COMMUNICATION ENGINEERING

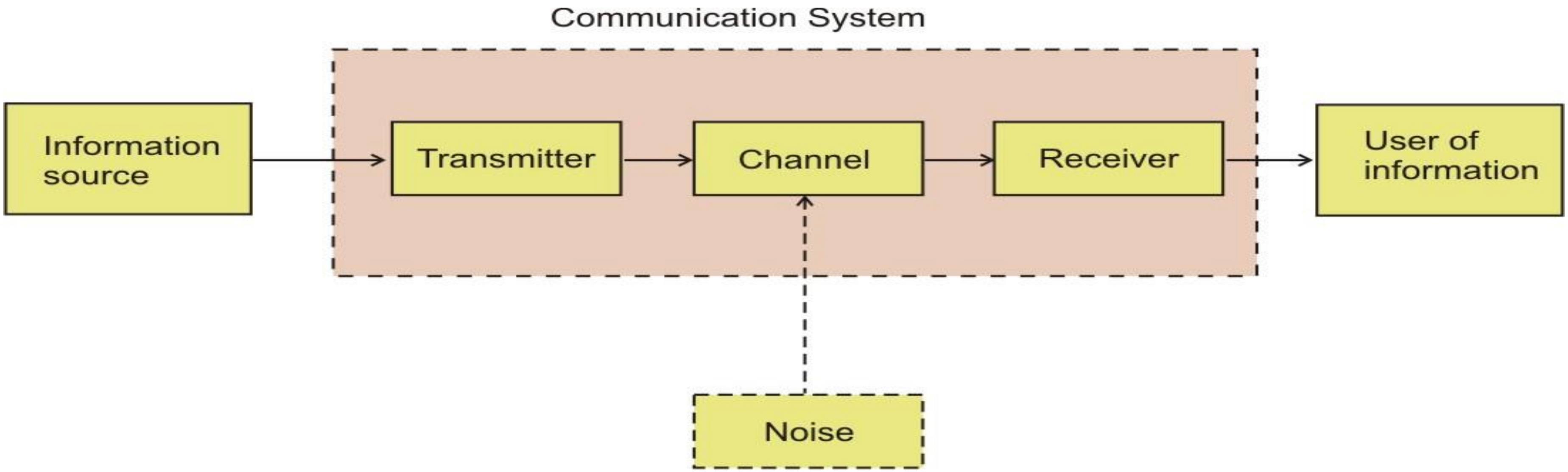
21EC651

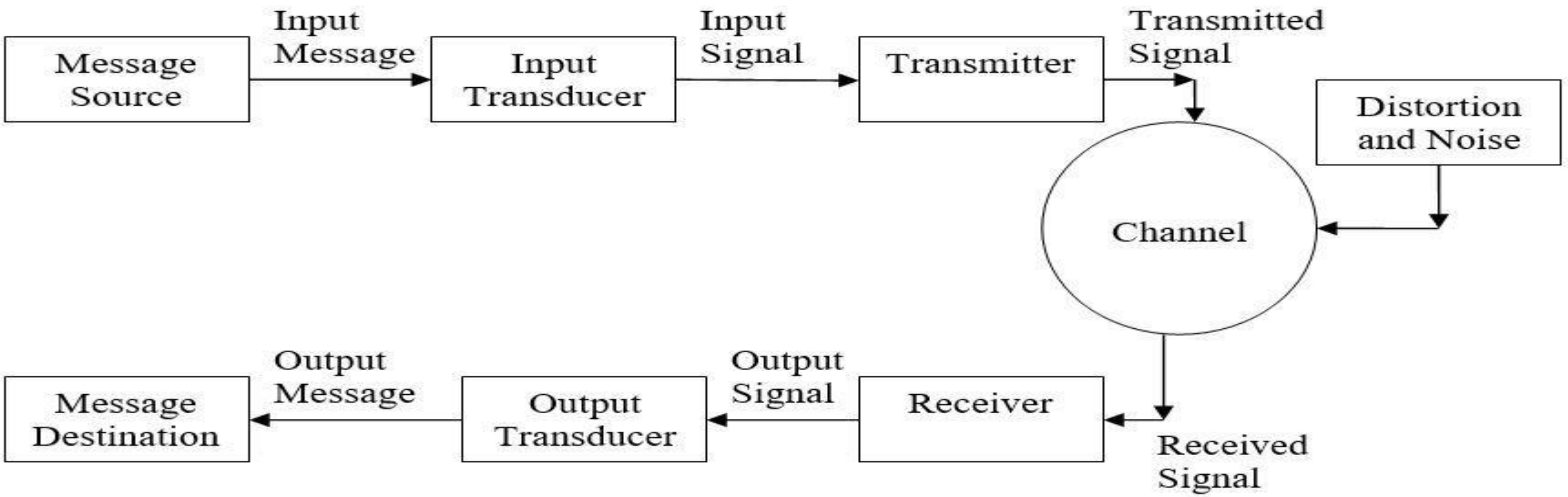
Module-1

Introduction to Electronic Communications:

- Historical perspective
- Electromagnetic frequency spectrum
- Signal and its representation
- Elements of electronic communications system
- primary communication resources
- signal transmission concepts
- Analog and digital transmission
- Modulation
- Concept of frequency translation
- Signal radiation and propagation

Introduction





Historical perspective

1. **Early Foundations (19th Century)**
   - Before the advent of electronic communication, people communicated across distances through physical methods like **written letters or messengers.** The earliest breakthroughs in electronic communication were in the mid-1800s:
   - **Telegraph**: The **telegraph** (1830s), invented by **Samuel Morse**, used electrical signals to transmit messages over wires. The **Morse code**, a system of dots and dashes, was used to encode text. This was the first practical form of long-distance electronic communication.
   - **Telephone**: In 1876, **Alexander Graham Bell** invented the **telephone**, which allowed voice transmission over wires. The telephone transformed personal and business communication by enabling people to talk to one another over great distances.

2. Wireless Communication and Radio (Early 20th Century)

- Wireless communication, which allowed signals to travel through the air without physical wires, was a breakthrough in the early 20th century:
- **Marconi and Radio**: **Guglielmo Marconi** developed the first practical **wireless telegraphy** system in the 1890s, allowing the transmission of signals via electromagnetic waves.
- The **radio** revolutionized mass communication. By the 1920s, radio stations began broadcasting music, news, and entertainment, reaching a wide audience.
- **Television**: In the 1930s, **television** was introduced, combining both sound and visual elements to communicate messages to the public. It became a major medium for news and entertainment.

3. The Rise of Digital Communication (Late 20th Century)

- The development of the **internet** and **digital communication technologies** in the late 20th century further revolutionized how information is transmitted.

- The **internet** began as a military project in the 1960s and expanded to become a global network in the 1990s, providing access to emails, websites, and file-sharing.

- **Cell phones** emerged in the 1980s, and **smartphones** became ubiquitous in the 2000s, allowing people to communicate not just via voice but also through text, email, social media, and more.

4. Modern Communication Technologies (21st Century)

- Today, communication is faster, more mobile, and more interactive than ever before:
- **Smartphones** integrate multiple communication methods in one device, including voice, text, email, internet browsing, and social media.
- **Social media platforms** like Facebook, Twitter, and Instagram have become major communication tools, facilitating both personal interactions and global discussions.
- Innovations like **5G networks** and **artificial intelligence (AI)** are setting the stage for even faster communication speeds and smarter devices.

Electromagnetic frequency spectrum

- The propagation of an **electrical signal** through the **transmitting medium or communication channel** can take place in the **form of electromagnetic signals** (or waves or energy).

➢ In **wireline type communication channel**, (Metallic wire)

➢ In **a wireless medium through free space**,(EMR signal)

➢ In **an optical fiber medium**, (light wave)

Relationship Between frequency and wavelength

- **Frequency:**

The number of oscillations of a wave per unit time being, Measured in **hertz(Hz).** Humans can hear sounds with frequencies ranging between **20 – 20000 Hz.**

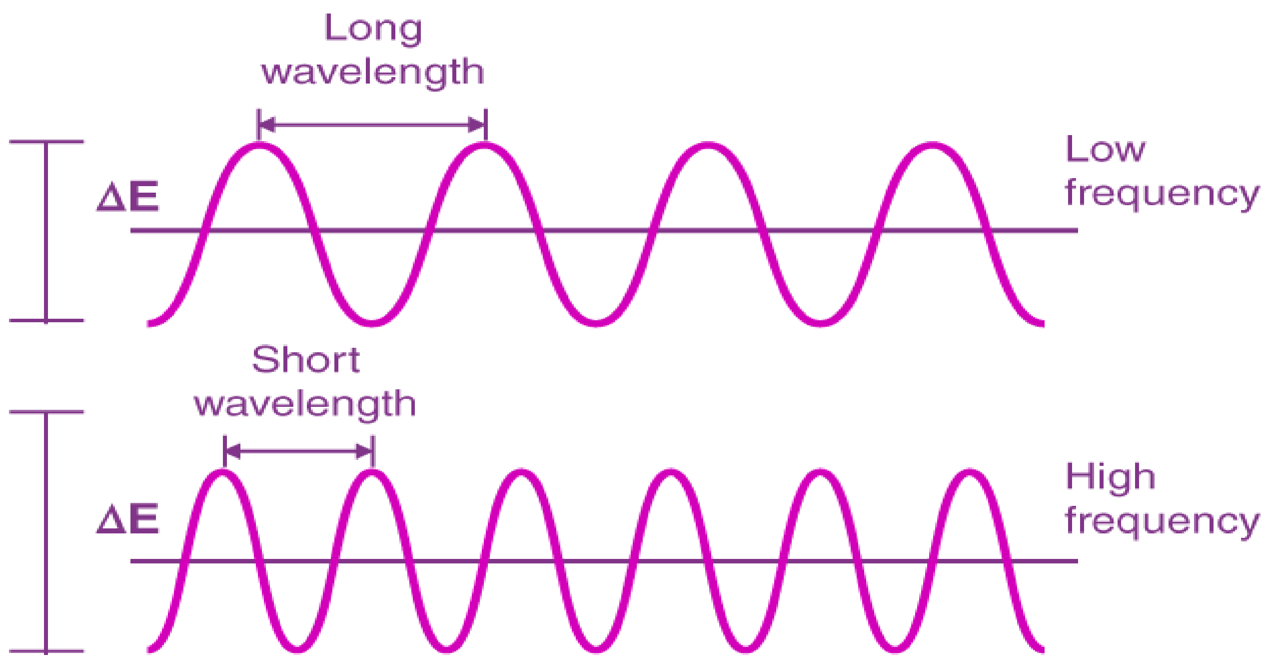
- **Wavelength:**

The distance between two most near points in phase,

we use the letter **lambda (λ)** to describe the wavelength of a wave.

Another quantity is Period (T) which can be used to describe a wave. It is defined as the time taken to complete one oscillation.
Because frequency determines the number of times a wave oscillates and it can be expressed as,

$$\mathbf{f = 1 / t}$$



- Wavelength is inversely proportional to the frequency and directly proportional to the velocity of propagation of the electromagnetic signal in free space.

$$\lambda = c/f$$

Where,

λ = wavelength (m)

c = velocity of electromagnetic waves in free space (3 × 10

f = frequency (Hz)

Electromagnetic wave

- The analog combination of electrical voltage and magnetic field propagates through air or space, and is called an electromagnetic wave
- simply an **‘em wave’.**

➢ By nature, radio signal transmissions take place on one radio frequency or with a very narrow bandwidth. Electromagnetic signal is distributed throughout an almost **infinite range** of frequencies.

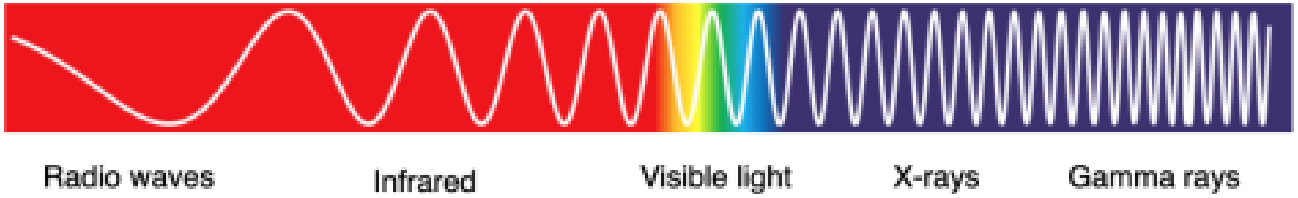
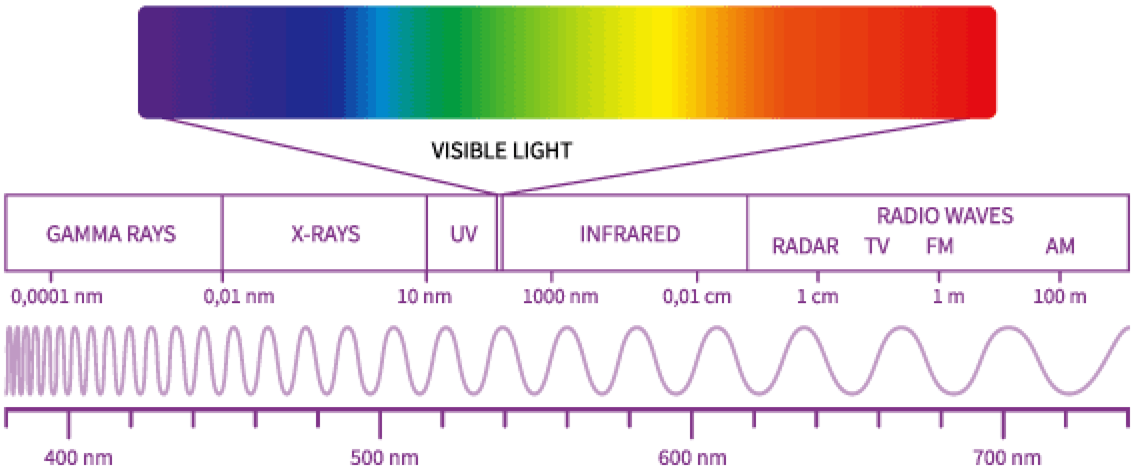


Fig 1. The Electromagnetic Spectrum of Waves.

- The useful electromagnetic frequency spectrum extends from approximately **10 kHz to several billions of Hz.**
- The electromagnetic radio-frequency (RF) spectrum is divided into several narrower frequency bands.

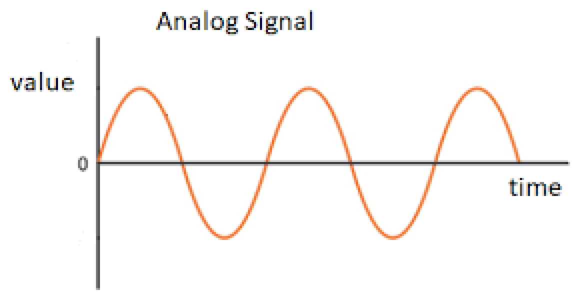


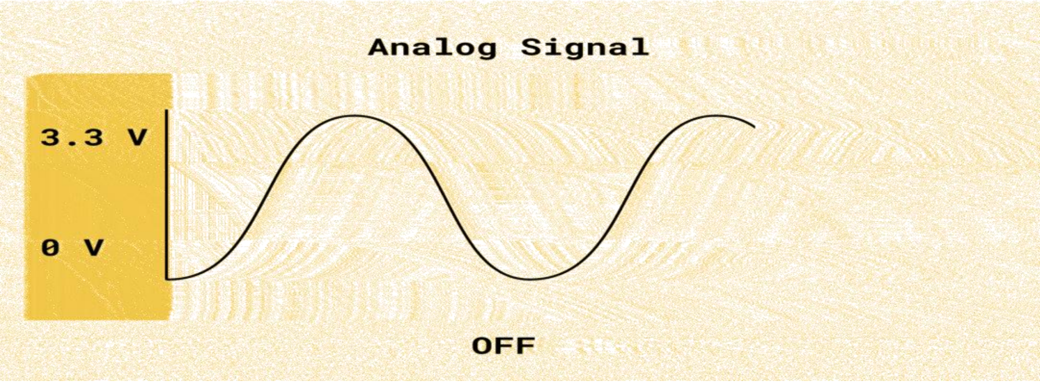
Signal and its representation

- A signal is referred to as transmission of information in **electrical or electromagnetic** form.

→**Analog Signal**

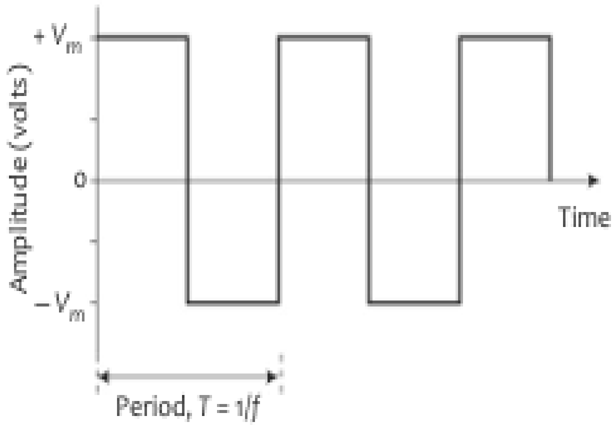
An analog signal is one in which its amplitude level or intensity varies continuously with respect to time with no breaks or discontinuities.

