# Unit 6
# Communication System

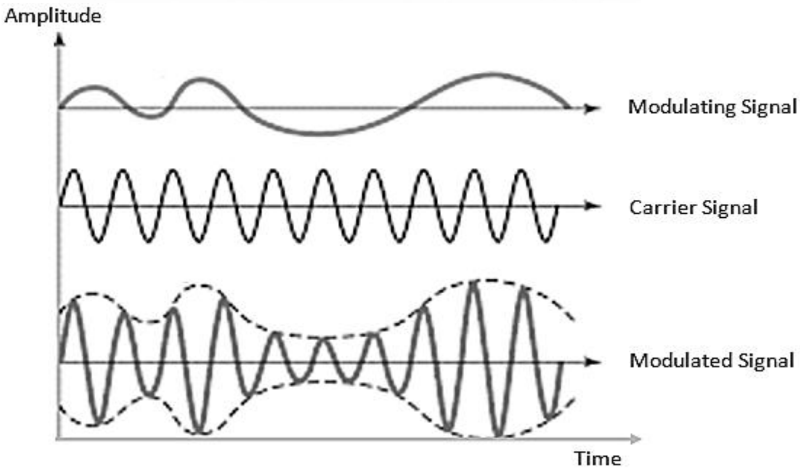
## INTRODUCTION TO MODULATION: AM, FM, PM

**What is Modulation?**
Modulation is the process of varying one or more properties of a high-frequency carrier signal in accordance with a low-frequency message (information) signal.
*Need for Modulation:*

1. *Efficient Transmission:* Low-frequency signals can't travel long distances due to high attenuation.
2. *Antenna Size:* Direct transmission of low-frequency signals requires impractically large antennas.
3. *Multiplexing:* Allows simultaneous transmission of multiple signals.
4. *Noise Reduction:* Modulated signals are less affected by noise than baseband signals.

**Types of Modulation**
There are three basic types of analog modulation:

1. **Amplitude Modulation (AM)**
   *Definition:* In AM, the amplitude of the carrier signal varies according to the instantaneous value of the modulating (message) signal, while frequency and phase remain constant.




*Mathematical Expression:*
Let,

- Carrier wave: $V_c(t) = A_c \sin(2\pi f_c t)$
- Modulating signal: $V_m(t) = A_m \sin(2\pi f_m t)$

Then, the AM wave is:

$$V_{am}(t) = [A_c + A_m \sin(2\pi f_m t)] \times \sin(2\pi f_c t)$$

*Modulation Index (μ):*

$$\mu = \frac{A_m}{A_C}$$

- μ < 1: Under modulation
- μ = 1: Perfect modulation
- μ > 1: Over modulation (causes distortion)

*Advantages of AM:*

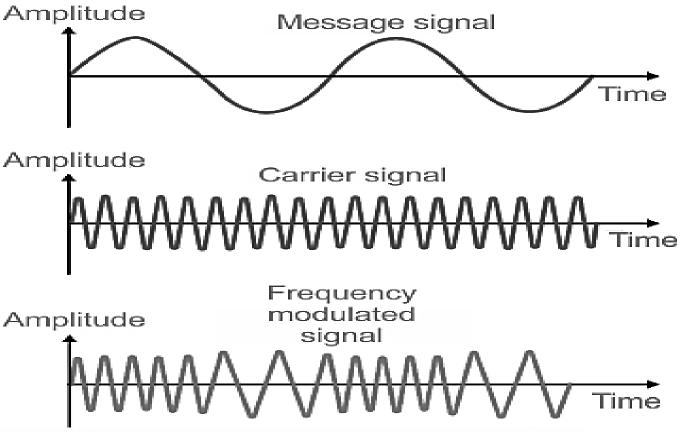
- Simple to implement and demodulate.
- Low-cost receivers.

*Disadvantages:*

- Poor sound quality.
- More susceptible to noise.
- Inefficient power usage.

2. **Frequency Modulation (FM)**

*Definition:* In FM, the frequency of the carrier wave is varied in proportion to the amplitude of the modulating signal, keeping amplitude and phase constant.




*Mathematical Expression:*

$$V_{fm}(t) = A_c \, sin \left[2\pi f_c t + \frac{\Delta f}{f_m} sin \,(2\pi f_m t)\right]$$

Where,

- $\Delta f$ = Frequency deviation
- $f_m$ = Maximum modulating frequency

*Modulation Index (β):*

$$\beta = \frac{\Delta f}{f_m}$$

*Advantages:*

- Better sound quality.
- Highly resistant to noise.
- Constant amplitude avoids distortion.

