Communication

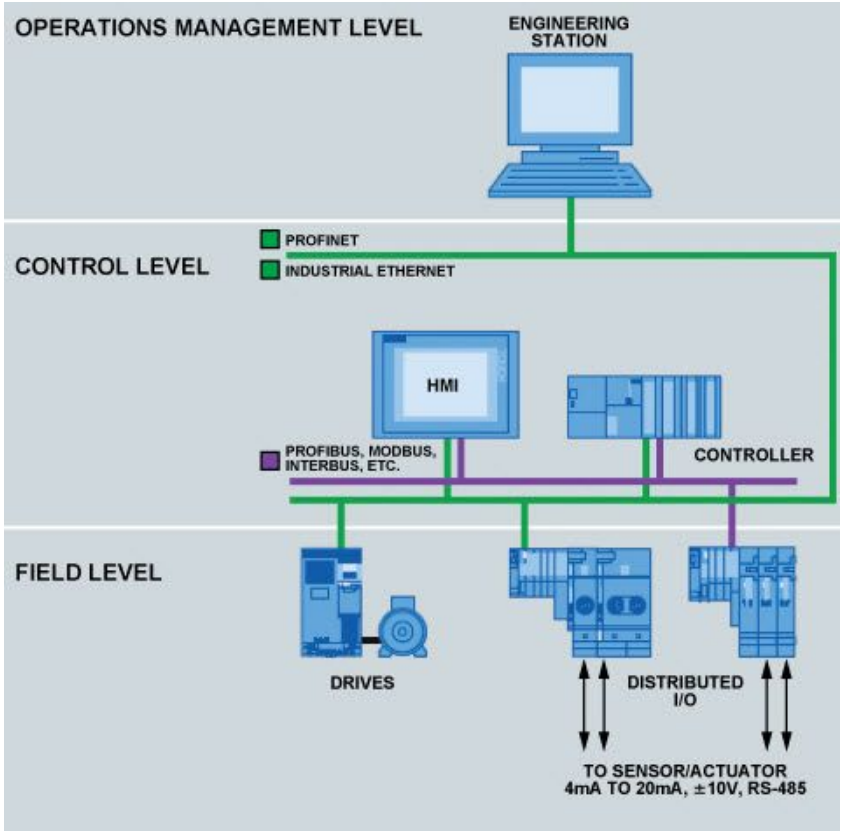
Nimal Skandhakumar

Faculty of Technology
University of Sri Jayewardenepura

2019

Hierarchical levels of communication

- Device Level/Field Level:
  - This lowest level consists of field devices such as sensors and actuators of processes and machines.
- Control Level:
  - This level consists of controllers, distributed control units, and computer systems.
- Information Level/Operations Level:
  - This is the top level of the industrial automation system which gathers the information from its lower level i.e., control level.



Data communication in control systems

Control systems need data communication to communicate:

- Between controllers and plants (controlled devices)
- Between controllers and sensors
- Between controllers and other related controllers
- Between controllers and systems managers/monitors

Communication concepts

- Point-to-point networks
  - Each node connected to every node
  - Simple and reliable
  - Dedicated links make it easy to meet real-time deadlines
  - Costly due to many wires required
- Shared media networks
  - Nodes are connected via bus or other topologies
  - Less wiring and hence cheaper
  - Easily extendable by adding new nodes to network
  - Complex network protocol

