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Review of Basics of Electrical / Electronic Communication

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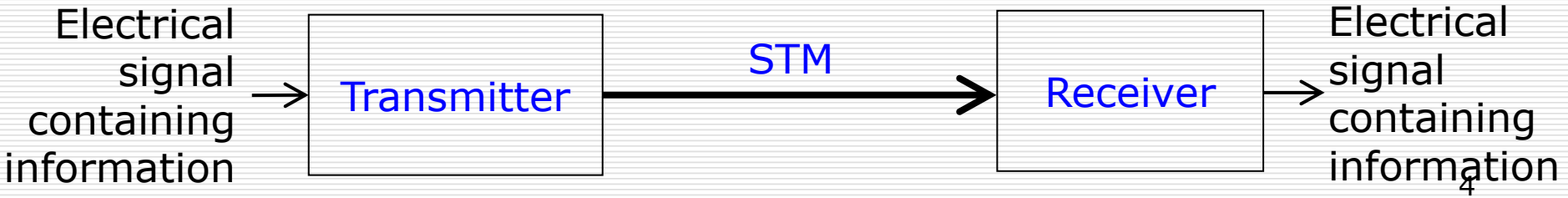
What is Electrical/ Electronic Communication?

- In present times, information is mostly communicated by electrical/electronic means.
- These communications are referred to as electrical or electronic communications, because
  a) the signal used for transmitting the information is some form of electrical signal or an electromagnetic wave, and
  b) the signal transmitting and receiving devices used are electronic.
- To use electrical/electronic communication, the information needs to be available in the form of an electrical signal.
- If the information is not in the form of an electrical signal, then it has to be converted into an electrical signal before electrical/electronic communication can be taken up.

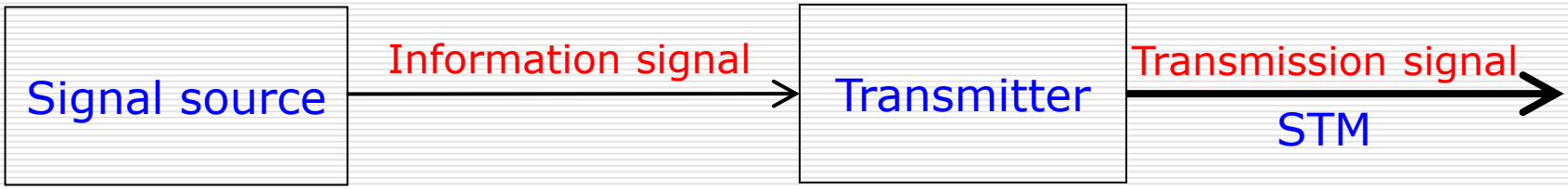
Basic Communication System

- A basic electrical/electronic communication system is shown below.
- Input to the system at the sending end is an electrical signal (generally a small voltage or sometimes a small current) containing the information to be communicated or transmitted from one point to the other.
- Output of the system at the receiving end is expected to be a similar electrical signal containing **exactly the same information** as was sent from the sending end.
- The basic system as shown is comprised of three components:
  a) Transmitter
  b) Receiver
  c) Signal transmission medium



Transmitter

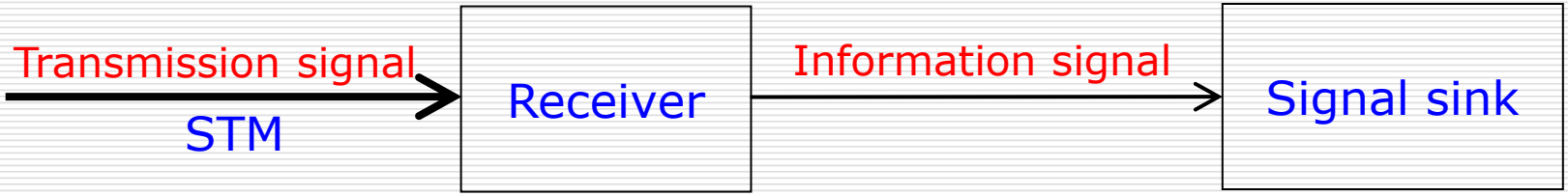
- The information signal (an electrical signal containing the information to be sent to a distant point) is not generally suitable as it is for transmission over long distances.
- The transmitter takes in this information signal from the signal source and converts it into another signal (an electrical signal or an electro-magnetic wave) suitable for long distance transmission over the given signal transmission medium (STM)), and called as transmission signal.
- This is illustrated in the figure below.



