ANALOG COMMUNICATION
Course Code: 328452(28)

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UNIT-II ANGLE MODULATION
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Text Books:

1. Principles of Communication Systems, Taub and Schilling, 2nd Edition., Tata McGraw Hill.(Unit-I,II,III,IV,V)
2. Electronic Communication Systems, George F Kennedy, Tata McGraw Hill. (Unit-I, II)
3. Communication Systems, Simon Haykins, Wiley India

Reference Books:

1. Communication Systems Engineering, Proakis, 2nd Edition, Pearson Education.
2. Modern Digital and Analog Communication, B.P. Lathi, Oxford University Press.
3. Communication Systems (Analog and Digital), Singh and Sapre, 2nd Edition, Tata McGraw Hill

UNIT-I Amplitude Modulation

- Introduction
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UNIT-I Amplitude Modulation

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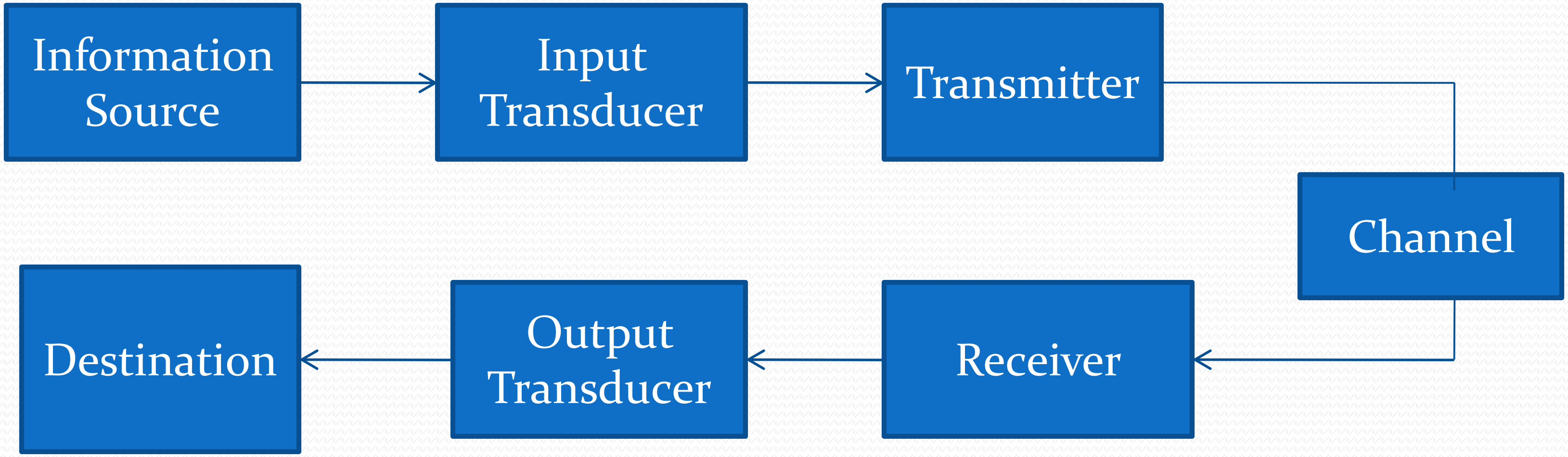
Introduction

- Communication is the transfer of information from one place to another.
- This should be done - as efficiently as possible - with as much fidelity/reliability as possible - as securely as possible
- Communication System: Components/subsystems act together to accomplish information transfer/exchange.
- Block diagram of a typical Communication system



Input Transducer: The message produced by a source must be converted by a transducer to a form suitable for the particular type of communication system.

Example: In electrical communications, speech waves are **converted** by a microphone to voltage variation.

Transmitter: The transmitter processes the input signal to produce a signal suits to the characteristics of the transmission channel.

Signal **processing** for transmission almost always involves **modulation** and may also include **coding**. In addition to modulation, other functions performed by the transmitter are **amplification**, **filtering** and coupling the modulated signal to the channel.

Receiver: The receiver's function is to extract the desired signal from the received signal at the channel output and to convert it to a form suitable for the output transducer.

Other functions performed by the receiver: amplification (the received signal may be extremely weak), demodulation and filtering.

Output Transducer: Converts the electric signal at its input into the form desired by the system user.

Example: Loudspeaker, personal computer (PC), tape recorders

Brief Chronology of Communication Systems

1844	Telegraph:
1876	Telephony:
1904	Radio:
1923-1938	Television:
1936	Armstrong’s case of FM radio
1938-1945	World War II Radar and microwave systems
1948-1950	Information Theory and coding. C. E. Shannon
1962	Satellite communications begins with Telstar I.
1962-1966	High Speed digital communication
1972	Motorola develops cellular telephone.

Types of Communication

BASEBAND COMMUNICATION:

- In this method the information after converted into electrical signals is transmitted as it is.
- The term baseband means the band of frequencies of the signals delivered by the source.
- Example: local telephone comm. ,short hand PCM between exchanges, long distance PCM over optical fibres.
- Disadvantages of BASEBAND COMMUNICATION:
- Antenna Size
- Attenuation/Narrow banding
- No multiplexing

CARRIER COMMUNICATION:

- Carrier is a sinusoidal signal of high frequency.
- Carrier Communication is the technique that uses modulation.
- Modulation is the process of translating a low frequency information –bearing signal to a high frequency carrier.
- A process by which some characteristic of a carrier is varied in accordance with a modulating wave (baseband signal).

What is Frequency translation?

- **Frequency translation** is the process of moving a signal from one region in the **frequency** domain to another region in the **frequency**.
- Suppose a signal is band limited to frequency range extending from f_1 to f_2.The process is one in which the original signal is replaced with a new signal with band of frequency from f_1' to f_2'. • This new signal bears the same information as original signal.

Need of Modulation

- Antenna Size/Height
- Narrow banding
- Multiplexing
- Avoids mixing of signals
- Increases the range of communication
- Improves quality of reception
- **1. Reduction in the height of antenna**
- For the transmission of radio signals, the antenna height must be multiple of $\lambda/4$,where λ is the wavelength .
- $\lambda = c/f$ where c : is the velocity of light
- f: is the frequency of the signal to be transmitted
- The minimum antenna height required to transmit a baseband signal of $f = 3$ kHz is calculated as follows : $\lambda/4 = 25$KM.The antenna of this height is practically impossible to install .

Need of Modulation……….

- Now, let us consider a modulated signal at f = 1 MHz . The minimum antenna height is calculated as $\lambda/4$ = 75 meter.
- This antenna can be easily installed practically . Thus, modulation reduces the height of the antenna .
- **Narrow banding**: Suppose the practicability of antenna is not a problem.When we want to broadcast a baseband signal having the frequency range from 50Hz to 10kHz directly then the ratio of highest to lowest wavelength is (10kHz / 50Hz)= 200.
- If an antenna is designed for 50Hz ,it will be too long for 10kHz and vice versa. A wide band antenna is required for band edge ratio of 200 is practically impossible.
- Lets us assume the audio signal is translated to radio range frequency of 1MHz then the ratio of lowest to highest frequency will be **$[(10^6+50)/(10^6+10^4)]$**= (1/1.01) approximately unity.
- The same antenna can be used for the frequency range from 50Hz to 10kHz.
- Thus frequency translation converts wideband signal to narrowband signal
- **2. Multiplexing :**
- Multiplexing is a process in which two or more signals can be transmitted over the same communication channel simultaneously .
- This is possible only with modulation.
- The multiplexing allows the same channel to be used by many signals .

Need of Modulation……….

- Hence, many TV channels can use the same frequency range, without getting mixed with each other or different frequency signals can be transmitted at the same time .
- **3. Avoids mixing of signals**
- If the baseband sound signals are transmitted without using the modulation by more than one transmitter, then all the signals will be in the same frequency range i.e. 0 to 20 kHz . Therefore, all the signals get mixed together and a receiver can not separate them from each other .
- Hence, if each baseband sound signal is used to modulate a different carrier then they will occupy different slots in the frequency domain (different channels). Thus, modulation avoids mixing of signals .
- **4. Increase the Range of Communication**
- The frequency of baseband signal is low, and the low frequency signals can not travel long distance when they are transmitted . They get heavily attenuated .
- The attenuation reduces with increase in frequency of the transmitted signal, and they travel longer distance .
- The modulation process increases the frequency of the signal to be transmitted . Therefore, it increases the range of communication.
- **5. Improves Quality of Reception**
- With frequency modulation (FM) and the digital communication techniques such as PCM, the effect of noise is reduced to a great extent . This improves quality of reception .

A method of frequency translation

- A signal may be translated to a new spectral range by multipling the signal with an auxiliary sinusoidal signal.
- Let us the signal and auxiliary sinusoidal signal is represented by $V_m(t)$ and $V_c(t)$ respectively .
- $V_m(t) = A_m \cos(\omega_m t) = A_m \cos(2\pi f_m t)$

$$= (A_{m/}2)(e^{+j\omega_m t} + e^{-j\omega_m t}) = (A_{m/}2)(e^{+j2\pi f_m t} + e^{-j2\pi f_m t})$$

Where A_m is the constant amplitude and $f_m = \omega_{m/}2\pi$ is the frequency.The two sided spectral amplitude pattern of this signal is shown in figure (a)

- $V_c(t) = A_c \cos(\omega_c t) = A_c \cos(2\pi f_c t)$

$$= (A_{c/}2)(e^{+j\omega_c t} + e^{-j\omega_c t}) = (A_{c/}2)(e^{+j2\pi f_c t} + e^{-j2\pi f_c t})$$

Where A_c is the constant amplitude and $f_c = \omega_{c/}2\pi$ is the frequency.

- The multiplication of $V_m(t)$ and auxiliary sinusoidal signal $V_c(t)$ is given by

- $V_m(t).V_c(t) = (A_m A_c/2)[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$
- $= (A_m A_c/4)(e^{+j(\omega_c + \omega_m)t} + e^{-j(\omega_c + \omega_m)t} + e^{+j(\omega_c - \omega_m)t} + e^{-j(\omega_c - \omega_m)t}$

Frequency domain Spectrum

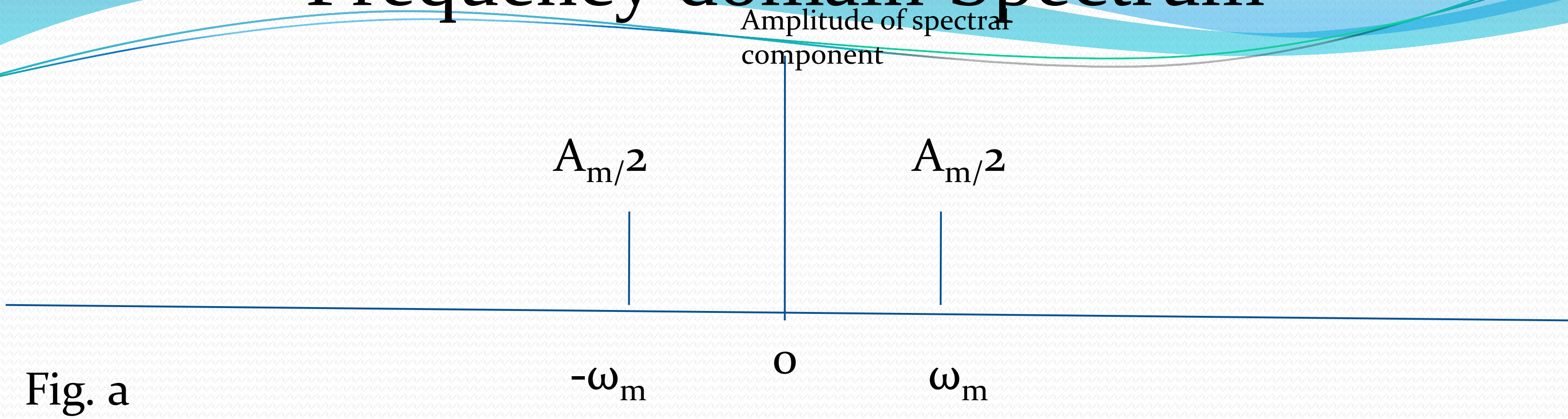


Fig. a

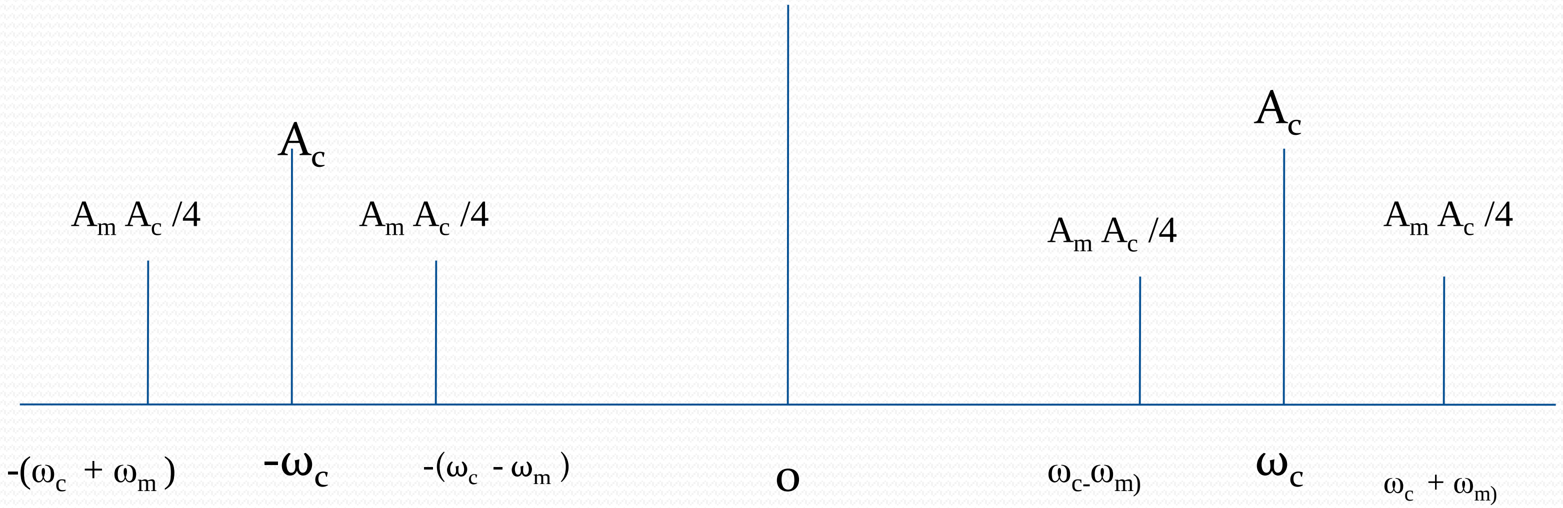


Fig. b

The new spectral amplitude pattern of this signal is shown in figure (b)

