UNIT I AMPLITUDE MODULATION

1. Determine the Hilbert transform of cosωt. (Nov/Dec-2017)

   Hilbert transform shifts the phase of positive frequency components by -90° and that of negative frequency components by +90°. Thus, the Hilbert transform of cosωt is sinωt.

   $$H[\cos\omega t] = \sin\omega t.$$

2. What is VSB? Where it is used? (Nov/Dec-2017)

   Vestigial Sideband Transmission (VSB)

   Vestigial Sideband (VSB) is a type of Amplitude Modulation (AM) technique (sometimes called VSB-AM) that encodes data by varying the amplitude of a single carrier frequency. Portion of one of the redundant sidebands are removed and vestige (portion) of the other sideband is transmitted to form a Vestigial Sideband signal.

   Uses of VSB:

   - VSB modulation has become standard for the transmission of Television signals.
   - VSB is used for TV picture broadcasting.

3. Does the modulation technique decide the antenna height? (APR/MAY– 2017)

   Yes. For the transmission of radio signals, the antenna height must be multiple of λ/10.

   $$\lambda = c / f$$

   where λ is the wavelength, c is the velocity of light and f is the frequency of the signal to be transmitted.

   The minimum antenna height required to transmit a baseband signal of f = 10 kHz is calculated as follows

   $$\text{Minimum Antenna Height} = \frac{\lambda}{10} = \frac{c}{10f} = \frac{3 \text{ x } 10^8}{10 \text{ x } 10 \text{ x } 10^3} = 3 \text{ km or } 3000 \text{ meters}$$

   The antenna of this height is practically impossible to install.

   Now, let us consider a modulated signal at f = 1 MHz. The minimum antenna height is given by,

   $$\text{Minimum Antenna Height} = \frac{\lambda}{10} = \frac{c}{10f} = \frac{3 \text{ x } 10^8}{10 \text{ x } 10 \text{ x } 10^6} = 30 \text{ meters}$$

The antenna of this height can be easily installed practically. Thus, modulation reduces the height of the antenna.

4. Define carrier swing. (APR/MAY– 2017)

   Carrier Swing (CS) is defined as the total variation in frequency from lowest to highest point.

   Carrier Swing = 2* frequency deviation of the FM signal = 2* $\Delta\omega$

5. Suggest a modulation scheme for broadcasting video transmission and justify. (NOV/DEC – 2016)

   Vestigial Sideband with Suppressed Carrier (VSB-SC) modulation is used for broadcasting video transmission.

   Some of the modulating signals of very large bandwidth such as video signals, TV and high speed data signals have very low frequency components along with the rest of the signal. These components give rise to sidebands, very close to the carrier frequency, which are difficult to remove by filters. So, it is possible to fully suppress one complete sideband in case of television signals.

   Similarly, the low video frequencies contain the most important information of the picture. If any of its sideband is suppressed, it would result in phase distortion at low frequencies.Therefore, a compromise has been made to suppress the part of the lower sideband. Then, the radiated signal consists of full upper sideband together with the carrier and vestige of the lower sideband. Thus VSB-SC is used for broadcasting video transmission.

6. What are the advantages of converting low frequency signal into high frequency signal? (NOV/DEC – 2016, MAY/JUNE - 2013) (or) why we need modulation?
   a) Reduction in the height of antenna
   b) Avoids mixing of signals
   c) Increases the range of communication
   d) Multiplexing is possible
   e) Improves quality of reception
   f) To reduce noise and interference.
7. What theorem is used to calculate the average power of a periodic signal $g_p(t)$? State the theorem. (MAY/JUNE – 2016) (or) The average power of a periodic signal $g_p(t)$ is calculated

using what theorem? State the theorem. (NOV/DEC – 2013) (or) State Parseval's theorem. (MAY/JUNE – 2011)

The average power of a periodic signal $g_p(t)$ is calculated using Parseval's theorem. It statesthat if x(t) is the periodic power signal with Fourier coefficient X(k), then average power in the signal is given by

$$g_p(t) = \sum_{k=-\infty}^{\infty} |X(k)|^2$$

8. What is pre-envelope and complex envelope? (MAY/JUNE – 2016)

Pre-envelope:

It is a complex signal created by taking a signal x(t) and then adding in quadrature part of its Hilbert Transform $j\hat{x}(t)$.