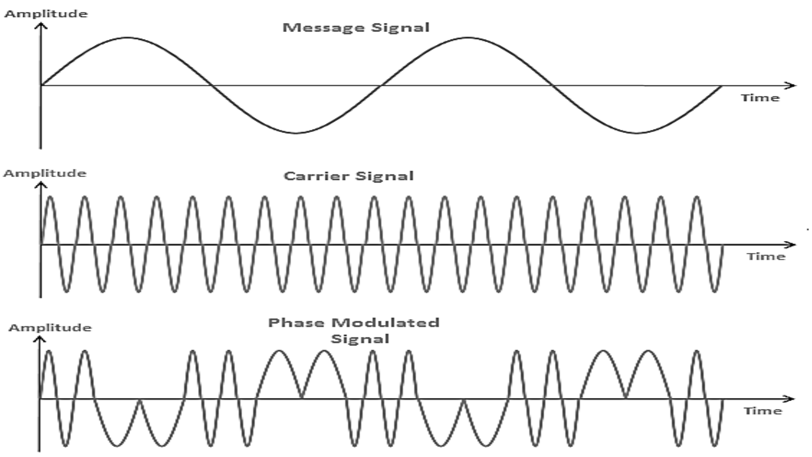
*Disadvantages:*

- Requires larger bandwidth.
- Complex circuitry.



3. **Phase Modulation (PM)**

*Definition:* In PM, the phase of the carrier wave is varied according to the message signal, keeping amplitude and frequency constant.



*Mathematical Expression:*

$$V_{pm}(t) = A_c \, sin \left[2\pi f_c t + k_p m(t)\right]$$

Where,

- $k_p$ is the phase sensitivity of the modulator.

*Characteristics:*

- Closely related to FM.
- Phase change depends on amplitude of the message signal.

*Advantages:*

- Less sensitive to noise than AM.
- Used in digital communication (e.g., PSK – Phase Shift Keying).

*Disadvantages:*

- Complex receiver and demodulation circuitry.
- Phase instability may cause errors.

**Comparative Table**

| Parameter | AM | FM | PM |
|---|---|---|---|
| *Varying Parameter* | Amplitude | Frequency | Phase |
| *Bandwidth* | $2 \times f_m$ | $2(\Delta f + f_m)$ | Depends on modulating signal |
| *Noise Immunity* | Poor | Good | Better than AM |
| *Power Efficiency* | Low | High | Moderate |
| *Application* | AM Radio | FM Radio, TV Audio | Mobile, Digital Systems |
| *Complexity* | Simple | Moderate | Complex |

**Applications of Modulation**

| Modulation Type | Applications |
|---|---|
| *AM* | AM radio, aviation communication |
| *FM* | FM radio, audio broadcasting, police radios |
| *PM* | Mobile communication, satellite, radar, telemetry |

## DEMODULATION

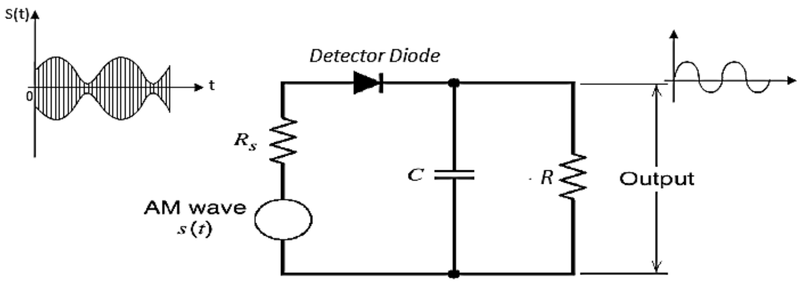
*Definition:* Demodulation is the process of recovering the original information signal (such as audio, video, or data) from a modulated carrier wave. It is the reverse process of modulation.

**Why is Demodulation Necessary?**

- To retrieve the actual message signal (such as a voice signal) from a modulated wave sent over long distances.
- Required in all communication receivers (like radios, TVs, mobile phones, etc.).

