Amplitude Modulation

Objectives

After going through this module the learners will be able to

- Understand Amplitude modulation
- Appreciate the need for Modulation index
- Know block diagram to show production and detection of amplitude modulated wave
- Be aware of applications of amplitude modulation

Content Outline

- Unit Syllabus
- Module Wise Distribution of Syllabus
- Words You Must Know
- Modulation
- Amplitude Modulation
- Modulation Index
- Production of AM Wave
- Detection of AM Wave
- Applications of AM Wave
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- Summary

Unit Syllabus

Unit 10 Communication Systems

Chapter 15 Communication Systems

Elements of a communication system (block diagram) bandwidth of signals speech , TV and digital data) bandwidth of transmission medium, propagation of electromagnetic waves in the atmosphere, sky and space wave propagation, satellite communication, need for modulation, types of modulation, amplitude modulation, production of amplitude modulated wave, detection of amplitude modulated wave, Internet and mobile phones

Module Wise Distribution Of Unit Syllabus - 6 Modules

Module 1	• History of communication • Special vocabulary • Signals and band width
Module 2	• Propagation of electromagnetic wave • Ground wave • Sky wave • Space wave • Satellite communication
Module 3	• Modulation • Need for modulation • Types of modulation • Amplitude modulation AM • Frequency modulation FM • Meaning of tuner frequencies 98.3FM
Module 4	• Amplitude modulation • Modulation index • Production of amplitude modulated wave • Detection of amplitude modulated wave • Applications of amplitude modulation
Module 5	• Short range communications • Increasing the area of influence using antenna • Use in factories, villages, towns for police work • Internet • Internet servers
Module 6	• Mobile phones • Mobile towers • 3G, 4G, 5G • Mobile companies, what do they do?

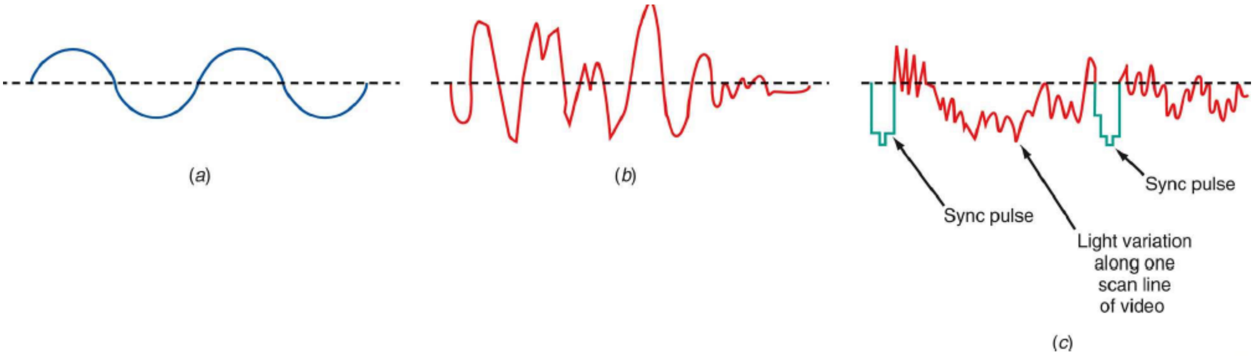
Module 4

Words You Should Know

- **Communication:** The process of putting across ideas through words and pictures
- **Audio Communication:** Communication by means of speech/sound or messages that can be received by our ears.
- **Video Communication-** Communication by means of pictures, still or moving or messages that can be received by our eyes.
- **Audio Video Communication-** Communication by means of speech/sound or messages that can be received by our ears.
- **Device-** an apparatus designed for special functions.
- **Mode of Transfer of Information-** method of transfer of information.
- **Antenna-** a device designed to send out and receive electromagnetic waves.
- **Electromagnetic Waves-** The range of electromagnetic signals encompassing all frequencies is referred to as the electromagnetic spectrum.
- **Frequency:** It is defined as the number of cycles per second or number of waves per second.
- **Wavelength** is the distance occupied by one cycle of a wave and is usually expressed in meters. Wavelength is also the distance traveled by an electromagnetic wave during the time of one cycle. The wavelength of a signal is represented by the Greek letter lambda (λ).
- **Transducer:** An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, temperature, etc.) into corresponding variations in the electrical signal at its output. For example, a microphone converts sound energy into electrical energy.
- **Signal:** Information converted in electrical form and suitable for transmission is called a signal. Signals can be either **analog or digital**.
- **Analog signals are continuous variations of voltage or current. They are essentially single-valued functions of time. Sine wave is a fundamental analog signal.**

  All other analog signals can be fully understood in terms of their sine wave components.