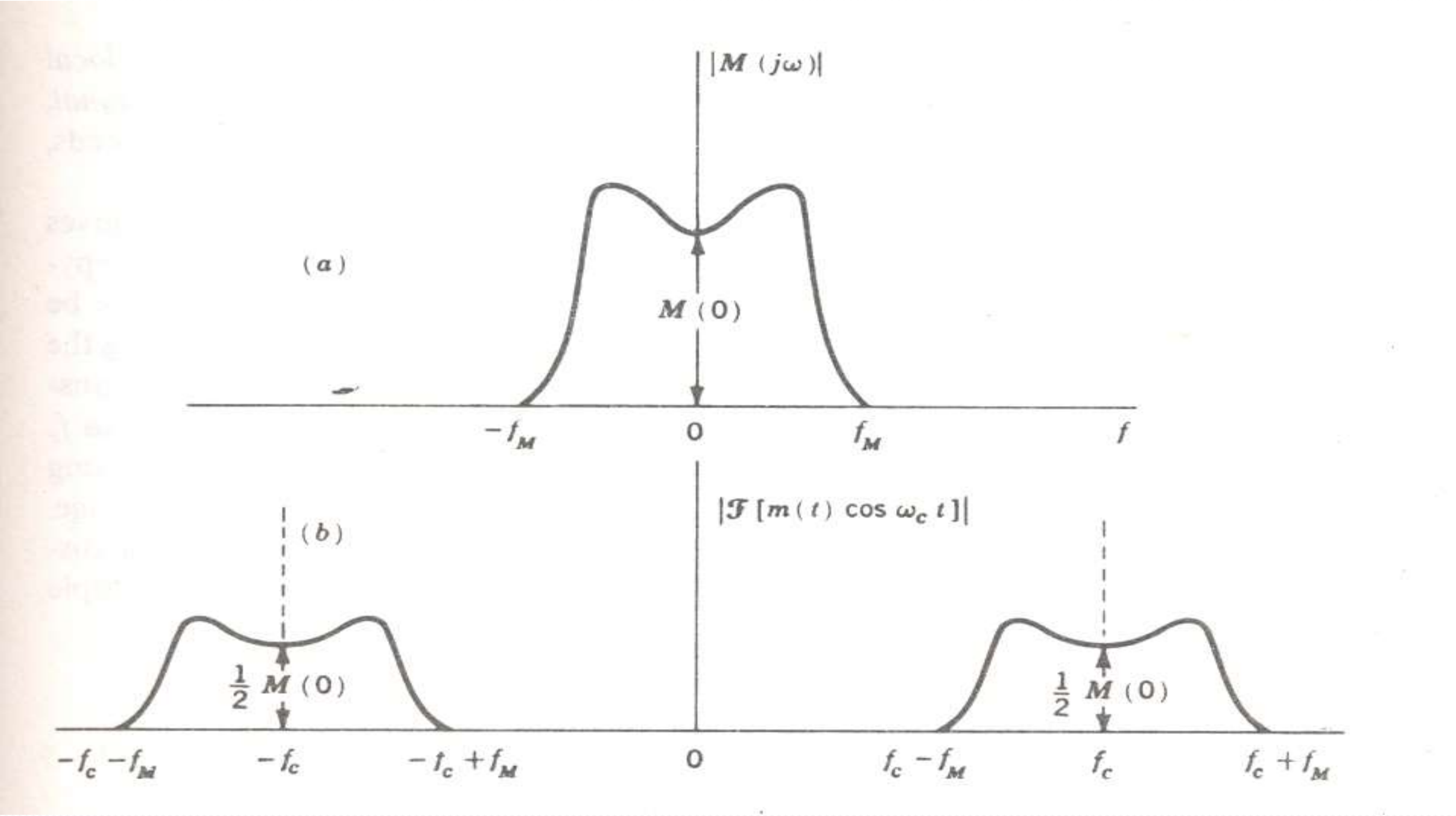
Observed that original spectral lines have translated , in both side.

There are four spectral components resulting in two sinusoidal waveform , one of the frequency ($f_c + f_m$) and ($f_c - f_m$).

The product signal has four spectral components each of amplitude ($A_m A_c /4$).

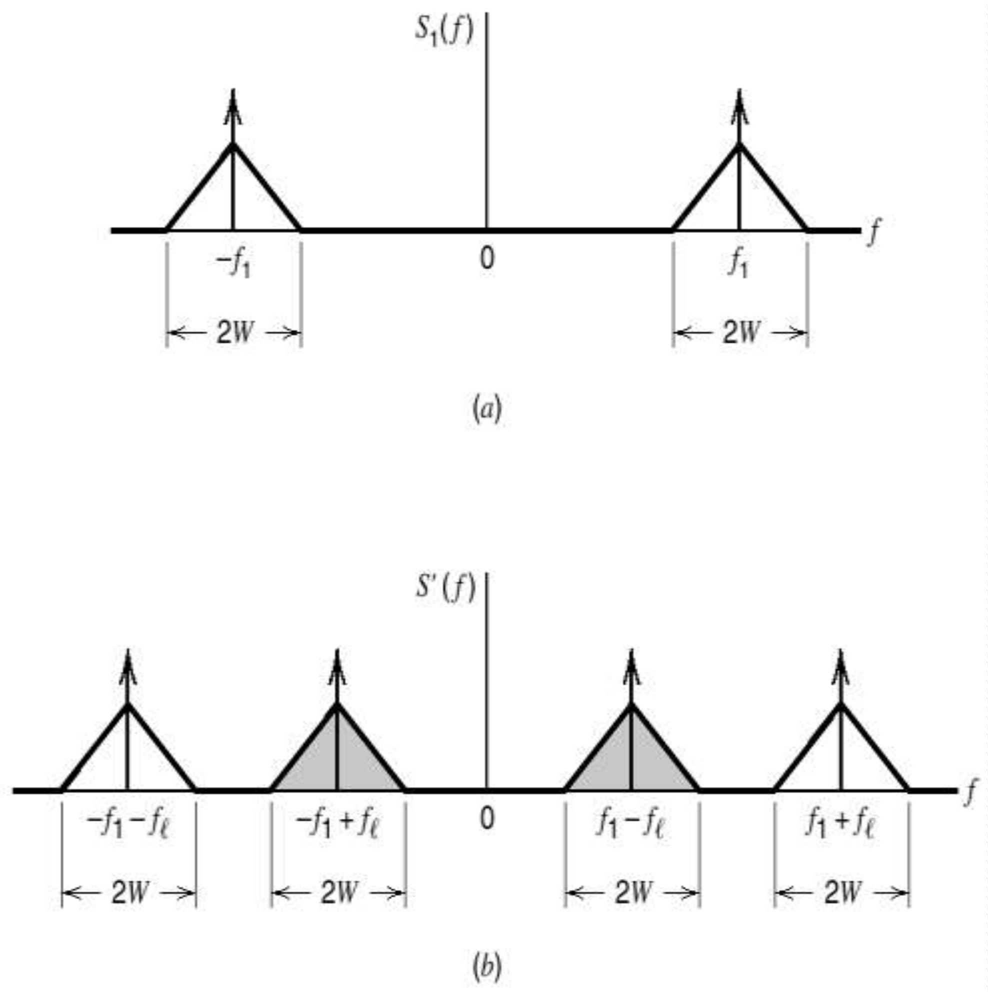
- DSB-SC

- F.T[m(t)]=M(jω)
- F.T[m(t) cos ω_c t]= (1/2)M[(jω+jω_c)t +(jω-jω_c)t]



Frequency Translation

- The process is named upconversion, if $f_1 + f_\ell$
- the wanted signal, and $f_1 - f_\ell$ is the unwanted image signal.
- The process is named downconversion, if $f_1 - f_\ell$ is the wanted signal, and $f_1 - f_\ell$ is the unwanted image signal.



Types of Carrier Communication

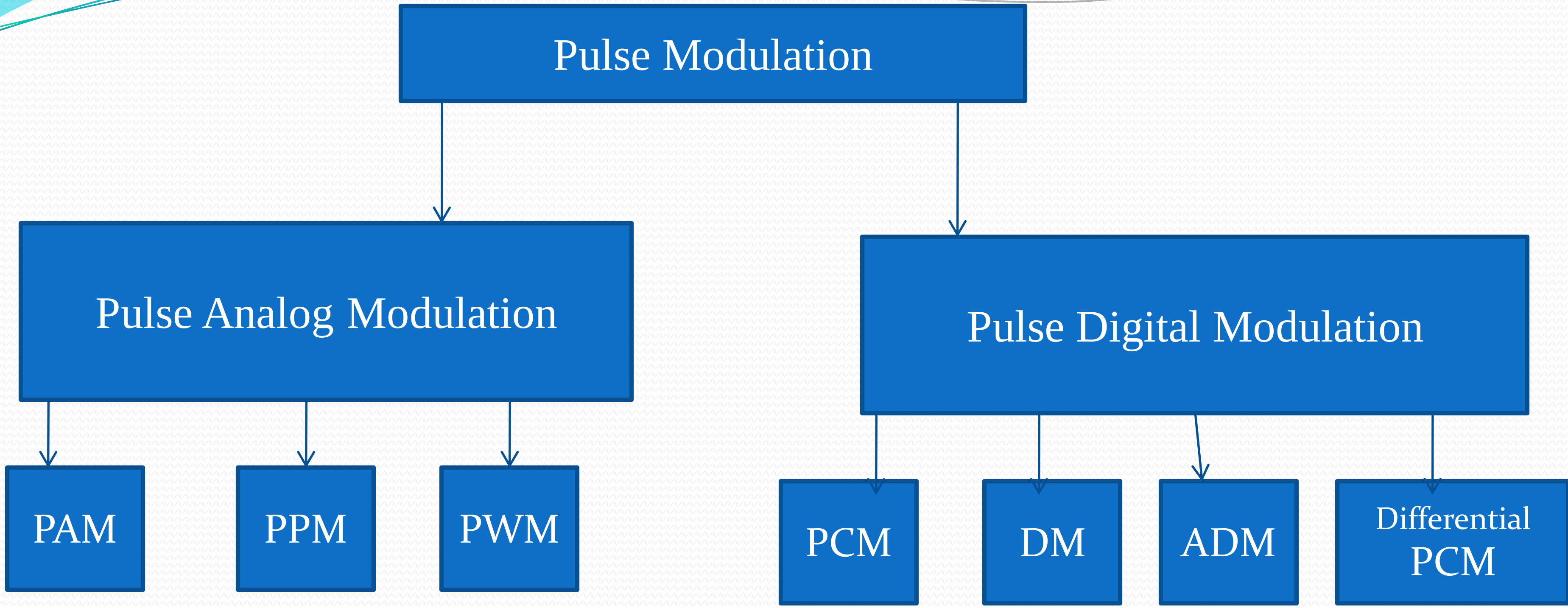
1.AMPLITUDE MODULATION:

- A modulation process in which amplitude of the carrier wave is varied in accordance with the instantaneous value of the modulating signal is known as
- amplitude modulation.
- Types of amplitude modulation **:** DSB-FC , DSB-SC , SSB-FC, SSB-SC,ISB and VSB
- Application: Radio broadcasting, TV pictures (video), facsimile transmission Frequency range for AM - 535 kHz – 1600 kHz
- Bandwidth - 10 kHz

2.ANGLE MODULATION:

- A modulation process in which the total phase angle of the carrier wave is varied in accordance with the instantaneous value of the modulating signal is known as amplitude modulation. The total phase angle can be varied either by frequency and phase modulation.
- Types of angle modulation :
- Frequency modulation : A modulation process in which the frequency of the carrier wave is varied in accordance with the instantaneous value of the modulating signal is known as amplitude modulation.
- Phase modulation : A modulation process in which the phase of the carrier wave is varied in accordance with the instantaneous value of the modulating signal is known as amplitude modulation.

3. PULSE MODULATION:



Electromagnetic Spectrum

S.NO.	Frequency Range	Band Designation	Application
1	3 Hz-30 Hz	Ultra Low Frequency (ULF)	
2	30 Hz-300 Hz	Extra Low Frequency (ELF)	Under water Communication, Include AC power distribution signals (60Hz) and low telemetry signals.
3	300 Hz-3000 Hz	Voice Frequency(VF)	Telephone/Baseband frequency
4	3 KHz-30 KHz	Very Low Frequency (VLF)	Navigation ,Sonar
5	30 KHz-300 KHz	Low Frequency (LF)	Radio Beacons. Navigational Aids
6	300 KHz-3000 KHz	Medium Frequency (MF)	AM Broadcasting,maritime radio,Coast Guard comm. ,Direction finding
7	3 MHz-30 MHz	High Frequency (HF)	Telephone,telegraph,fasimile,shortwavw international Broadcasting,amature radio,citizen's band,ship-to-coast,ship-to-aircraft communication
8	30 MHz-300 MHz	Very High Frequency (VHF)	Television,FM Broadcast,ATC,police taxi mobile radio,navigation aids
9	300 MHz-3 GHz	Ultra High Frequency (UHF)	Television,satellite comm.,radiosonde,surveillance radar, navigation aids
10	3 GHz-30 GHz	Super High Frequency S(HF)	Airborne radar,microwave links, satellite comm.

Electromagnetic Spectrum

- EM spectrum is shown in Table 1.1

S.NO.	Frequency Range	Band Designation	Application
11	30 GHz-300 GHz	Extreme High Frequency (EHF)	Radar, Experimental
12	300 GHz-300THz	Infrared	Not referred as radio waves. It refers to Electromagnetic radiation generally associated with heat. Used in heat seeking guidance systems, electronic photography , and astronomy.
13	300THz-3PTHz	visible	Includes electromagnetic frequencies that fall within the visible range of humans . Light wave communications is used with optical fiber systems.
14	3 PHz- 30 PHz	Ultraviolet light	Ultraviolet rays, X rays, Gamma Rays and cosmic rays have little application to electronic communication.
15	30 PHz – 300 PHz	X rays	Medical Science
16	0.3 EHz- 3 EHz	Gamma rays	
17	3 EHz – 30 EHz	Cosmic rays	

Microwave Region and Bands

- IEEE Microwave Frequency Bands shown in Table 1.3

S.No.	Designation	Frequency (GHz)
1	HF	0.003-0.030
2	VHF	0.030-0.300
3	UHF	0.300-1.000
4	L Band	1.000-2.000
5	S Band	2.000-4.000
6	C Band	4.000-8.000
7	X Band	8.000-12.000
8	Ku Band	12.000-18.000
9	K Band	18.000-27.000
10	Ka Band	27.000-40.000
11	Millimeter Band	40.000-300.000
12	Submillimiter Band	>300.000

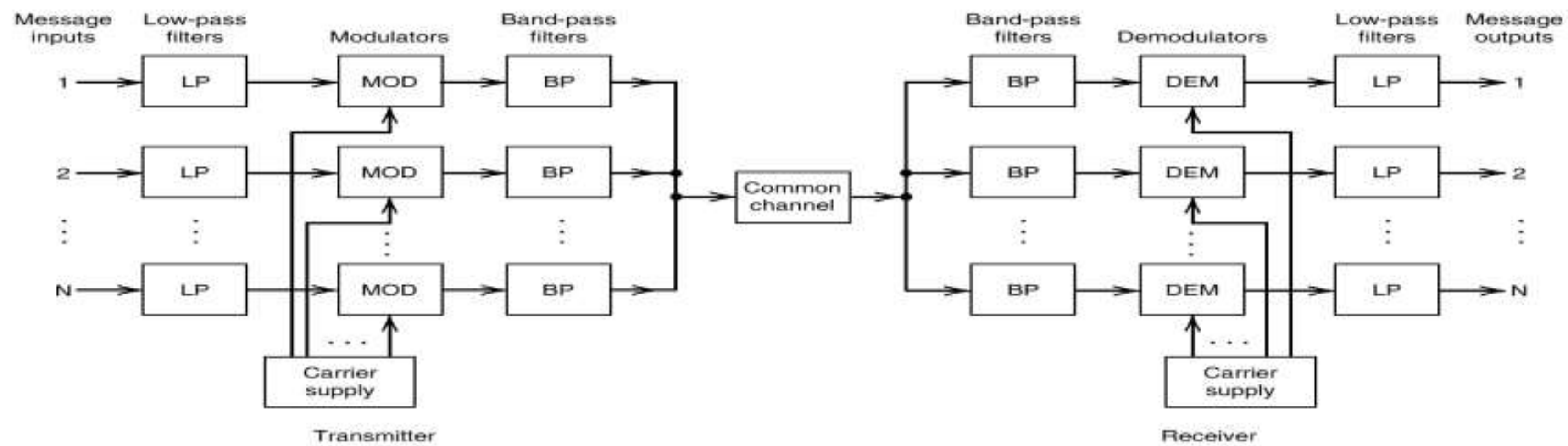
Multiplexer

- Multiplexing is a technique to combine a number of independent signals into a composite signal suitable for transmission over a common channels.
- Types : There are two conventional multiplexing techniques:-
  - Frequency-Division Multiplexing (FDM)
  - Time-Division Multiplexing (TDM)

1.Frequency division multiplexing (FDM) : FDM:FDM is derived from AM techniques in which the signals occupy the same physical 'line' but in different frequency bands. Each signal occupies its own specific band of frequencies all the time, *i.e.* the messages share the channel .

