Lesson #70 and 71
Chapter — Section: 10-1 to 10-4
Topics: Communication systems

Highlights:
- Geosynchronous orbit
- Transponders, frequency allocations
- Power budgets
- Antennas

Lesson #72 and 73
Chapter — Section: 10-5 to 10-8
Topics: Radar systems

Highlights:
- Acronym for RADAR
- Range and azimuth resolutions
- Detection of signal against noise
- Doppler
- Monopulse radar
Chapter 10

Sections 10-1 to 10-4: Satellite Communication Systems

Problem 10.1  A remote sensing satellite is in circular orbit around the earth at an altitude of 1,100 km above the earth’s surface. What is its orbital period?

Solution: The orbit’s radius is \( R_0 = R_e + h = 6,378 + 1,100 = 7,478 \) km. Rewriting Eq. (10.6) for \( T \):

\[
T = \left( \frac{4\pi^2 R_0^3}{GMe} \right)^{1/2} = \left[ \frac{4\pi^2 \times (7.478 \times 10^6)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}} \right]^{1/2} = 4978.45 \text{ s} = 82.97 \text{ minutes.}
\]

Problem 10.2  A transponder with a bandwidth of 400 MHz uses polarization diversity. If the bandwidth allocated to transmit a single telephone channel is 4 kHz, how many telephone channels can be carried by the transponder?

Solution: Number of telephone channels \( = \frac{2 \times 400 \text{ MHz}}{4 \text{ kHz}} = 2 \times 4 \times 10^8 \times 4 \times 10^3 = 2 \times 10^5 \) channels.

Problem 10.3  Repeat Problem 10.2 for TV channels, each requiring a bandwidth of 6 MHz.

Solution: Number of telephone channels \( = \frac{2 \times 4 \times 10^8}{6 \times 10^6} = 133.3 \simeq 133 \) channels. We need to round down because we cannot have a partial channel.

Problem 10.4  A geostationary satellite is at a distance of 40,000 km from a ground receiving station. The satellite transmitting antenna is a circular aperture with a 1-m diameter and the ground station uses a parabolic dish antenna with an effective diameter of 20 cm. If the satellite transmits 1 kW of power at 12 GHz and the ground receiver is characterized by a system noise temperature of 1,000 K, what would be the signal-to-noise ratio of a received TV signal with a bandwidth of 6 MHz? The antennas and the atmosphere may be assumed lossless.

Solution: We are given

\[
R = 4 \times 10^7 \text{ m}, \quad d_t = 1 \text{ m}, \quad d_r = 0.2 \text{ m}, \quad P_t = 10^3 \text{ W}, \quad f = 12 \text{ GHz}, \quad T_{\text{sys}} = 1,000 \text{ K}, \quad B = 6 \text{ MHz}.
\]
At $f = 12$ GHz, $\lambda = c/f = 3 \times 10^8/12 \times 10^9 = 2.5 \times 10^{-2}$ m. With $\xi_t = \xi_r = 1,$

$$G_t = D_t = \frac{4\pi A_t}{\lambda^2} = \frac{4\pi(\pi d_t^2/4)}{\lambda^2} = \frac{4\pi \times \pi \times 1}{4 \times (2.5 \times 10^{-2})^2} = 15,791.37,$$

$$G_r = D_t = \frac{4\pi A_r}{\lambda^2} = \frac{4\pi(\pi d_r^2/4)}{\lambda^2} = \frac{4\pi \times \pi (0.2)^2}{4 \times (2.5 \times 10^{-2})^2} = 631.65.$$

Applying Eq. (10.11) with $\Upsilon(\theta) = 1$ gives:

$$S_n = \frac{P_t G_t G_r}{K T_{sys} B} \left(\frac{\lambda}{4\pi R}\right)^2 = \frac{10^3 \times 15,791.37 \times 631.65}{1.38 \times 10^{-23} \times \frac{3 \times 10^8}{4 \pi \times 6 \times 10^6}} \left(\frac{2.5 \times 10^{-2}}{2 \pi \times 4 \times 10^7}\right)^2 = 298.$$

### Sections 10-5 to 10-8: Radar Sensors

**Problem 10.5** A collision avoidance automotive radar is designed to detect the presence of vehicles up to a range of 0.5 km. What is the maximum usable PRF?

**Solution:** From Eq. (10.14),

$$f_p = \frac{c}{2R_u} = \frac{3 \times 10^8}{2 \times 0.5 \times 10^3} = 3 \times 10^5 \text{ Hz}.$$

**Problem 10.6** A 10-GHz weather radar uses a 15-cm-diameter lossless antenna. At a distance of 1 km, what are the dimensions of the volume resolvable by the radar if the pulse length is 1 $\mu$s?

**Solution:** Resolvable volume has dimensions $\Delta x, \Delta y,$ and $\Delta R$.

$$\Delta x = \Delta y = \beta R = \frac{\lambda}{d} R = \frac{3 \times 10^{-2}}{0.15} \times 10^3 = 200 \text{ m},$$

$$\Delta R = \frac{c \tau}{2} = \frac{3 \times 10^8}{2} \times 10^{-6} = 150 \text{ m}.$$

**Problem 10.7** A radar system is characterized by the following parameters: $P_t = 1$ kW, $\tau = 0.1 \mu$s, $G = 30$ dB, $\lambda = 3$ cm, and $T_{sys} = 1,500$ K. The radar cross section of a car is typically 5 m$^2$. How far can the car be and remain detectable by the radar with a minimum signal-to-noise ratio of 13 dB?
Solution: \( S_{\text{min}} = 13 \) dB means \( S_{\text{min}} = 20 \). \( G = 30 \) dB means \( G = 1000 \). Hence, by Eq. (10.27),

\[
R_{\text{max}} = \left[ \frac{P_{\text{t}}G^2\lambda^2\sigma_t}{(4\pi)^3KT_{\text{sys}}S_{\text{min}}} \right]^{1/4}
\]

\[
= \left[ \frac{10^3 \times 10^{-7} \times 10^6 \times (3 \times 10^{-2})^2 \times 5}{(4\pi)^3 \times 1.38 \times 10^{-23} \times 1.5 \times 10^3 \times 20} \right]^{1/4} = 4837.8 \text{ m} = 4.84 \text{ km}.
\]

Problem 10.8 A 3-cm-wavelength radar is located at the origin of an \( x \)-\( y \) coordinate system. A car located at \( x = 100 \) m and \( y = 200 \) m is heading east (\( x \)-direction) at a speed of 120 km/hr. What is the Doppler frequency measured by the radar?

\[
\theta = \tan^{-1} \left( \frac{200}{100} \right) = 63.43^\circ,
\]

\[
u = 120 \text{ km/hr} = \frac{1.2 \times 10^5}{3600} = 33.33 \text{ m/s},
\]

\[
f_d = \frac{-2u}{\lambda} \cos \theta = \frac{-2 \times 33.33}{3 \times 10^{-2}} \cos 63.43^\circ = -993.88 \text{ Hz}.
\]

Figure P10.8: Geometry of Problem 10.8.