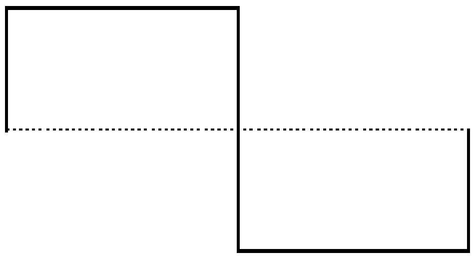




→Digital Signal

A digital signal is one in which the amplitude of the signal maintains a constant level for some period of time and then changes instantaneously to another constant level.





Difference between Analog and Digital Signals

Analog Signals	Digital Signals
Continuous signals	Discrete signals
Represented by sine waves	Represented by square waves
Human voice, natural sound, analog electronic devices are a few examples	Computers, optical drives, and other electronic devices
Continuous range of values	Discontinuous values
Only used in analog devices	Suited for digital electronics like computers, mobiles and more

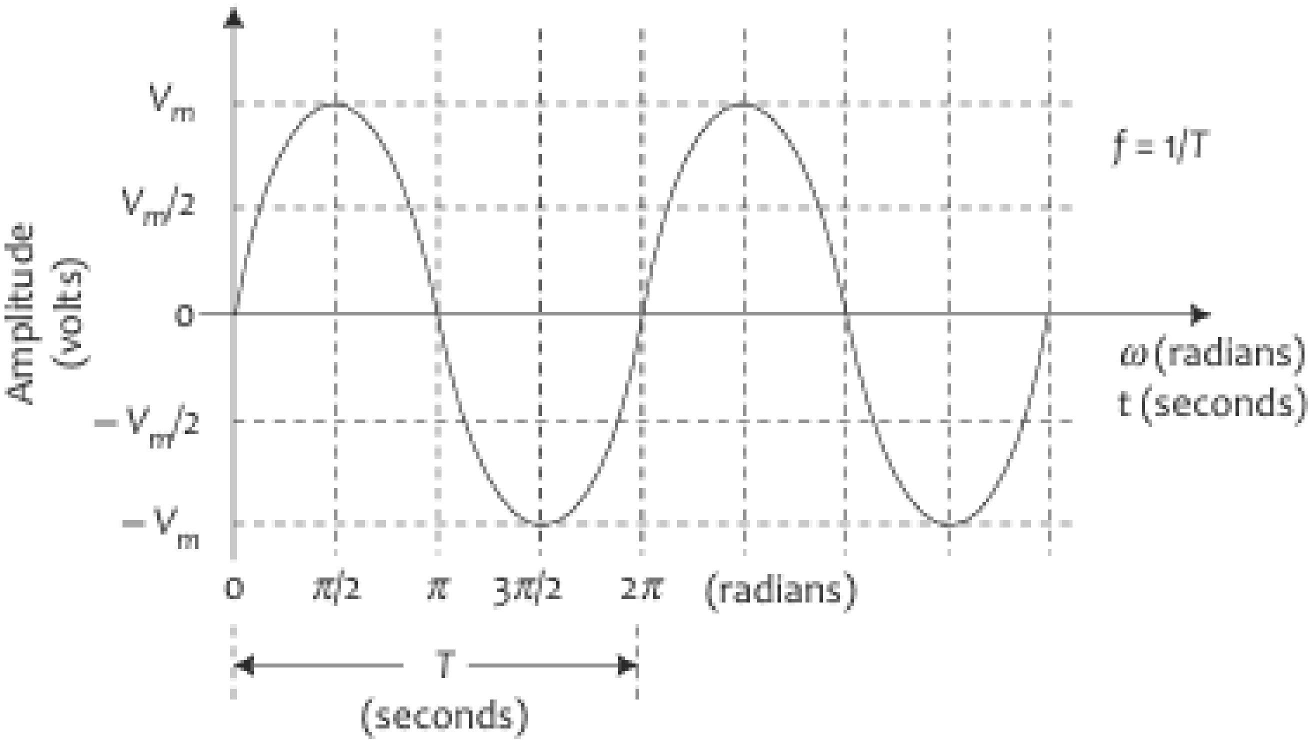
Time-Domain Representation

- A signal with respect to time is called a time-domain representation of the signal.
- An analog signal waveform shows the shape and instantaneous magnitude of the signal with respect to time but it does not indicate its frequency contents directly.
- The display on a standard oscilloscope is an example of amplitude-versus-time representation of the signal.

- It shows the signal waveform for a single-frequency sinusoidal signal with frequency of

$$f = 1/T \text{ Hz},$$

- where T is a constant time period of the signal.



- A signal s(t) is said to be periodic if and only if

$$s(t + T) = s(t) \quad -\infty < t < +\infty$$

where **t** is the smallest value of a constant time period of the signal that satisfies the equation.

The signal is aperiodic. Mathematically, a periodic analog signal such as a sinusoidal wave (or simply a sine wave) can be defined as

$$s(t) = V\,m \sin(2pi\ f\ t + \theta)$$

- **Peak amplitude (V_m)** It is the maximum value of the signal over a specified time, and is measured in volts.

- **Frequency (f)** It is the rate at which the signal repeats and is measured in cycles per second or Hz.

An equivalent parameter is the time period (T) of a sine signal, defined as the amount of time it takes to complete one complete cycle of repetition ($T = 1/f$).

- **Phase angle (θ)** It is a measure of the relative position in time within a single period of the sinusoidal signal. It is measured in radians of degrees ($360° = 2\pi$ radians).

Analog Spectrum analysis

- Analog spectrum analysis is the analysis of an **analog signal in its frequency domain representation**.
- A signal with respect to its frequency is known as a **frequency-domain representation**.
- The frequency-domain plot of a sinusoidal wave exhibits the relationship between **amplitude and frequency**.

Representation of electromagnetic signal

- Any electromagnetic signal basically consists of a combination of **periodic analog sine waves** at different amplitudes, frequencies, and phases.

Power Measurements

- When the power is measured relative to a reference level, it is expressed in **decibels (dB).**

Definition of dB→ dB is a relative measure of two different power levels, and is a logarithmic unit.

- Decibel is considered as a **dimensionless unit** because it is a ratio of two similar quantities with the same units.
- Let **P1 and P 2** be two different values of power specified in same units (watts or milliwatts), then the ratio of these two power le

$$dB = 10 \log P2/P1$$

dBm(Decibel Milliwatts)

Definition→ dBm stands for an **absolute power level** with reference to fixed constant reference power level as 1 mW.

- dBm is different but definitely related to dB.
- A dBm is a unit of measurement which means decibels relative to 1 milliwatt.

$$dBm = 10 \log P\ (mW) / 1mW$$

- 0 dBm means 1 mW power level.

Elements of electronic communications system

- An electronic communication system basically comprises of a transmitter, a communication channel, and a receiver.

A simplified block diagram of an electronic communication system.

- **Input transducer** is a device that converts a physical signal (information or message) from the source to an electrical signal suitable for processing in the transmitter.

- An electronic device or circuit, called **transmitter**, converts **the analog or digital form** of information signal to a form more suitable for transmission over a particular communications channel.
- The communication channel provides a means **of carrying electrical or electromagnetic signals between a transmitter and a receiver.**
- A communication channel can be wireline (twisted-pair telephone cable, coaxial cable, or an optical fiber) or wireless (free-space radio communication).
- Another electronic device, called **receiver**, accepts the signals from the communication channel and then converts it back to their original form.
- The recovered information signal is presented to **output transducer device** that converts it back into the desired analog or digital form of information.

primary communication resources

- ✓ **Average transmitted power**
- ✓ **channel bandwidth** are two primary communication resources in any communication system.

- The **transmitted power** determines the signal-to-noise ratio (SNR) at the receiver input.
- This, in turn, determines the allowable distance (operating range) between the transmitter and receiver for an acceptable signal quality.
- The SNR at the receiver determines the noise performance of the receiver which must exceed a specified level for satisfactory communication over the channel.

- A communication channel must pass every frequency component of the transmitted signal, while preserving its amplitude and phase. But no communication channel or transmission medium is perfect.
- Each type of communication channel has its own characteristics including frequency or range of frequencies, also called its bandwidth.
- Transmitted signal is distorted in propagating through a channel because of **noise, interference**, distortion due to nonlinearities and imperfections in the frequency response of the channel.

Importance of channel bandwidth

- Bandwidth gives important information about the signal in its frequency domain. The term bandwidth is used in **three distinct ways:**

➢ To characterize the **information signal** (signal bandwidth) as well as **the transmitted baseband or broadband signal** (transmission bandwidth).

➢ To design a wireless transmitter and receiver system. The frequency response of transmitter and receiver must be such that the **total system bandwidth must support the channel bandwidth**.

➢ To allocate a channel to the user to **allow the transmission of maximum frequency content**, that is, channel bandwidth. It decides the transmission capacity.

Types of information Sources

- Based on the **nature of the output signal**, information sources can be categorized as

✓ **analog information sources**

✓ **discrete information source**

- **Analog information sources** generate one or more continuously varying amplitude signals as functions of time.
  - Examples of analog information sources are a microphone actuated by speech, or a video camera scanning the pictures.
- **Discrete information sources** generate a sequence of discrete symbols.
  - Examples of discrete information sources are digital binary output of a computer or a teletype signal. By using proper encoding technique, an analog information can be transformed into a discrete information.

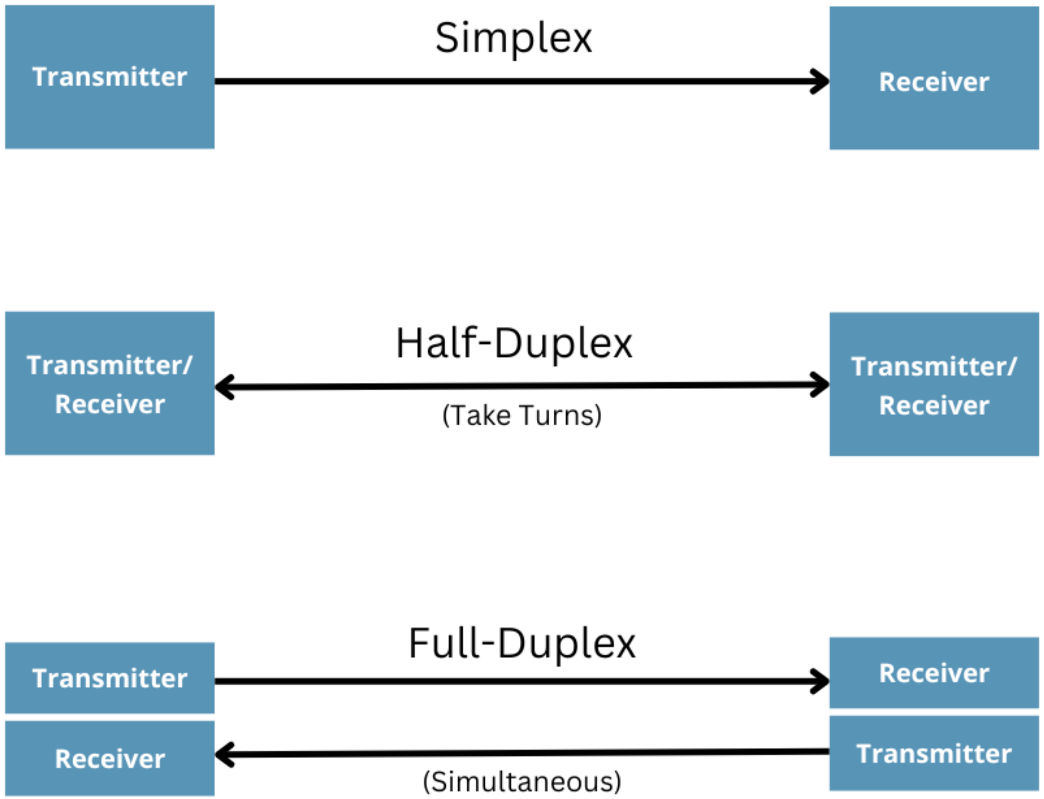
Types of Communication Channels

- **Transmission lines** carry electrical signals from very low power to extremely high power signals. Now-a-days voice/data communication is possible using transmission power lines.
- **A pair of open wire lines** has low pass filter characteristics and offers low bandwidth. It is generally used in the local loop of the Plain Old Telephone Services (POTS). These wires are prone to various forms of electromagnetic interference as there is no shielding of conductors in the wires.
- The **Unshielded Twisted Pair (UTP)** cable consists of two insulated copper wires which are twisted around each other to reduce interference. These are used to connect home telephones and business computers to the local telephone exchange.

- In **Shielded Twisted Pair (STP)** cable, the twisted pair cable is enclosed in a shield that functions as ground. These cables are suitable for operating environments which are more affected with electrical interference such as local area networks (LANs).
- The **Radio Frequency (RF) coaxial cable** has a single copper conductor at its center. A plastic layer provides insulation between the center conductor and a braided metal shield which serves as a ground to minimize external interference.
- RF coaxial cable offers less attenuation over greater distances between networks. It is mostly used for cable TV network and closed circuit TV, and for high data rate LAN cabling.

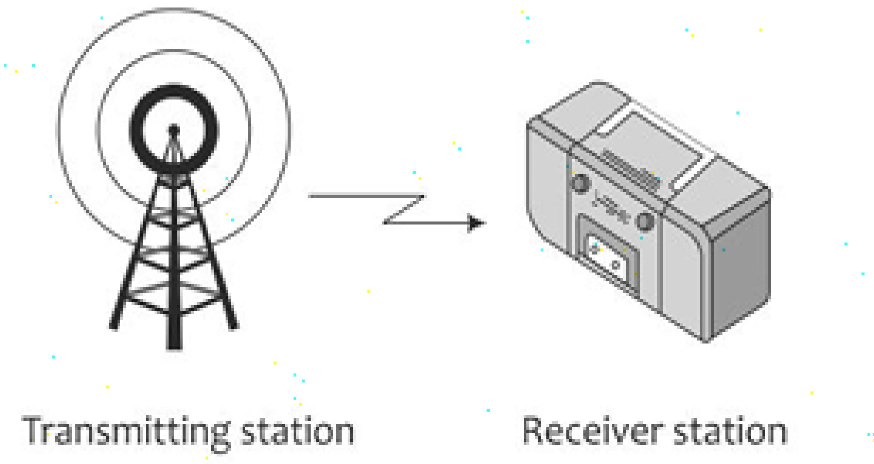
- **Optical Fiber Cable (OFC)** consists of a glass core surrounded by several layers of protective materials like cladding, jacket, etc.
- The optical fiber cable carries information signals in the form of light pulses rather than the electrical signals. It has the ability to transmit signals over much longer distances to carry information at much faster speeds. Therefore, it finds extensive applications in point-to-point voice/data services such as interactive internet and video conferencing.
- The main disadvantage of wired channels is that they require a man-made physical medium to be present between the transmitter and the receiver.

Modes of Communication

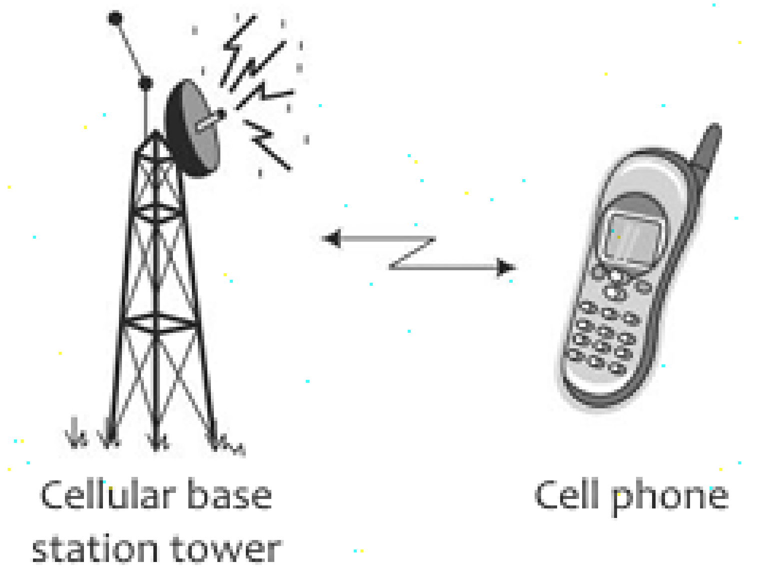


- There are three distinct modes of transmission for any communications link.

➤ **Simple Mode** In Simple Mode of communication, the information can be sent in only one direction.



- **Half-Duplex Mode** In the half-duplex mode of communication, the information can be sent in both directions but in one direction only at a time.
- In **full-duplex mode** of communication, the information can be sent in both directions simultaneously sharing the common communications channel.



signal transmission concepts

- Transmission is the communication of information data by the processing and propagation of signals.
- The information signal may be **analog or digital.**
- The transmissions may be **analog or signal**.
- The communication channels may be **wired or wireless**.
- The communication may be **baseband (narrow band) or passband (broadband).**
- The direction of transmission may be **unidirectional (simplex) or bidirectional (duplex).**
- The information may be **real-time or non-real time (stored date).**
- The data may be sent **one bit at a time (serial) or a symbol (more bits) at a time (parallel).**

- **Information Data Signaling:** The information data can be either in the form of analog or digital. Generally, the terms analog and digital correspond to the continuous and discrete form respectively.
- An analog signal is a continuously varying electromagnetic wave.
- A digital signal is a sequence of voltage pulses, having a constant positive and negative voltage levels.
- **Baseband and Passband Signals:** The information signals generated by the information sources or the input transducers are known as baseband signals.
- The term ‘baseband’ is used to represent the frequency band of the original information or message signal.

