Chapter – 5

Data Acquisition and Transmission

5.1 Analog and Digital Transmission

5.2 Transmission Schemes

Guided/wired schemes:

5.2.1 Fiber optics

Unguided/wireless schemes:

5.2.2 Satellite

5.2.3 Bluetooth

5.3 Data Acquisition System

5.3.1 Data Logger

5.3.2 Data Archiving & Storage

Analog and Digital Signals

- Means by which data are propagated
- Analog
  - Continuously variable
  - Various media
- wire, fiber optic, space
  - Speech bandwidth 100Hz to 7kHz
  - Telephone bandwidth 300Hz to 3400Hz
  - Video bandwidth 4MHz
- Digital
  - binary

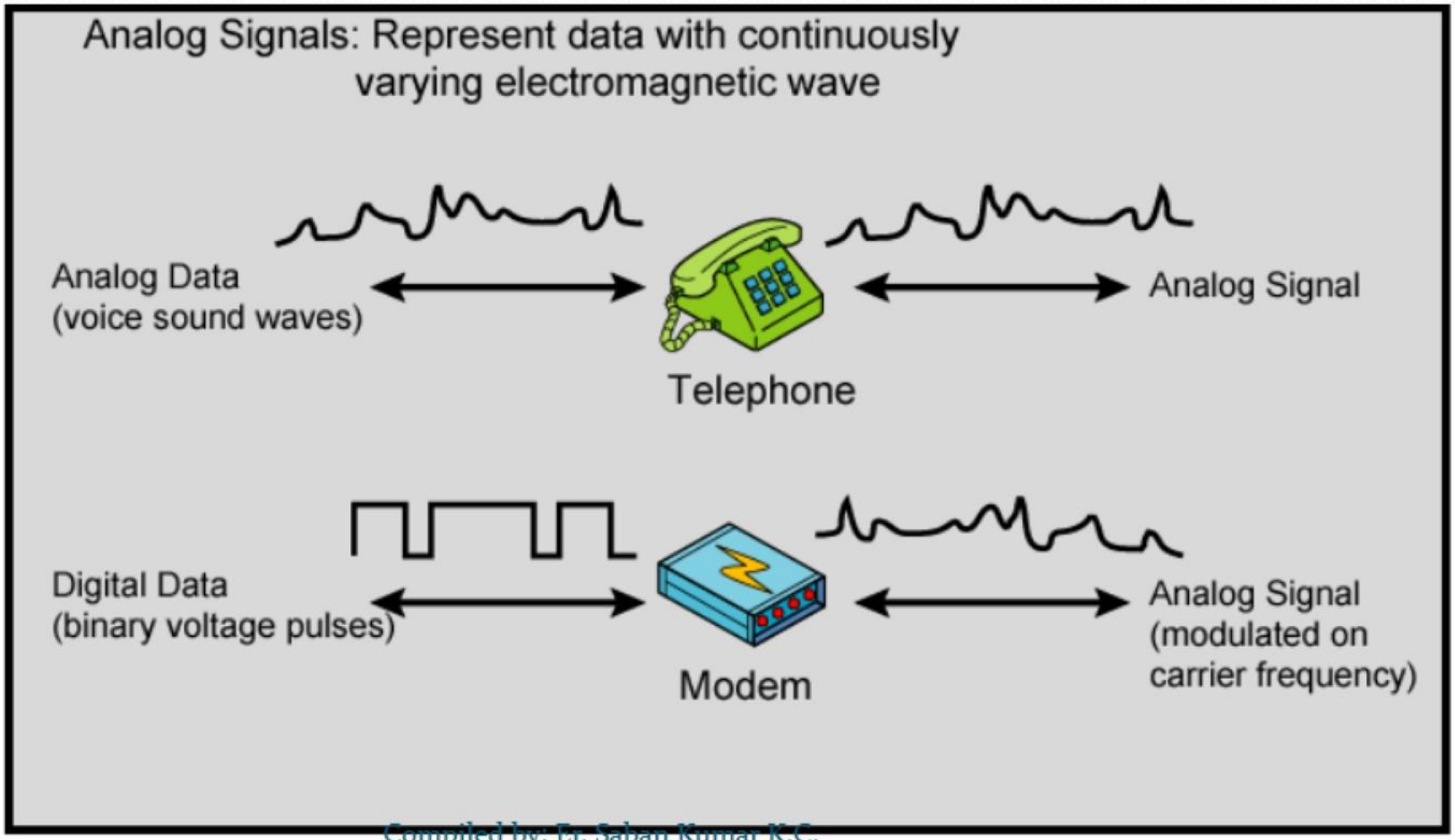
Analog and Digital Data Transmission

- **Data**
  - –Entities that convey meaning
- **Signals**
  - –Electric or electromagnetic representations of data
- **Transmission**
  - –Communication of data by propagation and processing of signals

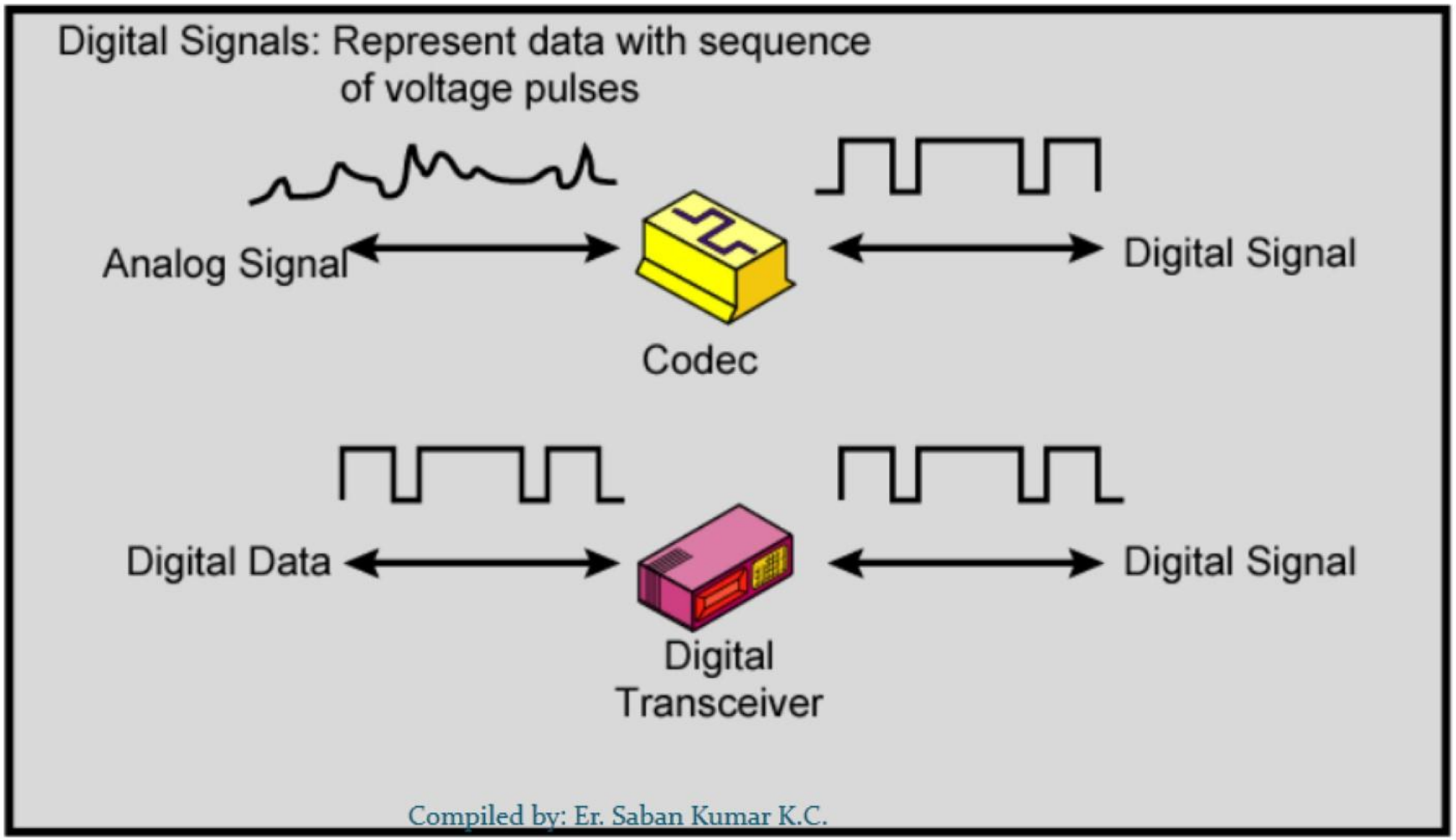
Analog and Digital Data Transmission: Data and Signals

- Usually use *digital signals for digital data* and *analog signals for analog data*
- Can use **analog signal to carry digital data**
  - Modem
- Can use **digital signal to carry analog data**
  - Compact Disc (CD) audio
  - Codec

Analog Signals Carrying Analog and Digital Data



Digital Signals Carrying Analog and Digital Data



5.1 a Analog Transmission/ Communication System

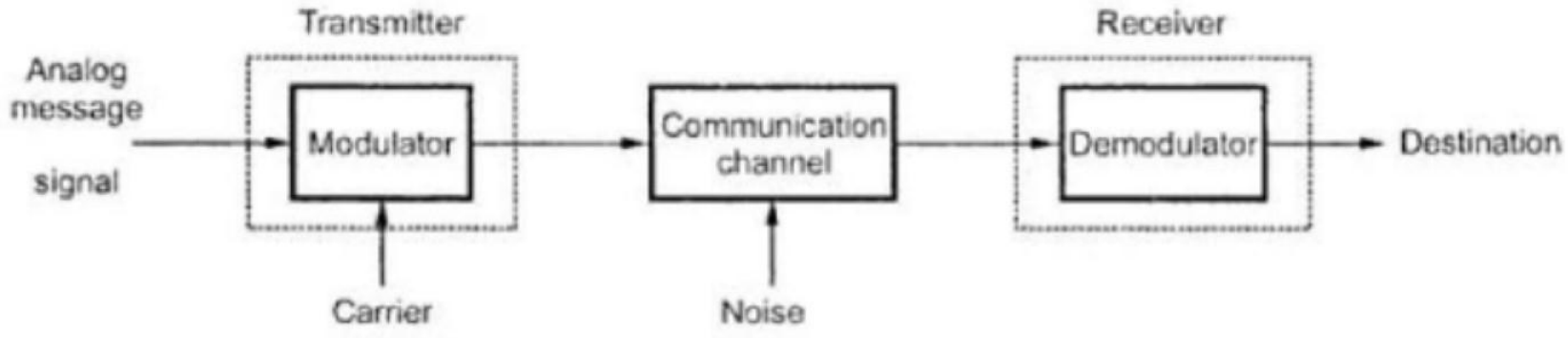


Fig: Analog communication system

- The message signal to be transmitted is analog. This analog message can be obtained from sources such as speech, video shooting etc
- The message signal is then modulated on some carrier frequency by the modulator.
- Presently, all the AM, FM radio transmission and TV transmission is analog communication.
- The analog communication needs lower bandwidth compared to digital communication. But the effect of noise interference is more in case of analog communication

5.1 b Digital Transmission/ Communication System

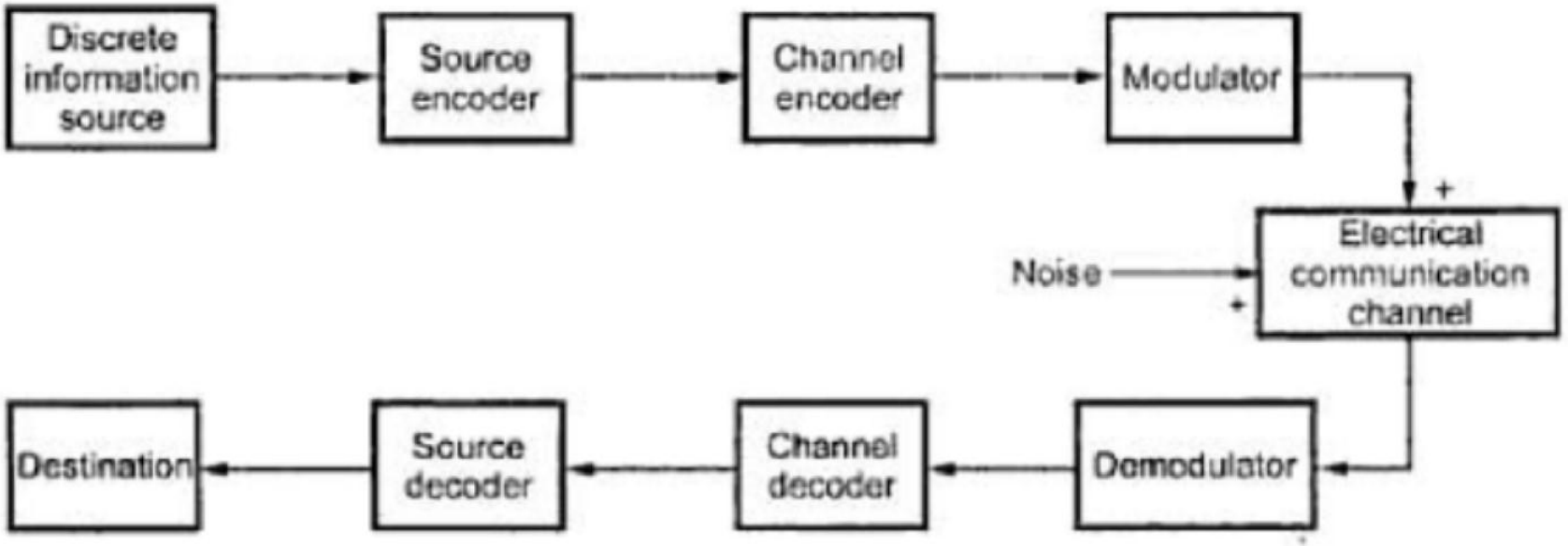


Fig: Digital communication system

- Efficiently converting the source into a sequence of binary digits is a process, which is called **source encoding** of data compression.
- **Channel encoder** adds some redundancy into binary information sequence that can be used for handle noise and interference effects at the receiver.
- **Digital modulator** maps the binary information sequence into signal waveforms.
- **Communication channel** is used to send the signal from the transmitter to the receiver. Physical channels: the atmosphere, wireless, optical, compact disk.