**Types of Demodulation Techniques**

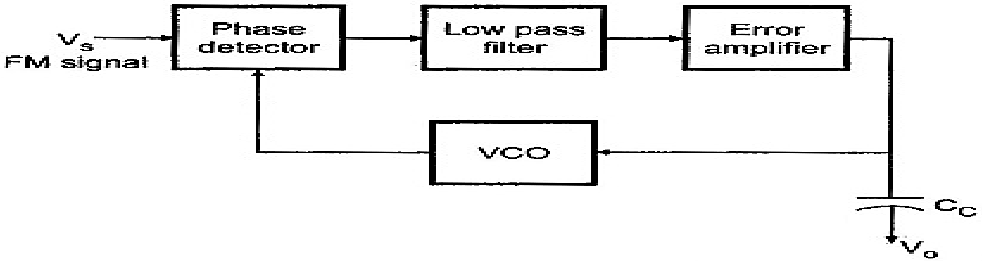
1. *AM Demodulation (Amplitude Demodulation):*
   Used to extract the message from an AM (Amplitude Modulated) signal.



*Envelope Detector (Simple AM Demodulator):*
  - Circuit: Diode + RC filter.
  - Working: The diode allows only positive half-cycles of AM wave; the RC filter smoothens the signal to follow the envelope.
  - Used In: Radios, simple receivers.

2. *FM Demodulation (Frequency Demodulation):*
   Used for Frequency Modulated signals.
   *Common FM Demodulators:*
     - Slope Detector (simple, low accuracy)
     - Phase-Locked Loop (PLL) (high accuracy and widely used)
     - Quadrature Detector

   *Phase-Locked Loop (PLL) Working:*
     - Tracks the input FM signal's frequency.
     - The difference in phase is used to recreate the original modulating signal.




3. *PM Demodulation (Phase Demodulation):*
   - Similar to FM demodulation, often done using PLLs.
   - Extracts changes in phase to determine the message.



**Applications of Demodulation**

- Radio and TV receivers
- Satellite communications
- Mobile phones
- Internet data transmission

## MULTIPLEXING

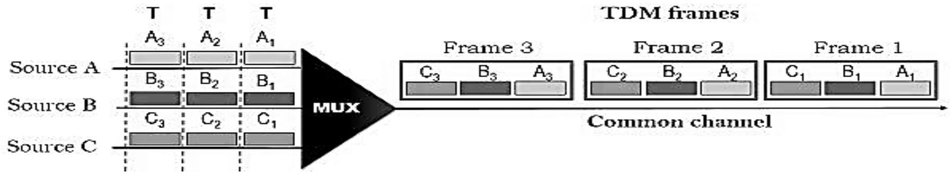
*Definition:* Multiplexing is a technique used to combine multiple signals (analog or digital) into one signal over a shared medium (like a cable or wireless channel), to maximize efficiency of communication systems.

**Why is Multiplexing Important?**

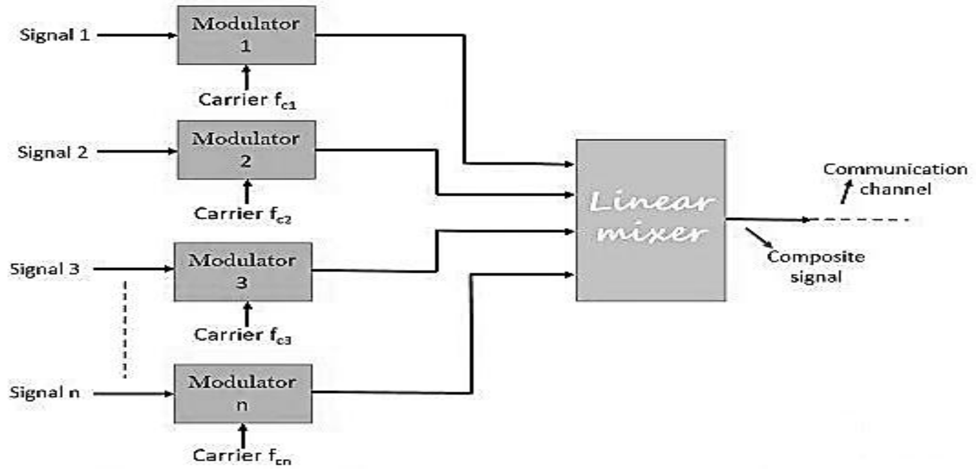
- **Saves bandwidth and cost.**
- **Efficient use** of available communication channels.
- Enables **simultaneous data transmission**.

**Types of Multiplexing**

1. *Time Division Multiplexing (TDM):*
   - Each signal gets a specific time slot in a repeating sequence.
   - Used in: Digital communication, computer networks.
   - TDM Working: If there are 4 signals, each one is sent in 1 out of every 4 time slots, very rapidly (so the receiver reconstructs all signals smoothly).