  Sound and picture signals in TV are analog in nature.



Analog signals (a) Sine wave “tone.” (b) Voice. (c) Video (TV) signal.

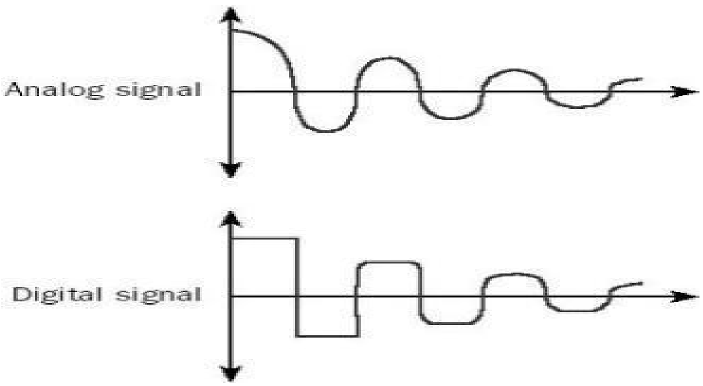
- **Digital signals are those which can take only discrete stepwise values.**
- **Binary system that is extensively used in digital electronics employs just two levels of a signal. ‘0’ corresponds to a low level and ‘1’ corresponds to a high level of voltage/ current.**

Digital signals (a) Telegraph (Morse code). (b) Continuous-wave (CW) code. (c) Serial binary code

Technically speaking, a signal is a wave, amplitude or frequency of which varies with time and the signal can be analog or digital.

- **Noise:** These are unwanted signals having the same or similar frequency as that of the required signal. They distort the transmission and receiving process. A virus in a computer is an example of noise. A virus is an unwanted program in the same language in which your required program is, it disrupts your program.
- **Communication Channel:** The communication channel is the medium by which the electronic signal is sent from one place to another. Types of media include electrical conductors, Optical media, Free space, and System-specific media (e.g., water is the medium for sonar).
- **Transmitter:** It is the device that converts the information (message) into a form suitable for transmission. In the above example the online shopping company is the transmitter.

- **Receiver:** It is the device that retrieves the information from received signals. In the shopping example, you are the receiver. A receiver is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back into a form understandable by humans. Receivers contain amplifiers, oscillators, mixers, tuned circuits and filters, and a detector that recovers the original intelligence signal from the modulated carrier.
- **Transceivers:** A transceiver is an electronic unit that incorporates circuits that both send and receive signals. Examples are: Telephones, Fax machines, radios, Cell, mobile phones, computers.
- **Amplification:** It is the process of increasing the strength of signal. Amplification compensates for attenuation. Amplification is done by an electronic circuit.
- **Attenuation:** It refers to loss in strength of signal while propagating from transmitter to receiver Signal attenuation, or degradation, exists in all media of wireless transmission. It is usually proportional to the square of the distance between the transmitter and receiver.



- **Range:** It is the maximum distance that a signal can travel with sufficient strength.
- **Band width:** It is the frequency range over which a system works. It is calculated as the highest frequency – lowest frequency. For example, the human audio frequency range is 20 Hz to 20,000 Hz, so audio bandwidth = 20,000 – 20 = 19,980 Hz **Bandwidth is** that portion of the electromagnetic spectrum occupied by a signal. **Channel Bandwidth** refers to the range of frequencies required to transmit the desired information.
- **Bandwidth of transmission medium the transmission channels are of three types** Wires, free space and optical fiber.
- **Repeater:** repeater station is equipped with Receiver, Amplifier and Transmitter.

The mobile phone towers in your area are repeater stations.

