# Lecture 44

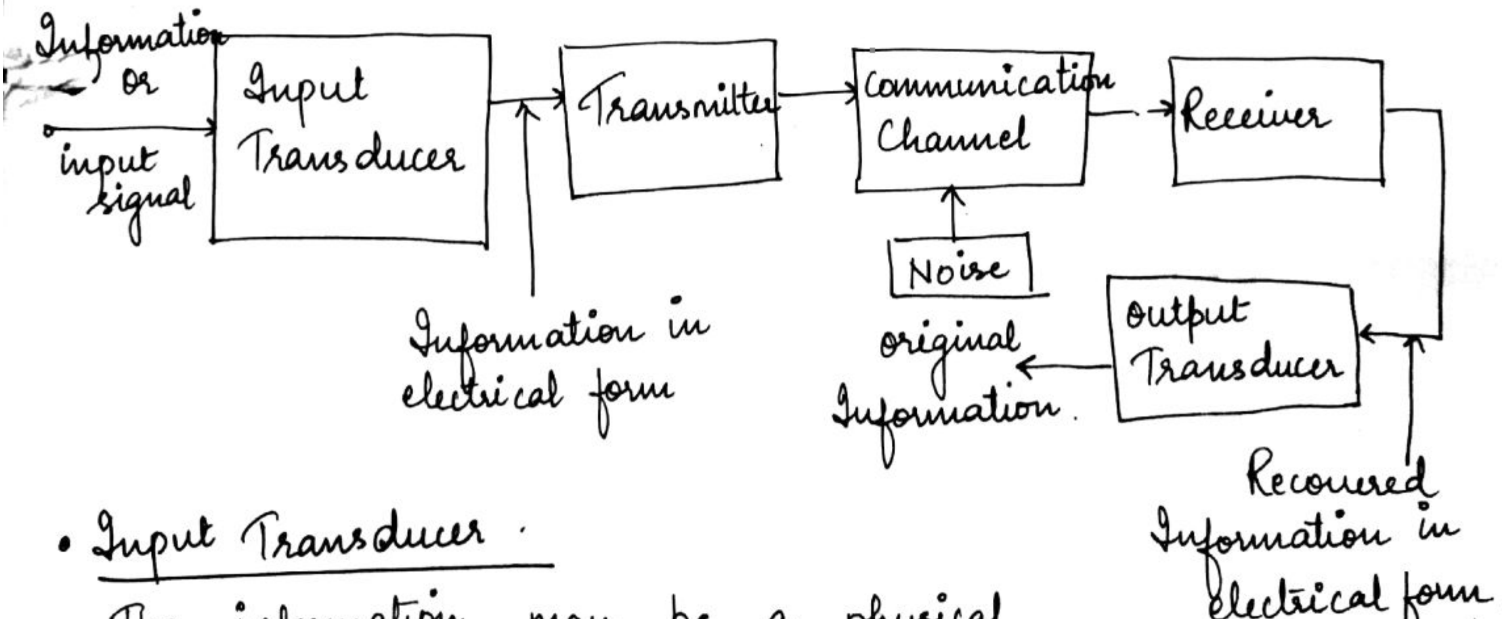
# Unit 5: Fundamentals of Communication Engineering

## Contents

- Introduction
- Elements of communication system.
- Modulation.

Communication is the transfer of information from source to destination via a communication channel.

## Elements of Communication system




- Input Transducer.

The information may be a physical signal such as sound, voice, picture etc. Input transducer is a device that converts a physical signal from source to an electrical signal, which is suitable for communication.

- Transmitter :

The transmitter consists of amplifier, mixer, oscillator, (modulator)

The functions of transmitter are :

→ to perform modulation

→ to increase the power level of the signal.

- Communication Channel

The communication channel is the medium used for transmission of signal from the transmitter to receiver. The communication channel can be of two types :

→ wired

→ wireless

Wired channel uses simple wires or cables or optical fibers. examples are telegraph and telephone systems, cable TV etc.

Wireless channel uses free space as communication medium examples are radio, tv broadcast, Satellite communication etc.

## Noise

Noise is a random unwanted signal that gets added to the signal travelling over the communicati system.

## Receiver

The reception is exactly the opposite process of transmissio

The receiver consist of demodulator, mixer, amplifier and oscillator, filter

The functions of receiver are:

→ to perform demodulation.

→ to remove noise.

## Output Transducer

The output transducer converts the electrical signal back to original information.

## University Questions

Q. Explain the functional elements of communication system. (2014-15 odd & even sem) (10 Marks).

Q. Explain the block diagram of communication system (10 Marks) (2015-16).

Q What is baseband signal? What is Baseband transmission?

→ The electrical equivalent of the original information is called as baseband signal.

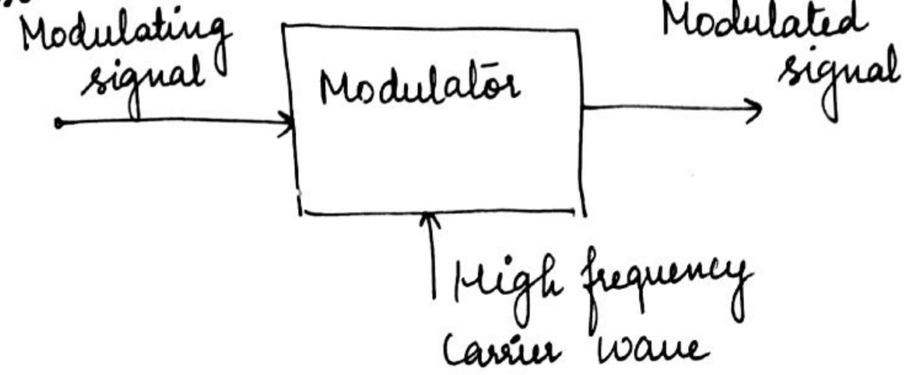
The transmission in which the electrical equivalent of original information is sent directly without any modulation is called baseband transmission.

## Modulation

The basic concept of modulation is to translate the frequency of ~~information signal~~ transmitted signal from low to high frequency.

The process in which some parameters of a high frequency carrier wave are varied according to the message signal or information signal or modulating signal is called modulation.