- **Baseband Communication:** When the baseband signals are directly transmitted using dedicated communication channels such as twisted pairs of copper wires or coaxial cables, it is referred to as baseband communication.
- Generally, the baseband transmission is preferred at low frequencies.
- **Passband Signals:** If the low-frequency baseband signal (also called the information signal or the message signal or the modulating signal) is impressed upon a fixed high-frequency analog carrier signal, the passband signal (also known as bandpass signal or modulated signal) is produced.
- The bandpass transmission is generally used at high-frequency spectrum.

Analog and digital transmission

- **Analog transmission** is a means of transmitting analog signals irrespective of the type of original information.
- The analog signals may represent analog information such as voice or digital information such as digitized analog signal or computer data.
- In either case, transmission of analog signals will suffer signal level attenuation that limits the distance between transmitter and receiver.

- **Digital transmission** is concerned with the digital signals which may represent digital data or may be an encoded analog signal.
- A digital signal can be propagated through a limited distance only, otherwise higher signal attenuation can introduce unacceptable errors.
- At appropriate distance intervals, the digital transmission system has retransmission devices known as repeaters.
- Digital repeaters reconstruct the received digital data by minimizing the effect of signal attenuation and distortion.

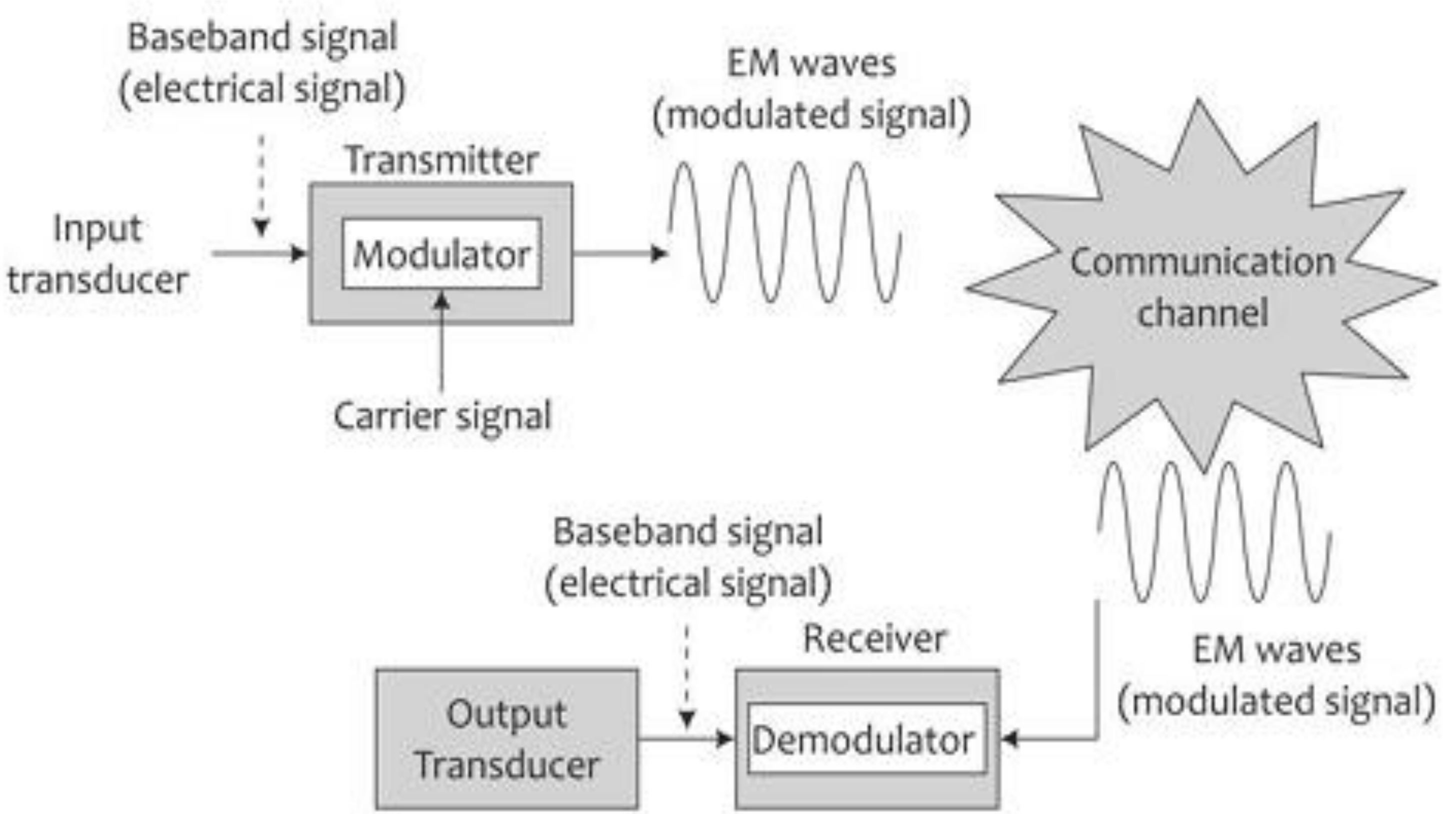
Analog Communications

- Analog communications is defined as transmission of analog information data using analog transmission signals.

Simple mode of Analog Communication

- In analog communications system, the electromagnetic energy is transmitted and received in analog form either using wireline or wireless communications channel.

- Since the baseband signal contains frequencies in the audio frequency range (up to 3 kHz), some form of frequency-band shifting must be employed for the radio communication system to operate properly.



- This process is accomplished by a device, called modulator, contained in the transmitter block.
- The modulator modulates a higher-frequency carrier signal which has a frequency that is selected from an appropriate band in the radio spectrum.
- The receiver block in any electronic communications system contains the demodulator device.
- The demodulator extracts the original baseband signal from the received modulated signal.

Digital Transmission

- Digital transmission is defined as transmission of **analog information data using digital transmission signal.**
- The analog information data is encoded to produce a digital bit stream using a device known as codec (coder-decoder).
- The digital signal thus produced is also called digitized analog data, and the process is also known as digitization.

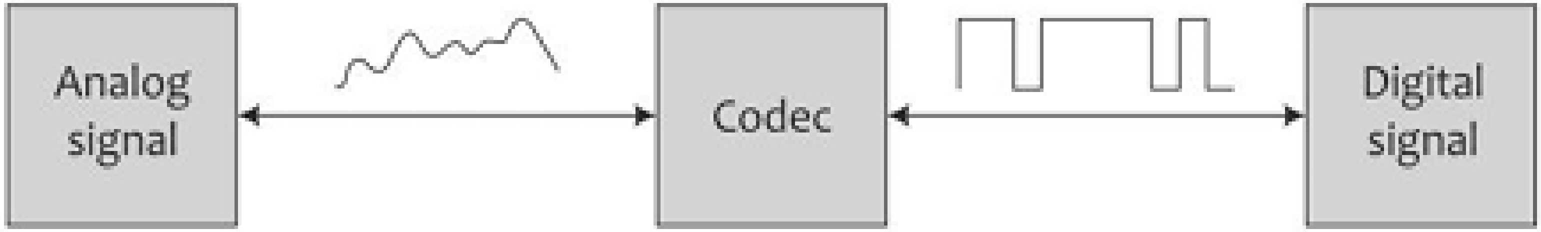


Fig. 1.16 *A Simple Model of Digital Transmission*

Digital Line Coding

- Digital line coding is defined as **transmission of digital information data using digital transmission signal suitable for a communication channel.**
- Digital line coding is carried out to optimize the performance of digital data transmission in terms of bandwidth requirement, synchronization, error detection, clock signal recovery, etc.
- The device used for encoding of digital data into digital signal is called a digital transceiver.

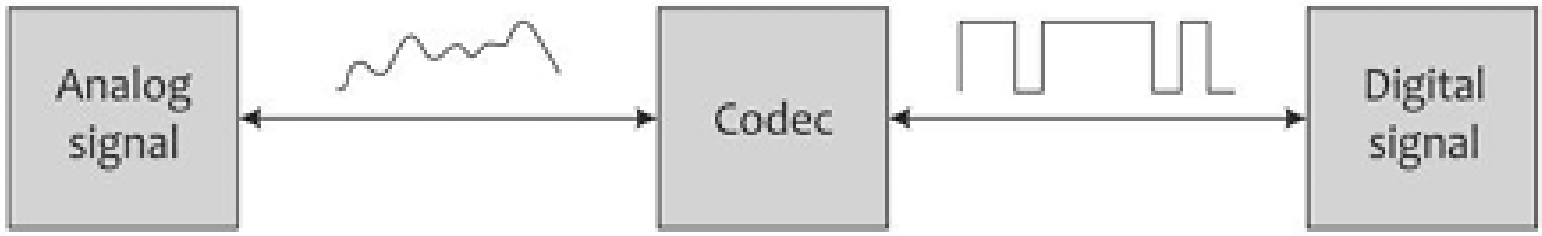


Fig. 1.16 *A Simple Model of Digital Transmission*

Digital Communication

- Digital communications is defined as transmission of digital information data using analog transmission signals.
- Digital information data are encoded to produce analog transmission signals using a modem (modulator + demodulator).
- The modem converts binary digital data into an analog signal by modulating an analog carrier signal of high frequency.

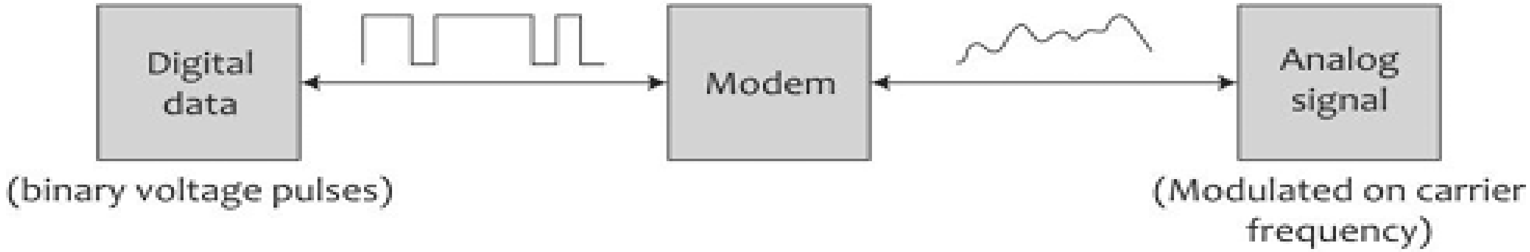


Fig. 1.18 *A Simple Model of Digital Communications*

Elements of Digital Communication System

- In digital communications system, the original source information may be in the form of **digital data or analog data**.
- The analog data is converted to digital pulses (digitized analog) prior to transmission and converted back to analog form at the receiver end.
- Digitizing an analog information signal often results in improved transmission quality, with a reduction in signal distortion and an improvement in signal-to-noise power ratio.
- The digital pulses are propagated between source and destination using a physical channel such as a metallic wire or an optical fiber cable.
- The use of **digital signal processing and transmission techniques** with information data is one of the fastest growing areas in communications.

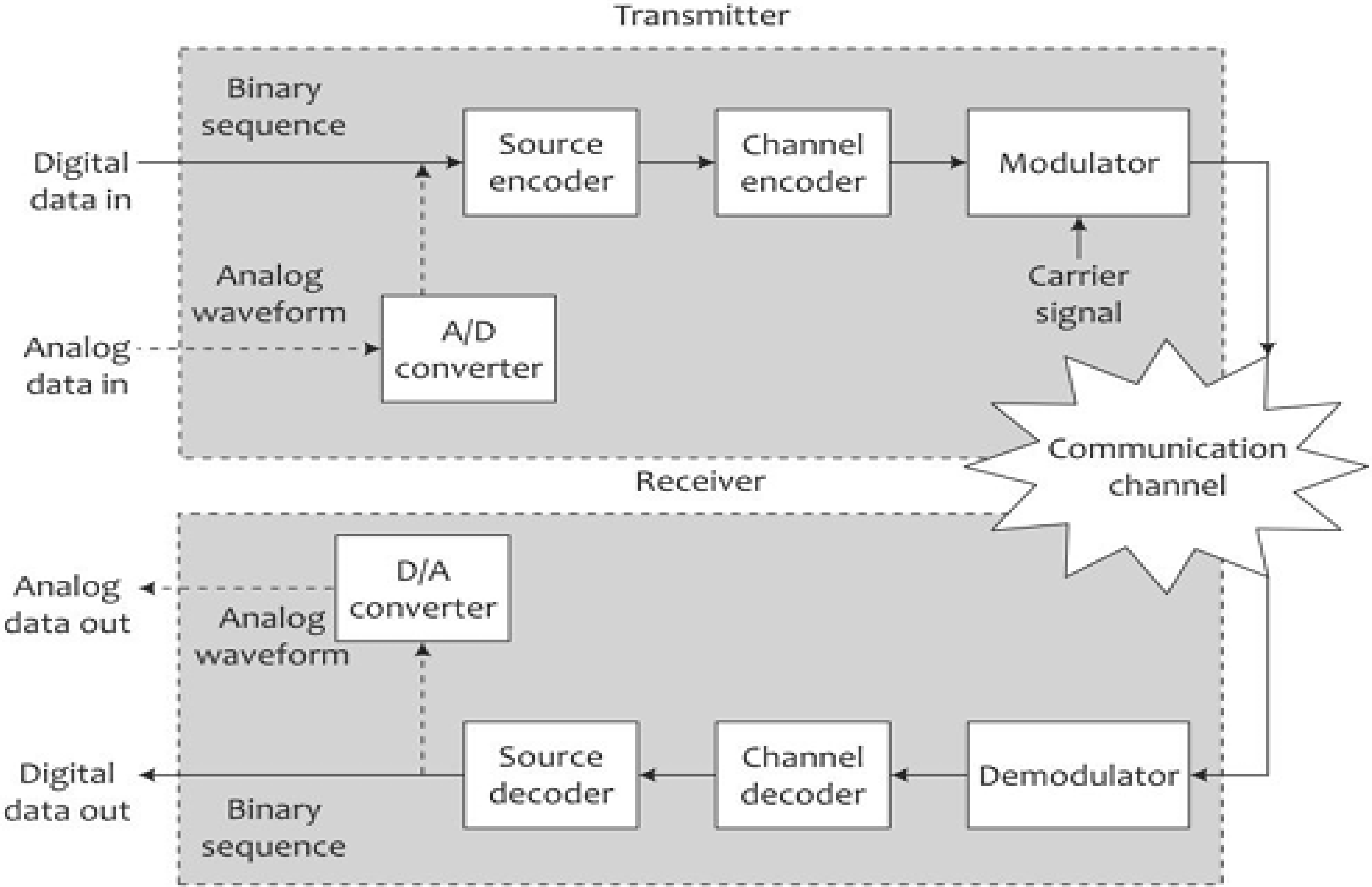


Fig. 1.19 *A Typical Digital Communications System*

Elements of a data Communication System

- Data communication links provide a transmission path to transfer **digital information from one node to another node using electronic circuits**.
- Data communication links utilize electronic communications equipment and facilities to interconnect the digital computers.

Fig. 1.20 *Block Diagram of a Data Communications Link*

- For two-way communications, the transmission path would be bidirectional and the source and destination interchangeable.
- The source or destination must have **three fundamental devices:**

➢ Data Terminal Equipment (DTE)

➢ Data Communications Equipment (DCE)

➢ Interface between DTE and DCE

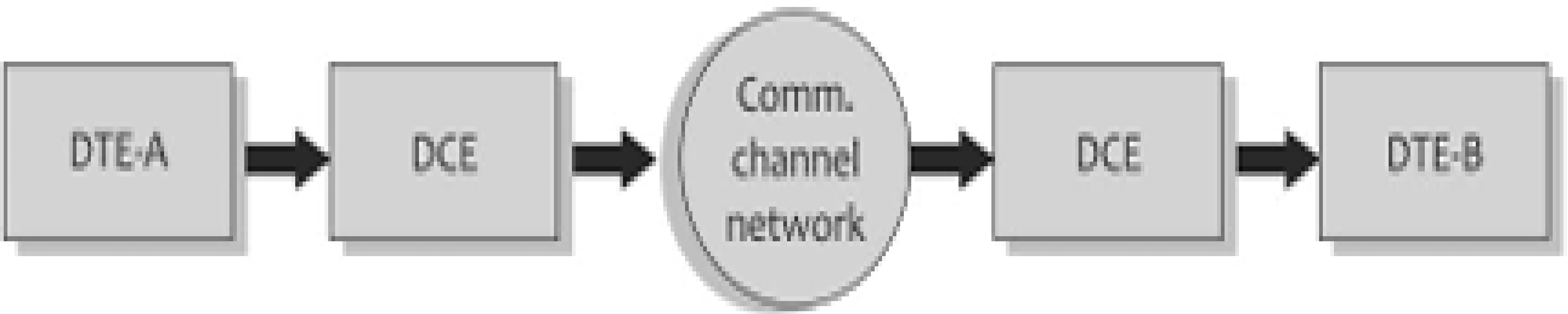
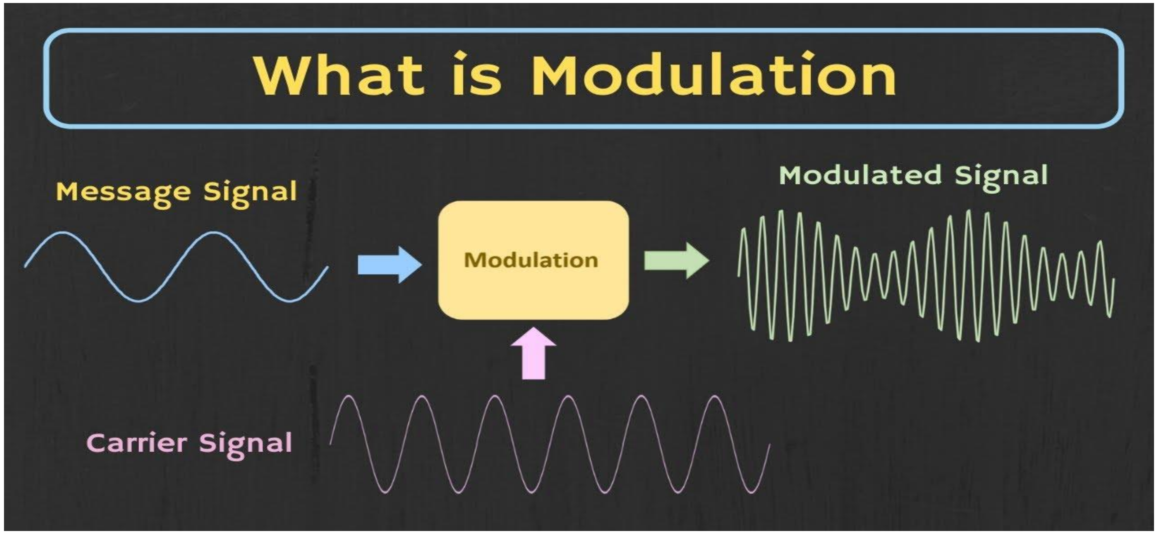


Fig. 1.21 *Two-point Data Communications Circuits*

Modulation

- Modulation is defined as the process of changing one or more characteristics of the high-frequency carrier signal in proportion with the instantaneous value of the analog information or digital data signal. Or
- Modulation is the process of encoding information in a transmitted signal, while demodulation is the process of extracting information from the transmitted signal.