- **Communication Satellites** are repeater stations in space. They receive a signal from one ground station, amplify it and transmit it to another ground station.
- **Antenna:** It is the device through which transmission and receiving process are done. The dish connected to your TV set is an antenna in itself.
- **Carrier Wave:** A **carrier** is a high frequency signal that is modulated by audio, video, or data. A radio-frequency **(RF)** wave is an electromagnetic signal that is able to travel long distances through space.
- **Broadcasting** is the distribution of audio or video content to a dispersed audience via any electronic mass communications medium, but typically one using the electromagnetic spectrum (radio waves), in a one-to-many model.
- **Mode of EM Wave Propagation:** EM waves travel in three ways through the atmosphere, ground wave, sky wave and space wave.
- **The modulated wave is a combination of message signal and carrier wave.**
- A sinusoidal carrier wave can be represented as

  $c(t) = A_c \sin sin \left(\omega_c t + \theta\right)$

  Where,

    - $c(t)$ is the signal strength (voltage or current),
    - A_c is the amplitude,
    - ω_c (= 2πfc) is the angular frequency

      and
    - θ is the initial phase of the carrier wave.
- During the process of modulation, any of the three parameters, *Viz* **A_c, ω_c and θ,** of the carrier wave can be controlled by the message or information signal.

  This results in three types of modulation:

    - **Amplitude Modulation (AM),**
    - **Frequency Modulation (FM)**
    - **Phase Modulation (PM),**

Introduction

We have so far in this unit, studied the most basic meaning of communication which is transmission of information from one point to another. The setup used for the purpose is called a communication system. The purpose of a communication system is, therefore, to transmit information from a source, located at one place, and to a receiver located at another point. The system primarily has three major parts

- Transmitter which is a combination of audio video, data converter to electrical analog or digital signal (transducers) modulators to convert the base band signal to AM,FM or PM modulated electrical signal. This is done in case wireless transmission is required.
- Communication channels could be wired or wireless.
- Receiver contains transducers to tune on the electromagnetic waves and retrieve the baseband signal.

We must realize here that we are only studying the processes of communication systems without actually going into circuits and their appropriate designs. There is a lot of technical design to amplify and modulate signals that reach us from a source. Example consider a mobile phone, we dial an antenna digit number and out of the entire mobile phones in use across the world only the desired one is connected or when we google a map the search engine places the options before us on the screen.

In this module we will now attempt to understand amplitude modulation

The first amplitude modulated signal was transmitted in 1901 by a Canadian engineer named Reginald Fessenden. He took a continuous spark transmission and placed a carbon microphone in the antenna lead.

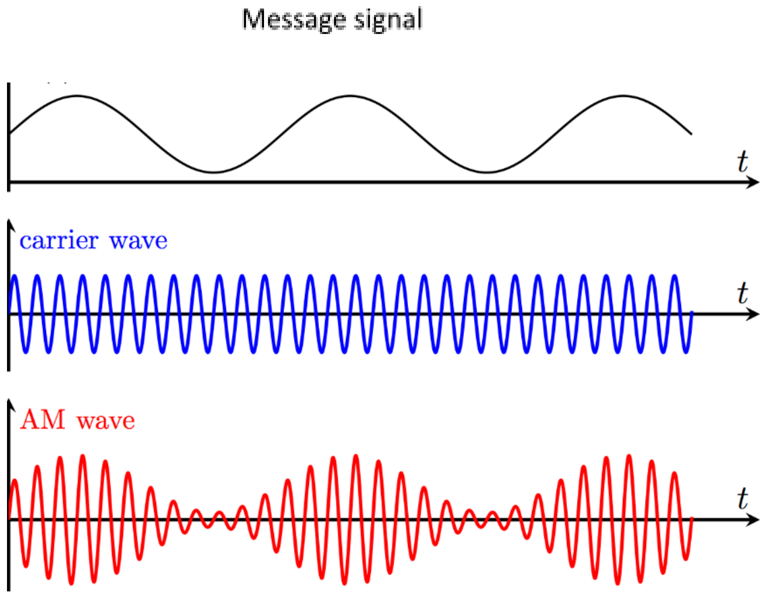
The sound waves impacting on the microphone varied its resistance and in turn this varied the intensity of the transmission. Although very crude, signals were audible over a distance of a few hundred meters, although there was a rasping sound caused by the spark.

With the introduction of continuous sine wave signals, transmissions improved significantly, and AM soon became the standard for voice transmissions. Nowadays,amplitude modulation, AM, is used for audio broadcasting on the long medium and short wave bands, and for two way radio communication at VHF for aircraft.

However as there now are more efficient and convenient methods of modulating a signal, its use is declining, although it will still be very many years before it is no longer used.

