ANALOG COMMUNICATIONS

(III B.Tech ECE I Semester)

K.Prabhakara Rao

ANALOG COMMUNICATIONS

SYLLABUS

III B.Tech ECE I Semester

UNIT-1. INTRODUCTION TO COMMUNICATION SYSTEM

Introduction, Orientation Introduction to communication system, Need for modulation, Amplitude modulation, Time domain and Frequency domain description, Power relations in AM wave, , Square law modulator, Switching modulator, Detection of AM waves, Square law detector, Envelope detector.

UNIT-2. DSB MODULATION

DSB-SC modulation, time domain and frequency domain description, Generation of DSB-SC waves, Balanced Modulator, Ring Modulator, Coherent detection of DSB-SC Modulated waves, COSTAS Loop, Radio transmitter, Classification, AM Transmitter block diagram

UNIT-3. SSB MODULATION

Frequency domain description, Frequency discrimination method for generation of AM- SSB Modulated wave, Time domain description, Phase discrimination method for generating of AM SSB Modulated waves, Demodulation of SSB Waves, Vestigial side band modulation, Generation of VSB modulated wave, Time domain description, Envelop detection of VSB wave pulse carrier, Comparison of AM techniques, Applications of different AM waves.

UNIT-4. ANGLE MODULATION CONCEPTS

Frequency Modulation, Single tone frequency modulation, Spectrum Analysis of Sinusoidal FM Wave, Narrow band FM, Wide band FM, Constant Average Power, Transmission band width of FM wave, Generation of FM Waves, Comparison of AM & FM

UNIT-5. ANGLE MODULATION METHODS

Generation of FM wave: Direct method, Parametric variation method, varactor diode, Reactance modulator, Armstrong method, Detection of FM waves, Balanced frequency discriminator, Zero crossing detector, Phase locked loop, Foster seely discriminator, ratio detector, FM transmitter block diagram.

UNIT-6. NOISE

Nose in DSB and SSB system, Nose in A M system, Nose in angle modulated system, Threshold effect in Angle modulation system, Pre-emphasis and De-emphasis.

UNIT-7. RECEIVERS

Receiver types, Tuned Radio Frequency receivers, Super heterodyne receiver, RF section and characteristics, Frequency changing and Tracking, Intermediate frequency, AGC, FM receiver, Comparison with AM receiver, amplitude limiting.

UNIT-8. PULSE MODULATION

Types of pulse modulation PAM, PWM, Generation and Demodulation of PWM, PPM, Generation and Demodulation of PPM

TEXT BOOKS:

1. Principles of Communication Systems–Taub & Schilling, Gautam Sahe, TMH, 3rd Ed.
2. Principles of Communication Systems - Simon Haykin, John Wiley, 2nd Ed.

REFERENCES:

1. Electronics & Communication System – George Kennedy and Bernard Davis, TMH
2. Analog communications-K.N.Hari Bhat & Ganesh Rao, Pearson Publication, 2nd Ed-
3. Communication Systems Second Edition – R.P. Singh, SP Sapre, TMH, 2007.
4. Communication Systems – B.P. Lathi, BS Publication, 2006.

PRE REQUISITES:

1. Engineering Mathematics
2. Basic Electronics
3. Signals & Systems

PREFACE

As we approach the close of 21ST century, we live in a world in which electronic communication is so commonplace that we pick up our cell phones without a second thought. Yet the importance of such communication in today's world is so crucial that we cannot imagine modern society with out it. We are in an era of change, which same people refer to as the 'information age', much like the era –more than 100 years ago- when the world underwent drastic changes because of the industrial revolution. The prosperity and continued development of modern nations depends primarily on the originating and disseminating of information, rather than of manufacture goods. For example, a hotel in Saudi Arabia mite will be designed by an architectural firm in the United States, built with steel produced in Japan, and constructed by workers from Korea. All phases of such a project depend for their successful completion on rapid worldwide communications.

Almost every day we are aware, or make use, of concepts such as electronic mail, wired cities, overnight stock market quotes fed into our home computers, tele conferencing, and a host of space and military applications of electronic communication. This subject is concerned with the theory of systems for the conveyance of information.

UNIT I

INTRODUCTION TO COMMUNICATION SYSTEMS

Objective:

The transmission of information-bearing signal over a band pass communication channel, such as telephone line or a satellite channel usually requires a shift of the range of frequencies contained in the signal to another frequency range suitable for transmission. A shift in the signal frequency range is accomplished by modulation. This chapter introduces the definition of modulation, need of modulation, types of modulation- AM, PM and FM, Various types of AM, spectra of AM, bandwidth requirements, Generation of AM & DSB-SC, detection of AM & DSB-SC, and power relations. After studying this chapter student should be familiar with the following

- Need for modulation
- Definition of modulation
- Types of modulation techniques – AM, FM, PM
- AM definition - Types of AM –Standard AM, DSB, SSB, and VSB
- Modulation index or depth of modulation and % modulation
- Spectra and Bandwidth of all types of AM
- Generation of AM wave using Square law modulator & Switching modulator
- Generation of DSB wave using Balanced modulator & Ring modulator
- Detection of AM wave using Square law detector & Envelope detector
- Detection of DSB wave using Synchronous detection & Costas loop
- Power and current relations
- Problems
- Frequency Translation

Communication is a process of conveying message at a distance. If the distance is involved is beyond the direct communication, the communication engineering comes into the picture. The branch of engineering which deals with communication systems is known as telecommunication engineering.

Telecommunication engineering is classified into two types based on Transmission media. They are:

- Line communication
- Radio communication

In Line communication the media of transmission is a pair of conductors called transmission line. In this technique signals are directly transmitted through the transmission lines. The installation and maintenance of a transmission line is not only costly and complex, but also overcrowds the open space.

In radio communication transmission media is open space or free space. In this technique signals are transmitted by using antenna through the free space in the form of EM waves.

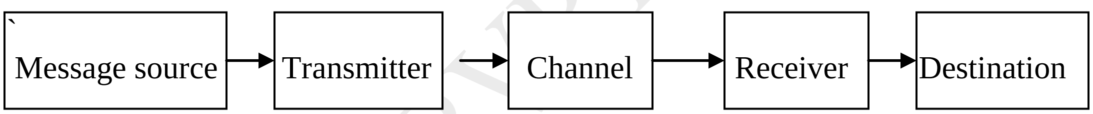


Fig. Block diagram of Communication system

The communication system consists of three basic components.

- Transmitter
- Channel
- Receiver

Transmitter is the equipment which converts physical message, such as sound, words, pictures etc., into corresponding electrical signal.

Receiver is equipment which converts electrical signal back to the physical message.

Channel may be either transmission line or free space, which provides transmission path between transmitter and receiver.

Modulation: Modulation is defined as the process by which some characteristics (i.e. amplitude, frequency, and phase) of a carrier are varied in accordance with a modulating wave.

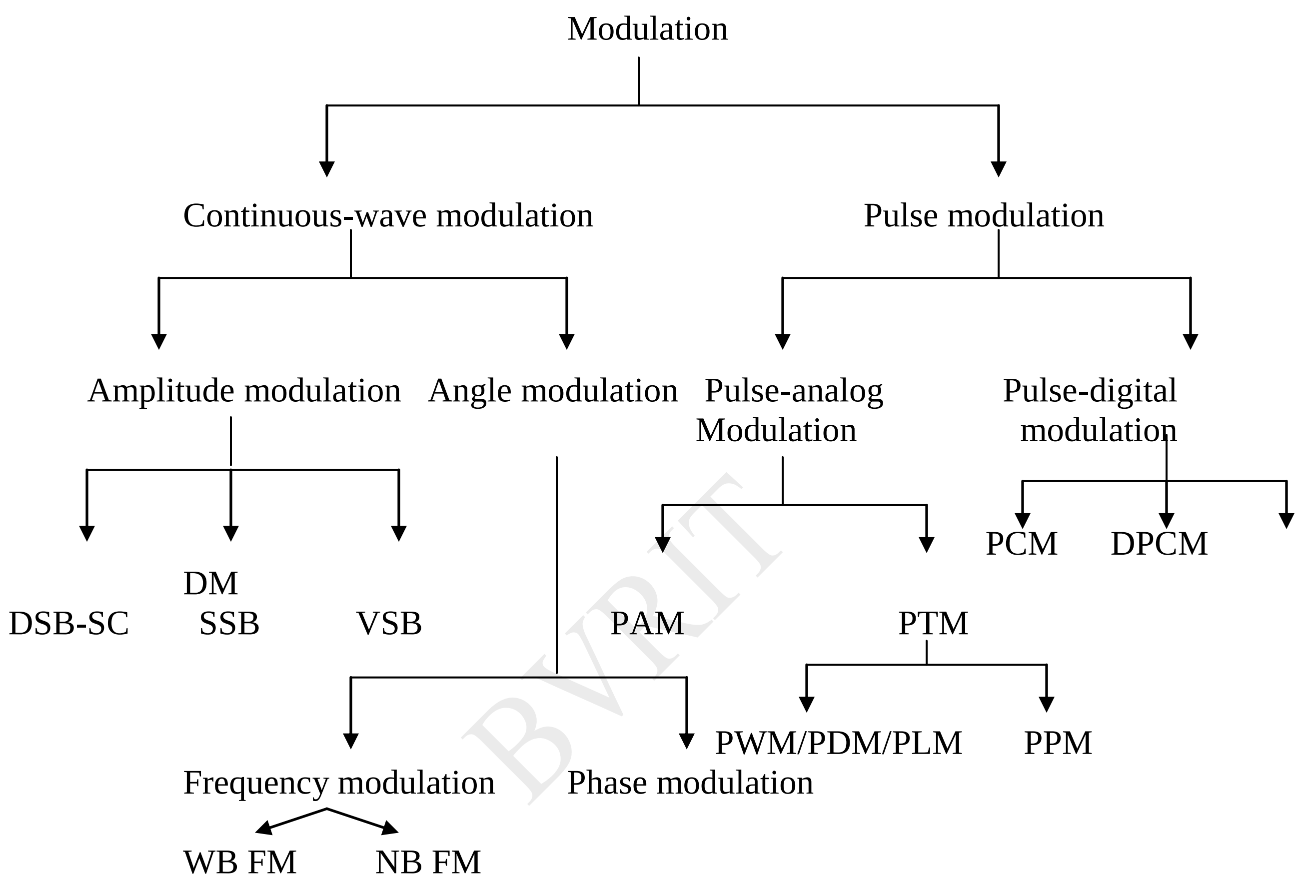
Demodulation is the reverse process of modulation, which is used to get back the original message signal. Modulation is performed at the transmitting end whereas demodulation is performed at the receiving end.

In analog modulation sinusoidal signal is used as carrier where as in digital modulation pulse train is used as carrier.

Need for modulation*:*
Modulation is needed in a communication system to achieve the following basic needs

1) Multiplexing
2) Practicability of antennas
3) Narrow banding

Types of modulation:



Continuous wave modulation (CW): When the carrier wave is continuous in nature the modulation process is known as continuous wave modulation.

Pulse modulation: When the carrier wave is a pulse in nature the modulation process is known as continuous wave modulation

Amplitude modulation (AM): A modulation process in which the amplitude of the carrier is varied in accordance with the instantaneous value of the modulating signal.

<u>Amplitude modulation</u>

Amplitude modulation is defined as the process in which the amplitude of the carrier signal is varied in accordance with the modulating signal or message signal.

Consider a sinusoidal carrier signal C (t) is defined as

$$C(t) = A_c \mathrm{Cos}\,(2\pi f_c t + \phi)\, t$$

Where Ac= Amplitude of the carrier signal
f_c= frequency of the carrier signal
ϕ= Phase angle.

For our convenience, assume the phase angle of the carrier signal is zero. An amplitude-modulated (AM) wave S(t) can be described as function of time is given by

$$S(t) = A_c\,[1+k_a m(t)]\cos 2\pi f_c t$$

Where k_a = Amplitude sensitivity of the modulator.

The amplitude modulated (AM) signal consists of both modulated carrier signal and un modulated carrier signal.

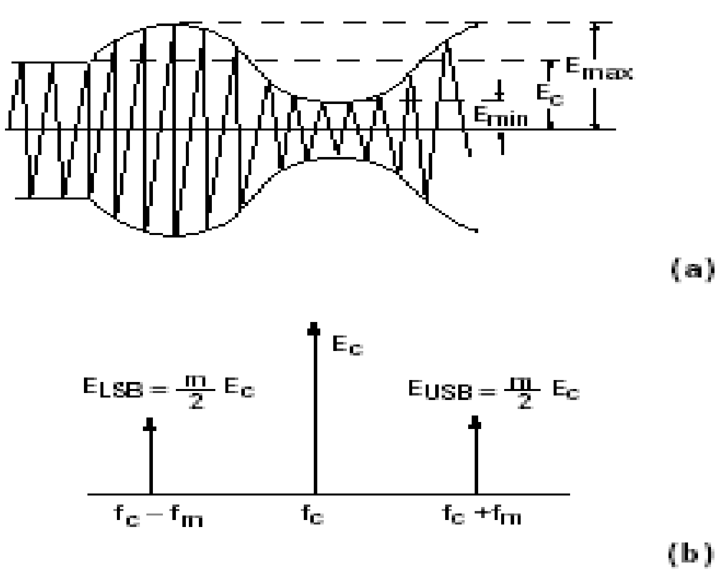


Figure 2(a)(b). Calculation of degree of amplitude modulation from time domain and frequency domain displays

There are two requirements to maintain the envelope of AM signal is same as the shape of base band signal.

- The amplitude of the $k_a m(t)$ is always less than unity i.e., $|k_a m(t)|<1$ for all 't'.
- The carrier signal frequency f_c is far greater than the highest frequency component W of the message signal m (t) i.e., $f_c >> W$

Assume the message signal m (t) is band limited to the interval $-W \le f \le W$

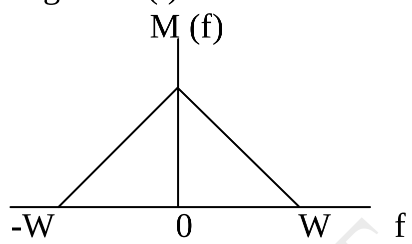


Fig. 1: Spectrum of message signal

The Fourier transform of AM signal S (t) is

$$S(f) = A_c/2\,[\delta(f-f_c)+\delta(f+f_c)]+k_a A_c/2[M(f-f_c)+M(f+f_c)]$$

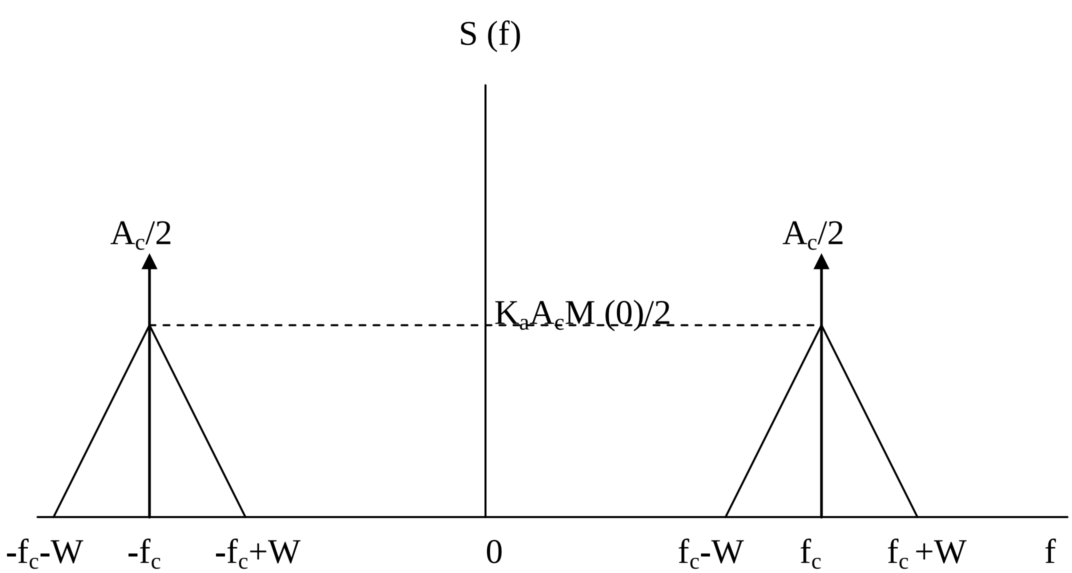


Fig : Spectrum of AM signal

The AM spectrum consists of two impulse functions which are located at f_c and $-f_c$ and weighted by $A_c/2$, two USBs, band of frequencies from f_c to f_c+W and band of frequencies from $-f_c-W$ to $-f_c$, and two LSBs, band of frequencies from f_c-W to f_c and $-f_c$ to $-f_c+W$.

The difference between highest frequency component and lowest frequency component is known as transmission bandwidth. i.e.,

$$B_T = 2W$$

The envelope of AM signal is $A_c\,[1+k_a m\,(t)]$.

Single-tone modulation:

In single-tone modulation modulating signal consists of only one frequency component where as in multi-tone modulation modulating signal consists of more than one frequency component.

$$S\,(t) = A_c[1+k_a m(t)]\cos 2\pi f_c t \quad \ldots\ldots\ldots\ldots(i)$$

$$\text{Let } m\,(t) = A_m \cos 2\pi f_m t$$

Substitute m (t) in equation (i)

$$S\,(t) = A_c\,[1+k_a\,A_m \cos 2\pi f_m t]\,\cos 2\pi f_c t$$

Replace the term $k_a\,A_m$ by μ which is known as modulation index or modulation factor.

Modulation index is defined as the ratio of amplitude of message signal to the amplitude of carrier signal. i.e.,

$$\mu = A_m/A_c$$

(In some books modulation index is designated as ***"m"***)

Which can also be expressed in terms of A_{max} and $A_{min?}$

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

Where A_{max} = maximum amplitude of the modulated carrier signal

A_{min} = minimum amplitude of the modulated carrier signal

$$S(t) = A_c \cos(2\pi f_c t)+A_c\mu/2[\cos 2\pi(f_c+f_m)t]+ A_c\mu/2[\cos 2\pi(f_c-f_m)t]$$

Fourier transform of S (t) is

$$S(f) =A_c/2[\delta(f-f_c) + \delta(f+f_c)] +A_c\mu/4[\delta(f-f_c-f_m) + \delta(f+f_c+f_m)]$$

$$+ A_c\mu/4[\delta(f- f_c+f_m) + \delta(f+f_c-f_m)]$$

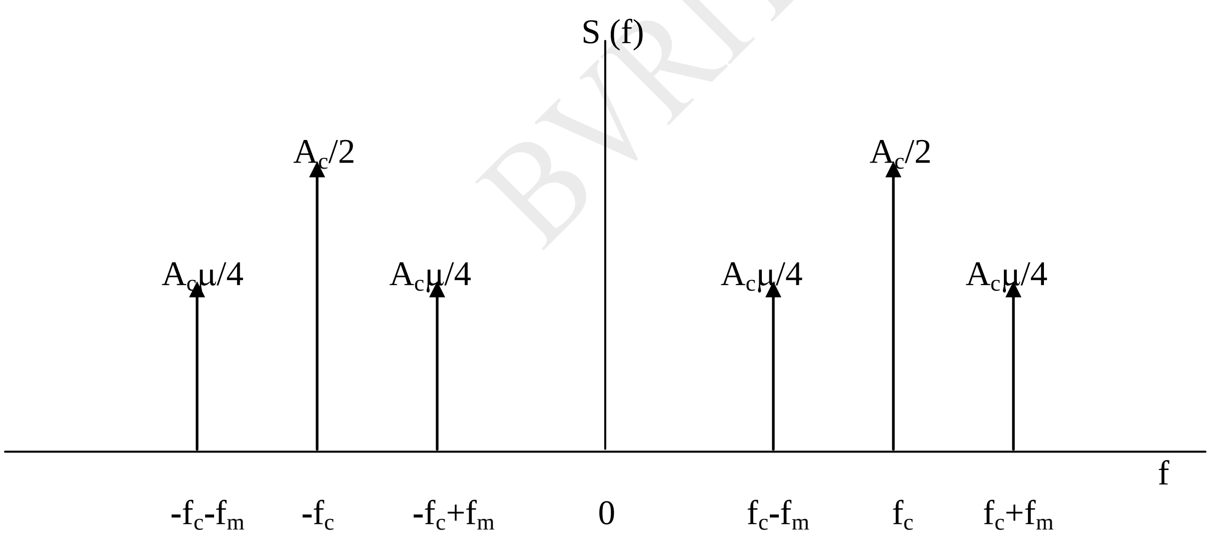


Fig. Spectrum of Single tone AM signal

Power calculations of single-tone AM signal:

The standard time domain equation for single-tone AM signal is given by

$S(t) = A_c\cos(2\pi f_c t) + A_c\mu/2[\cos 2\pi(f_c+f_m)t] + A_c\mu/2[\cos 2\pi(f_c-f_m)t]$

$\boxed{\text{Power of any signal is equal to the mean square value of the signal}}$

Carrier power $P_c = A_c^2/2$

Upper Side Band power $P_{USB} = A_c^2\mu^2/8$

Lower Side Band power $P_{LSB} = A_c^2\mu^2/8$

Total power $P_T = P_c + P_{LSB} + P_{USB}$

Total power $P_T = A_c^2/2 + A_c^2\mu^2/8 + A_c^2\mu^2/8$

$$P_T = P_c[1+\mu^2/2]$$

Multi-tone modulation:

In multi-tone modulation modulating signal consists of more than one frequency component where as in single-tone modulation modulating signal consists of only one frequency component.

$S(t) = A_c[1+k_a m(t)]\cos 2\pi f_c t$ ……….. (i)

Let $m(t) = A_{m1}\cos 2\pi f_{m1}t + A_{m2}\cos 2\pi f_{m2}t$

Substitute m (t) in equation (i)

$$S(t) = A_c[1+k_a A_{m1}\cos 2\pi f_{m1}t + k_a A_{m2}\cos 2\pi f_{m2}t]\cos 2\pi f_c t$$

Replace the term $k_a A_{m1}$ by μ_1 and A_{m2} by μ_2

$$S(t) = A_c\cos(2\pi f_c t) + A_c\mu_1/2[\cos 2\pi(f_c+f_{m1})t] + A_c\mu_1/2[\cos 2\pi(f_c-f_{m1})t]$$

$$+A_c\mu_2/2[\cos 2\pi(f_c+f_{m2})t] + A_c\mu_2/2[\cos 2\pi(f_c-f_{m2})t]$$

Fourier transform of S (t) is

$S(f)=A_c/2[\delta(f-f_c)+\delta(f+f_c)]+A_c\mu_1/4[\delta(f-f_c-f_{m1})+\delta(f+f_c+f_{m1})]+$

$A_c\mu_1/4[\delta(f-f_c+f_{m1})+\delta(f+f_c-f_{m1})]+A_c\mu_2/4[\delta(f-f_c-f_{m2})+\delta(f+f_c+f_{m2})]+A_c\mu_2/4[\delta(f-f_c+f_{m2})+\delta(f+f_c-f_{m2})]$

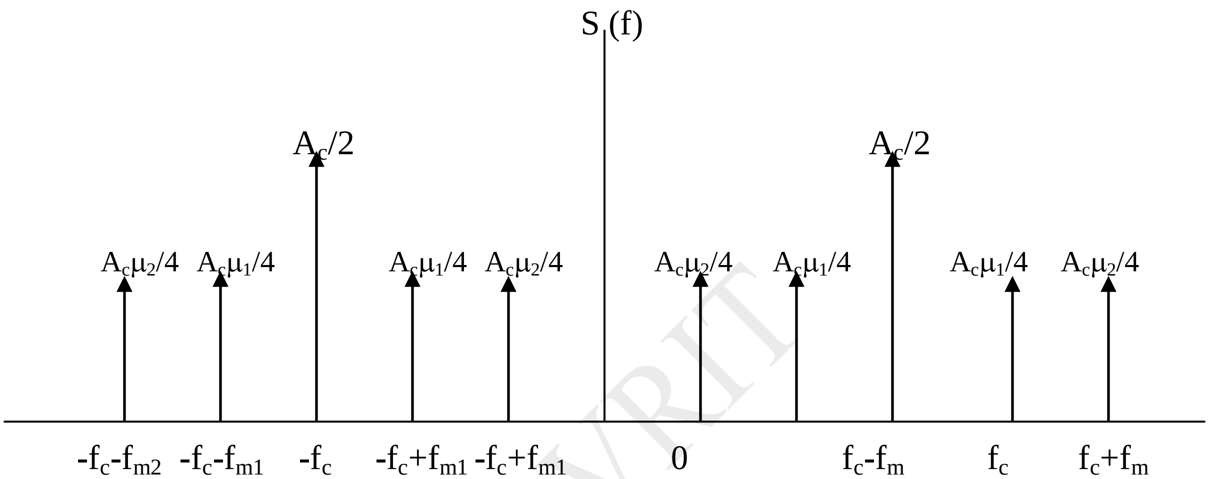


Fig. Spectrum of Multi tone AM signal

Power of Multi-tone AM signal is given by

$P_T = P_c\,[1+\mu_1^2/2+\mu_2^2 2+ \ldots\ldots\ldots +\mu_n^2 2]$

$P_T = P_c\,[1+\mu_t/2]$

Where $\mu_t=\sqrt{\mu_1^2+\mu_2^2+\ldots\ldots\ldots +\mu_n^2}$

Transmission efficiency (η):-

Transmission efficiency is defined as the ratio of total side band power to the total transmitted power.

i.e., $\eta = P_{SB}/P_T$ or $\mu^2/(2+\mu^2)$

Advantages of Amplitude modulation:-

- Generation and detection of AM signals are very easy
- It is very cheap to build, due to this reason it I most commonly used in AM radio broad casting

Disadvantages of Amplitude of modulation:-

- Amplitude modulation is wasteful of power
- Amplitude modulation is wasteful of band width

Application of Amplitude modulation: -

AM Radio Broadcasting

Generation of AM waves

There are two methods to generate AM waves

- Square-law modulator
- Switching modulator

Square-law modulator: -

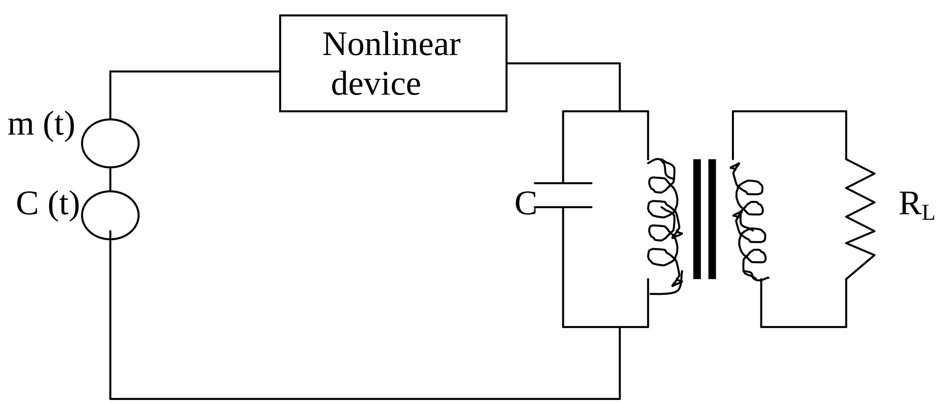


Fig. Square-law Modulator.

