Wireless Networking
CS4222/5422

Tutorial 2

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Q1

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?

(a) What is the gain of the receiver antenna?

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

2X10⁹ → f: 2×10^9

π(1)² → A_e: $\pi(1)^2$

3X10⁸ → c: 3×10^8

= 1755 or 32.44dB

$10 \times \log_{10}(1755/1) = 32.44$

- G = antenna gain
- A_e = effective area
- f = carrier frequency
- c = speed of light 3×10^8 m/s
- Lambda = carrier wavelength

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(b) What is the received power if the receiver is 1km away from the transmitter?

- *Friis propogation model*

$$P_r = \underbrace{\boxed{G_r}}_{1755}\,\underbrace{\boxed{G_t}}_{10{,}000}\left(\frac{c}{4\pi \underbrace{\boxed{f_c}}_{2\times 10^9}\,\underbrace{\boxed{d}}_{1000}}\right)^{\overset{2}{\boxed{\alpha}}}\overset{100}{\boxed{P_t}} = 0.2498\text{W}$$

- f_c is the center frequency in Hz
- c is speed of light
- d is the distance between transmitter and receiver
- Alpha is the path loss component
- G is antenna gain

c) Recalculate a) and b) for f_c = 900 MHz

- $G_r = \frac{4\pi^2}{0.33^2} = 362.15$ or 25.589dB
- $P_r = \frac{100 \times 362.15 \times 10000}{(4\pi \times 3.03 \times 1000)^2} = 0.250\text{W}$

- **Observation:**
  - Lower carrier frequency ➔ Lower Antenna Gain
  - However, also, Lower carrier frequency ➔ Better propagation characteristics
  - Received signal power remains **similar**

Q2

a) Can you explain the difference between a microcontroller, system-on-chip, and microprocessor?

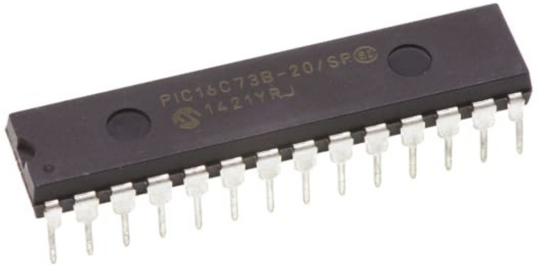
b) What processor does Texas Instruments CC2650 (used for projects) use and the reasoning behind this choice?

c) Can you also provide an estimate for the maximum communication range (BLE) for CC2650, taking into consideration Gt and Gr equal to 2 dBi, as well as identifying other relevant parameters from the datasheet?

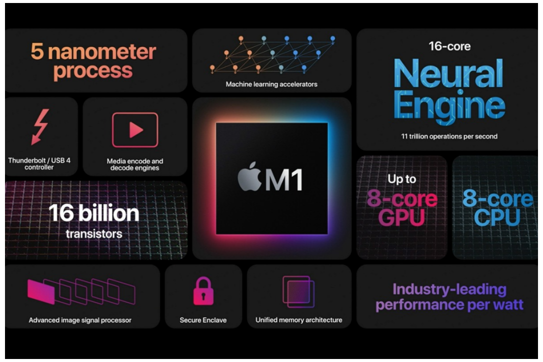
a) Microprocessor vs Microcontroller vs system-on-chip?

- **Microprocessor:**
  - Powerful processing units, suitable for dynamic/complex tasks
  - Allow connection to peripherals
  - E.g. Laptop, PC

- **Microcontroller:**
  - Dedicated to perform a task/application
  - CPU *+ Memory + I/O built in*
  - E.g. Calculator, Washing Machine



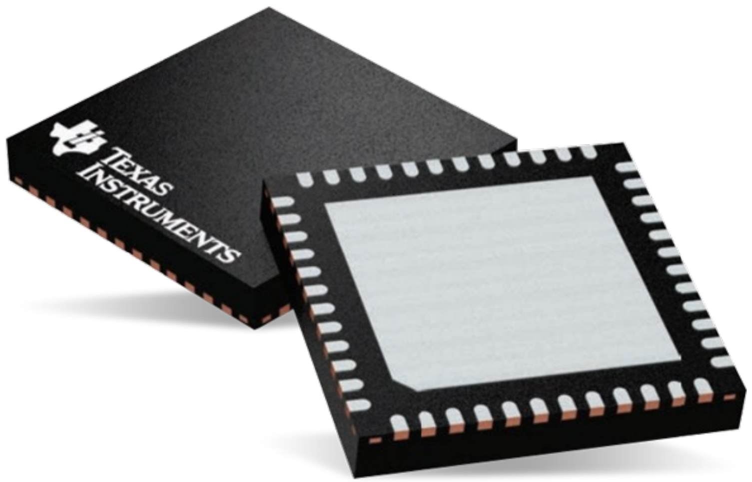
- **System on Chip (SoC):**
  - IC integrating most or all components of a computer
  - CPU + Memory + I/O *+ Radio + Graphics*
  - E.g. Smartphones



*Credit: Google Images

b) What processor does Texas Instruments CC2650 use?

- System on Chip (SoC)
- Includes CPU, Radio, Power Management block, etc. all built into the same chip



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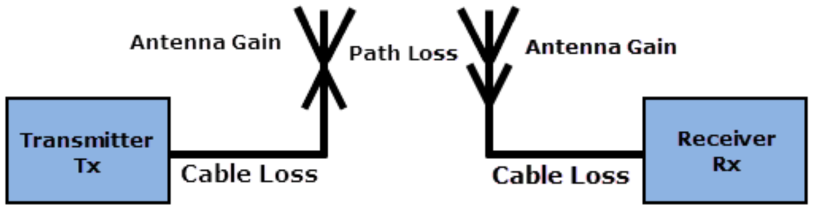
c) Estimate the maximum communication range (BLE) for CC2650



- Free Space Path Loss Equation

$$\overset{102}{\boxed{FSPL}} = 20\log_{10} d + 20\log_{10} \overset{2.4 \times 10^9}{\boxed{f_c}} + 20\log_{10}\frac{4\pi}{c} - \overset{2}{\boxed{G_t}} - \overset{2}{\boxed{G_r}}$$

  - fc = Carrier frequency = 2.4 GHz.
  - Gt = Transmitter gain = 2 dB
  - Gr = Receiving gain = 2 dB
  - λ = Wavelength = c (speed of light) / fc = 0.125 m
  - Pt = Transmitter power = 5 dBm
  - Receiver sensitivity (BLE) = -97 dBm
    - Therefore, We need to find distance d for which FSPL is 102 dB
    - 5 – 102 = -97 dBm (Minimum sensitivity)

d ≅ 1983 m

Thank you

Feel free to contact me at kanav.Sabharwal@u.nus.edu for any clarifications