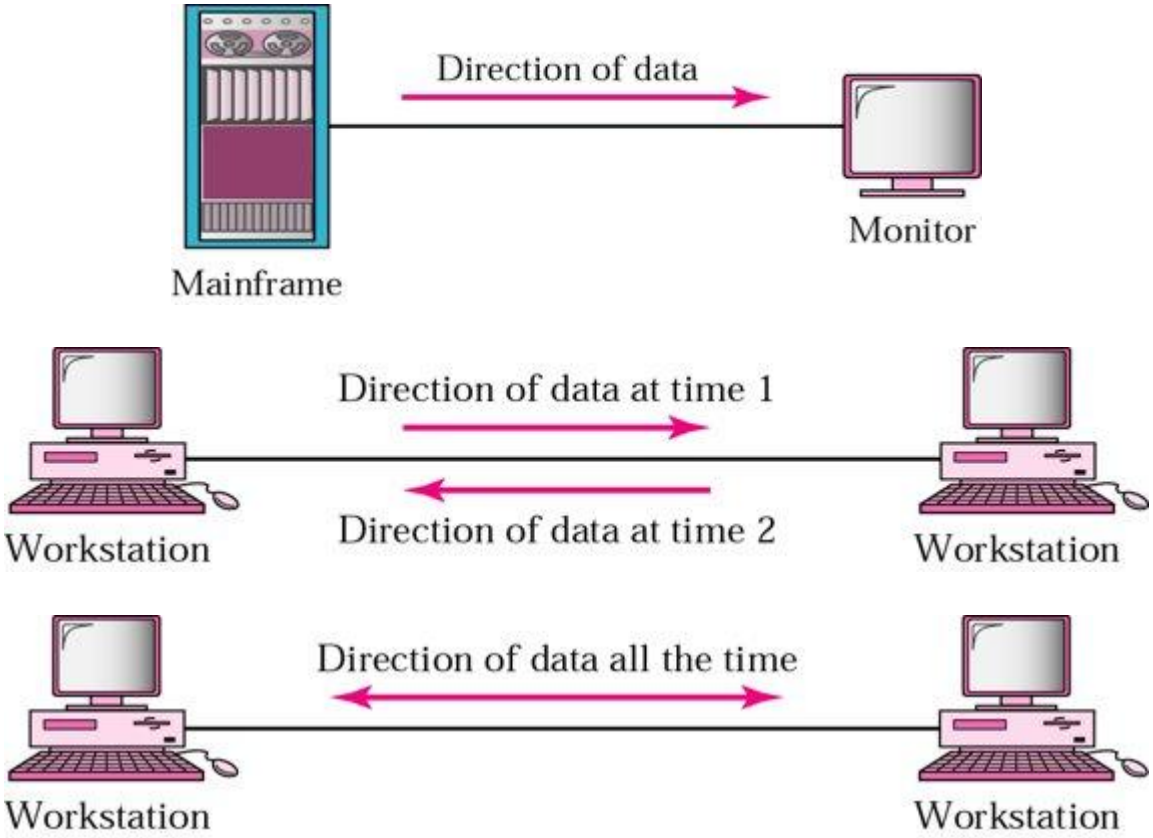
Communication concepts

- Event based communication
  - E.g. alarm, user inputs, requests for data from other systems
  - Efficient use of network resource
  - Needs high reliability (event based data comes once in a while)
  - May need acknowledgement
  - Hard to predict delay in case of overloading (e.g. alarm)
- State based communication
  - E.g. regular sensor readings
  - Messages sent at predefined, regular intervals.
  - Less efficient due to regular occupation of communication channel by nodes.
  - More tolerance. Missed message may be ok, since the next one will be coming.

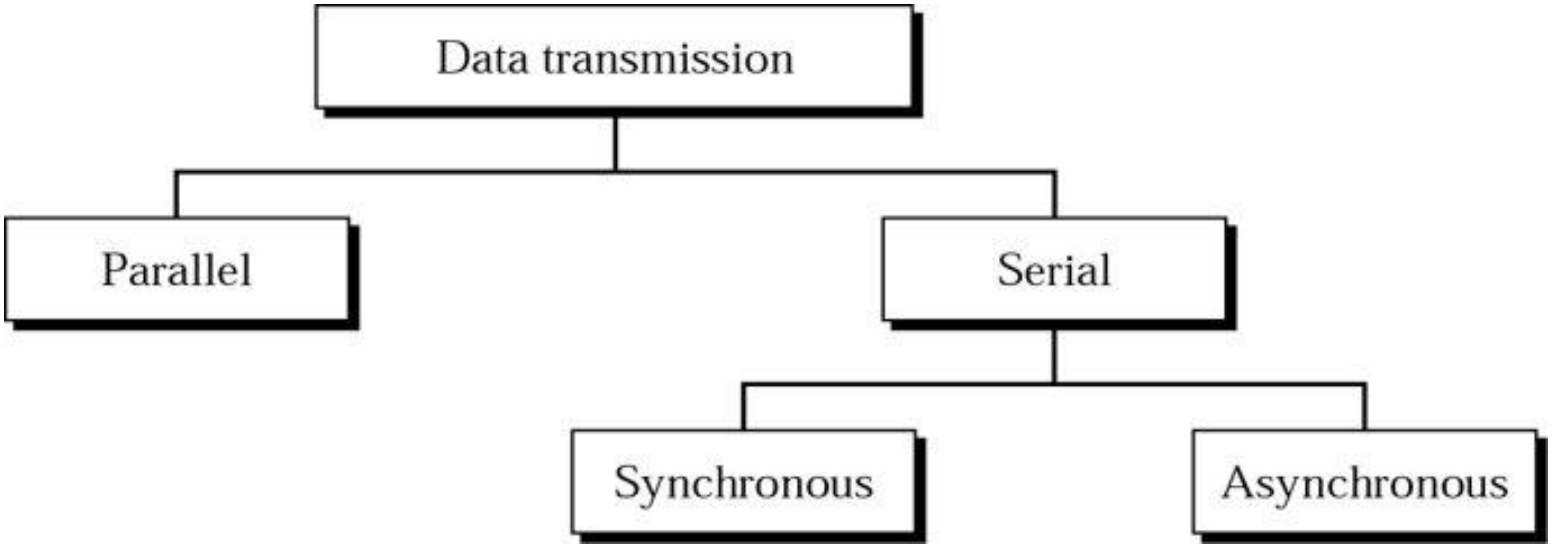
Basic communication methods

- It is essential to understand some of the basic communication methods that can be used to interconnect control systems.
- Characteristics of communication methods:
  - Simplex, Duplex & Semi Duplex
  - Serial Vs Parallel
  - Synchronous Vs Asynchronous
  - Data Throughput

Simplex, half-duplex, full-duplex

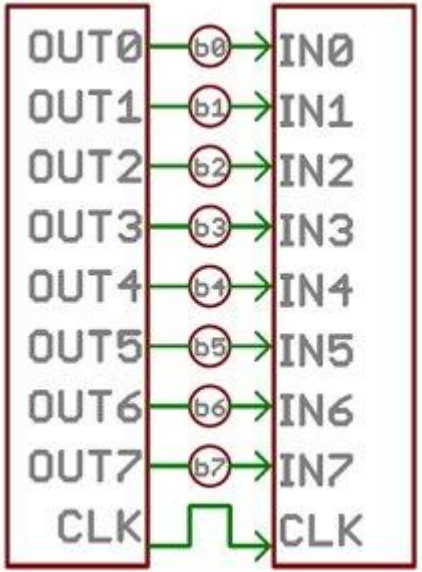


Types of data transfer



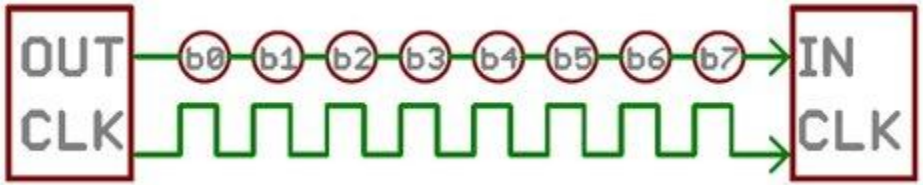
Parallel communication

- Parallel interfaces transfer multiple bits at the same time.
- They usually require buses of data - transmitting across eight, sixteen, or more wires.
- It's fast, straightforward, and relatively easy to implement.
- But it requires many more input/output (I/O) lines.
- High data throughput with short distances
- Typically used when connecting devices on same IC or same circuit board
- Higher cost, bulky