A Square-law modulator requires three features: a means of summing the carrier and modulating waves, a nonlinear element, and a band pass filter for extracting the desired modulation products. Semi-conductor diodes and transistors are the most common nonlinear devices used for implementing square law modulators. The filtering requirement is usually satisfied by using a single or double tuned filters.

When a nonlinear element such as a diode is suitably biased and operated in a restricted portion of its characteristic curve, that is ,the signal applied to the diode is relatively weak, we find that transfer characteristic of diode-load resistor combination can be represented closely by a square law :

$$V_0 (t) = a_1 V_i (t) + a_2 V_i^2(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots(i)$$

Where a_1, a2 are constants

Now, the input voltage V_i (t) is the sum of both carrier and message signals

i.e., $V_i (t) = A_c \cos 2\pi f_c t + m (t) \quad \ldots\ldots\ldots\ldots\ldots (ii)$

Substitute equation (ii) in equation (i) we get

$$V_0 (t) = a_1 A_c [1+k_a m (t)] \cos 2\pi f_c t + a_1 m (t) + a_2 A_c^2 \cos^2 2\pi f_c t + a_2 m^2 (t) \ldots\ldots\ldots (iii)$$

Where $k_a = 2a_2/a_1$

Now design the tuned filter /Band pass filter with center frequency f_c and pass band frequency width 2W.We can remove the unwanted terms by passing this output voltage $V_0(t)$ through the band pass filter and finally we will get required AM signal.

$$V_0 (t) = a_1 A_c [1+2a_2/a_1\, m (t)] \cos 2\pi f_c t$$

Assume the message signal m (t) is band limited to the interval $-W \le f \le W$

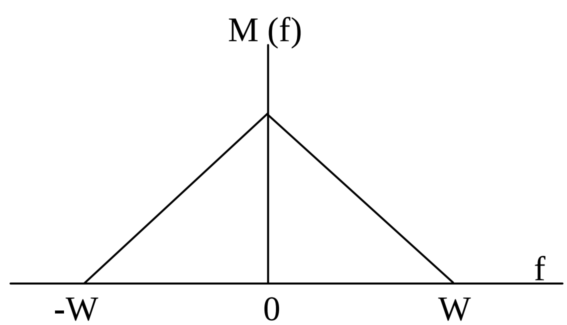


Fig .Spectrum of message signal

The Fourier transform of output voltage V_O (t) is given by

$$V_O(f) = a_1A_C/2[\delta(f-f_c) + \delta(f+f_c)] + a_2 A_C [M(f-f_c) + M(f+f_c)]$$

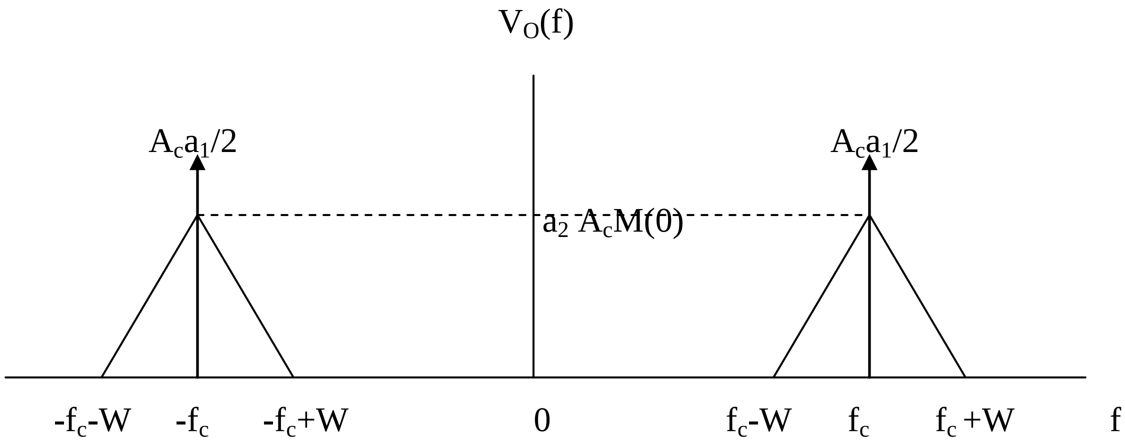
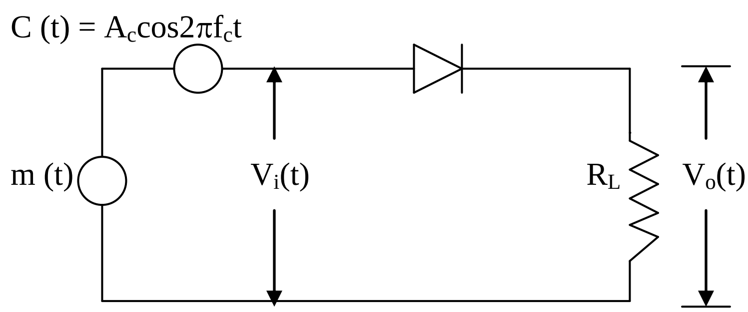


Fig: Spectrum of AM signal

The AM spectrum consists of two impulse functions which are located at f_c & $-f_c$ and weighted by $A_ca_1/2$ & $a_2A_c/2$, two USBs, band of frequencies from f_c to f_c +W and band of frequencies from $-f_c$-W to $-f_c$, and two LSBs, band of frequencies from f_c-W to f_c & $-f_c$ to $-f_c$+W.

Switching Modulator: -



Assume that carrier wave C (t) applied to the diode is large in amplitude, so that it swings right across the characteristic curve of the diode .we assume that the diode acts as an ideal switch, that is, it presents zero impedance when it is forward-biased and infinite impedance when it is reverse-biased. We may thus approximate the transfer characteristic of the diode-load resistor combination by a piecewise-linear characteristic.

The input voltage applied V_i (t) applied to the diode is the sum of both carrier and message signals.

$$V_i(t) = A_c \cos 2\pi f_c t + m(t) \qquad \ldots\ldots\ldots\ldots\ldots(i)$$

During the positive half cycle of the carrier signal i.e. if C (t)>0, the diode is forward biased, and then the diode acts as a closed switch. Now the output voltage V_o (t) is same as the input voltage V_i (t) . During the negative half cycle of the carrier signal i.e. if C (t) <0, the diode is reverse biased, and then the diode acts as a open switch. Now the output voltage V_O (t) is zero i.e. the output voltage varies periodically between the values input voltage V_i (t) and zero at a rate equal to the carrier frequency f_c.

i.e., $V_o(t) = [A_c \cos 2\pi f_c t + m(t)]\, g_P(t) \ldots\ldots\ldots(ii)$

Where $g_p(t)$ is the periodic pulse train with duty cycle one-half and period $T_c=1/f_c$ and which is given by

$$g_P(t) = \tfrac{1}{2} + 2/\pi \sum_{n=1}^{\infty} [(-1)^{n-1}/(2n-1)] \cos[2\pi f_c t(2n-1)] \ldots\ldots\ldots\ldots(iii)$$

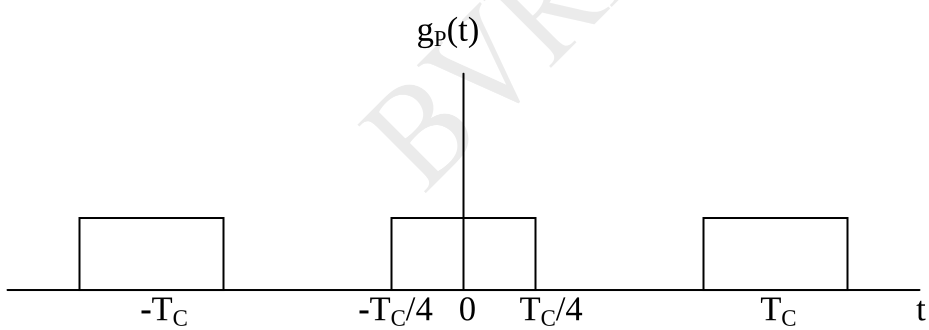


Fig. Periodic pulse train

$$V_0(t) = A_c/2[1+k_a m(t)] \cos 2\pi f_c t + m(t)/2 + 2A_C/\pi \cos^2 2\pi f_c t \ldots\ldots\ldots(iii)$$

Where $k_a = 4/\pi A_C$

Now design the tuned filter /Band pass filter with center frequency f_c and pass band frequency width 2W.We can remove the unwanted terms by passing this output voltage $V_0(t)$ through the band pass filter and finally we will get required AM signal.

$$V_0(t) = A_c/2[1+k_a m(t)] \cos 2\pi f_c t$$

Assume the message signal m(t) is band limited to the interval $-W \le f \le W$

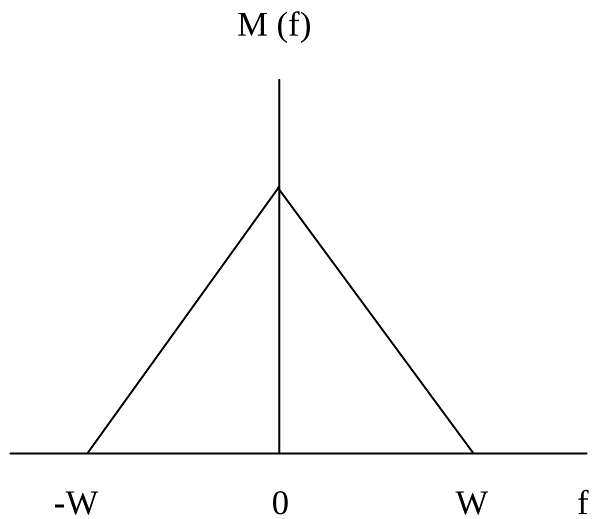


Fig: Spectrum of message signal

The Fourier transform of output voltage V_O (t) is given by

$V_O (f) = A_C/4[\delta(f-f_c) + \delta(f+f_c)] + A_C/\pi[M(f-f_c) + M(f+f_c)]$

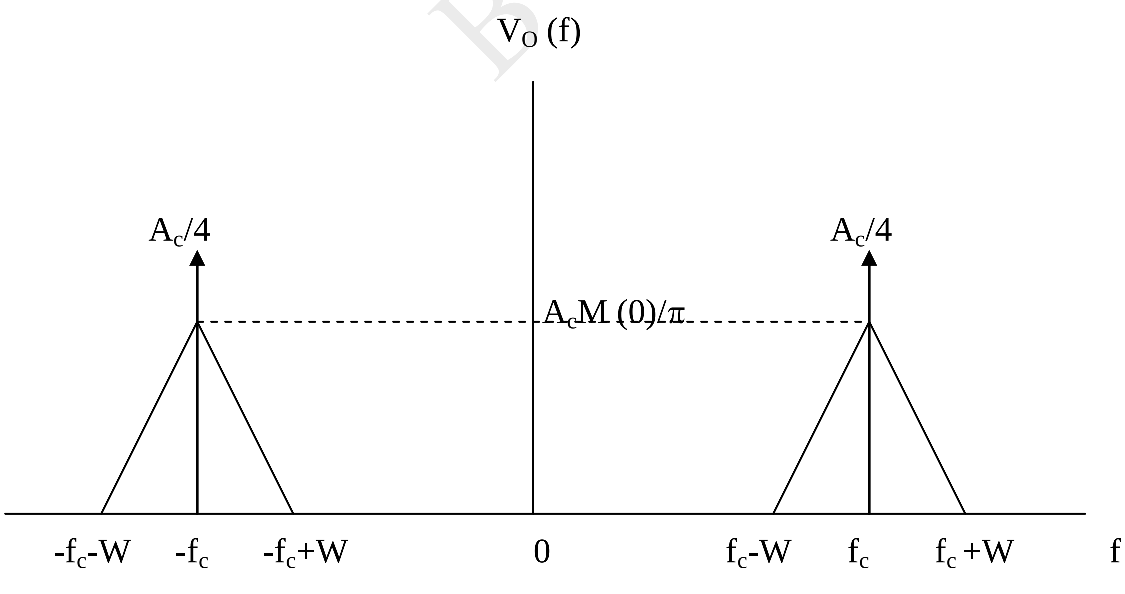


Fig. Spectrum of AM signal

The AM spectrum consists of two impulse functions which are located at f_c & $-f_c$ and weighted by $A_c a_1/2$ & $a_2 A_c/2$, two USBs, band of frequencies from f_c to $f_c + W$ and band of frequencies from $-f_c-W$ to $-f_c$, and two LSBs, band of frequencies from f_c-W to f_c & $-f_c$ to $-f_c+W$.

Demodulation of AM waves:

There are two methods to demodulate AM signals. They are:

- Square-law detector
- Envelope detector

Square-law detector:-

A Square-law modulator requires nonlinear element and a low pass filter for extracting the desired message signal. Semi-conductor diodes and transistors are the most common nonlinear devices used for implementing square law modulators. The filtering requirement is usually satisfied by using a single or double tuned filters.

When a nonlinear element such as a diode is suitably biased and operated in a restricted portion of its characteristic curve, that is ,the signal applied to the diode is relatively weak, we find that transfer characteristic of diode-load resistor combination can be represented closely by a square law :

$$V_0 (t) = a_1 V_i (t) + a_2 V_i^2 (t) \quad \text{……………….(i)}$$

Where a_1, a2 are constants

Now, the input voltage V_i (t) is the sum of both carrier and message signals

i.e., $V_i (t) = A_c [1+k_a m (t)] \cos 2\pi f_c t$ …………….(ii)

Substitute equation (ii) in equation (i) we get

$$V_0 (t) = a_1 A_c [1+k_a m (t)] \cos 2\pi f_c t + \frac{1}{2} a_2 A_c^2 [1+2 k_a m (t) + k_a^2 m^2 (t)] [\cos 4\pi f_c t] \text{………..(iii)}$$

Now design the low pass filter with cutoff frequency f is equal to the required message signal bandwidth. We can remove the unwanted terms by passing this output voltage V_0 (t) through the low pass filter and finally we will get required message signal.

$$V_0(t) = A_c^2 a_2 m(t)$$

The Fourier transform of output voltage V_O (t) is given by

$$V_O(f) = A_c^2 a_2 M(f)$$

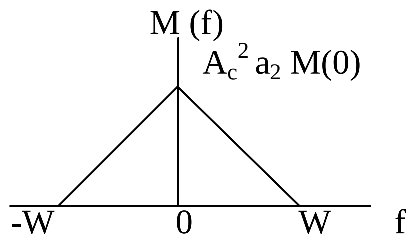


Fig: Spectrum of Output signal

Envelope Detector:

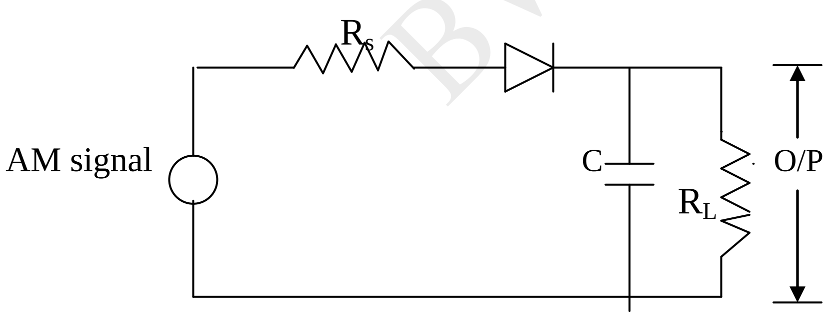


Fig: Envelope detector

Envelope detector is used to detect high level modulated levels, whereas square-law detector is used to detect low level modulated signals (i.e., below 1v). It is also based on the switching action or switching characteristics of a diode. It consists of a diode and a resistor-capacitor filter.

The operation of the envelope detector is as follows. On a positive half cycle of the input signal, the diode is forward biased and the capacitor C charges up rapidly to the peak value of the input signal. When the input signal falls below this value, the diode becomes reverse biased and the capacitor C discharges slowly through the load resistor R_l . The discharging process continues until the next positive half cycle. When the input signal becomes greater than the voltage across the capacitor, the diode conducts again and the process is repeated.

The charging time constant R_sC is very small when compared to the carrier period $1/f_c$ i.e.,

$$R_sC << 1/f_c$$

Where R_s = internal resistance of the voltage source.
C = capacitor
f_c = carrier frequency

i.e., the capacitor C charges rapidly to the peak value of the signal.
The discharging time constant R_lC is very large when compared to the charging time constant i.e.,

$$1/f_c << R_lC << 1/W$$

Where R_l = load resistance value
W = message signal bandwidth
i.e., the capacitor discharges slowly through the load resistor.

Advantages:

- It is very simple to design
- It is inexpensive
- Efficiency is very high when compared to Square Law detector

Disadvantage:

- Due to large time constant, some distortion occurs which is known as diagonal clipping i.e., selection of time constant is somewhat difficult

Application:

- It is most commonly used in almost all commercial AM Radio receivers.

Types of Amplitude modulation:-

There are three types of amplitude modulation. They are:

- Double Sideband-Suppressed Carrier(DSB-SC) modulation
- Single Sideband(SSB) modulation
- Vestigial Sideband(SSB) modulation

Descriptive questions

1. Define modulation. Why is modulation required?
2. What are the various types of modulations?
3. Explain Amplitude modulation with spectrum? Show that a non-linear device can be used for generating AM signal. What are its limitations?
4. What is modulation index?
5. What is envelope distortion?
6. explain the generation of AM wave using a)square law modulator b)switching modulator
7. Explain the DSB-SC wave modulation with spectrum?
8. Explain the generation of DSB-SC wave using a)balanced modulator b)ring modulator
9. Explain the detection of AM wave using a)square law detector b)envelope detector
10. Explain the detection of DSB-SC wave using a)synchronous detector b)costas loop
11. What is frequency translation?
12. Derive $P_t=P_c\sqrt{}(1+m_a^2/2)$?
13. Compare Square law detector with envelope detector?
14. Distinguish between envelope detection and synchronous detection?
15. What are the various types of distortions in diode detectors and explain them. How to reduce these distortions?

Problems

1. The antenna current of an AM transmitter is 8A when only the carrier is sent, but it increases to 8.93A when the carrier is modulated by a sine wave .Find the percentage modulation. Determine the antenna current when the depth of modulation changes to 0.8?
2. A 360W carrier is simultaneously Amplitude modulated by two audio waves with modulation percentages of 55 and 65 respectively. What is the total sideband power radiated?
3. A transmitter supplies 8kw to the antenna when unmodulated. Determine the total power radiated when modulated to 30%?
4. The rms value of the antenna current before modulation is 10A and after modulation is 12A. Calculate the percentage modulation employed assuming no distortion.
5. A Radio transmitter using AM has unmodulated carrier output power of 10kw and can be modulated to a maximum depth of 90% by a sinusoidal modulating voltage without causing overloading. find the value to which unmodulated carrier power may be increased without resulting in overloading if the maximum permitted modulation index is restricted to 40%?
6. A Certain AM transmitter is coupled to an antenna. The input power to the antenna is measured although monitoring of the input current , when there is no modulation ,the current is 10.8A.With modulation ,the current rises to 12.5A.Determine the depth of modulation?
7. A 1MHz carrier is amplitude modulated by a 400Hz modulating signal to a depth of 50%.The unmodulated carrier power is 1kw.Calculate the power of the modulated signal?
8. An AM signal is represented by
   $v(t) = 0.1(1+0.1\cos(2512t)+0.5\cos(6280t))\sin(10^7+45^o)$ volts.
   What information can you get from this? Plot the amplitude spectrum of the signal?

Objective questions

1) Amplitude sensitivity is measured in _______________
2) In amplitude modulation, the carrier frequency is f_c and highest frequency component of the message signal is f_m which are related by ________________
3) For positive frequencies, the portion of the spectrum of an AM wave lying above the carrier frequency f_c is referred to as the __________,whereas the symmetric portion below f_c is referred to as the __________.
4) For positive frequencies , the highest frequency component of the AM wave equals __________ and the lowest frequency component equals ___________
5) The transmission bandwidth required for an AM wave is _____________
6) For an AM wave $S(f) = A_c/2[\delta(f - f_c) + \delta(f + f_c)] + k_a A_c/2 \; [M(f - f_c) + M(f + f_c)]$ represents ____________________
7) For an AM wave $S(f) = A_c/2\,[M(f - f_c) + M(f + f_c)]$ represents ______________
8) The transmission bandwidth required by DSB-SC modulation is ____________
9) A ring modulator followed by a band pass filter generates ____________
10) The total transmitted power for an AM wave is ______________
11) The percentage of power saving achieved by suppressing the carrier with 100% modulation is__________
12) If $m(t) = 5\cos(200\pi t)$ is the message signal & $c(t) = 10\cos(2000\pi t)$ is the carrier signal ,then modulation index of the AM wave is_____
13) The modulation index of an AM wave is changed from 0 to 1 then transmitted power is ___________.
14) $m(t) = A_m \cos(w_m t)$ is message signal & $c(t) = A_c \sin(w_c t)$ is the carrier signal then the modulation index of the AM wave is ______________
15) The process of varying some characteristic of the carrier by the message signal is given the name ______________
16) For over modulated wave the modulation index is ________
17) The baseband signal can be recovered from the AM wave by using
18) Advantages of frequency translation are ______

19) A 1000 KHz carrier is simultaneously modulated with 300HZ audio sine wave. What will be the frequencies present in the output?

20) A broad cast AM transmitter radiates 50KW of carrier power. what will be the radiated power at 85% modulation?

21) When the modulation percentage is 75%, an AM transmitter produces 10KW. How much of this is carrier power?

22) When the modulation percentage is 75% an AM transmitter produces 10KW. What would be the percentage power saving if the carrier and one of the side bands were suppressed before the transmission took place?

23) A 360W carrier is simultaneously modulated by two audio waves with modulation percentage of 55 & 65 respectively. What is the total side band power radiated?

24) When a broadcast AM transmitter is 50% modulated its antenna current is 12A. What will the current be when the modulation depth is increased to 0.9?

25) The output current of a 60% modulated AM Generator is 1.5A.To what value will this current rise if the generator is modulated additionally by another audio wave, whose modulation index is 0.7?

TUTORIAL – 1

1. The message signal m (t) = 2 cos400t+4sin (500t+π/3) modulates the carrier signal c(t)=Acos(8000πt),using DSB amplitude modulation. Find the time domain and frequency domain representation of the modulated signal and plot the spectrum (Fourier transform) of the modulated signal. What is the power content of the modulated signal?