- **Definition of analog Modulation** :When the carrier signal is analog in nature such as sinusoidal signal, the process of modulation is known as analog modulation. It is also called continuous wave (CW) modulation.

- **Modulation and Demodulation :** The process of modifying baseband frequencies so that signals may be transmitted or ‘communicated’ is called **modulation (at transmitter end) and demodulation (at receiver end).**

- **Why we need modulation**

- Increase the signal strength
- Wireless communication system
- Prevention of message signal from mixing

Type of Modulation

Type of modulation Technique	Modulating or Information signal	Carrier Signal	Parameter of carrier signal which is varied in proportion to information signal	Modulation Type
Analog	Analog	Analog	Amplitude Frequency Phase	AM FM PM
Pulse	Analog	Digital	Amplitude Width Position	PAM PWM PPM
Digital	Digital	Analog	Amplitude Frequency Phase Amplitude Phase	ASK FSK PSK QAM

Concept of frequency translation

- Frequency is defined **as the number of waves that pass a certain point in one second**. The unit for frequency is the hertz (Hz).

➢ **Liner and Nonlinear Mixing**

➢ **Linear Mixing**

- Two or more signals are combined in a linear device such as a passive network or a small signal amplifier.
- **Nonlinear Mixing**
- Two or more signals are combined in a nonlinear device such as a diode or a large signal amplifier
- There is a linear and nonlinear relationship between the input and output.

Frequency Division Multiplexing

- Frequency Division Multiplexing (FDM) is the set of techniques that **allows the simultaneous transmission of many baseband signals over a common communications channel.**
- The individual baseband signals have identical frequency bands.
- To transmit a number of such baseband signals over the same channel, the signals must be separated in frequency so that they do not interfere with each other.
- The translated to different higher-frequency spectrum so that they do not overlap with each other.
- At the receiving end, the FDM signal is applied to individual bandpass filters which pass only the desired baseband signals.

Signal radiation and propagation

- Transmitter antennas couple electromagnetic energy from a coaxial cable connected to the transmitter in space for radiating the signal.
- The receiver antenna can be used to receive the radio signals from the space and couples it to a coaxial cable connected to receiver.
- The antenna is an interface between **RF cable** connected to transmitter/receiver units and the space.
- The primary function of transmitting antenna is to **convert the electrical energy from a RF cable from a transmitter unit into electromagnetic** waves in space.

Types of Antenna

1. Isotropic Antenna

- A hypothetical loss-less antenna having **equal radiation in all directions.** The actual radiation pattern for the isotropic antenna is a sphere with the antenna at the center.

2. Omnidirectional Antenna

- An omnidirectional antenna allows transmission of **radio signals with equal signal power in all directions**. It is difficult to design omnidirectional antennas.

3. Directional Antenna

- Directional antennas generally cover an area of **120 degrees or 60 degrees.** A directional antenna, also called Yagi antenna, is one which has the property of radiating or receiving electromagnetic waves more effectively

Antenna Parameters

1. **Antenna Radiation Pattern:** It is defined as a mathematical function or graphical representation of the radiation properties of the antenna as a function of the space coordinates.
2. **Field Pattern :** A graph of the spatial variation of the electric or magnetic field along a constant distance path is called a field pattern.
3. **Effective Isotropic Radiated Power(EIRP) :** The power radiated within a given geographic area is usually specified either with reference to isotropic antenna or an omnidirectional dipole antenna.
4. **Directivity :** The ratio of the radiation intensity flowing in a given direction to the radiation intensity average over all direction.

5. **Absolute Gain :** The ratio of the radiation intensity flowing in that direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotopically.

6. **Relative Gain :** The ratio of the absolute gain of the antenna in the given direction to the absolute gain of a reference antenna in the same direction.

7. Antenna Gain : Antenna gain is directional gain, not power gain, due to focusing of the radiated energy in specified direction.

8. Radiation Resistance : The radiation resistance of a half-wave dipole antenna situated in free space and fed at the center is approximately 70 W.

9. Polarization : The polarization of a radio wave is the orientation of its electric field vector

10**. Front to back Ratio :** The ratio between the gains to the front and back lobes is the front-to-back ratio.

11. Effective Area or Aperture of Receiving Antenna :

The ratio of the available power at the terminals of the antenna to the radiation intensity of a plane wave incident on the antenna in the given direction.

The relationship between antenna gain and effective area is

$$G_r = (4\pi A_{eff})/\lambda_c^2$$

where Gr is receiver antenna gain,

Aeff is the effective area

lamda is the carrier wavelength.

Free Space Propagation

- The free-space environment could be categorized as one having less obstruction due to man-made structures such as buildings and natural hills or vegetation.
- Free-space propagation model is the fundamental for all propagation path-loss models for any wireless communication application.
- Free-space propagation model is used to predict the received signal strength when the transmitter and receiver has clear line-of-sight signal path between them.
- The transmitted RF signal strength decreases with distance.

Power Density of Received Signal

- An isotropic antenna radiates equally in all directions. Therefore, the power density is simply the transmitted power divided by the surface area of the sphere. That is,

$$P_D = P_t/(4\,\pi r^2)$$

- where PD is the power density in watts/m2,

  Pt is the transmitter power in watts,

  r is the distance from the transmitting antenna in meter

  4 pi r2 is surface area of the sphere.

- Practical antennas do not radiate equally in all directions as in case of isotropic antennas. Let Gt be the transmitting antenna gain. Then, power density including transmitting antenna gain, Gt is given by

$$P_D = (P_t\, G_t)/(4\,\pi r^2)$$

$$\mathrm{EIRP} = P_t G_t$$

$$P_D = (\mathrm{EIRP})/(4\pi r^2)$$

Friis Free Space Equation

- A receiving antenna absorbs some of the signal energy from radio waves that pass through it.
- That simply means receiver antennas too have power gain.
- The power extracted from the radio wave by a receiving antenna depends on its physical size as well as its gain.
- The effective area of a receiving antenna can be defined as

$$A_{eff} = P_r / P_D$$

Aeff = effetive area of the receiving antenna in m2

Pr = power delivered by a receiving antenna to the receiver in watts

PD = power density of the radio wave in watts/m

It implies that the effective area of a receiving antenna is the area from which all the power in the incident radio wave is extracted and delivered to the receiver unit.

$$P_r = P_D A_{eff}$$

$$P_r = [(P_t\, G_t)/(4\,\pi r^2)]\, A_{eff}$$

The effective area of a receiving antenna depends on its gain, Gr as well as the wavelength of the incident radio wave lc, and is given as

$$A_{eff} = G_r\, \lambda_c^2/(4\,\pi)$$

$$P_r = [(P_t\, G_t)/(4\,\pi r^2)]\, [G_r\, \lambda_c^2/(4\,\pi)]$$

$$\boxed{P_r = P_t\, G_t\, G_r\, [\lambda_c/(4\,\pi r)]^2}$$

Module -2

- **Amplitude Modulation Techniques:**

    Types of analog modulation

    Principle of amplitude modulation

    AM power distribution

    Limitations of AM

- **Angle Modulation Techniques:**

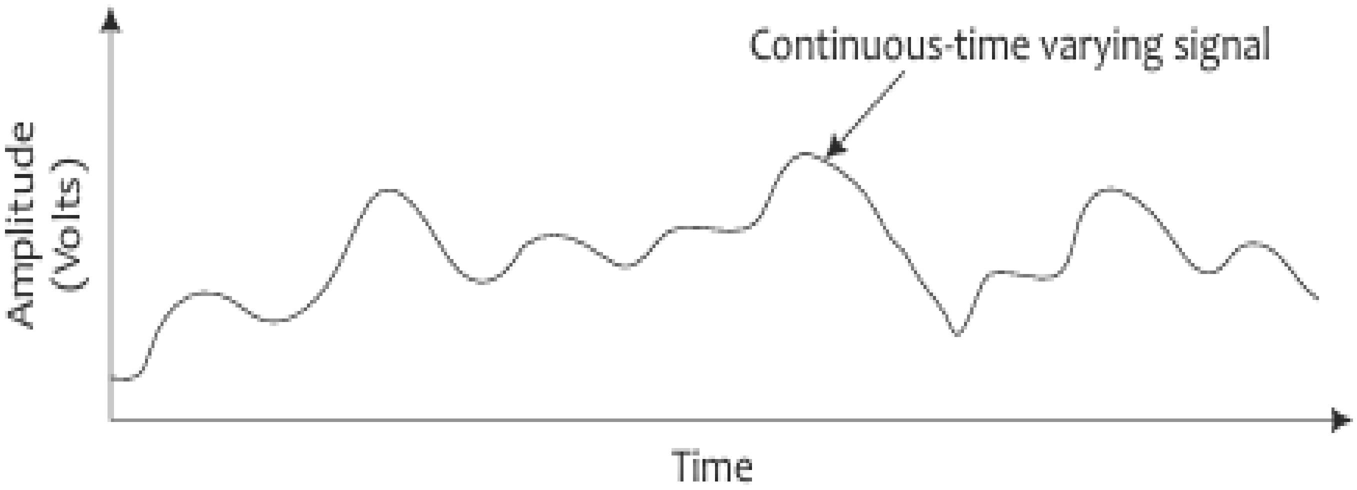
    Principles of Angle modulation

    Theory of FM-basic Concepts

    Theory of phase modulation

Types of analog modulation

- modulation is the process of changing some characteristics of a signal, known as the carrier signal, in proportion with the instantaneous value of the modulating signal, also called as information signal or baseband signal.
  - ✓ Usually the frequency of **modulating signal is relatively low**.
  - ✓ The frequency of the **carrier frequency is usually much greater than that of the modulating signal**.
- When the carrier signal is continuous in nature such as fixed frequency sinusoidal signal, the process of modulation for analog information signal is known as **analog modulation, also known as Continuous Wave (CW) modulation**.



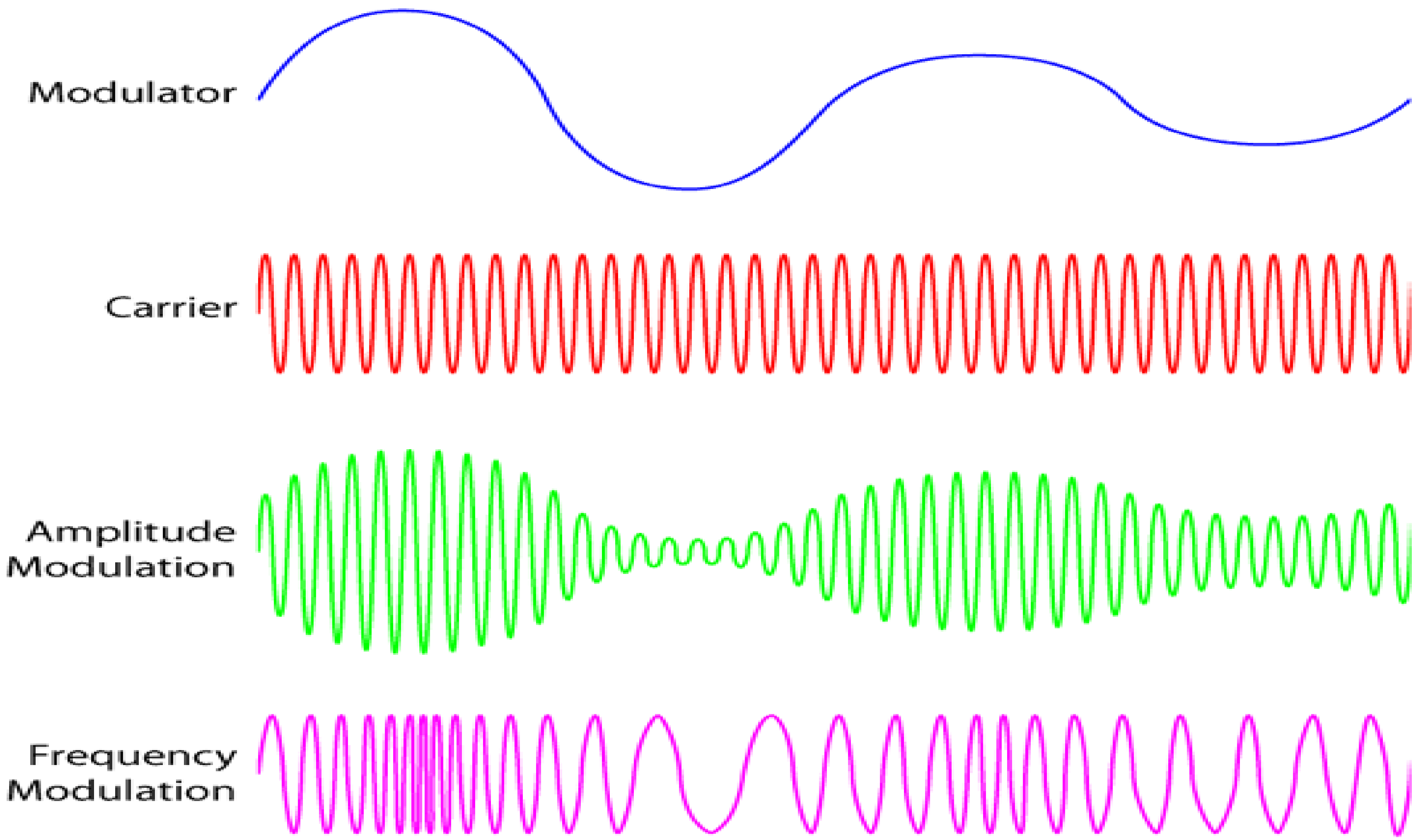
- Let the time-varying carrier signal be a high-frequency analog sinusoidal signal of the form

$$v_c(t) = V_c \sin(2\pi f_c t + \theta)$$

  - V c is the maximum amplitude (volts)
  - f c is the carrier signal frequency (Hz)
  - Teta is phase angle (radians) of the carrier signal.
- **It is obvious that amplitude, frequency, and phase are three characteristics of analog carrier signal**

- If the amplitude (V c) of the carrier signal is varied in proportion to the instantaneous value of the analog information signal, the process is known as **Amplitude Modulation (AM).**
- If the frequency (f c) of the carrier signal is varied in proportion to the instantaneous value of the analog information signal, the process is known as **Frequency Modulation (FM).**
- If the phase angle (Teta) of the carrier signal is varied in proportion to the instantaneous value of the analog information signal, the process is known as **Phase Modulation (PM).**
- Amplitude modulation, frequency modulation, and phase modulation are collectively known as Analog Modulation.

Principle of amplitude modulation



- Let the modulating signal be a low-frequency analog sinusoidal signal which can be expressed a

$$v_m(t) = V_m \sin(2\pi f_m t)$$

  - vm(t) is the instantaneous value of the modulating signal
  - Vm is the maximum amplitude of modulating signal in volts
  - fm is the modulating frequency in Hz.