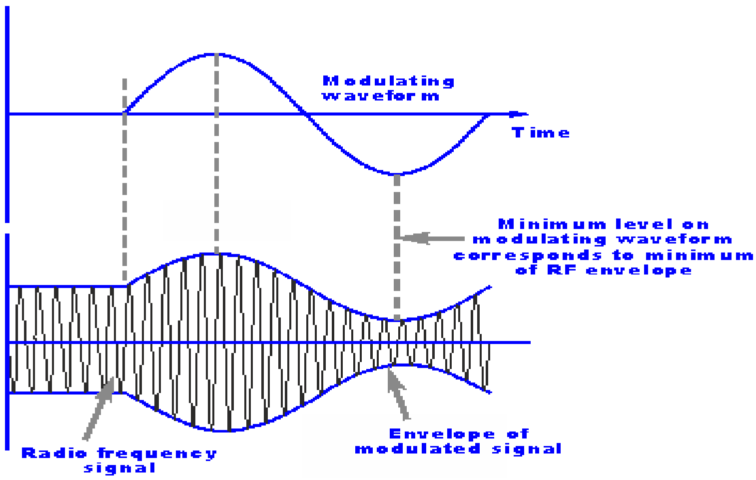
Amplitude Modulation

In amplitude modulation the amplitude of the carrier wave is **changed** according to the message or information signal. Here we explain the process of amplitude modulation.



The process of varying amplitude of a high frequency carrier wave in accordance with the signal (code, voice or music) to be transmitted, keeping the frequency and phase of the carrier wave unchanged is known as amplitude modulation.

When an **amplitude modulated wave** is created, the amplitude of the carrier wave is varied in line with the variations in intensity of the message signal, say an audio wave. In this way the overall amplitude or envelope of the carrier is modulated to carry the audio signal. Here the envelope of the carrier can be seen to change in line with the modulating signal.



Amplitude modulation, AM is the most straightforward way of modulating a signal. Demodulation or the process where the radio frequency signal is converted into an audio frequency signal is also very simple. An amplitude modulation signal only requires a simple diode detector circuit. The circuit that is commonly used has a diode that rectifies the signal, only allowing the one half of the alternating radio frequency waveform through. A capacitor is used to remove the radio frequency parts of the signal, leaving the audio waveform. This can be fed into an amplifier after which it can be used to drive a loudspeaker. As the circuit used for demodulating AM is very cheap, it enables the cost of radio receivers for AM to be kept low.

Let us consider a sinusoidal (sine wave) message signal m (t) and carrier wave.

The expression for sinusoidal Message/modulating signal is

$m(t) = A_m sin\omega_m t$

A_m is the amplitude **of a message signal.**

and

ω_m is the angular **frequency of the message signal.**

The expression for sinusoidal carrier wave is given by;

$c(t) = A_c sin\omega_c t$

where;

A_c is **amplitude of carrier wave**

ω_c is the angular frequency of a carrier wave.

After modulation a new wave is formed called a modulated wave. **The modulated wave is a combination of message signal and carrier wave.**

The expression for modulated wave is given by,

$m(t) = A_m sin\omega_m t \ + \ c(t) = A_c sin\omega_c t$

By superposition the two signals are combined

$C_m(t) = \left(A_c + A_m sin\omega_m t\right) sin\omega_c t$

$= A\left(1 + \frac{A_m}{A_c} sin\omega_c t\right) sin\omega_c t$

Note that the modulated signal contains the message signal.

($A_c + A_m \sin \omega_m t$) is amplitude of modulated wave and ω_c is frequency of modulated wave.

Also note that amplitude of modulated wave is changing with time “t” and frequency of modulated wave is same as of carrier.It is because we have changed only the amplitude of the carrier not it’s frequency.so the modulated signal contains the message signal.

We can write the above equation as

$$C_m(t) = A\left(1 + \frac{A_m}{A_c} sin\omega_c t\right) sin\omega_c t$$

$$\mu = \frac{A_m}{A_c} \text{ called the modulating index}$$

In practice μ is kept ≤ 1 to avoid distortion, physically it means that the amplitude of the baseband or message signal is kept slightly less than the amplitude of the carrier wave.