The pre-envelope of the signal $x_p(t)$ is defined as

$$x_p(t) = x(t) + j\hat{x}(t)$$

Thus the signal x(t) is real part of pre-envelope and Hilbert transform $\hat{x}(t)$ is the imaginary part of pre-envelope.

Complex envelope:

Complex Envelope is just the frequency shifted version of the pre-envelope signal.

The complex envelope of the bandpass signal $x_c(t)$ is given by

$$x_c(t) = x_p(t)e^{-j2\pi f_c t}$$

Here $x_c(t)$ is the complex envelope and $x_p(t)$ is the pre-envelope.

9. A carrier is amplitude modulated to a depth of 80%. Calculate the total power in the modulated wave, if the carrier is 10 Watts. (MAY/JUNE – 2015)

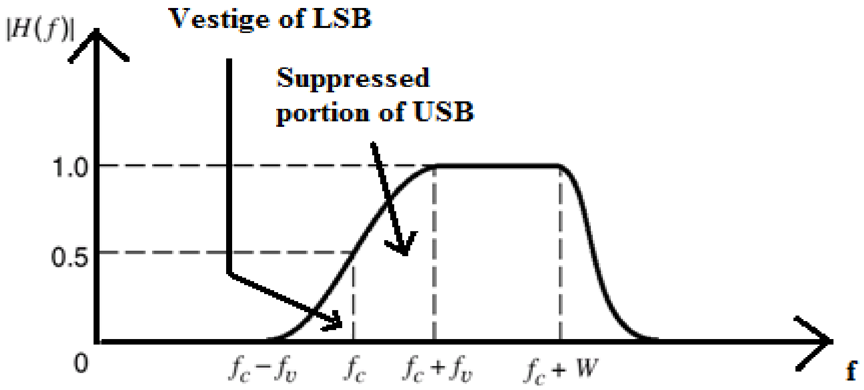
Solution:

Given P_c = 10 Watts, m = 80% = 80/100 = 0.8

$$\text{Total Power } P_{Total} = P_c\left(1 + \frac{m^2}{2}\right) = 10\left(1 + \frac{0.8^2}{2}\right) = 13.2 \text{ Watts.}$$

10. Draw the frequency spectrum of VSB. Where it is used? (MAY/JUNE – 2015)

Frequency spectrum of VSB:



Uses of VSB:

1. VSB modulation has become standard for the transmission of Television signals.
2. VSB is used for TV picture broadcasting.

11. Define heterodyning. (MAY/JUNE – 2015)

The process of mixing two different frequencies to produce a new frequency is called as heterodyning. It is also termed as mixer or converter. It is used to get fixed Intermediate Frequency (IF) in AM detection.

12. What is meant by frequency translation? (NOV/DEC – 2011)

In Single Sideband modulation (SSB), the message spectrum is shifted by an amount equal to the carrier frequency f_c. This is called frequency translation. It is used at transmitter side.

13. State the differences between single side band and vestigial side band transmission systems. (MAY/JUNE – 2014)

S. No.	Single Sideband transmission	Vestigial Sideband transmission
1.	Only one sideband is transmitted.	In VSB modulation, one sideband is passed almost completely whereas just a trace or vestige of the other sideband is transmitted.
2.	Frequencies near edge are attenuated.	Frequencies near edge are not attenuated.
3.	Bandwidth (BW) is f_m	$f_m < BW < 2f_m$
4.	Transmission Efficiency (η) is 83%	$33.3\% < \eta < 100\%$
5.	It is used in Two way radio Communication and military communications.	It is used for transmitting Television signals.

14. For an AM system, the instantaneous values of carrier and modulating signal are $60\sin\omega_c t$ and $40\sin\omega_c t$ respectively. Determine the modulation index. (MAY/JUNE – 2014)

Solution:

Given $e_c = 60\sin\omega_c t$ and $e_m = 40\sin\omega_m t$

Compare the given signals with standard AM equations,

$e_c = E_c\sin\omega_c t$ and $e_m = E_m\sin\omega_m t$

$E_c = 60$ V and $E_m = 40$ V

Modulation index, $m = E_m / E_c = 40 / 60 = 0.6667$.