2. *Frequency Division Multiplexing (FDM):*
    - Each signal is assigned a different frequency band.
    - Used in: Radio and TV broadcasting, cable TV, telephony.
    - FDM Working: Different audio stations are modulated on different carrier frequencies and sent over the same medium.




3. *Wavelength Division Multiplexing (WDM):*
    - Specific to optical fiber communication.
    - Each signal is transmitted using different wavelengths (colours) of light.
    - Used in: Fiber-optic communication.
4. *Code Division Multiplexing (CDM / CDMA):*
    - All users use the same bandwidth at the same time, but with unique codes.
    - Used in: Mobile communications (3G networks), GPS.

**Applications of Multiplexing**

- Mobile networks (CDMA, FDMA)
- Satellite and cable TV
- Optical fiber data transmission (WDM)
- Telecommunication systems
- Internet data transmission (TDM)

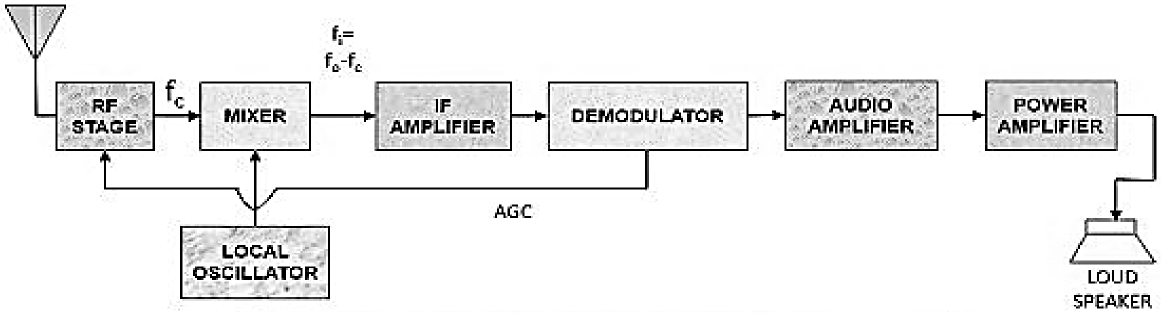


## SUPERHETERODYNE RADIO RECEIVER

A Superheterodyne Receiver is a type of radio receiver that uses frequency mixing to convert a received signal to a fixed intermediate frequency (IF) which can be processed more conveniently than the original radio carrier frequency.

It is widely used in AM, FM, and TV receivers due to:

- Better selectivity
- Greater sensitivity
- High gain
- Easier tuning



**Working Principle**

1. *Antenna:* Captures the incoming modulated RF signals.
2. *RF Amplifier:* Amplifies weak signals and selects the desired frequency range.
3. *Mixer:* Combines the amplified signal with a local oscillator signal to produce an Intermediate Frequency (IF) using heterodyning:

$$f_{\mathrm{IF}} = | f_{\mathrm{LO}} - f_{\mathrm{RF}} |$$

4. *IF Amplifier:* Amplifies the IF signal. Since IF is fixed (typically 455 kHz for AM), filters can be optimized.
5. *Detector/Demodulator:* Extracts the audio (original) signal from the modulated carrier.
6. *Audio Amplifier:* Increases the strength of audio signal to drive the loudspeaker.
7. *Speaker:* Converts electrical signal into sound.

**Advantages**

- High gain and selectivity
- Constant bandwidth (due to fixed IF)
- Better image frequency rejection

**Disadvantages**

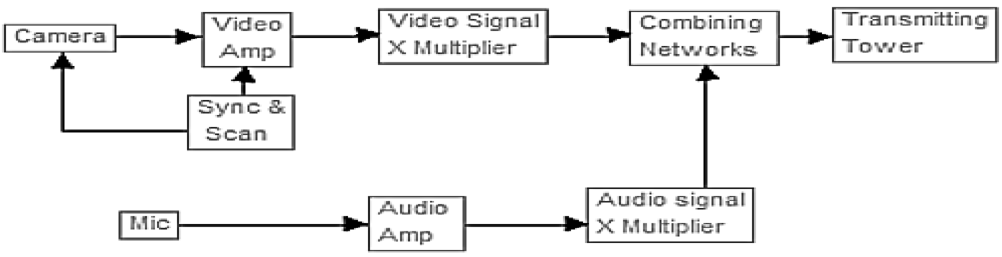
- Slightly complex
- Expensive compared to simple detectors

## TELEVISION

Television is a system for transmitting visual images and sound that are reproduced on screens, mainly used to broadcast programs for entertainment, information, and education.