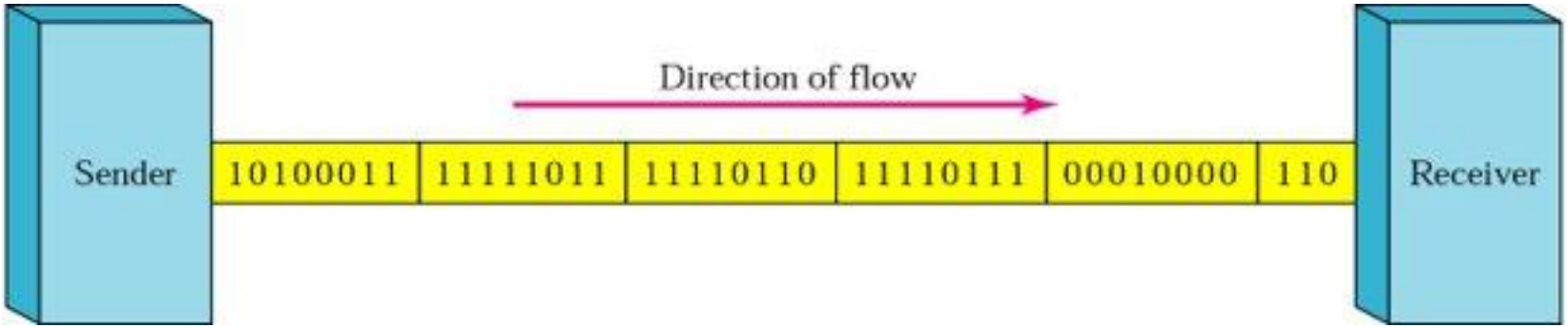


Serial communication

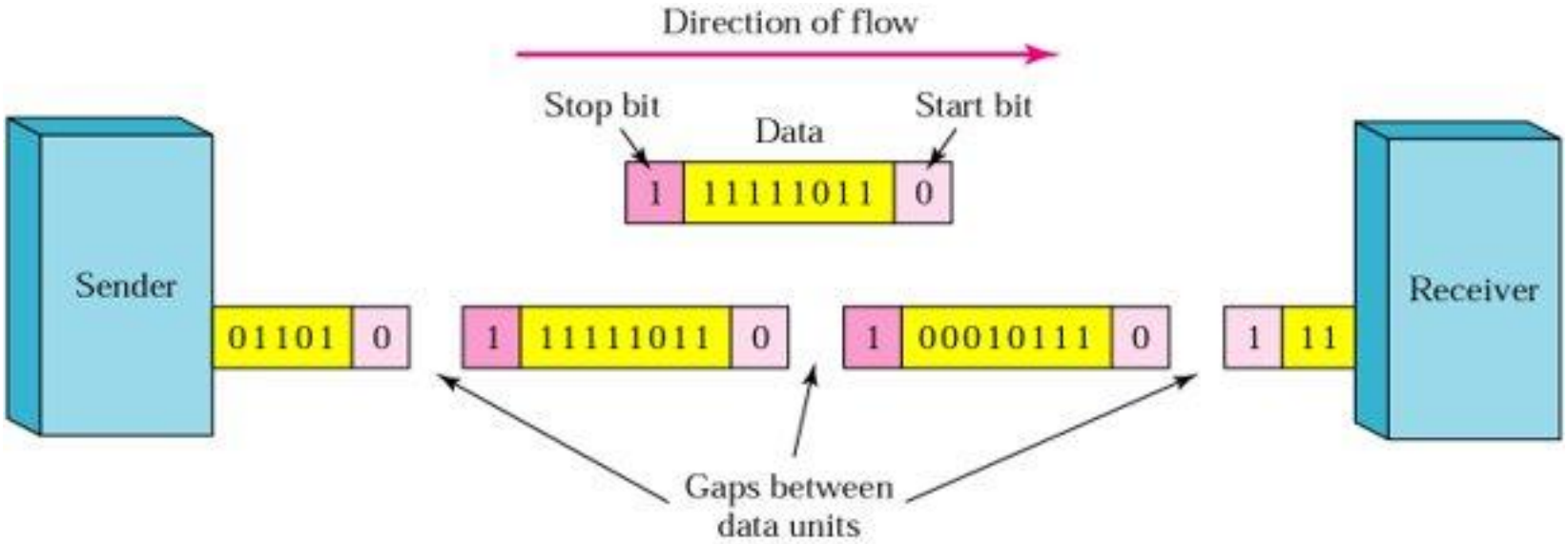
- Serial communication is the process of sending/receiving data in one bit at a time.
- Serial interfaces stream their data, one single bit at a time.
- These interfaces can operate on as little as one wire, usually never more than four.
- Words transmitted one bit at a time
- Higher data throughput with long distances
- Cheaper, less bulky



Synchronous serial transfer



Asynchronous serial transfer



Advantages of serial over parallel

- A serial connection requires fewer interconnecting cables (e.g. wires/fibers) and hence occupies less space.
  - The extra space allows for better isolation of the channel from its surroundings.
  - Crosstalk is not a much significant issue, because there are fewer conductors in proximity.
- In many cases, serial is a better option because it is cheaper to implement.
  - Many devices and sensors relevant to control systems have serial interfaces, as opposed to parallel ones, so that they have fewer pins and are therefore less expensive.