5.1 b Digital Transmission/ Communication System

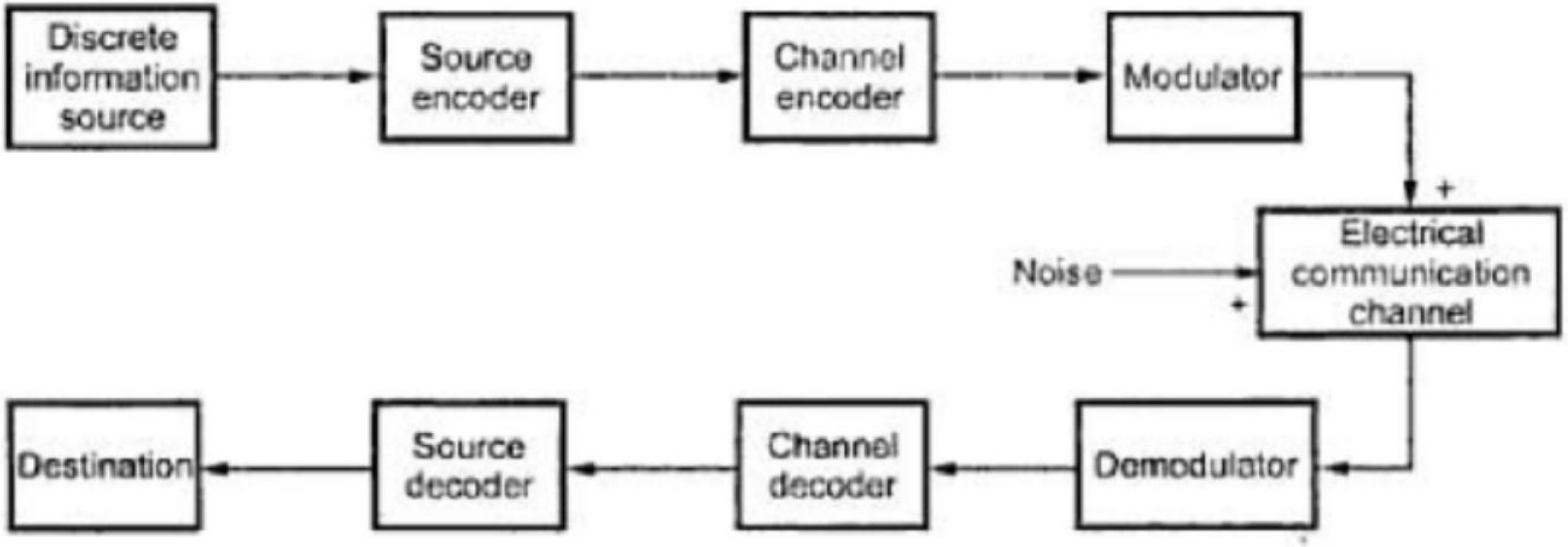


Fig: Digital communication system

- **Digital demodulator** receives transmitted signal contains the information which is corrupted by noise.
- **Cannel decoder** attempts the reconstruct the original information sequence from knowledge of the code used by channel encoder.
- **Source decoder** attempts the reconstruct the original signal from the binary information sequence using the knowledge of the source encoding methods.
- The difference between the original signal and the reconstructed signal is measured of the distortion introduced by the digital communication system

5.1 b Digital Transmission/ Communication System

Advantages of Digital Transmission

- Increased immunity to channel noise and external interferenc
- Flexible operation
- Low cost LSI/VLSI technology
- Easy to use
- Common Format

o Data, audio, video can be transmitted through same channel

- Security & Privacy

o Encryption and coding

- Integration

o Can treat analog and digital data similarly

Disadvantages of Digital Transmission

- High bandwidth requires
- Complex circuitry than analog

Transmission Schemes

- Guided transmission media – wire (twisted pair, cable, fiber)
- Unguided – wireless (radio wave, microwave, satellite, Bluetooth)
- Characteristics and quality determined by medium and signal
- For guided, the medium is more important
- For unguided, the bandwidth produced by the antenna is more important
- Key concerns are **data rate** and **distance**

Transmission Schemes :Design Factors

- Bandwidth
  - –Higher bandwidth gives higher data rate
- Transmission impairments
  - –Attenuation
- Interference
- Number of receivers
  - –In guided media
  - –More receivers (multi-point) introduce more attenuation (need more amplifies or repeaters)

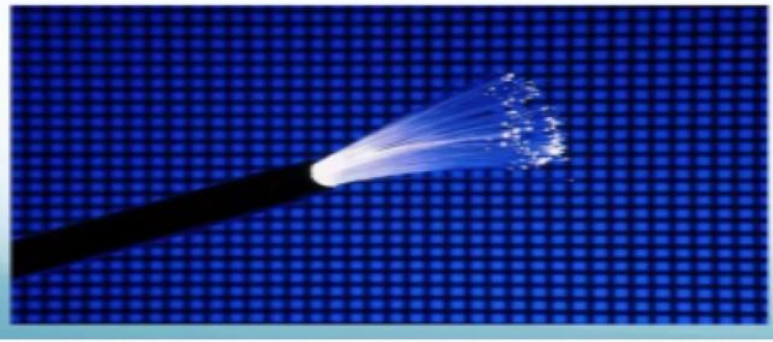
5.2.1 Fiber Optics Introduction

- Method of transmitting information from one place to another by sending pulses of light through an optical fiber.

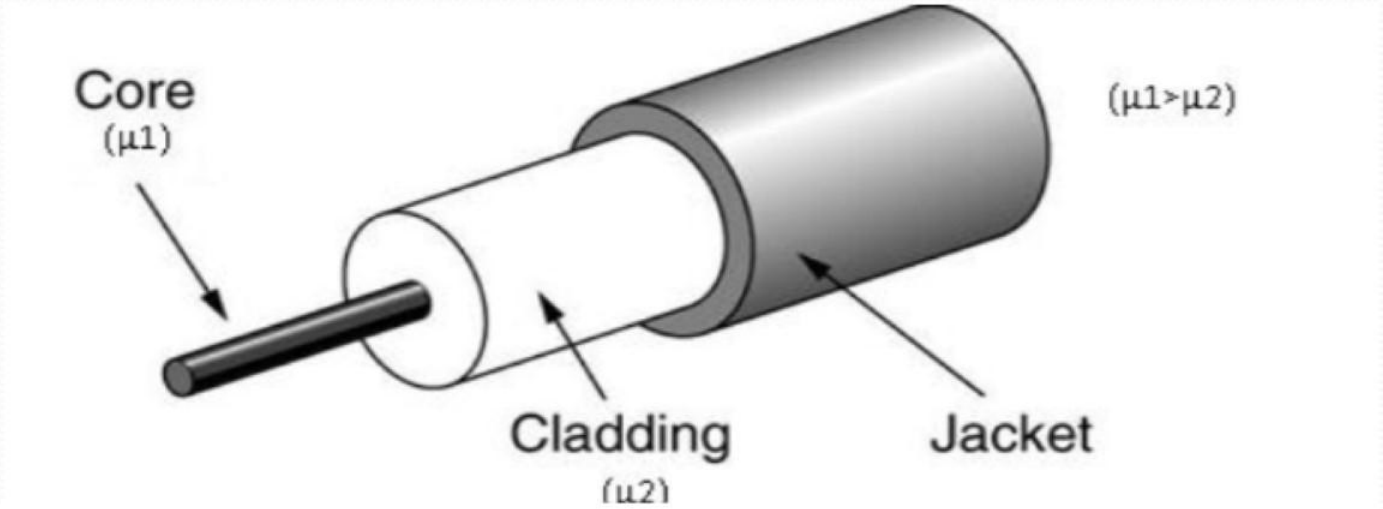
- Optical fiber is a cylindrical waveguide system through which the optical wave can propagate.

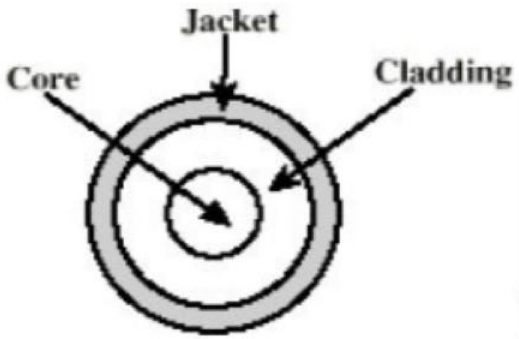
Fiber Optics = Fiber + Optics

In Essence: Light Guided in Optical Fiber

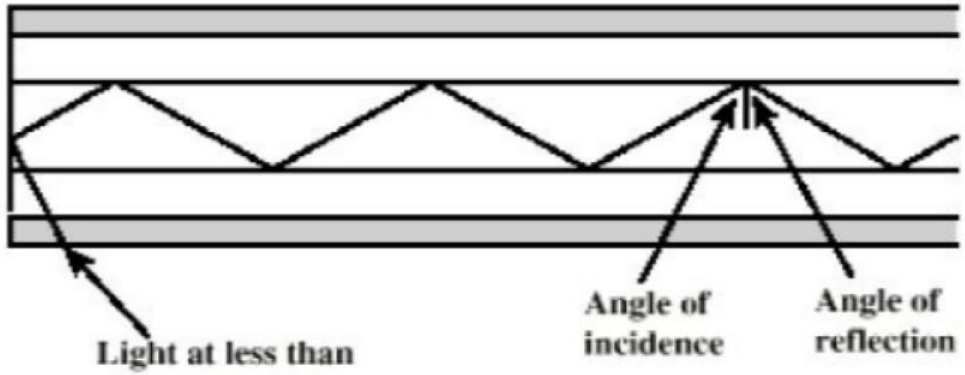


Construction



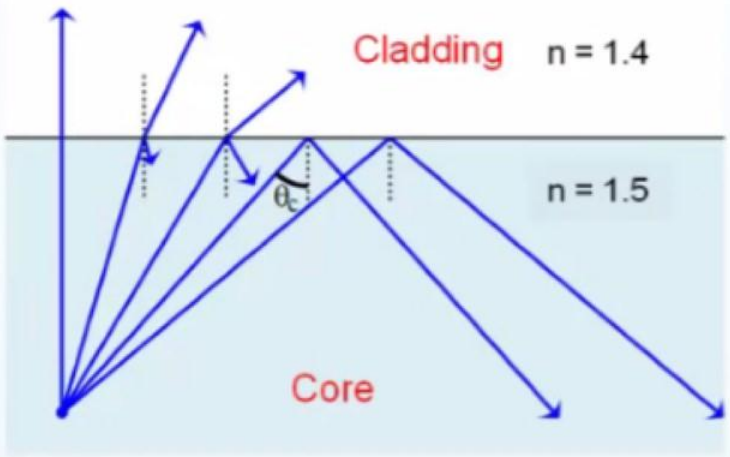


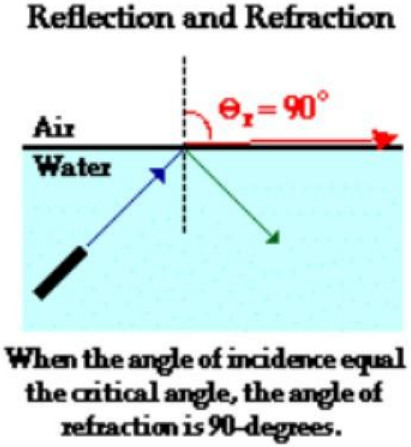
—Glass or plastic core
—Laser or light emitting diode
—Specially designed jacket
—Small size and weight