- Let the analog carrier signal be expressed as

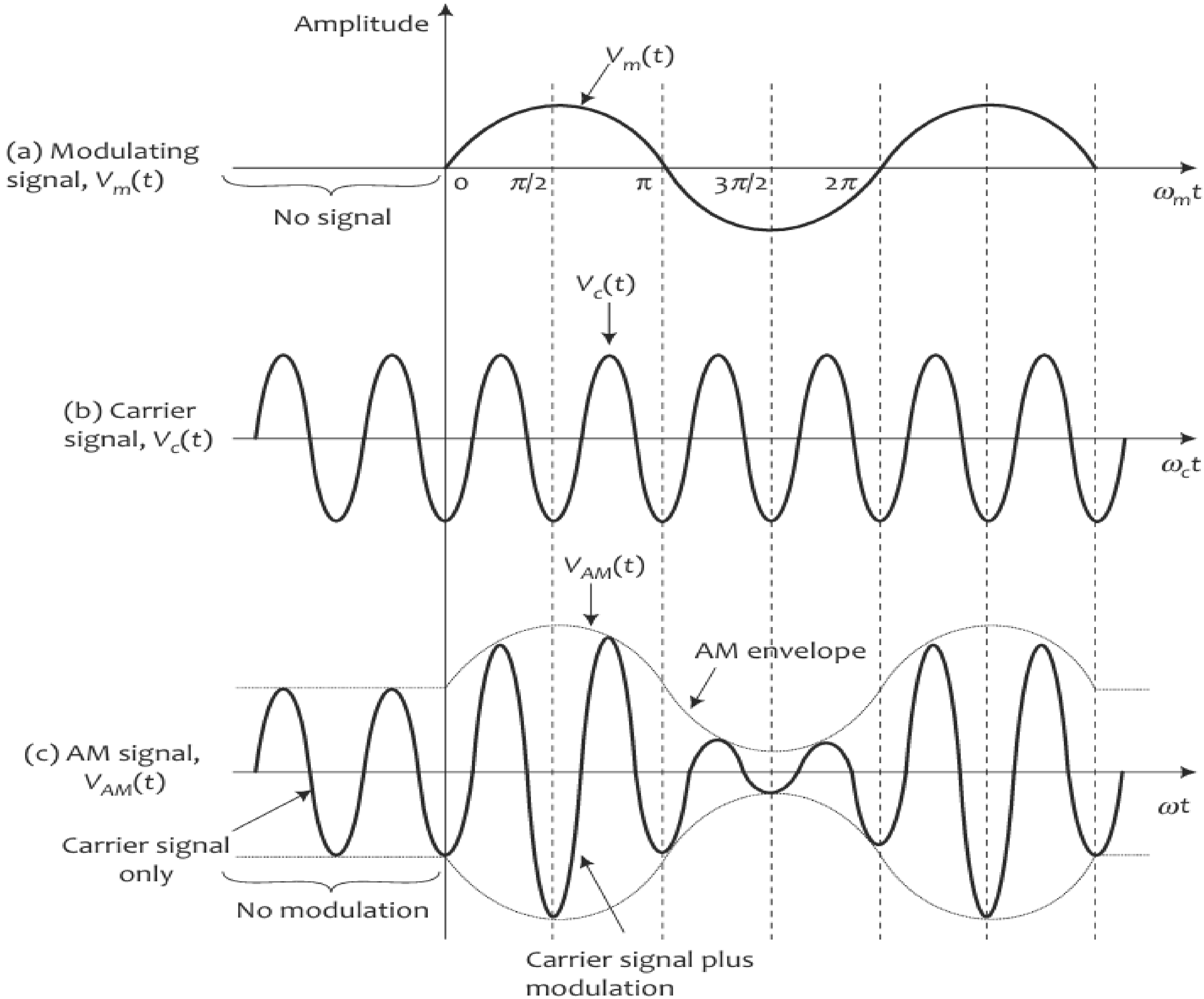
$$v_c(t) = V_c \sin(2\pi f_c t)$$

- As per the definition of amplitude modulation, the instantaneous value of the amplitude modulated (AM) signal can be expressed as

$$v_{AM}(t) = [V_c + v_m(t)] \sin(2\pi f_c t)$$

- From the amplitude-modulated signal waveform, it is observed that
  - When no modulating signal is applied, the modulated AM signal waveform is simply the unmodulated carrier signal.
  - When a modulating signal is applied, the amplitude of modulated signal waveform varies in accordance with the amplitude of the modulating signal.
  - The frequency of the carrier signal in the amplitude modulated signal waveform remains the same as that of the original unmodulated carrier signal.

- The AM Envelop
  - The time-varying shape of the amplitude-modulated waveform is called the envelope of the AM signal or simply the AM envelope.



Amplitude
$V_m(t)$
(a) Modulating signal, $V_m(t)$
0
$\pi/2$
π
$3\pi/2$
2π
$\omega_m t$
No signal
$V_c(t)$
(b) Carrier signal, $V_c(t)$
$\omega_c t$
$V_{AM}(t)$
AM envelope
(c) AM signal, $V_{AM}(t)$
ωt
Carrier signal only
No modulation
Carrier signal plus modulation

Time domain analysis of AM Signal

- Rewriting the general expression of AM signal as defined in Equation

$$v_{AM}(t) = [V_c + v_m(t)] \sin(2\pi f_c t)$$

- Substituting

$$v_m(t) = V_m \sin(2\pi f_m t)$$

$$v_{AM}(t) = [V_c + V_m \sin(2\pi f_m t)] \sin(2\pi f_c t)$$

Modulation Index

- The ratio of the **maximum amplitude of the modulating signal (Vm)** and the **maximum amplitude of the carrier signal (Vc)** is known as the modulation index for AM wave.

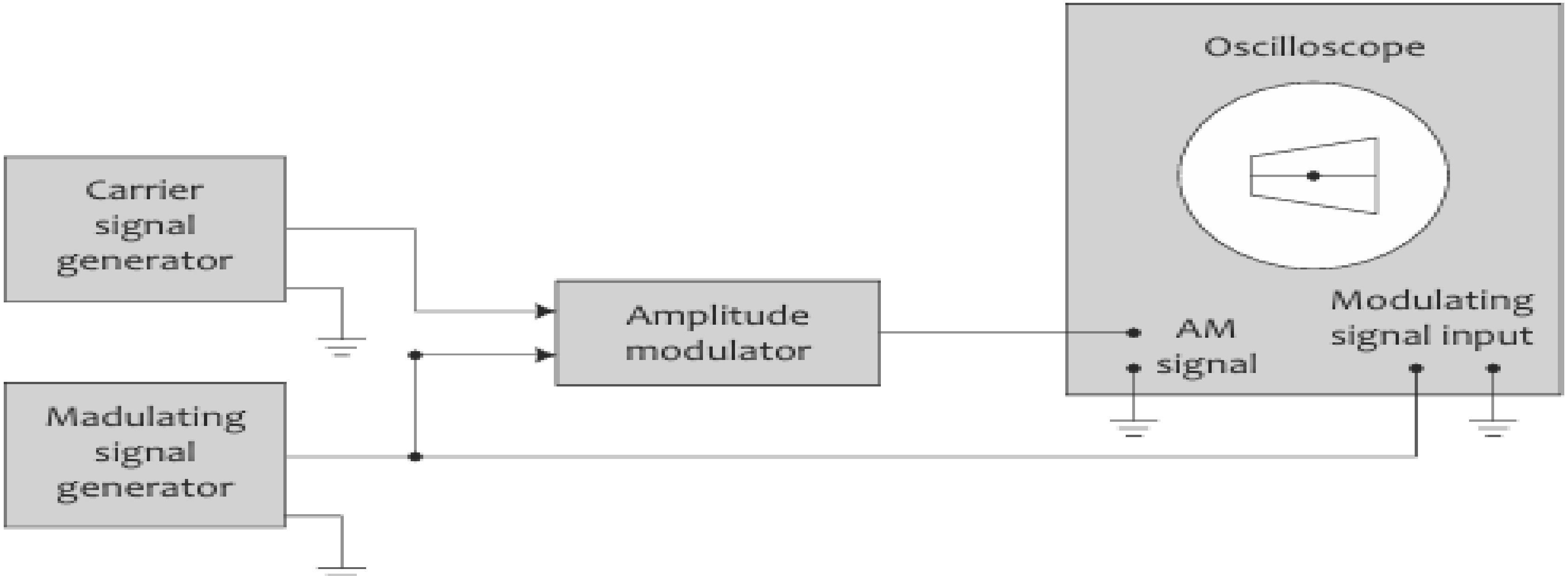
$$m_a = \frac{V_m}{V_c}$$

- **Percent Modulation**
- The modulation index can be expressed as a percent modulation, Ma.

$$M_a = m_a \times 100$$

Trapezoidal Pattern

- Trapezoidal pattern is a display on a standard oscilloscope used for measurement of the modulation characteristics (**modulation index, percent modulation, coefficient of modulation, and modulation symmetry**) of amplitude-modulated waveform.



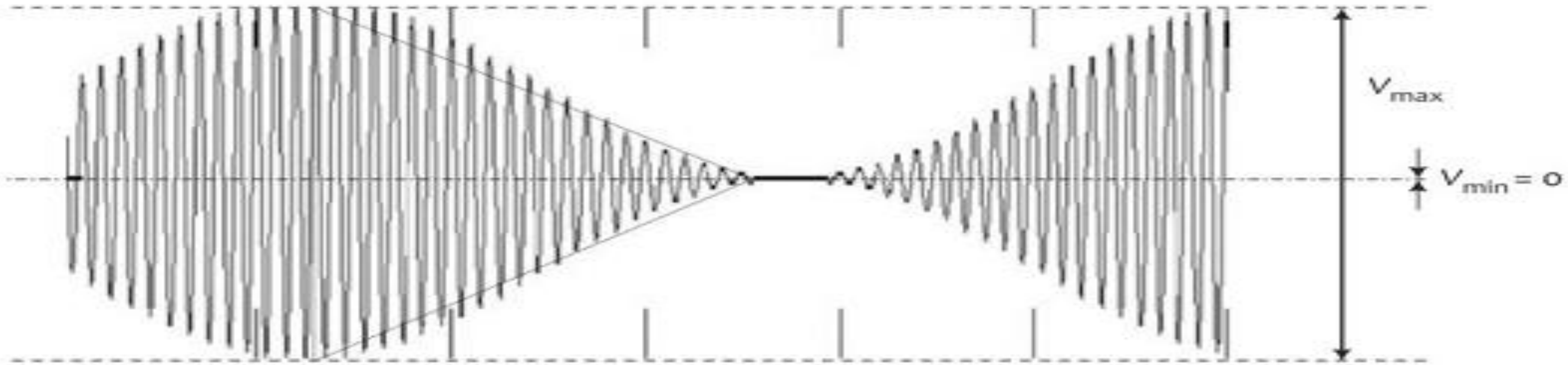


Fig. 4.8 *AM Trapezoidal Pattern for 100% Modulation*

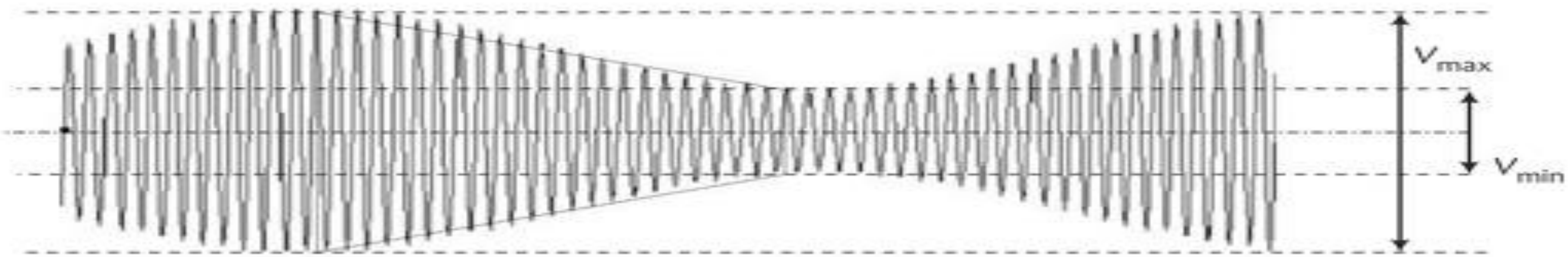


Fig. 4.9 *AM Trapezoidal Pattern for 50% Modulation*

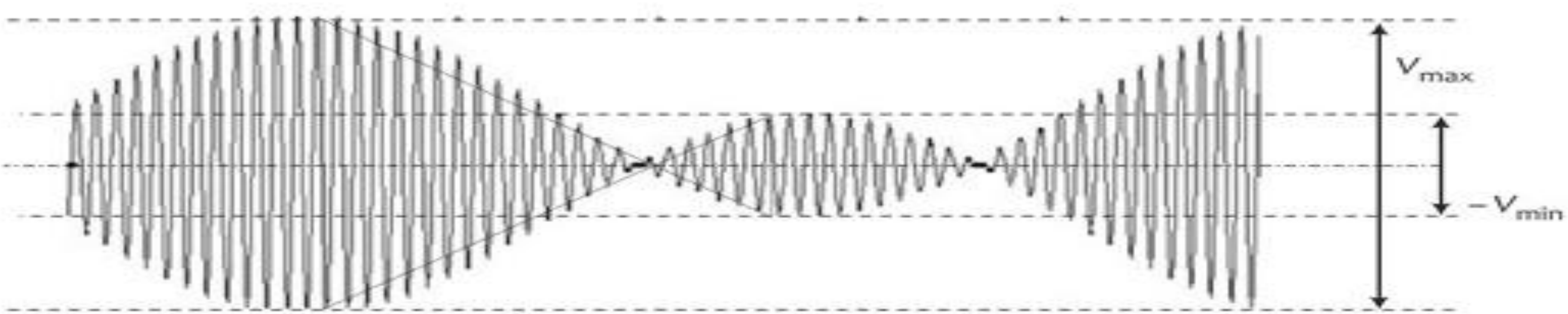


Fig. 4.10 *AM Trapezoidal Pattern for 200% Modulation*

Measurement of Modulation Index

- The amplitude modulation index, ma can be computed by displaying the AM envelope on an oscilloscope, and then measuring the **maximum and minimum peak-to-peak values for the envelope voltage**.

Derivation

AM signal Bandwidth

- The AM frequency spectrum extends from lower sideband frequency (fc – fm) to upper-sideband frequency (fc + fm), where fc is the carrier signal frequency, and fm is the maximum modulating signal frequency.
- The bar is called the lower-si

$$B_{AM} = (f_c + f_m) - (f_c - f_m)$$

- Similarly (fc + fm) is called th

$$\boxed{B_{AM} = 2 f_m}$$

The bandwidth of the amplitude-modulated signal (BAM) is equal to the difference between the maximum upper-sideband frequency and the minimum lower-sideband frequency.

AM power Distribution

- The AM signal consists of three frequency components—the **carrier signal and the two sidebands: upper sideband and lower sideband.**
- The easiest way to compute the total average power in an AM signal is to add the individual average power contents in each of three frequency components
- Total power in AM signal = Carrier power + Lower-sideband power + Upper-sideband power

$$P_{AM} = P_c + P_{lsb} + P_{usb}$$

- The power of a signal is given as the ratio of square of RMS value of signal voltage and the load resistance. That is,
- The power of a signal is given as the ratio of square of RMS value of signal voltage and the load resistance.

$$\text{Signal Power} = \frac{(\text{RMS value of carrier-signal voltage})^2}{\text{Load Resistance}}$$

- The expression for AM signal in the frequency-domain is rewritten as

$$v_{AM}(t) = V_c \sin(2\pi f_c t) + \left(m_a \frac{V_c}{2}\right) \cos\{2\pi(f_c - f_m)t\} - \left(m_a \frac{V_c}{2}\right) \cos\{2\pi(f_c + f_m)t\}$$