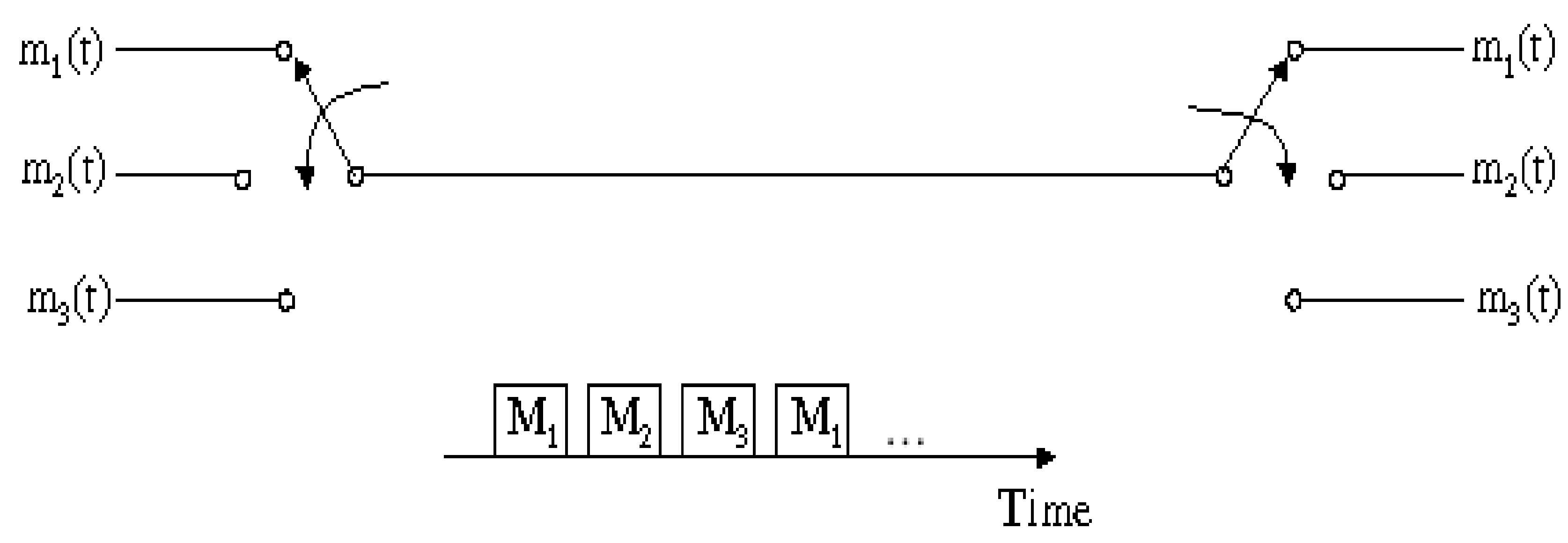
Bandwidth:FDM – messages occupy **narrow** bandwidth – all the time.

The signals are separately modulated and transmitted. Any type of modulation can be used, however SSB (Single Side Band) modulation is most widely used. At the receiver the signals are separated by Band pass filters and then demodulated. The FDM is used in telephony, telemetry and TV communications. The FDM suffers from the problem of "cross talk".

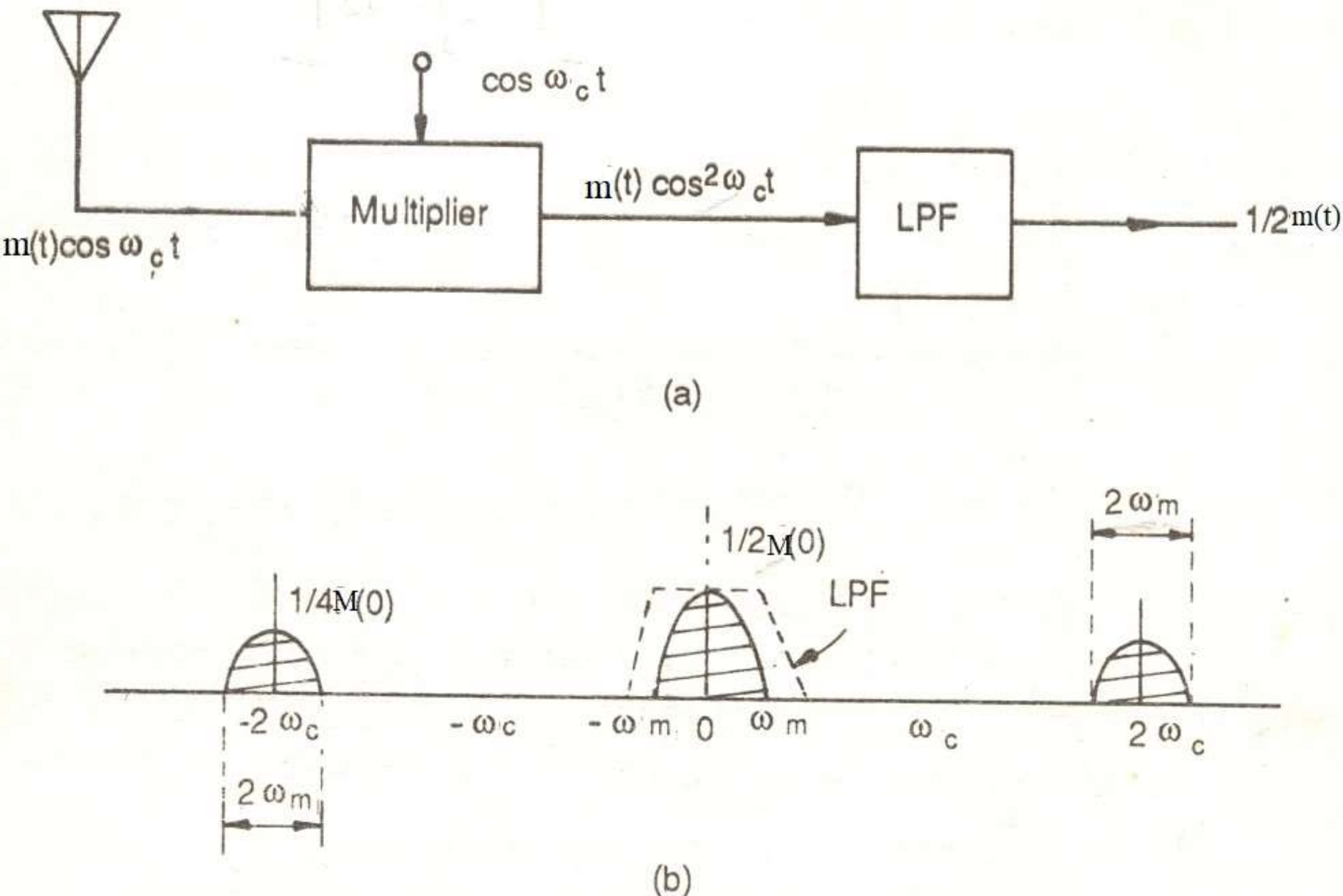


Multiplexer………….

2. Time division multiplexing (TDM) : In this, complete channel width is allotted to one user for a fixed time slot. This technique is suitable for digital signals as these signals are transmitted intermittently and the time between two successive signals can be utilized for other signals. The TDM suffers from inter symbol interference (I.S.I).



Recovery of the baseband signal:Synchronous Detection



Recovery of the baseband signal:Synchronous Detection

- $[m(t) \cos \omega_c t] \cos \omega_c t = m(t) \cos^2(\omega_c t)$
- $= (1/2)\ m(t)(1+ \cos 2\omega_c t) = m(t)/2+(m(t)/2) \cos 2\omega_c t$
- $m(t) \cos^2(\omega_c t) \longleftrightarrow (1/2)M(j\omega)+ (1/4)[M[(j\omega+j2\omega_c)t +M(j\omega-j2\omega_c)t]$

Synchronous or Coherent or Homodyne Detection

- The detector requires a local oscillator. The synchronous detection is effective only when the locally generated carrier is properly synchronous (identical)with the transmitted carrier. Any shift in the phase or frequency of the locally generated carrier distortion occur in the demodulated output signal.
- Demerit: It requires an additional system at the receiver to ensure that locally generated carrier is synchronous with the transmitter carrier, making the receiver complex and costly.
- Effect of phase and frequency Errors in synchronous detection
- Let the modulated signal at receiver is $m(t) \cos \omega_c t$.
- Assuming locally generated carrier with phase or frequency error equal to ϕ and $\Delta\omega$.
- The output of the multiplier will be $m(t) \cos \omega_c t \cdot \cos[(\omega_c + \Delta\omega)t+ \phi]$

Recovery of the baseband signal:Synchronous Detection

The output of the multiplier will be= $(1/2)\ m(t)\{\cos[(\Delta\omega)t+\phi]+\cos[(2\omega_c+\Delta\omega)t+\phi]\}$

- The output at LPF will be $(1/2)\ m(t)\cos[(\Delta\omega)t+\phi]$
- Message signal is multiplied by a slow time varying function.
- IF BOTH ϕ and $\Delta\omega$ are ZERO
- The detected output will be distortion less i.e. $(1/2)\ m(t)$
- IF there is only phase error and $\Delta\omega = 0$
- when ϕ is time independent there is no distortion .the detected output will be distortion less i.e. $(1/2)\ m(t)\cos\phi$
- The output is maximum when $\phi = 0$ and minimum when $\phi=90$ this is called Quadrature Null Effect. Local carrier is phase quadrature with transmitter carrier.
- IF there is only frequency error and $\phi=0$
- when $\Delta\omega$ is time dependent so there is distortion The detected output will be distorted i.e. $(1/2)\ m(t)\cos(\Delta\omega)t$
- IF BOTH ϕ and $\Delta\omega$ are NON-ZERO
- Phase error causes attenuation and frequency error causes distortion in the detected output.

Synchronization Techniques

- 1. Pilot Carrier :A small amount of carrier signal is transmitted along with the modulated signal from the transmitter is called Pilot Carrier. It is separated by an appropriate filter at receiver and is used to phase lock the locally generated carrier.
- The locally generated carrier provides Synchronization.
- 2.Squaring Circuit:

$S_i(t) = A\cos(\omega_m t)\cos(\omega_c t)$ → Squaring circuit → Filter centered at $2f_c$ → Divide by 2 → Synchronizing signal

- The received signal is $S_i(t) = A\cos(\omega_m t)\cos(\omega_c t)$ this signal does not have
- Spectral component at frequency ω_c
- The output of squaring circuit is $S^2_i(t) = A^2\cos^2(\omega_m t)\cos^2(\omega_c t)$

$$= (A^2/4)(1+\cos 2\omega_m t)(1+\cos 2\omega_c t)$$

$$S^2_i(t) = (A^2/4)[1+\cos 2\omega_m t + \cos 2\omega_c t + (1/2)\cos 2(\omega_c+\omega_m)t + (1/2)\cos 2(\omega_c-\omega_m)t]$$

The output of Filter centered at $2f_c$ is $(A^2/4)\cos 2\omega_c t$ this O/P is applied to a circuit which divides the frequency by a factor of 2.(Bistable multivibrator).

The output of the divider is used to demodulate the incoming signal to recover the baseband signal.

AMPLITUDE MODULATION

The process of varying the amplitude of the carrier signal according to the instantaneous amplitude of the modulating signal is called AMPLITUDE MODULATION.

AM BROADCAST BANDS

- Long wave 200-400 kHz
- Medium wave 540-1650 kHz
- Short-wave 3.2-26.1 MHZ

MATHEMATICAL REPRESENTATION OF AM WAVE

- Carrier Signal $c(t)= E_c \sin(\omega_c t)$

Modulating Signal $m(t)=E_m \sin(\omega_m t)$

Modulated Signal $V(t)=E_c [1+ k_a m(t)] \sin(\omega_c t)$

$$V(t)= E_c [1+ k_a E_m \sin(\omega_m t)] \sin(\omega_c t)$$

$V(t)=E_c [1+ m \sin(\omega_m t)] \sin(\omega_c t)$ Where $k_a E_m = m$(Modulation Index)

Modulation index depends upon the ratio of E_m and E_c , $m = E_m / E_c$

Modulation index is a number lying between 0 & 1 and is often expressed as percentage and called **percentage modulation**

$$V(t)=E_c \sin(\omega_c t) + m E_c \sin(\omega_m t) \sin(\omega_c t)$$

$$V(t) = E_c \sin \omega_c t + m E_c /2 \cos(\omega_c - \omega_m) t$$

$$- m E_c/ 2 \cos(\omega_c + \omega_m) t \text{ -------- } (1)$$

- Therefore the AM wave consists of three components:

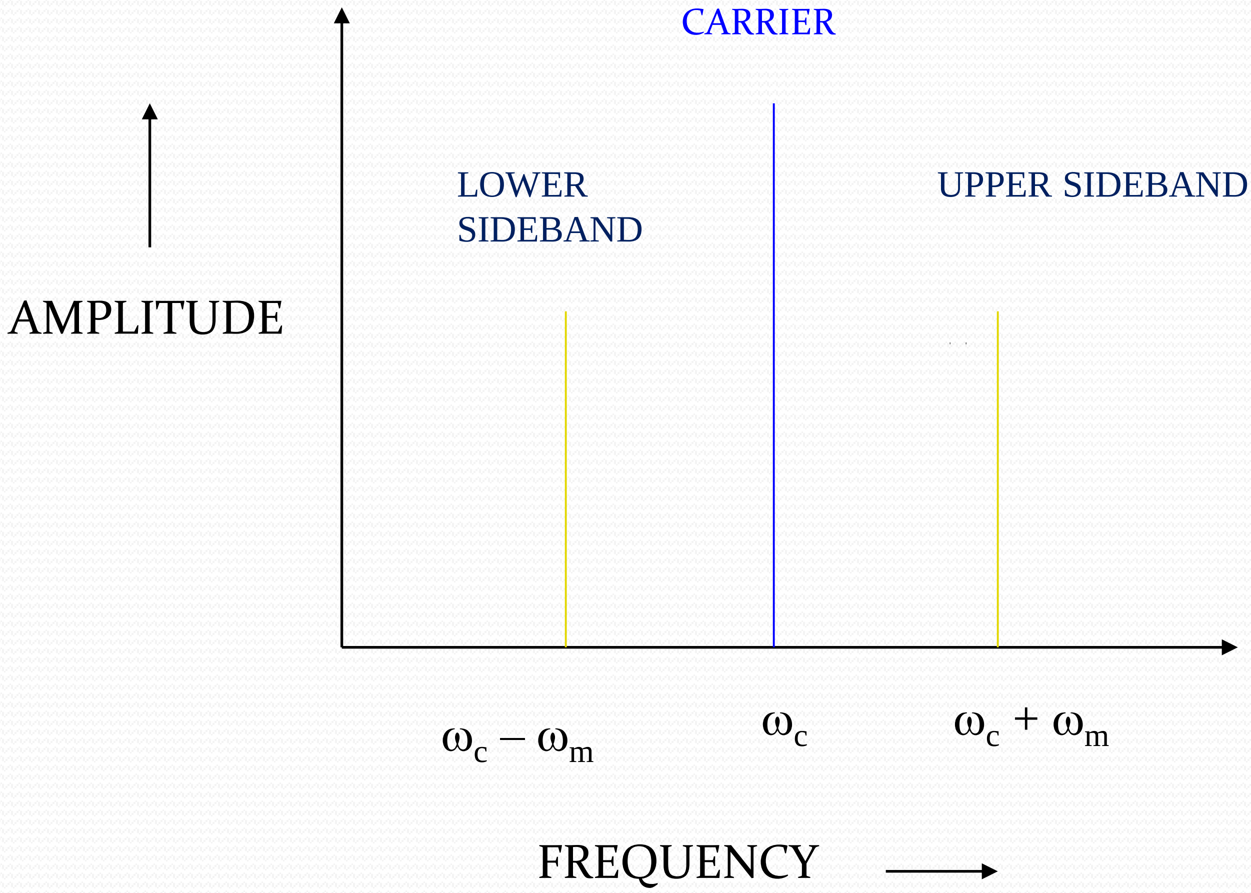
1. CARRIER ---- ω_c
2. UPPER SIDEBAND (USB) ---- $(\omega_c + \omega_m)$
3. LOWER SIDEBAND (LSB) ---- $(\omega_c - \omega_m)$