The parameters can be amplitude, frequency or phase.



# Lecture 45

## Unit 5 : Fundamentals of Communication Engineering

### Contents

- Need of Modulation
- Electromagnetic spectrum.

### Need of Modulation

- To reduce antenna height

The minimum antenna height required to transmit a signal is $\lambda/4$

$$H = \lambda/4$$

$$C = \lambda f$$

$$\lambda = C/f$$

$$\Rightarrow \quad H = \frac{C}{4f}$$

Now let us consider two cases :

**Case 1**

$f = 10\,KHz$

$$H = \frac{3 \times 10^8}{4 \times 10 \times 10^3}$$

$$\boxed{H = 7.5\ km}$$

**Case 2**

$f = 1\,MHz$.

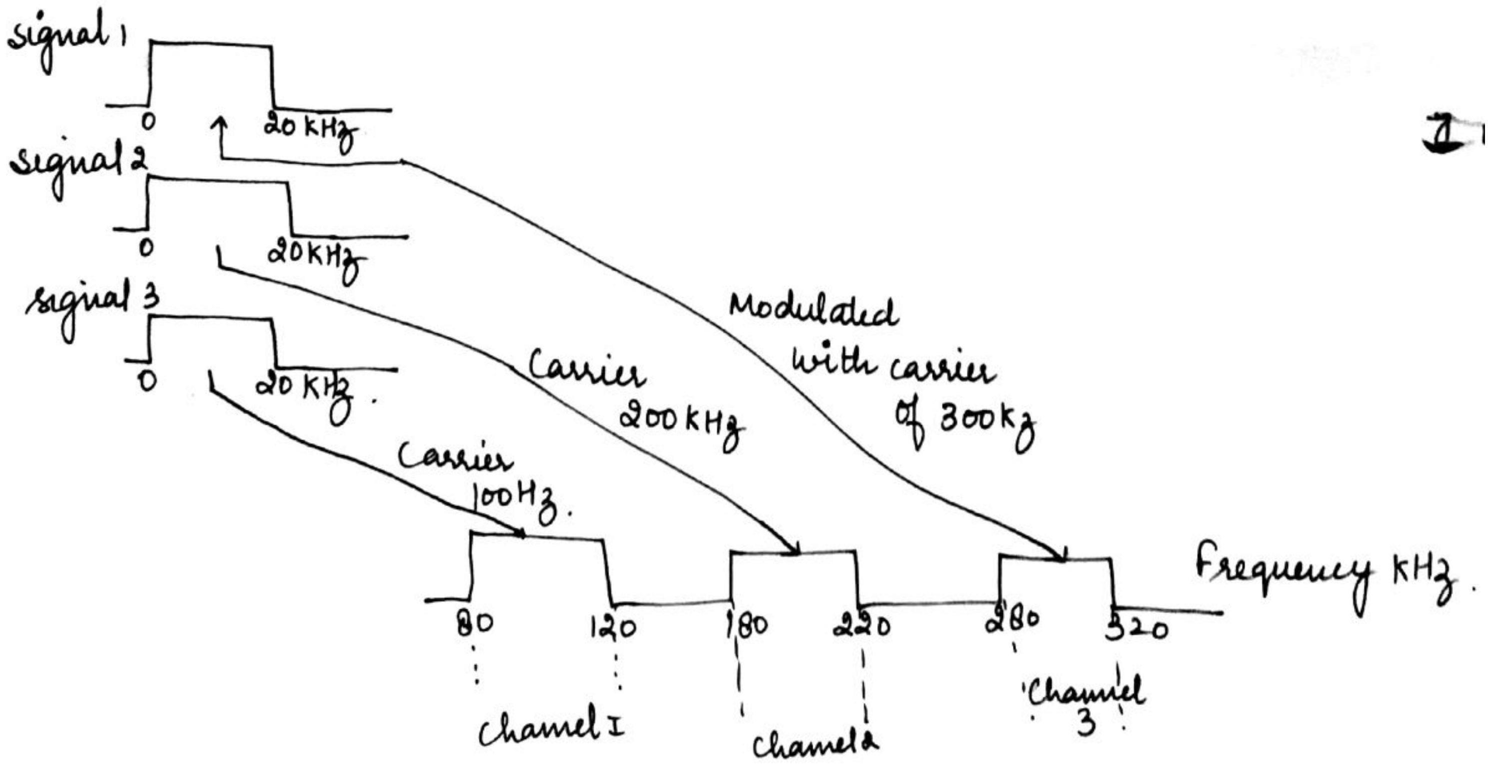
$$H = \frac{3 \times 10^8}{4 \times 10^6}$$

$$\boxed{H = 75\,m}$$

The antenna for case 1 is practically impossible to install.
The antenna for case 2 can be easily installed.
Thus modulation is necessary to reduce the antenna height.

- <u>To avoid mixing of signals</u>

If a same signal is to be transmitted by more than one transmitter, then all the signals will be mixed and receiver will not be able to separate them. But if each signal is used to modulate a different carrier frequency, then they will not get mixed at the receiver side.



## Enable Multiplexing

Multiplexing is a process in which two or more signals can be transmitted over the same chamel simultaneously. This is possible by modulation. eg: Many TV channels can use same frequency range without getting mixed. or different frequency signals can be transmitted at same time.

- **Increases the range of communication**

The modulation process increases the frequency of the signal to be transmitted. and a high frequency signal can travel long distances. Hence, modulation increases the range of communication.

- **Improves Quality of Reception**

Modulation improves the quality of reception by reducing the effect of Noise.