Serial communication protocols

- There are various protocols that can be used with digital control systems for serial communication.
  - UART (Universal Asynchronous Receiver/Transmitter)
  - SPI (Serial Peripheral Interface)
  - I2C (Inter-Integrated Circuits)
  - CAN (Controller Area Network)
  - USB (Universal Serial Bus)
  - 1-wire

https://www.deviceplus.com/how-tos/arduino-guide/arduino-communication-protocols-tutorial/
https://www.embedded.com/design/connectivity/4023975/Serial-Protocols-Compared

Wireless communication

- Infrared (IR)
  - Electronic wave frequencies just below visible light spectrum
  - Diode emits infrared light to generate signal
  - Infrared transistor detects signal, conducts when exposed to infrared light
  - Cheap to build
  - Need line of sight, limited range
- Radio frequency (RF)
  - Electromagnetic wave frequencies in radio spectrum
  - Analog circuitry and antenna needed on both sides of transmission
  - Line of sight not needed, transmitter power determines range

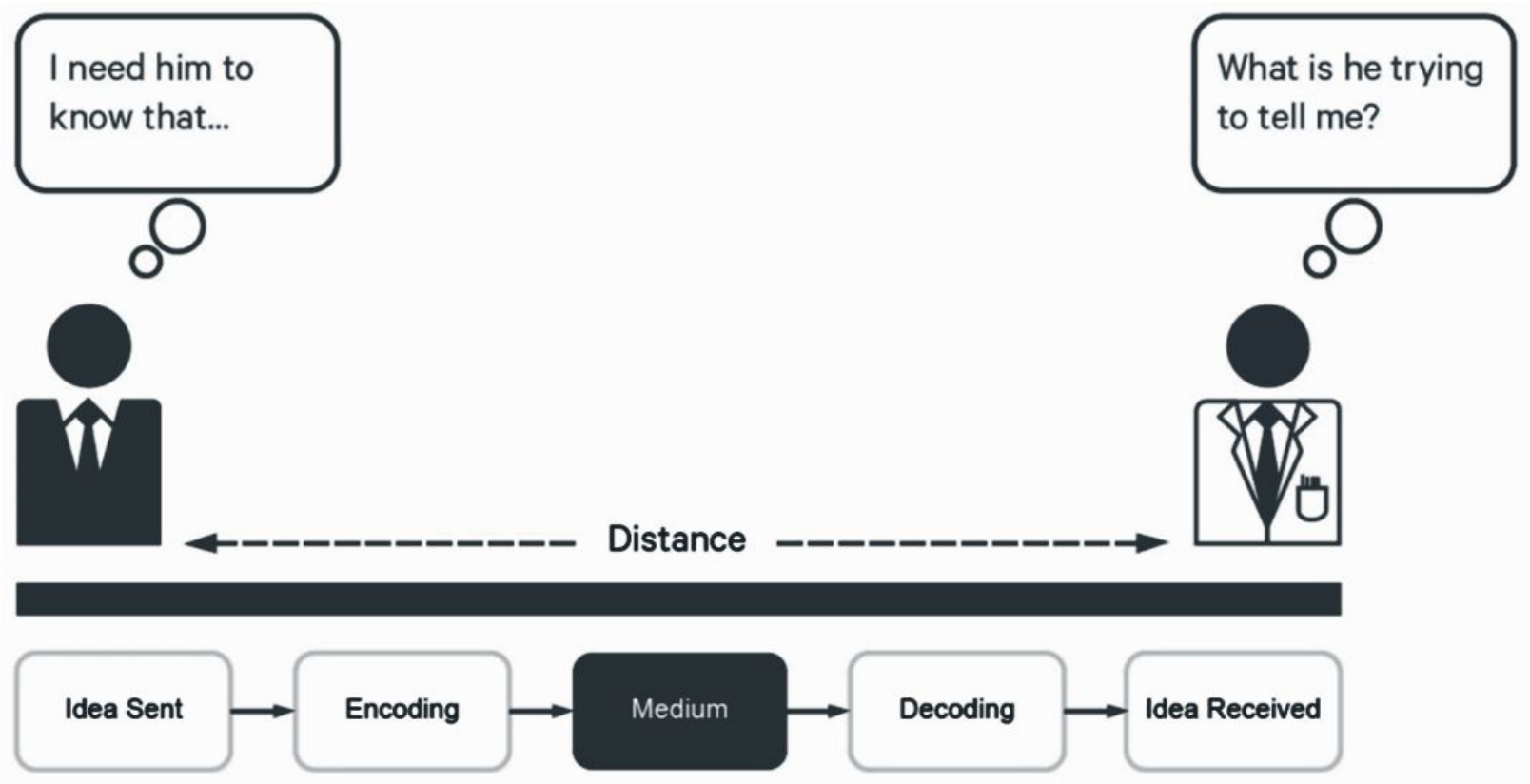
Error detection and correction

- Often part of bus protocol
- Error detection:
  - ability of receiver to detect errors during transmission
- Error correction:
  - ability of receiver and transmitter to cooperate to correct problem
  - typically done by acknowledgement/retransmission protocol

- Bit error:
  - single bit is inverted
- Burst of bit error:
  - consecutive bits received incorrectly
- Parity:
  - extra bit sent with word used for error detection
- Checksum:
  - extra word sent with data packet of multiple words
  - e.g., extra word contains XOR sum of all data words in packet