BANDWIDTH = $2 \omega_m$

MATHEMATICAL REPRESENTATION OF AM WAVE

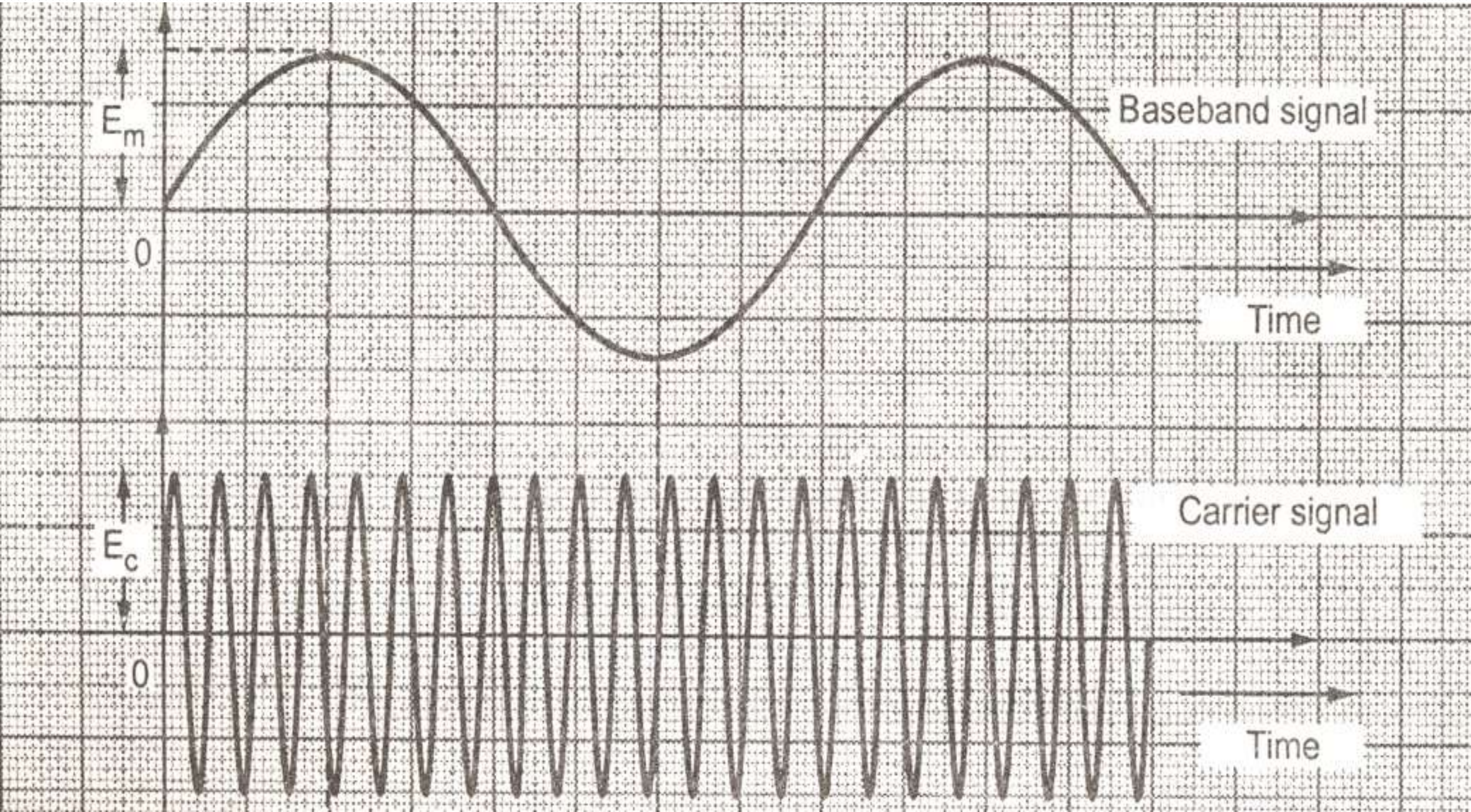
- BW required for amplitude modulation is twice the frequency of the modulating signal
- In the case of modulation by several sine waves simultaneously, **as in broadcasting service** , bandwidth required is twice the highest modulating frequency

FREQUENCY COMPONENTS OF AM SIGNAL



Amplitude Modulation(Time Domain)

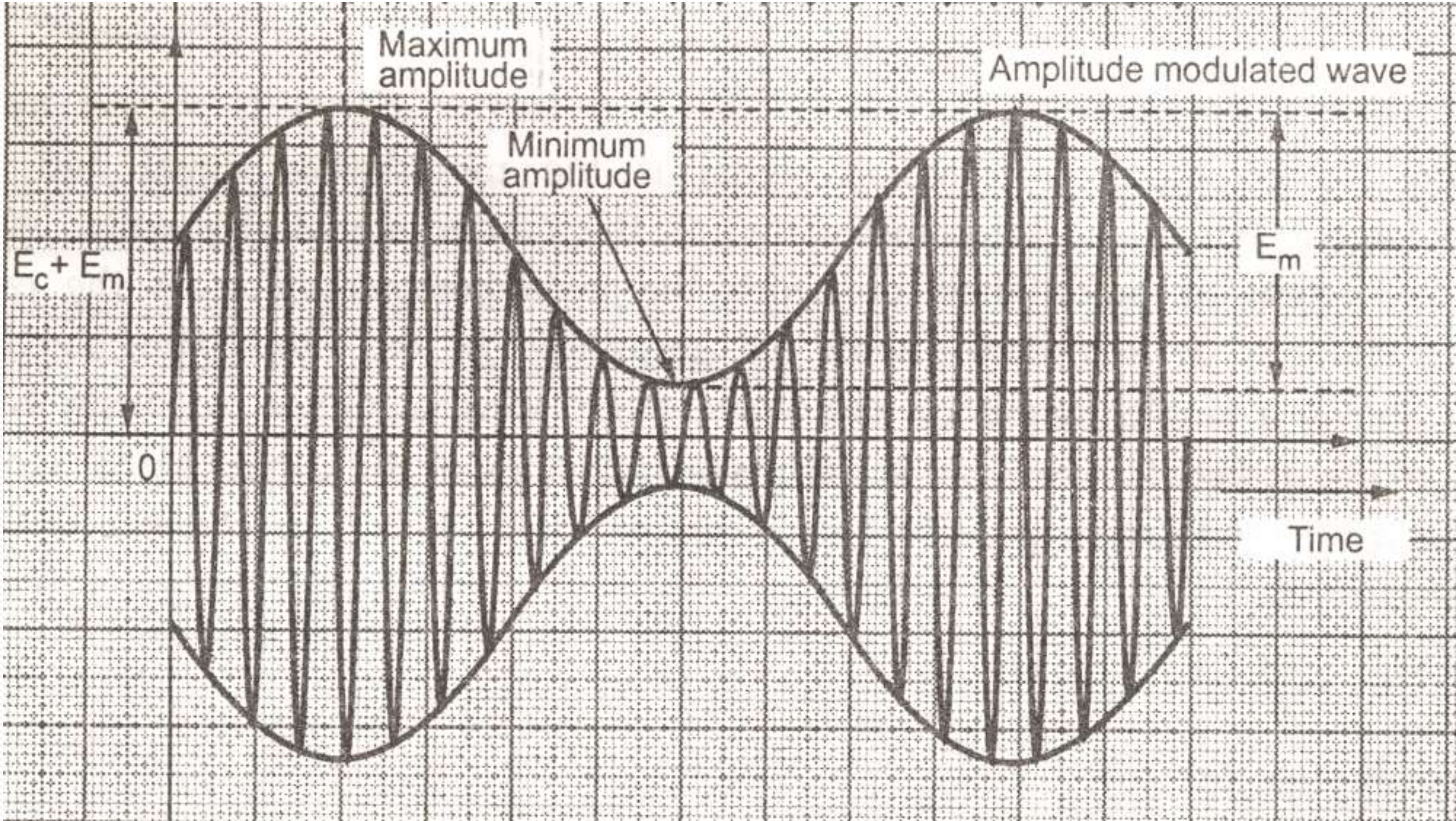
- Modulating Signal Carrier Signal
- $m(t)=E_m \sin(\omega_m t)$ $c(t)= E_c \sin(\omega_c t)$



Amplitude Modulation(Time Domain)

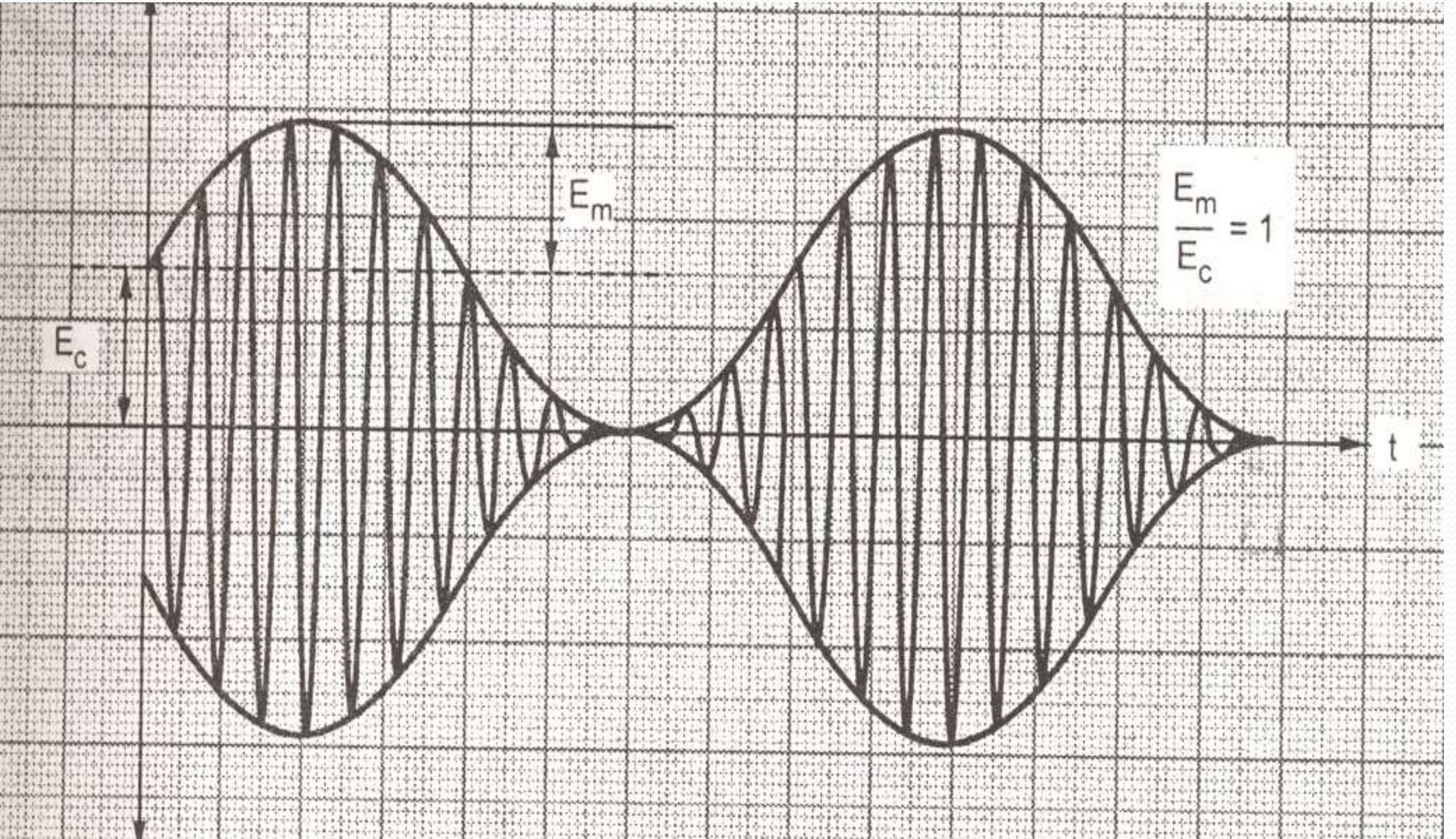
- Modulated Signal $V(t)=E_c\,[1+k_a m(t)]\sin(\omega_c t)$

$1 + k_a\, m(t) \geq 0$, which is ensured by $|k_a\, m(t)| \leqq 1$.The case of $|k_a\, m(t)| < 1$ is called under modulation.



Maximum Allowable Modulation
Critical Modulation

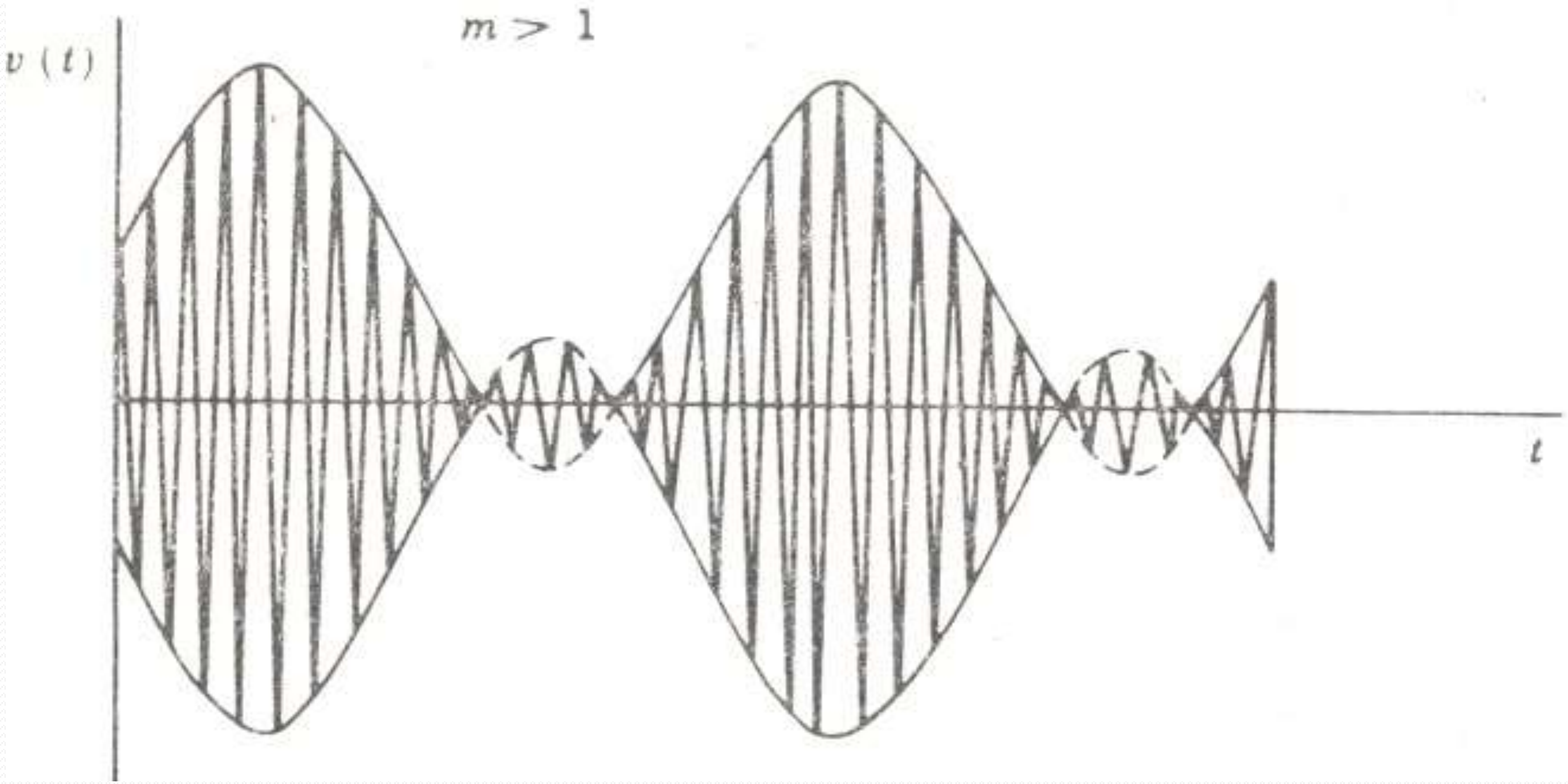
- Modulated Signal $V(t)=E_c\,[1+k_a m(t)]\sin(\omega_c t)$
- The case of $|k_a\, m(t)| = 1$ is called Critical modulation



Over modulation

$1 + k_a\, m(t) \geq 0$, which is ensured by $|k_a\, m(t)| \leqq 1$.
The case of $|k_a\, m(t)| > 1$ is called over modulation.