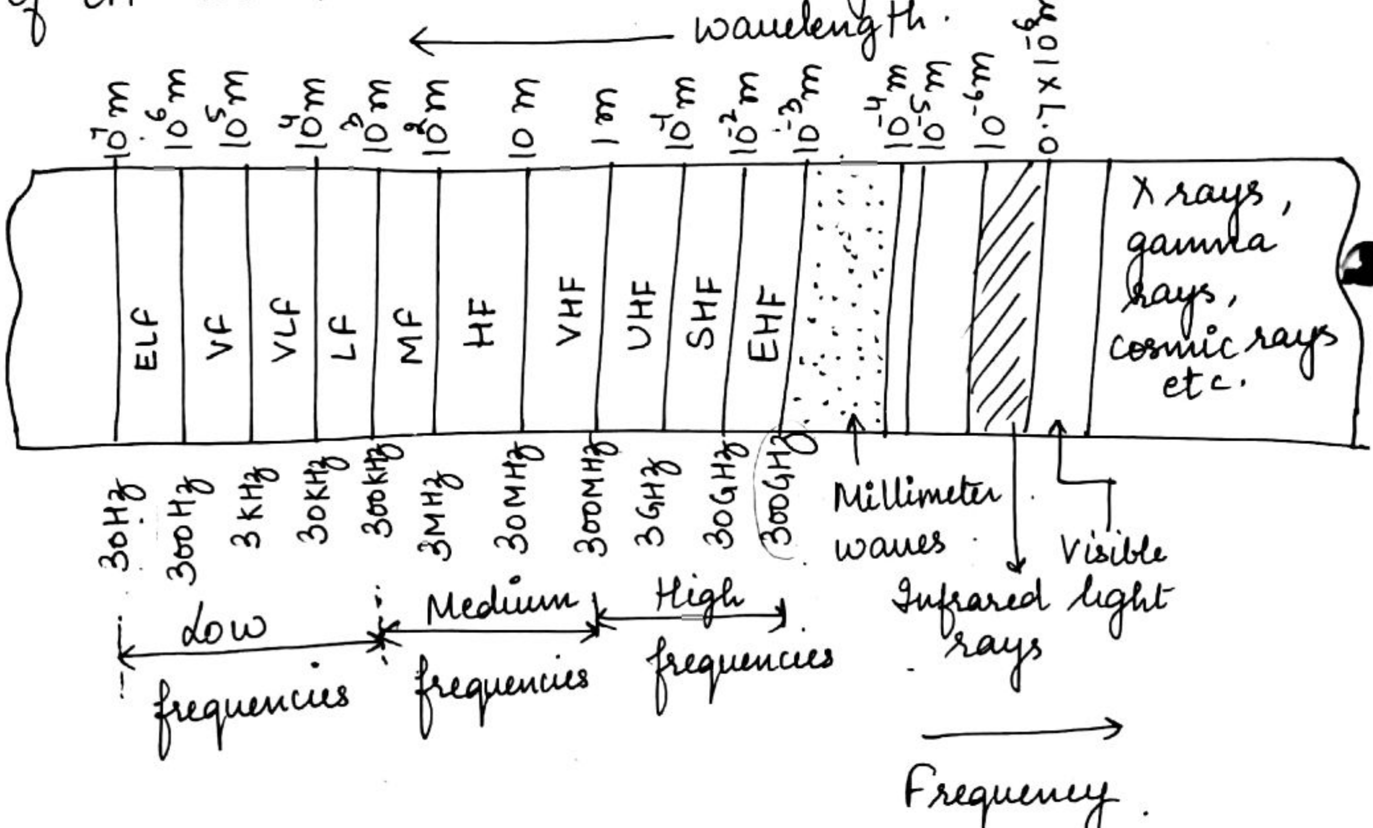
University Question.

Q1. Explain the need of modulation in communication system. (2015-16 odd sem). (10 Marks)

Q2. What is modulation? Why is it required (2014-15 odd sem) (2015-16 even sem) (10 Marks)

# IEEE frequency spectrum

Wireless communication takes place using the electromagnetic waves.
The frequency of EM waves can be very low or can be very high. This entire range of frequencies of EM waves is called Electromagnetic Spectrum.




## Complete Electromagnetic spectrum

## Applications

etic

| S.N. | Frequency Band | Applications |
|---|---|---|
| 1. | ELF (Extremely low frequencies) | Power transmission |
| 2. | VF (Voice Frequencies) | Audio applications. |
| 3. | VLF. (very low frequencies) | Submarine communications, Navy, Military communications. |
| 4. | LF (low frequencies) | Aeronautical and marine, navigation, these frequencies act as sub carriers. |
| 5. | MF (Medium frequencies) | AM radio broadcast, Marine and aeronautical communications. |
| 6. | HF (High frequencies) | Shortwave transmission. |
| 7. | VHF (very high frequencies) | TV Broadcasting, FM broadcasting |
| 8. | UHF (ultra high frequencies) | UHF TV channels, TV. cellular phones, Military applications. |
| 9. | SHF (super High frequencies) | Satellite communication & Radar |
| 10. | EHF (Extremely high frequencies) | Satellites and specialized Radars |

# Lecture 46

## Unit 5: Fundamentals of Communication Engineering

### Contents :

- Types of Modulation systems
- Amplitude Modulation.

## Types of Modulation systems

Modulation Systems

- Analog modulation systems
  - Amplitude Modulation (AM)
  - Angle Modulation
    - Frequency Modulation (FM)
    - Phase Modulation (PM)
  - Pulse analog modulation
    - Pulse amplitude Modulation (PAM)
    - Pulse Width Modulation (PWM)
    - Pulse position Modulation (PPM)
- Digital modulation systems
  - Pulse Code Modulation (PCM)
  - Delta Modulation (DM)
  - DPCM (Differential Pulse Code Modulation)
  - ADM (Adaptive Delta Modulation)

## Analog Modulation techniques :

The modulation systems or techniques in which one of the characteristics of the carrier is changed in proportion with the instantaneous value of modulating signal is called as analog modulation systems.

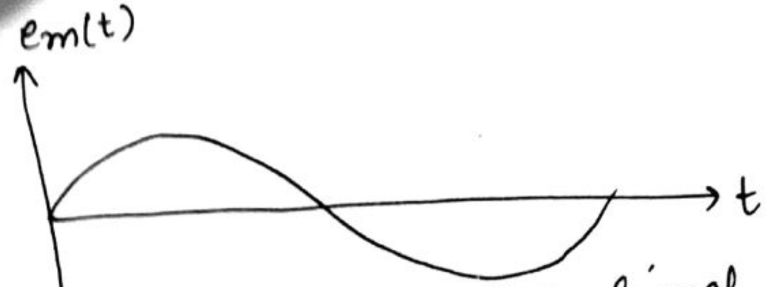
Analog modulation can be pulsed modulation as well. Here the carrier is in the form of rectangular pulses. The amplitude, width or position of the carrier pulses is varied in accordance with the modulating signal to obtain PAM, PWM or PPM.