2. The modulating signal m(t)= 2 cos 4000πt +5 cos 6000πt is multiplied by the carrier c(t)= 100 cos $2\pi f_c t$ where f_c = 50kHz.Determine and sketch the power spectral density of the DSB signal?

3. An AM signal has the form
   $u(t) = [20 + 2\cos 3000\pi t + 10\cos 6000\pi t] \cos 2\pi f_c t$
   Where $f_c = 10^5$ Hz.
   a. Sketch the spectrum of u (t)?
   b. Determine the power in each of the frequency components?
   c. Determine the modulation index?
   d. Determine the power in the sidebands, the total power, and the ratio of the sidebands power to the total power?
4. A message signal $m(t) = \cos 2000\pi t + 2\cos 4000\pi t$ modulates the carrier $c(t) = 100\cos 2\pi f_c t$ where f_c=1MHz to produce the DSB signal m(t)c(t).
   a) Determine the expression for the upper sideband signal?
   b) Determine and sketch the spectrum of the USB signal?
5. An AM signal is generated by modulating the carrier f_c=800kHz by the signal $m(t) = \sin 2000\pi t + 5\cos 4000\pi t$. The AM signal $u(t) = 100[1+m(t)]\cos 2\pi f_c t$ is fed to a 50Ω load.
   a) Determine and sketch the spectrum of the AM signal.
   b) Determine the average power in the carrier and in the sidebands.
   c) What is the modulation index?
   d) What is the peak power delivered to the load?

6. The output signal from an AM modulator is
   $u(t) = 5\cos 1800\pi t + 20\cos 2000\pi t + 5\cos 2200\pi t$
   a) Determine the modulating signal m(t) and the carrier c(t) ?
   b) Determine the modulation index?
   c) Determine the ratio of the power in the sidebands to the power in the carrier?

7. A multiple-tone modulating signal f(t), consisting of three frequency components, is given by
   $f(t) = E_1\cos\omega_1 t + E_2\cos\omega_2 t + E_3\cos\omega_3 t$
   Where $\omega_3 > \omega_2 > \omega_1$ and $E1 > E_2 > E_3$
   This signal f(t) modulates a carrier $e_c = E_c\cos\omega_c t$.
   a) Derive an expression for an AM wave ?
   b) Draw a single-sided spectrum, and find the bandwidth of the AM wave?

8. Sketch the ordinary AM signal for a single-tone modulation with modulation indices of $\mu=0.5$ and $\mu=1$?

9. The efficiency η of ordinary AM is defined as the percentage of the total power carried by the sidebands, that is

$$\eta = P_s/P_t \times 100\%$$

Where P_s is the power carried by the sidebands and P_t is the total power of the AM signal.

a) Find η for $\mu=0.5$.
b) Show that for a single-tone AM, η_{max} is 33.33% at $\mu=1$.

UNIT-II

DSB SYSTEMS

Objective:

The theory of AM showed that a carrier and two side bands are produced in AM generation. This chapter will show that it is not necessary to transmit all those signals to provide the receiver with enough information to reconstruct the original signal. Thus, it will be seen, the carrier signals may be removed or attenuated, and so can one of the two sidebands. The resulting signals will require less transmitted power and will occupy less bandwidth, and yet perfectly acceptable communications will be possible.

This chapter introduces Several SSB AM systems (i.e. SSBSC, VSB), Generation of SSB and VSB waves, Detection of SSB and VSB waves, bandwidth requirements, and advantages & disadvantages of choosing them over conventional DSB AM. After studying this chapter the student should be familiar with the following

- SSB- Spectral characteristics
- SSB Generation –filter method, Phase shift method
- Demodulation of SSB wave
- Effects of frequency and phase errors in synchronous detection-DSB-SC, SSB-SC cases.
- Comparison of AM systems.
- VSB: generation, spectra, demodulation
- Application of different AM systems.

DOUBLE SIDEBAND-SUPPRESSED CARRIER (DSBSC) MODULATION

Double sideband-suppressed (DSB-SC) modulation, in which the transmitted wave consists of only the upper and lower sidebands. Transmitted power is saved through the suppression of the carrier wave, but the channel bandwidth requirement is same as in AM (i.e. twice the bandwidth of the message signal).

Basically, double sideband-suppressed (DSB-SC) modulation consists of the product of both the message signal m (t) and the carrier signal c(t),as follows:

$$S(t) = c(t)\, m(t)$$

$$S(t) = A_c \cos(2\pi f_c t)\, m(t)$$

The modulated signal s (t) undergoes a phase reversal whenever the message signal m (t) crosses zero. The envelope of a DSB-SC modulated signal is different from the message signal.

The transmission bandwidth required by DSB-SC modulation is the same as that for amplitude modulation which is twice the bandwidth of the message signal, 2W.
Assume that the message signal is band-limited to the interval $-W \leq f \leq W$

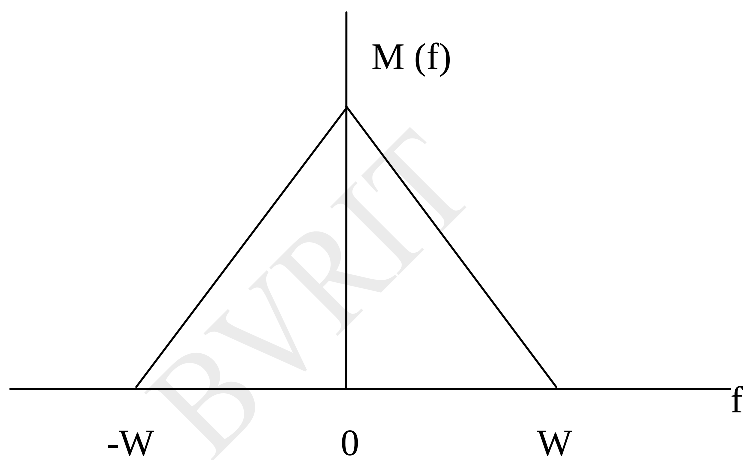


Fig. Spectrum of Baseband signal

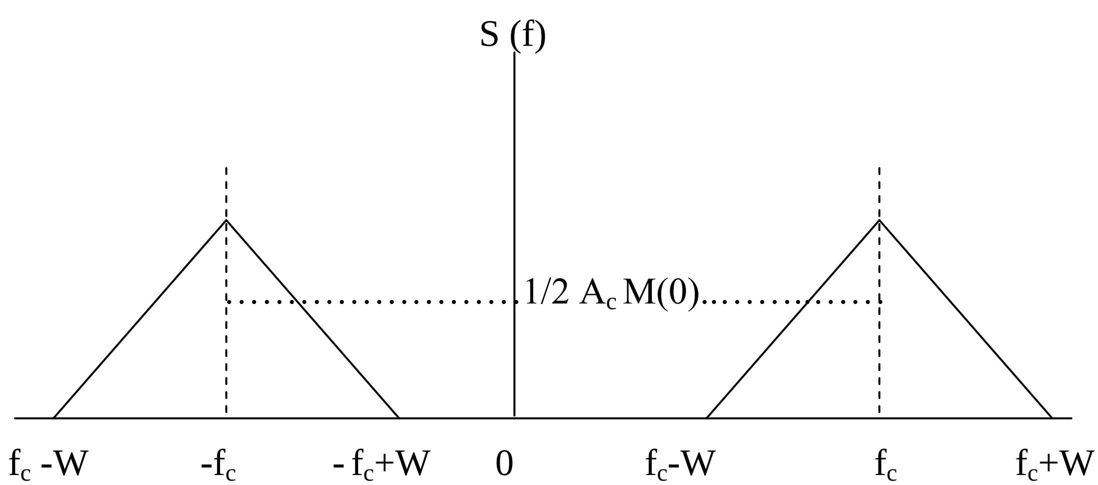


Fig. Spectrum of DSBSC wave

Single-tone modulation:-

In single-tone modulation modulating signal consists of only one frequency component where as in multi-tone modulation modulating signal consists of more than one frequency components.

The standard time domain equation for the DSB-SC modulation is given by

$S(t) = A_c \cos(2\pi f_{ct})\, m(t)$………………… (1)

Assume $m(t) = A_m \cos(2\pi f_m t)$……………….. (2)

Substitute equation (2) in equation (1) we will get

$S(t) = A_c A_m \cos(2\pi f_{ct}) \cos(2\pi f_m t)$

$S(t) = A_c A_m/2[\cos 2\pi (f_c - f_m) t + \cos 2\pi (f_c + f_m) t]$…………… (3)

The Fourier transform of s (t) is

$S(f) = A_c A_m/4[\delta (f - f_c - f_m) + \delta (f + f_c + f_m)] + A_c A_m/4[\delta (f - f_c + f_m) + \delta (f + f_c + f_m)]$

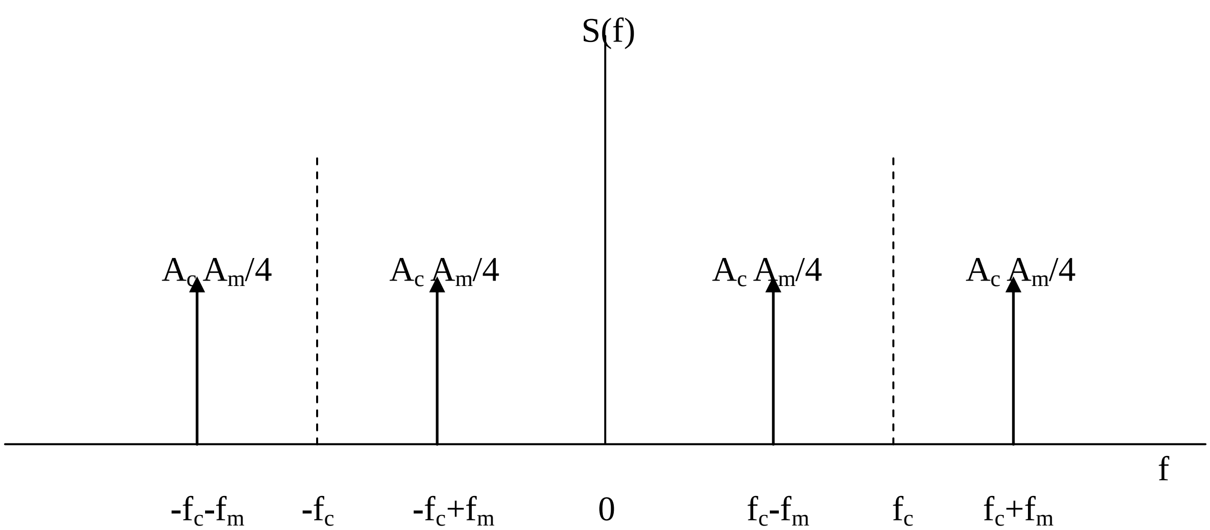


Fig. Spectrum of Single tone DSBSC wave

<u>Power calculations of DSB-SC waves:-</u>

Total power $P_T = P_{LSB} + P_{USB}$

Total power $P_T = A_c^2 A_m^2/8 + A_c^2 A_m^2/8$

Total power $P_T = A_c^2 A_m^2/4$

Generation of DSB-SC waves:-

There are two methods to generate DSB-SC waves. They are:

- Balanced modulator
- Ring modulator

<u>Balanced Modulator</u>:-

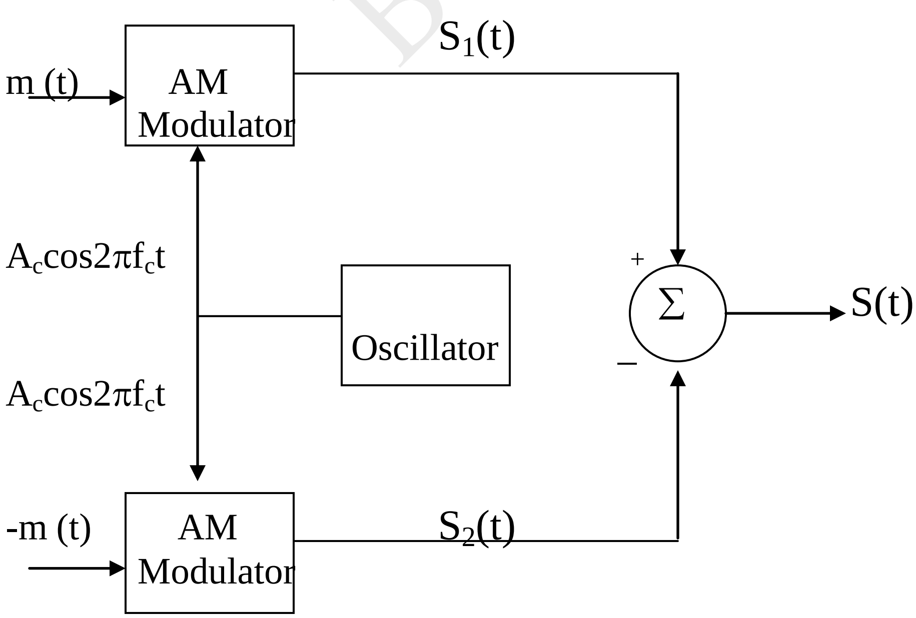


Fig. Balanced Modulator

One possible scheme for generating a DSBSC wave is to use two AM modulators arranged in a balanced configuration so as to suppress the carrier wave, as shown in above fig. Assume that two AM modulators are identical, except for the sign reversal of the modulating signal applied to the input of one of the modulators. Thus the outputs of the two AM modulators can be expressed as follows:

$$S_1 (t) = A_c [1+k_a m (t)] \cos 2\pi f_c t$$

and

$$S_2 (t) = A_c [1- k_a m (t)] \cos 2\pi f_c t$$

Subtracting $S_2 (t)$ from $S_1 (t)$, we obtain

$$S (t) = S_1 (t) – S_2 (t)$$

$$S (t) = 2A_c k_a m (t) \cos 2\pi f_c t$$

Hence, except for the scaling factor $2k_a$ the balanced modulator output is equal to product of the modulating signal and the carrier signal

The Fourier transform of s (t) is

$$S (f) = k_a A_c [M (f-f_c) + M (f+f_c)]$$

Assume that the message signal is band-limited to the interval $–W \leq f \leq W$

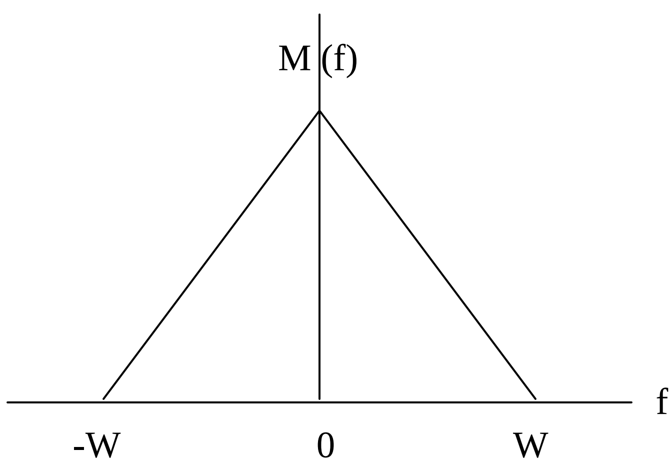


Fig. Spectrum of Baseband signal

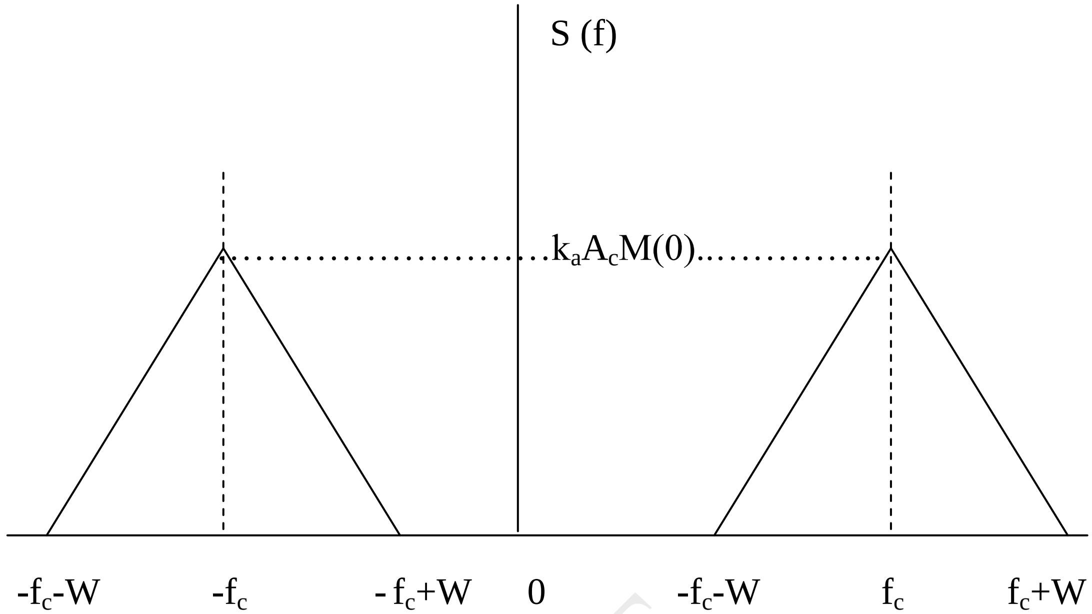


Fig. Spectrum of DSBSC wave

Ring modulator:-

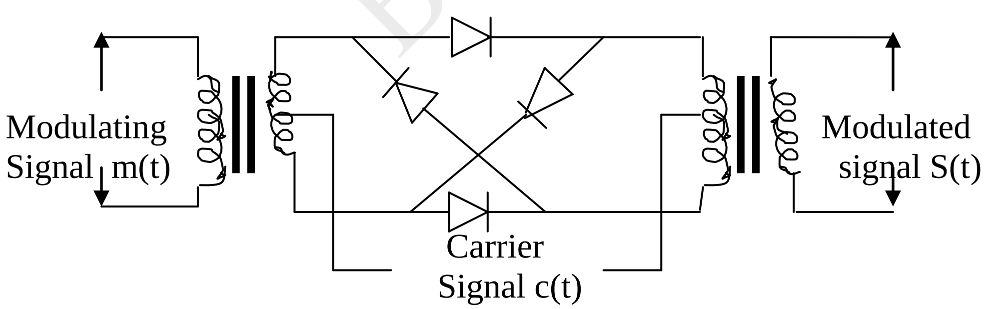


Fig: Ring modulator

One of the most useful product modulator, well suited for generating a DSB-SC wave, is the ring modulator shown in above figure. The four diodes form ring in which they all point in the same way-hence the name. The diodes are controlled by a square-wave carrier c (t) of frequency f_c, which applied longitudinally by means of to center-tapped transformers. If the transformers are perfectly balanced and the diodes are identical, there is no leakage of the modulation frequency into the modulator output.

On one half-cycle of the carrier, the outer diodes are switched to their forward resistance r_f and the inner diodes are switched to their backward resistance r_b .on other half-cycle of the carrier wave, the diodes operate in the opposite condition.

The square wave carrier c (t) can be represented by a Fourier series as follows:

$$c(t) = 4/\pi \sum_{n=1}^{\infty} (-1)^{n-1}/(2n-1) \cos[2\pi f_c t(2n-1)]$$

When the carrier supply is positive, the outer diodes are switched ON and the inner diodes are switched OFF, so that the modulator multiplies the message signal by +1

When the carrier supply is positive, the outer diodes are switched ON and the inner diodes are switched OFF, so that the modulator multiplies the message signal by +1.when the carrier supply is negative, the outer diodes are switched OFF and the inner diodes are switched ON, so that the modulator multiplies the message signal by -1.

Now, the Ring modulator output is the product of both message signal m (t) and carrier signal c (t).

$$S(t) = c(t)\, m(t)$$

$$S(t) = 4/\pi \sum_{n=1}^{\infty} (-1)^{n-1}/(2n-1) \cos[2\pi f_c t(2n-1)]\, m(t)$$

For n=1

$$S(t) = 4/\pi \cos(2\pi f_c t)\, m(t)$$

There is no output from the modulator at the carrier frequency i.e the modulator output consists of modulation products. The ring modulator is sometimes referred to as a double-balanced modulator, because it is balanced with respect to both the message signal and the square wave carrier signal.

The Fourier transform of s (t) is

$$S(f) = 2/\pi\, [M(f-f_c) + M(f+f_c)]$$

Assume that the message signal is band-limited to the interval $-W \le f \le W$

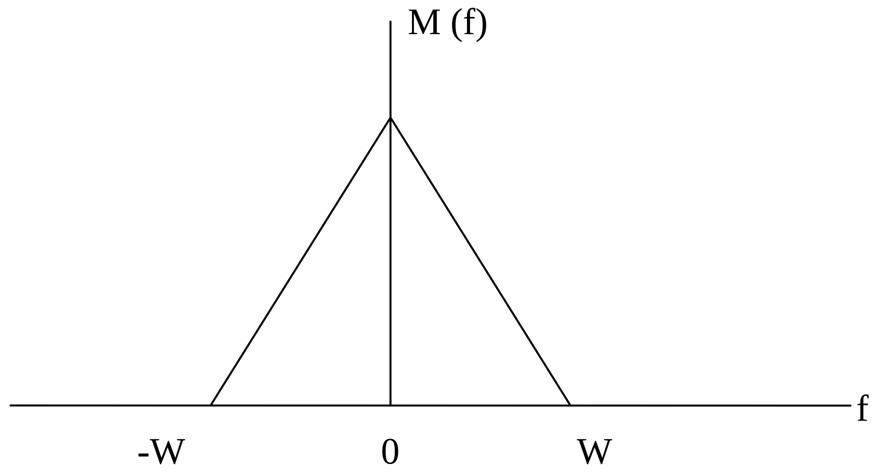


Fig. Spectrum of message signal

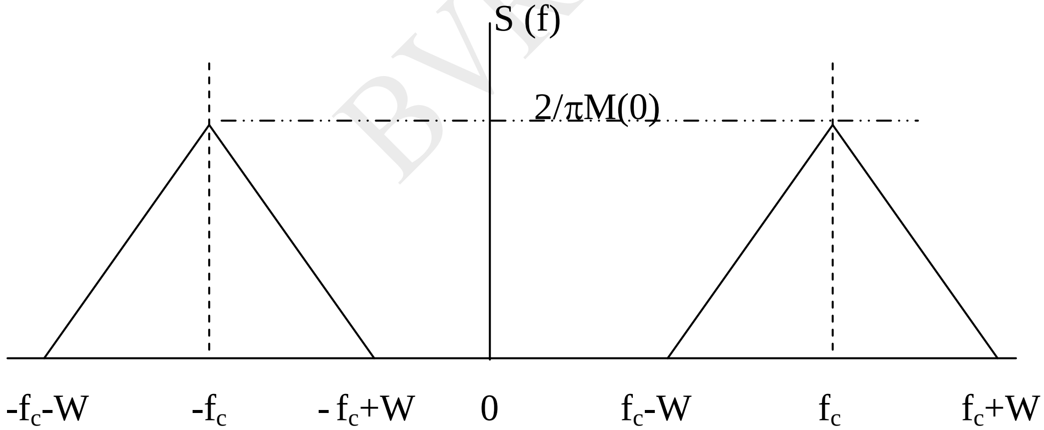


Fig. Spectrum of DSBSC wave

Coherent Detection of DSB-SC Waves:-

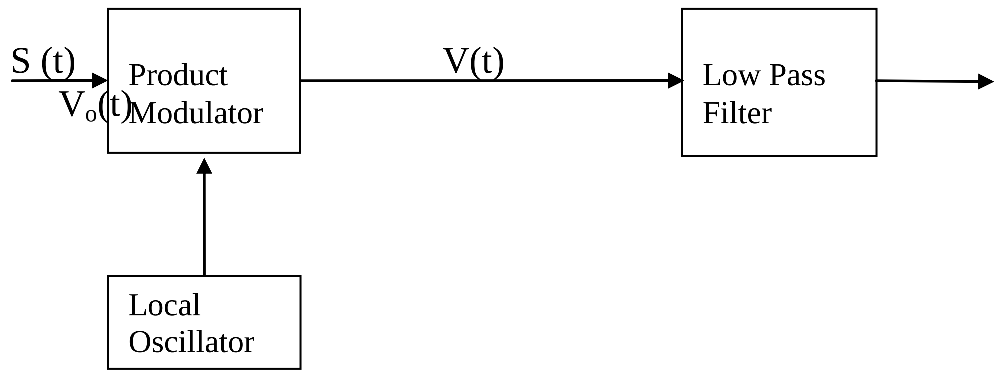


Fig. Coherent detection of DSBSC waves.