15. Derive an equation for the modulated signal of an AM system. (MAY/JUNE – 2014)

Let us represent the modulating signal by e_m and it is given as

$e_m = E_m\sin\omega_m t$

and carrier signal can be represented by e_c

$e_c = E_c\sin\omega_c t$

Here E_m is maximum amplitude of modulating signal, E_c is maximum amplitude of carrier signal, ω_m is frequency of modulating signal and ω_c is frequency of carrier signal.

Thus AM modulated wave expression is

$E_{AM} = E_c + e_m = E_c + E_m\sin\omega_m t \rightarrow (1)$

The instantaneous value of the amplitude modulated wave can be given as

$e_{AM} = E_{AM} \sin \omega_c t \rightarrow (2)$

Sub (2) in (1)

$e_{AM} = (E_C + E_m \sin \omega_m t) \sin \omega_c t$

This is an equation of AM wave.

16. Calculate the local oscillator frequency if incoming frequency is f_1 and translated carrier frequency is f_2. (NOV/DEC – 2012, MAY/JUNE – 2011)

If incoming frequency is f_1 and translated carrier frequency is f_2, then thelocal oscillator frequency (f_o) is the summation of incoming signal frequency f_1 and translated carrier frequency f_2. Thus, Local oscillator frequency, $f_o = f_1 + f_2$.

17. Compute the bandwidth of the amplitude modulated signal given by
$S(t) = 23 [1+0.8 \cos (310\pi t)] \cos (230000\pi t)$. (MAY/JUNE – 2012, MAY/JUNE – 2009)

Solution:

Given $S(t) = 23 [1+0.8 \cos (310\pi t)] \cos (230000\pi t)$

Compare the given signal with standard AM equation,

$S(t) = E_C [1+ m \cos\omega_m t] \cos\omega_c t$

From given equation, $\omega_m = 310\pi \Rightarrow 2\pi f_m = 310\pi$

$2f_m = 310$

Bandwidth of amplitude modulated signal, $BW = 2f_m = 310$ Hz.

18. Compare bandwidth and power requirement in terms of carrier power P_C for AM, DSB-SC and SSB. (MAY/JUNE – 2013)

S. No	Parameter	AM	DSB-SC	SSB
1.	Bandwidth	$2f_m$	$2f_m$	f_m
2.	Power requirement	$P_C (1 + \frac{m^2}{2})$	$P_C (\frac{m^2}{2})$	$P_C (\frac{m^2}{4})$

19. An amplitude modulation transmitter radiates 1000 Watts of unmodulated power. If the carrier is modulated simultaneously by two tones of 40% and 60% respectively, calculate the total power radiated. (NOV/DEC – 2012)

Solution:

Given $P_C = 1000$ Watts, $m_1 = 40\% = 40/100 = 0.4$ and $m_2 = 60\% = 60/100 = 0.6$