## Digital Modulation Systems

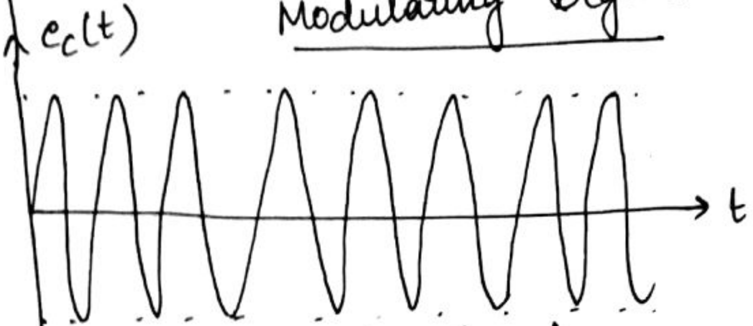
The modulation system or techniques in which the transmitted signal is in the form of digital pulses of constant amplitude, constant frequency and phase is called as digital modulation systems.

## Amplitude Modulation

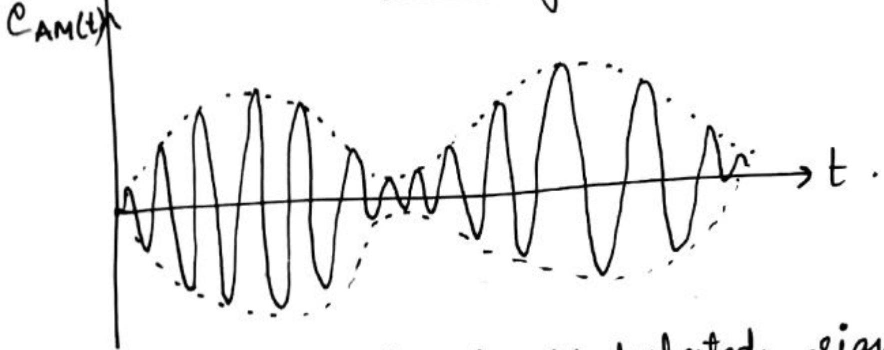
Amplitude Modulation is the process of changing the amplitude of high frequency carrier signal according to instantaneous value of modulating signal.




Modulating Signal




carrier signal




Amplitude Modulated signal

## Mathematical Representation of an AM Wave

$$e_m(t) = E_m \cos\omega_m t$$

$$e_c(t) = E_c \cos\omega_c t$$

$$e_{AM}(t) = A \cos\omega_c t$$

$$A = e_m(t) + E_c$$

$$A = E_c + E_m \cos\omega_m t$$

$$A = E_c\left(1 + \frac{E_m}{E_c} \cos\omega_m t\right)$$

$m$ = modulation index .

$$e_{AM}(t) = A\cos\omega_c t$$
$$= \left[E_c + E_m\cos\omega_m t\right]\cos\omega_c t .$$
$$e_{AM}(t) = E_c\cos\omega_c t + E_m\cos\omega_m t\cos\omega_c t$$
$$= E_c\cos\omega_c t + \frac{E_m}{2}\left(\cos(\omega_c+\omega_m)t + \cos(\omega_c-\omega_m)t\right)$$

$$\boxed{e_{AM}(t) = E_c\cos\omega_c t + \frac{mE_c}{2}\cos(\omega_c+\omega_m)t + \frac{mE_c}{2}\cos(\omega_c-\omega_m)t}$$

Carrier — upper side band (USB) — Lower Side band (LSB).

Thus an amplitude modulated wave has three components i.e carrier, USB and LSB.

amplitude of carrier $= E_c$

frequency of carrier $f_c = \frac{\omega_c}{2\pi}$

frequency of modulating $f_m = \frac{\omega_m}{2\pi}$

amplitude of USB $= \frac{mE_c}{2}$

frequency of USB $f_{USB} = (f_c + f_m)$

amplitude of LSB $= \frac{mE_c}{2}$

frequency of LSB $f_{LSB} = (f_c - f_m)$

# Lecture 47

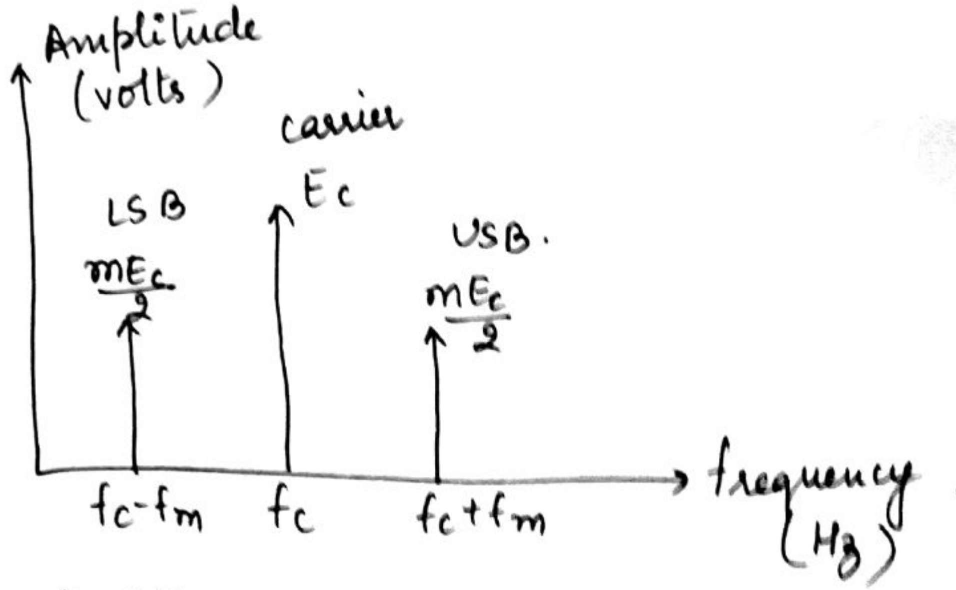
## Unit 5: Fundamentals of Communication Engineering

**Contents:**

- frequency spectrum of AM wave
- Bandwidth of AM
- Power.