Using trigonometric identity

$$sinA\ sinB = \frac{1}{2}[cos(A - B) - cos(A + B)]$$

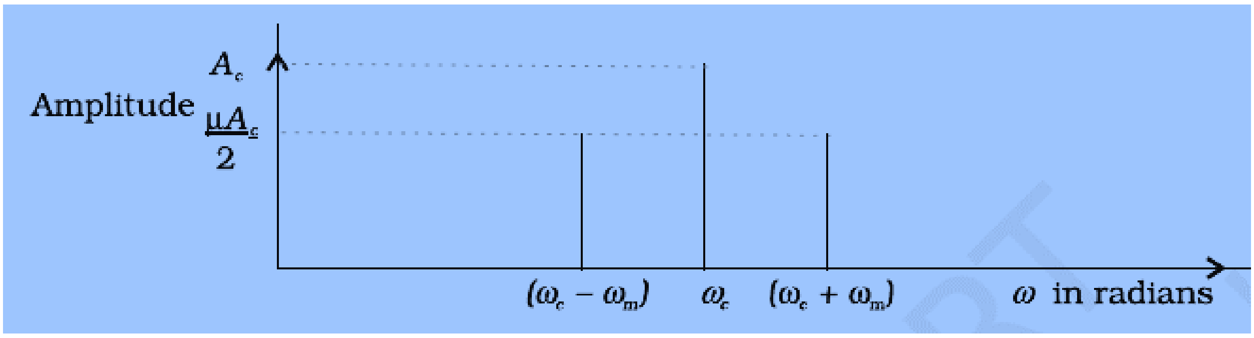
$$C_m(t) = A_c sin\omega_c t + \frac{\mu A_c}{2} cos\left(\omega_c - \omega_m\right)t - \frac{\mu A_c}{2} cos\left(\omega_c + \omega_m\right)t$$

Here $\left(\omega_c - \omega_m\right)$ and $\left(\omega_c + \omega_m\right)$ are called **side band frequencies.**

$\left(\omega_c - \omega_m\right)$= **Lower side band frequency**

$\left(\omega_c + \omega_m\right)$= **Upper side band frequency**

The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different, known as sidebands .The frequency spectrum of the amplitude modulated signal is shown in the figure.



A plot of amplitude versus ω for an amplitude modulated signal

So, apart from original frequency ω_c there develops two more frequencies

$$\left(\omega_c - \omega_m\right) \text{ and } \left(\omega_c + \omega_m\right)$$

Therefore,

bandwidth of AM wave = highest freq. - Lowest freq.

$= USB - LSB$

$= (\omega_c + \omega_m) - (\omega_c - \omega_m)$

$= \mathbf{2\ \omega_m}$

Bandwidth of the AM wave is twice of message signal frequency.

Why should transmitters broadcasting programmers use different carrier frequencies?

Different stations or transmitters can operate properly without interfering with each other as long as the broadcast frequencies (carrier waves) or transmitter frequencies are sufficiently spaced out so that their side bands do not overlap.

Example A message signal of frequency 10 KHz and peak voltage of 10 volts is used to modulate a carrier wave of frequency of 1 MHz and peak voltage of 20 volts.

Determine the

a. modulation index
b. the side bands produced.

Solution

1. Given,

   $A_m = 10$ volts and $A_c = 20$ volt

   Modulation index $\boldsymbol{\mu = A_m/A_c}$

   $= 10/20$

   $= \mathbf{0.5}$

2. Given,

   $\boldsymbol{\omega_c} = 1$ MHz and $\boldsymbol{\omega_m} = 10$ kHz = 0.01 MHz

   The side band frequencies produced are

   Lower side band (LSB) = $(\omega_c - \omega_m)$

   $= (1 - 0.01)$

   = 0.99 MHz or 990 kHz

   Upper side band (USB) = $(\omega_c + \omega_m)$

   $= (1 + 0.01)$

   = 1.01 MHz or 1010 kH

Modulation Index (M)

It signifies the level of modulation achieved. It is defined differently in different types of modulation. In **amplitude modulated wave (AM wave)**

It is measured as the ratio of peak value of modulating signal (message signal) to peak value of carrier wave.

$$\mu = A_m / A_c$$

Sometimes it is represented in percentage also.

If a value of **μ = 50% or 0.5** means the carrier wave is modulated by 50% means the amplitude of the carrier has varied by 50% .