The base band signal m (t) can be recovered from a DSB-SC wave s (t) by multiplying s(t) with a locally generated sinusoidal signal and then low pass filtering the product. It is assumed that local oscillator signal is coherent or synchronized, in both frequency and phase ,with the carrier signal c(t) used in the product modulator to generate s(t).this method of demodulation is know as coherent detection or synchronous demodulation.

The product modulator produces the product of both input signal and local oscillator and the output of the product modulator v (t) is given by

$$v(t) = \acute{A}_c \cos(2\pi f_c t + \text{Ø})\, s(t)$$
$$v\, t) = \acute{A}_c \cos(2\pi f_c t + \text{Ø})\, A_c \cos 2\pi f_c t\, m(t)$$
$$v(t) = A_c \acute{A}_c /2 \cos(2\pi f_c t + \text{Ø})\, m(t) + A_c \acute{A}_c/2 \cos\text{Ø}\, m(t)$$

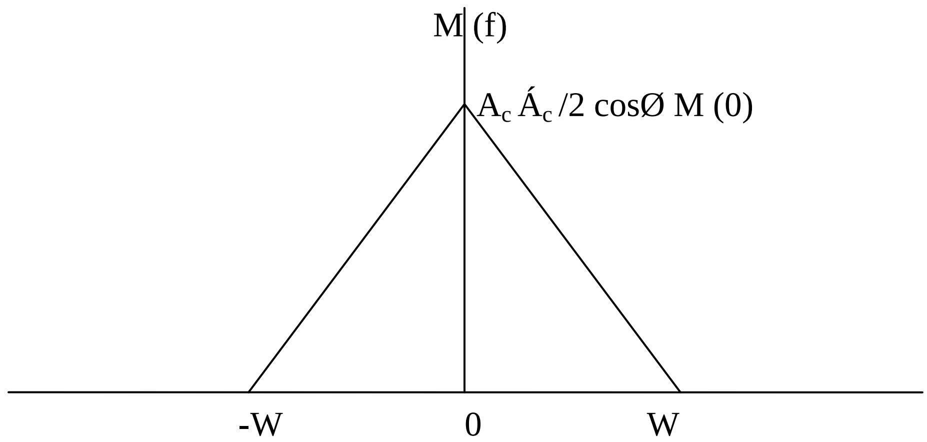
The high frequency can be eliminated by passing this output voltage to the Low Pass Filter.

Now the Output Voltage at the Low pass Filter is given by

$$v_0(t) = A_c \acute{A}_c /2 \cos\text{Ø}\, m(t)$$

The Fourier transform of v_o (t) is

V_O (f) = $A_c \acute{A}_c /2 \cos Ø M (f)$

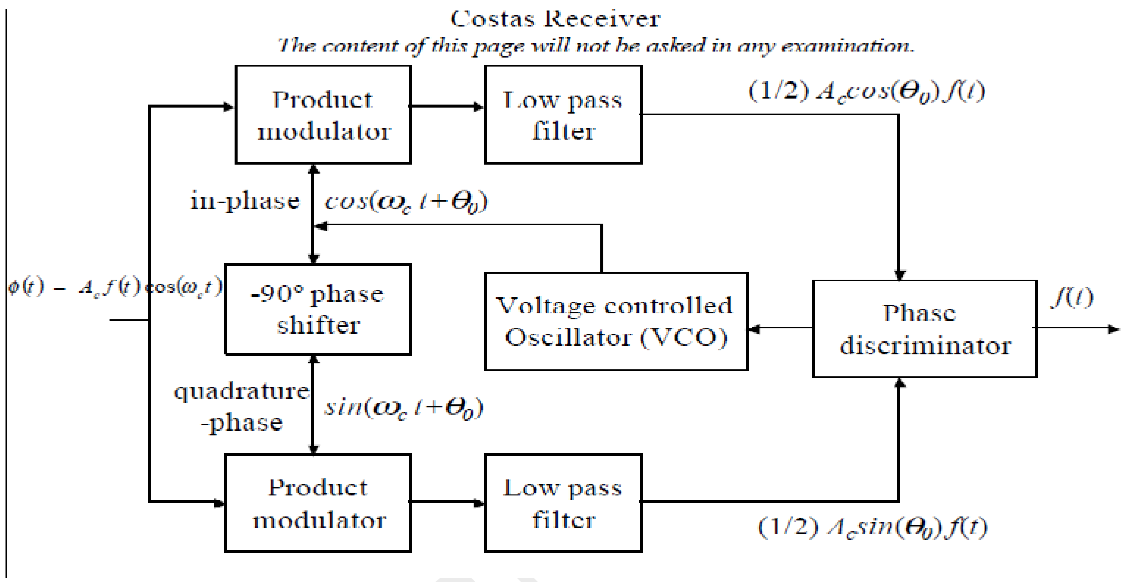


The demodulated signal is proportional to the message signal m (t) when the phase error is constant. The Amplitude of this Demodulated signal is maximum when Ø=0, and it is minimum (zero) when Ø=±π/2 the zero demodulated signal, which occurs for Ø=±π/2 represents quadrature null effect of the coherent detector.

Conventional AM DSB communication systems have two inherent disadvantages.

- First, with conventional AM, carrier power constitutes two thirds or more of the total transmitted power .This is a major drawback because the carrier contains no information.
- Conventional AM systems utilize twice as much bandwidth as needed with SSB systems. With SSB transmission, the information contained in the USB is identical the information contained in the LSB.Therefore, transmitting both sidebands is redundant.
- Consequently, Conventional AM is both power and bandwidth inefficient, which are the two predominant considerations when designing modern electronic communication systems.

COSTA'S Loop



Types of AM

- A3E – Standard AM
- R3E – SSB-Reduced carrier (Pilot carrier system)
- H3E – SSB-FC
- J3E – SSB-SC
- B8E – ISB
- C3F – VSB

Descriptive questions:

1. Explain SSB Modulation with its Spectral characteristics?
2. What are the Advantages of SSB systems?
3. How to Generate SSB using a) filter method & b) Phase shift method?
4. Explain Demodulation of SSB wave using Coherent detection?
5. Explain the Effects of frequency and phase errors in synchronous detection-DSB-SC, SSB-SC cases?
6. Compare different AM systems?
7. Explain VSB: generation, spectra and demodulation?
8. List Application of different AM systems?
9. What is Multiplexing? Explain FDM?

Objective questions:

1) The spectrum of DSB wave contains ____________
2) A3E stands for ____________
3) C3F stands for ____________
4) Vestigial side band modulation (C3F) is normally used for ____________
5) Advantages of DSB ____________
6) Suppressed carrier system are well suited for ____________
7) Commercial AM radio broad cast system employs ______modulation system
8) DSB-SC SSB & VSB modulation are examples of _______modulation
9) Complete information of the message signal is contained in _______
10) The condition for demodulation of AM by an envelope detector is ____
11) When modulation index is greater than one, then the carrier is said to be ____
12) Over modulation results in ____________

TUTORIAL –2

1. A SSB AM signal is generated by modulating an 800kHz carrier by the signal m(t)= cos $2000\Pi t$ +2 sin $2000\Pi t$. The amplitude of the carrier is A_c=100.

   a) Determine the signal $\hat{m}(t)$

   b) Determine the (time domain) expression for the lower sideband of the SSB AM signal.

   c) Determine the magnitude spectrum of the lower sideband SSB signal.

2. The normalized signal $m_n(t)$ has a bandwidth of 10000Hz and its power content is 0.5W.The carrier A cos $2\Pi f_o t$ has a power content of 200W.

   a) If $m_n(t)$ modulates the carrier using SSB AM, What will be the bandwidth and power content of the modulated signal?

   b)If the modulation scheme is DSB-SC, What will be the answer to part (a)?

3. Find the various frequency components and their amplitude in the voltage given below
   E=50(1+0.7cos5000t-0.3cos1000t) sin $5x10^6$t.Draw the single sided spectrum. Also evaluate the modulated and sideband powers.

4. A sinusoidal carrier e_o=100 cos(2Л15^5t) is amplitude modulated by a sinusoidal voltage e_m=50cos(2Л10^3t) up to a modulation depth of 50%. Calculate the frequency and amplitude of each sideband and rms voltage of the modulated carrier.
5. A carrier wave of a frequency of 20kHz is amplitude-modulated by a modulating signal f(t)=cos 2Л10^3t+cos 4Л10^3t. Find the expression for the corresponding SSB-SC signal.
6. Show that if the output of the phase-shift modulator is an SSB signal,
   a. The difference of the signals at the summing junction produces the USB SSB signal and
   b. the sum produces the LSB SSB signal.

7. Show that an SSB signal can be demodulated by the synchronous detector a)by Sketching the spectrum of the signal at each point and b)by the time domain expression of the signals at each point(see Schaum’s series page 66,prob no:2-11)
8. Show that for distortion less demodulation of a VSB signal using synchronous detector the frequency response H(ω) of the VSB filter must satisfy equation

$$H(\omega + \omega_c) + H(\omega - \omega_c) = \text{constant for } |\omega| \le \omega_M$$

UNIT III

SSB MODULATION

Generation of SSB waves:

- Filter method
- Phase shift method
- Third method (Weaver's method)

Demodulation of SSB waves:

- Coherent detection: it assumes perfect synchronization between the local carrier and that used in the transmitter both in frequency and phase.

Effects of frequency and phase errors in synchronous detection-DSB-SC, SSB-SC:

Any error in the frequency or the phase of the local oscillator signal in the receiver, with respect to the carrier wave, gives rise to distortion in the demodulated signal.

The type of distortion caused by frequency error in the demodulation process is unique to SSB modulation systems. In order to reduce the effect of frequency error distortion in telephone systems, we have to limit the frequency error to 2-5 Hz.

The error in the phase of the local oscillator signal results in phase distortion, where each frequency component of the message signal undergoes a constant phase shift at the demodulator output. This phase distortion is usually not serious with voice communications because the human ear is relatively insensitive to phase distortion; the presence of phase distortion gives rise to a Donald Duck voice effect.

Generation of VSB Modulated wave:

To generate a VSB modulated wave, we pass a DSBSC modulated wave through a sideband-shaping filter.

***Comparison of amplitude modulation techniques*:**

- In commercial AM radio broadcast systems standard AM is used in preference to DSBSC or SSB modulation.
- Suppressed carrier modulation systems require the minimum transmitter power and minimum transmission bandwidth.

- Suppressed carrier systems are well suited for point –to-point communications.
- SSB is the preferred method of modulation for long-distance transmission of voice signals over metallic circuits, because it permits longer spacing between the repeaters.
- VSB modulation requires a transmission bandwidth that is intermediate between that required for SSB or DSBSC.
- VSB modulation technique is used in TV transmission
- DSBSC, SSB, and VSB are examples of linear modulation.
- In Commercial TV broadcasting, the VSB occupies a width of about 1.25MHz, or about one-quarter of a full sideband.

Multiplexing:

It is a technique whereby a number of independent signals can be combined into a composite signal suitable for transmission over a common channel. There are two types of multiplexing techniques

1. Frequency division multiplexing (FDM) : The technique of separating the signals in frequency is called as FDM
2. Time division multiplexing: The technique of separating the signals in time is called as TDM.

Descriptive questions:

10. Explain SSB Modulation with its Spectral characteristics?
11. What are the Advantages of SSB systems?
12. How to Generate SSB using a) filter method & b) Phase shift method?
13. Explain Demodulation of SSB wave using Coherent detection?
14. Explain the Effects of frequency and phase errors in synchronous detection-DSB-SC, SSB-SC cases?
15. Compare different AM systems?
16. Explain VSB: generation, spectra and demodulation?
17. List Application of different AM systems?
18. What is Multiplexing? Explain FDM?

Objective questions:

13) The spectrum of SSB wave contains _____________
14) A3E stands for _____________
15) C3F stands for _____________
16) Vestigial side band modulation (C3F) is normally used for _____________
17) Advantages of SSB _____________
18) Suppressed carrier system are well suited for _____________
19) Commercial AM radio broad cast system employs ______modulation system
20) VSB modulation requires a transmission Band Width that is intermediate between that required for _____________& _____________ systems.
21) DSB-SC SSB & VSB modulation are examples of _______modulation
22) Complete information of the message signal is contained in _______
23) The disadvantage of SSB is ______________
24) In VSB _____is transmitted
25) The typical Band width required to transmit a VSB signal is about _____ times that of SSB
26) VSB is used for transmission of the _______ in commercial TV
27) SSB signal can be generated from DSB signal by ______one of the side bands
28) Demodulation of SSB signal can be achieved easily by using the _______
29) The condition for demodulation of AM by an envelope detector is ____
30) When modulation index is greater than one, then the carrier is said to be ____
31) Over modulation results in _____________
32) Third method of generating SSB wave also called as ____________

TUTORIAL –3

1.A SSB AM signal is generated by modulating an 800kHz carrier by the signal m(t)= cos 2000Πt +2 sin 2000Πt. The amplitude of the carrier is A_c=100.

a) Determine the signal $\hat{m}(t)$

b) Determine the (time domain) expression for the lower sideband of the SSB AM signal.

c) Determine the magnitude spectrum of the lower sideband SSB signal.

2. The normalized signal m_n (t) has a bandwidth of 10000Hz and its power content is 0.5W.The carrier A cos $2\Pi f_o t$ has a power content of 200W.

a) If m_n (t) modulates the carrier using SSB AM, What will be the bandwidth and power content of the modulated signal?

b) If the modulation scheme is DSB-SC, What will be the answer to part (a)?

3. Find the various frequency components and their amplitude in the voltage given below
   E=50(1+0.7cos5000t-0.3cos1000t) sin $5x10^6$t.Draw the single sided spectrum. Also evaluate the modulated and sideband powers.
9. A sinusoidal carrier e_o=100cos(2Л15^5t) is amplitude modulated by a sinusoidal voltage e_m=50cos(2Л10^3t) up to a modulation depth of 50%. Calculate the frequency and amplitude of each sideband and rms voltage of the modulated carrier.
10. A carrier wave of a frequency of 20kHz is amplitude-modulated by a modulating signal f(t)=cos 2Л10^3t+cos 4Л10^3t. Find the expression for the corresponding SSB-SC signal.
11. Show that if the output of the phase-shift modulator is an SSB signal,
    a. The difference of the signals at the summing junction produces the USB SSB signal and
    b. the sum produces the LSB SSB signal.
12. Show that an SSB signal can be demodulated by the synchronous detector a)by Sketching the spectrum of the signal at each point and b)by the time domain expression of the signals at each point(see Schaum's series page 66,prob no:2-11)

13. Show that for distortion less demodulation of a VSB signal using synchronous detector the frequency response H (ω) of the VSB filter must satisfy equation

$$H(\omega + \omega_c) + H(\omega - \omega_c) = \text{constant for } |\omega| \leq \omega_M$$

UNIT-IV

ANGLE MODULATION CONCEPTS

Objective:

It is another method of modulating a sinusoidal carrier wave, namely, angle

Modulation in which either the phase or frequency of the carrier wave is varied according to the message signal. After studying this the student should be familiar with the following

- Definition of Angle Modulation
- Types Angle Modulation- FM & PM
- Relation between PM & FM
- Phase and Frequency deviation
- Spectrum of FM signals for sinusoidal modulation – sideband features, power content.
- Narrow band and Wide band FM
- BW considerations-Spectrum of a constant BW FM, Carson's Rule
- Phasor Diagrams for FM signals
- Multiple frequency modulations – Linearity.
- FM with square wave modulation.

Key points:

Angle modulation: there are two types of Angle modulation techniques namely

1. Phase modulation
2. Frequency modulation

Phase modulation (PM) is that of angle modulation in which the angular argument θ (t) is varied linearly with the message signal m(t), as shown by

$$\theta(t) = 2\pi f_c t + k_p m(t)$$

where $2\pi f_c t$ represents the angle of the unmodulated carrier

k_p represents the phase sensitivity of the modulator(radians/volt)

The phase modulated wave $s(t)=A_c\cos[2\pi f_c t+k_p m(t)]$

Frequency modulation (FM) is that of angle modulation in which the instantaneous frequency $f_i(t)$ is varied linearly with the message signal m(t), as shown by

$$f_i(t) = f_c + k_f m(t)$$

Where f_c represents the frequency of the unmodulated carrier

k_f represents the frequency sensitivity of the modulator(Hz/volt)

The frequency modulated wave $s(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_o^t m(t)dt]$

- FM wave can be generated by first integrating m(t) and then using the result as the input to a phase modulator
- PM wave can be generated by first differentiating m(t) and then using the result as the input to a frequency modulator.

Frequency modulation is a Non-linear modulation process.

Single tone FM:

Consider $m(t) = A_m \cos(2\pi f_m t)$

The instantaneous frequency of the resulting FM wave

$$f_i(t) = f_c + k_f A_m \cos(2\pi f_m t)$$
$$= f_c + \Delta f \cos(2\pi f_m t)$$

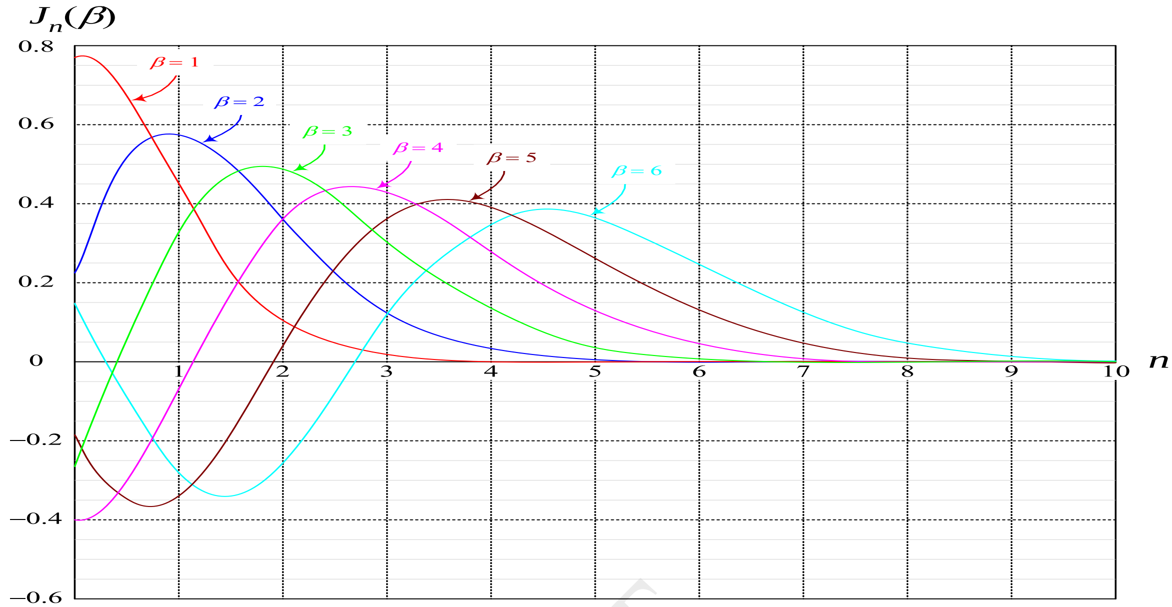
where $\Delta f = k_f A_m$ is called as frequency deviation

$$\theta(t) = 2\pi \int f_i(t)dt$$
$$= 2\pi f_c t + \Delta f / f_m \sin(2\pi f_m t)$$
$$= 2\pi f_c t + \beta \sin(2\pi f_m t)$$

Where $\beta = \Delta f / f_m$ = modulation index of the FM wave

- When $\beta << 1$ radian then it is called as narrowband FM consisting essentially of a carrier, an upper side-frequency component, and a lower side-frequency component.
- When $\beta >> 1$ radian then it is called as wideband FM which contains a carrier and an infinite number of side-frequency components located symmetrically around the carrier.
- The envelope of an FM wave is constant, so that the average power of such a wave dissipated in a 1-ohm resistor is also constant.

Plotting the Bessel function of the first kind $J_n(\beta)$ for different orders n and different values of β is shown below.



$J_n(\beta)$	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 4$	$\beta = 5$	$\beta = 6$
n = 0	0.7652	0.2239	–0.2601	–0.3971	–0.1776	0.1506
n = 1	0.4401	0.5767	0.3391	–0.0660	–0.3276	–0.2767
n = 2	0.1149	0.3528	0.4861	0.3641	0.0466	–0.2429
n = 3	0.0196	0.1289	0.3091	0.4302	0.3648	0.1148
n = 4	0.0025	0.0340	0.1320	0.2811	0.3912	0.3576
n = 5	0.0002	0.0070	0.0430	0.1321	0.2611	0.3621
n = 6	0.0000	0.0012	0.0114	0.0491	0.1310	0.2458
n = 7	0.0000	0.0002	0.0025	0.0152	0.0534	0.1296
n = 8	0.0000	0.0000	0.0005	0.0040	0.0184	0.0565
n = 9	0.0000	0.0000	0.0001	0.0009	0.0055	0.0212
n = 10	0.0000	0.0000	0.0000	0.0002	0.0015	0.0070

Frequency Spectrum of FM

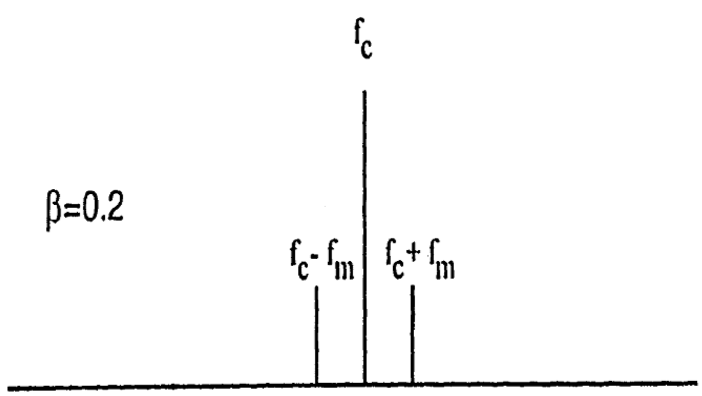
The FM modulated signal in the time domain is given by

$$S(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos[(\omega_c + n\omega_m)t]$$

- From this equation it can be seen that the frequency spectrum of an FM waveform with a sinusoidal modulating signal is a discrete frequency spectrum made up of components spaced at frequencies of $\omega_c \pm n\omega_m$.
- By analogy with AM modulation, these frequency components are called sidebands.
- We can see that the expression for s(t) is an infinite series. Therefore the frequency spectrum of an FM signal has an infinite number of sidebands.
- The amplitudes of the carrier and sidebands of an FM signal are given by the corresponding Bessel functions, which are themselves functions of the modulation index

Spectra of an FM Signal with Sinusoidal Modulation

The following spectra show the effect of modulation index, β, on the bandwidth of an FM signal, and the relative amplitudes of the carrier and sidebands



- **Carson's Rule**: Bandwidth is twice the sum of the maximum frequency deviation and the modulating frequency.

$$BW=2(\Delta f+ f_m)$$

  - The nominal BW $\approx 2\Delta f = 2\ \beta f_m$

Descriptive Questions

1. What is Angle modulation? What are different types of Angle modulation?
2. Define PM & FM? What is frequency deviation & phase deviation?
3. Generate PM wave from FM ?
4. Generate PM wave from FM ?
5. Derive the equations for FM & PM waves?
6. Explain the spectrum of FM wave?
7. What is Carson's Rule?
8. What is wideband FM & Narrowband FM?
9. What is deviation ratio?
10. Plot FM wave taking modulating wave m(t) as
    a. Sine wave
    b. Square wave
11. Explain the Spectrum of Sinusoidal FM wave?
12. Explain the Phasor diagram of FM signals?
13. What are Advantages & Applications of FM?
14. Compare AM and FM?

Objective questions

1) In FM, frequency deviation is proportional to the _____ of the modulating wave and is independent of the modulation_______________
2) In FM Δf = ___________________
3) The modulation index (β) of the FM wave is _________________
4) $s(t)=A_c\ COS[2\pi f_c\ t +k_p m(t)]$ represents ___________________
5) $s(t)=A_c\ COS[2\pi f_c t+2\pi k_f \int_o^T m(t)\ dt]$ represents _____________
6) The phase sensitivity of the modulator is expressed in _______
7) The frequency sensitivity of the modulator is expressed in _______
8) The envelope of a PM or FM wave is ______

9) For narrow band FM modulation index β is _____ for wide band FM, modulation index β is _______

10) PM wave can be generated by passing modulating signal through a ______

11) FM wave can be generated by passing modulating signal through a ___

12) The spectrum of FM wave contains a carrier component and an ____________ set of side frequencies located symmetrically on either side of the carrier

13) For small values of β, $J_o(\beta) =$ _____________

14) For small values of β, $J_n(\beta)$ approximately = ____________ for n _____

15) Carson's rule is _____________

16) The nominal bandwidth of an FM wave is _____

17) FM wave is ______ immune to noise compared to AM

18) Band width of FM wave is _______the sum of the __ frequency deviation and modulating frequency

19) In FM the actual bandwidth is ____ than the constant bandwidth

20) Consider an angle modulated signal $x_c(t)=10COS\ [(10)^8\ \pi t+5Sin\ 2\pi(10^3)\ t\ ]$ find the maximum phase deviation? __

21) Consider an angle modulated signal $x_c(t) =10\ COS\ [(10)^8\ \pi t+5Sin\ 2\pi(10)^3\ t]$ Find the maximum frequency deviation ?