### Frequency spectrum of AM wave

$$e_{AM}(t) = E_c \cos \omega_c t + \frac{mE_c}{2} \cos(\omega_c + \omega_m)t + \frac{mE_c}{2} \cos(\omega_c - \omega_m)t$$




### Bandwidth of AM

$$\text{Bandwidth} = f_{USB} - f_{LSB}$$
$$= f_c + f_m - (f_c - f_m)$$

$$\boxed{B.W = 2f_m}$$

**Note:** In AM wave, only the sidebands i.e LSB and USB (amplitude $\frac{mE_c}{2}$) contain the information to be transmitted while the carrier component does not contain any information.

## Power

$$e_{AM}(t) = \underbrace{E_c \cos\omega_c t}_{\text{Carrier}} + \underbrace{\frac{mE_c}{2}\cos(\omega_c-\omega_m)t}_{\text{LSB}} + \underbrace{\frac{mE_c}{2}\cos(\omega_c+\omega_m)t}_{\text{USB}}$$

$$P_c = \frac{(E_c)^2}{2}$$

$$P_{LSB} = P_{USB} = P_{SB} = \left(\frac{mE_c}{2}\right)^2 \times \frac{1}{2} = \frac{m^2E_c^2}{8}$$

$$P_{SB} = P_{LSB} + P_{USB}$$

$$= \frac{(mE_c)^2}{8} + \frac{(mE_c)^2}{8}$$

$$P_{SB} = \frac{(mE_c)^2}{4}$$

Total Power $P_t = P_c + P_{SB}$

$$= \frac{E_c^2}{2} + \frac{(mE_c)^2}{4}$$

$$\boxed{P_t = \frac{E_c^2}{2}\left(1 + \frac{m^2}{2}\right)}$$

$$\boxed{P_t = P_c\left(1+\frac{m^2}{2}\right)}$$

$$\boxed{I_t = I_c\left(1+\frac{m^2}{2}\right)^{1/2}}$$

## Numericals

Q1. A 460W carrier is modulated to a depth of 60%. Calculate the total power in the modulated wave. (2015-16 odd sem) (5 Marks)

→ $$\boxed{P_t = P_c\left(1+\frac{m^2}{2}\right)}$$

$P_c = 460\,W$

$m = \frac{60}{100} = 0.6$

$$P_t = 460\left(1+\frac{(0.6)^2}{2}\right)$$

$$\boxed{P_t = \cancel{557.175\,W}\ 542.8\,W}$$

Q2. A 320W carrier is simultaneously modulated by two audio waves with modulation % of 45 and 60 respectively. What is the side band power radiated? (2015-16 odd sem) (2 Marks)

→ $$\boxed{P_t = P_c + P_{SB}} \Rightarrow P_{SB} = P_t - P_c$$

$P_c = 320\,W.$ $\qquad P_t = P_c\left(1+\frac{m^2}{2}\right)$

case 1 $\quad m = 0.45$

$$P_{t1} = 320\left(1 + \frac{(0.45)^2}{2}\right)$$

$$P_{t1} = 352.4\,W$$

$$P_{SB1} = P_{t1} - P_c$$
$$= 352.4\,W - 320\,W$$

$$\boxed{P_{SB1} = 32.4\,W}$$

Case 2 $\quad m = 0.6$

$$P_{t2} = 320\left(1 + \frac{(0.6)^2}{2}\right)$$

$$P_{t2} = 377.6\,W$$

$$P_{SB2} = P_{t2} - P_c$$
$$= 377.6 - 320$$

$$\boxed{P_{SB2} = 57.6\,W}$$

Total side band Power $P_{SB} = P_{SB1} + P_{SB2} = 32.4 + 57.6$

$$\boxed{P_{SB} = 90\,W}$$

Q3. A 400 W carrier is modulated to a depth of 75%. Calculate the total power in the modulated wave. (2014-15 odd) (5 Marks)

Ans: 562.5 W.

Q4. The antenna current of an AM transmitter is 8 A, when only the carrier is sent, but it increases to 8.93 A when the carrier is modulated by single single sine wave. Find % modulation. Determine Antenna current when % m changes to 0.8

Ans. $m = 0.7$ $\quad I = 9.12\,A$

Q5. The tuned circuit of the oscillator in a simple AM transmitter employs a 50 µH coil and 1 nf capacitor. If the oscillator output is modulated by audio frequencies up to 10 KHz, what is the frequency ranged occupied by side bands. (2014-15) odd sem (5 Marks)

⇒ $f_{LSB} = f_c - f_m$

$f_{USB} = f_c + f_m$

Given

$f_m = 10\text{ KHz}$.

$$\boxed{f_c = \frac{1}{2\pi\sqrt{LC}}}$$

$f_c \approx 712\text{ kHz}$.

$f_{LSB} = f_c - f_m = 702\text{ kHz}$.

$f_{USB} = f_c + f_m = 722\text{ kHz}$

∴ frequency range 702 kHz to 722 kHz

Q6. Define Amplitude Modulation. Derive the expression of AM Modulated waveform. Define modulation index of AM (2016-17).

P.T.O

Q7. A 500 W carrier is modulated to a depth of 60%. Calculate Total power in amplitude modulated wave. (2016-17). (7 Marks)

Q8. The unmodulated rms current of an AM wave is 8.93A and it increase to 11.25 A with modulation. Determine the modulation index. (2017-18). (7 Marks)

Q9. Define amplitude Modulation. Derive an expression for amplitude modulated wave. (2017-18) (even) (7 Marks).

Q10. A sinusodial carrier of 1 MHz and amplitude 100V is amplitude modulated by a sinusodial modulating frequency 5kHz providing 50% modulation. Calculate the frequency and amplitude of USB and LSB.

# Lecture 48

## Unit 5 : Fundamentals of Communication Engineering

### Contents :

- Numericals on AM
- Effect of modulation index.
- Modulation techniques of AM.

### Numericals on AM.

Q1. Calculate the percentage saving when the carrier and one of the sidebands are suppressed in AM modulated wave to a depth of
(2015-16 even sem) (5 Marks)

(i) 100%.