- Some examples of signal source:
  a) Microphone for voice communication
  b) Smart sensor for remote measurement or remote monitoring
  c) Data memory or computer keyboard for data communication.

Receiver

- The receiver takes in the transmission signal from the STM and converts it back to information signal by extracting the information from the former and placing the same on to the latter.
- The output information signal from the receiver is expected to contain the same information as was there in the original information signal, either in the same form or in a different form. For example, the original information may be in analog form, whereas now it may be in digital form.
- This information signal is delivered to an appropriate signal sink.



- Examples of signal sink:
  a) Speaker in case of voice communication
  b) Display device in case of remote measurement/ monitoring
  c) Data storage or video monitor in case of data communication.

Transmitter Functions

- Transmitter may perform some or all the functions listed below as per requirement:
  1. Modulation
  2. Amplification of information signal before using it as modulating signal
  3. Amplification of modulated carrier before transmission
  4. Filtering the information signal for removal of noise
  5. Filtering the modulated carrier for limiting its band-width before transmission
  6. Analog to digital conversion of information signal, if the information signal is in analog form while digital communication is desired for getting better performance.
  7. Multiplexing in a multi-channel communication system.
- Modulation is the most important function of a transmitter.

Receiver Functions

- Receiver may perform some or all the functions listed below as per requirement:
  1. Demodulation
  2. Amplification of the signal received by it before demodulating the same
  3. Amplification of the signal after demodulation
  4. Filtering the signals for removal of noise
  5. Digital to analog conversion, if the demodulator output is in digital form while the signal sink (end device) works with analog input. For example, speaker in case of voice communication.
  6. De-multiplexing in a multi-channel communication system.
- Demodulation is the most important function of a receiver.

Signal Transmission Media (STM)

- Three types of media (or links or path-ways) are used for transmission of signals from transmitter to the receiver:
  a. Metal wire link
  b. Radio link
  c. Optical fibre link
- The transmission signals used with these STM are as under:
  a. Metal wire link: Electrical current or voltage signal
  b. Radio link: High-frequency electromagnetic waves, popularly called as radio waves. These radio waves do not require any physical medium, and can travel through space between the transmitter and the receiver.
  c. Optical fibre link: Optical beams of wavelengths falling in the infra-red region of light, that is, infra-red optical beam.
- (a) and (c) are physical media, whereas (b) is a non-physical medium.

Metal Wire Link (1)

- A pair of copper wires (or conductors) provides a closed-circuit path for the flow of an electrical signal from transmitter to receiver.
- The electrical signal, in most of communication systems, is a voltage signal.
- In some communication systems, it is a current signal.
- Three types of copper cables are used for signal transmission:
  a. Unshielded twisted pair (UTP) cable
  b. Shielded twisted pair (STP) cable
  c. Coaxial cable
- UTP cables do not have a metallic shield and, therefore, are suitable for only low frequency signal transmission.
- UTP cables can have:
  a. Single twisted pair of insulated copper conductors: Meant to carry one signal only; or
  b. Multiple twisted pairs of insulated copper conductors: Can carry several signals (each twisted pair is meant to carry one signal).

Metal Wire Link (2)

- STP cables have a metallic shield that encloses twisted pairs of conductors and are, therefore, capable of transmitting signals of relatively higher frequencies with minimal interference with any close-by parallel circuits.
- Like UTP cables, the STP cables can have:
  a. Single twisted pair of insulated copper conductors: Meant to carry one signal only; or
  b. Multiple twisted pairs of insulated copper conductors: Can carry several signals (each twisted pair is meant to carry one signal).
- Coaxial cable has an inner conductor, generally a solid insulated conductor of copper, and a pipe-shaped woven-copper conductor with the same axis. The latter acts as a shield as well as the outer conductor providing a return path to the current carried by the inner conductor.
- The coaxial cable can transmit signals of still higher frequencies with minimal interference and nearly zero energy loss by radiation.

Radio Link

- The antenna of the transmitter converts high-frequency modulated carrier (which is an electrical signal) into corresponding high-frequency electromagnetic waves, called as radio waves.
- The space between the antennas of transmitter and receiver provides a radio link or path between the transmitter and the receiver by allowing the propagation of these radio waves.
- The antenna of the receiver catches a fraction of the energy of these radio waves. It converts the high-frequency electromagnetic waves back into corresponding electrical signal.
- The frequencies used for various types of radio communication range from 500 kHz to 100 GHz.
- Frequencies of 1 GHz and above are conventionally called as microwave frequencies.