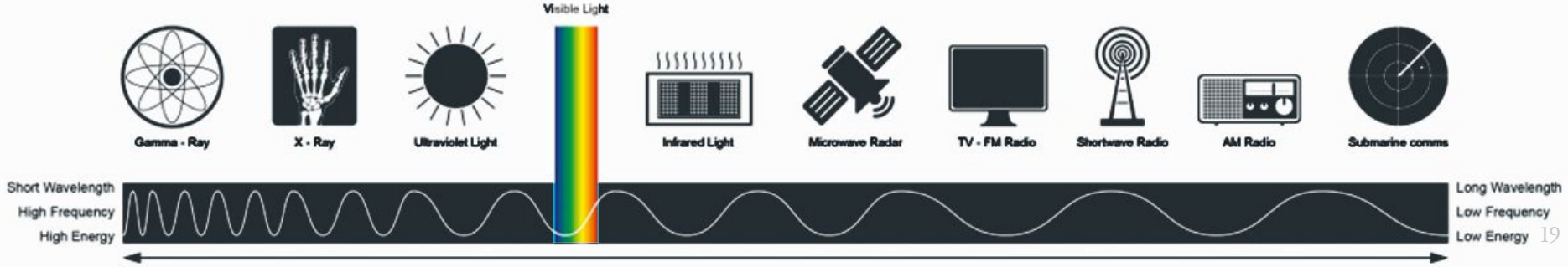
Fundamentals of Radio Communications

What is Communication?



What is a radio wave?

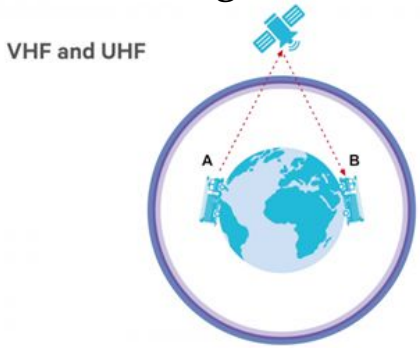
- Energy is pumped into the atmosphere to compress molecules together.
- The high point of the energy which squashes the molecules closer together is called the crest of the wave.
- The low point of the energy, when the molecules are far apart, is called the trough of the wave.
- The number of waves passing by in a single second that would be the frequency.
- The distance between the same positions on two waves is the wavelength.

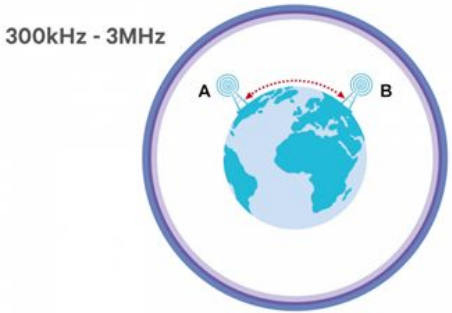


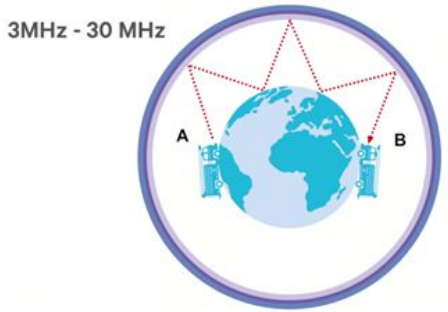
Propagation

Radio waves propagate differently depending on their wavelength

- Line of sight
  - VHF/UHF bands travels in a straight line
- Curve around the horizon or the curvature of the Earth
  - Lower short wave
- Bounces off a top layer of the atmosphere
  - Higher short wave