Derivation

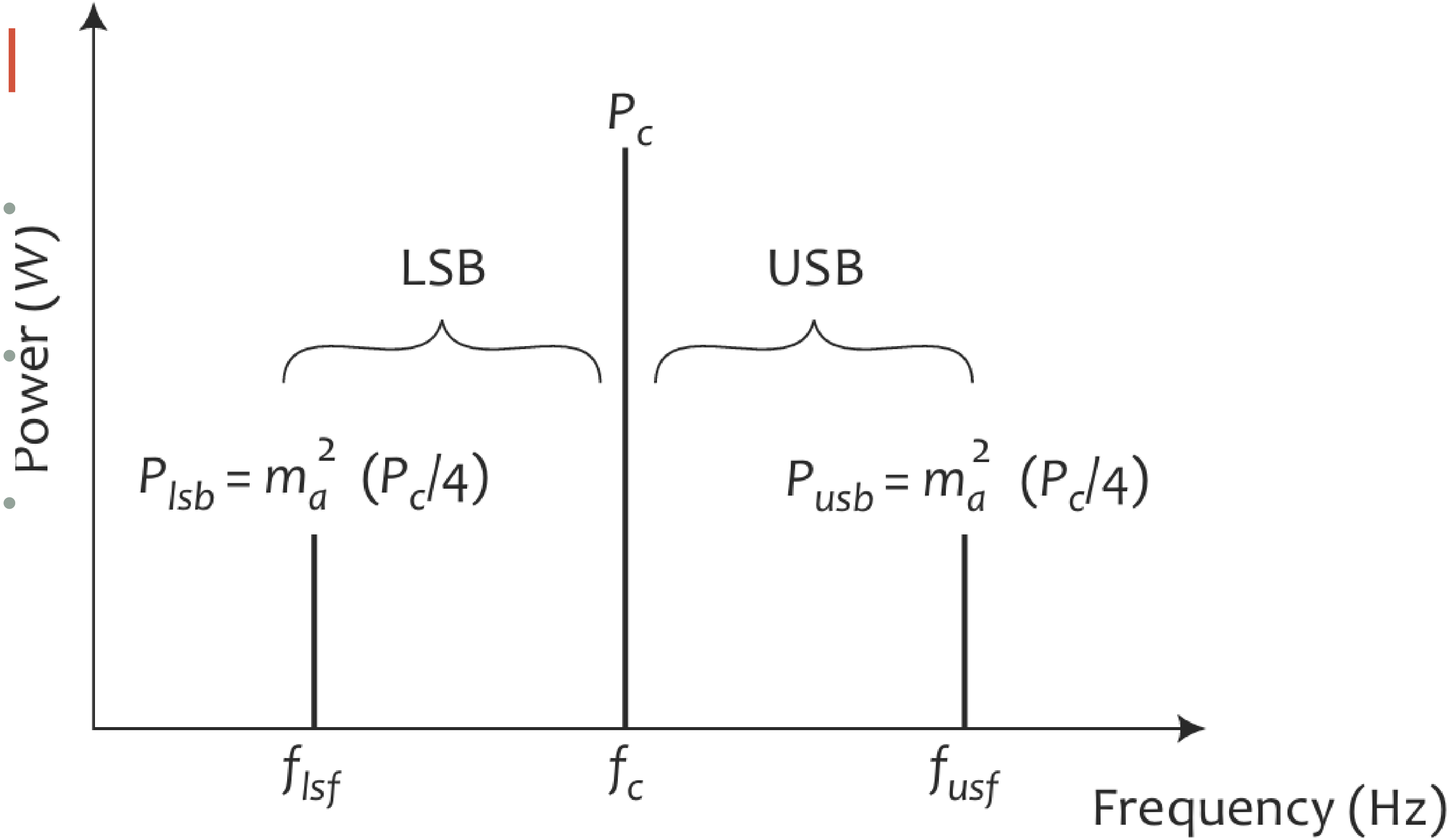


Fig. 4.15 *Power Spectrum of an AM Signal*

Transmission Efficiency of AM Signal

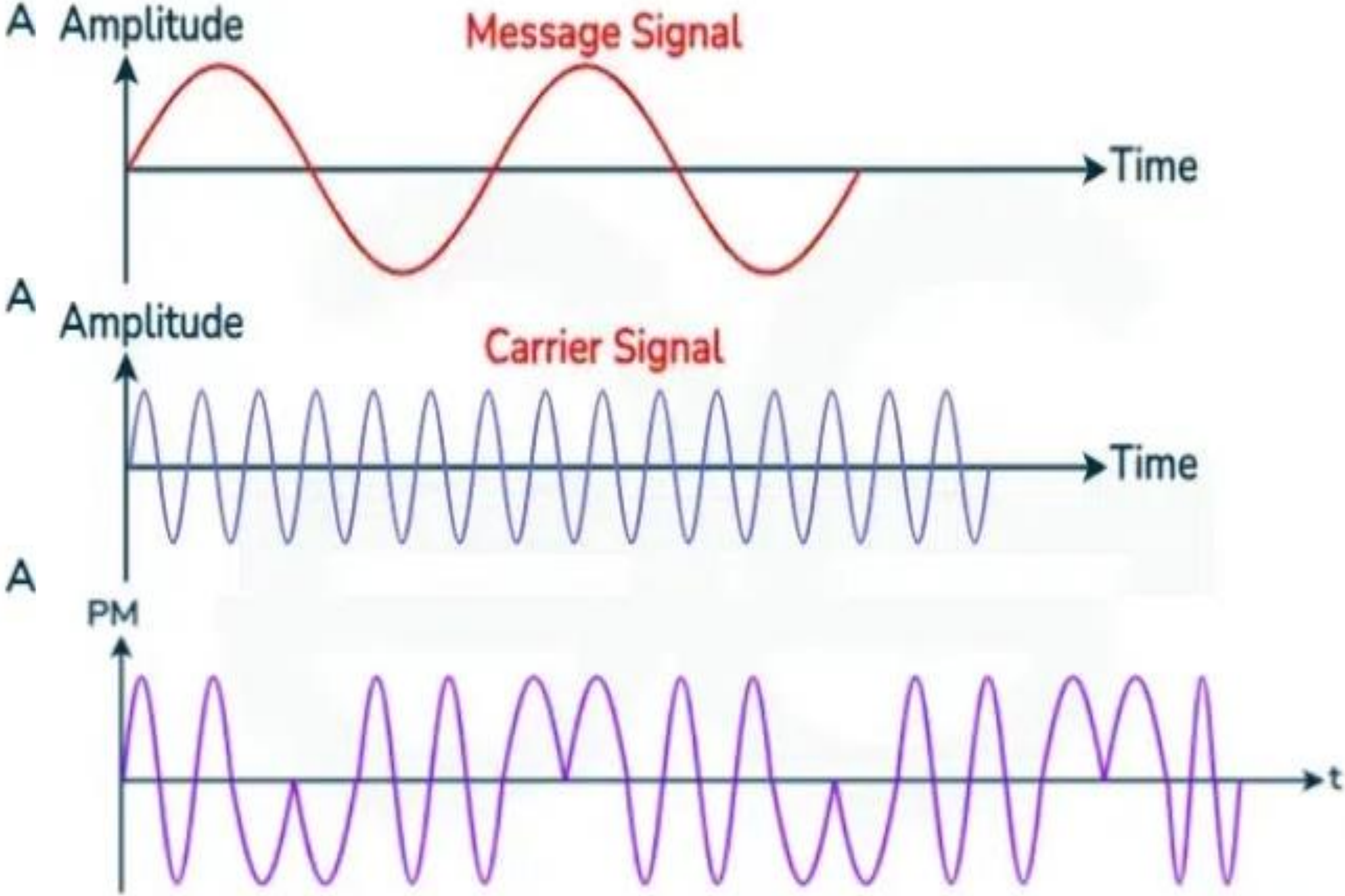
- Transmission efficiency of AM signal is defined as the **percentage of total AM power contained in the sidebands.**
- Transmission efficiency of AM signal

$$\eta_{P_{AM}} = \frac{P_{sb}}{P_{AM}}$$

Limitations of AM

- Amplitude modulation, or also called double sideband with carrier (DSB-C). since **amplitude-modulated signal has carrier-signal frequency as well as two sidebands having sum and difference of carrier and modulating frequency**.

1. **Low transmitted Power efficiency**
2. **Limited Operating Radio Range**
3. **Poor Reception Quality**
4. **Noisy Signal Reception**


A Amplitude
Message Signal
Time
A Amplitude
Carrier Signal
Time
A
PM
t

Generalized concept of Angle Modulation

- For angle modulation, the modulated carrier signal is mathematically represented by

$$x_c(t) = V_c \cos \theta(t)$$

Derivation

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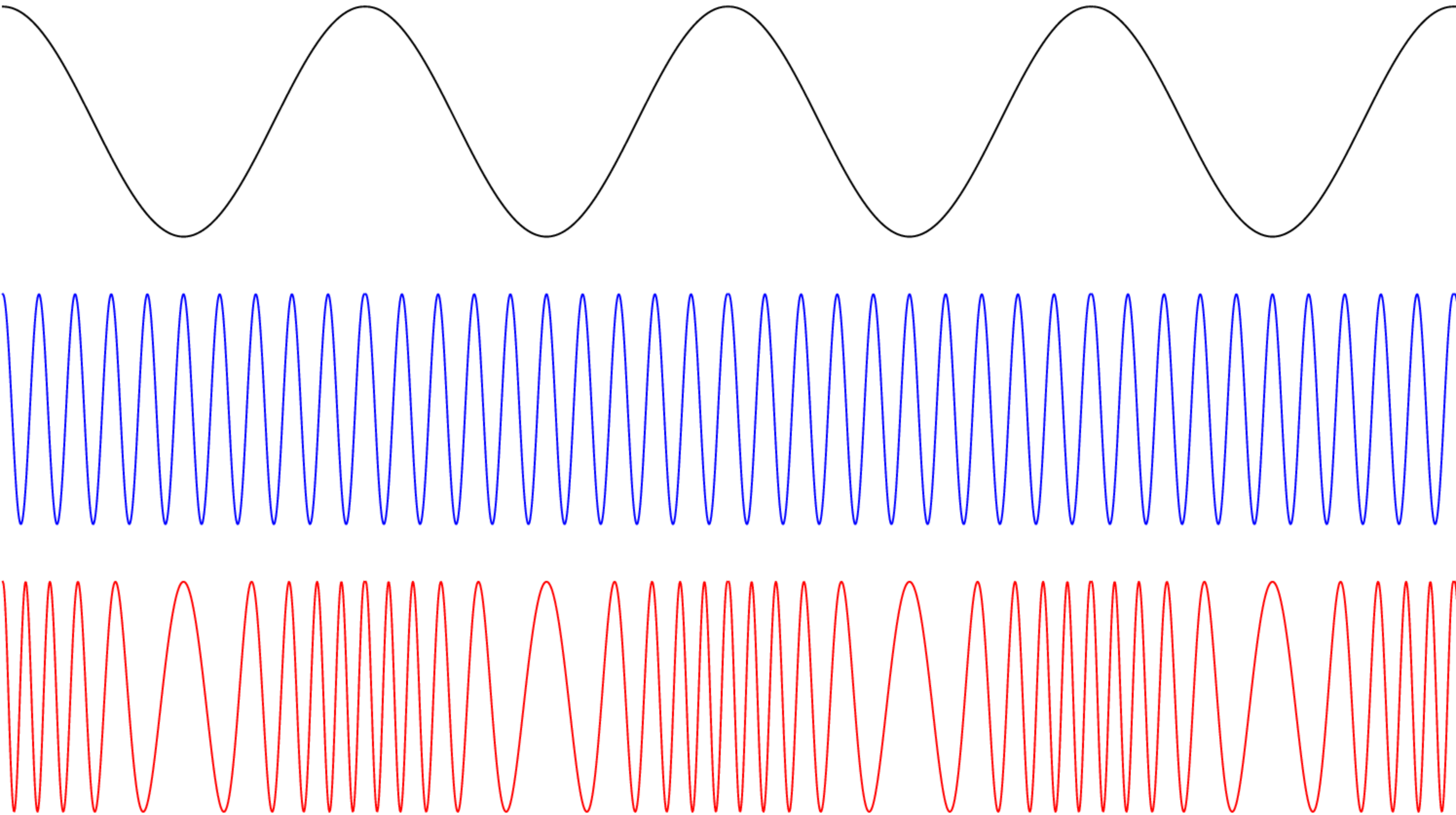
Theory of FM-basic Concepts



Concept of instantaneous Frequency

Frequency-Modulation Index

Frequency-modulation index (mf) is defined as the ratio of **peak frequency deviation (d) and the modulating frequency (fm).**

Instantaneous Frequency Deviation

The instantaneous frequency deviation is directly proportional to the instantaneous amplitude of the modulating signal

$$\Delta f = k_f v_m$$

Theory of phase modulation

- Phase modulation is the that form of angle modulation in which the angle of sinusoidal carrier signal is varied linearly with the modulating signal.

Derivation

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Module-3

- **Sampling Theorem and Pulse Modulation Techniques:**
  - Digital Versus Analog Transmissions,
  - Sampling Theorem
  - Classification of pulse modulation techniques

    PAM, PWM, PPM, PCM, Quantization of signals

Digital Versus Analog Transmissions

- Analog Transmission using **Baseband Channel**

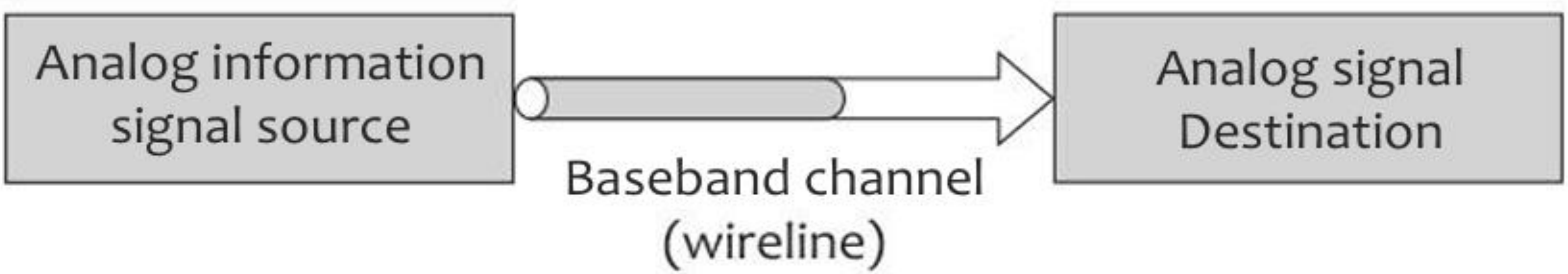


Fig. 7.1 *Analog Transmission over Baseband Channel*

- Analog signal transmission over baseband channel is a public address system using twisted pair wire as a channel, and mainly comprises of a microphone, an audio amplifier, and a speaker.

- Analog Transmission using **Bandpass Channel**

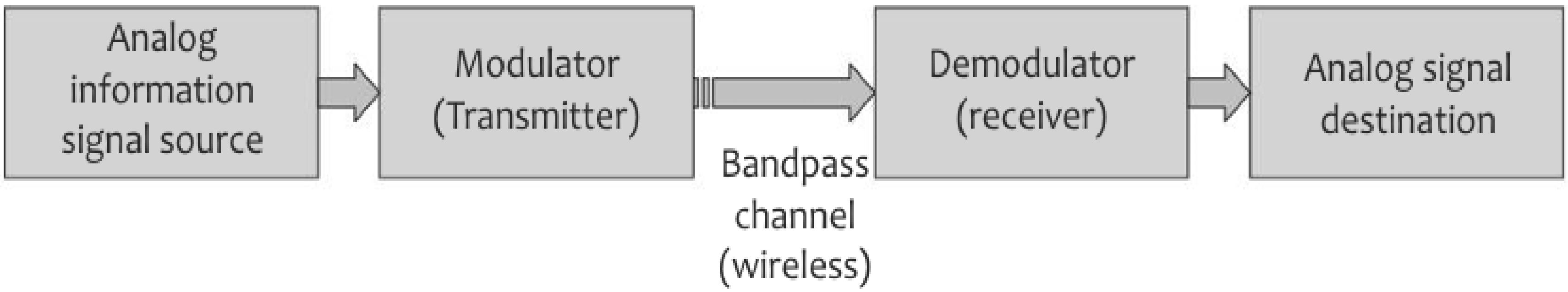
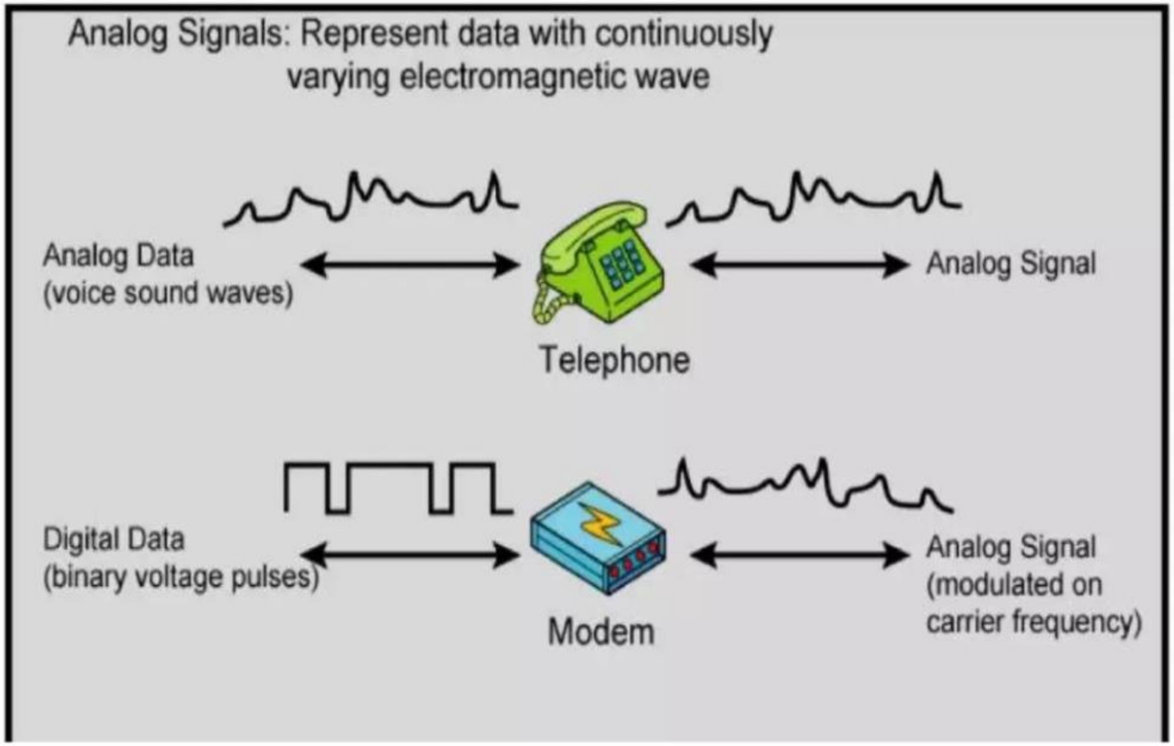


Fig. 7.2 *Analog Transmission over Bandpass Channel*

- Analog signal transmission over bandpass channel is broadcast radio and television systems.

Analog Signals Carrying Analog and Digital Data



- Digital Transmission over **Digital Channel**

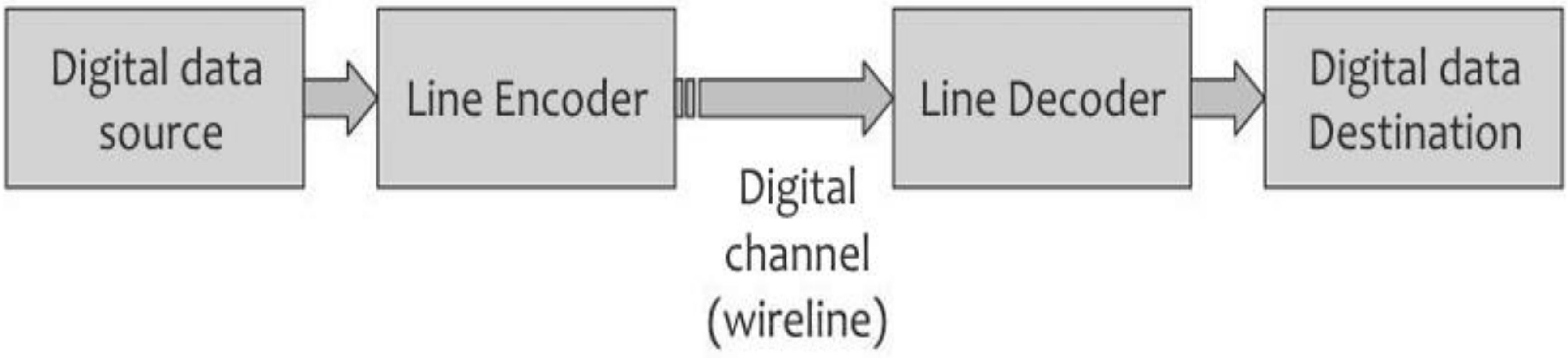


Fig. 7.3 *Digital Transmission over Digital Channel*

- Digital transmission over digital channel is transmission of digital data such as a data file from PC over digital communication channel (usually wireline).