(ii) 50%.

$$\Rightarrow e_{AM}(t) = E_c \cos\omega_c t + \frac{mE_c}{2}\cos(\omega_c-\omega_m)t + \frac{mE_c}{2}\cos(\omega_c+\omega_m)t$$

Power $\qquad \frac{E_c^2}{2} \qquad \frac{(mE_c)^2}{8} \qquad + \qquad \frac{(mE_c)^2}{8}$

$\frac{E_c^2}{2} \downarrow$ Suppressed, $\frac{(mE_c)^2}{8} \downarrow$ Suppressed.

$$\underbrace{\text{Suppressed} \quad \text{Suppressed}}_{\text{Power saved}}$$

$$\boxed{\%\ \text{saving} = \frac{\text{Power Saved}}{\text{Total Power}} \times 100}$$

Power saved $= \frac{E_c^2}{2} + \frac{(mE_c)^2}{8}$

$$= \frac{E_c^2}{2}\left(1+\frac{m^2}{4}\right)$$

Total Power $P_t = P_c\left(1+\frac{m^2}{2}\right)$

$$= \frac{E_c^2}{2}\left(1+\frac{m^2}{2}\right)$$

% saving $= \frac{\frac{E_c^2}{2}\left(1+\frac{m^2}{4}\right)}{\frac{E_c^2}{2}\left(1+\frac{m^2}{2}\right)} \times 100$

$$= \left(\frac{4+m^2}{2+m^2}\right) \times \frac{1}{2} \times 100$$

case (i) $m\% = 100\%$

$\Rightarrow m = 1$

% saving $= \left(\frac{4+1}{2+1}\right) \times \frac{1}{2} \times 100$

$$= 83.3\%$$

(ii) $m\% = 50\%$

$m = 0.5$

$$\% \text{ saving} = \left(\frac{4+0.25}{2+0.25}\right) \times \frac{1}{2} \times 100$$

$$= 94.4\%$$

Q2. A modulating signal $10 \sin(2\pi \times 10^3 t)$ is used to modulate a carrier signal $20 \sin(2\pi \times 10^4 t)$. Find the modulation index, percentage modulation, frequencies of sideband components and their amplitudes. What is the bandwidth of the modulated signal? Also draw the spectrum of AM wave.

→ $e_m(t) = E_m \cos \omega_m t = 10 \sin(2\pi \times 10^3 t)$ — (1)

$e_c(t) = E_c \cos \omega_c t = 20 \sin(2\pi \times 10^4 t)$ — (2)

From (1) and (2)

$E_m = 10\,V$ $\quad E_c = 20\,V$.

$$m = \frac{E_m}{E_c} = \frac{10}{20} = 0.5$$

$$\boxed{m = 0.5}$$

$\%$ modulation $= 50\%$

$f_{LSB} = f_c + f_m$

$f_{USB} = f_c - f_m$

from ① and ②

$$f_m = \frac{\omega_m}{2\pi} = \frac{10^3 \times 2\pi}{2\pi} = 10^3\ Hz$$

$$f_m = 1\ KHz.$$

$$f_c = \frac{\omega_c}{2\pi} = \frac{2\pi \times 10^4}{2\pi} = 10^4\ Hz$$

$$f_c = 10\ KHz.$$

$$f_{LSB} = f_c - f_m = 9\ KHz$$

$$f_{USB} = f_c + f_m = 11\ KHz.$$

amplitude of sidebands $= \frac{mE_c}{2}$

$$= \frac{0.5 \times 20}{2}$$

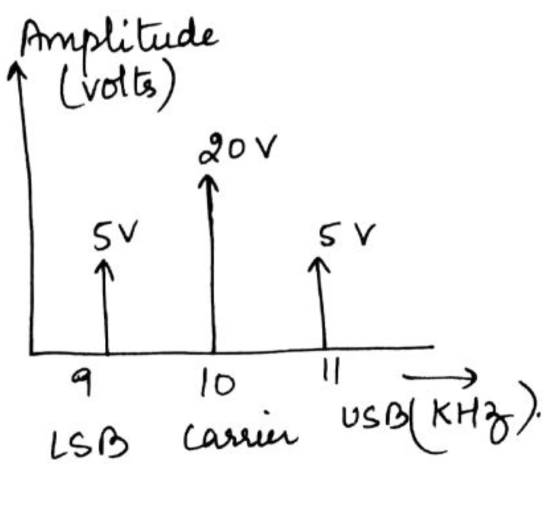
$$= 5V$$

Bandwidth of AM wave $= 2f_m$

$$= 2 \times 1\ KHz$$

$$\boxed{B.W = 2\ KHz.}$$

Spectrum



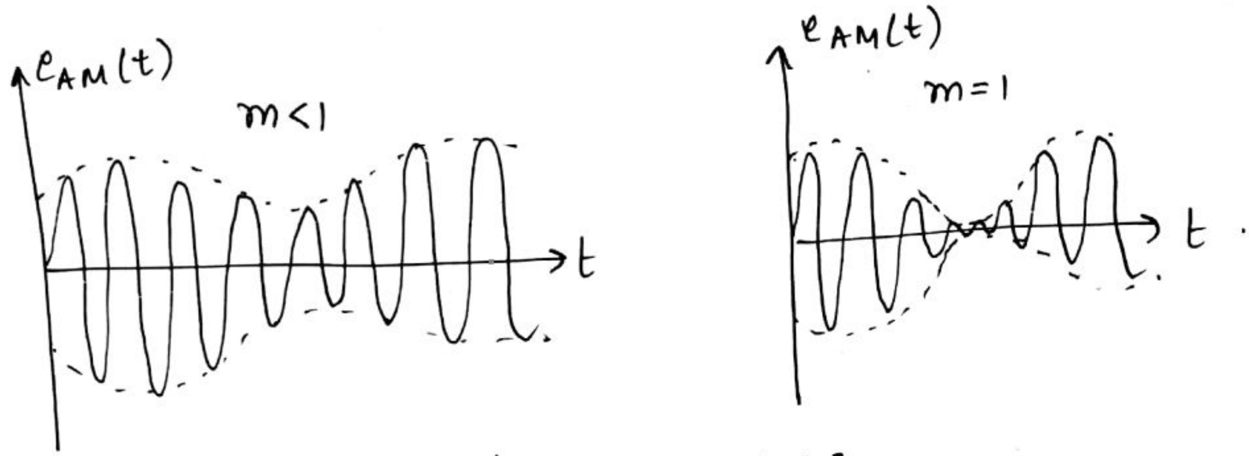
## Effect of Modulation index (m) on AM wave.

