td>refraction</td>
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<tr>
<td>crosstalk</td>
<td>intermodulation noise</td>
<td>scattering</td>
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<tr>
<td>diffraction</td>
<td>isotropic antenna</td>
<td>selective fading</td>
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<tr>
<td>dipole</td>
<td>line of sight (LOS)</td>
<td>sky wave propagation</td>
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<tr>
<td>diversity</td>
<td>multipath</td>
<td>slow fading</td>
</tr>
<tr>
<td>fading</td>
<td>noise</td>
<td>thermal noise</td>
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<tr>
<td>fast fading</td>
<td>optical LOS</td>
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</table>

Review Questions

5.1 What two functions are performed by an antenna?
5.2 What is an isotropic antenna?
5.3 What information is available from a radiation pattern?
5.4 What is the advantage of a parabolic reflective antenna?
5.5 What factors determine antenna gain?
5.6 What is the primary cause of signal loss in satellite communications?
5.7 Name and briefly define four types of noise.
5.8 What is refraction?
5.9 What is fading?
5.10 What is the difference between diffraction and scattering?
5.11 What is the difference between fast and slow fading?
5.12 What is the difference between flat and selective fading?
5.13 Name and briefly define three diversity techniques.
5.1 For radio transmission in free space, signal power is reduced in proportion to the square of the distance from the source, whereas in wire transmission, the attenuation is a fixed number of dB per kilometer. The following table is used to show the dB reduction relative to some reference for free space radio and uniform wire. Fill in the missing numbers to complete the table.

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Radio (dB)</th>
<th>Wire (dB)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>-6</td>
<td>-3</td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
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<td></td>
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</table>

5.2 Find the optimum wavelength and frequency for a half-wave dipole of length 16 m.

5.3 It turns out that the depth in the ocean to which airborne electromagnetic signals can be detected grows with the wavelength. Therefore, the military got the idea of using very long wavelengths corresponding to about 30 Hz to communicate with submarines throughout the world. If we want to have an antenna that is about one-half wavelength long, how long would that be?

5.4 The audio power of the human voice is concentrated at about 300 Hz. Antennas of the appropriate size for this frequency are impractically large, so that to send voice by radio the voice signal must be used to modulate a higher (carrier) frequency for which the natural antenna size is smaller.
   a. What is the length of an antenna one-half wavelength long for sending radio at 300 Hz?
   b. An alternative is to use a modulation scheme, as described in Chapter 6, for transmitting the voice signal by modulating a carrier frequency, so that the bandwidth of the signal is a narrow band centered on the carrier frequency. Suppose we would like a half-wave antenna to have a length of 1 m. What carrier frequency would we use?

5.5 Stories abound of people who receive radio signals in fillings in their teeth. Suppose you have one filling that is 2.5 mm (0.0025 m) long that acts as a radio antenna. That is, it is equal in length to one-half the wavelength. What frequency do you receive?

5.6 Section 5.1 states that if a source of electromagnetic energy is placed at the focus of the paraboloid, and if the paraboloid is a reflecting surface, then the wave will bounce back in lines parallel to the axis of the paraboloid. To demonstrate this, consider the parabola \( y^2 = 2px \) shown in Figure 5.17. Let \( P(x_1, y_1) \) be a point on the parabola and \( PF \) be the line from \( P \) to the focus. Construct the line \( L \) through \( P \) parallel to the \( x \)-axis and the line \( M \) tangent to the parabola at \( P \). The angle between \( L \) and \( M \) is \( \beta \), and the angle between \( PF \) and \( M \) is \( \alpha \). The angle \( \alpha \) is the angle at which a ray from \( F \) strikes the parabola at \( P \). Because the angle of incidence equals the angle of reflection, the ray reflected from \( P \) must be at an angle \( \alpha \) to \( M \). Thus, if we can show that \( \alpha = \beta \), we have demonstrated that the rays reflected from the parabola starting at \( F \) will be parallel to the \( x \)-axis.
   a. First show that \( \tan \beta = (p/y_1) \). *Hint:* Recall from trigonometry that the slope of a line is equal to the tangent of the angle the line makes with the positive \( x \)-direction. Also recall that the slope of the line tangent to a curve at a given point is equal to the derivative of the curve at that point.
   b. Now show that \( \tan \alpha = (p/y_1) \), which demonstrates that \( \alpha = \beta \). *Hint:* Recall from trigonometry that the formula for the tangent of the difference between two angles \( \alpha_1 \) and \( \alpha_2 \) is \( \tan(\alpha_2 - \alpha_1) = (\tan \alpha_2 - \tan \alpha_1)/(1 + \tan \alpha_2 \times \tan \alpha_1) \).
5.7 For each of the antenna types listed in Table 5.2, what is the effective area and gain at a wavelength of 30 cm? Repeat for a wavelength of 3 mm. Assume that the actual area for the horn and parabolic antennas is $\pi m^2$.

5.8 It is often more convenient to express distance in km rather than m and frequency in MHz rather than Hz. Rewrite Equation (5.2) using these dimensions.

5.9 Assume that two antennas are half-wave dipoles and each has a directive gain of 3 dB. If the transmitted power is 1 W and the two antennas are separated by a distance of 10 km, what is the received power? Assume that the antennas are aligned so that the directive gain numbers are correct and that the frequency used is 100 MHz.

5.10 Suppose a transmitter produces 50 W of power.
   a. Express the transmit power in units of dBm and dBW.
   b. If the transmitter's power is applied to a unity gain antenna with a 900-MHz carrier frequency, what is the received power in dBm at a free space distance of 100 m?
   c. Repeat (b) for a distance of 10 km.
   d. Repeat (c) but assume a receiver antenna gain of 2.

5.11 A microwave transmitter has an output of 0.1 W at 2 GHz. Assume that this transmitter is used in a microwave communication system where the transmitting and receiving antennas are parabolas, each 1.2 m in diameter.
   a. What is the gain of each antenna in decibels?
   b. Taking into account antenna gain, what is the effective radiated power of the transmitted signal?
   c. If the receiving antenna is located 24 km from the transmitting antenna over a free space path, find the available signal power out of the receiving antenna in dBm units.
radius of 6370 km, derive this equation. *Hint:* Assume that the antenna is perpendicular to the earth's surface, and note that the line from the top of the antenna to the horizon forms a tangent to the earth's surface at the horizon. Draw a picture showing the antenna, the line of sight, and the earth's radius to help visualize the problem.

5.14 Determine the height of an antenna for a TV station that must be able to reach customers up to 80 km away.

5.15 What is the thermal noise level of a channel with a bandwidth of 10 kHz carrying 1000 watts of power operating at 50°C? Compare the noise level to the operating power.

5.16 The square wave of Figure 2.5c, with \( T = 1 \) ms, is passed through a low-pass filter that passes frequencies up to 8 kHz with no attenuation.
   a. Find the power in the output waveform.
   b. Assuming that at the filter input there is a thermal noise voltage with \( N_0 = 0.1 \mu W/Hz \), find the output signal to noise ratio in dB.

5.17 If the received signal level for a particular digital system is \(-151\) dBW and the receiver system effective noise temperature is 1500 K, what is \( E_b/N_0 \) for a link transmitting 2400 bps?

5.18 Suppose a ray of visible light passes from the atmosphere into water at an angle to the horizontal of 30°. What is the angle of the ray in the water? *Note:* At standard atmospheric conditions at the earth's surface, a reasonable value for refractive index is 1.0003. A typical value of refractive index for water is 4/3.