- Digital Transmission over **Analog Channel**

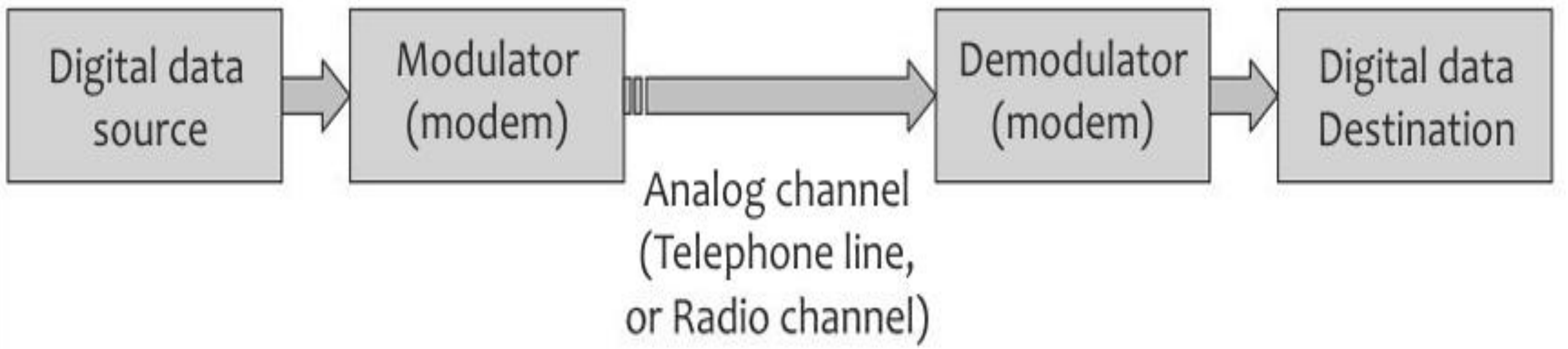
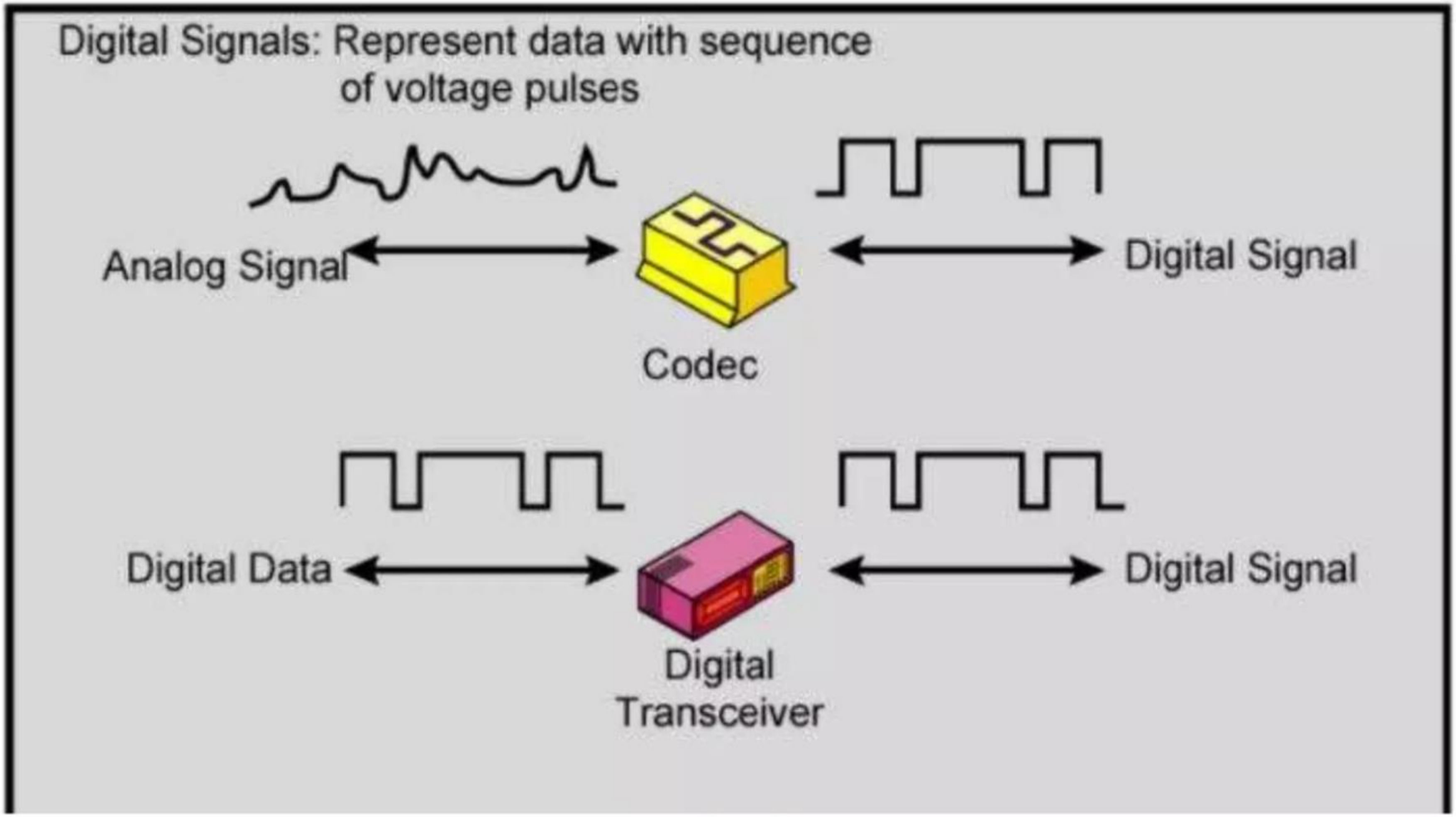


Fig. 7.4 *Digital Transmissions over Analog Channel*

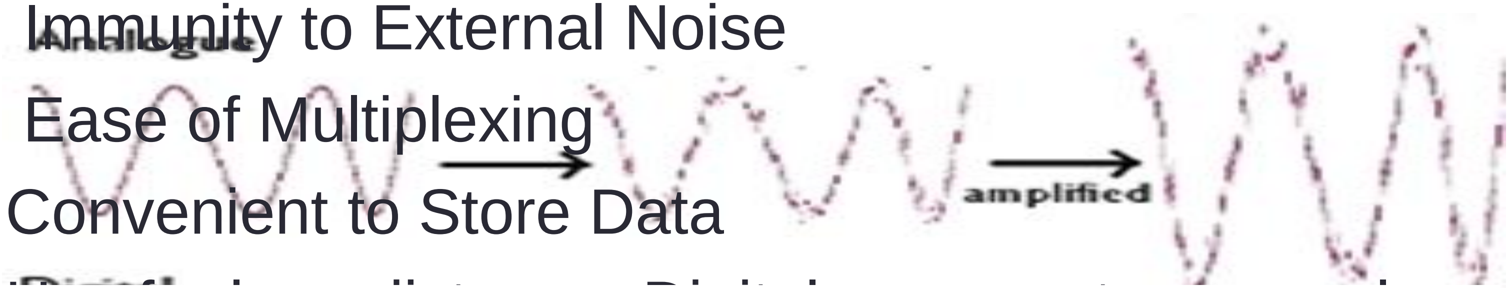
- Digital transmission over analog channel include transmission of digitized speech signals over analog channels (usually an ordinary telephone line, or a radio channel which requires a modulation process).

Digital Signals Carrying Analog and Digital Data

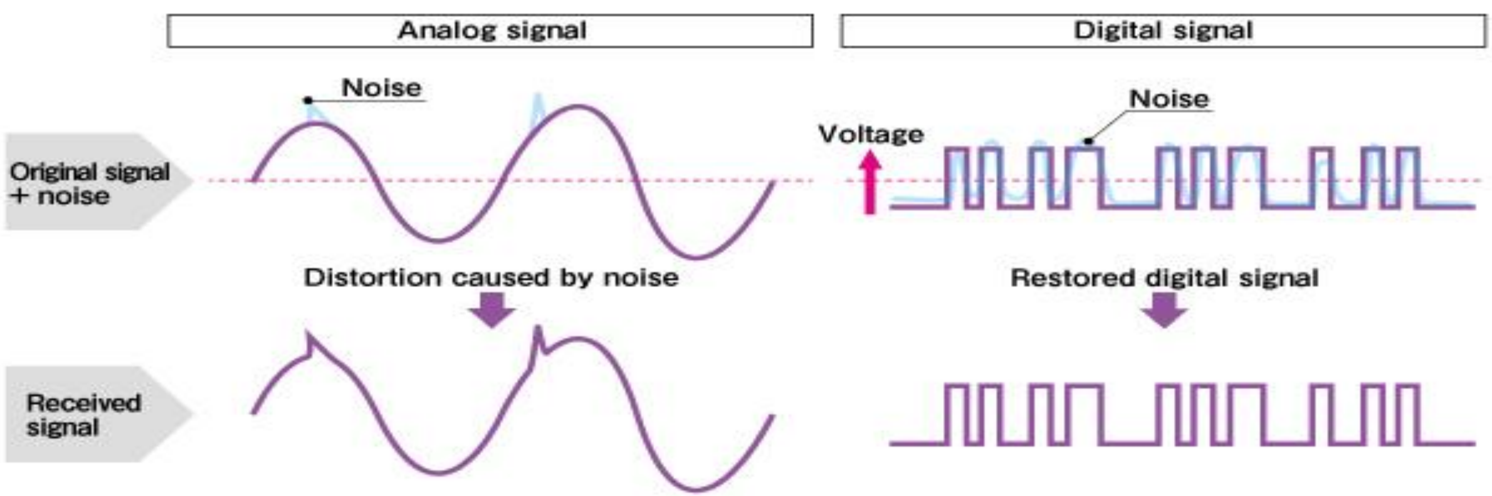


Advantages of Digital Transmissions

1. Resistant to Additive Noise
2. Immunity to External Noise
3. Ease of Multiplexing
4. Convenient to Store Data



5. oisy gnal s.

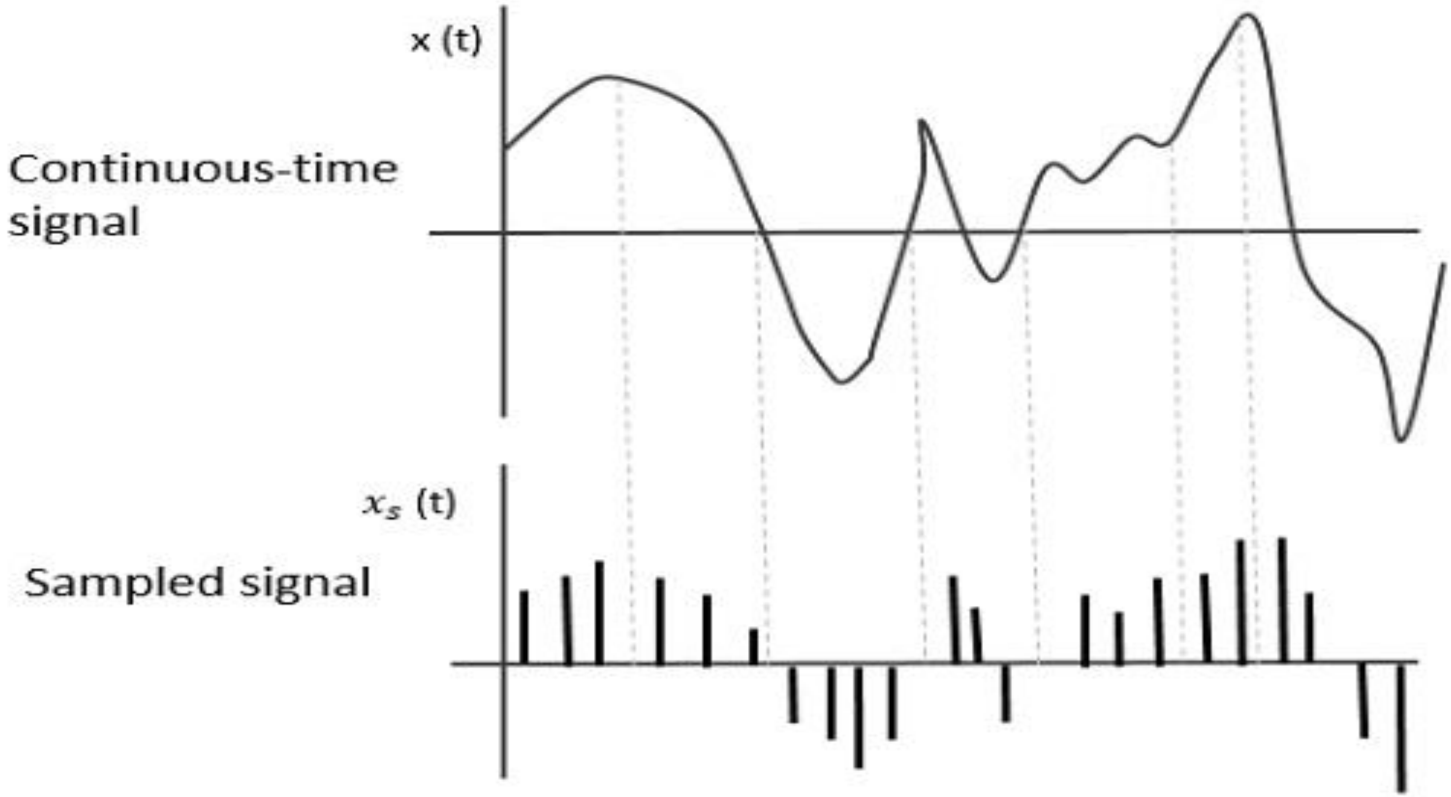


6. ore signals.

Difference Between Digital Transmission and Analog Transmissions

Digital Transmission	Analog Transmission
Digital transmission involves encoding data into **discrete binary signals** (0s and 1s), which are less noise and can be accurately reconstructed.	Analog transmission, on the other hand, **sends continuous signals** that vary in amplitude or frequency, more vulnerable to noise interference and signal degradation over distances.
Multiplexing of several digital signals is achieved by individual signals like **TDM** , occupying less spectrum bandwidth.	Multiplexing of many analog information signals can be achieved by **FDM** which may occupy relatively larger spectrum bandwidth.
SNR of about 10–12 dB only is sufficient to recover digital data	SNR of about 40–60 dB is required to recover acceptable analog information signal

Sampling Theorem



- A continuous time signal can be represented in its samples and when sampling frequency f_s is greater than or equal to the twice the highest frequency component of message signal. i. e.

$$fs \geq 2fm$$

- Nyquist Rate :- the minimum Sampling for the perfect reconstruction of the continuous time signals from samples

$$\text{Nyquist rate} = 2fm$$

Sampling rate must be greater than or equal to Nyquist rate

Proof of sampling theorems

- There are two parts
  1. Representation of X(t) in its samples
  2. Reconstruction of X(t)

Representation of X(t) in its samples

1. Define x∂(t)
2. Take fourier transform of x∂(t)) (i.e) x∂(f)
3. Relation between x(f) and x∂(f) 4.Relation between x(t) and x(nTs)

Reconstruction of X(t)

1. inverse fourier transform of x∂(f)
2. Show that x(t) is obtained back with the help of interpolation function