If the value of **μ = 100% or 1** means the carrier wave is modulated by 100% means the amplitude of the carrier has varied by 100% . In this condition, the amplitude of the modulated wave at certain places will become zero.We cannot increase the value of **μ beyond** 1 then amplitude of the modulated wave will become negative and then the noise increases . Hence the value of **μ is** kept less than equal to 1 (**μ ≤ 1).**

We can also consider the modulation index in another way.

The amplitude of modulated wave $A = A_c + A_m \sin(\omega_m t)$

Amplitude is maximum if $\sin(\omega_m t) = +1$ **, therefore**

$$A_{max} = A_c + A_m$$

Amplitude is minimum if $\sin(\omega_m t) = -1$ **, therefore**

$$A_{min} = A_c - A_m$$

$$A_{max} + A_{min} = 2A_c$$

Also $A_{max} - A_{min} = 2A_m$

$$\mu = A_m / A_c ,$$

therefore,

$$\mu = A_{max} - A_{min} / A_{max} + A_{min}$$

Example

For an AM wave the max. Amplitude is found to be 10 V and min. amplitude is found to be 2 V. Find the modulation index μ.

Solution

Given, $\mathbf{A_{max} = 10\ v}$ **and** $\mathbf{A_{min} = 2\ v}$

$$\mu = (A_{max} - A_{min})/(A_{max} + A_{min})$$

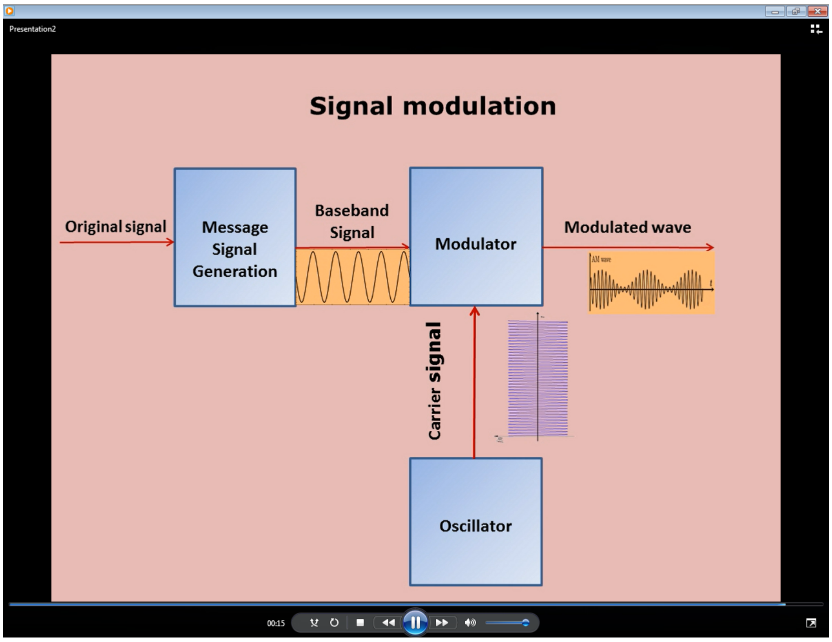
$$= (10 - 2)/(10 + 2)$$

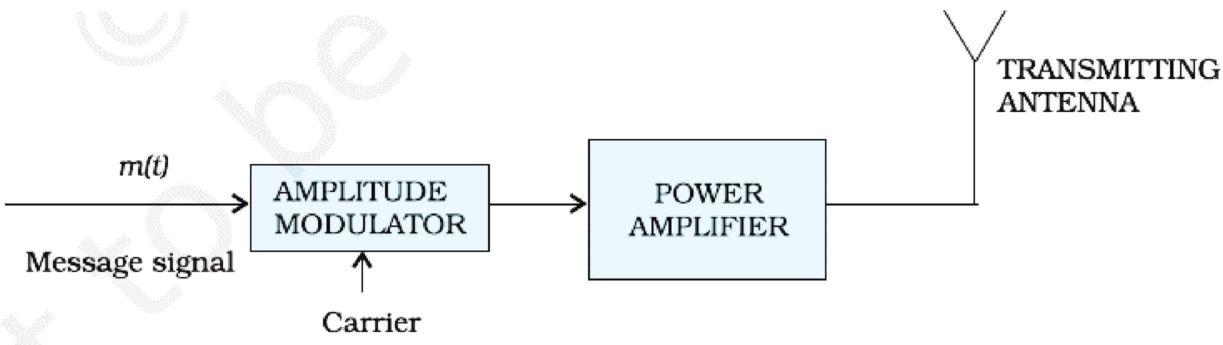
$$= 8/12$$

$$= 0.667$$

Production of AM Wave

The production of amplitude modulated wave is done at transmitter end block diagram of which is given as under,Many processes are done in the modulator, so a detailed Block diagram of the modulator is shown below.





