CS356R (Spring 2026) – Homework 1 Solutions

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Problem 1: Power Unit Conversions

(a) Convert 10 W to dBm and dBW

To dBW:

$$P(\text{dBW}) = 10 \log_{10}\left(\frac{P(\text{W})}{1 \text{ W}}\right)$$

$$P(\text{dBW}) = 10 \log_{10}(10) = 10 \text{ dBW}$$

To dBm:

First convert watts to milliwatts:

$$10 \text{ W} = 10{,}000 \text{ mW}$$

$$P(\text{dBm}) = 10 \log_{10}(10{,}000) = 40 \text{ dBm}$$

$$\boxed{10 \text{ W} = 10 \text{ dBW} = 40 \text{ dBm}}$$

(b) Convert 0.01 mW to dBm and dBW

To dBm:

$$P(\text{dBm}) = 10 \log_{10}(0.01) = -20 \text{ dBm}$$

To dBW:

Convert to watts:

$$0.01 \text{ mW} = 10^{-5} \text{ W}$$

$$P(\text{dBW}) = 10 \log_{10}(10^{-5}) = -50 \text{ dBW}$$

$$\boxed{0.01 \text{ mW} = -20 \text{ dBm} = -50 \text{ dBW}}$$

Problem 2: Received Power Calculation

Given:

$$P_t = 1 \text{ mW} = 0 \text{ dBm}, \quad G_t = G_r = 1$$

$$f = 2.4 \text{ GHz}, \quad d = 100 \text{ m}$$

$$h_t = 10 \text{ m}, \quad h_r = 1 \text{ m}$$

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*typesetted with ChatGPT

Wavelength

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.4 \times 10^9} = 0.125 \text{ m}$$

For both parts (a) and (b), $L = 1$ is assumed in the equations.

(a) Free-Space Model (Friis Equation)

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2$$

In dB form:

$$P_r(\text{dBm}) = 0 + 20 \log_{10}\left(\frac{0.125}{4\pi(100)}\right)$$

$$P_r \approx -80.05 \text{ dBm}$$

$$\boxed{P_r \approx -80 \text{ dBm (Free-space)}}$$

(b) Two-Ray Ground Reflection Model

The far-field two-ray approximation is

$$P_r \approx P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$

However, this approximation is valid only when the transmitter and receiver separation is larger than the crossover distance:

$$d_c = \frac{4\pi h_t h_r}{\lambda}$$

Substituting:

$$d_c = \frac{4\pi(10)(1)}{0.125} \approx 1005 \text{ m}$$

Since:

$$d = 100 \text{ m} \ll d_c = 1005 \text{ m}$$

the far-field two-ray approximation is **not valid** for this scenario.

Therefore, the received power does not yet follow the d^{-4} decay behavior. Instead, it behaves similarly to the free-space model with possible constructive and destructive interference effects between the direct and reflected paths. So, the received power P_r will be same as part (a) $\boxed{i.e.,-80 \text{ dBm}}$

For completeness, if one were to (incorrectly) apply the far-field two-ray formula:

$$\frac{h_t^2 h_r^2}{d^4} = \frac{10^2 \cdot 1^2}{100^4} = 10^{-6}$$

$$P_r = 1 \text{ mW} \times 10^{-6} = 10^{-6} \text{ mW}$$

$$P_r(\text{dBm}) = 10\log_{10}(10^{-6}) = -60 \text{ dBm}$$

Note: -60 dBm is not physically valid here because $d < d_c$.

Problem 3: Shannon Capacity and Minimum SNR

Bandwidth:
$$B = 5.05 - 5.00 = 0.05 \text{ GHz} = 50 \text{ MHz}$$

Shannon capacity formula:
$$C = B\log_2(1 + \text{SNR})$$

$$20 \times 10^6 = 50 \times 10^6 \log_2(1 + \text{SNR})$$

$$\log_2(1 + \text{SNR}) = 0.4$$

$$1 + \text{SNR} = 2^{0.4}$$

$$\text{SNR} = 2^{0.4} - 1 \approx 0.3195$$

$$\boxed{\text{SNR}_{\min} \approx 0.3195 \text{ (linear)}}$$

In dB:
$$\text{SNR}_{\text{dB}} = 10\log_{10}(0.3195) \approx -4.96 \text{ dB}$$

If noise floor is:
$$N = -100 \text{ dBm}$$

Required signal strength:
$$S = N + \text{SNR}_{\text{dB}}$$
$$S \approx -100 + (-4.96) = -104.96 \text{ dBm}$$

$$\boxed{S_{\min} \approx -105 \text{ dBm}}$$

Problem 4: Modulation Scheme Selection

(1) High-Throughput Wi-Fi

Choice: **64/256/1024-QAM**

    Reason: High spectral efficiency for high-SNR environments.

    Advantage: Very high data rate.

Disadvantage: Sensitive to noise and distortion.

(2) Satellite Communication

Choice: **BPSK/QPSK**

  Reason: Power-efficient and robust at lower SNR.

  Advantage: Good robustness.

Disadvantage: Lower spectral efficiency.

Problem 5: Narrowband Interference

Normally, the central frequency of the microwave oven is 2.45GHz. Hence there is an overlapping between the frequency-bands of microwave and indoor Wi-Fi (2.4GHz). Hence, there are several ways to mitigate the effect of this narrowband interference.

- Using Direct-sequence spread spectrum (DSSS)

- Using Frequency Hopping Spread Spectrum (FHSS)

(b) Preferred for IoT

FHSS is preferred due to simplicity, lower power consumption, and robustness against unknown narrowband interference.