CS4222/CS5422 Semester 2, 2022/2023
<u>Tutorial for Week 4 (Jan 30th, 2023)</u>

Question 1: A wireless receiver with an effective radius of 100cm is receiving signals at 2 GHz from a transmitter that transmits at a power of 100W and a gain of 40dB (or 10,000). Assume path loss exponent is 2.

(a) What is the gain of the receiver antenna?
(b) What is the received power if the receiver is 1km away from the transmitter?
(c) If the receiver is receiving signals at 900 MHz frequency (instead of 2GHz), please calculate (a) and (b) again? What do you notice and why?

Answer 2:

d_e = Effective radius = 100 cm.
f_c = Carrier frequency = 2 GHz.
P_t = Transmitter power = 100W
Gt = Transmitter gain = 40 dB = 10,000.
d = Distance of receiver = 1 km.
Ae = Effective area = (π r^2) = π m^2
λ = Wavelength = c (speed of light) / fc = 0.15 m

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

$$P_r = G_r G_t \left(\frac{c}{4\pi f_c d} \right)^{\alpha} P_t$$

(a) Gr = $4\pi (\pi) / (0.15*0.15) = 1755$ or 32.44dB

(b) Pr = 100W * 1755 * 10,000/$(4\pi*6.67*1000)^2$ = 0.2498W

For 900 MHz:
λ = Wavelength = c (speed of light) / fc = 0.33 m

(c) Gr = $4\pi (\pi) / (0.33 * 0.33)$ = 362.15 / 25.5889 dB (900MHz)
Pr = 100W * 362.15 * 10,000/ $(4\pi*3.03*1000)^2$ = 0.250 W (900 MHz)

First, we note that the antenna gain decreases at lower frequencies (if the remaining factors are kept constant). Second, despite lower antenna gain due to higher frequencies, better propagation characteristics mean that the received signal power remains similar to one we had calculated at a higher frequency. Lower frequencies have better propagation characteristics.

Question 2: Can you explain the difference between a microcontroller, system-on-chip, and microprocessor? Furthermore, what processor does Texas Instruments CC2650 (used for projects) use and the reasoning behind this choice? Can you also provide an estimate for the maximum communication range (BLE) for CC2650, taking into consideration Gt and Gr equal to 2 dB, as well as identifying other relevant parameters from the datasheet?

Answer 2: Microcontroller can be thought of as a microprocessor with several peripherals. System on chip, combines microcontroller with other functionalities, like radio transceivers, AI accelerators, peripherals etc.

CC2650 can be considered a system on chip. It is SoC because it has radio, microcontroller, power management block, and other peripherals all built into the same chip.

b) From the datasheet we can find the following values:

f_c = Carrier frequency = 2.4 GHz.
G_t = Transmitter gain = 2 dBi
G_r = Receiving gain = 2 dBi
λ = Wavelength = c (speed of light) / f_c = 0.125 m
P_t = Transmitter power = 5 dBm
Receiver sensitivity (BLE) = -97 dBm

We need the receiving signal to be above the threshold of -97 dBm (Receive sensitivity derived from CC2650 datasheet) to successfully receive BLE transmissions.

We can use Friis propogation equation to estimate maximum communication range. We can use the logarithmic form of the equation, as stated below:

$$
\begin{aligned}
[P_r(d)]_{dBm} = [P_t]_{dBm} + [G_t]_{dBi} + [G_r]_{dBi} \\
+ 20\ log_{10}(\lambda) - 20\ log_{10}(4\pi d) - 10\ log_{10}(L)
\end{aligned}
$$

Where L accounts for losses, and in this question can be considered to be 1.

We want to estimate d, while other terms are known.

d (or maximum communication range) can be calculated to be about **1985 meters**

Of course, in real world, wireless signal encounters various effects, such as multipath fading, diffraction, scattering, interference, and actual range would be much lower.