TUTORIAL-4

1. A single-tone modulating signal $\cos(15\pi 10^3 t)$ frequency modulates a carrier of 10MHz and produces a frequency deviation of 75kHz.find
   i) The modulation index
   ii) Phase deviation produced in the FM wave
   iii) If another modulating signal produces a modulation index of 100 while maintaining the same deviation, find the frequency and amplitude of the modulating signal, assuming K_f=15kHz per volt.
2. Consider an FM broadcast signal which has been modulated by a single-tone modulating signal of frequency f_m=15kHz. The frequency deviation is the same as allowed by the international regulation. Find the significant sidebands and the bandwidth of the FM signal as a result of these sidebands.

3. The maximum frequency deviation allowed in an FM broadcast system is 75 kHz. If the modulating signal is a single-tone sinusoid of 10 kHz, find the bandwidth of the FM signal. What will be the change in the bandwidth, if modulating frequency is doubled? Determine the bandwidth when modulating signals amplitude is doubled?

4. Carrier $A\cos\omega_c t$ is modulated by a signal $f(t)=2\cos 10^4.2\pi t + 5\cos 10^3.2\pi t + 3\cos 10^4.4\pi t$. Find the bandwidth of the FM signal by using Carson's rule. Assume $K_f=15\text{x}10^3$Hz/volt. Also find modulation index?
5. A modulating signal $5\cos 2\pi 15\text{x}10^3 t$, angle modulates a carrier $A\cos\omega_c t$.
   i) Find the modulation index and the bandwidth for a) FM b)PM
   ii) Determine the change in the bandwidth and the modulation index for both FM and PM, if f_m is reduced to 5 kHz.
6. A carrier wave $20\cos 8\pi.10^6 t$ is frequency-modulated by a modulating signal $2\cos(2\pi.10^3 t) + \cos(3\pi.10^3 t) + 5\cos(8\pi.10^3 t)$.Calculate the bandwidth. Assume K_f = 40 kHz/volt.
7. A single-tone FM signal is given by
   $E_{FM}=10\sin(16\pi\text{x}10^6 t + 20\sin 2\pi\text{x}10^3 t)$ volts.
   Find the modulation index, modulating frequency deviation, carrier frequency, and the power of the FM signal.
8. The normalized signal $m_n(t)$ has a bandwidth of 10000Hz and its power content is 0.5W. The carrier $A\cos 2\pi f_o t$ has a power content of 200W.
   a)if $m_n(t)$ modulates the carrier using SSB-AM, what will be the bandwidth and the power content of the modulated signal?
   b)if the modulation scheme is DSB-SC, what will the answer to part (a)?
   c)if the modulation scheme is AM with modulation index of 0.6, what will be the answer to part (a)?
   d)if the modulation is FM with k_f=50000, what will be the answer to part (a)?
9. An angle modulated signal has the form
   $u(t)=100\cos[2\pi f_c t+4\sin 2000\pi t]$
   Where f_c=10MHz.
   a) Determine the average transmitted power.
   b) Determine the peak-phase deviation.
   c) Determine the peak-frequency deviation.
   d) Is this an FM or a PM signal? Explain.

10. An angle-modulated signal has the form

$u(t)=100\cos[2\pi f_c t+4\sin 2\pi f_m t]$

Where f_c=10MHz and f_m=1000Hz.

a) Assuming that this is an FM signal, determine the modulation index and the transmitted signal bandwidth.

b) Repeat part (a) if f_m is doubled.

c) Assuming that this is an PM signal, determine the modulation index and the transmitted signal bandwidth.

d) Repeat part (c) if f_m is doubled.

UNIT-V

ANGLE MODULATION METHODS

Objective:

This deals with the generation of Frequency modulated wave and detection of original message signal from the Frequency modulated wave. After studying this chapter student should be familiar with the following

Generation of FM Signals

i. Direct FM – Parameter Variation Method (Implementation using varactor, FET)
ii. Indirect FM – Armstrong system, Frequency Multiplication.

FM demodulators- Slope detection, Balanced Slope Detection, Phase Discriminator (Foster Seely), Ratio Detector.

Key points:

Generation of FM waves:

1. Indirect FM: This method was first proposed by Armstrong. In this method the modulating wave is first used to produce a narrow-band FM wave, and frequency multiplication is next used to increase the frequency deviation to the desired level.
2. Direct FM: In this method the carrier frequency is directly varied in accordance with the incoming message signal.

Detection of FM waves:

To perform frequency demodulation we require 2-port device that produces an output signal with amplitude directly proportional to the instantaneous frequency of a FM wave used as the input signal.

FM detectors –

- Slope detector
- Balanced Slope detector(Travis detector, Triple-tuned-discriminator)
- Phase discriminator (Foster seeley discriminator or center-tuned discriminator)
- Ratio detector
- PLL demodulator and
- Quadrature detector

- The Slope detector, Balanced Slope detector, Foster seeley discriminator, and Ratio detector are one forms of tuned –circuit frequency discriminators.
- Tuned circuit discriminators convert FM to AM and then demodulate the AM envelope with conventional peak detectors.
- Disadvantages of slope detector – poor linearity, difficulty in tuning, and lack of provisions for limiting.
- A Balanced slope detector is simply two single ended slope detectors connected in parallel and fed 180^o out of phase.
- Advantage of Foster-seeley discriminator: output voltage-vs-frequency deviation curve is more linear than that of a slope detector, it is easier to tune.
- Disadvantage of Foster-seeley discriminator: a separate limiter circuit must precede it.
- Advantage of Ratio detector over Foster seeley discriminator: it is relatively immune to amplitude variations in its input signal.

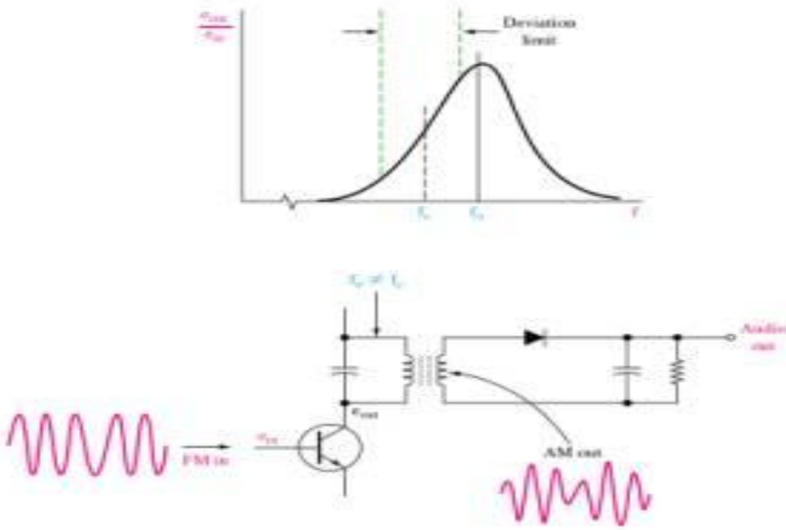
FM DETECTORS:

FM detectors convert the frequency variations of the carrier back into a replica of the original modulating signal. There are 5 basic types of FM detectors:

1. Slope detector
2. Foster-Seely Discriminator
3. Ratio Detector
4. Quadrature Detector
5. Phase-Locked Loop (PLL) detector

1. SLOPE DETECTOR

The slope detector is the simplest type of FM detector. A schematic diagram of a slope detector appears below:



The operation of the slope detector is very simple. The output network of an amplifier is tuned to a frequency that is slightly more than the carrier frequency + peak deviation. As the input signal varies in frequency, the output signal across the LC network will vary in amplitude because of the band pass properties of the tank circuit. The output of this amplifier is AM, which can be detected using a diode detector.

The circuit shown in the diagram above looks very similar to the last IF amplifier and detector of an AM receiver, and it is possible to receive NBFM on an AM receiver by detuning the last IF transformer. If this transformer is tuned to a frequency of approximately 1 KHz above the IF frequency, the last IF amplifier will convert NBFM to AM.

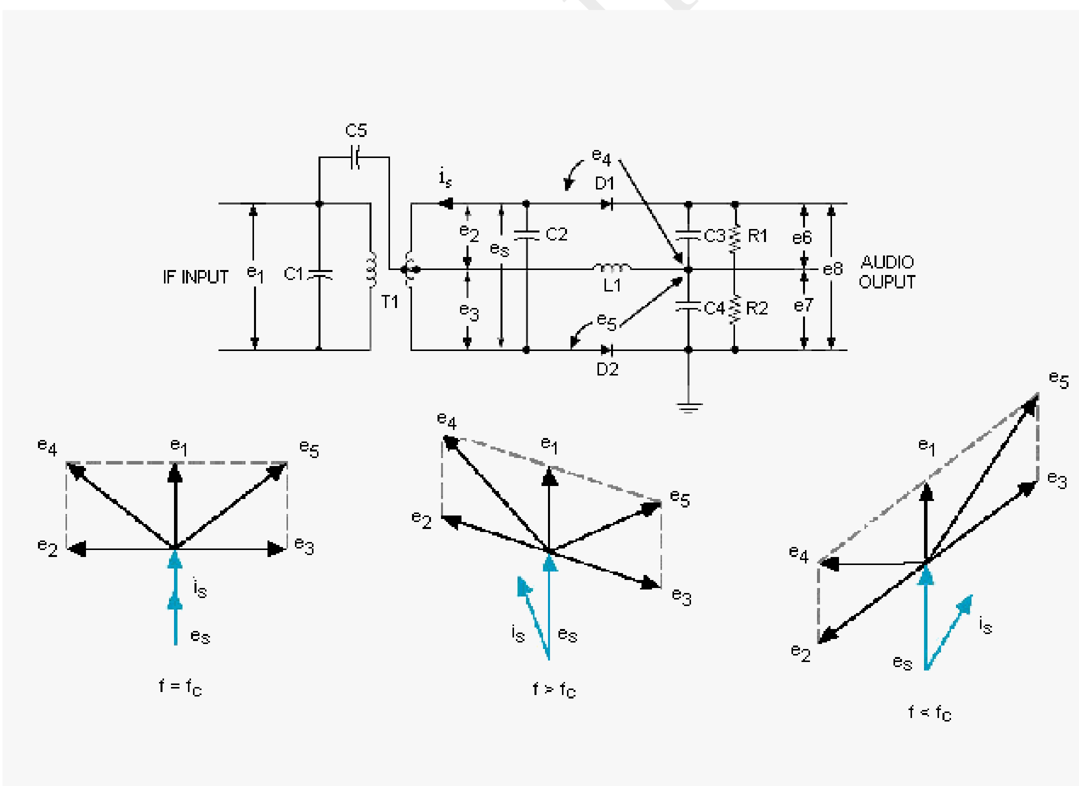
In spite of its simplicity, the slope detector is rarely used because it has poor linearity. To see why this is so, it is necessary to look at the expression for the voltage across the primary of the tuned transformer in the sloped detector:

$$V_{PRI} = I_{PRI} X_{PRI} = I_{PRI} \cdot \frac{j\omega L_{PRI}}{1 - \left(\frac{\omega}{\omega_0}\right)^2}$$

The voltage across the transformer's primary winding is related to the square of the frequency. Since the frequency deviation of the FM signal is directly proportional to the modulating signal's amplitude, the output of the slope detector will be distorted. If the bandwidth of the FM signal is small, it is possible to approximate the response of the slope detector by a linear function, and a slope detector could be used to demodulate an NBFM signal

2. FOSTER-SEELY DISCRIMINATOR

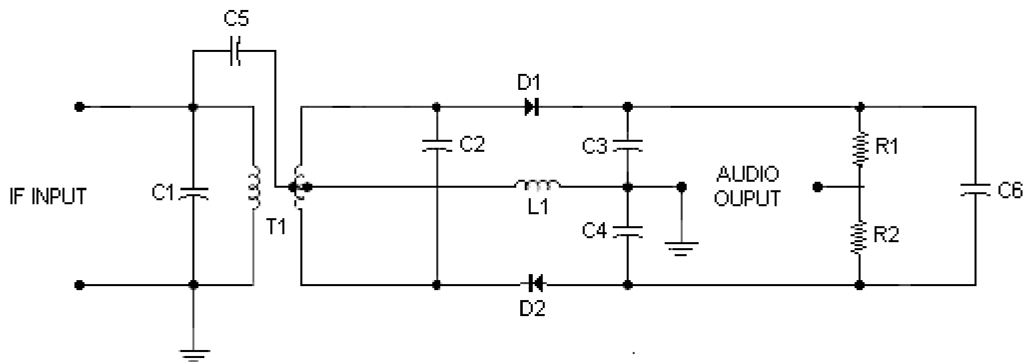
The Foster-Seely Discriminator is a widely used FM detector. The detector consists of a special center-tapped IF transformer feeding two diodes. The schematic looks very much like a full wave DC rectifier circuit. Because the input transformer is tuned to the IF frequency, the output of the discriminator is zero when there is no deviation of the carrier; both halves of the center tapped transformer are balanced. As the FM signal swings in frequency above and below the carrier frequency, the balance between the two halves of the center-tapped secondary are destroyed and there is an output voltage proportional to the frequency deviation.



The discriminator has excellent linearity and is a good detector for WFM and NBFM signals. Its major drawback is that it also responds to AM signals. A good limiter must precede a discriminator to prevent AM noise from appearing in the output.

3. RATIO DETECTOR

The ratio detector is a variant of the discriminator. The circuit is similar to the discriminator, but in a ratio detector, the diodes conduct in opposite directions. Also, the output is not taken across the diodes, but between the sum of the diode voltages and the center tap. The output across the diodes is connected to a large capacitor, which eliminates AM noise in the ratio detector output. The operation of the ratio detector is very similar to the discriminator, but the output is only 50% of the output of a discriminator for the same input signal.



Descriptive questions

1) What are the various methods of generating an FM wave?
2) Explain generation of FM wave using a) parameter variation method b) Armstrong method?
3) What is Frequency multiplication?
4) What is FM demodulation?
5) Explain the operation of the following a) Balanced slope detector b) Foster seeley discriminator?
6) Explain the operation of the following a) slope detector b) Ratio detector?
7) Compare Ratio detector and foster seeley discriminator?
8) Compare different types of FM demodulators?
9) Why limiting is necessary in FM demodulators?

Objective questions

1) Generation of FM wave by indirect method is also called as ______
2) A frequency multiplier is a combination of a _____and a _____
3) Any oscillator whose frequency is controlled by the modulating signal voltage is called a ______
4) FM wave can be generated by ____________
5) ______ is a device whose output voltage is proportional to the instantaneous frequency of the FM wave applied to its input
6) VCO can be implemented by using a sinusoidal oscillator having a ______
7) A process that enables us to recover the original modulating wave from FM wave is called as ______
8) A frequency de modulator produces an output voltage whose instantaneous _______is directly proportional to the instantaneous _______ of the input FM wave
9) The frequency discriminator also can be used to demodulated _______signals
10) A simple approximation to the ideal discriminator is an _______ followed by an ______
11) What is the other name for phase discriminator ____________
12) Balanced slope detector uses ____slope detector which are connected back to back to the opposite ends of a center tapped transformer and hence fed ____out of phase
13) Better linearity is obtained in ______ than in _______
14) The other name for balanced slope detector _______
15) The shape of the response curve for foster –seeley discriminator ____
16) The disadvantage of ratio detector over foster seeley discriminator _________
17) The _____ is very widely used in practice
18) foster seeley discriminator is preferred in situations in which ____ is an important characteristic
19) In TV receivers for sound section which frequency detector is used ___________

TUTORIAL-5

1. An Armstrong FM modulator is required in order to transmit an audio signal of bandwidth 50Hz to 15kHz. The Narrowband (NB) phase modulator used for this purpose utilizes a crystal controlled oscillator to provide a carrier frequency of f_{c1}=0.2MHz. The output of the NB phase modulator is multiplied by n_1 by a multiplier and passed to a mixer with a local oscillator frequency f_{c2}=10.925MHz. The desired FM wave at the transmitter output has a carrier frequency f_c=90MHz, and a frequency deviation Δf=75kHz, which is obtained by multiplying the mixer output frequency with n_2 using another multiplier. Find n_1 and n_2. Assume that NBFM produces deviation of 25Hz for the lowest baseband signal.

2. A semiconductor junction diode is used to modulate the frequency of an oscillator. The junction capacitance is the total tuning capacitance of the oscillator tank circuit. When a d.c.bias voltage of 15volts is applied to the diode, the oscillator frequency generated is 5MHz. If a single-tone modulating voltage 4sin (12560t) modulated the carrier: find (a)the percentage second harmonic distortion; and (b) the frequency modulation index?

3. A Miller capacitance FM modulator utilizes an FET with the following parameters,
   g_{mo}=3m mho, V_p=2.5v, C_{gs}=2pF, C_{gd}=1.5pF and C_o=10pF. The oscillator frequency without modulation is 10MHz. The modulating signal is, $0.5\cos 2\pi 10^3 t$. Determine (i) the percentage second harmonic distortion if R_L=2K ohms.(ii)The frequency modulation index?

4. Show that a non-linear square-law device used for frequency multiplication of an FM signal doubles the carrier frequency as well as the frequency deviation?

UNIT-VI

NOISE

Objective:

Noise is ever present and limits the performance of virtually every system. The presence of noise degrades the performance of the Analog and digital communication systems. This chapter deals with how noise affects different Analog modulation techniques. After studying this chapter the should be familiar with the following

- Various performance measures of communication systems
- SNR calculations for DSB-SC, SSB-SC, Conventional AM, FM (threshold effect, threshold extension, pre-emphasis and de-emphasis) and PM.
- Figure of merit of All the above systems
- Comparisons of all analog modulation systems – Bandwidth efficiency, power efficiency, ease of implementation.

Key points:

- The presence of noise degrades the performance of the Analog and digital communication systems
- The extent to which the noise affects the performance of communication system is measured by the output signal-to-noise power ratio or the probability of error.
- The SNR is used to measure the performance of the Analog communication systems, whereas the probability of error is used as a performance measure of digital communication systems
- figure of merit = γ = SNR_o/SNR_i
- The loss or mutilation of the message at low predetection SNR is called as the threshold effect. The threshold occurs when SNR_i is about 10dB or less.
- Output SNR :

S_o= output signal power
S_i = input signal power

f_M = base band signal frequency range
The input noise is white with spectral density = $\eta/2$

1. SSB-SC:

$S_o/S_i = 1/4$

$N_o = \eta f_M/4$

$SNR_o = S_i/\eta f_M$

2. DSB-SC:

$S_o/S_i = 1/2$

$N_o = \eta f_M/2$

$SNR_o = S_i/\eta f_M$

3. DSB-FC:

$SNR_o = \{m^2/(2+m^2)\}S_i/\eta f_M$

- Figure of merit of FM:

  $\gamma_{FM} = 3/2\beta^2$
- Figure of merit of AM & FM :

  $\gamma_{FM}/\gamma_{AM} = 9/2\beta^2 = 9/2\,(B_{FM}/B_{AM})^2$
- The noise power spectral density at the output of the demodulator in PM is flat within the message bandwidth whereas for FM the noise power spectrum has a parabolic shape.
- The modulator filter which emphasizes high frequencies is called the pre-emphasis filter(HPF) and the demodulator filter which is the inverse of the modulator filter is called the de-emphasis filter(LPF).

Descriptive Questions:

1. Explain how noise affects performance of analog modulation systems?
2. Derive SNR for DSB-SC, SSB-SC and conventional AM?
3. Derive SNR for FM and PM?
4. Explain the following
   a) threshold effect
   b) threshold extension
   c) pre-emphasis
   d) de-emphasis
5. What is figure of merit?
6. Compare all analog modulation systems with respect to SNR, Band width efficiency, power efficiency, ease of implementation, and figure of merit?

Objective Questions:

1) The extent to which noise affects the performance of communication system is measured by the ________
2) _______ is used to measure the performance of analog communication system
3) ________ is used to measure the performance of digital communication system
4) Detector gain or figure of merit is = ____________
5) Output SNR in AM is at least ____ worse than that in DSB &SSB system
6) The figure of merit of SSB SC is _____________
7) The figure of merit of DSB with sinusoidal modulation is ________
8) Above threshold the synchronous demodulator the square law de modulator, and the envelope demodulator all perform, provided ____________
9) Threshold in square law demodulation is ______than the threshold in envelope demodulation
10) On weak signals synchronous demodulation does best since it exhibits _____ threshold.
11) The ratio of SNR at output to input for an AM wave is _____
12) The ratio of figure of merit of an AM wave to FM wave is _____
13) The pre modulation filtering in the transmitter to raise the power spectral density of the base band signal in its _____ is called pre emphasis
14) Pre emphasis is particularly effective in ______
15) The filtering at the receiver to undo the signal _____ and to suppress noise is called _______
16) Figure of merit of DSB-SC is ____________
17) When the input noise is not small in comparison with the input signal power, the system performance may be improved by restricting the ____ by reducing the _____
18) In SSB-SC, So/ S_i =______
19) In DSB SC S_o/ S_i= ____
20) The limiter is used to suppress ______variation of carrier

TUTORIAL – 6

1. The message signal m(t) has a bandwidth of 10KHz, a power of 16W and a maximum amplitude of 6.It is desirable to transmit this message to a destination via a channel with 80dB attenuation and additive white noise with power-spectral density $S_n(f)= N_0/2 =10^{-12}$W/Hz, and achieve a SNR at the modulator output of at least 50dB.What is the required transmitter power and channel bandwidth if the following modulation schemes are employed?

   a) DSB AM b)SSB AM c)Conventional AM with modulation index=0.8

2. Design an FM system that achieves an SNR at the receiver equal to 40dB and requires the minimum amount of transmitter power. The bandwidth of the channel is 120KHz,the message bandwidth is 10KHz,the average-to-peak-power ratio for the message,$P_{Mn}=P_M/(\max|m(t)|)^2$ is ½, and the (one sided)noise power spectral density is $N_0=10^{-8}$W/Hz.What is the required transmitter power if the signal is attenuated by 40dB in transmission through the channel?

3. A certain communication channel is characterized by 90dB attenuation and additive white noise with power-spectral density of $N_0/2 =0.5\times10^{-14}$W/Hz.The bandwidth of the message signal is 1.5MHz and its amplitude is uniformly distributed in the interval [-1,1].If we require that the SNR after demodulation be 30dB,in each of the following cases find the necessary transmitter power.

   a)SSB b)DSBSC c)Conventional AM with modulation index=0.5

4. In a broadcasting communication system the transmitter power is 40KW, the channel attenuation is 80dB, and the noise power-spectral density is 10^{-10}W/Hz.The message signal has a bandwidth of 10^4Hz.

   a) find the predetection SNR(SNR in r(t)=ku(t)+n(t))

   b)find the output SNR if the modulation is DSB

   c) find the output SNR if the modulation is SSB

   d)find the output SNR if the modulation is conventional AM with a modulation index of 0.85 and normalized message power of 0.2.

5. A communication channel has a bandwidth of 100KHz.This channel is to be used for transmission of an analog source m(t),where |m(t)|<1, whose bandwidth is W=4KHz. The power content of the message signal is 0.1W.

   a)find the ratio of the output SNR of an FM system that utilizes the whole bandwidth, to the output SNR of a conventional AM system with a modulation index of a=0.85? what is this ratio in dB?

   b)Show that if an FM system and a PM system are employed and these systems have the same output signal to noise ratio, we have

$$\frac{B_{PM}}{B_{FM}} = \frac{\sqrt{3}\beta_f + 1}{\beta_f + 1}$$

6. The normalized message signal $m_n(t)$ has a bandwidth of 5000Hz and power of 0.1W,and the channel has a band width of 100KHz and attenuation of 80dB. The noise is white with power spectral density $0.5x10^{-12}$W/Hz and the transmitter power is 10KW.

   a)If AM with a=0.8 is employed what is SNR_o?

   b) If FM is employed what is the highest possible SNR_o?

7. The normalized message signal has a bandwidth of W=8 KHz and power of P_{Mn}=0.5. It is required to transmit this signal via a channel with an available band width of 60 KHz and attenuation of 40dB. The channel noise is additive and white with power spectral density of $N_o/2=10^{-12}$W/Hz. A frequency modulation scheme, with no pre-emphasis/de-emphasis filtering, has been proposed for this purpose.

   a. If it is desirable to have an SNR of at least 40dB at the receiver output, what is the minimum required transmitter power and the corresponding modulation index?

   b. If the minimum required SNR is increased to 60dB, how would your answer change?

   c. If in part b, we are allowed to employ pre-emphasis/de-emphasis filters with a time constant of τ =75 μsec?