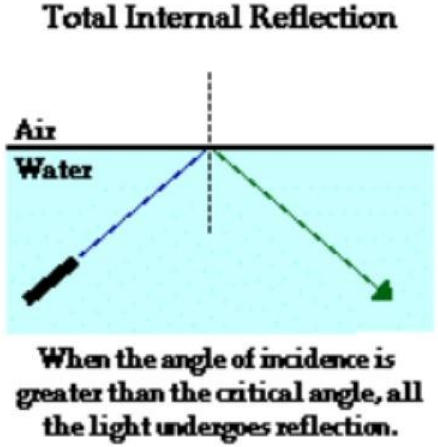


Light at less than ciritical angle is absorbed in jacket

Working principle: Total Internal Reflection(TIR)







TIR only takes place when both of the following two conditions are met:

I. a light ray is in the more dense medium and approaching the less dense medium.
II. the angle of incidence for the light ray is greater than the so-called critical angle

Fiber optics communication system

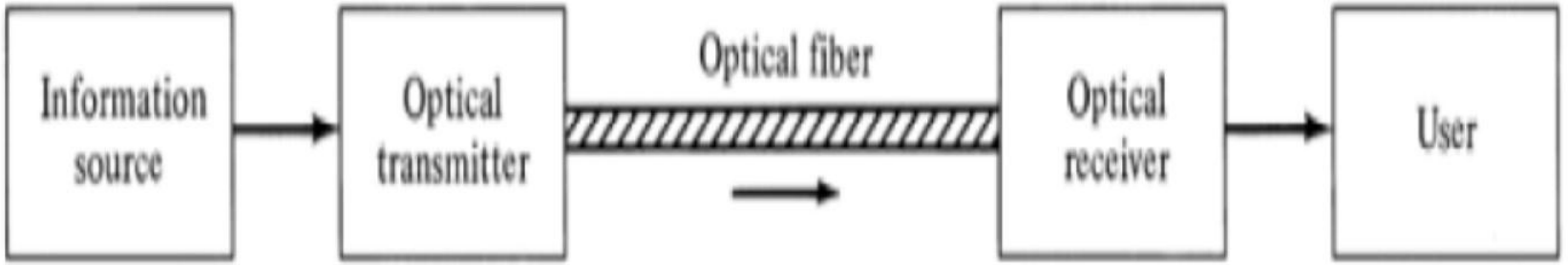
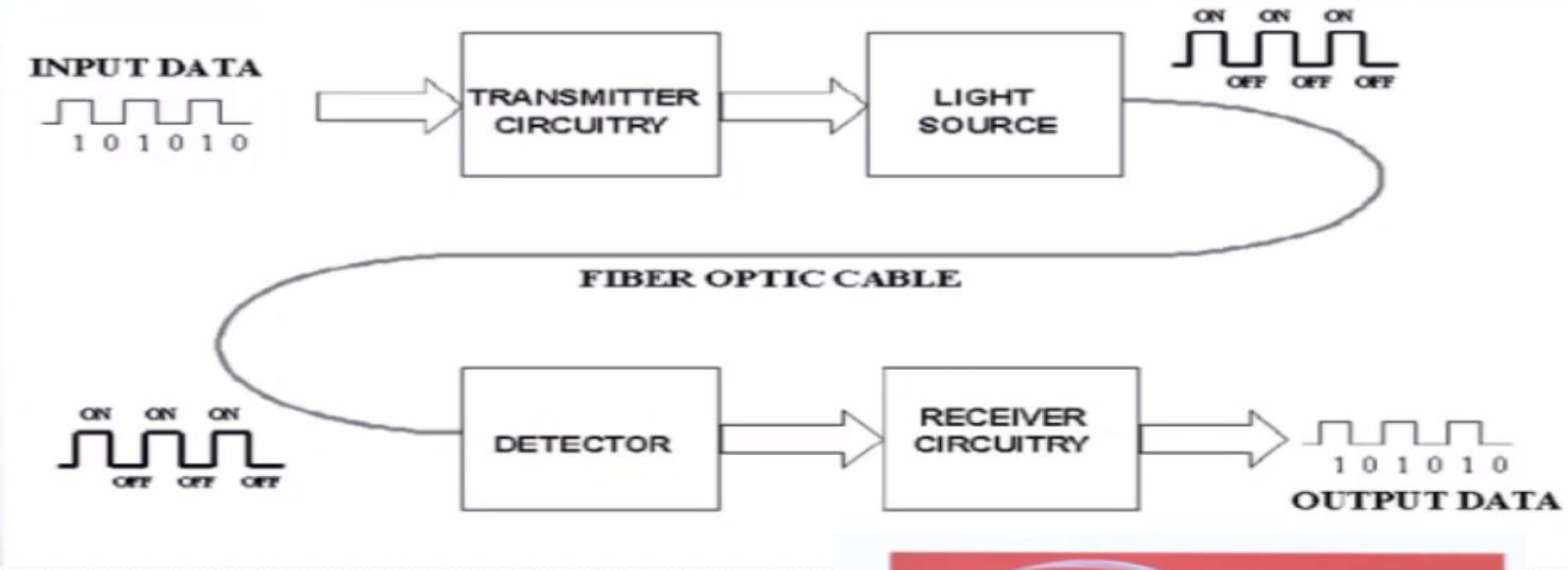
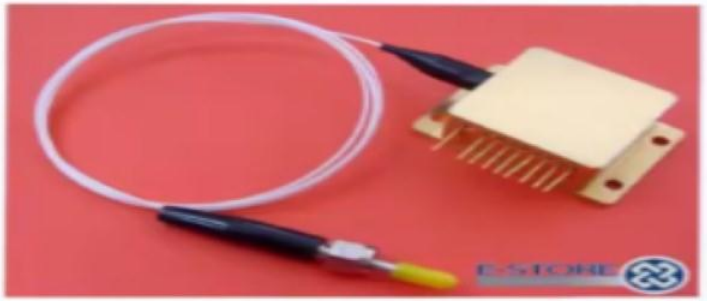


Fig: Optical Fiber transmission block diagram





Laser Coupled Into Fiber

Photodetector

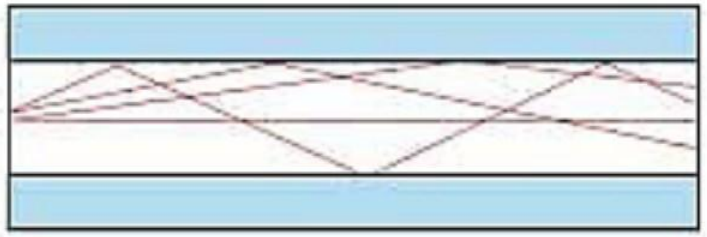
Types of optical fiber

1. Single-mode fibers

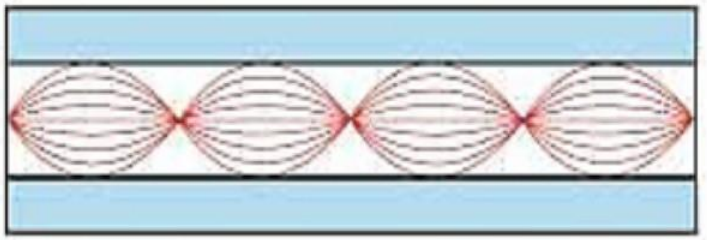
2. Multi-mode fibers

2.1 Step Index

2.2 Graded Index



Multimode, Step-index



Multimode, Graded Index

Singlemode

Types of optical fiber

1. Single-mode fibers

-Used to transmit one signal per fiber used in telephone and cable TV

-Small cores (9 microns diameter)

-Transmit infrared from laser

2. **Multi-mode fibers**: used to transmit many signals per fiber used in computer networks, larger cores (62.5 microns diameter) and transmit infrared from LED

   2.1 **Step Index**: core and cladding has their uniform refractive index, light rays are in the form of *meridional rays*.

   2.2 **Graded Index:** refractive index of core gradually decrease from the center towards the core-cladding interface, light rays are in the form of *skew or helical rays*

Advantages of Optical Fiber

- Thinner
- Less Expensive
- Higher Carrying Capacity
- Less Signal Degradation& Digital Signals
- Light Signals
- Non-Flammable
- Light Weight
- Enormous capacity
- Low transmission loss
- Cables and equipment have small size and weight
- Immunity to interference
- Electrical isolation
- Signal security
- Silica fibers have abundant raw material

Disadvantages of Optical Fiber

- Requires skilled manpower for installation
- Difficult to repair and maintenance
- High equipment and manufacturing cost
- Splicing (joining two optical fibers) is difficult

Application

- In communication – Compared to a conventional system they offer better reliability, large information transmission capacity, cost effective etc.

- In Medical Science – With the advent of fiber optics the otherwise inaccessible parts of the body are now visible to the surgeon without actually cutting through the body. Ex. Endoscopy.

- Military Applications – Optical Fiber are lighter in transportation and more reliable in terms of secrecy as compared to conventional systems.

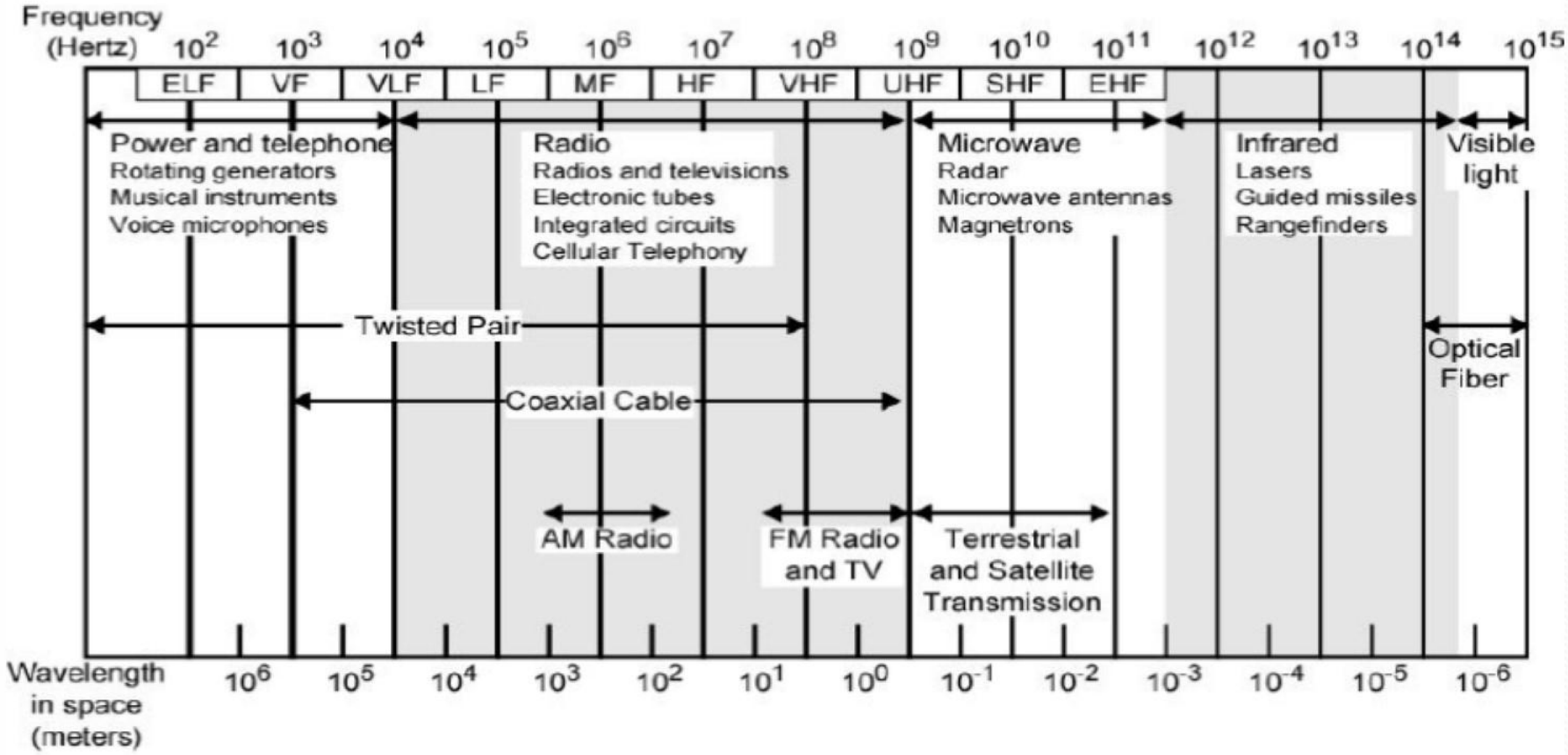
- Entertainment – A coherent Optical Fiber bundle offers better enlargement of the image displayed on a TV or screen.