- It may be seen that distortion will occur if E_m is greater than E_c



Measurement of modulation index

When a carrier is amplitude modulated , the instantaneous modulating voltage variations are superimposed on the carrier amplitude .

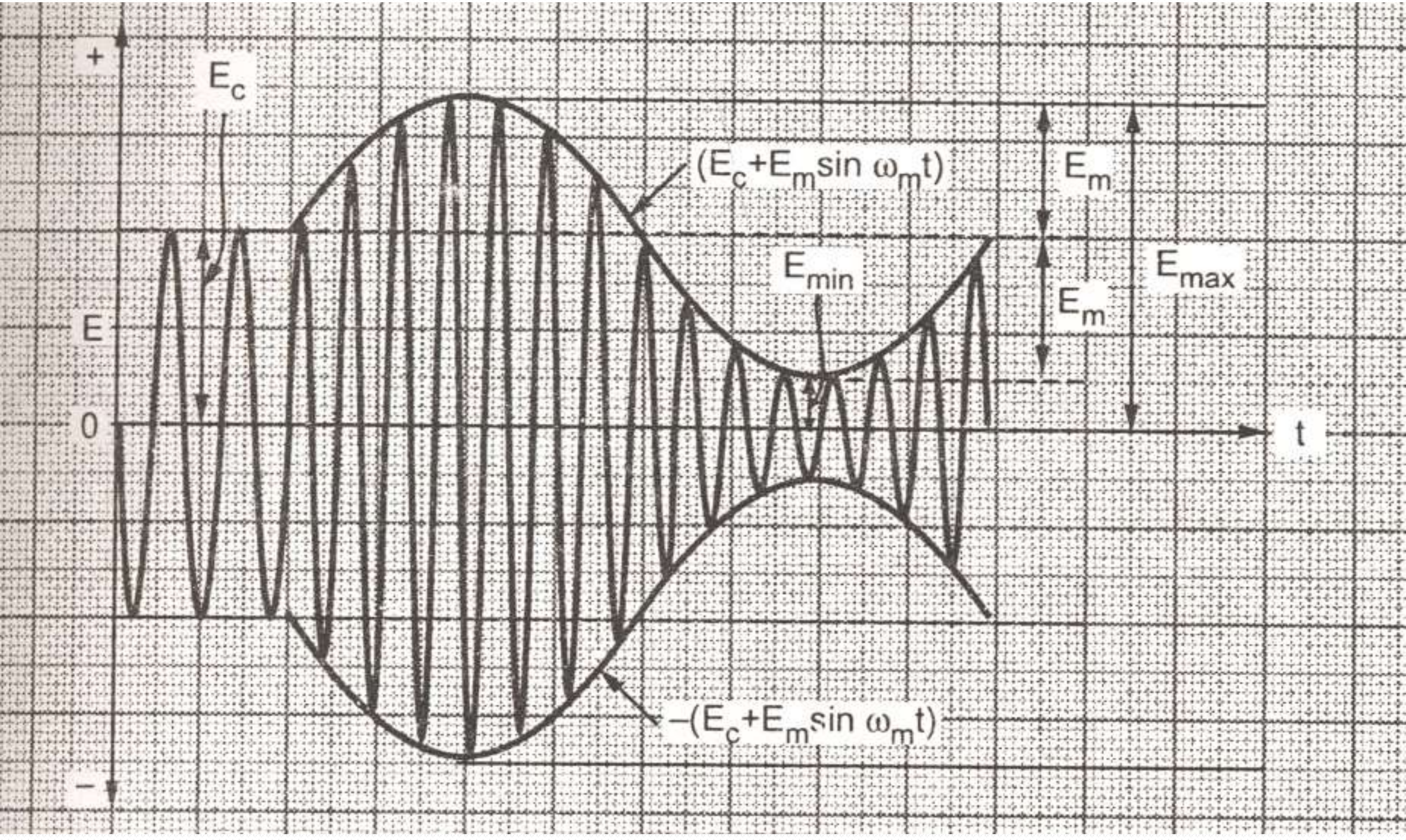
For amplitude **modulation**, the **modulation index** is defined as the measure of extent of amplitude variation about an un-**modulated** carrier.

Modulation index is the factor by which carrier signal varies (amplitude or frequency or phase)with respect to message signals

1. By measurement of peak to peak amplitude

2. By measurement of trapezoidal patterns

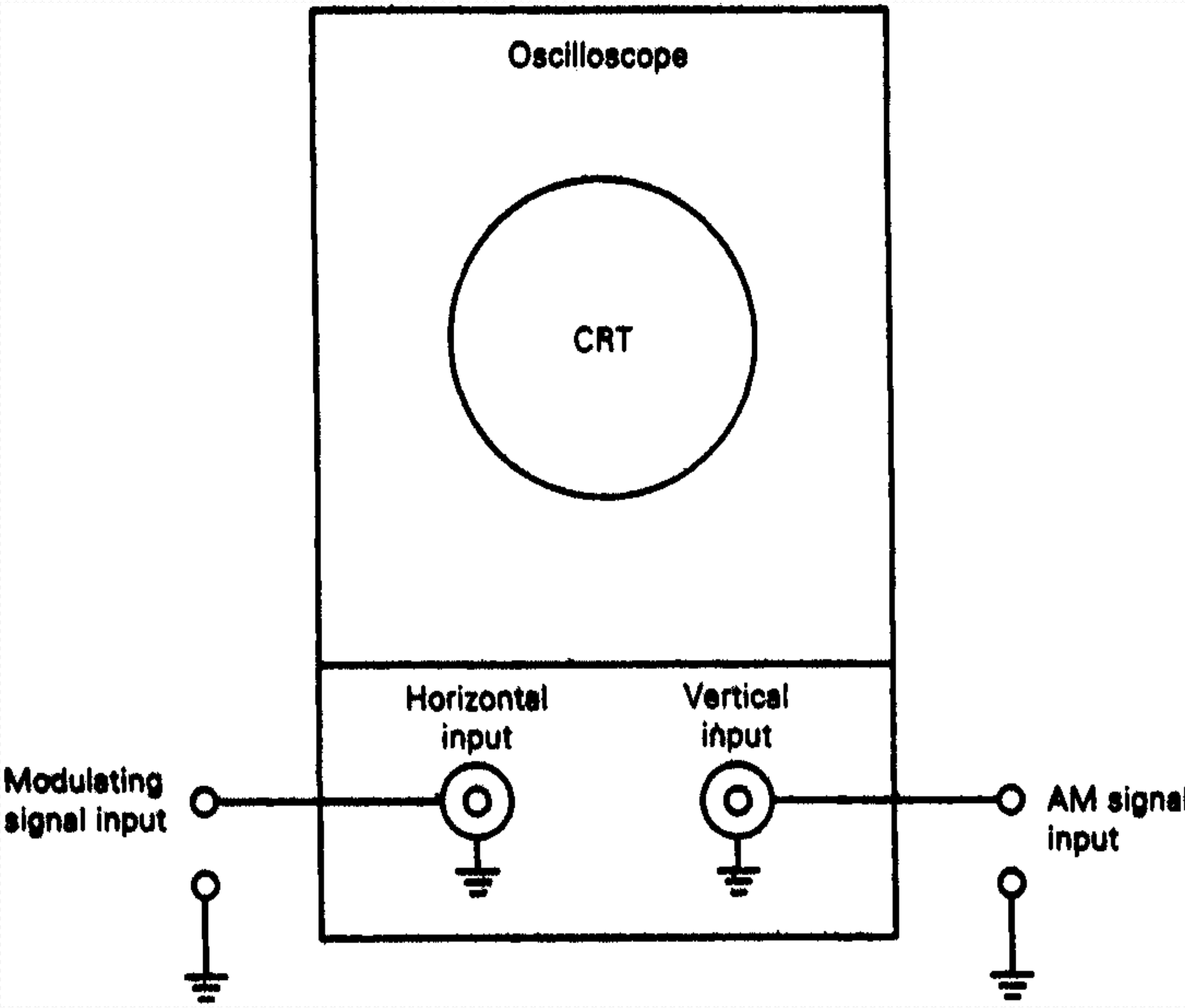
1.By measurement of peak to peak amplitude



1.By measurement of peak to peak amplitude

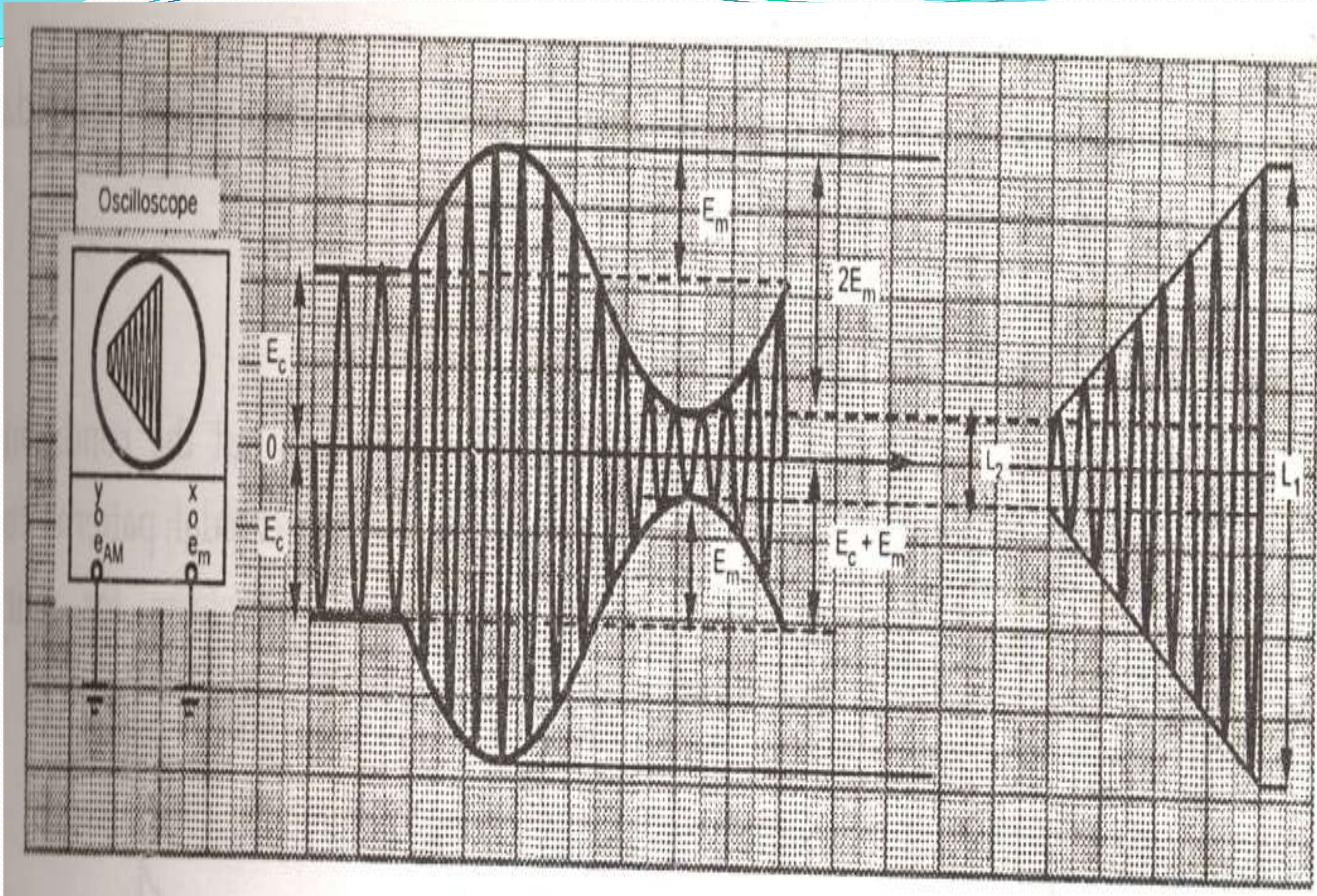
- $m = E_m/E_c$
- $E_m=(E_{max}- E_{min})/2$
- $E_c=E_m+E_{min}$
- $E_c= (E_{max}- E_{min})/2+E_{min}$
- $E_c =(E_{max}+E_{min})/2$
- Therefore
- $m= (E_{max}- E_{min})/(E_{max}+E_{min})$

2.By measurement of trapezoidal patterns

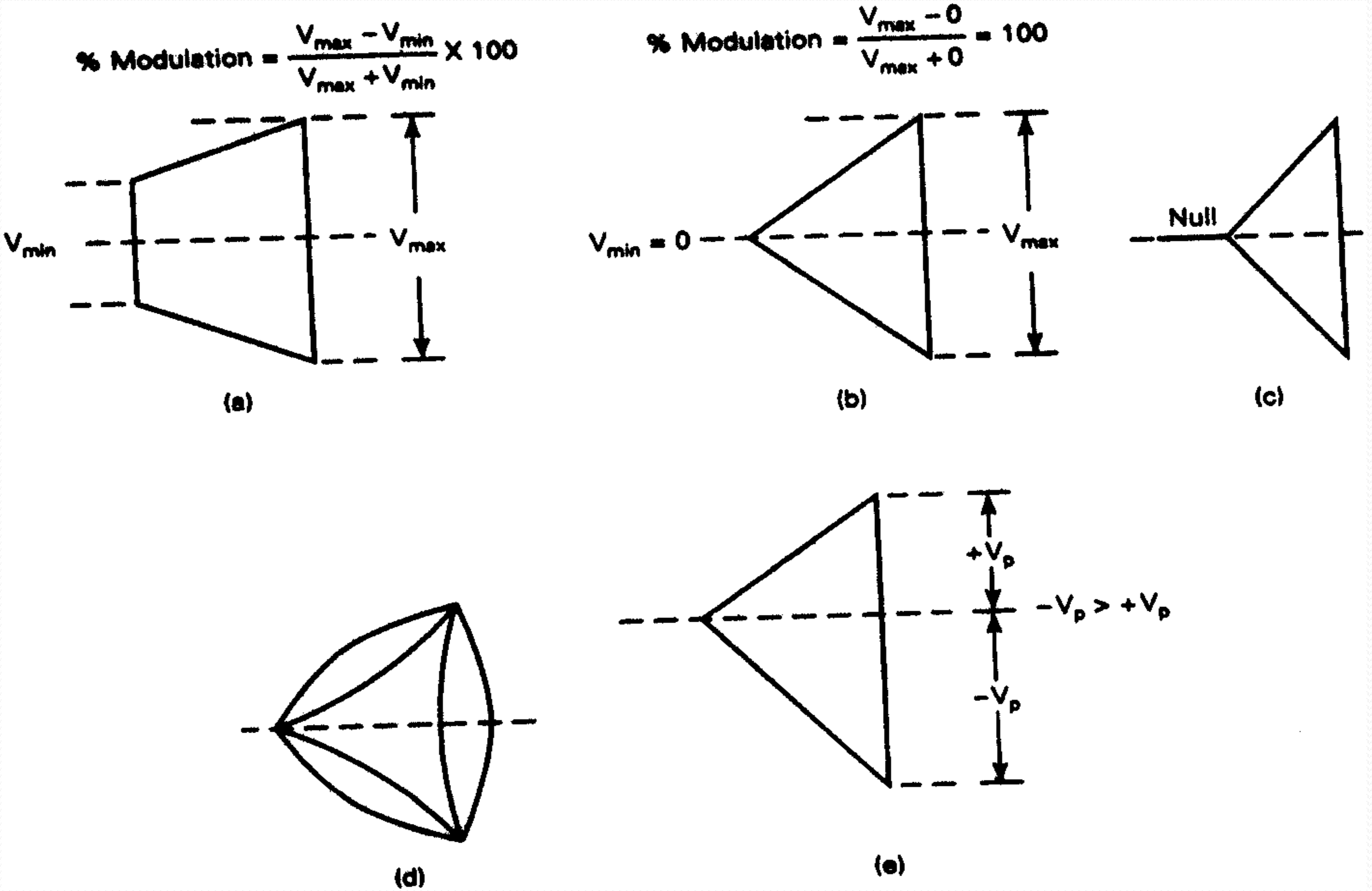


Test set up for generating trapezoidal patterns

2.By measurement of trapezoidal patterns…………



2.By measurement of trapezoidal patterns………….