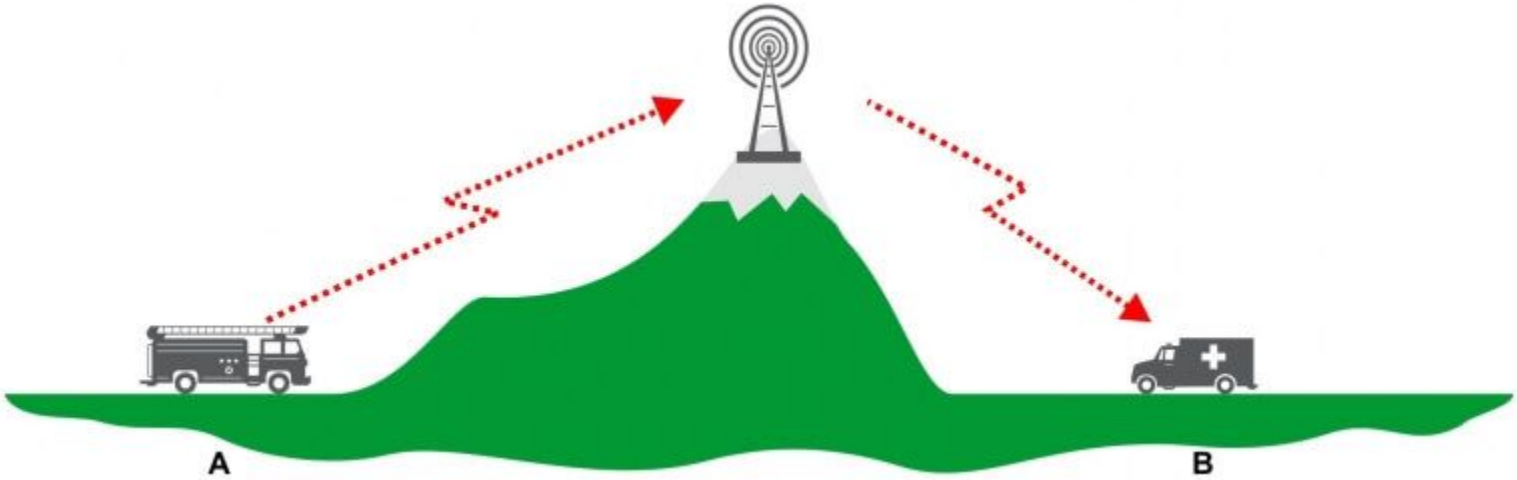






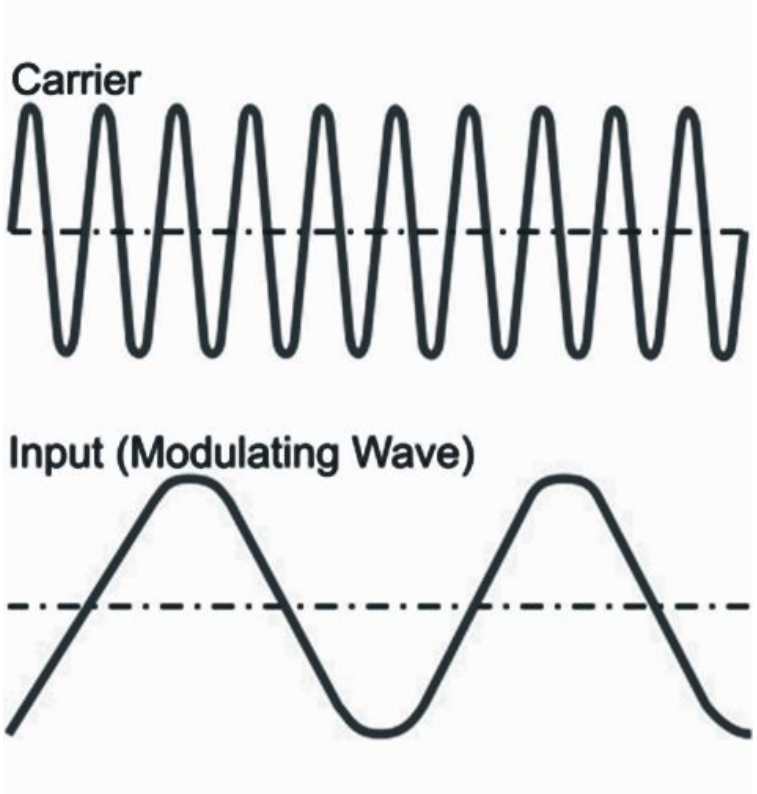
Repeaters

- The repeater needs to receive the frequency that the caller transmitted with.
- Then the repeater re-transmits that same message down to the user on the other side of the mountain.
- It works similarly to the satellite discussed with VHF radio propagation.



Modulation

- A carrier wave is a pure wave of constant frequency, like a sine wave.
- To include speech information or data information, another wave needs to be imposed, called an input signal, on top of the carrier wave.
- This process of imposing an input signal onto a carrier wave is called modulation.



Modulation

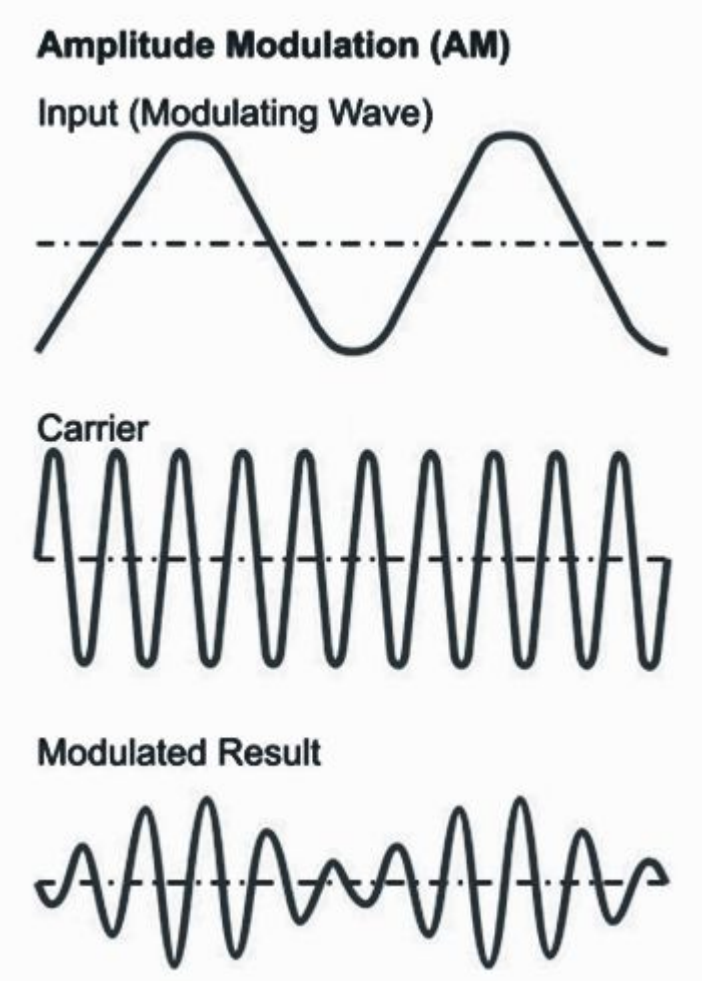
- Why have carrier waves in modulation at all? Why not simply use the input signal directly?
- The input signals could be carried (without a carrier wave) by very low frequency electromagnetic waves.
- The problem, however, is that this will need quite a bit of amplification in order to transmit those very low frequencies.
- The input signals themselves do not have much power and need a fairly large antenna in order to transmit the information.

Modulation

- Modulation changes the shape of a carrier wave to somehow encode the speech or data information that we were interested in carrying.
- There are different strategies for modulating the carrier wave based on the basic properties of any wave:
    1. Amplitude – the height of the wave
    2. Frequency – a number of waves passing through in a given second
    3. Phase – where the phase is at any given moment.