Optical Fibre Link

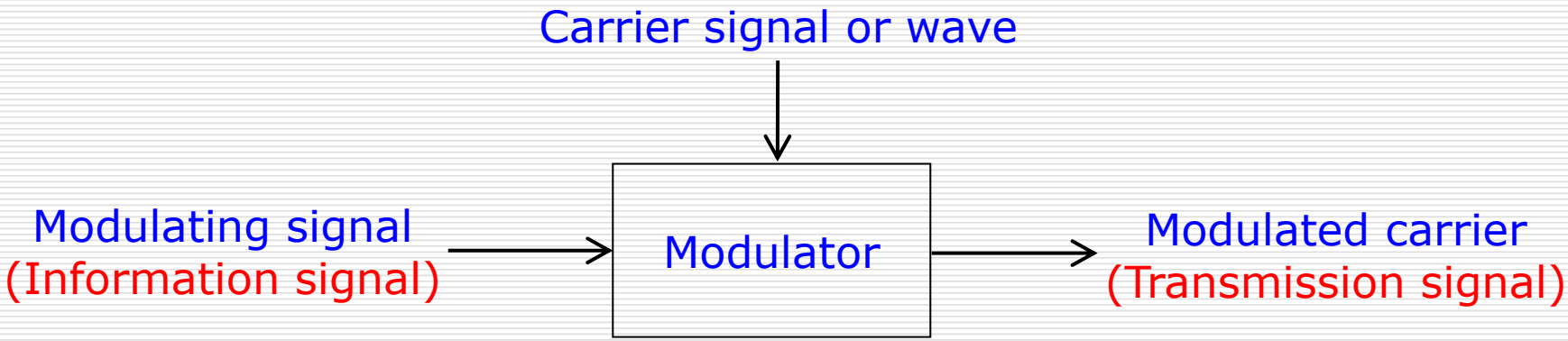
- An optical fibre, acting as a waveguide for the propagation of an optical beam (in infra-red wavelength band) generated by the transmitter, delivers the same to the receiver.
- It acts as a signal transmission link (or path) for the optical-pulse signal between the transmitter and the receiver.
- An optical fibre cable (OFC) can have:
  a. Single optical fibre: It can carry one optical beam; or
  b. Multiple optical fibres: Each fibre is used for transmitting a separate beam.
- OFCs are of two different types:
  a. **Multi-mode fibre (MMF) cable:** Suitable for low data rates because the large modal-dispersion of MMF distorts the optical pulses at high frequencies**.**
  b. **Single-mode fibre (SMF) cable:** More expensive, but suitable for very high data rates because of near-zero modal dispersion of SMF.

Modulation : What and Why?

- As mentioned earlier (under Transmitter), the information signal is generally not suitable for transmission over long distances, and hence it needs to converted into another signal suitable for **long distance** transmission over the **given signal transmission medium (STM).**
- It means that the information contained in the information signal must be **truthfully transferred** to a second signal chosen to "carry" the information from transmitter to receiver. The process used is known as modulation and the second signal as the carrier signal.
- Defined in simple terms, "modulation consists in modifying some characteristic (or attribute) of a carrier signal (or carrier wave) in relation to the instantaneous value of the information signal, which takes on the role of the modulating signal".
- The electronic circuit used for carrying out modulation is called as modulator.

Modulator Schematic

- As mentioned earlier, **the electronic circuit used for carrying out modulation is called as modulator**.
- Its functional schematic is given below:



- The primary input to the modulator is the modulating signal, which in the case of a transmitter is the information signal.
- The secondary input is the carrier signal or wave.
- The output is the modulated carrier, which (as it is or after some processing) becomes the transmission signal.

Types of Carrier & Modulating Signal

- The carrier signal or wave can be of one of the following types:
  a) AC carrier wave (sinusoidal carrier)
  b) Pulse carrier wave (pulses)
- The modulating signal can be of one of the following types:
  a) Analog signal
  b) Digital signal
- Thus, modulation will fall into one of the following **four** categories:
  i. **AC analog modulation**: where an AC carrier wave is modulated by an analog modulating signal.
  ii. **Pulse analog modulation**: where a pulse carrier wave is modulated by an analog modulating signal.
  iii. **AC digital modulation**: where an AC carrier wave is modulated by a digital modulating signal.
  iv. **Pulse digital modulation**: where a pulse carrier wave is modulated by a digital modulating signal.