5.2.2 SATELLITE

Introduction

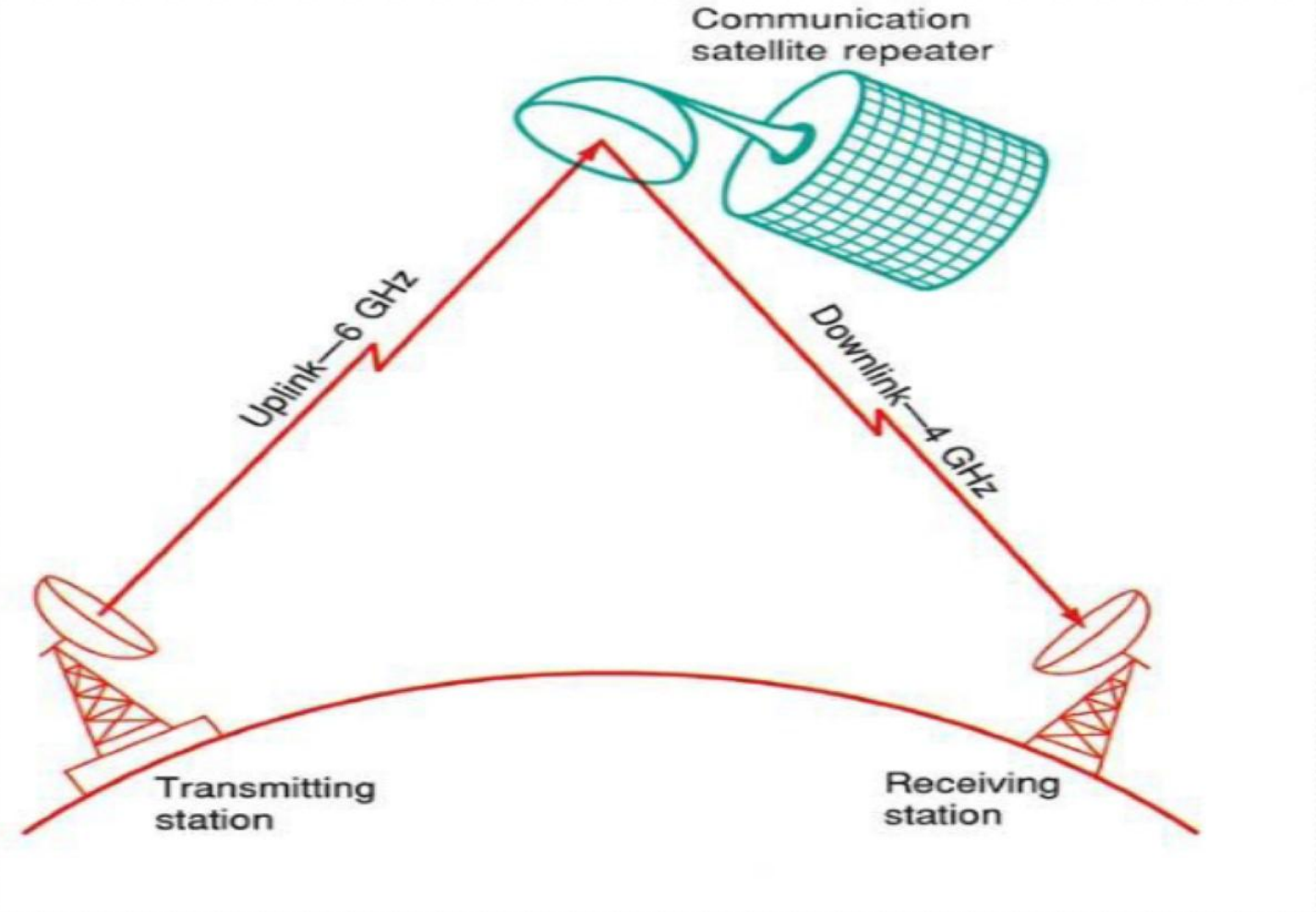
- A body moving in an orbit around a planet.
- A Satellite communication system consists of ground stations for transmitting and receiving signals and a communication satellite in the space.
- The range of frequencies used for transmission of signals from ground station to the satellite is ***uplink frequency*** and those used for transmission of signals from satellites to ground station is ***downlink frequency***. Uplink and downlink frequencies are different to avoid interference.

Electromagnetic Spectrum



ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Satellite Communication System



Elements of A Satellite System

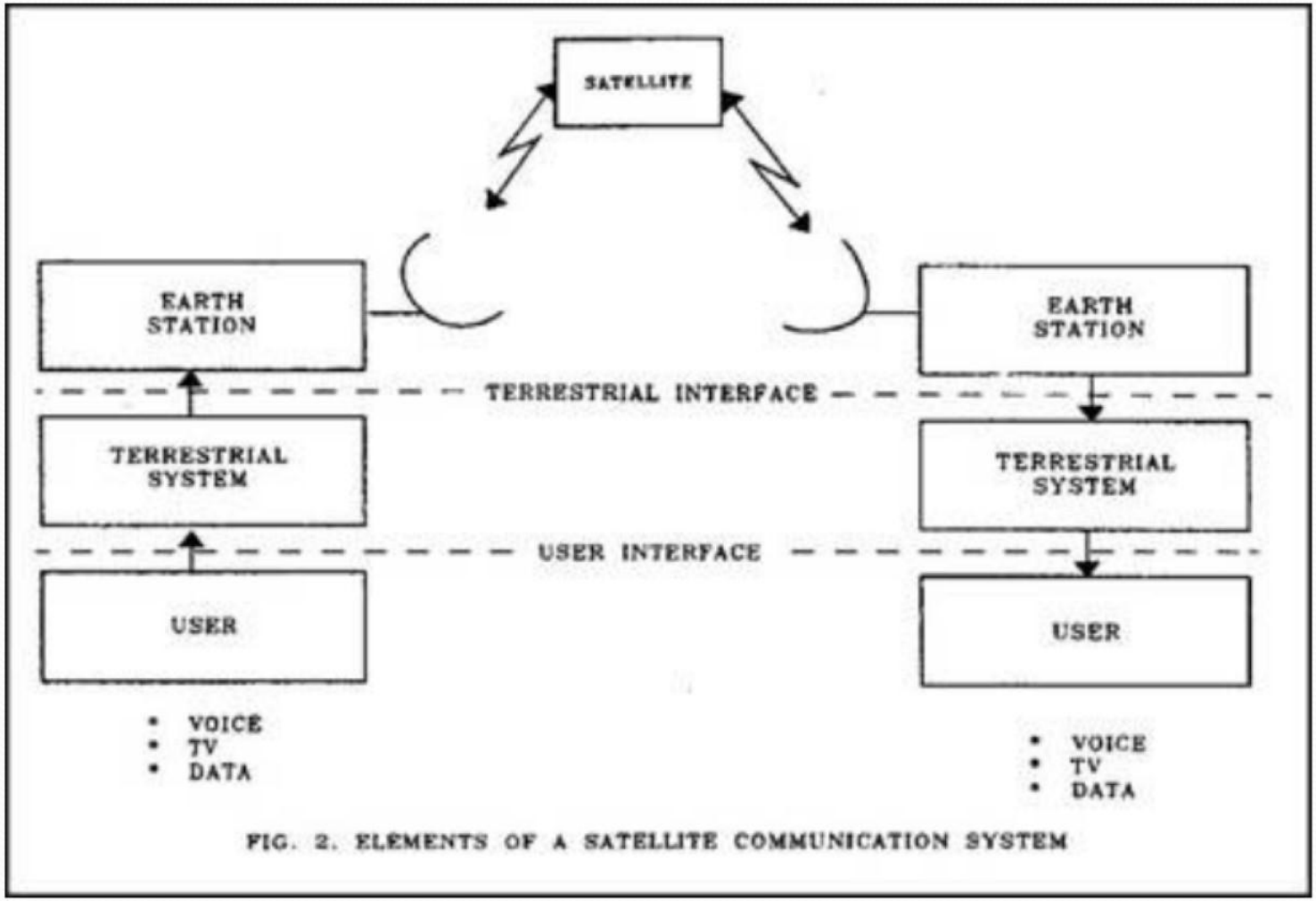
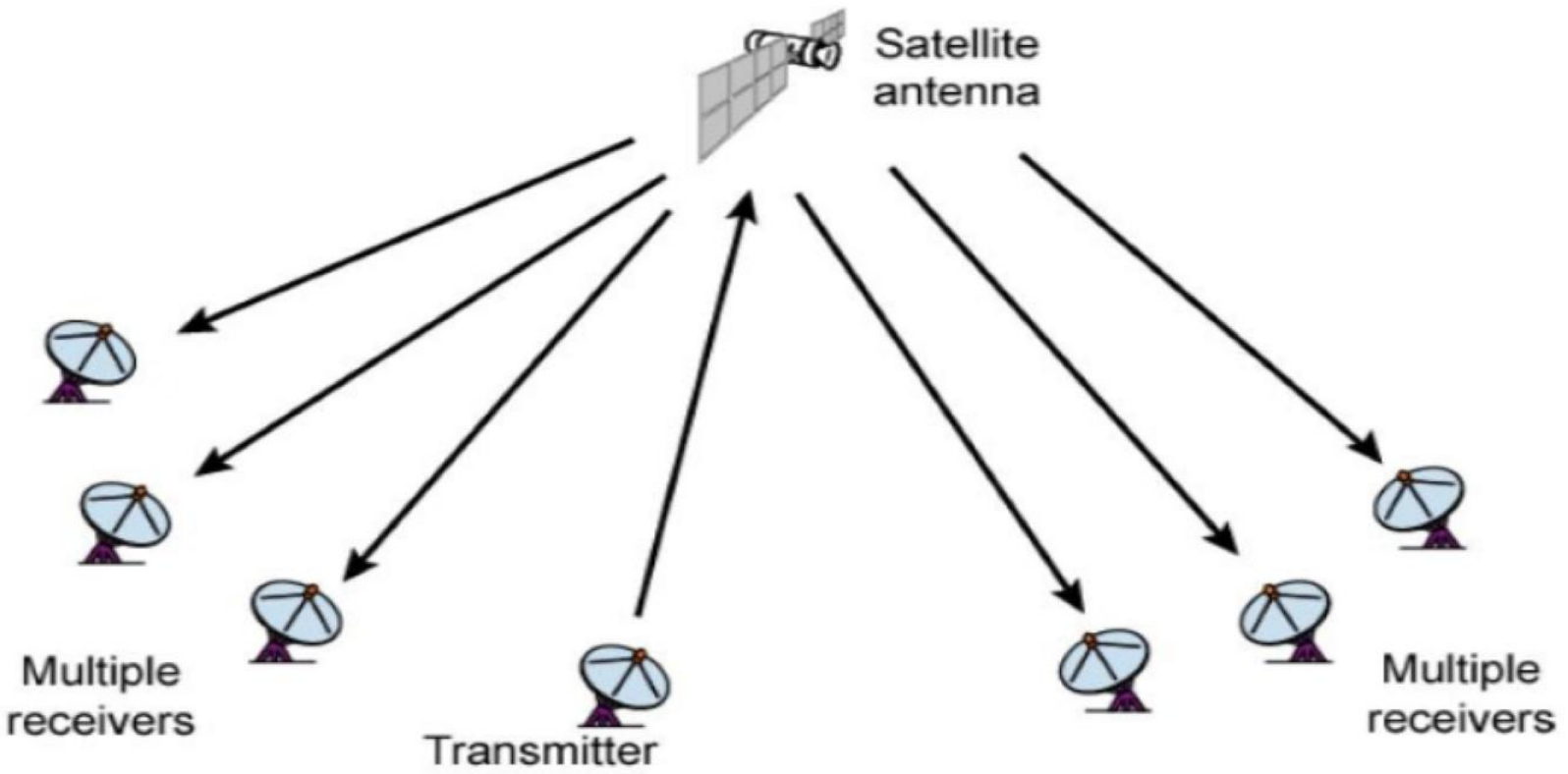


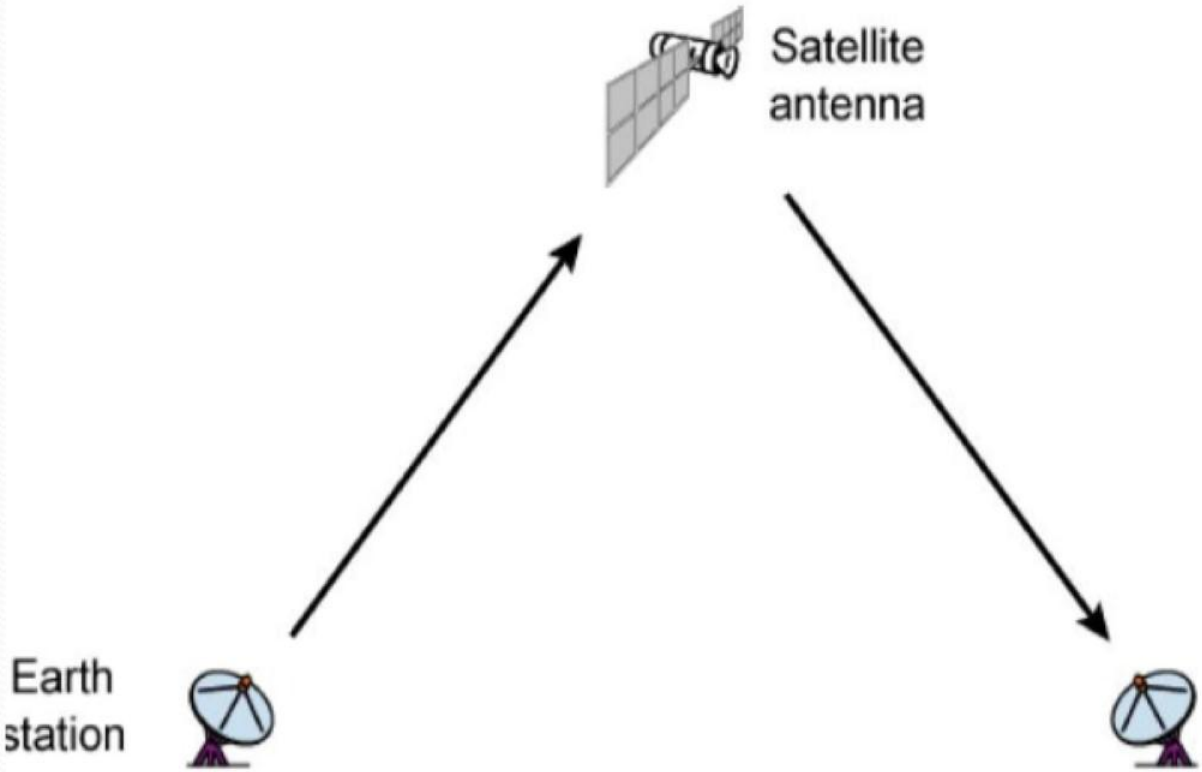
FIG. 2. ELEMENTS OF A SATELLITE COMMUNICATION SYSTEM

Satellite Broadcast Link



(b) Broadcast link

Satellite Point to Point Link



(a) Point-to-point link

Types of Satellite

1. Low Earth Orbit (LEO)

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.