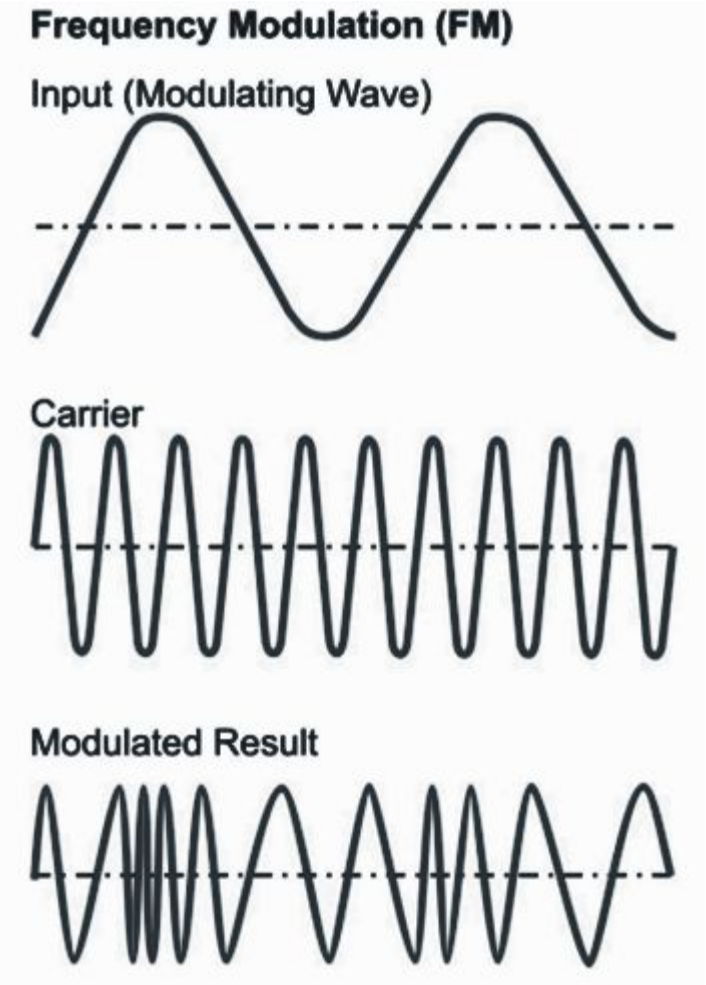
Amplitude Modulation (AM)

- Tweak the height of the carrier.
- If an input signal's height varies with the loudness of a user's voice and then adds this to the carrier.
- The carrier's amplitude will change corresponding to the input signal that's been fed into it.



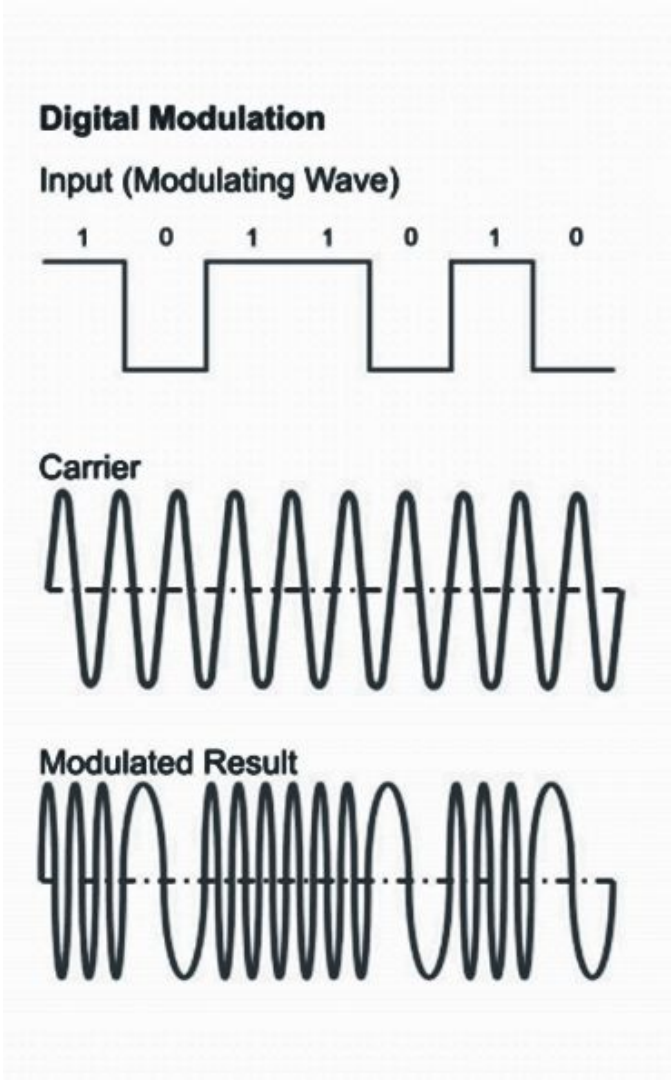
Frequency Modulation (FM)

- Frequency of an input signal can also be changed.
- If this input signal is added to the pure carrier wave, it will thereby change the frequency of the carrier wave.
- In that way, users can use changes of frequency to carry speech information.