UNIT VII

RECEIVERS

Introduction

This unit centers around basic principles of the super heterodyne receiver. In the article, we will discuss the reasons for the use of the super heterodyne and various topics which concern its design, such as the choice of intermediate frequency, the use of its RF stage, oscillator tracking, band spread tuning and frequency synthesis. Most of the information is standard text book material, but put together as an introductory article, it can provide somewhere to start if you are contemplating building a receiver, or if you are considering examining specifications with an objective to select a receiver for purchase.

TRF Receiver

Early valve radio receivers were of the Tuned Radio Frequency (TRF) type consisting of one or a number of tuned radio frequency stages with individual tuned circuits which provided the selectivity to separate one received signal from the others. A typical receiver copied from a 1929 issue of "The Listener In" is shown in Figure 1. Tuned circuits are separated by the radio frequency (RF) amplifier stages and the last tuned circuit feeds the AM detector stage. This receiver belongs to an era before the introduction of the screen grid valve and it is interesting to observe the grid-plate capacity neutralisation applied to the triode RF amplifiers to maintain amplifier stability. In these early receivers, the individual tuning capacitors were attached to separate tuning dials, as shown in Figure 2, and each of these dials had to be reset each time a different station was selected. Designs evolved for receivers with only one tuning dial, achieved by various methods of mechanical ganging the tuning capacitors, including the ganged multiple tuning capacitor with a common rotor shaft as used today.

The bandwidth of a tuned circuit of given Q is directly proportional to its operational frequency and hence, as higher and higher operating frequencies came into use, it became more difficult to achieve sufficient selectivity using the TRF

Receiver system.

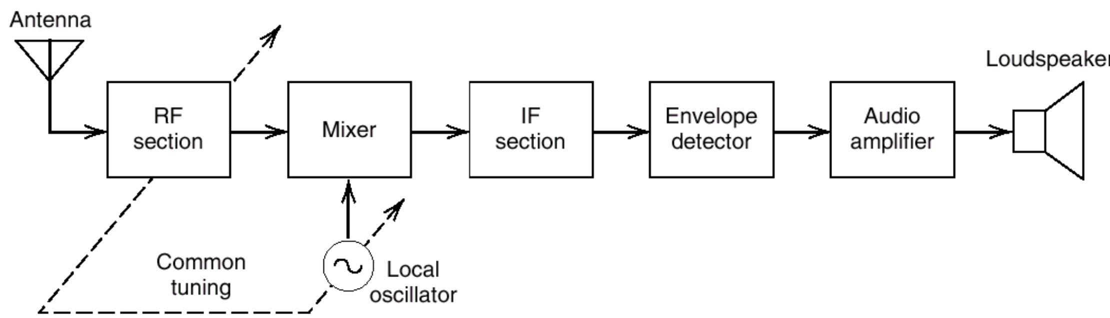


FIGURE: AM RECEIVER

The Super Heterodyne Principle

The super heterodyne (short for supersonic heterodyne) receiver was first evolved by Major Edwin Howard Armstrong, in 1918. It was introduced to the market place in the late 1920s and gradually phased out the TRF receiver during the 1930s.

The principle of operation in the super heterodyne is illustrated by the diagram in Figure 4. In this system, the incoming signal is mixed with a local oscillator to produce sum and difference frequency components. The lower frequency difference component called the intermediate frequency (IF), is separated from the other components by fixed tuned amplifier stages set to the intermediate frequency. The tuning of the local oscillator is mechanically ganged to the tuning of the signal circuit or radio frequency (RF) stages so that the difference intermediate frequency is always the same fixed value. Detection takes place at intermediate frequency instead of at radio frequency as in the TRF receiver.

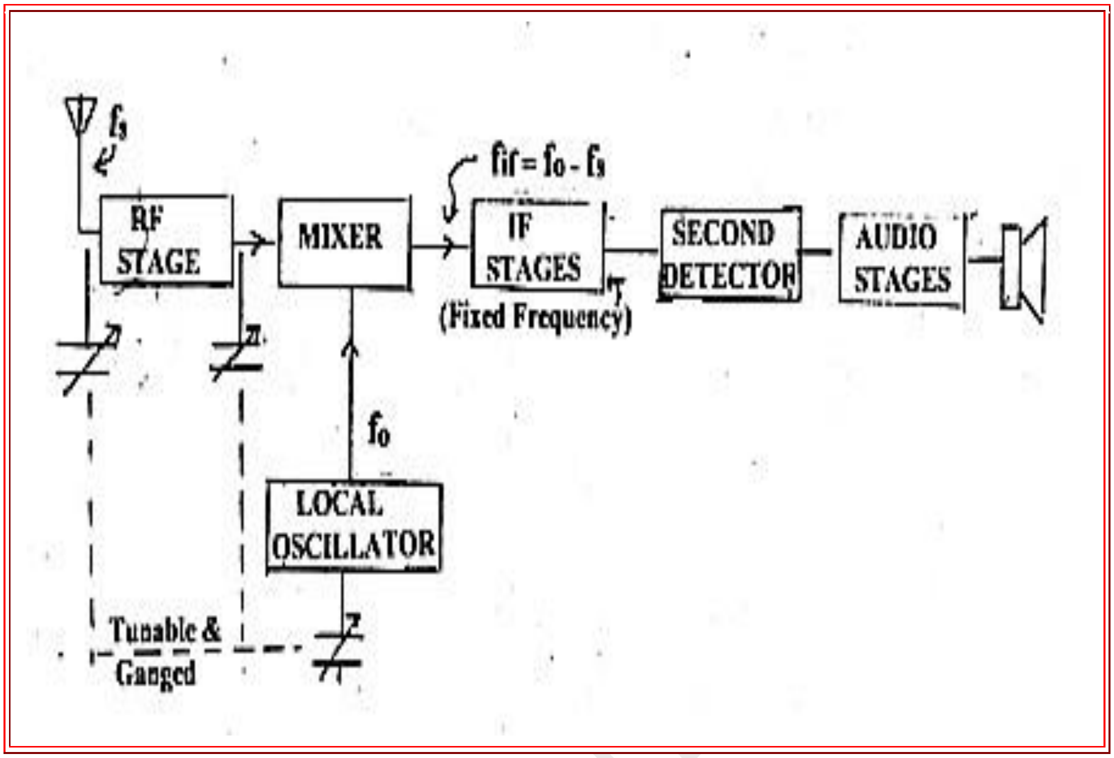


Figure : Super heterodyne Receiver.

Use of the fixed lower IF channel gives the following advantages:

1. For a given Q factor in the tuned circuits, the bandwidth is lower making it easier to achieve the required selectivity.

2. At lower frequencies, circuit losses are often lower allowing higher Q factors to be achieved and hence, even greater selectivity and higher gain in the tuned circuits.

3. It is easier to control, or shape, the bandwidth characteristic at one fixed frequency. Filters can be easily designed with a desired band pass characteristic and slope characteristic, an impossible task for circuits which tune over a range of frequencies.

4. Since the receiver selectivity and most of the receiver pre-detection gain, are both controlled by the fixed IF stages, the selectivity and gain of the super heterodyne receiver are more consistent over its tuning range than in the TRF receiver.

<u>Second Channel or Image frequency</u>

One problem, which has to be contended within the super heterodyne receiver, is its ability to pick up a second or imago frequency removed from the signal frequency by a value equal to twice the intermediate frequency.

To illustrate the point, refer Figure 5. In this example, we have a signal frequency of 1 MHz which mix to produce an IFof 455kHz. A second or image signal, with a frequency equal to 1 MHz plus (2 x 455) kHz or 1.910 MHz, can also mix with the 1.455 MHz to produce the 455 kHz.

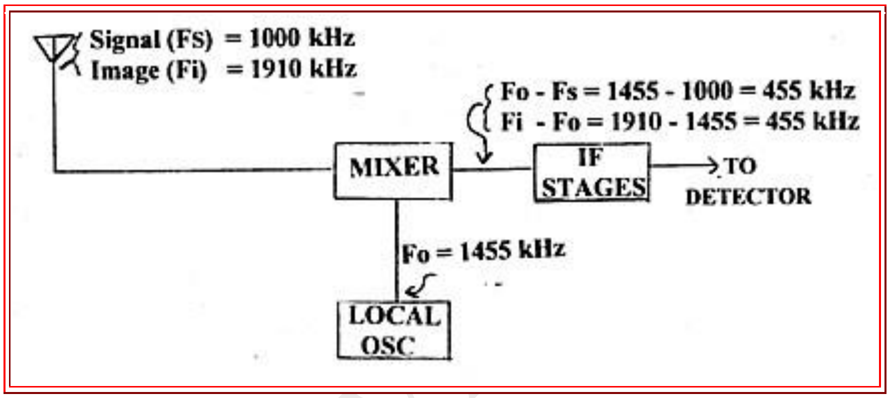


Figure : An illustration of how image frequency provides a second mixing product.

Reception of an image signal is obviously undesirable and a function of the RF tuned circuits (ahead of the mixer), is to provide sufficient selectivity to reduce the image sensitivity of the receiver to tolerable levels.

<u>Choice of intermediate frequency</u>

Choosing a suitable intermediate frequency is a matter of compromise. The lower the IF used, the easier it is to achieve a narrow bandwidth to obtain good selectivity in the receiver and the greater the IF stage gain. On the other hand, the higher the IF, the further removed is the image frequency from the signal frequency and hence the better the image rejection. The choice of IF is also affected by the selectivity of the RF end of the receiver. If the receiver has a number of RF stages, it is better able to reject an image signal close to the signal frequency and hence a lower IF channel can be tolerated.

Another factor to be considered is the maximum operating frequency the receiver. Assuming Q to be reasonably constant, bandwidth of a tuned circuit is directly proportional to its resonant frequency and hence, the receiver has its widest RF bandwidth and poorest image rejection at the highest frequency end of its tuning range.

A number of further factors influence the choice of the intermediate frequency:

1. The frequency should be free from radio interference. Standard intermediate frequencies have been established and these are kept dear of signal channel allocation. If possible, one of these standard frequencies should be used.

2. An intermediate frequency which is close to some part of the tuning range of the receiver is avoided as this leads to instability when the receiver is tuned near thefrequency of the IF channel.

3. Ideally, low order harmonics of the intermediate frequency (particularly second and third order) should not fall within the tuning range of the receiver. This requirement cannot always be achieved resulting in possible heterodyne whistles at certain spots within the tuning range.

4. Sometimes, quite a high intermediate frequency is chosen because the channel must pass very wide band signals such as those modulated by 5 MHz video used in television. In this case the wide bandwidth circuits are difficult to achieve unless quite high frequencies are used.

5. For reasons outlined previously, the intermediate frequency is normally lower than the RF or signal frequency. However, there we some applications, such as in tuning the Low Frequency (LF) band, where this situation could be reversed. In this case, there are difficulties in making the local oscillator track with the signal circuits.

Some modern continuous coverage HF receivers make use of the Wadley Loop or a synthesised VFO to achieve a stable first oscillator source and these have a first intermediate frequency above the highest signal frequency. The reasons for this will be discussed later.

Standard intermediate frequencies

Various Intermediate frequencies have been standardised over the years. In the early days of the superheterodyne, 175 kHz was used for broadcast receivers in the USA and Australia. These receivers were notorious for their heterodyne whistles caused by images of broadcast stations other than the one tuned. The 175 kHz IF was soon overtaken by a 465 kHz allocation which gave better image response. Another compromise of 262kHz between 175 and 465 was also used to a lesser extent. The 465 kHz was eventually changed to 455 kHz, still in use today.

In Europe, long wave broadcasting took place within the band of 150 to 350 kHz and a more suitable IF of 110 kHz was utilised for this band.

The IF of 455 kHz is standard for broadcast receivers including many communication receivers. Generally speaking, it leads to poor image response when used above 10 MHz. The widely used World War 2 Kingsley AR7 receiver used an IF of 455 kHz but it also utillised two RF stages to achieve improved RF selectivity and better image response. One commonly used IF for shortwave receivers is 1.600 MHz and this gives a much improved image response for the HF spectrum.

Amateur band SSB HF transceivers have commonly used 9 MHz as a receiver intermediate frequency in common with its use as a transmitter intermediate frequency. This frequency is a little high for ordinary tuned circuits to achieve the narrow bandwidth needed in speech communication; however, the bandwidth in the amateur transceivers is controlled by specially designed ceramic crystal filter networks in the IF channel.

Some recent amateur transceivers use intermediate frequencies slightly below 9 MHz. A frequency of 8.830 MHz can be found in various Kenwood transceivers and a frequency of 8.987.5 MHz in some Yaesu transceivers. This change could possibly be to avoid the second harmonic of the IF falling too near the edge of the more recently allocated 18 MHz WARC band. (The edge of the band is 18.068 MHz).

General coverage receivers using the Wadley Loop, or a synthesised band set VFO, commonly use first IF channels in the region of 40 to 50 MHz

An IF standard for VHF FM broadcast receivers is 10.7 MHz In this case, the FM deviation used is 75 kHz and audio range is 15 kHz. The higher IF is very suitable as the wide bandwidth is easily obtained with good image rejection. A less common IF is 4.300 MHz believed to have been used in receivers tuning the lower end of the VHF spectrum.

As explained earlier, a very high intermediate frequency is necessary to achieve the wide bandwidth needed for television and the standard in Australia is the frequency segment of 30.500 to 30.6.000 MHz

Multiple Conversion Super Heterodyne Receiver

In receivers tuning the upper HF and the VHF bands, two (or even more) IF channels are commonly used with two (or more) stages of frequency conversion. The lowest frequency IF channel provides the selectivity or bandwidth control that is needed and the highest frequency IF channel is used to achieve good Image rejection. A typical system used in two meter FM amateur transceivers is shown in Figure 6. In this system, IF channels of 10.7 MHz and 455 kHz are used with double conversion. The requirement Is different to that of the wideband FM broadcasting system as frequency deviation is only 5 kHz with an audio frequency spectrum limited to below 2.5 kHz. Channel spacing is 25 kHz and bandwidth is usually limited to less than 15 kHz so that the narrower bandwidth 455 kHz IF channel is suitable.

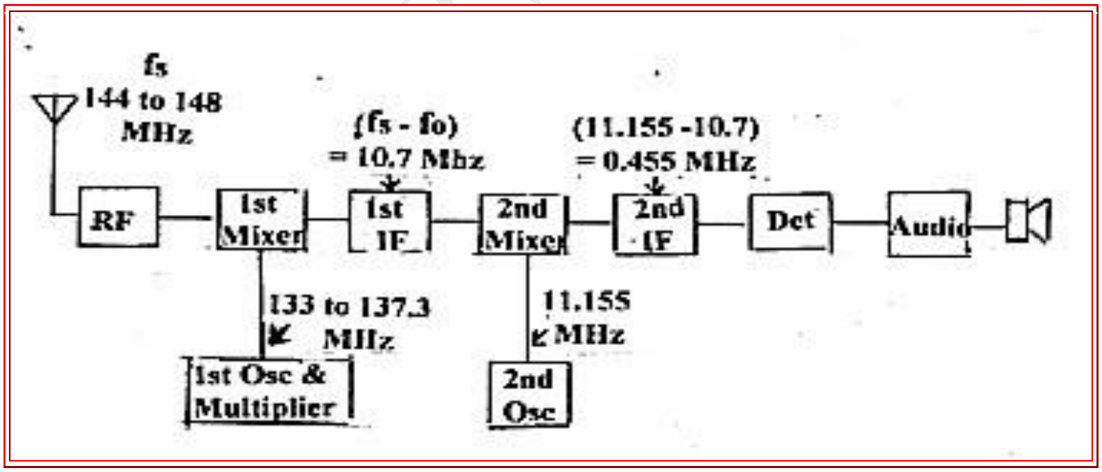


Figure : Receiver using Double Conversion.

Some modern HF SSB transceivers use a very high frequency IF channel such as 50 MHz. Combined with this, a last IF channel of 455 KHz is used to provide selectivity and bandwidth control. Where there is such a large difference between the first and last intermediate frequency, three stages of conversion and a middle frequency IF channel are needed. This is necessary to prevent on image problem initiating in the 50 MHz IF channel due to insufficient selectivity in that channel. For satisfactory operation, the writer suggests a rule of thumb that the frequency ratio between the RF channel and the first IF channel, or between subsequent IF channels, should not exceed a value of 10.

The RF Amplifier

A good receiver has at least one tuned RF amplifier stage ahead of the first mixer. As discussed earlier, one function of the RF stage is to reduce the image frequency level into the mixer. The RF stage also carries out a number of other useful functions:

1. The noise figure of a receiver is essentially determined by the noise generated in the first stage connected to the aerial system. Mixer stages are inherently more noisy than straight amplifiers and a function of the RF amplifier is to raise the signal level into the mixer so that the signal to noise ratio is determined by the RF amplifier characteristics rather than those of the mixer.

2. There Is generally an optimum signal Input level for mixer stages. If the signal level is increased beyond this optimum point, the levels of inter modulation products steeply increase and these products can cause undesirable effects in the receiver performance. If the signal level is too low, the signal to noise rate will be poor. A function of the RF amplifier is to regulate the signal level into the mixer to maintain a more constant, near optimum, level. To achieve this regulation, the gain of the RF stage is controlled by an automatic gain control system, or a manual gain control system, or both.

3. Because of its non-linear characteristic, the mixer is more prone to cross-modulation from a strong signal on a different frequency than is the RF amplifier. The RF tuned circuits, ahead of the mixer, help to reduce the level of the unwanted signal into the mixer input and hence reduce the susceptibility of the mixer to cross-modulation.

4. If, by chance, a signal exists at or near the IF, the RF tuned circuits provide attenuation to that signal.

5. The RF stage provides isolation to prevent signals from the local oscillator reaching the aerial and causing interference by being radiated.

Oscillator Tracking

Whilst the local oscillator circuit tunes over a change in frequency equal to that of the RF circuits, the actual frequency is normally higher to produce the IF frequency difference component and hence less tuning capacity change is needed than in the RF tuned circuits. Where a variable tuning gang capacitor has sections of the same capacitance range used for both RF and oscillator tuning, tracking of the oscillator and RF tuned circuits is achieved by capacitive trimming and padding.

Figure shows a local oscillator tuned circuit (L2,C2) ganged to an RF tuned circuit (Ll,Cl) with Cl and C2 on a common rotor shaft. The values of inductance are set so that at the centre of the tuning range, the oscillator circuit tunes to a frequency equal to RF or signal frequency plus intermediate frequency.

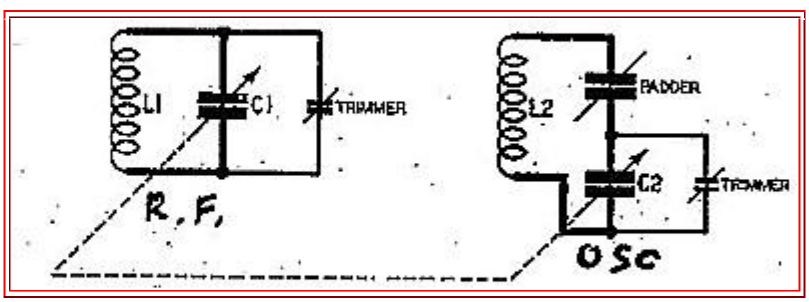


Figure : Tracking Circuit

A capacitor called a padder, in series with the oscillator tuned circuit, reduces the maximum capacity in that tuning section so that the circuit tracks with the RF section near the low frequency end of the band.

Small trimming capacitors are connected across both the RF and oscillator tuned circuits to adjust the minimum tuning capacity and affect the high frequency end of the band. The oscillator trimmer is preset with a little more capacity than the RF trimmer so that the oscillator circuit tracks with RF trimmer near the high frequency end of the band.

Curve A is the RF tuning range. The solid curve B shows the ideal tuning range required for the oscillator with a constant difference frequency over the whole tuning range. Curve C shows what would happen if no padding or trimming were applied. Dotted curve B shows the correction applied by padding and trimming. Precise tracking is achieved at three points in the tuning range with a tolerable error between these points.

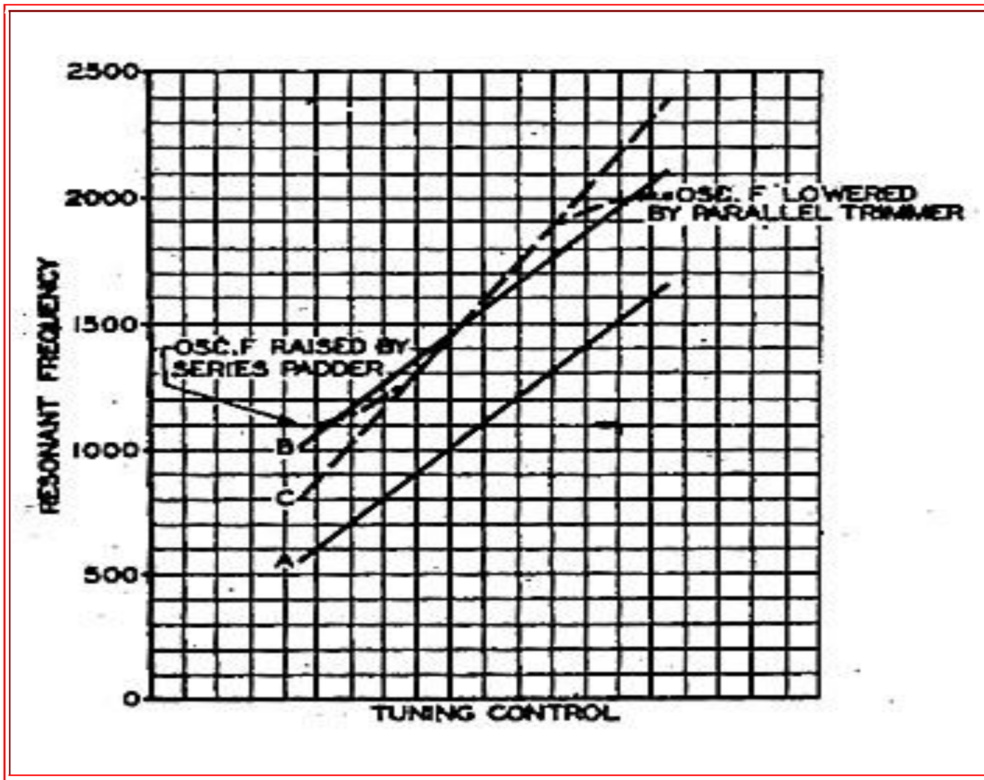


Figure: RF and Oscillator Tracking

Where more than one band is tuned, not only are separate inductors required for each band, but also separate trimming and padding capacitors, as the degree of capacitance change correction is different for each band.

The need for a padding capacitor can be eliminated one band by using a tuning gang capacitor with a smaller number of plates in the oscillator section than in the RF sections. If tuning more than one band, the correct choice of capacitance for the oscillator section will not be the same for all bands and padding will still be required on other bands.

Alignment of the tuned circuits can be achieved by providing adjustable trimmers and padders. In these days of adjustable magnetic cores in the inductors, the padding capacitor is likely to be fixed with the lower frequency end of the band essentially set by the adjustable cores.

OSCILLATOR STABILITY

The higher the input frequency of a receiver, the higher is the first local oscillator frequency and the greater is the need for oscillator stability. A given percentage frequency drift at higher frequencies amounts to a larger percentage drift in IF at the detector. Good stability is particularly important in a single sideband receiver as a small change in signal frequency is very noticeable as a change in the speech quality, more so than would be noticeable in AM or FM systems.

Frequency stability in an oscillator can be improved by care in the way it is designed and built. Some good notes on how to build a stable variable frequency oscillator were prepared by Draw Diamond VK3XU, and published in Amateur Radio, January 1 1998.

One way to stabilize a receiver tunable oscillator is to use an automatic frequency control (AFC) system. To do this, a frequency discriminator can be operated from the last IF stage and its output fed back via a low pass filter (or long time constant circuit) to a frequency sensitive element in the oscillator. Many of today's receivers and transceivers also make use of phase locked loop techniques to achieve frequency control.

Where there are several stages of frequency conversion and the front end is tuned, the following oscillator stages, associated with later stage conversion, are usually fixed in frequency and can be made stable by quartz crystal control. In this case, receiver frequency stability is set by the first oscillator stability.

One arrangement, which can give better stability, is to crystal lock the first oscillator stage but tune the first IF stage and second oscillator stage as shown in Figure. In this case, the RF tuned circuits are sufficiently broadband to cover a limited tuning range (such as an amateur band) but selective enough to attenuate the image frequency and other possible unwanted signals outside the tuning range. This is the method used when a converter Is added to the front end of a HF receiver to tune say the two meter band.