Depending on the value of m, the modulation of AM wave can be classified into two categories.

1. Linear Modulation
2. Over modulation.

### Linear Modulation

If $m \leq 1$ or if percentage modulation is less than 100%, then this type of modulation is linear modulation.

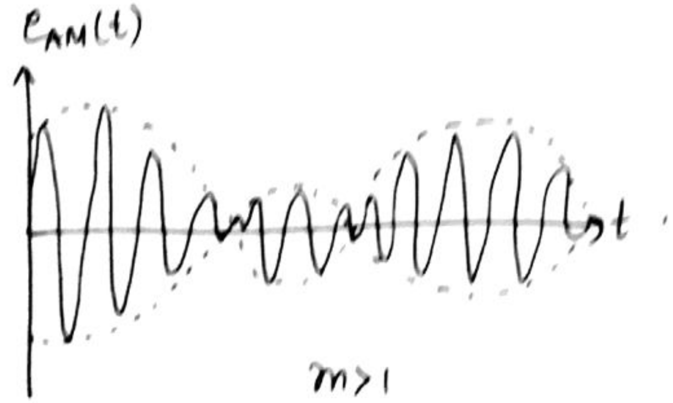



Linear Modulation

### Over Modulation

If $m>1$ or if percentage modulation is greater than 100%, then this type of modulation is over modulation.

Overmodulation introduces envelope distortion. Hence it should be avoided.




Over Modulation

## Advantages of AM wave

- Less complex (AM transmitters)
- AM receivers are simple, detection is easy.
- AM receivers are cost efficient.
- AM waves can travel a longer distance.
- Low bandwidth.

## Disadvantages of AM

- Power wastage takes place
- easily affected due to noise.

# Lecture 50

## Unit 5 : Fundamentals of Communication Engineering

### Contents

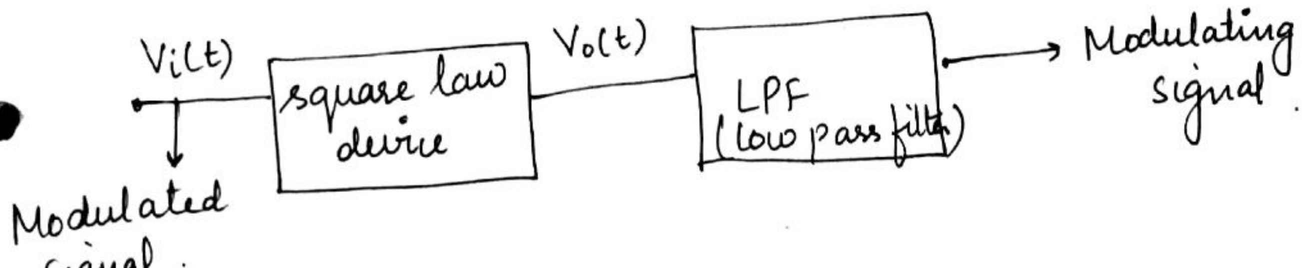
- Demodulation techniques of AM.

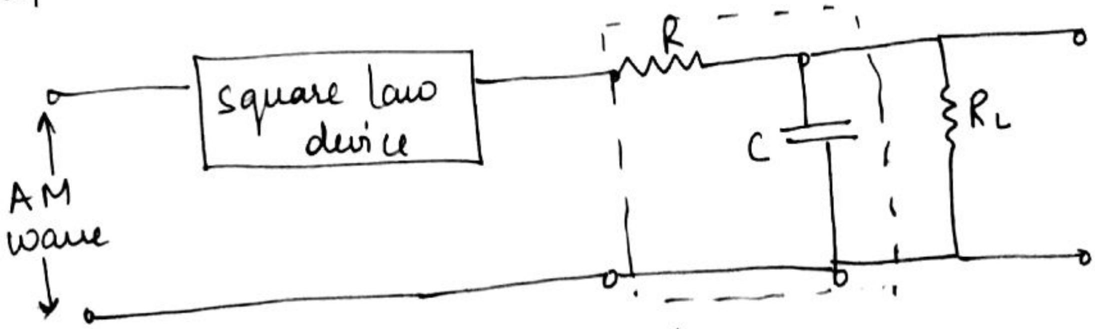
### Demodulation Techniques of AM

Two types of AM detectors are as under :

- square law detector
- Envelope detector.

### Square law detector




Low Pass filter.

$$V_i(t)\ \left(\text{AM wave}\right) = E_c(1+m)\cos\omega_c t$$

$$V_o(t) = aV_i(t) + bV_i^2(t)$$

(o/p of square law device)

$$V_o(t) = aE_c(1+m)\cos\omega_c t + bE_c^2(1+m)^2\cos^2\omega_c t$$

$$= aE_c\cos\omega_c t + amE_c\cos\omega_c t + bE_c^2(1+m^2+2m)\cos^2\omega_c t$$

$$= aE_c\cos\omega_c t + amE_c\cos\omega_c t + \left[bE_c^2 + bm^2E_c^2 + 2mbE_c^2\right]\cos^2\omega_c t$$

$$V_o(t) = aE_c\cos\omega_c t + amE_c\cos\omega_c t + bE_c^2\cos^2\omega_c t + bm^2E_c^2\cos^2\omega_c t + 2mbE_c^2\cos^2\omega_c t$$

$$= aE_c\cos\omega_c t + amE_c\cos\omega_c t + bE_c^2\left(\frac{1+\cos 2\omega_c t}{2}\right) + bm^2E_c^2\left(\frac{1+\cos 2\omega_c}{2}\right)t$$

$$+ 2mbE_c^2\left(\frac{1+\cos 2\omega_c t}{2}\right)$$

$$V_o(t) = aE_c\cos\omega_c t + amE_c\cos\omega_c t + \frac{bE_c^2}{2} + \frac{bE_c^2}{2}\cos 2\omega_c t + \frac{bm^2E_c^2}{2} + \frac{bm^2E_c^2}{2}\cos 2\omega_c t$$

$$+ \cancel{2}\, mbE_c^2 + mbE_c^2\cos 2\omega_c t$$

Range of LPF is 0 to $\omega_m$.