Power relations in the AM Wave (Single tone)

- Carrier component of the modulated wave has the same amplitude as the unmodulated carrier .
- Thus the modulated wave contains extra energy in the two sidebands
- Therefore , the AM signal has more power than the carrier had before the modulation took place
- since the amplitude of the sidebands varies with modulation index Em /Ec ,total power in the modulated wave also depends on modulation index .
- $V(t) = E_c \sin \omega_c t + m E_c /2 \cos (\omega_c - \omega_m) t - m E_c/ 2 \cos (\omega_c + \omega_m) t$
- Total power in the modulated wave is
- $P_t = V^2_c / R + V^2_{LSB} / R + V^2_{USB} / R$
- Now $V^2_c / R = P_c$ = Unmodulated Carrier Power
- Similarly $P_{LSB} = P_{USB} = V^2_{SB} / R = Pc (m^2_a / 4)$
- Therefore
- $P_t = P_c (1 + m^2_a / 2)$ ---------- (2)
- This equation is useful for calculating modulation index if total power and carrier power are known. It is interesting to note from eq (2) that maximum power in am wave is
- $P_t = 1.125 P_c$ FOR $m = 0.5$.
- $P_t = 1.5 P_c$ FOR $m = 1$.
- $P_t = 3 P_c$ FOR $m = 2$.
-

CURRENT CALCULATIONS

- In AM transmitters , normally modulated and Unmodulated currents are easily measurable and we are required to calculate modulation index from them .
- if I_c is unmodulated current and I_t the current with modulation , then

$$P_t = P_c\,(1 + m^2_a / 2)$$

$$(P_t / P_c) = (1 + m^2_a / 2)$$

- $(I^2_t.R / I^2_c .R) = (1 + m^2_a / 2)$
- $(I_t / I_c) = \sqrt{(1 + m^2_a / 2)}$
-
- $I_t = I_c \sqrt{(1 + m^2_a / 2)}$

Power relations in the AM Wave (Multi- tone)

- $V(t) = E_c \sin \omega_c t + m_1 E_c/2 \cos(\omega_c - \omega_{m1})t - m_1 E_c/2 \cos(\omega_c + \omega_{m1})t + m_2 E_c/2 \cos(\omega_c - \omega_{m2})t - m_2 E_c/2 \cos(\omega_c + \omega_{m2})t + \ldots\ldots\ldots\ldots\ldots$

Total average, power = $(P_{SB})_t = P_{SB_1} + P_{SB_2} + \ldots\ldots\ldots$

$$(P_C m^2)_t = \frac{P_C m_1^2}{2} + \frac{P_C m_2^2}{2} + \frac{P_C m_3^2}{2} + \frac{P_C m_4^2}{2}$$

Where, total modulating index,

$$(m^2)_t = m_1^2 + m_2^2 + m_3^2 + m_4^2 + \ldots\ldots$$

or,
$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + m_4^2 + \ldots\ldots}$$

Where m_1, m_2, m_3, m_4, ... are defined for each harmonic frequency.

(*b*) If E_{m_1}, E_{m_2} are the simultaneous modulating voltages the total modulating voltage will be

$$(E_m)_t = \sqrt{Em_1^2 + Em_2^2 + \ldots}$$

$$\frac{(E_m)_t}{E_c} = \sqrt{\frac{Em^2 + Em^2}{E_c} + \ldots..} = \sqrt{\frac{Em_1^2}{E_c^2} + \frac{Em_2^2}{E_c^2} + \ldots\ldots.}$$

Total modulating index,

$$(m)_t = \sqrt{m_1^2 + m_2^2 + \ldots..}$$

LIMITATIONS OF AM

- 1.AM IS NOT BANDWIDTH EFFICIENT
- AM wave has two sidebands spaced at modulating frequency on each side of the carrier
- Thus it occupies a transmission bandwidth BW = $2 f_m$
- This is twice the bandwidth of the modulating signal
- Thus the double sideband nature of AM halves the number of independent stations
- One solution is to have **single sideband systems**
- 2 . AM IS LESS ECONOMICAL
- Because additional power has to be added to the system as modulation index increases
- It can be proved that total power in an AM signal is
- $P_t = P_c \;.\; (1 + m_a^2/2)$
- $= P_c + (m_a^2 / 2) P_c$
- $= P_c + P_m$
- $P_m / P_t = m_a^2 / (m_a^2 + 2) = 1 / 3$ (FOR 100 % MODULATION)
- Therefore the Transmission efficiency $\%\eta = m_a^2 / (m_a^2 + 2)$
- Thus (2/3) rd of transmitted power is used in sending the carrier for m = 1
- % POWER SAVING = $P_c + P_m / P_t = (2+m_a^2)/(2 m_a^2 + 4)$

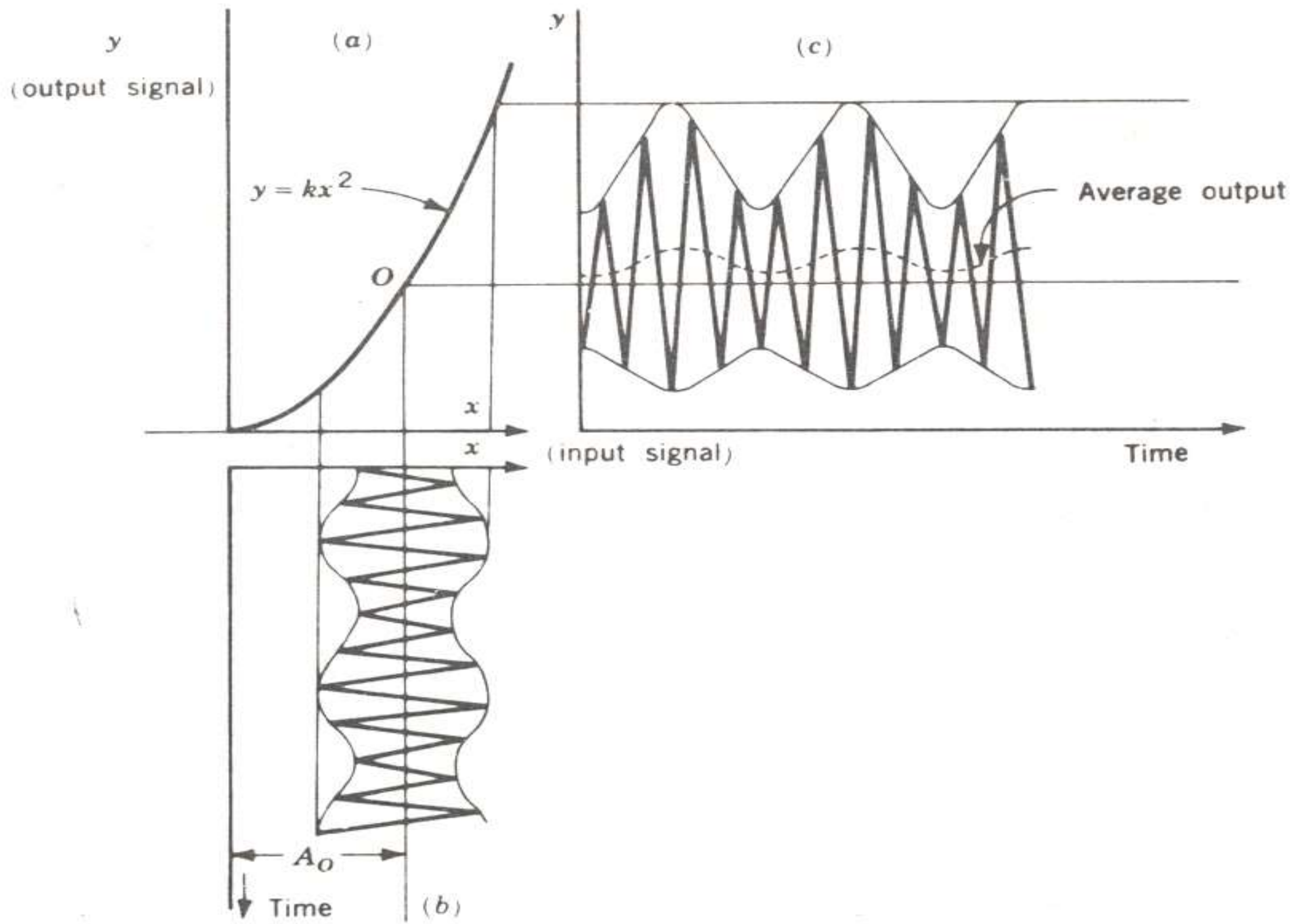
3. AM prone to noise and interference

- Since information is contained in amplitude variations of the carrier , am is inherently prone to interference and noise .
- The AM detector demodulates the noise/ interfering signal alongwith the desired signal
- That is why AM radio tends to suffer from crackles , clicks , buzzes etc
- Other forms of modulation have less sensitivity and are less prone to unwanted interference

Square Law Demodulator/Detector

- An alternative method of recovery of the baseband signal is to pass the AM signal through a non linear device. The non linear device has a square law relationship between input signal x (current or voltage) and output signal y .Thus $y=kx^2$,with k is a constant.
- Because the nonlinearity of the transfer characteristics of the device, the output response is different for positive and for negative excursion of the carrier away from the quiescent operating point O of the device.
- Figure (a) shows the relationship between input signal x and output y of non linear device .
- Figure (b) shows the input signal x given to the non linear device .
- Figure (c) shows the output signal y averaged over many carrier cycles.

Square Law Detector



Square Law Demodulator/Detector

- The output ,when averaged over many carrier cycles but only a very small part of the modulation cycle, has the waveshape of the envelop.
- The applied signal is
- $x=A_o+A_c[1+m(t)] \cos \omega_c t$
- Thus the output of the squaring circuit is
- $y=k\{ A_o+A_c[1+m(t)] \cos \omega_c t \}^2$
- $y=k\{ A^2{}_o+A^2{}_c[1+m(t)]^2 \cos^2 \omega_c t +2 A_oA_c[1+m(t)] \cos \omega_c t \}$
- $y=k\{ A^2{}_o+A^2{}_c[1+m^2(t)+2 m(t)] \cos^2 \omega_c t +2 A_oA_c[1+m(t)] \cos \omega_c t \}$
- $y=k\{ A^2{}_o+A^2{}_c[1+m^2(t)+2 m(t)] (1+\cos 2 \omega_c t)/2+2 A_oA_c[1+m(t)] \cos \omega_c t \}$
- $y=k\{ A^2{}_o+A^2{}_c[1+m^2(t)+2 m(t)] /2+ A^2{}_c[1+m^2(t)+2 m(t)] \cos 2\omega_c t)/2+2 A_oA_c[1+m(t)] \cos \omega_c t \}$
- After dropping DC term as well as spectral components located near
- ω_c and $2\omega_c$. the output signal after the squaring circuit is
- $y=kA^2{}_c[m(t)+m^2(t)/2]$

Square Law Detector

- the output signal contains $m^2(t)$ .Thus the recovered signal is a distorted version of original modulation .The distortion is small , if $m^2(t)/2 << |m(t)|$ or $|m(t)| << 2$
- The two points are noted for the above Square Law demodulator.
- First one is that the demodulation does not depends on nonlinearity being Square Law .Any type of nonlinearity which does not have odd function symmetry with respect to initial operating point will similarly accomplish demodulation.
- The second point is that even when demodulation is not indended,such demodulation may appear incidently when the modulated signal is passed through a system which exhibits some nonlinearity.(amplifier)

Linear Diode /Envelop Detector

- A diode operating in the linear region of its characteristic can extract the modulating signal from the AM wave is called envelop detector.
- The figure shows the circuit for the linear diode detector. The circuit basically consists of a diode and a RC net work.

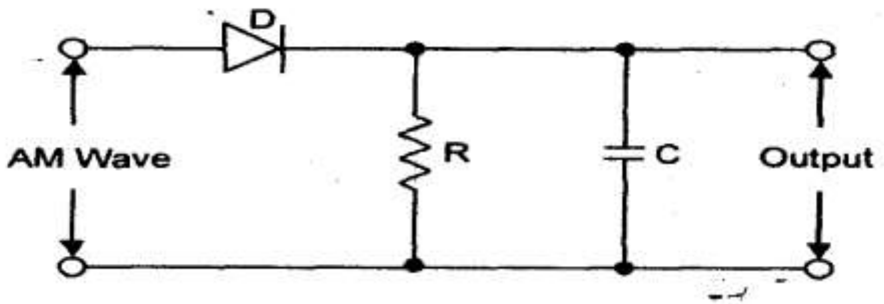


Fig. 36

- Operation. The A.M. wave is applied at the input terminals of the circuit. As the diode is operated in the linear region of its characteristic, during positive cycle of the A.M. wave, the output is proportional to the input signal voltage.
- During the negative cycle of the input the diode does not conduct and output is
- theoretically zero. If the time constant RC is correctly chosen the output will follow exactly the envelope of the A.M. wave, but spikes are introduced by charging and discharging of the capacitor, which can be reduced by taking a large RC constant.
- The detector basically performs two functions

Envelop Detector

- The detector basically performs two functions
- 1. The diode rectifies the A.M. wave, i.e., eliminates the
- negative cycle of the wave. We know that average of both
- the cycles of an A.C. wave is zero. In
- such case if both the cycles of wave
- is fed to the speaker without rectification it will have no impact (due to its zero average value) on
- the
- speaker's diaphragm. This job is done by the diode.
- Now, the positive cycle of the A.M. wave (containing carrier + signal) starts its journey towards speaker.
-

Envelop Detector

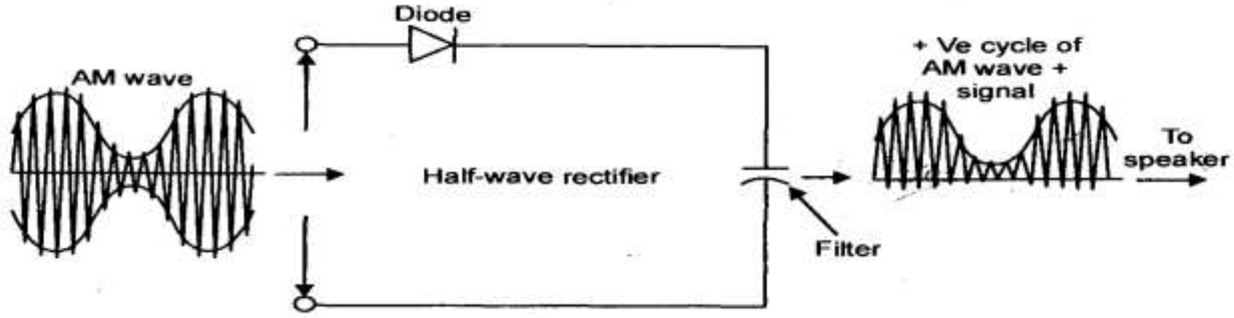


Fig. 37

2.The positive cycle of the A.M. wave is passed through a ca.pacitor filter circuit which suppresses the H.F. carrier and the carrier is grounded.

- The Fig. 38 shows modulated wave, the Fit. (b) shows voltage across diode and Fig. 39 shows output wave form of the detector.