Analog and Digital Communications

- Based on the form of the information signal, the two types of communication are:
  a) Analog communication
  b) Digital communication.
- If the information signal is an analog (continuous) signal, its communication will be called as **analog communication**.
- If the information signal is a digital (discrete) signal or data, its communication will be called as **digital communication**.
- However, the carrier wave in either type of communication may be either AC (sinusoidal) or pulses.

Analog Modulation Methods

- As stated earlier, two categories of **analog modulation** (used for **analog communication**) are:
  - **i. AC analog modulation**: where an AC carrier wave is modulated by an analog modulating signal.
  - **ii. Pulse analog modulation**: where a pulse carrier wave is modulated by an analog modulating signal.
- Methods used for **AC analog modulation**:
  1. Amplitude modulation or AM
  2. Frequency modulation or FM
  3. Phase modulation or PM
- Methods used for **pulse analog modulation**:
  1. Pulse amplitude modulation or PAM
  2. Pulse frequency modulation or PFM
  3. Pulse phase modulation or PPM
  4. Pulse width modulation or PWM

Digital Modulation Methods

- As stated earlier, two categories of **digital modulation** (used for **digital communication**) are:
  i. AC digital modulation: where an AC carrier wave is modulated by a digital modulating signal.
  ii. Pulse digital modulation: where a pulse carrier wave is modulated by a digital modulating signal.
- Methods used for **AC digital modulation**:
  1. Amplitude shift keying or ASK
  2. Frequency shift keying or FSK
  3. Phase shift keying or PSK
- Methods used for **pulse digital modulation**:
  1. Pulse code modulation or PCM

Analog versus Digital Communication

S. No.	Feature	Analog Communication	Digital Communication
1	Information signal	In analog form	In digital form
2	Transmission signal or carrier signal	Either AC or pulse signal	Either AC or pulse signal
3	Modulation techniques for AC carrier	AM, FM, PM	ASK, FSK, PSK
4	Modulation techniques for pulse carrier	PAM, PFM, PPM, PWM	PCM
5	Tolerance to signal attenuation	Low	High
6	Tolerance to waveform distortion	Low	High
7	Tolerance to noise	Low	High
8	Error detection and correction	Neither detection nor correction is possible	-Both are possible -At least detection is always used

Popularity of Digital Communication

- Digital communication techniques are now used much more widely than analog communication techniques.
- The reasons are given below, and supported by the comparison chart in the previous slide:
  1. Better performance : As per above chart.
  2. Higher reliability : As digital devices and circuits are more reliable than analog devices and circuits.
  3. Cost competitiveness : Cost of digital communication system for a given application is almost the same or even lower than that of analog communication system serving similar purpose.
  4. Wider use of digital devices and gadgets in daily life.

Digital and Data Communications

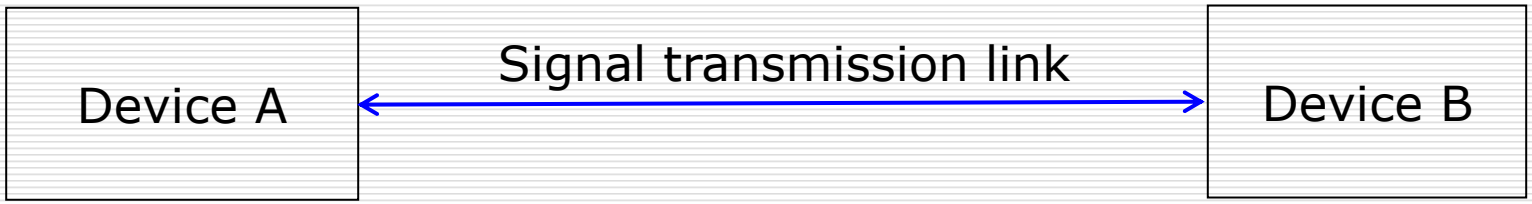
- Sources/ forms of digital information are:
  - **a)** **Digital signals** obtained by A-to-D conversion of analog output signals of analog devices (microphone, analog sensors, analog instruments, analog electronic controllers, etc.)
  - **b)** **Digital signals** produced by digital devices (digital sensors, digital instruments, digital cameras, digital controllers, programmable logic controllers, remote terminal units, etc.)
  - **c)** **Data** generated by digital computers/ data processors.
- As the digital information now-a-days is largely in the form of data, the two terms, namely **digital communication** and **data communication**, are often used interchangeably.