Advantages

- A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for **point to point communication**.
- A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

Disadvantages

- A network of LEO satellites is needed, which can be costly
- LEO satellites have to compensate for Doppler shifts cause by their relative movement.
- Atmospheric drag affects LEO satellites, causing gradual orbital deterioration.

2. Medium Earth Orbit (MEO)

- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth's surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- MEO satellites have a larger coverage area than LEO satellites.

Advantage

- A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.

Disadvantage

- A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

3. Geostationary Earth Orbit (GEO)

- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.

Advantages

- A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.
- GEO satellites have a 24 hour view of a particular area.
- These factors make it ideal for **satellite broadcast** and other multipoint applications.

Disadvantages

- A GEO satellite's distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
- GEO satellites, centered above the equator, have difficulty broadcasting signals to near Polar Regions.

Advantages of Satellites

- The coverage area of a satellite greatly exceeds that of a terrestrial system.
- Multiple signals can be superimposed at a time so capacity increased
- Transmission cost of a satellite is independent of the distance from the center of the coverage area.
- Satellite to Satellite communication is very precise.
- Higher Bandwidths are available for use.

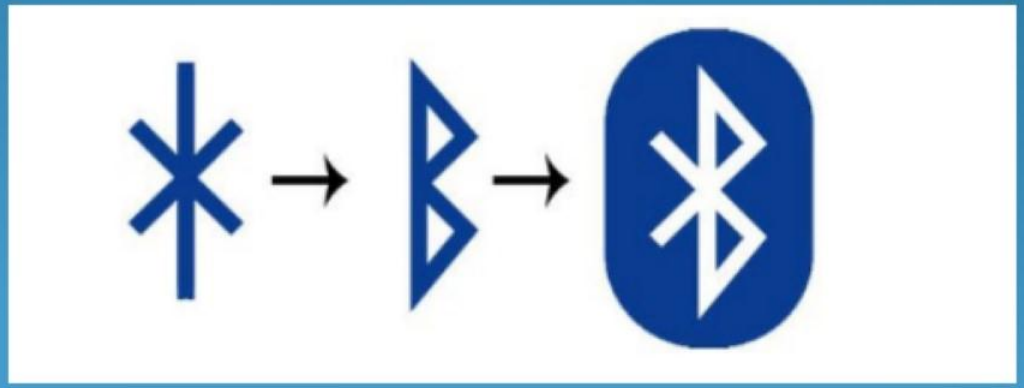
Disadvantages of satellite

- Launching satellites into orbit is costly.
- There is a larger propagation delay in satellite communication than in terrestrial communication.

Service type/ application areas

- **Fixed Service Satellites(FSS)**
  - **point to point communication**
- **Broadcast Service Satellite(BSS)**
  - **Satellite TV/Radio**
- **Mobile Service Satellite(MSS)**
  - **Satellite phones**

5.2.3 Bluetooth



What is Bluetooth?

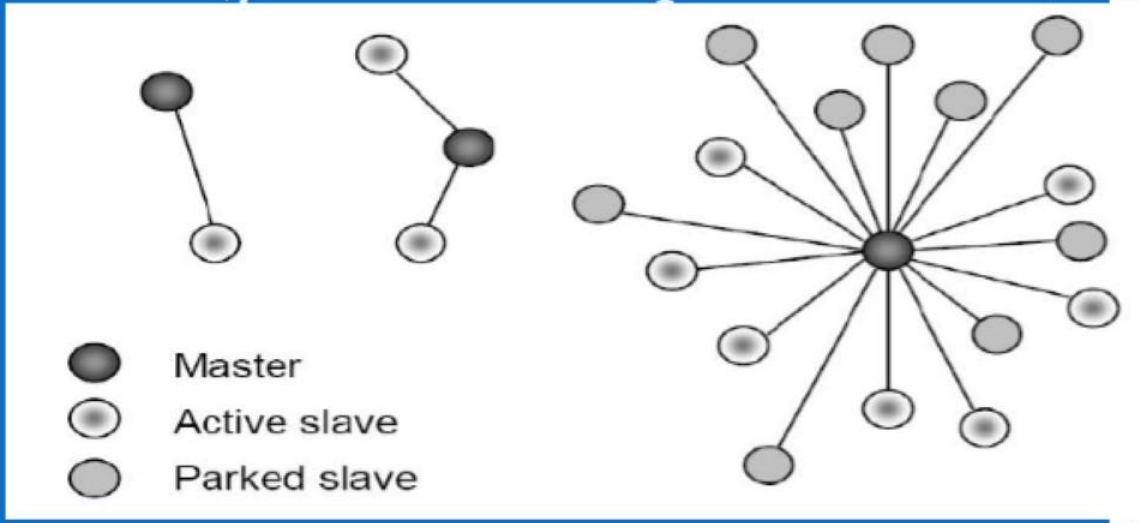
- Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM(Industrial-Scientific-Medical) band from 2.4 to 2.485 GHz) from (10m-100 m) fixed and mobile devices, and building personal area networks (PANs).

Applications of Bluetooth

- Telephones
- Headsets
- Computers
- Computer accessories
- LAN peripherals
- Multimedia Devices

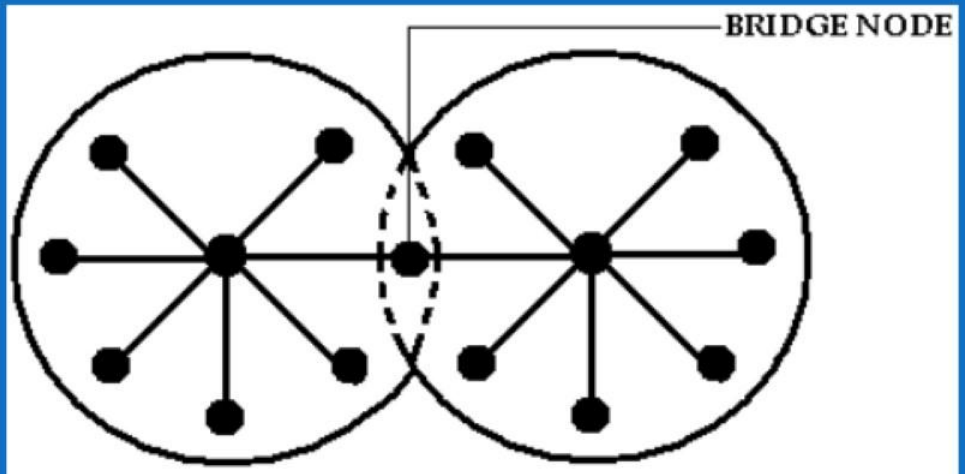
Bluetooth Network Topology

- A set of BLUETOOTH devices sharing a common channel is called a **PICONET**
- A maximum of 8 devices (7 active slaves plus 1 master) form a Piconet



Bluetooth Network Topology

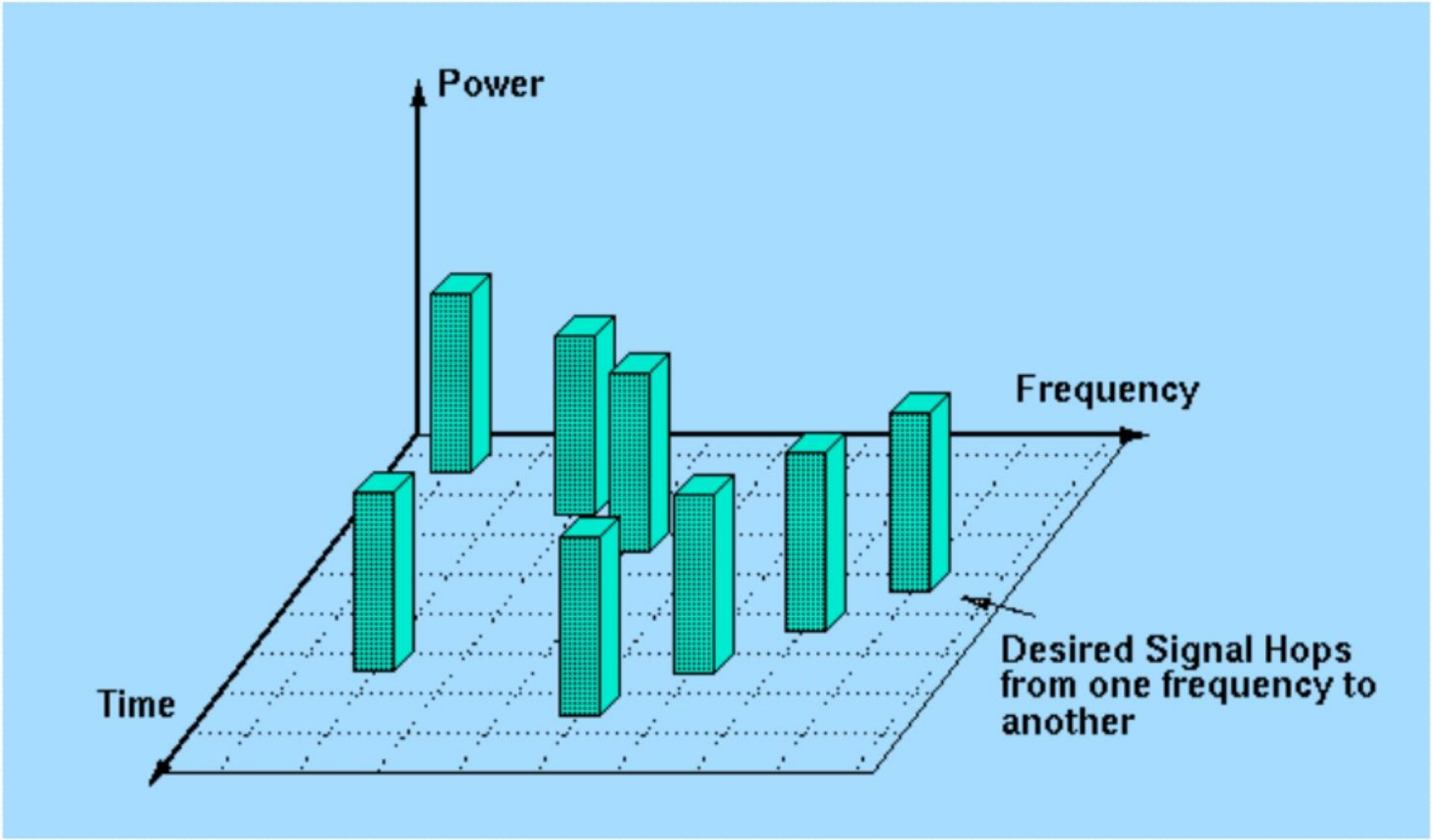
- Scatternets are two or more independent and non-synchronized piconets that communicate with each other by making bridge nodes.