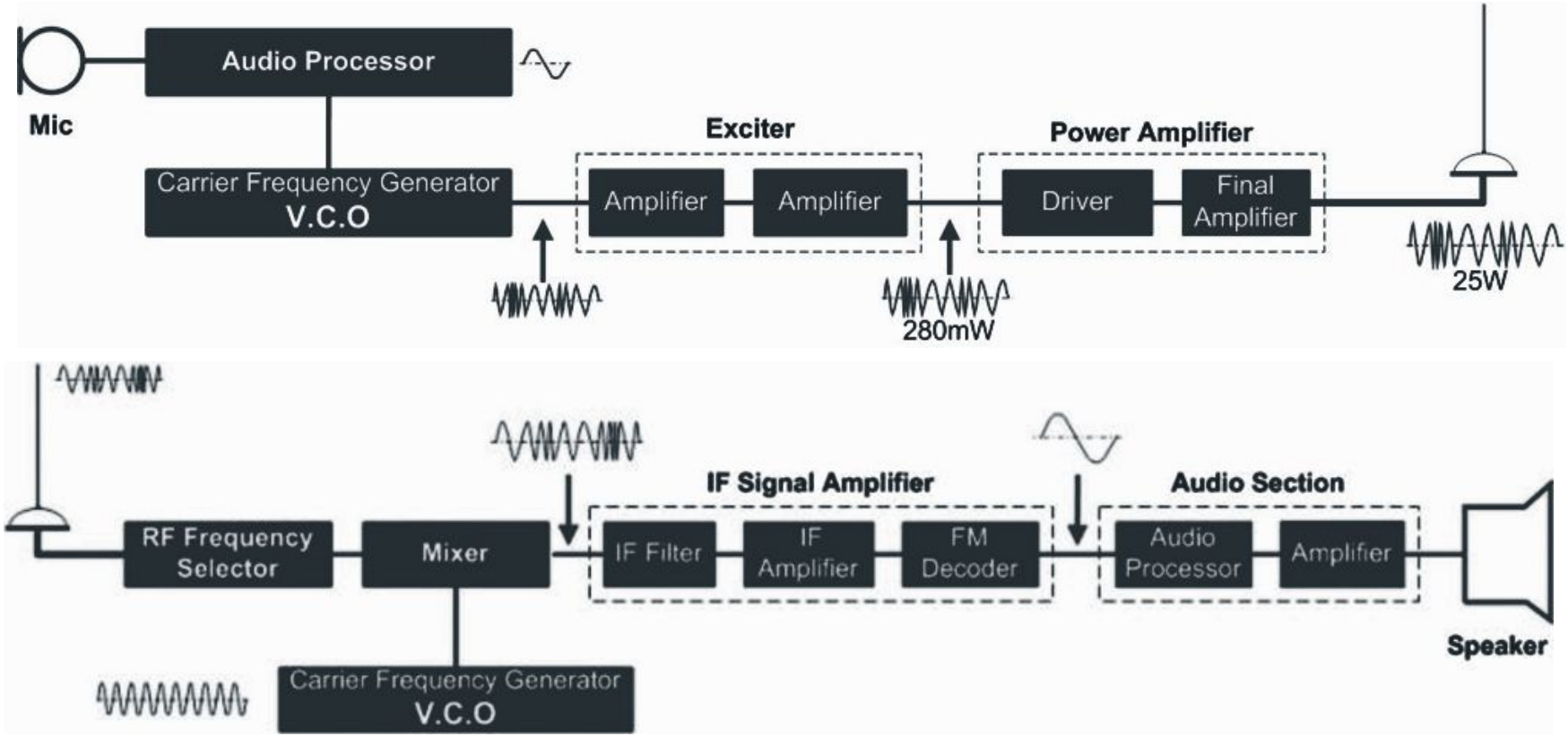


Digital Modulation

- Modulation schemes can be analog or digital.
- In digital modulation scheme, voice is sampled at some rate and then compressed and turned into a bit stream.
- This in turn is created into a particular kind of wave which is then superimposed on the carrier.



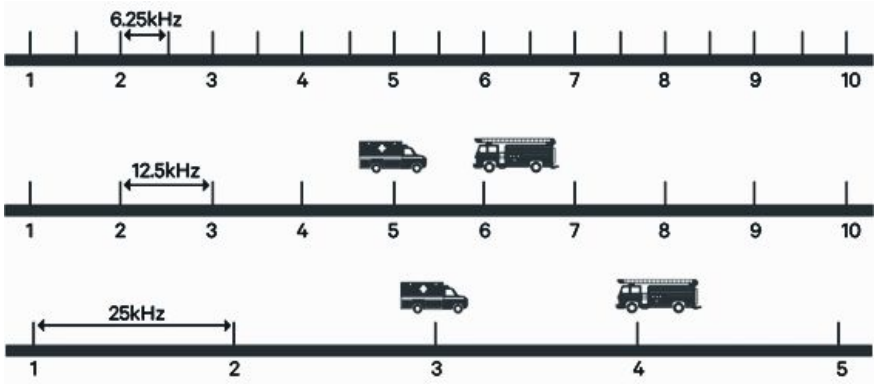
How does an FM Transceiver work?



Channel Spacing

- Radio spectrum is very limited.
- Every user of radio spectrum needs a “pipeline” or block of pipelines in order to communicate over.
- These pipelines are called channels and they are differentiated by their frequency.

- **Wideband** channels occupy 25 kilohertz of radio spectrum
- **Narrowband** channel is half that size and occupies 12.5 kilohertz
- **Ultra narrowband** is half the size again at 6.25 kilohertz



Multiple Access

- An RF channel occupies a certain amount of radio spectrum.
- How to efficiently use of this small?
- There are two different techniques:
  - Frequency division multiple access (FDMA)
    - There is only one conversation and one user at a time per radio channel. More radio channels require more frequencies.
  - Time division multiple access (TDMA)
    - It allows two users to occupy the same channel at what appears to them to be the same time.
    - This process is so fast that each user thinks they have exclusive use of the frequency channel.