Communication Topologies

- Communication topology means the way the communicating devices are inter-connected (or inter-linked) and the way they communicate with each other.
- Basically, three communication topologies are used:
  - A. Point-to-Point Communication
  - B. Broadcasting
  - C. Communication Network

A- Point-to-Point Communication

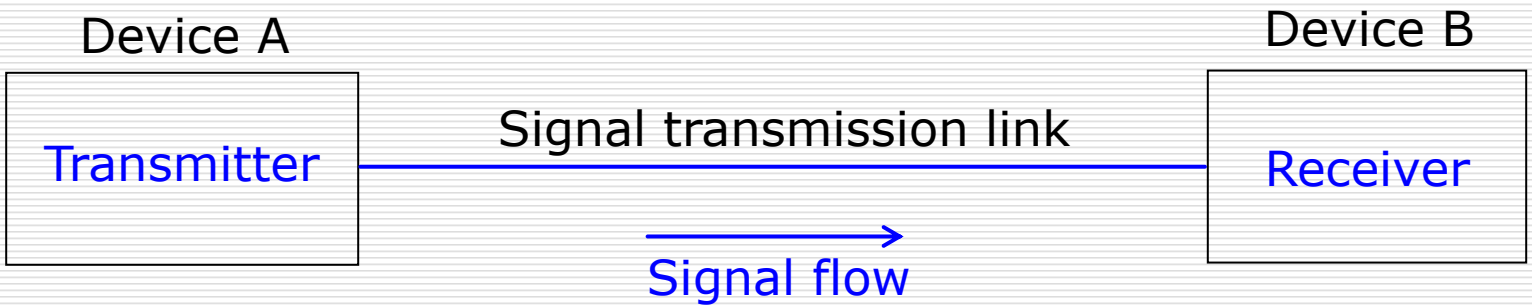
- It means communication between only two devices connected with each other through a **signal transmission link**.
- A basic point-to-point communication system is shown below.



- Communication may take place in one of the following modes:
  a) Simplex mode
  b) Half-duplex mode
  c) Full-duplex mode

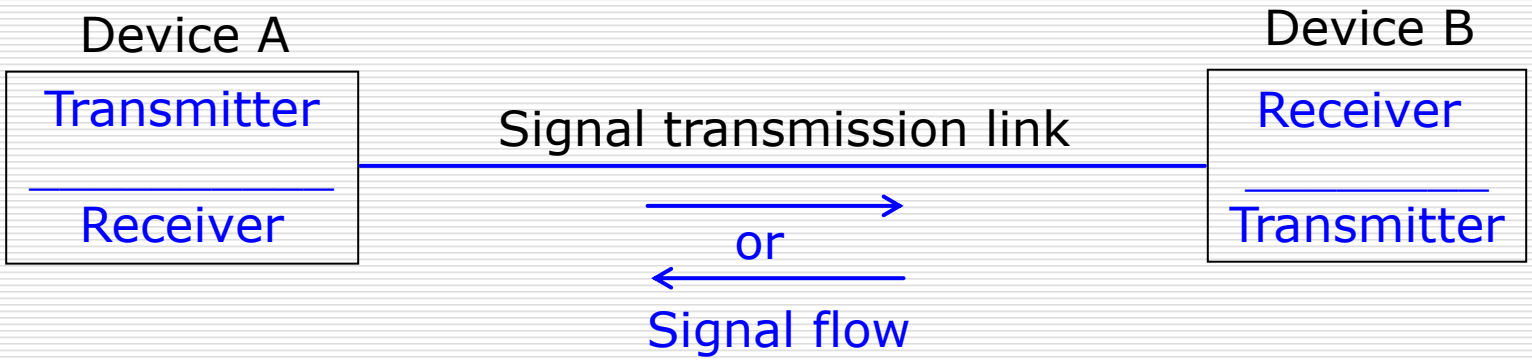
(a) Simplex Communication

- In this mode, communication or signal flow takes place from device A to device B only.
- So, device A should be a transmitter and device B a receiver.



