1. **Link Budget**

A wireless communication system’s transmitted signals are attenuated according to the following path loss model:

\[ L_P(dB) = -50 + 10 \cdot \log_{10}(f_c) + 30 \cdot \log_{10}(d), \]

where \( d \) denotes the distance between transmitter and receiver in meters and the carrier frequency \( f_c = 1 \text{ GHz} \). Further, the system is characterized by

- transmit and receive antenna gains \( G_T = G_R = 0 \text{ dB} \),
- receiver implementation loss \( L_R = 2 \text{ dB} \),
- noise figure \( F = 2 \text{ dB} \),
- thermal noise PSD \( kT_0 = -174 \text{ dBm/Hz} \),
- signal bandwidth and symbol rate \( B = R_S = 1 \text{ MHz} \),
- required \( \frac{E_S}{N_0} = 10 \text{ dB} \).

(a) Compute the receiver sensitivity.

(b) Assuming the transmitter power equals 1 Watt, what is the transmission range \( d \)?

(c) How much transmit power is required to communicate over a distance of 2 km.

(d) For a given transmit power, by how much does the range increase if the symbol rate \( R_S \) is reduced to 100 KHz?

(e) Assume now that the path loss is subject to log-normal fading with standard deviation \( \sigma = 4 \text{ dB} \). Assume further that the system is characterized by the parameters tabulated above and that the transmit power equals \( P_t = 30 \text{ dBm} \). What is the probability that \( \frac{E_S}{N_0} \) is below 10 dB?

(f) What provisions must be made to ensure that the probability that \( \frac{E_S}{N_0} \) is below 10 dB is smaller than \( 10^{-3} \)?
2. Modify the MATLAB function `two_ray_loss.m` to include a second reflector. For example, you may include a wall behind one of the antennas. Plot the resulting path loss; you may use `plot_two_ray_loss.m` as a starting point. Describe what you did and explain if the path loss makes sense.

3. Goldsmith: Problem 2.18

4. Goldsmith: Problem 2.23

5. Goldsmith: Problem 2.25