$$m_t = \sqrt{m_1^2 + m_2^2} = \sqrt{0.4^2 + 0.6^2} = 0.721$$

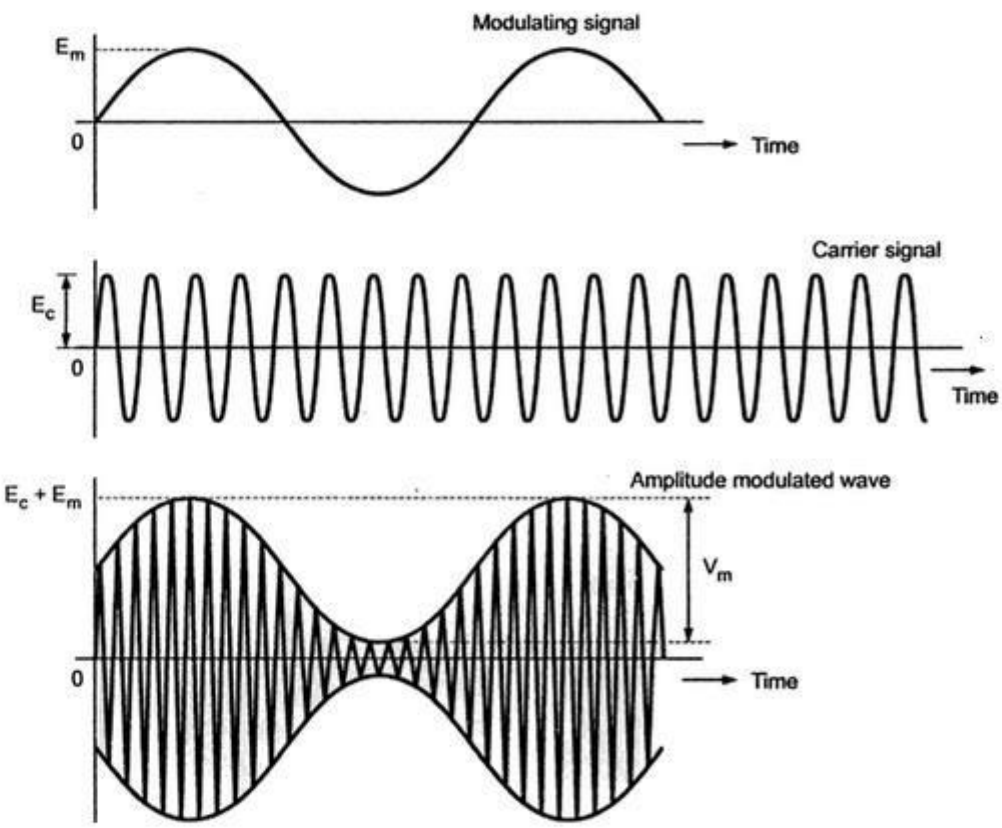
$$P_{Total} = P_c\left(1 + \frac{m_t^2}{2}\right) = 1000\left(1 + \frac{0.721^2}{2}\right) = 1260 \text{ Watts}$$

20. What are the advantages of Vestigial Side Band? (MAY/JUNE – 2011)

- Low frequencies near f_c are transmitted without any attenuation.
- Bandwidth is greater than Single Sideband Suppressed Carrier (SSB-SC) but less than Double Sideband Suppressed Carrier (DSB-SC) AM.
- Power transmission is greater than DSB-SC but less than SSB-SC systems. i.e., 75%.

21. Represent an amplitude modulated wave as a function of time with amplitude sensitivity of the modulator as the constant. (NOV/DEC – 2013)

The amplitude sensitivity of the modulator is basically variation in amplitude of the carrier with respect to its modulating signal. The figure shows the AM wave with amplitude sensitivity of 1.



22. Define sensitivity characteristics of a radio receiver. (MAY/JUNE – 2014)

The ability of the receiver to pick up weak signals and amplify them is called sensitivity. It is often defined in terms of voltage that must be applied to the receiver input terminals to give the standard output power measured at output terminals.

23. What are advantages and disadvantages of AM?

Advantages

- AM is used for long distance communication.
- AM is relatively inexpensive.

Disadvantages

- AM is more likely to be affected by noise than FM.
- High complexity
- 66.67% of transmitted power is wasted.
- Large bandwidth is required.

24. Compare AM with DSB-SC and SSB-SC.

S. No.	AM	DSB-SC	SSB-SC
1.	It contains carrier and two sidebands.	It contains only sidebands. Only carrier is suppressed.	It contains only one sideband. Carrier and one sideband are suppressed.
2.	Bandwidth is $2f_m$.	Bandwidth is $2f_m$.	Bandwidth is f_m.
3.	More power is required for transmission.	Power required is less than that of AM.	Power required is less than that of AM and DSB-SC.

25. What is Super-heterodyne Receiver?

The Super-heterodyne receiver converts all incoming RF frequencies to a fixed lower frequency, called intermediate frequency (IF). This IF is then amplified and detected to get the original signal.