SCATTERNET

Bluetooth Characteristic

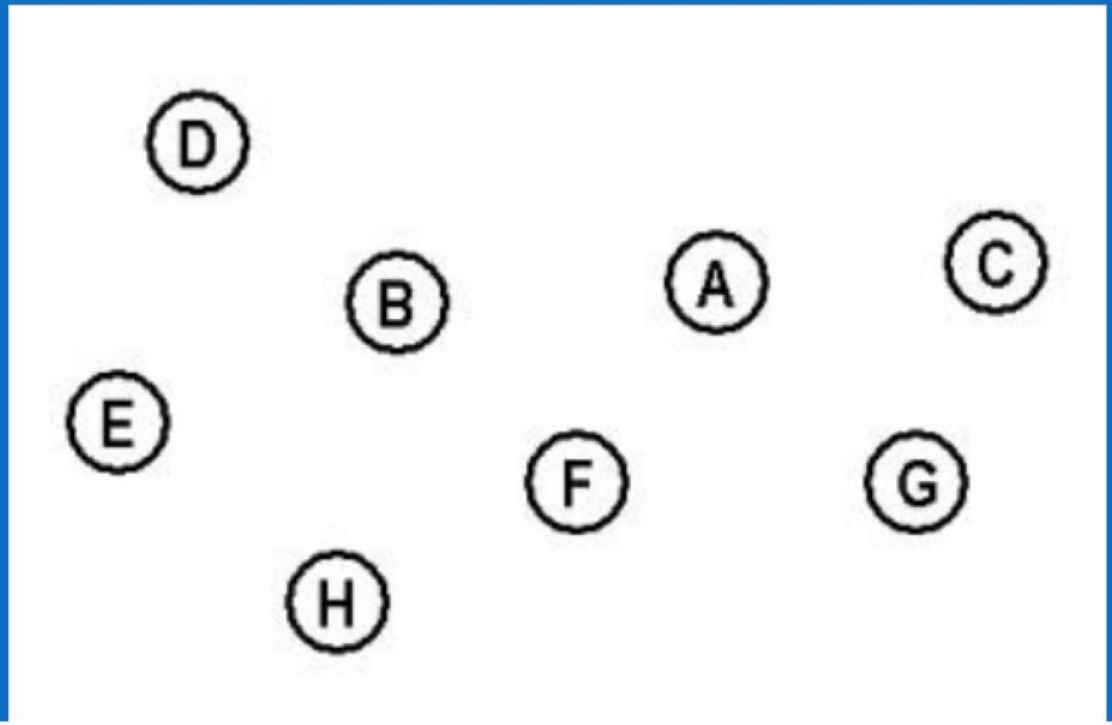
- Bluetooth uses a technique called **spread-spectrum frequency hopping.**
- In this technique, a device will use 79 individual, randomly chosen frequencies within a designated range, changing from one to another on a regular basis. In the case of Bluetooth, the transmitters change frequencies 1,600 times every second


Power
Frequency
Time
Desired Signal Hops
from one frequency to
another

- Operates in the 2.4 GHz Industrial-Scientific-Medical (ISM) band.
- Supports up to 8 devices in a piconet (two or more Bluetooth units sharing a channel).
- Non line-of-sight transmission through walls and briefcases.
- Omni-directional.

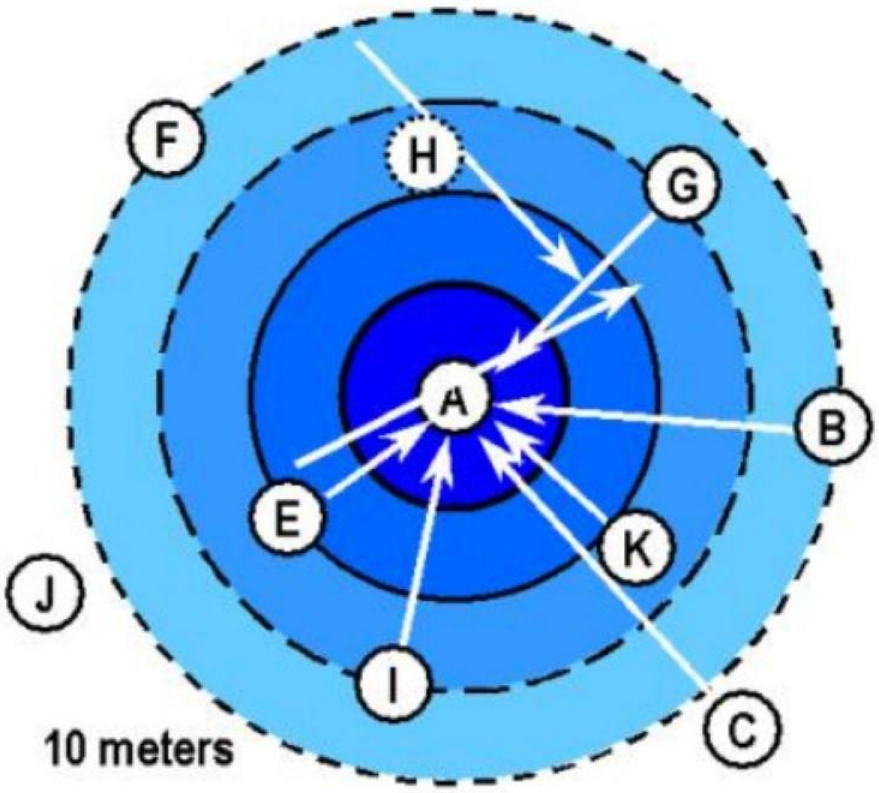
How does Bluetooth work?

- When device is put in discoverable mode, each device only knows about itself.