**Basic Elements**

1. *Transmitter Section*
    - Camera Tube (e.g., CCD): Converts visual scene into electric signals.
    - Microphone: Captures sound.
    - Modulation: Video is AM, audio is FM.
    - Combining Circuit: Synchronizes video and audio signals.
    - Transmitting Antenna: Radiates the signal.
2. *Receiver Section*
    - Receiving Antenna: Captures modulated signal.
    - Tuner: Selects desired channel frequency.
    - Demodulators: Separate video and audio signals.
    - Video Amplifier: Amplifies video for screen display.
    - Audio Amplifier: Drives speaker.
    - CRT/LCD/LED: Displays image.

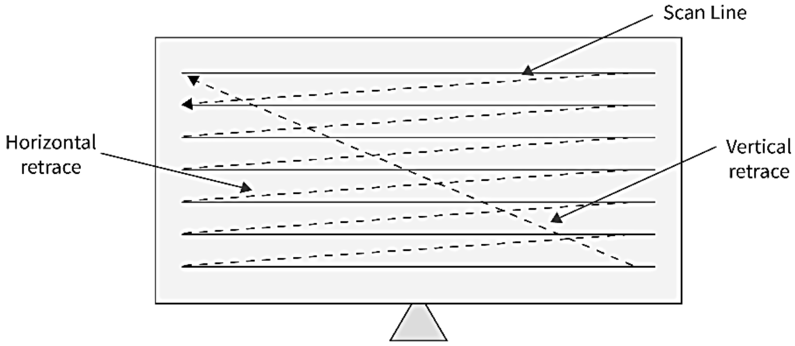



**Scanning Process**

- Converts 2D image into 1D time-varying signal.
- Done line-by-line, then frame-by-frame.
- Interlaced scanning improves stability.

### Colour TV Concepts

- Primary colors: Red, Green, Blue (RGB)
- Color mixing at transmitter and receiver
- Chrominance and Luminance signals are separated




### Types of Modulation Used

- AM for video signals
- FM for audio signals

## ELEMENTARY CONCEPTS OF OPTICAL COMMUNICATION, SATELLITE COMMUNICATION AND MOBILE COMMUNICATION

### Optical Communication

*Definition:* Transmission of data using light (typically infrared or visible) through optical fibers.

*Basic Components*

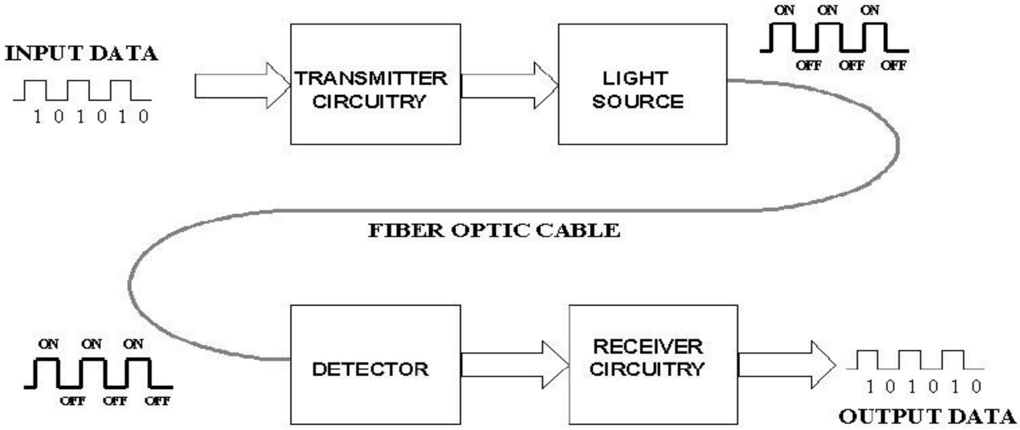
1. Transmitter (LED/Laser Diode): Converts electrical signal into light
2. Optical Fiber: Transmits light via Total Internal Reflection
3. Receiver (Photodiode): Converts light back to electrical signal