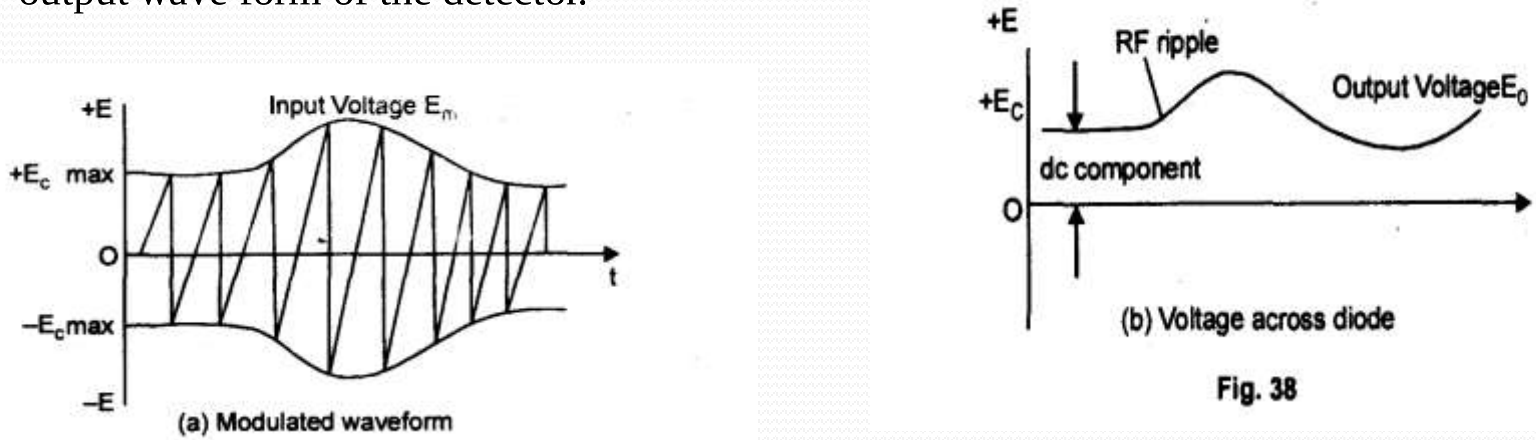


Fig. 38

Envelop Detector

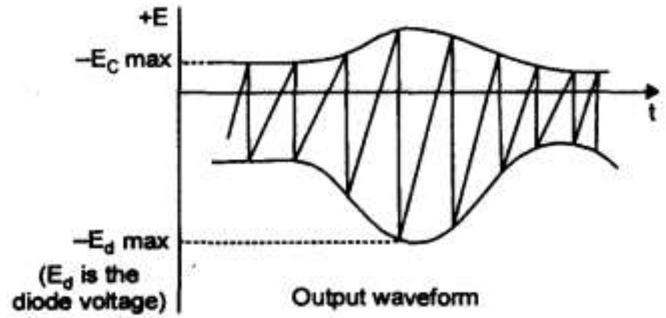


Fig. 39

- (c) This detector is very much used in commercial receivers as it cheap, simple and provides satisfactory performance. The circuit suffers from the disadvantage that the output contains DC component and also R.F. ripples which are unwanted.
- scan0022.jpg
- scan0023.jpg

1.10.5.4 Comparison

S.N.	Parameter	Filter method	Phase shift method	Third method
1.	Method used	Filter is used to remove unwanted sideband.	Phase-shifting techniques is used to remove unwanted sideband.	Similar to phase-shift method, but carrier signal is phase shifted by 90°.
2.	90° phase shift	Not required	Requires complex phase shift network	Phase shift network is simple RC circuit
3.	Possible frequency range of SSB	Not possible to generate SSB at any frequency.	Possible to generate SSB at any frequency.	Possible to generate SSB at any frequency.
4.	Need for up-conversion	Required	Not required	Not required
5.	Complexity	Less	Medium	High
6.	Design aspects	Q of tuned circuit, filter type, it size, weight and upper frequency limit.	Design of 90° phase shifter for entire modulating frequency range. Symmetry of balanced modulators.	Symmetry of balanced modulators.
7.	Bulkyness	Yes	No	No
8.	Switching ability	Not possible with existing circuit. Extra filter and switching network is necessary.	Easily possible	Easily possible. But extra crystal is required.

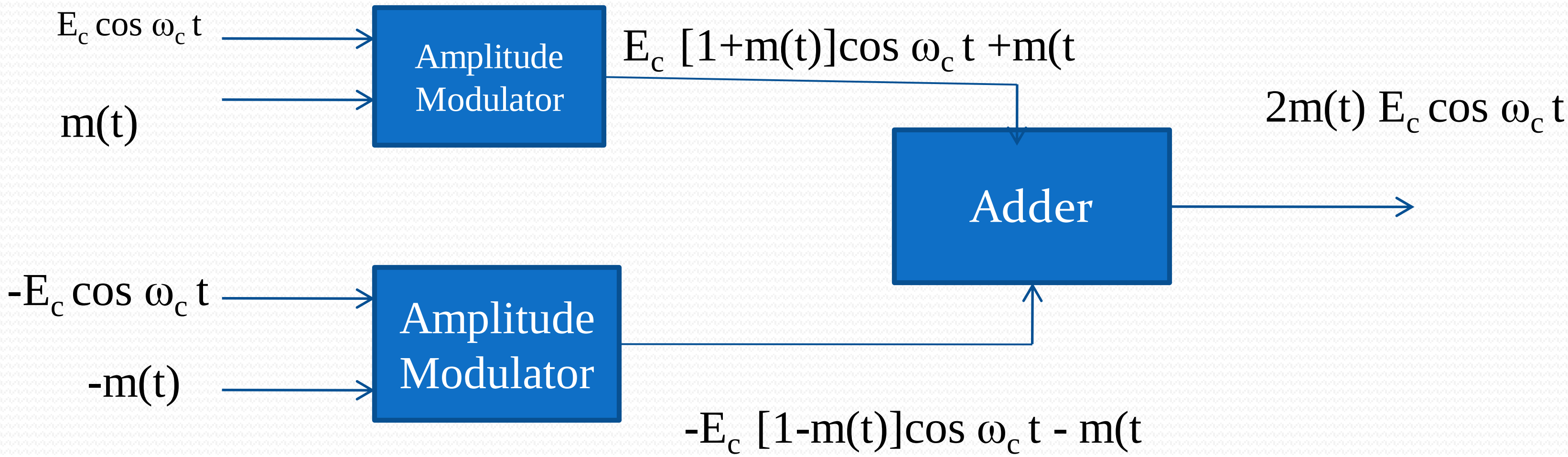
... single sideband suppression methods

techniques.

Sr. No.	Parameter	Standard AM (DSBFC)	SSB	DSBSC	ISB	V
1	Power	High	Less	Medium	Moderate	Less DSBS great SSB
2	Bandwidth	$2 f_m$	f_m	$2 f_m$	$f_{m1} + f_{m2}$	$f_m < B$
3	Carrier supression	No	Yes	Yes	Partially	
4	Receiver complexity	Simple	Complex	Complex	Complex	S
5	Application	Radio communication	Point to point communication preferred for long distance transmission.	Point to point communication	Telegraphy and telephony	Telev broad

Modulators and balanced modulators

The value of $|k_a\, m(t)|$ is sometimes represented by
"percentage" (because it is limited by 1), and is named $(|k_a\, m(t)|\times 100)\%$ modulation.
$f_c >> W$, where W is the message bandwidth.
Violation of this condition will cause **no visualized envelope**.

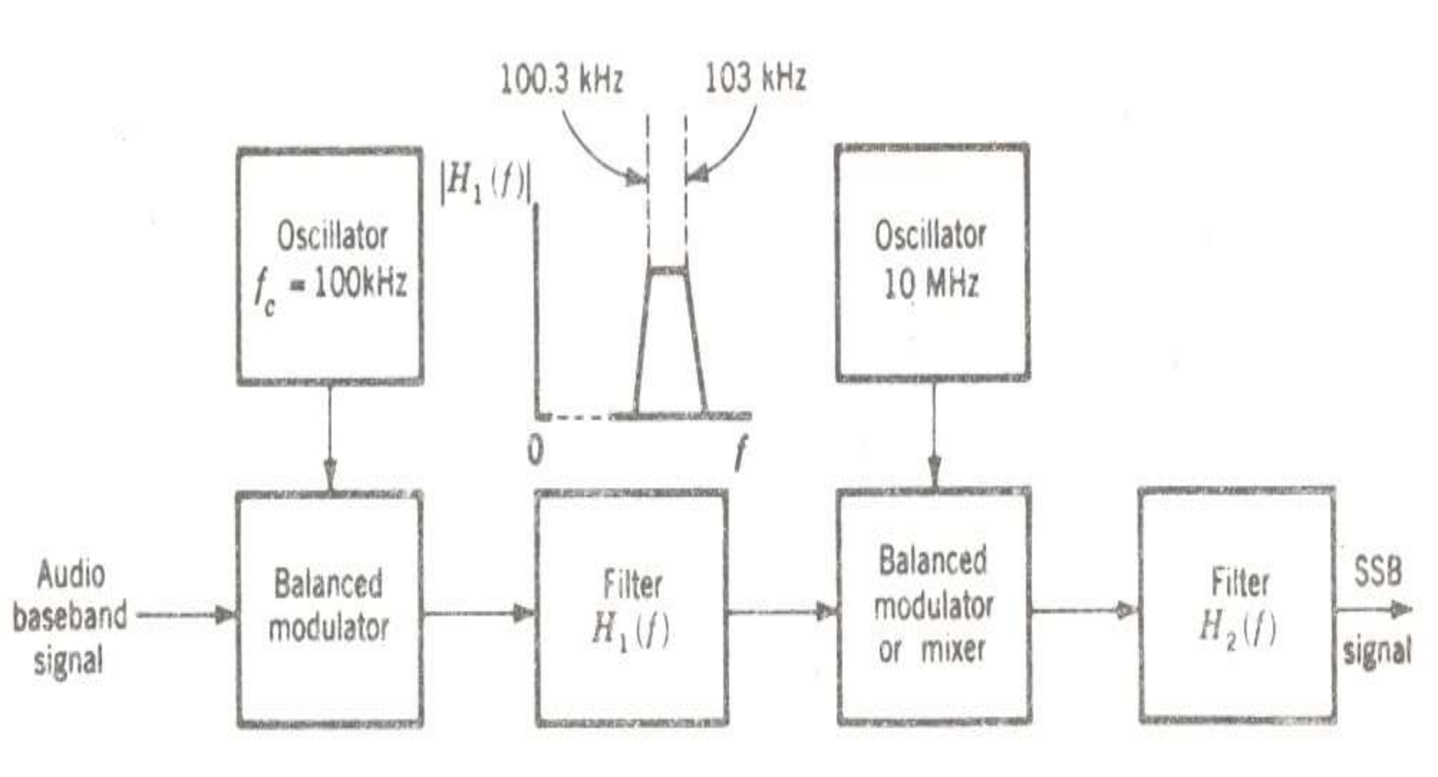


Single Sideband modulation

- A commercial radio communication system contains not only the “transmission” but also some other functions, such as:
  - Carrier-frequency tuning, to select the desired signals
  - Filtering, to separate the desired signal from other unwanted signals
  - Amplifying, to compensate for the loss of signal power incurred in the course of transmission

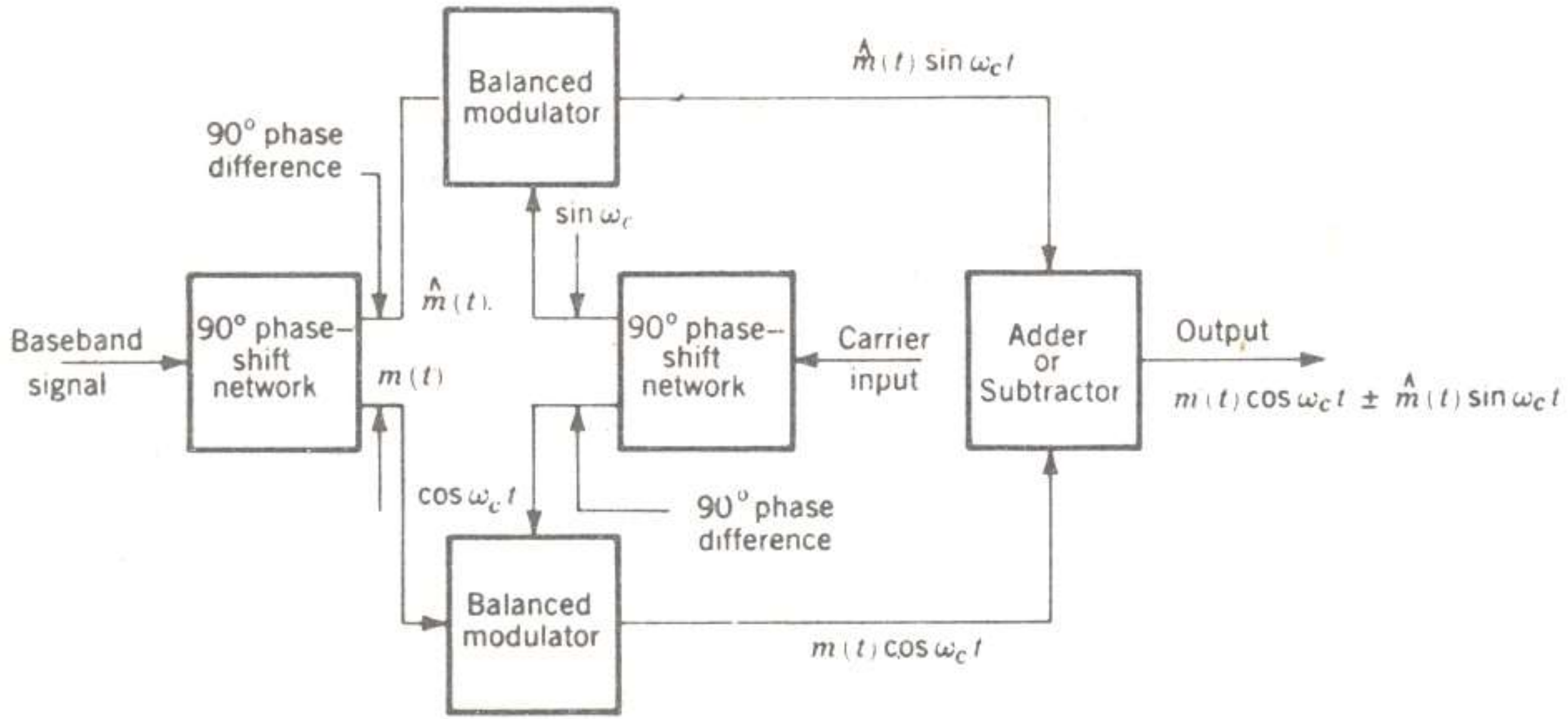
Methods of generating an SSB signal
First Method

- A commercial radio communication system contains not only the "transmission" but also some other functions, such as:



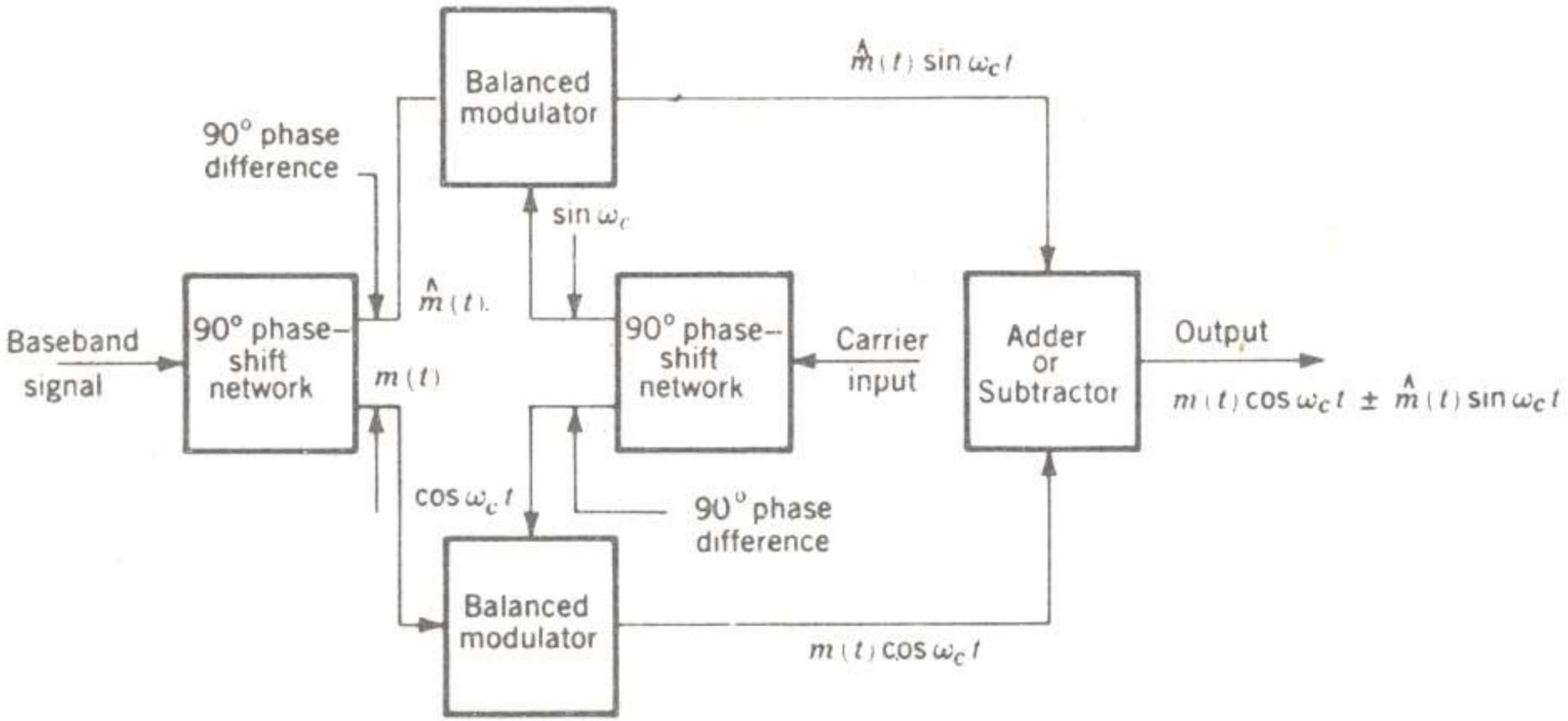
Methods of generating an SSB signal
Phasing Method

- A commercial radio communication system contains not only the "transmission" but also some other functions, such as:



Methods of generating an SSB signal
Phasing Method

- A commercial radio communication system contains not only the "transmission" but also some other functions, such as:



Vestigial sideband Modulation

- A commercial radio communication system contains not only the “transmission” but also some other functions, such as:

$$f_1(t) = A(1 + m \cos \omega_m t) \cos \omega_c t$$
$$= A \cos \omega_c t + \frac{mA}{2} [\cos (\omega_c + \omega_m)t + \cos (\omega_c - \omega_m)t$$

If one of the sidebands is removed, leaving, however, the carrier, we have

$$f_2(t) = A \cos \omega_c t + \frac{mA}{2} \cos (\omega_c + \omega_m)t$$

To calculate the response of a diode demodulator to $f_2(t)$ we need to h form of the envelope of $f_2(t)$. We have

$$f_2(t) = A \cos \omega_c t + \frac{mA}{2} \cos \omega_c t \cos \omega_m t - \frac{mA}{2} \sin \omega_c t \sin \omega_m t$$
$$= A\left(1 + \frac{m}{2} \cos \omega_m t\right) \cos \omega_c t - \frac{mA}{2} \sin \omega_m t \sin \omega_c t$$

The amplitude $A(t)$ of $f_2(t)$ is

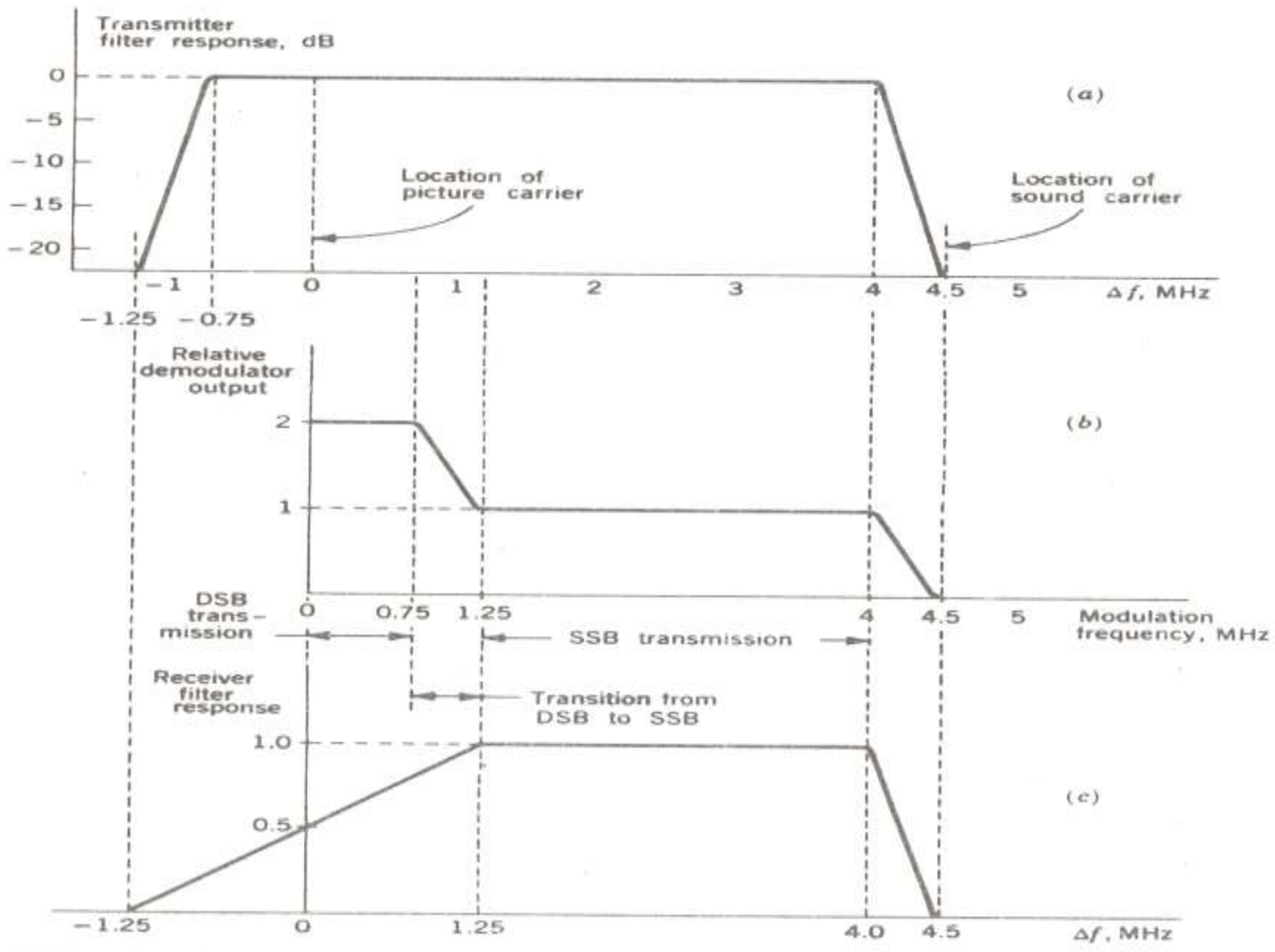
$$A(t) = \sqrt{A^2\left(1 + \frac{m}{2} \cos \omega_m t\right)^2 + \left(\frac{mA}{2} \sin \omega_m t\right)^2}$$
$$= \sqrt{A^2\left(1 + \frac{m^2}{4}\right) + A^2 m \cos \omega_m t}$$

and for $m \ll 1$,

$$A(t) \cong A\left(1 + \frac{m}{2} \cos \omega_m t\right)$$

Vestigial sideband Modulation…………

- A commercial radio communication system contains not only the "transmission" but also some other functions, such as:



Radio Receiver

- In radio communications, a **radio receiver** (**receiver** or simply **radio**) is an electronic device that receives **radio** waves and converts the information carried by them to a usable form.
- A commercial radio communication system contains not only the "transmission" but also some other functions, such as:
  - Carrier-frequency tuning, to select the desired signals
  - Filtering, to separate the desired signal from other unwanted signals
  - Amplifying, to compensate for the loss of signal power incurred in the course of transmission
- **Types of Receivers:**
- **Tuned Radio Frequency Receiver**
- **Super heterodyne Receiver**

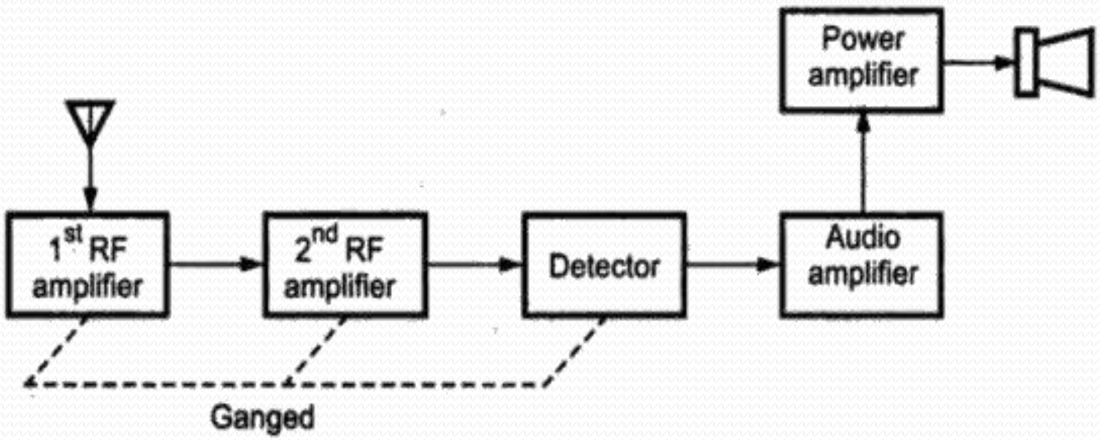


Fig. 1 shows the block diagram of TRF receiver.

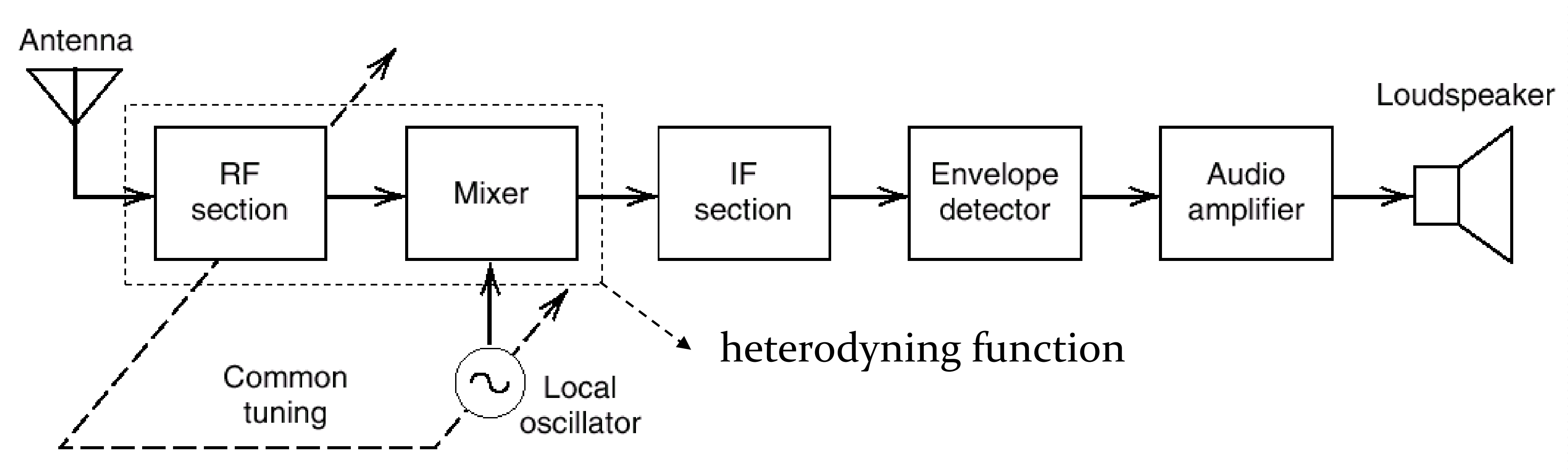
It consists of two or three stages of RF amplifiers, detector, audio amplifier and

Problems in TRF Receivers

- Tracking of tuned circuit
- Instability
- Variable Bandwidth
- TRR.docx
- **Characteristics of Radio Receiver:**
- Selectivity
- Sensitivity
- Fidelity
- Image frequency and its Rejection ratio
- Double spotting
- C RR.docx

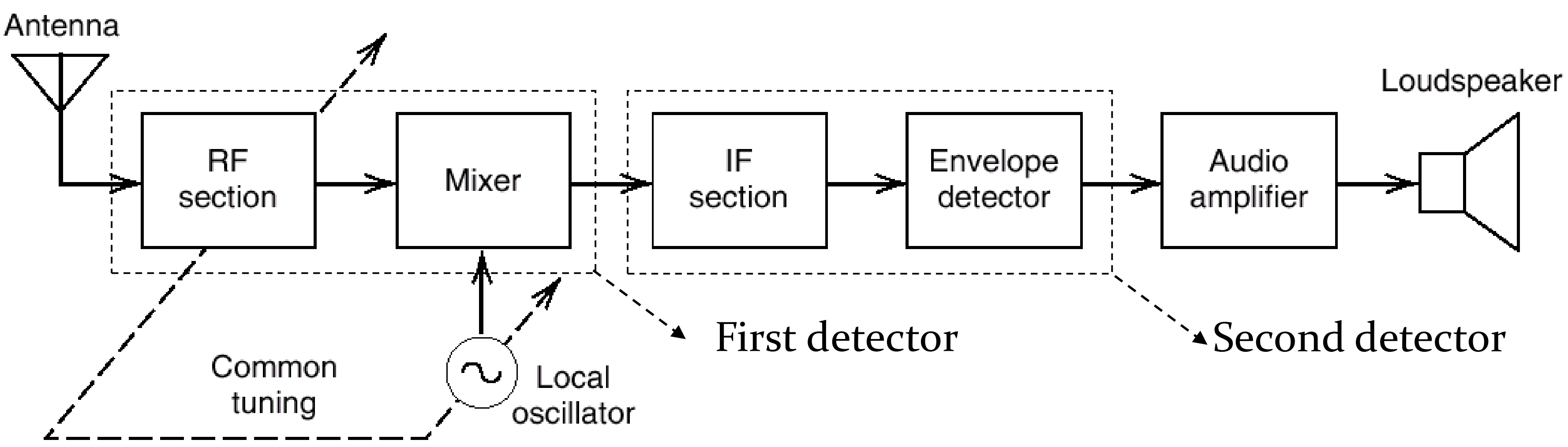
Superheterodyne Receiver

- A superheterodyne receiver or superhet is designed to facilitate the fulfillment of these functions, especially the first two.
  - It overcomes the difficulty of having to build a tunable highly selective and variable filter (rather a fixed filter is applied on IF section).



2.9 Superheterodyne Receiver

Example	*AM Radio*	*FM Radio*
RF carrier range	0.535-1.605 MHz	88-108 MHz
Midband frequency of IF section	0.455 MHz	10.7 MHz
IF bandwidth	10 kHz	200 kHz



2.9 Image Interference

- A cure of image interference is to employ a highly selective stages in the RF session in order to favor the desired signal (at f_{RF}) and discriminate the undesired signal (at $f_{RF} + 2f_{IF}$ or $f_{RF} - 2f_{IF}$).

2.9 Advantage of Constant Envelope for FM modulation

- Observations
  - For FM modulation, any variation in amplitude is caused by noise or interference.
  - For FM modulation, the information is resided on the variations of the instantaneous frequency.
  - So we can use an *amplitude limiter* to remove the amplitude variation, but to retain the frequency variation after the IF section.

UNIT-I Amplitude Modulation

- Radio Receivers
- Receiver types: TRF receivers
- Superhetrodyne receivers
- Sensitivity ,selectivity and fidelity
- Image frequency and its rejection

THANKS

ANY QUERIES