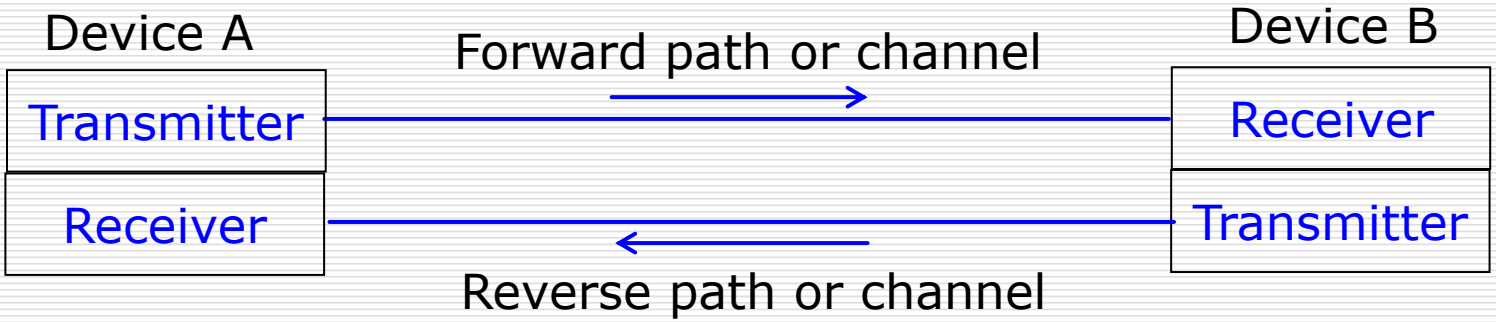
(b) Half-Duplex Communication

- In this mode, communication at any time can take place either from device A to device B or from device B to device A, but not in both directions at the same time.
- In the first case, which may be called as communication in forward direction, device A should work as a transmitter and device B as receiver.
- In the second case, that is for communication in the reverse direction, their roles will need to be reversed, that is device B should work as a transmitter and device A as receiver.
- Only a **single communication channel** is needed.



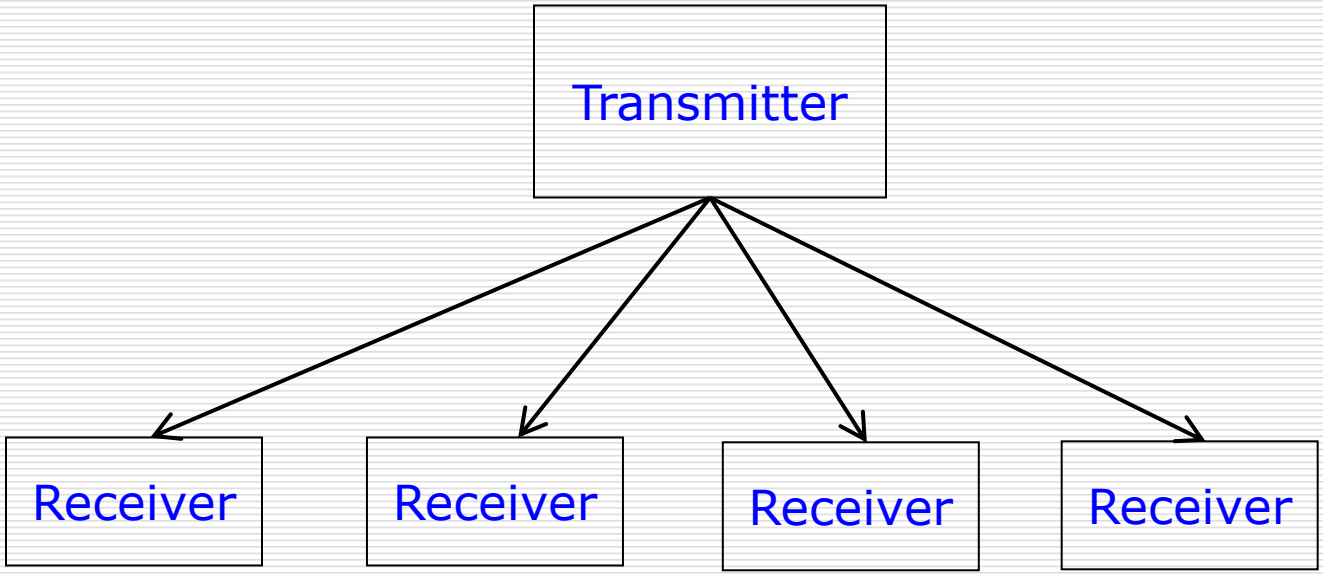
(c) Full-Duplex Communication

- In this mode, communication at any time can take place simultaneously from device A to device B and from device B to device A.
- Both the devices should contain a transmitter as well as a receiver.
- The combined instrument is called as transceiver.
- **Two independent communication channels** are there, a forward communication channel and a reverse communication channel.