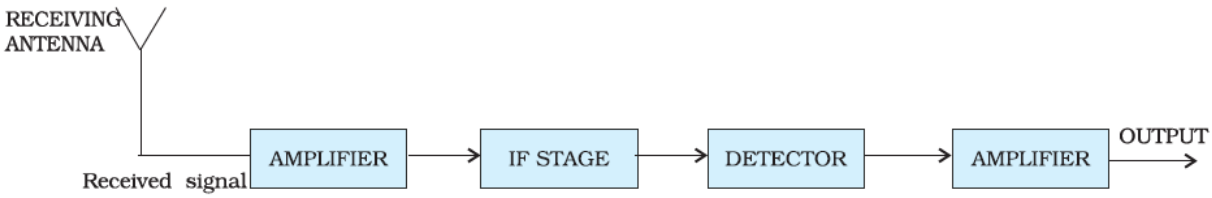
Block Diagram of a Transmitter

Working

- The message signal and carrier wave are superimposed in adder.
- The output of adder is fed to a device which produces the required side bands.
- The output of the device is sent to a band pass filter centered at ω_c. This filter allows the required frequencies of sidebands and carrier waves and rejects the other unwanted frequencies.
- The filtered wave is the required AM wave which is amplified in the power amplifier of the transmitter and transmitted through the transmitting antenna.

Detection of Am Wave

The detection process is done at the receiver end. Block diagram of the receiver is shown as under.The transmitted message gets attenuated in propagating through the channel. The receiving antenna is therefore to be followed by an amplifier and a detector.



Block Diagram of Detector or Demodulator

The received modulated wave has frequencies

- ω_c, $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$

From this the original message signal of frequency ω_m is obtained in a demodulator or detector.Demodulation as said earlier is the process of getting the original signal back from the modulated wave.Detailed processes done in the detector are shown in the block diagram of detector or demodulator.

Working

- The receiver receives a signal through the receiving antenna.
- The received signal has suffered attenuation during its journey, so is first amplified.

- The high frequency of the carrier wave is changed to a lower frequency in what we call intermediate frequency stage (IF stage). It is done because it is difficult to handle high frequency carriers.
- Then the received signal is sent to the detector for actual processing.
- In the detector, the AM wave is first passed through a half wave rectifier to reject the lower envelope.
- The rectified wave is now sent to the envelope detector.
- The envelope picks the low frequency envelope and rejects the high frequency part.
- This envelope is our original message m(t). It is again amplified and sent to the user.

Applications of AM Wave

Amplitude modulation is the oldest method used to transmit voice by radio broadcast. In marine and aircraft navigation also AM waves are used because they can travel longer distances.

These waves are used in

- **Citizen Band Radio** (CB Radio). CB radio is a club of people around the globe. It is also called **amateur radio**.
- **Broadcast Transmissions***:* AM is still widely used for broadcasting on the long, medium and short wave bands. It is simple to demodulate and this means that radio receivers capable of demodulating amplitude modulation are cheap and simple to manufacture.
- Used in Navy and Aviation for communications as AM signals can travel longer distances.
- Used by traffic , mela police for messaging.
- **Air Band Radio***:* VHF transmissions for many airborne applications still use AM.. It is used for ground to air radio communications as well as two way radio links for ground staff as well.
- **HF Radio Links:** Amplitude modulation in the form of single sideband is still used for HF radio links. Using a lower bandwidth and providing more effective use of the transmitted power this form of modulation is still used for many point to point HF links.

- **Short Range Wireless Links:** AM is widely used for the transmission of data in everything from short range wireless links such as Wi-Fi to cellular telecommunications and much more.

These form some of the main uses of amplitude modulation. However in its basic form, this form of modulation is being used less as a result of its inefficient use of both spectrum and power.

While amplitude modulation is one of the simplest and easiest forms of signal modulation to implement, it is not the most efficient in terms of spectrum efficiency and power usage. As a result, the use of amplitude modulation is falling in preference to other modes such as frequency modulation, and a variety of digital modulation formats.