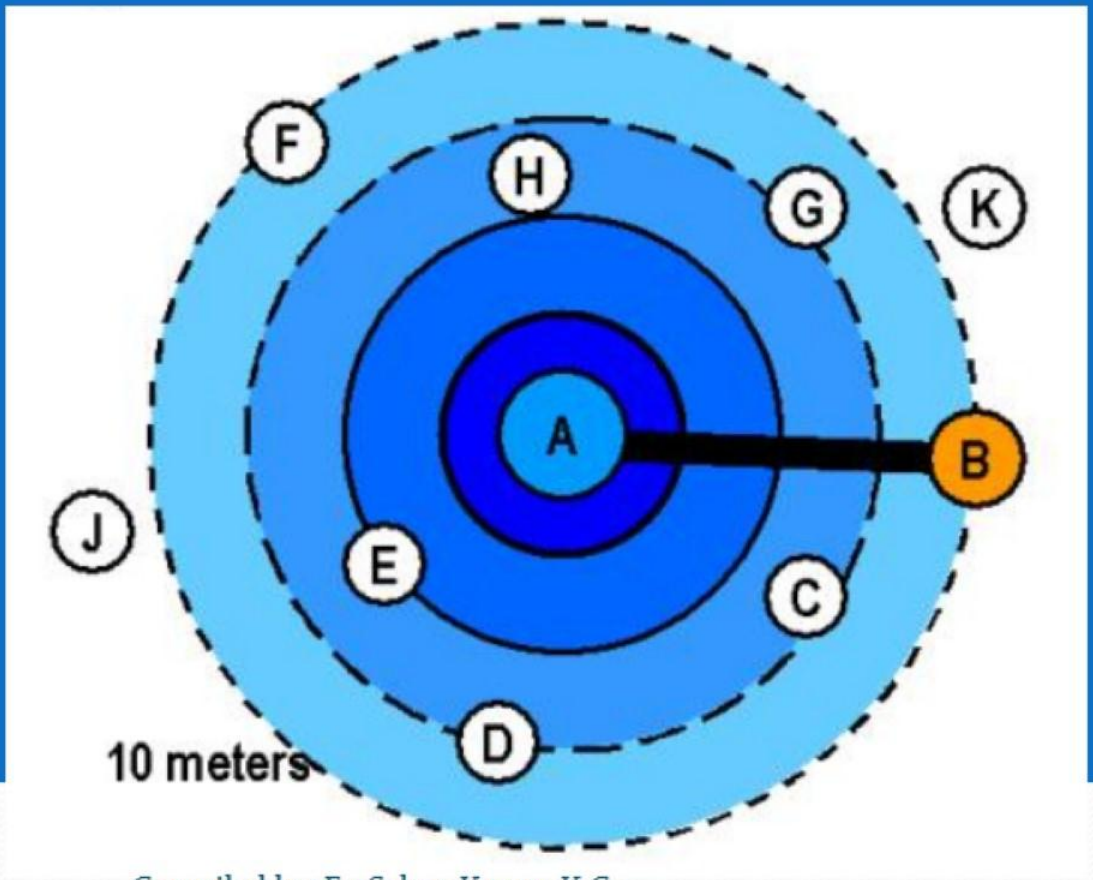
How does Bluetooth work? Cont'd

- **INQUIRY** identifies who else is in the range



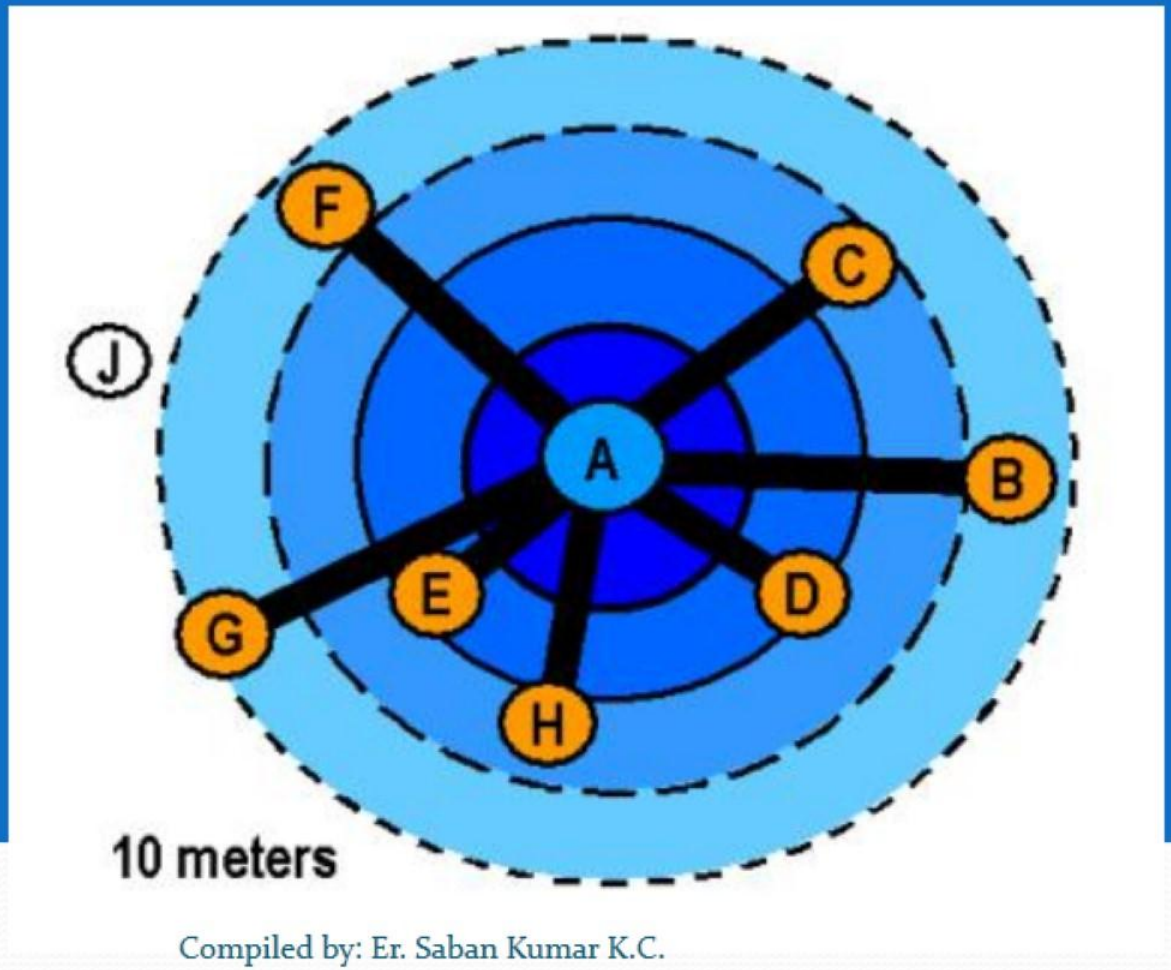
How does Bluetooth work? Cont'd

- **PAGING** creates a link between a device

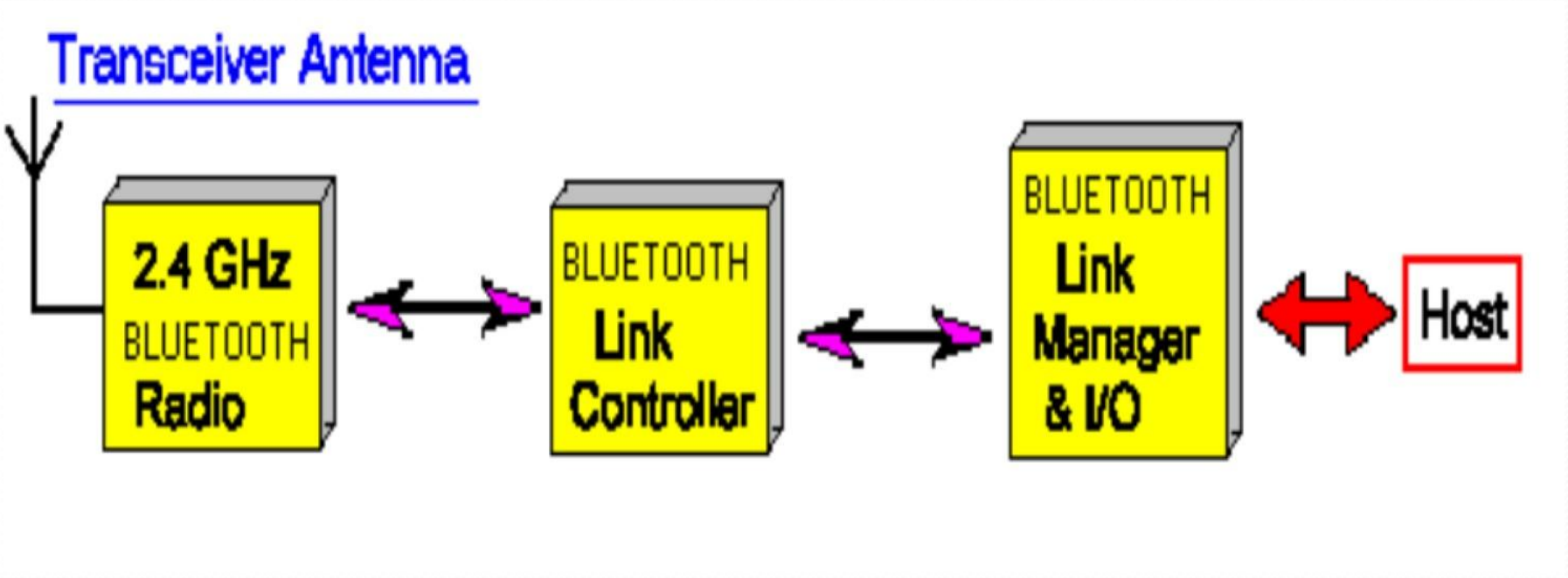


How does Bluetooth work? Cont'd

- **EXPANDING** creates link between following devices



Functional Block of Bluetooth System



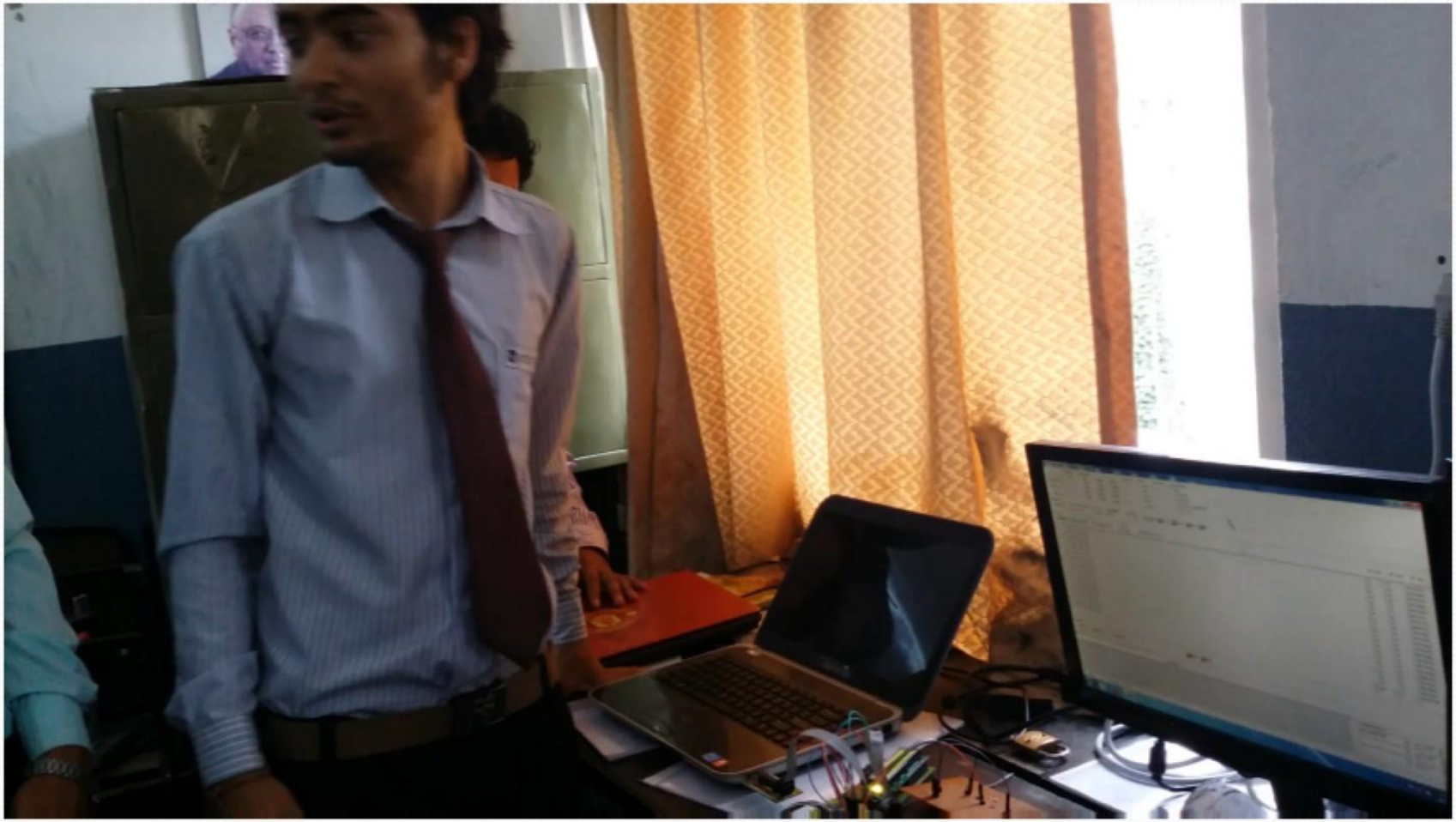
- Radio Front End (RF)
  - Defines characteristics of **RF, frequency bands, channel arrangements & receiver sensitivity level.**
- Logical Link Control & Adaptation Protocol (L2CAP)
  - packet segmentation and reassembly, and the conveying of quality of service information
- **Link Manager Protocol (LMP)**
  - PICONET, master slave role assignments and link configuration.
  - Security configuration by device authentication using secret key.

Advantages vs. Disadvantages

Advantages	Disadvantages
• Offers a great deal of possibilities	• Data rate of only 1 MBps.
• Freedom from cables	• Open to interception and attack
• Accuracy in Local Area Networks (LAN)	• Battery use increased on devices
• Operating range of up to 100 metres	• Cannot work in a long distance environment
• Low power and low processing	
• Applications are virtually endless	
• Inexpensive	
• Does not need to be configured	
•Security features of authentication, authorization, and encryption	

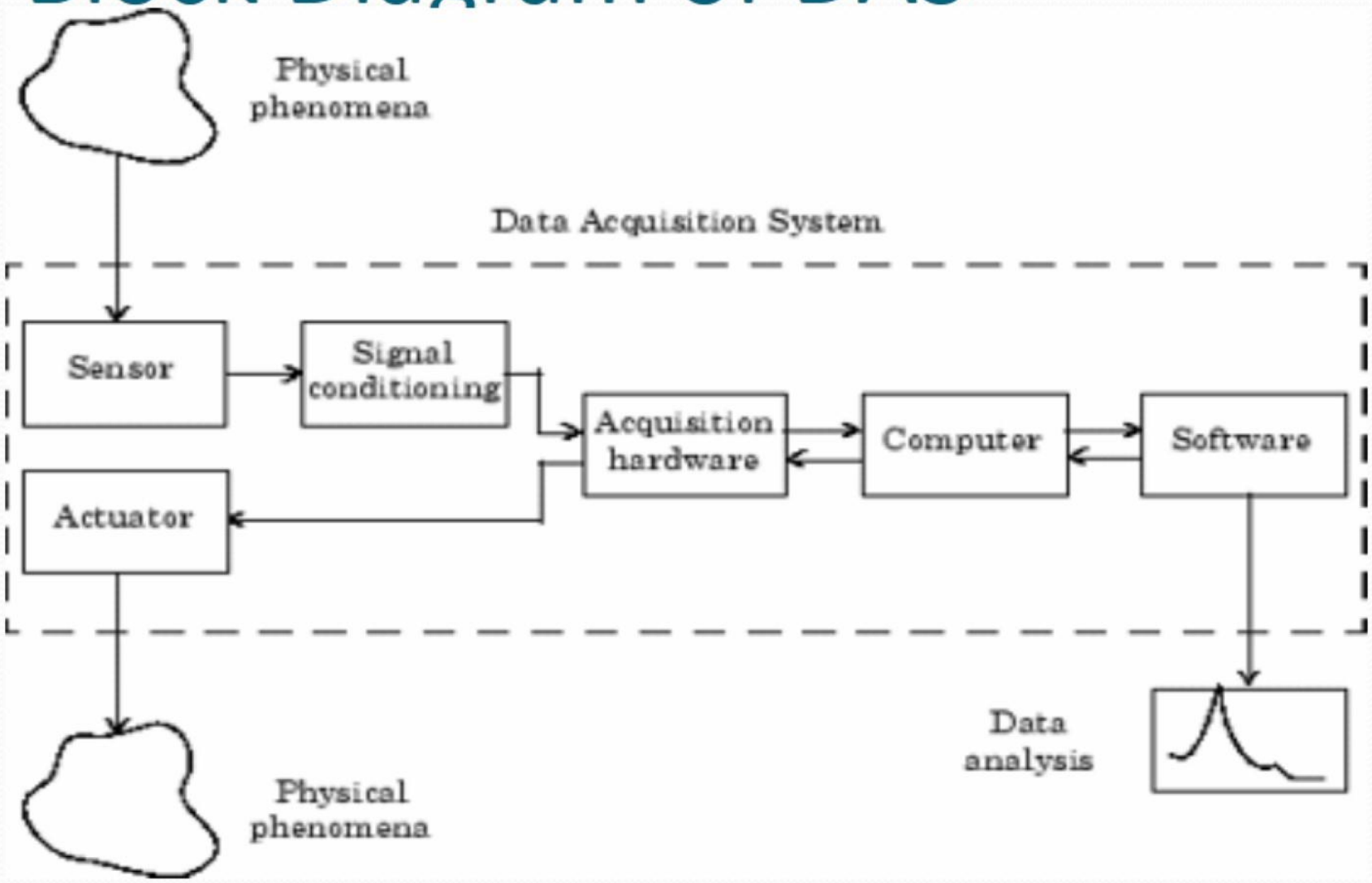
Data Acquisition System and Data Loggers

What is Data Acquisition System ?

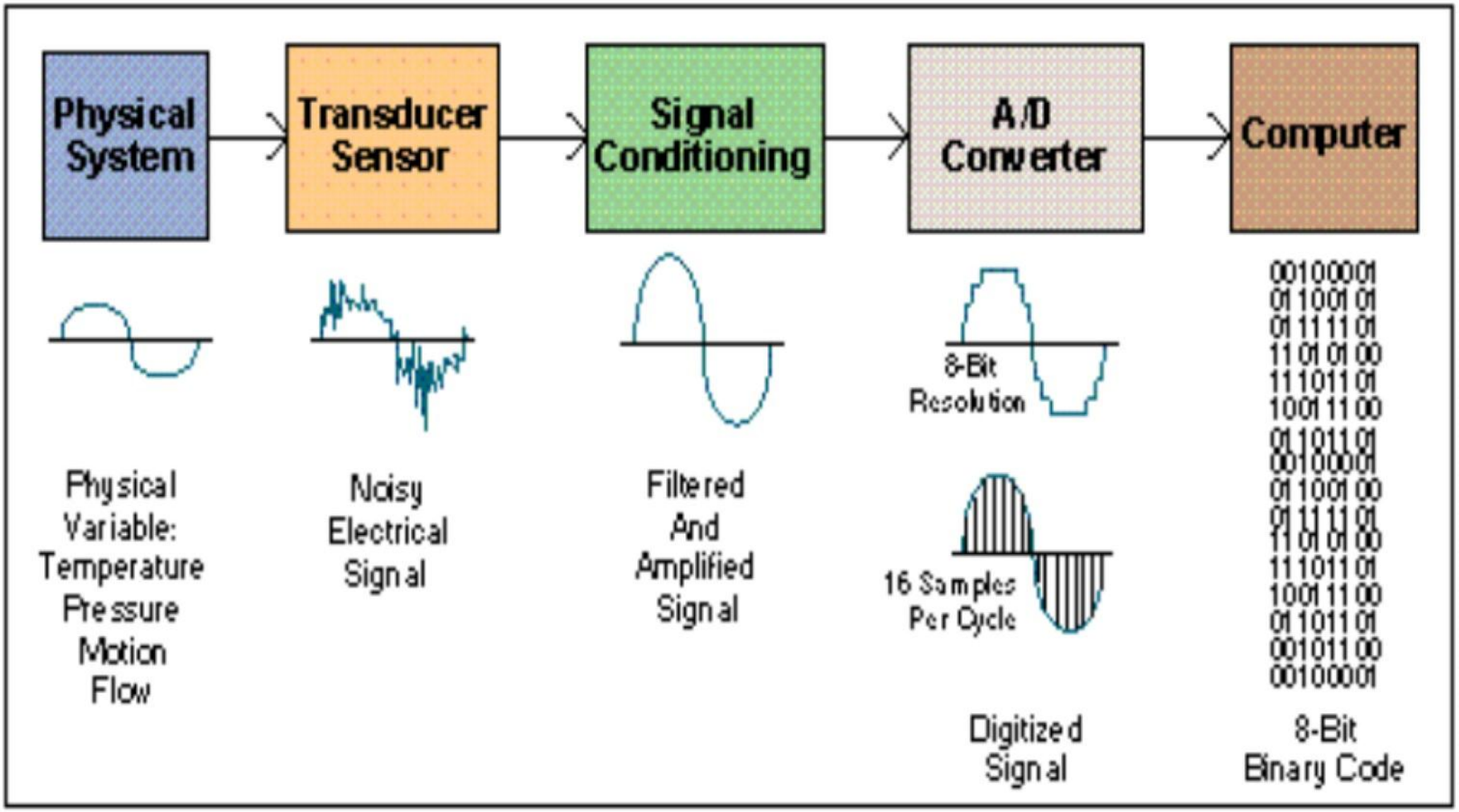


- DAQ systems capture, measure, and analyze physical phenomena from the real world.
- Light, temperature and pressure are examples of the different types of signals that a DAQ system can measure.
- Data acquisition is the process of collecting and measuring electrical signals and sending them to a computer for processing.
- Electrical signals comes from Transducers.