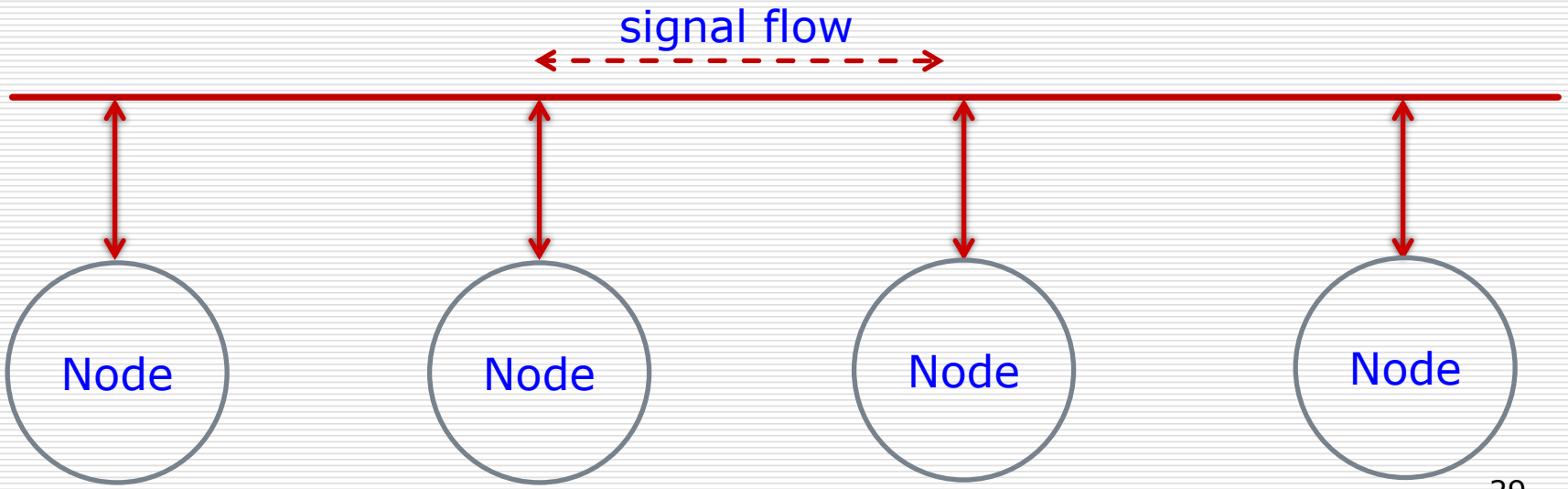
B- Broadcasting

- It means communication from one transmitting device (that is, transmitter) to several or all receiving devices (that is, receivers) to which the transmitting device is connected through signal transmission links.
- The communication is essentially one-way or simplex.
- A basic broadcasting system is shown below.



C- Communication Network

- In this topology, communication is allowed among a number of devices interconnected by a network of signal transmission links.
- Any device in the communication network can communicate with any other device connected in the network.
- The communicating devices connected in the network are called as ***nodes***, which are basically transceivers.
- A communication network of ***bus topology*** (the simplest topology) is shown below.



ISM Frequency Bands

- License-free microwave frequency bands
- Available for **I**ndustrial, **S**cientific and **M**edical purposes only
- Only low-power transmitter (≤1W, say) is allowed
- Three ISM frequency bands are earmarked:
  - ISM-900: A frequency band around 900 MHz
  - ISM-2.4: A frequency band between 2.4 & 2.5 GHz
  - ISM-5: A frequency band a little above 5 GHz
- **ISM-900 Band**: 900-MHz devices are least expensive, but 900-MHz band is not very suitable for LoS transmissions and the signal bandwidth is small.
- **ISM-2.4 Band**: Most widely used ISM band.
- **ISM-5 Band**: Signal bandwidth is large. But as 5-GHz devices are very expensive, this ISM band is not widely used.