Yet despite this decrease, amplitude modulation is in such widespread use, especially for broadcasting, and many amplitude modulation signals can still be heard on the various long, medium and short wavebands where they will undoubtedly be heard for many years to come.

- **Why do we not use AM for transmitting music?**

  Adding noise for amplitude modulated signals will be more when compared to frequency modulated signals. Data loss is also more in amplitude modulation due to noise addition. Demodulators cannot reproduce the exact music or modulating signal due to noise.
- **Why more power is needed to transmit AM signals?**

  More power is required during modulation because Amplitude modulated signal frequency should be double than modulating signal or message signal frequency. Due to this reason more power is required for amplitude modulation.
- **Why is a higher level of noise produced in AM signal transmission?**

  Sidebands are also transmitted during the transmission of carrier signals. More chances of getting different signal interfaces and adding of noise is more when compared to frequency modulation. Noise addition and signal interferences are less for frequency modulation. That is why Amplitude modulation is not used for broadcasting songs or music.

Advantages and Disadvantages of Amplitude Modulation

Advantages: The modulation requires simple modulator circuits; they are cheap and so are commercially used for audio and speech transmission. The hand held toy radio sets use AM circuits; demodulation can be easily done with low cost circuits.

Disadvantages: The poor performance due to noise is their greatest disadvantage .They require greater power, since the band width is twice that of the signal the AM devices are not very efficient

Try These

i. Distinguish between modulation and amplitude modulation.
ii. Draw block diagram of transmitter.
iii. Draw block diagram of modulator.
iv. Draw block diagram of receiver.
v. What is the function of the IF stage in the receiver?
vi. Explain in brief the working of the detector.

Summary

- Modulation is the process of superimposing a low frequency signal over a high frequency wave called a carrier wave.
- After modulation a new wave is formed called a modulated wave. The modulated wave is a combination of message signal and carrier wave.
- There are 3 types of modulation
  - Amplitude Modulation (AM)
  - Frequency Modulation (FM) and
  - Phase Modulation (PM)
- The process of varying amplitude of a high frequency carrier wave in accordance with the signal (code, voice or music) to be transmitted , keeping the frequency and phase of the carrier wave unchanged is known as amplitude modulation
- In amplitude modulation the amplitude of the carrier wave is changed according to the message or information signal.
- The expression for amplitude modulated wave is given by,

  $$C_m(t) = (A_c + A_m sin\omega_m t)\, sin\omega_c t$$
  $$= A_c(1 + A_m / A_c\, sin\omega_m t)\, sin\omega_c t$$

- The modulated signal contains the message signal.
- $(A_c + A_m sin\,\omega_m t)$ is amplitude of modulated wave and ω_c is frequency of modulated wave. The amplitude of modulated wave changes with time “t” and

frequency of modulated wave is same as of carrier. It is because we only change the amplitude of the carrier wave and not its frequency.

- An amplitude modulated wave has frequencies $(\omega_c - \omega_m)$, ω_c and $(\omega_c + \omega_m)$.
  $(\omega_c - \omega_m)$ = Lower side band frequency
  $(\omega_c + \omega_m)$ = Upper side band frequency.
- Bandwidth of AM wave = highest freq. - Lowest freq.

$$= USB - LSB$$
$$= (\omega_c + \omega_m) - (\omega_c - \omega_m)$$
$$= 2\,\omega_m$$

  - Bandwidth of the AM wave is twice the message signal frequency.
  - Different stations or transmitters can operate properly without interfering with each other as long as the broadcast frequencies (carrier waves) or transmitter frequencies should be sufficiently spaced out so that their side bands do not overlap.
- $\mu = A_m/A_c$ is called modulation index in practice $\mu \le 1$ to avoid distortion of signal.
- If the value of μ = 100% or 1 means the carrier wave is modulated by 100% means the amplitude of the carrier has varied by 100% . In this condition, the amplitude of the modulated wave at certain places will become zero.
- We cannot increase the value of μ beyond 1 then amplitude of modulated wave will become negative and chances of introduction of noise increases a lot. Hence the value of μ is kept less than equal to 1 ($\mu \le 1$).
- The electrical /electronic circuits used for amplitude modulated waves, for their transmission and retrieval, are cheap and relatively simple.
- AM waves are used by amateur radio designers; police patrol work, marine and aircraft navigation because they can travel longer distances as compared to wired or cabled transmissions.