26. What is modulation index or depth of modulation or co-efficient of modulation and percent modulation?

The ratio of maximum amplitude of modulating signal (E_m) to the maximum amplitude of carrier signal (E_c) is called modulation index i.e, Modulation index (m) = E_m / E_c

Percent modulation (m) = $(E_m / E_c) * 100$

27. What is single tone and multi tone modulation?

If modulation is performed for a message signal with more than one frequency component, then the modulation is called multi tone modulation.

If modulation is performed for a message signal with one frequency component, then the modulation is called single tone modulation.

28. Define fidelity and selectivity of a receiver.

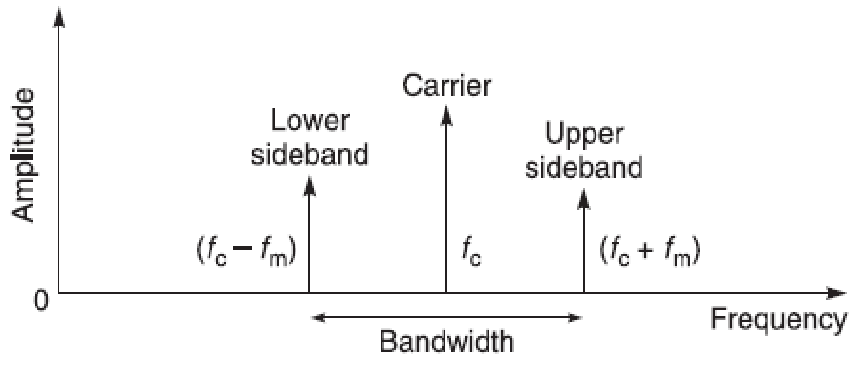
Fidelity

The ability of the receiver to reproduce all the range of modulating frequencies equally is called fidelity of the receiver. For good fidelity, more bandwidth of Radio Frequency (RF) and Intermediate Frequency (IF) stages are required.

Selectivity

The selectivity is defined as the ability of the receiver to select a signal of a desired frequency while rejecting all others. The selectivity depends upon tuned LC circuits used in RF and IF stages.

29. Draw the spectrum of AM signal.



30. As related to AM what is over modulation, under modulation and 100% modulation? (or)When a carrier does is said to be over, under modulated in Amplitude modulation?

a. In Over modulation (or) 150% modulation, modulation index m>1(i.e.,)$E_m > E_c$, where E_m is the maximum amplitude of modulating signal and E_c is the maximum amplitude of carrier signal. Here the envelope of Amplitude modulated signal crosses the zero axis.

b. In Under modulation (or) 50% modulation, modulation index m<1(i.e.,)$E_m < E_c$. Here the envelope of Amplitude modulated signal does not reach the Zero amplitude axis. Hence the Message signal is fully preserved in the envelope of the AM Wave.

c. In critical (or) 100% modulation, modulation index m=1(i.e.,) $E_m = E_c$. Here the envelope of the Amplitude modulated signal just reaches the zero amplitude axis. The message signal remains preserved.

31. Write down the comparison of amplitude and frequency modulation.

S. No.	Amplitude Modulation	Frequency Modulation
1.	Amplitude of the carrier is varied according to amplitude of modulating signal.	Frequency of the carrier is varied according to amplitude of the modulating signal.
2.	AM has poor fidelity due to narrow bandwidth.	Since the bandwidth is large, fidelity is better.
3.	Noise interference is more.	Noise interference is minimum.
4.	Adjacent channel interference is present.	Adjacent channel interference is avoided due to wide bandwidth.
5.	Most of the power is in carrier hence less efficient.	All the transmitted power is useful.

32. SSB is suitable for speech signals and not for video signals. Why?

- To generate SSB, the message spectrum must have an energy gap centered at the origin. This criterion is satisfied by speech signals, for which the energy gap is from -300 Hz to +300 Hz (600 Hz wide).Hence any one sideband can be easily isolated with the help of practical bandpass filters.
- But in case of video signals, there is no such energy gap near origin. In other words, the video signal extends from DC (0 Hz) to 5 MHz. Hence lower and upper sidebands are practically joined at origin. Hence with the help of practical bandpass filters, it is not possible to isolate one sideband from other. Hence for video signals vestigial sideband transmission is suitable, rather than SSB.