Block Diagram of DAS



Block diagram of DAS



Data loggers:

OM-CP-TEMP100
Single Input Logger

OM-DAQPRO-5300
Portable Datalogger

OM-CP-QUADTEMP
Fixed Input Logger

OM-320
Modular Logger

- Data logger is an electronic device that automatically makes a record of the readings of instruments located at different parts of plant.

- They generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors.

Characteristics of Data Logger

a) Modularity

b) Reliability and Raggedness

c) Accuracy

d) Management Tool

e) Easy to Use

Applications

a) Weather station recording e.g. wind speed, wind direction, temperature, relative humidity

b) Hydrographic recording e.g. water level, depth, water flow PH, conductivity

c) Soil moisture level

d) Gas pressure

e) Environmental Monitoring

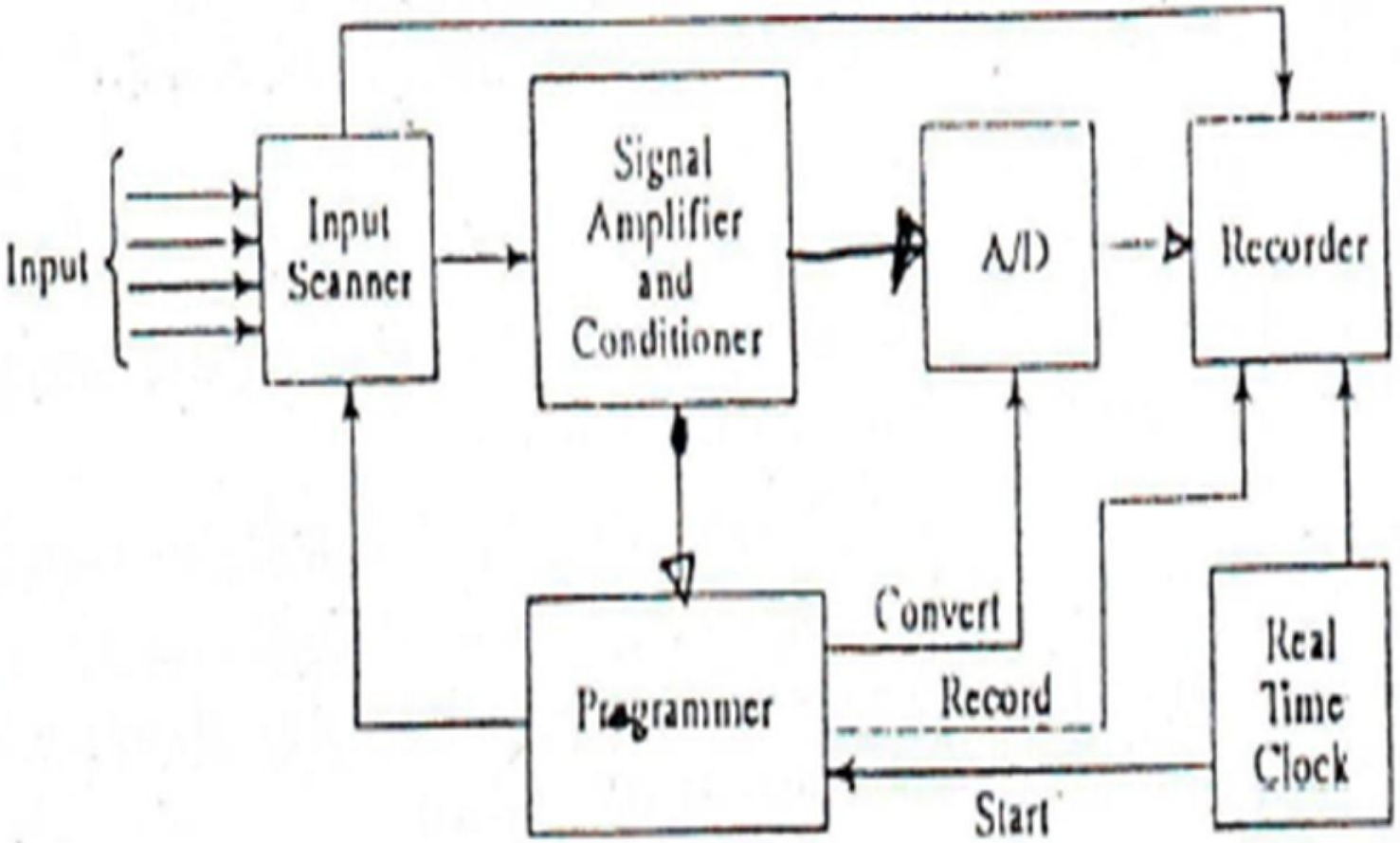


Fig. 17.27 Block Diagram of a Data Logger

Input Signals

- Pressure, transducers
- Thermocouple
- AC signal
- Signals from relay, switch
- Tachometer pulses etc.

Input Scanner

It is an automatic sequence switch which selects each signal in turn. Modern scanner have input scanner which can scan at a rate of 150 inputs per second. Characteristics of input scanner may be:

- Low closed resistance
- High open circuit resistance
- Low contact potential
- Negligible interaction between switch, enter going signal and input signal
- Short operating time
- Negligible contact bounce
- Long operation life

Signal Amplifier & Conditioner

- Amplifier for gain adjustment i.e. low level signal amplified up to 5v output. Characteristics are:
  - High SNR
  - High CMRR
  - Low output impedance
  - High input impedance
  - Good linearity
  - Wide bandwidth

- Conditioner for scaling linear transducer or correcting curvature of non linear transducer i.e. signal is changed to more linear from and suitable for digital analysis. Characteristics are:
  - Linear scale
  - Correcting the curvature of non linear transducer
  - It may include sample and hold circuit

A/D Converter

- Converts analog sample into digital data. Characteristics are:
- Resolution
- Accuracy
- Conversion time
- Full scale output voltage
- Linearity

Recorder

- Output from data logger may be recorded in any of following:
- Typewriter, strip printer, digital tape recorder, punched tape, computer (hard drive), magnetic tape etc.

Characteristics are:

- Speed
- Memory
- Writing technique (Serial / Parallel)

Programmer

- Control all units of data conversion and operation
- Microcontroller or microprocessor based system
- Basic units: main frames, front panel assembly, power supply unit, scanner controller, input interface etc.

Operation performed by programmer:

- Set amplifier
- Set linearity factor
- Set high and low alarm value
- Start A/D conversion
- Record reading channel
- Identify channel and time of recording
- Display recording
- Reset logger

Types of data acquisition systems

- Data acquisition systems can be of a number of forms:
  - **Pocket loggers** - small, battery powered, stand alone devices with simple functionality
  - **Intelligent data loggers** - stand alone devices with own intelligence, sophisticated data manipulation, alarms, backed up power supply, displays, etc. Accessed continuously or periodically by a PC.
  - **Plug in cards** - plugged into the ISA bus or USB port of a PC to provide basic data acquisition functionality. The PC provides power, control, data storage, etc.

Compact Data Logger

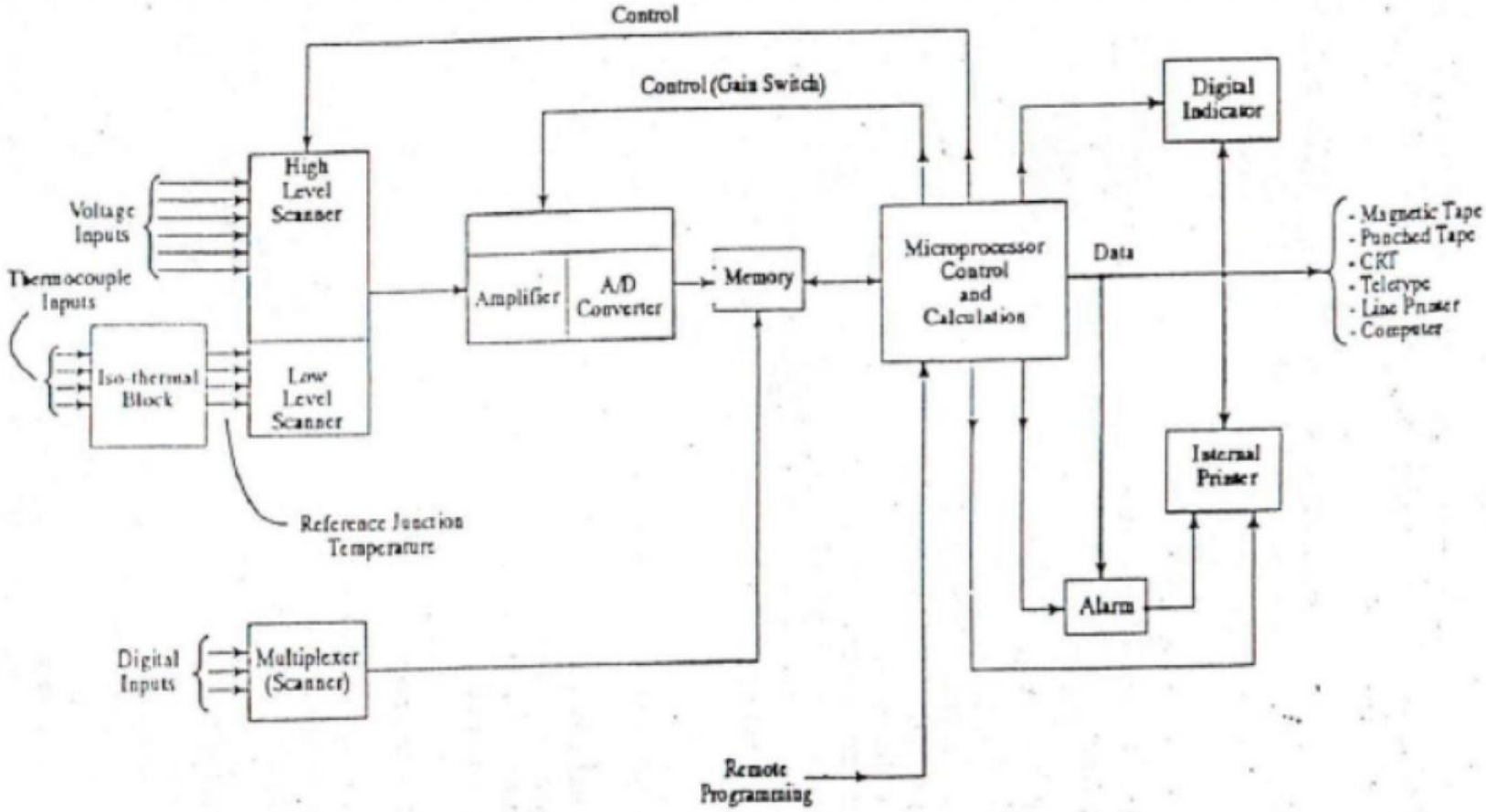


Fig. 17.29 Compact Data Logger Configuration

ADVANTAGES:

- Data logging devices can be sent to places that humans can not easily get to. e.g. to the planet Mars, in to the bottom of a volcano and on to a roof of a tall building to get to a weather station.

- Graphs and tables of results can be produced automatically by the data logging software.

DISADVANTAGES:

- The main **disadvantage** of using a data logging system is the initial cost of purchasing the equipment. While a thermometer can be purchased for less than one pound, the price of the components of a data logging system to record the temperature will be considerable.

Data Acquisition VS Data Logging

- Data loggers typically have slower sample rates than Data Acquisition System.
- Data loggers are implicitly stand-alone devices, while typical data acquisition system must remain tethered to a computer to acquire data.
- data loggers must be extremely reliable than Data Acquisition System

Data Archiving and Storage

- Data archives are indexed and have search capabilities so that files and parts of files can be easily located and retrieved.

- Data archives are often confused with data backups, which are copies of data. Data backups are used to restore data in case it is corrupted or destroyed. In contrast, data archives protect older information that is not needed for everyday operations but may occasionally need to be accessed.

Data Storage

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Er. Binod Chandra Shrestha:
H. Aryal, "Instrumentation II,"
haryal4@gmail.com, Kathmandu,
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