Classification of pulse modulation techniques

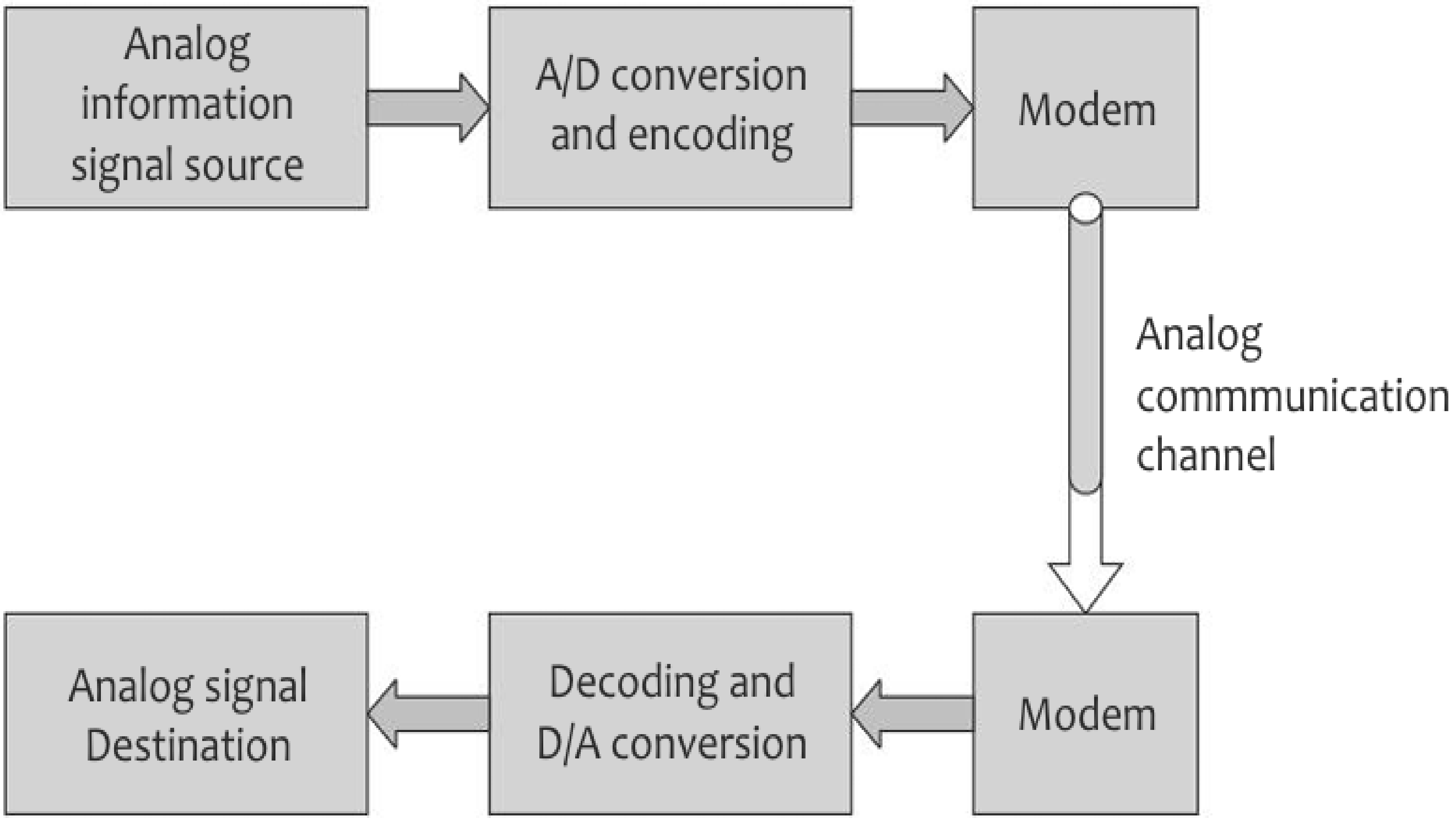


Fig. 7.16 *Transmission of Analog Signal over Analog Communication Channel*

- **Digital communication Channel** can carry digital pulses, so the digitized analog signal can be directly transmitted digitally

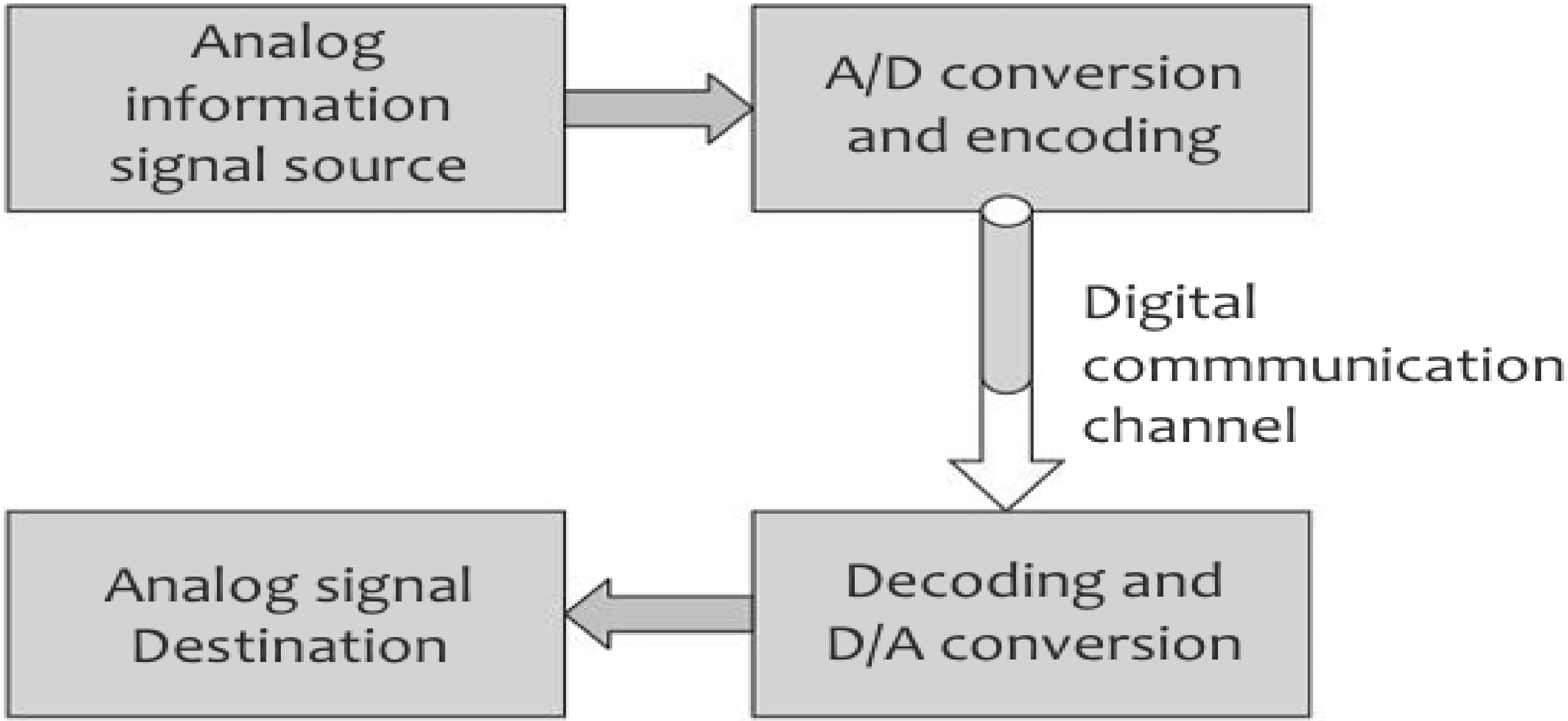
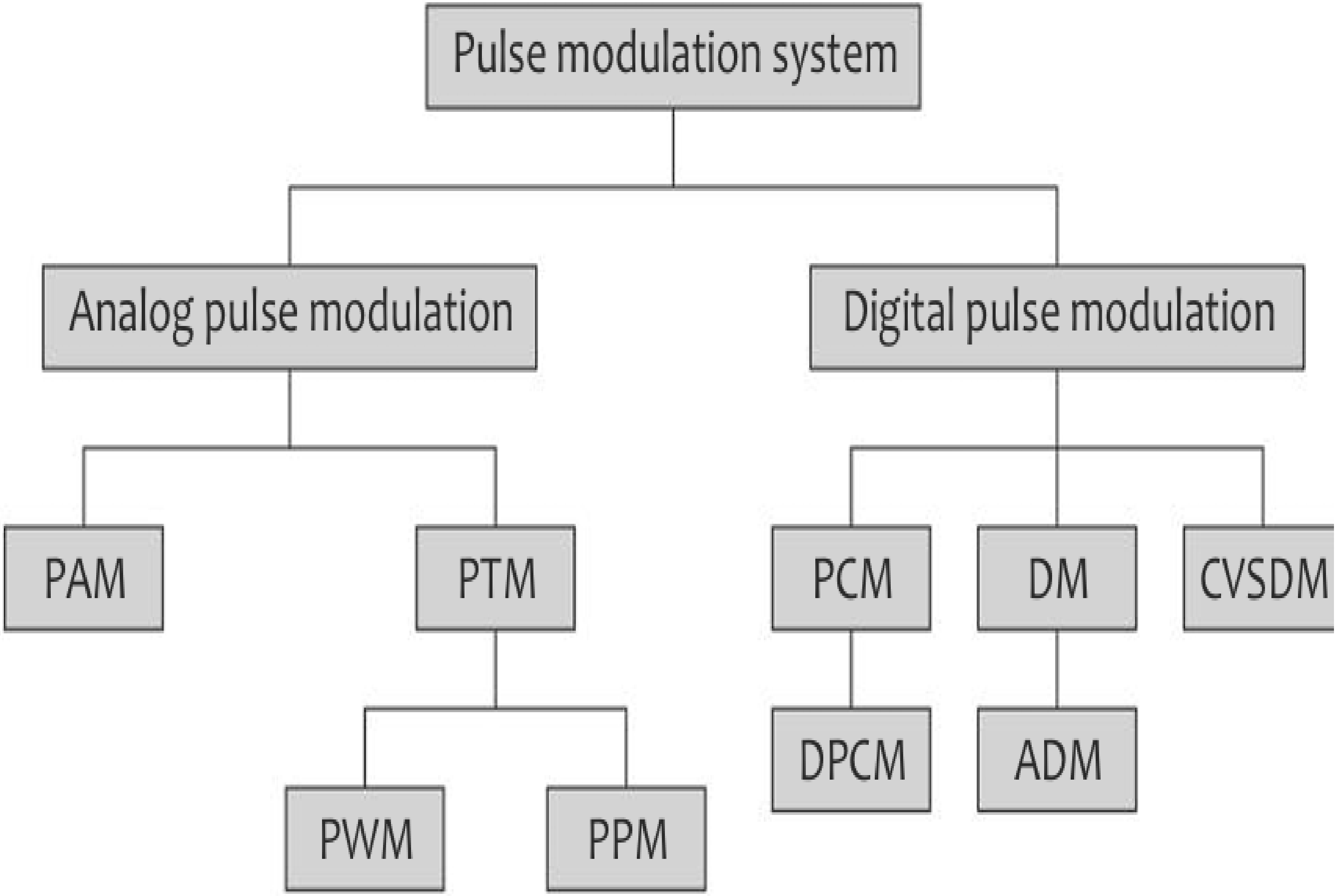


Fig. 7.17 *Transmission of Analog Signal over Digital Communication Channel*

Pulse Modulation

- Pulse Modulation techniques can be classification in two main

1. **Analog Pulse Modulation :** When amplitude or time of the carrier pulse train is varied in proportion to the instantaneous value of the analog modulating signal
2. **Digital Pulse Modulation :** when analog modulating signal converted to discrete signal by varying the amplitude of the carrier pulse train followed by representation of discrete levels by digital



Pulse modulation system
Analog pulse modulation
Digital pulse modulation
PAM
PTM
PWM
PPM
PCM
DM
CVSDM
DPCM
ADM

Pulse Amplitude Modulation(PAM)

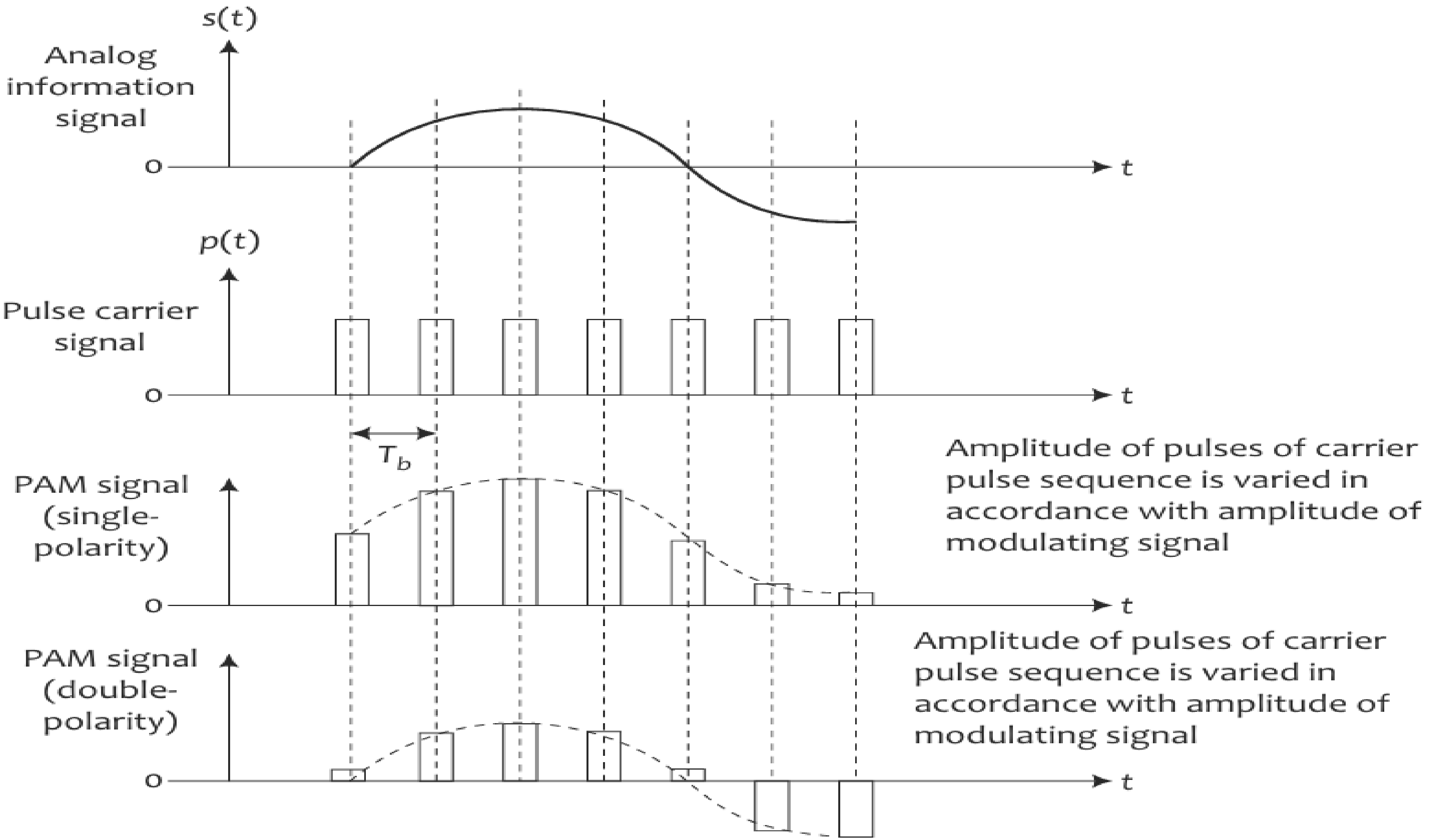


Fig. 7.19 *Analog Pulse Modulation—PAM Technique*

Methods of sampling

There are three distinct methods of sampling in PAM:

1. **Ideal sampling**—an impulse at each sampling instant
2. **Natural sampling**—a pulse of short width with varying amplitude
3. **Flat-top sampling**—sample and hold (like natural sampling) but with fixed amplitude value

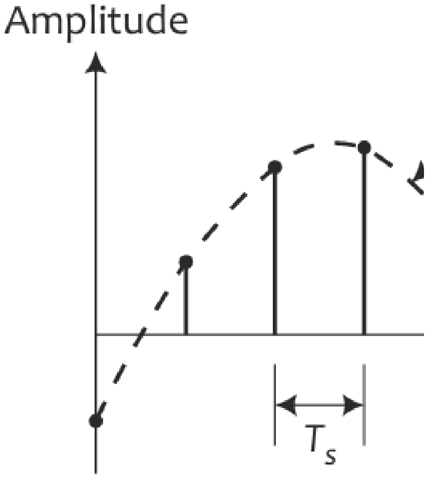


Fig. 7.20

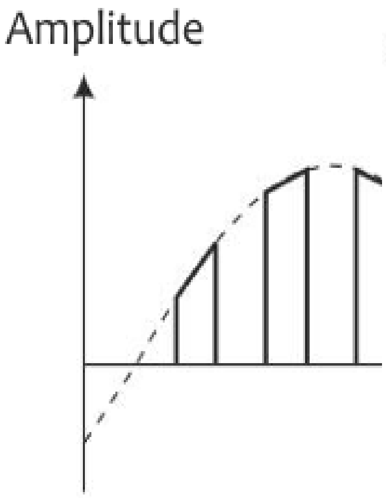


Fig. 7.21

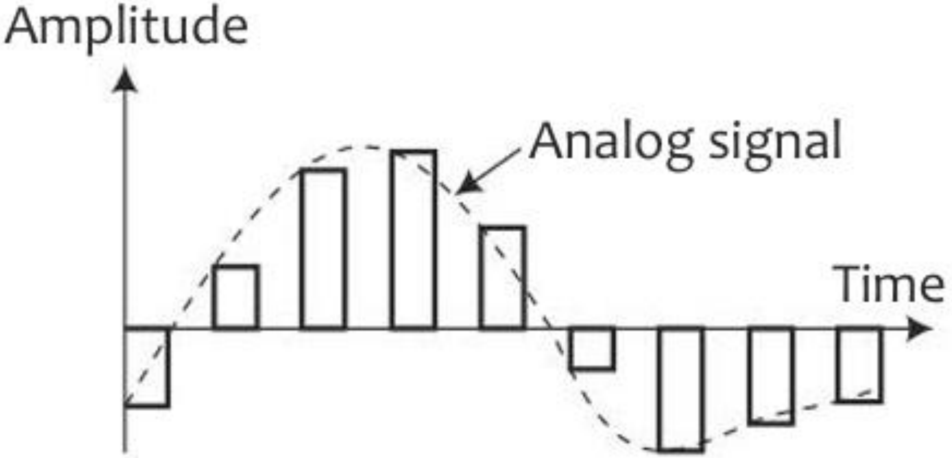


Fig. 7.22 *Flat-top Sampling*