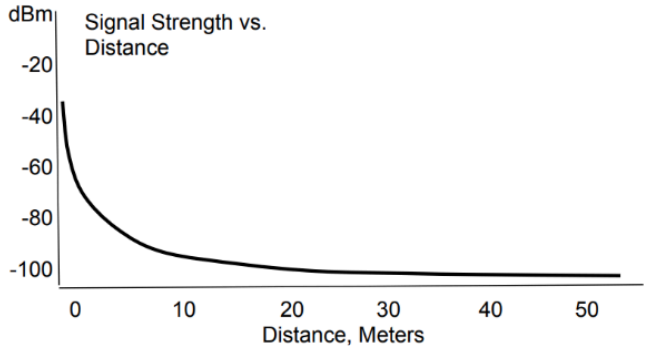
Wireless communications

- wireless transmissions modulate a high frequency sinusoid (carrier signal) based on the message transmitted
- allows for **frequency division multiplexing (FDM)**
  - multiple msg can be transmitted at the same time at different frequencies
- *analog* carrier signal is modulated by a discrete signal
  - **modulation uses DAC, demod uses ADC**

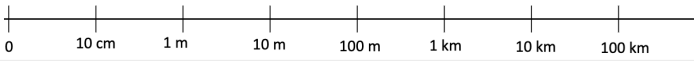
Protocols

- Wi-Fi, Bluetooth/BLE, NFC, Zigbee, LoRaWAN, Z-Wave...
  - short vs long distance
  - high vs low speeds



Protocol	Range	Data Rate	Latency	Power	Maximum devices
Bluetooth	~10-100m	1-3 Mbps	~100ms	High	7 per controller
BLE	~10-50m	125 kbps - 2 Mbps	~3-6ms	Medium	100s (using BLE mesh)
Wi-Fi	~30-100m	10 Mbps - 10 Gbps	~1-10ms	Very High	255 per access point
Zigbee	~10-100m	250 kbps	~30ms	Medium	65,000+
Z-Wave	~30-100m	9.6 - 100 kbps	~50-100ms	Medium	232
NFC	~10 cm	106 - 424 kbps	~50ms	Low	2
LoRa	~2-15 km	0.3 - 50 kbps	Seconds	Low	1,000s

Protocol	Bluetooth	BLE	Wi-Fi	Zigbee	Z-Wave	NFC	LoRa
Range	~10-100m	~10-50m	~30-100m	~10-100m	~30-100m	~10 cm	~2-15 km



Bluetooth

- short range (10m - 100m)
  - controller-device
  - 1-3Mbps
- frequencies
  - 2.4 GHz ~ 2.48 GHz
  - 79 channels, each 1MHz bandwidth
- uses **Frequency Hopping Spread Spectrum** (FH-SS)
  - breaks data into packets, sends each one 1/79 channels
  - spread data *across many frequencies* avoids interference
  - FH-SS performs 1600 hops per second

Class	Max Transmit Power	Typical Range	Power Consumption
Class 1	100 mW (20 dBm)	~100 meters	High
Class 2	2.5 mW (4 dBm)	~10 meters	Medium
Class 3	1 mW (0 dBm)	~1 meter	Low

- designed for cont. data transmission
  - not good at bursts (common in sensor)
- BLE introduces sleep mode, wake up at transfer

Parameter	Bluetooth Classic	BLE
Typical packet size	150-250 B	20-27 B
Connection latency	~100 ms	~3-6 ms
Frequency hopping	79 channels (1 MHz each)	40 channels (2 MHz each)
Peak current	~30-100 mA	~5-15 mA
Idle Mode	~1-10 mA	~10-100 µA
Deep Sleep Mode	~1-2 mA	~1-5 µA
Average Power Consumption	1-50 mW	0.01-0.5 mW