$\therefore$ $\omega_c$ terms can be neglected.

$$V_o(t) = \underbrace{\frac{bE_c^2}{2}}_{\text{dc term}} + \underbrace{\frac{bm^2E_c^2}{2}}_{\text{undesired (distortion)}} + \underbrace{mbE_c^2}_{\text{desired}}$$

The terms which pass through low pass filters are

$$\frac{bm^2 E_c^2}{2} + mbE_c^2$$

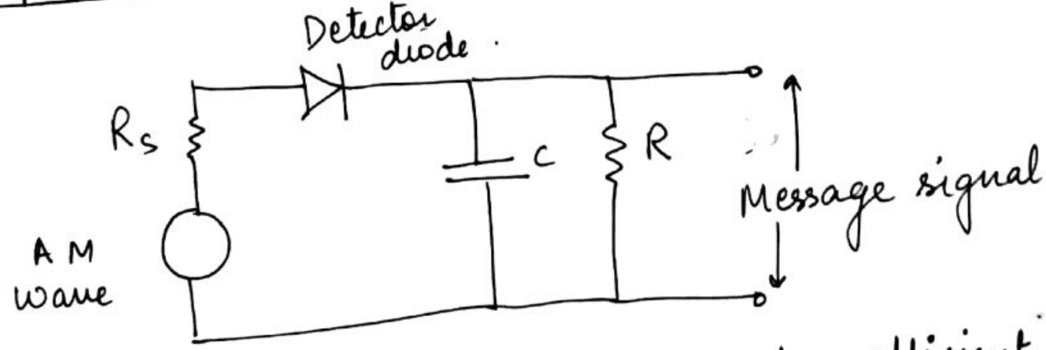
The ratio of desired signal $= \frac{\text{desired component}}{\text{distortion component}}$.

$$= \frac{mbE_c^2}{bm^2E_c^2} \times 2$$

$$= \frac{2}{m}$$

- This ratio should be maximized in order to minimize distortion $\frac{2}{m} >> 1$

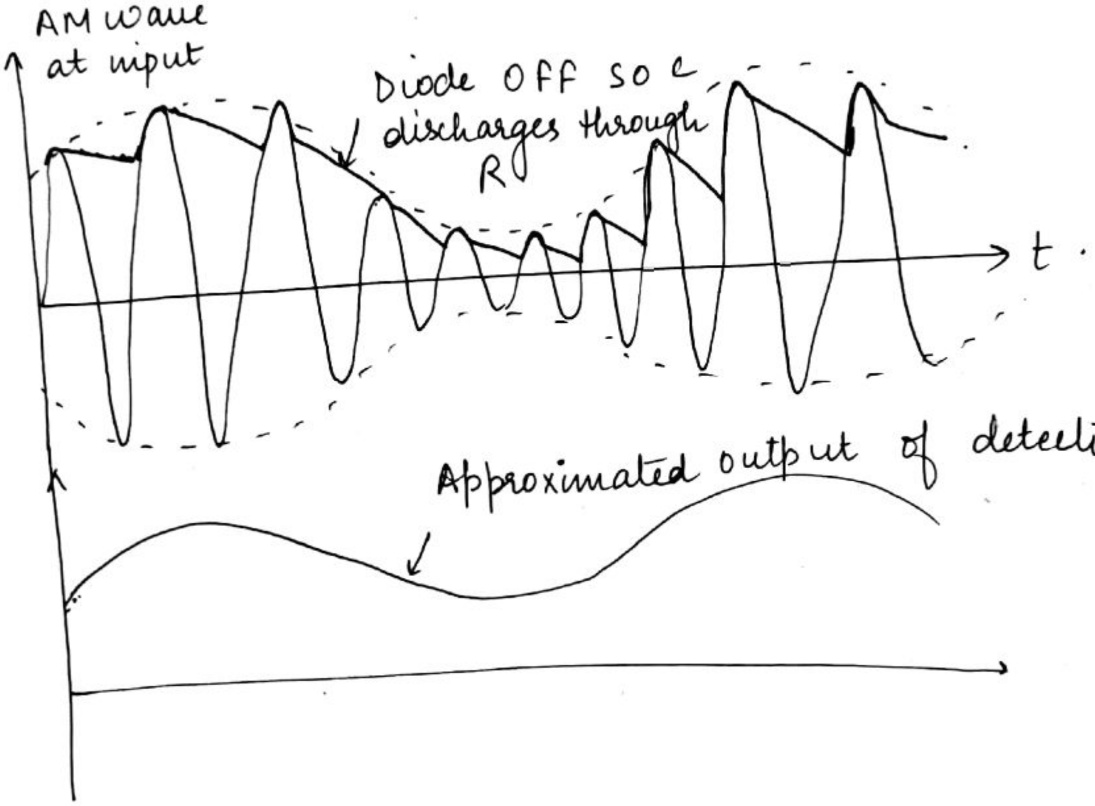
## Envelope detector




Envelope detector is a simple and efficient device which is suitable for the detection of a narrow band AM signal.

An envelope detector produces an output signal that follows the envelope of the input AM signal exactly. used in all commercial AM radio receivers.

In every positive half cycle of the input, the detector diode is forward biased. It will charge the filter capacitor C to the peak value of input voltage. As soon as the capacitor charges to peak value, diode stops conducting and capacitor will discharge through R. The discharging process continues until the next positive half cycle.




Input output wave waveforms of Envelope detector.

## University Question

Q1. What do you understand by modulation? Explain various modulation techniques. Also explain the demodulation techniques of AM with the help of necessary diagram. (10 Marks) (2014-15 even sem).

Q2. Compare AM, FM & PM (2017-18) even (3.5 Marks)

Q3. Explain DSB-SC Techniques (2017-18) even (3.5 Marks)