The RF circuits in the converter are fixed, the converter oscillator is crystal locked and the HF receiver RF and first oscillator circuits become the tunable first IF stage and second tunable oscillator, respectively. Since the HF receiver tunable oscillator is working at a lower frequency than the first oscillator in the converter, the whole system is inherently more stable than if the converter oscillator were tuned. As stated earlier, the system is restricted to a limited tuning range and this leads to a discussion on band spread tuning and other systems incorporating such ideas as the Wadley Loop.

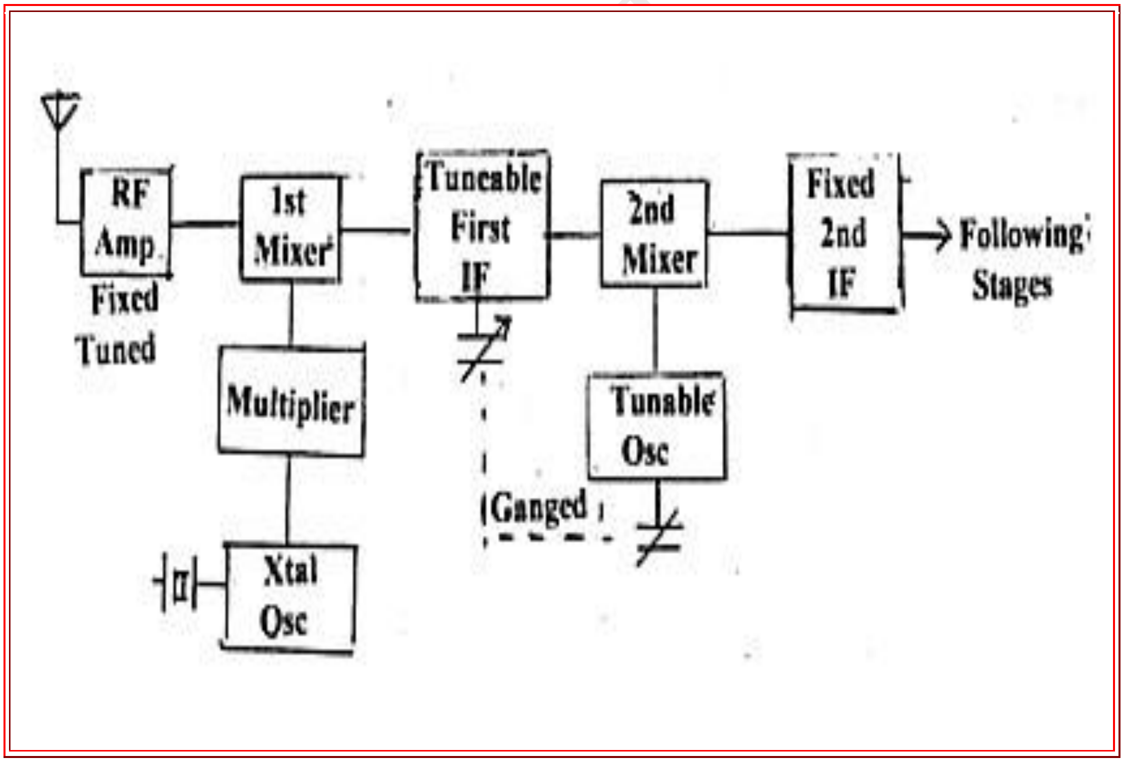


Figure 9: Tuning at the First IF and Second Heterodyne Oscillator Level.

UNIT-VIII

PULSE MODULATION SYSTEMS

Pulse Time Modulation:

Pulse Width Modulation & Pulse Position Modulation

Pulse Time Modulation (PTM) is a class of signaling technique that encodes the *sample values* of an analog signal onto the *time axis* of a digital signal.

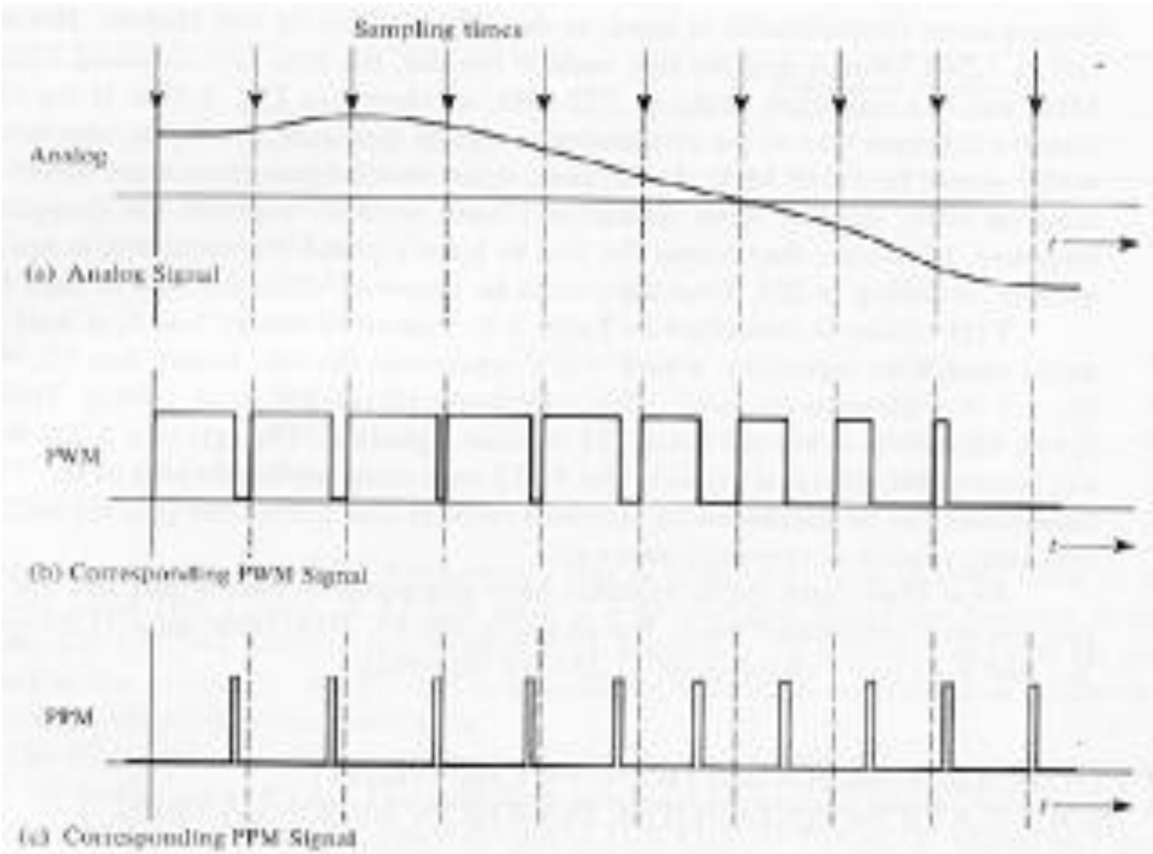
The two main types of pulse time modulation are:

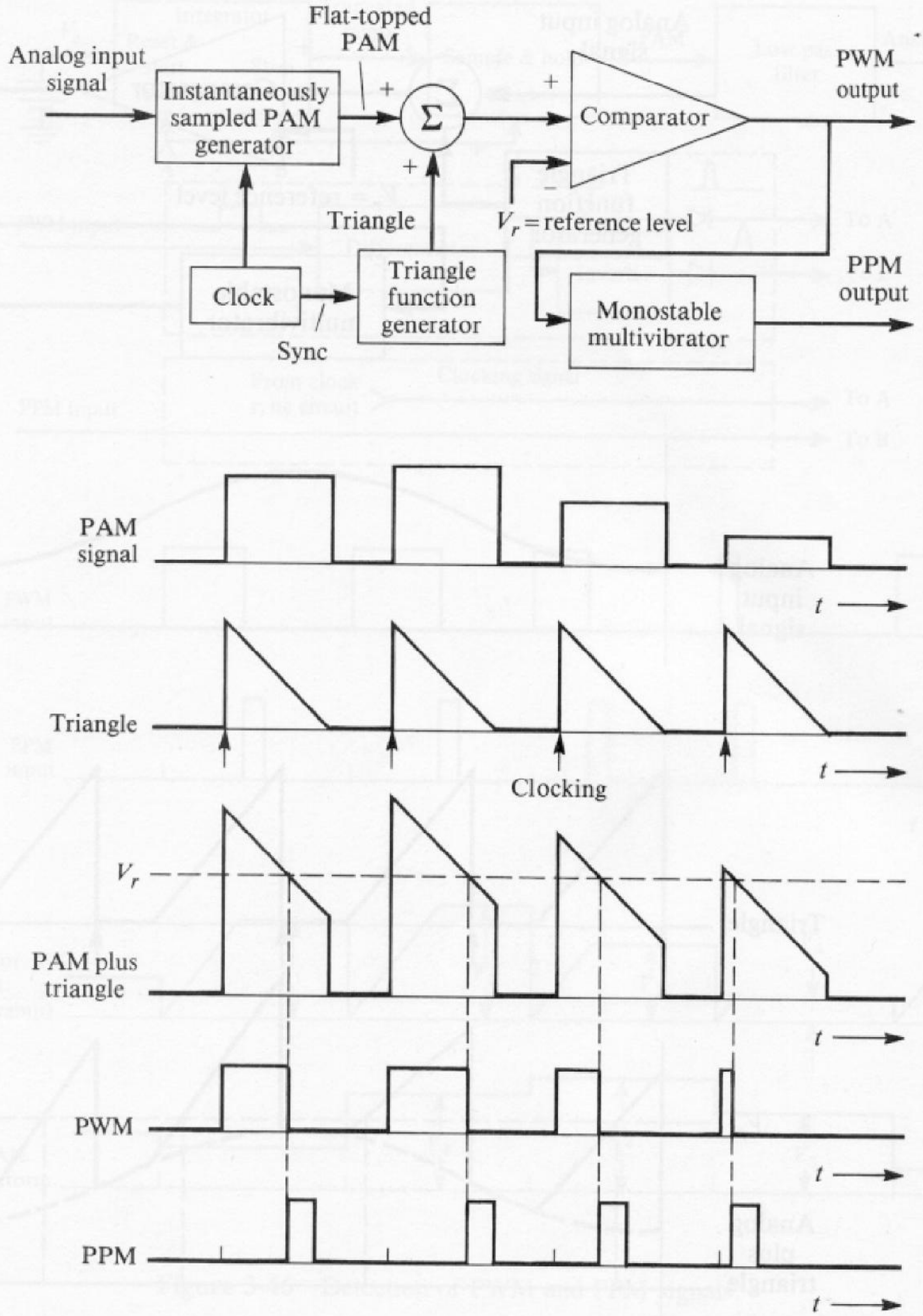
1. Pulse Width Modulation (PWM)
2. Pulse Position Modulation (PPM)

In PWM the sample values of the analog waveform are used to determine the width of the pulse signal. Either instantaneous or natural sampling can be used.

In PPM the analog sample values determine the position of a narrow pulse relative to the clocking time. It is possible to obtain PPM from PWM by using a mono-stable multivibrator circuit.

Figure below shows PWM generation using *instantaneous sampling*





Technique for generating instantaneously sampled PTM signals.

Figure shows PWM signal generation using *natural sampling*.

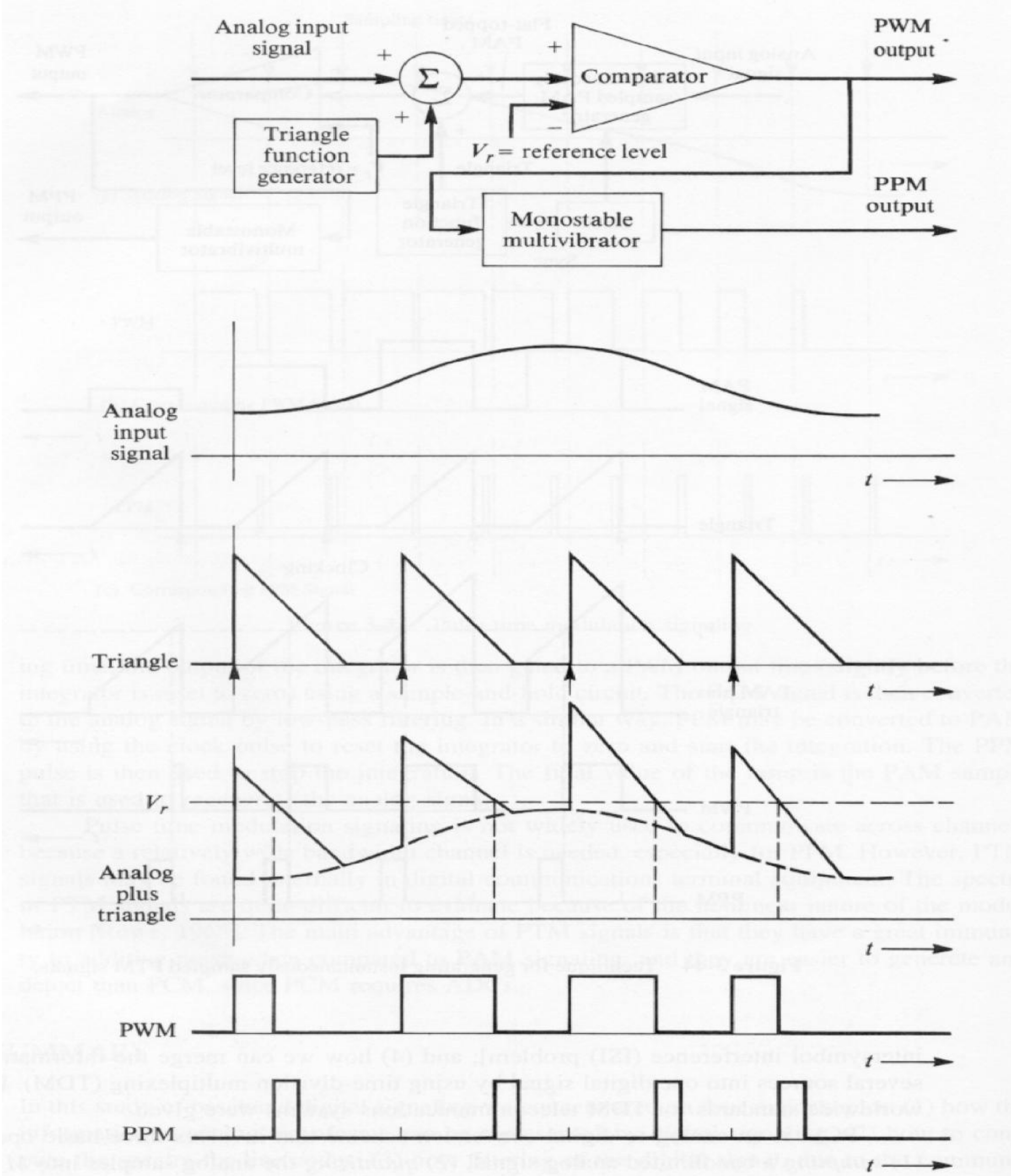
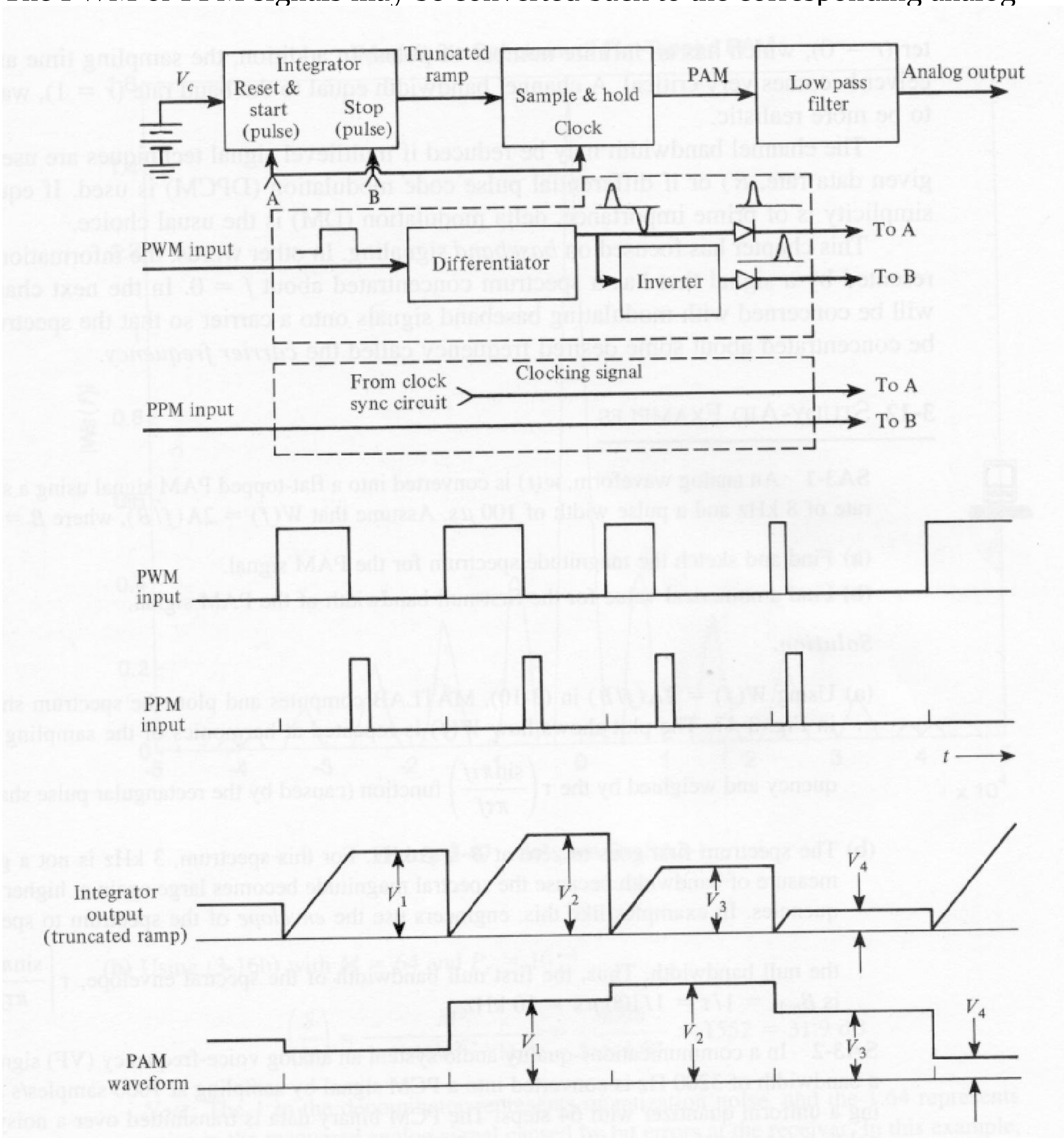


Figure 3-45 Technique for generating naturally sampled PTM signals.

The PWM or PPM signals may be converted back to the corresponding analog



Detection of PWM and PPM signals.

For PWM detection the PWM signal is used to start and stop the integration of the integrator. After reset integrator starts to integrate during the duration of the pulse and will continue to do so till the pulse goes low.

If integrator has a DC voltage connected as input , the output will be a truncated ramp. After the PWM signal goes low, the amplitude of the truncated ramp will be equal to the corresponding PAM sample value. Then it goes to zero with reset of the integrator.

QUESTION BANK (Old question papers)

1. a) Give the complete analysis of a diode detector and explain its operation. Obtain an expression for its efficiency. Account for distortion and discuss the methods to reduce them.
   b) What is Amplitude modulation? Show that a nonlinear device can be used for generating AM signal. What are its limitations?

2. a) Draw the block diagram of a phase cancellation SSB generation and explain how the carrier and unwanted side bands are suppressed. What changes are necessary to suppress the other sideband?

3. b)Calculate the percentage of power saving when the carrier and one of the sidebands are suppressed in an AM wave modulated to a depth of
   (i) 100% (ii) 50%.

4. Explain the operation of a square law detector and compare it with envelope detector.

b) The signal $v(t) = (1 + 0.1\cos\omega_1 t + 0.1\cos 2\omega_1 t)\cos\omega_c t$ is detected by a square law detector $Vo = 2v^2$. Draw the amplitude -frequency characteristic of vo(t).

5. a) Explain with the help of a block diagram SSB signal generation using phase discrimination method. State the advantage of SSB modulation over DSB.
   b)Consider a composite wave obtained by adding a non coherent carrier $A_c \cos(2\Pi f_c t + \phi)$ to DSB-SC wave $X(t)\cos(2\Pi f_c t)$ where $X(t)$ is the message waveform. This composite waveform is applied to ideal envelope detector. Find the resulting detector out put.
   c) Evaluate this for (1) $\phi = 0$ *and* (2) $\phi \neq 0$ *and* $|X(t)| << A_c$

6. Show that for an AM wave

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

Pt	=	Total Power
Pc	=	Carrier Power
m	=	modulation index.

7. Differentiate between SSB and VSB systems

8. Draw the circuit of practical diode detector for AM signals and explain its operation.

9. a) Explain third method of SSB generators with a neat block diagram.
b) Define and describe VSB Transmission. What is its application? What are its merits?

10. The antenna current of an AM Transmitter is 8A when only the carrier is sent, but it increases to 8.93A when the carrier is modulated by a single sine wave. Find the percentage modulation. Determine the antenna current when the Depth of modulation changes to 0.8?

11. a) What are the types of distortions in diode detectors and explain them. How to reduce theses distortions.
b) Explain envelope detection of AM signals.

12. a)Explain third method of SSB generators with a neat block diagram.
b)Define and describe VSB Transmission. What is its application? What are its merits?

13. a) Derive the formula for instantaneous value of AM voltage.
b) Explain the filter method and phase shift method to generate SSB signals.

14. a) Draw the practical diode detector circuit and explain the function of each component in it.
b) A 360 w carrier is simultaneously Amplitude modulated by two audio waves with modulation percentages of 55 and 65 respectively. What is the total sideband power radiated.

15. a)What is the need for modulation
b) Explain phase shift method of SSB signal generation with neat block diagram.

16. a) Explain the concept of frequency translation using the spectrum of DSB-SC wave.
b) Explain with block diagram the phase-shift method of sideband suppression.

17. a) Explain the operation of square law modulator.
b) Explain the phase discrimination method for generating an SSB modulated wave.

18. a) Give & explain radio frequency spectrum used for various communications.
b) Draw the block diagram of a filter type SSB-SC transmitter with 20 KHZ oscillator and emission frequency in the range of 6 MHZ. Explain the function of each stage.

19. a) An AM transmitter of 1KW power is fully modulated. Calculate the power transmitted if it is transmitted as SSB.

b) Calculate the filter requirement to convert DSB signal to SSB Signal, given that the two side bands are separated by 200HZ. The suppressed carrier is 29 MHZ.

20. a)What are the disadvantages of SSB-SC over normal AM. And compare AM And FM.
b)Explain the frequency discrimination method for generating an SSB modulated wave.

21. Write the expressions for AM,DSB-SC and SSB signals. Draw their time and frequency plots.
a) An AM wave $10[1 + 0.6\cos 2000\pi t]$ cos $200000\pi t$ is to be detected by a linear diode detector. Find the time constant and the resistance for C= 100PF.
b) Describe the generation of VSB signal.
c) Consider a square law detector using a non linear device whose transfer characteristics is defined by $v_2(t) = a_1 v_1(t) + a_2 v_1^2(t)$ where a_1 and a_2 are constants. v_1 is the input and v_2 is the output. The input consists of an AM wave $v_1(t) = A_c[1 + K_a m(t)]\cos(2\Pi f_c t)$. Evaluate $v_2(t)$ and find the condition to extract the signal $v_2(t)$.

22. a) Derive the Expression for AM and DSB-SC signals.
b) Sketch the spectrum of s(t)=50(1+0.7 cos 500t–0.3 cos 1000t)x sin 100000 π t.
c) Evaluate the modulated and sideband powers.
d) With the help of neat block diagram, explain the generation and detection of SSB signal.

23. a) Describe the relationship between FM and PM. Derive the FM equation for Narrow Band and Wide Band FM signals and explain their spectral features.
b) What is zero crossing detectors? Explain how it works and can be used as an FM demodulator?

24. a) Explain the Foster – Seely discriminator.
b) Explain the demodulation of FM signals.

25. Draw the phasor diagram for an angle modulated signal corrupted by additive noise and explain.

26. a. An angle modulated signal has the form $v(t) = 100\cos(2\Pi f_c\, t + 4\sin 2000\,\Pi t)$ when f_c = 10 MHz. (a)Determine the average transmitted power.(b) Determine the peak phase deviation.(c) Determine the peak frequency deviation.(d) Is this an FM or a PM signal? Explain.
b. Bring out the comparison between FM and AM.