*Advantages*

- Very high bandwidth
- Immune to EMI
- Low loss, secure transmission

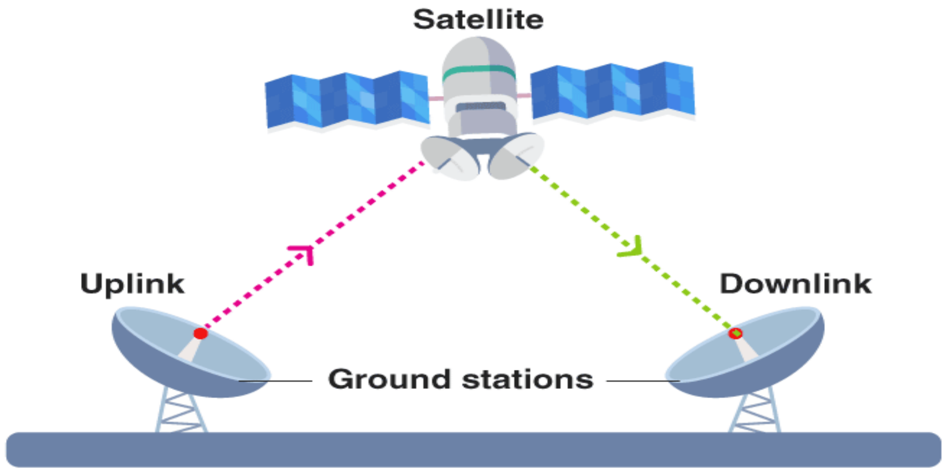
*Applications*

- Internet backbone
- Long-distance telephony
- Medical imaging (endoscopy)




### Satellite Communication

*Definition:* Satellite communication uses orbiting satellites to relay and amplify radio signals between source and receiver.




*Components*

- Uplink: Signal from Earth to satellite
- Downlink: Signal from satellite to Earth
- Transponder: Receives, amplifies, and retransmits signals
- Earth Station: Ground-based sending/receiving unit

*Frequency Bands*

- C Band: 4–8 GHz
- Ku Band: 12–18 GHz
- Ka Band: 26–40 GHz

*Advantages*

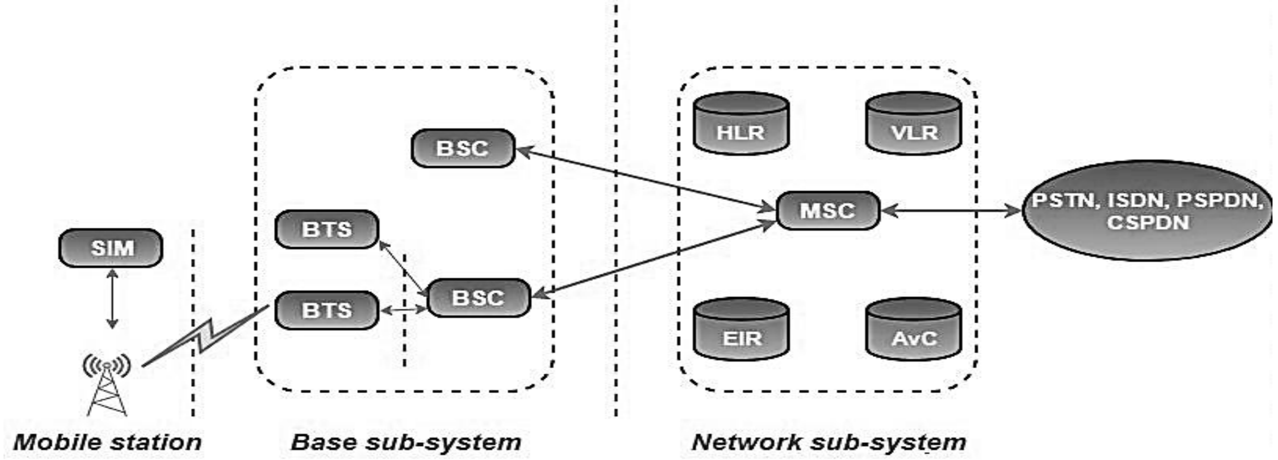
- Wide area coverage
- Useful in remote areas
- Reliable for global broadcasting

*Applications*

- TV, internet, GPS, military communication

**Mobile Communication**

*Definition:* Mobile communication refers to the wireless transmission of voice and data through a network of base stations and cell towers.




*Evolution*

- 1G: Analog voice
- 2G: Digital voice (GSM)
- 3G: Mobile internet
- 4G: High-speed data (VoLTE)
- 5G: Ultra-high-speed, low-latency, IoT connectivity

*Key Components*

- Cell Towers (Base Stations)
- Mobile Switching Center (MSC)
- SIM and Mobile Device
- Network Backbone

*Technologies*

- CDMA, GSM, LTE, OFDM, MIMO

*Applications*

- Voice, SMS, Internet
- Video streaming, GPS, Banking