27. a. Explain the method of FM demodulator.
b. Distinguish between envelop detection and synchronous detection methods.

28. Draw the schematic diagram of the modulator demodulator for FM and prove the signal to noise power ratio at the demodulator output
(SNR)0, fm=3Ac^2 k f ^{2} p /2NoW^3.

29. a)Explain how the frequency modulation is generated using Armstrong system with neat block diagram. In which circumstances can we dispense with the mixer?
b)When the modulation frequency in FM system is 400 Hz and modulating voltage is 2.4v the modulating index is 60. Calculate the maximum deviation. What is the modulation index when the modulating frequency is reduced to 250Hz and the modulating voltage is simultaneously raised to 3.2V?

30. a) Explain the Foster – Seely discriminator.
b) Explain the demodulation of FM signals.

31. a) Draw the receiver model and explain its various functional blocks.
Define (i) input SNR
(ii) Output SNR
(iii) Channel SNR
(iv) Figure of merit

32. a) Distinguish between phase and frequency modulation. Show that FM can be derived using PM and vice versa with the help of differentiator or integrator networks.
b) Compute the bandwidth requirement for the transmission of FM signal having a frequency deviation 75 KHz and an audio bandwidth of 10 KHz.

33. a) Explain the method of FM demodulator.
b) Distinguish between envelop detection and synchronous detection methods.

34. Derive for SNR and Figure of merit in AM receivers.

35. When the modulating frequencies in an FM system is 400Hz and the modulating voltage is 2.4v the modulation index is 60. Calculate the maximum deviation. What is the modulation index when the modulating frequency is reduced to 250 Hz and the modulating voltage is simultaneously raised to 3.2v.

36. Explain pre-emphasis and De emphasis with necessary circuits

37. What is the necessity of limiter in FM receivers?

38. Describe Foster seeley Discriminator with a neat circuit diagram and explain its principle with necessary Equations. What are its merits and Demerits?

39. Differentiate between Foster seely discriminator and ratio detector

40. Write short notes on a) Communication receivers (b) NBFM, WBFM

41. a) Explain one method to generate FM signal with circuit diagram.
b) Explain the principle of ratio detector with the help of neat circuit diagram and necessary sketches and Equations. Compare foster seeley and ratio detectors.

42. Explain the necessity of De-emphasis and pre-emphasis in FM.

43. List different FM signal demodulation methods. Describe one method of Fm signal demodulation with neat block diagram.

44. a) What are the different types of distortions in diode detectors. How to reduce them.
b) Distinguish between AM, FM and PM.

45. Write short notes on the following.
i) NBFM, WBFM
ii)Significance of signal to Noise ratio in communication systems.
iii)De-emphasis and pre-emphasis.

46. Derive the formula for instantaneous value of FM voltage.

47. Explain one method to generate FM wave.

48. a) Distinguish between phase and frequency modulation. Show that FM can be derived using PM and vice versa with the help of differentiator or integrator networks.
b)Compute the bandwidth requirement for the transmission of FM signal having a frequency deviation 75 KHz and an audio bandwidth of 10KHz.

c) In a FM system the frequency deviation constant is 1KHz/v. A sinusoidal modulating signal of amplitude 15 V and frequency 3 MHz is applied. Calculate (i)Peak frequency deviation(ii)Modulating index.

49. a) Explain the envelope detector with a circuit diagram and waveforms.
b) Draw the Foster-Seely discriminator and explain.

50. Obtain the expression for SNR &Figure of merit of coherent reception of SSB modulated wave.

51. a)The sinusoidal modulating wave $m(t) = A_m \cos(2\Pi f_m t)$ is applied to a phase modulation with phase sensitivity K_p. The unmodulated carrier wave has frequency f_c and amplitude A_c. Determine the spectrum of the resulting phase modulated wave, assuming that the maximum phase deviation $\beta_p = K_p \ A_m$ does not exceed 0.5 radians.

b)A carrier wave of frequency 100 MHz is frequency modulated by sine wave of amplitude 20 volts and frequency 100 KHz. The frequency sensitivity of the modulation is 25 KHz per volt. Determine the approximate bandwidth of FM wave using Carson's rule.

52. a) An FM signal $X_c(t) = A_0 \cos(\omega_0 t + \beta \sin \omega_m t)$is applied as input to an RC high pass network. Assume that $\frac{1}{\omega RC} >> 1$in the frequency band occupied by $Xc(t)$. Show that the output voltage of RC network is an AM signal. Find the modulation index of AM signal.

53. a) What is zero crossing detectors? Explain how it works and can be used as an FM demodulator?

b)Give and explain 3 areas of applications where standard FM transmission is needed?

54. Obtain the expression for SNR &Figure of merit of coherent reception of DSB modulated wave.

55. In an Armstrong Modulator the crystal oscillator frequency is 200 KHz. It is desired in order to avoid distortion to limit the maximum angular deviation to ϕ_m = 0.2. The system is to accommodate modulation frequencies down to 40Hz. At the output of the modulator the carrier frequency is to be 108 MHz and the frequency deviation be 80KHz. Select multiplier and mixer oscillator frequencies to accomplish this.

56. a) Compare and contrast the performance and applications of the various types of frequency demodulation techniques.

b) Explain the operation of the balanced slope detector using a circuit diagram and draw its response characteristics. Discuss in particular the method of combining the outputs of the individual diodes. In what way is this circuit an improvement on the slope detector and in turn what are the advantages?

57. a) Show that for AM, when the noise is small compared to the signal the performance of the envelope detector is identical to that of synchronous detector.
b) What is the use of calculating noise figure?

58. a) Explain clearly the difference between AM, FM, and PM, beginning with the definition of each type and the meaning of the modulation index in each case.
b) Compare the various methods of DSB.

59. a) In a FM system if modulation index is doubled by halving modulating frequency, what will be the effect on the maximum deviation.
b)FM is called a 'Constant Band Width' system – Justify with suitable illustrations.
c)An FM wave with modulation index $\beta = 1$ is transmitted through an ideal band pass filter with mid band frequency f_c and bandwidth is $5\,f_m$, where f_c is the carrier frequency and f_m is the frequency of the sinusoidal modulating wave. Determine the amplitude spectrum of the filter output.

60. Explain demodulation of FM signal with the help of PLL.

61. Show that for tone modulation for a fixed peak power transmitted the output SNR of AM is 5db below that DSB-SC.

62. a) Derive the expression for wideband FM signal.
b) How is FM generated indirectly.
c)A modulating signal 5 cos 30000 π t angle modulates a carrier A cos $2\pi f_c t$. Assume $K_\delta = K_p$ = 15 KHz/volt. Determine the modulation index and bandwidth for FM and PM signals.

63. Evaluate the modulated and sideband powers.

64. With the help of neat block diagram, explain the generation and detection of SSB signal.

65. a) Illustrate the relation between frequency and phase and hence show the interconversion between FM and PM utilizing this concept.
How is Narrow Band FM generated?
b) An FM signal is given by s(t) = 2 cos 20000πt+cos 2000πt + 3 cos 40000πt. Determine the bandwidth and β assuming $K_f = 10^4$ Hz/volt.

66. a) A 10V, 1MHz sinusoid is modulated by a sinusoid modulation signal with A_1=1V, f_1=1 KHz and A_2 = 1V, f_2=10 KHz. Sketch the spectra of corresponding AM, DSB-SC and SSB signals.
b) Discuss the generation of DSB signal using balanced modulator.
c) Explain envelope detection process with neat waveform. What is the constraint on the time constant of the circuit?

67. a) Describe the generation of FM signal using reactance modulation.
b) Give the expressions for NBFM and WBFM signals for single tone and two tone modulations.
c) Draw the preemphasis and de-emphasis circuits and their frequency responses.

68. Write short notes on the following.
a) Ring modulator (b) Ratio detector

69. a) Bring out the need and benefits with modulation. Classify modulation techniques.
b) With neat schematic, explain the generations of VSB signal.
c) What is the effect of phase shift in the local carrier on demodulation of DSB-SC signal?

70. a) With the help of neat block diagram, explain Armstrong FM generation.
b) Draw the circuit and explain FM demodulation by ration detector.
c) An FM signal is 10 sin ($16\pi x10^6$t + 20 sin $2\pi x10^3$ t). Find the modulation index and power of FM signal.

71. a) Draw schematic diagram for generation of DSB-SC wave and explain its operation.

72. Discuss about VSB.

73. Draw a diode detection circuit and explain the limitations.

74. a) Draw the block diagram of Armstrong method transmitting FM signal and explain the working of each stage.
b)Explain in detail how it is possible to improve the performance of FM system by employing pre emphasis and de-emphasis.

75. Write Short note on the following a) Compare AM and FM b)Amplitude limiting in FM c)TDM and FDM.

76. a) Draw the freq domain representation of AM, DSB-SC, SSB and VSB signals.
b) How is FM superior to AM with reference to noise?

77. Show the block diagram of a Transmitter generating VSB signals. Explain its working. How do we recover the modulating signal from the received VSB explain.

78. a) With the aid of schematic diagrams, explain 'AM-DSBSC' generation and detection.
b)Illustrate FM demodulation using balanced slope detector. Use Phasor diagrams also.

79. a) Explain the generation of SSB signals using filtering and phase shifting method. Which is the popular technique? Why?
b) Draw the circuit diagram of a diode AM detector and explain its working. Show that if the demodulator O/P is to follow the envelope, it is required that,

$$\frac{1}{RC} \geq \frac{W_M}{\sqrt{1-m^2}}$$

80. Draw the circuit diagram of varactor diode FM modulator and explain its working clearly deriving the necessary equations.

81. a)Write down an expression for A.M wave and sketch its frequency spectrum. Show that the maximum power in A.M wave is equal to 1.5 times the power in the carrier wave.
b)Draw the circuit diagram of an envelope detector for the detection of AM signals and explain its operation.

82. Explain peak clipping and diagonal clipping in AM detection.

83. a)Explain any one method of F.M generation. Define modulation index for F.M. State Carson's rule for the bandwidth of the F.M wave.
b)In an F.M system, the frequency deviation is 6kHZ. When a modulating signal with amplitude 4 volts and frequency 600HZ, modulates the carrier. Determine the modulation index, "m_f" and frequency deviation "Δf" if It's amplitude is increased to 8 volts at the same frequency 600HZ and It's amplitude is increased to 12 volts while modulating signal frequency is decreased to 400HZ.

84. a)Compare F.M and A.M systems from the view point of noise performance, bandwidth requirements, power distribution and areas of application.
b)What is zero crossing detector? Explain how it works and how it can be used as an F.M demodulator.

85. a)Explain the principle of square law modulator. Illustrate with suitable figures input and output spectral relations.
b)With a block diagram explain any one method of generating SSB wave. What are the advantages and disadvantages of SSB communication system?

86. a)With a neat block diagram explain the generation of WBFM wave. Derive an expression for FM wave.

87. Draw a neat circuit of a ratio detector and explain its operation.

88. Write short notes on the following: a)VSB b)Thermal noise

89. a) How we can demodulate AM wave using square-law detector?
b) Explain the working of costas loop.
c) What is Carson's rule?

90. a) Explain the indirect method of generating narrow band FM wave.
b) Compare the three side band suppression methods.

91. a) Draw a block diagram of a basic filter system SSB transmitter, describe its operation.
b) The output voltage of a transmitter is given by
$300(1 + 0.3 \sin 5210t) \sin 2.14 \times 10^7 t$. This voltage is fed to a load of 500Ω resistance – Determine carrier power, modulating frequency, total power output and peak power output.

92. a) Derive the relation between the output power of an AM transmitter and the depth of modulation.
b) A 360 W carrier is simultaneously modulated by two audio waves with modulation percentages of 50 and 60 respectively. What is the total side band power radiated?

93. Write a note on zero crossing detector.

94. The positive RF peaks of an AM voltage wave rise to a maximum value of 12V and drop to a minimum value of 3V. Determine the modulation index and the un-modulated carrier amplitude, assuming sinusoidal modulation.

95. a) Define amplitude modulation and derive equation for AM wave.
b) Draw the circuit of a ring modulator and explain its working. Show that it generates DSBSC waves.
c) List the advantages of SSB over standard AM.

96. a) 1A, 1200 KHz carrier is simultaneously modulated with 350Hz, 850Hz and 1.2KHz audio sine waves. What will be the frequencies present in the output?
b) What are the prime characteristics of the foster seeley detector and compare with ratio detector.

97. a) Write a note on companded single side band.
b)Compare pilot carrier system with independent sideband system.

98. a)Derive the expression of AM wave for modulation by several sine waves.
b)What are the advantages and disadvantages of standard AM?
c)Why is a narrow-band system is superior to wideband for voice transmission?

99. a)Prove that the balanced modulator produces an output consisting of sidebands only with the carrier removed.
b)Explain various direct methods of AM demodulation.

100. Compare various modified SSB systems

Code No: 07A4EC11 **R07** **Set No. 1**

II B.Tech II Semester Examinations,December 2010
ANALOG COMMUNICATIONS
Common to Electronics And Telematics, Electronics And Communication Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Define pulse amplitude modulation Draw the waveform, and explain the operation. [16]

2. Explain the principle of operation of Costa's loop? [16]

3. (a) Show that an AM signal can be recovered, irrespective of the value of percentage modulation by using synchronous detection technique?
   (b) What is the maximum modulating signal frequency that can be used with an AM (DSBFC) system with a 30kHz bandwidth? [8+8]

4. A channel has a uniform noise power density spectrum $S_n(\omega)$=0.5×10^{-3}. A DSB-SC signal with carrier frequency of 200kHz is transmitted over this channel. The modulating signal band limited to 10kHz.the power of the sideband signal is 5kW. The incoming signal at the receiver is filtered through an ideal band pass filter before it is fed to the demodulator.
   (a) What is the transfer function of this filter at the receiver.
   (b) Find the S/N ratio of demodulator input and output.
   (c) Find and sketch the noise power density spectrum at the demodulator output. [16]

5. (a) Show that a low pass filter can be used as a discriminator?
   (b) An FM radio link has a frequency deviation of 30kHz.The modulating frequency is 4kHz.calculate the bandwidth needed for the link. What will be the bandwidth if the deviation is reduced to 10 kHz? [8+8]

6. Draw the circuit and explain the generation of SSB-SC wave using the "third" method? [16]

7. What is three point tracking? How do tracking errors arise in the first place? What is the name given to the element that helps to achieve three point tracking? Where is it placed. [16]

8. Write short note on the following:
   (a) AM transmitters
   (b) Armstrong FM transmitters. [8+8]

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Code No: 07A4EC11 **R07** **Set No. 2**

II B.Tech II Semester Examinations,December 2010
ANALOG COMMUNICATIONS
Common to Electronics And Telematics, Electronics And Communication Engineering

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. Explain about AM transmitter? Why feedback is used in the AM transmitter? And explain its uses? [16]

2. (a) A carrier $A\cos\varpi_c t$ is modulated by a signal $2\cos 10^4.2\pi t + 5\cos 10^3 2\pi t + 2\cos 10^4.4\pi t$.find the bandwidth of the FM signal using Carson's rule.Assume K_f=12kHz/V. also find modulation index?
   (b) Draw the circuit for ratio detector and explain how it is derived from phase discriminator? [8+8]

3. (a) Describe the demodulation of AM wave using square law device?
   (b) Define modulation coefficient and percent modulation? [8+8]

4. An amplitude modulated amplifier provides an output of 106 watts at 100% modulation. The internal loss is 20Watt.
   (a) What is the un modulated carrier power.
   (b) What is the sideband power? [16]

5. (a) What, exactly does a noise limiter do in an AM receiver? How does it do this?
   (b) Describe the differences between FM and AM receivers, bearing in mind the different frequency ranges and bandwidths over which they operate? [8+8]

6. Derive the necessary equations to show the SNR improvement with pre emphasis circuit? [16]

7. How to obtain PWM from PPM. Explain the various components in the block diagram. [16]

8. Describe how single sideband suppressed carrier is used with frequency division multiplexing? [16]

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Code No: 07A4EC11 **R07** **Set No. 3**

II B.Tech II Semester Examinations,December 2010

ANALOG COMMUNICATIONS

Common to Electronics And Telematics, Electronics And Communication Engineering

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

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1. (a) Compare and contrast the performance of various types of frequency demodulators?
   (b) An angle modulated signal is given by $X_c(t) = 5\cos[2\pi(10^6)t + 0.2\cos 200\pi t]$. Can you identify whether $X_c(t)$ is a PM or an FM signal? [8+8]
2. With the aid of vector diagrams, explain what happens when a carrier is modulated by a single noise frequency? [16]
3. Describe the operation of a phase locked loop direct FM transmitters? [16]
4. Using circuit diagrams ,explain the operation of the self excited transistor mixer by the three frequency approach? [16]
5. (a) Show that if every frequency component of a signal f(t) is shifted by $\pi/2$, the resultant signal is the Hilbert transform of f(t)?
   (b) Draw the circuit and explain the generation of SSB-SC wave using phase shift method? [8+8]
6. (a) Sketch the envelope for a maximum positive envelope voltage of 12V and a minimum positive envelope amplitude of 4V,determine the modulation coefficient & percent modulation?
   (b) Describe the demodulation of AM wane using square law device? [8+8]
7. (a) What is single polarity and double polarity in PAM.
   (b) How is TDM different from FDM. [8+8]
8. The modulating signal f(t) in an DSB-SC system is multiple-tone signal given by $f(t)=E_1\cos\omega_1 t + E_2\cos\omega_2 t + E_3\cos\omega_3 t$. The signal f(t) modulates a carrier $E_c\cos\omega_c t$. Plot the single sided trigonometric spectrum and find the bandwidth of the modulated signal. Assume that $\omega_3 > \omega_2 > \omega_1$ and $E_3 > E_2 > E_1$. [16]

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Code No: 07A4EC11 **R07** **Set No. 4**

II B.Tech II Semester Examinations,December 2010

ANALOG COMMUNICATIONS

Common to Electronics And Telematics, Electronics And Communication Engineering

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

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1. In an DSB-SC system the modulating signal is single tone sinusoid 10cos (2π 10t) which modulates a carrier signal 10 cos(2π 1000t).Plot the spectrum of the modulated wave? [16]

2. Discuss the generation & demodulation of PWM. [16]

3. (a) Define phase deviation and modulation index?

   (b) Compare the advantages and disadvantages of angle modulation with amplitude modulation? [8+8]

4. Describe the operation of direct FM transmitters? Describe two methods to up convert the frequency of angle modulated waves? [16]

5. A channel has a uniform noise power density spectrum $S_n(\omega)$=0.5×10^{-3}. A SSB-SC signal with carrier frequency of 200kHz is transmitted over this channel. The modulating signal band limited to 10kHz.the power of the sideband signal is 5kW. The incoming signal at the receiver is filtered through an ideal band pass filter(upper side bands) before it is fed to the demodulator.

   (a) What is the transfer function of this filter at the receiver.

   (b) Find the S/N ratio of demodulator input and output.

   (c) Find and sketch the noise power density spectrum at the demodulator output. [16]

6. (a) Explain what double spotting is and how it arises.

   (b) Describe the general process of frequency changing in a super hetero dyne receiver. [16]

7. Compare the three methods of SSB generation by drawing a table with its outstanding characteristics? [16]

8. One input to an AM modulator is a 500kHz carrier with a peak amplitude of 32V.The second input is a 12-kHz modulating signal whose amplitude is sufficient to provide a 14-Vp change in the amplitude of the envelope. determine the following:

   (a) upper and lower side frequencies.

   (b) modulation coefficient, percent modulation?

   (c) maximum and minimum amplitudes of the envelope.

(d) draw the output envelope.

(e) draw the output frequency spectrum. [16]

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Code No: 07A4EC11 Set No. 1

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

II B.Tech. II Sem., I Mid-Term Examinations, March – 2010

ANALOG COMMUNICATIONS

Objective Exam

Name: ______________________________ **Hall Ticket No.** | | | | | | |A| | | | |

Answer All Questions. All Questions Carry Equal Marks.Time: 20 Min. Marks: 20.

I Choose the correct alternative:

1. The modulation index of an AM wave is changed from 0 to 1. The transmitted power is [ ]
   A. unchanged B. decreased by 50% C. doubled D. increased by 50%

2. Indicate in which one of the following, one side band is fully transmitted and one side band is partly transmitted. [ ]
   A. DSB B. VSB C. SSB D. AM

3. Vestigial side band modulation is normally used for [ ]
   A. HF point-to-point communication B. Monaural broadcasting
   C. TV broadcasting D. Stereo broadcasting.

4. In a balanced modulator the devices used to suppress the carrier wave are [ ]
   A. Linear devices B. Class A amplifier C. Non-linear devices D. Tuned oscillator

5. Demodulation of VSB modulated wave is achieved by passing VSB wave through [ ]
   A. low pass filter B. coherent detector C. high pass filter D. side band shaping filter

6. The distortion in SSB modulation is reduced by [ ]
   A. using a filter B. reducing the percentage modulation
   C. using a band pass filter D. reducing the carrier frequency

7. The band width of VSB modulated wave is [ ]
   A. $f_m < BW < 2 f_m$ B. $2 f_m$ C. f_m D. $BW > f_m$

8. Frequency deviation in FM wave is given by [ ]
   A. $K - f_m$ B. highest frequency – carrier frequency C. 2 x carrier frequency D. $f_c - f_m$

9. Zero – crossing detector is also called [ ]
   A. frequency detector B. frequency counter C. zero detector D. zero counter

10. In FM the modulation index [ ]
    A. is always less than one B. is always greater than one
    C. is either less than or more than one D. is either zero or one

Cont....2

II Fill in the blanks:

11. At 100% an modulation the sum of the voltages in both side bands is equal to ___________ % of the un- modulated carrier voltage.

12. An AM wave is generated when _____________ characteristic of the sine wave is varied.

13. In SSB modulation the boosting of carrier frequency up to the transmitter frequency by the balanced modulator is called ___________.

14. The basic information signal in a communication system is called as ____________.

15. Standard AM wave is mostly used for _________________.

13. The band width of standard AM is _______.

16. An example for indirect method of demodulation is ___________________.

18. A direct FM wave is generated by using a device called _________________.

19. The filter used in an envelope detector for AM wave is _____________.

20. DSBSC is mostly used for __________________.

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Code No: 07A4EC11 Set No. 2

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

II B.Tech. II Sem., I Mid-Term Examinations, March – 2010

ANALOG COMMUNICATIONS

Objective Exam

Name: ____________________________ **Hall Ticket No.** | | | | | | A | | | | |

Answer All Questions. All Questions Carry Equal Marks.Time: 20 Min. Marks: 20.

I Choose the correct alternative:

1. In a balanced modulator the devices used to suppress the carrier wave are [ ]
   A. Linear devices B. Class A amplifier C. Non-linear devices D. Tuned oscillator

2. Demodulation of VSB modulated wave is achieved by passing VSB wave through [ ]
   A. low pass filter B. coherent detector C. high pass filter D. side band shaping filter

3. The distortion in SSB modulation is reduced by [ ]
   A. using a filter B. reducing the percentage modulation
   C. using a band pass filter D. reducing the carrier frequency

4. The band width of VSB modulated wave is [ ]
   A. $f_m < BW < 2 f_m$ B. $2 f_m$ C. f_m D. $BW > f_m$

5. Frequency deviation in FM wave is given by [ ]
   A. $K - f_m$ B. highest frequency – carrier frequency C. 2 x carrier frequency D. $f_c - f_m$

6. Zero – crossing detector is also called [ ]
   A. frequency detector B. frequency counter C. zero detector D. zero counter

7. In FM the modulation index [ ]
   A. is always less than one B. is always greater than one
   C. is either less than or more than one D. is either zero or one

8. The modulation index of an AM wave is changed from 0 to 1. The transmitted power is [ ]
   A. unchanged B. decreased by 50% C. doubled D. increased by 50%

9. Indicate in which one of the following, one side band is fully transmitted and one side band is partly transmitted. [ ]
   A. DSB B. VSB C. SSB D. AM

10. Vestigial side band modulation is normally used for [ ]
    A. HF point-to-point communication B. Monaural broadcasting
    C. TV broadcasting D. Stereo broadcasting.

Cont....2

II Fill in the blanks:

11. The basic information signal in a communication system is called as ____________.
12. Standard AM wave is mostly used for _________________.
13. The band width of standard AM is ________.
14. An example for indirect method of demodulation is ___________________.
15. A direct FM wave is generated by using a device called _________________.
16. The filter used in an envelope detector for AM wave is _____________.
17. DSBSC is mostly used for __________________.
18. At 100% an modulation the sum of the voltages in both side bands is equal to ___________ % of the un- modulated carrier voltage.
19. An AM wave is generated when _____________ characteristic of the sine wave is varied.
20. In SSB modulation the boosting of carrier frequency up to the transmitter frequency by the balanced modulator is called ___________.

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