UNIT II ANGLE MODULATION

1. A frequency modulated signal is given as $s(t) = 20\cos[2\pi f_c t + 4\sin(200\pi t)]$. Determine the required transmission bandwidth. (Nov/Dec – 2017)

   Solution:

   Given $s(t) = 20\cos[2\pi f_c t + 4\sin(200\pi t)]$

   Compare the given FM signal equation with standard FM signal,

   $s(t) = E_c\cos[2\pi f_c t + m_f \sin 2\pi f_m t)]$

   Here $E_c = 20$ V, $m_f = 4$,

   $2\pi f_m t = 200\pi t \Rightarrow f_m$(or) $f_{m(max)} = 100$ Hz

   We know that, modulation index of FM $(m_f) = \delta/f_m$

   Hence $\delta = m_f f_m = 4 \times 100$ Hz $= 400$ Hz.

   Bandwidth of FM $= 2(\delta + f_{m(max)})$

   $= 2(400 + 100) = 2(500) = 1000$ Hz (or) 1 kHz.

2. How is narrowband signal distinguished from wideband signal? (Nov/Dec – 2017) (or) Compare narrowband and wideband FM. (MAY/JUNE – 2015, NOV/DEC – 2013, MAY/JUNE – 2011)

S. No.	Narrowband Signal	Wideband Signal
1.	Modulation index is less than 1.	Modulation index is greater than 1.
2.	It contains two sidebands and carrier.	It contains infinite number of sidebands and carrier.
3.	Bandwidth = $2f_m$	Bandwidth = $2(\delta + f_{m\,(max)})$
4.	Maximum Deviation is 5 kHz	Maximum Deviation is 75 kHz
5.	It is used for FM Mobile Communication like Police wireless, ambulance etc.	It is used for Entertainment broadcasting.

3. State the Carson's rule. (MAY/JUNE – 2017, MAY/JUNE – 2015, MAY/JUNE – 2013)

   FM bandwidth is given as twice the sum of the frequency deviation and the highest modulating frequency.

Carson's rule of FM bandwidth = $2(\delta + f_{m\,(max)})$

Where $f_{m(max)}$ is the maximum modulating signal frequency and δ is maximum frequency deviation.

4. Distinguish the features of Amplitude Modulation (AM) and Narrowband Frequency Modulation (NBFM). (MAY/JUNE – 2017)

S. No.	Amplitude Modulation (AM)	Narrowband Frequency Modulation (NBFM)
1.	If the modulation index is less than or equal to 1, then it is called AM	If the modulation index is less than 1, then it is called NBFM.
2.	Most of the power is in carrier hence less efficient.	All the transmitted power is useful.
3.	AM receivers are not immune to noise.	FM receivers are immune to noise.
4.	Adjacent channel interference is present.	Adjacent channel interference is avoided due to guard bands.
5.	It is used in Two-way radios, Very High Frequency aircraft radio, Citizen's Band Radio.	It is used in FM mobile communication like police wireless and ambulances.

5. Define modulation index of frequency modulation and phase modulation. (NOV/DEC – 2016, NOV/DEC – 2013, MAY/JUNE – 2013)

Modulation index of frequency modulation:

The modulation index of FM is

$$m_f = \frac{k_f E_m}{f_m}$$

wherek_f is frequency deviation constant of FM, E_m is the voltage of modulating signal and f_m is the frequency of modulating signal.

Modulation index of phase modulation:

The modulation index of PM signal is

$$m_p = k_p E_m$$

wherek_p is phase deviation constant of PM and E_m is the voltage of modulating signal.

6. What is the need for pre-emphasis and de-emphasis in FM? (NOV/DEC – 2016, MAY/JUNE – 2016)

Pre-emphasis and de-emphasis circuits are used for the suppression of unwanted noise. The noise has greater effect on higher modulating frequencies than on the lower ones. The effect of noise on the higher frequencies can be reduced by artificially boosting them at transmitter and correspondingly attenuating them at the receiver. This is done with the help of pre-emphasis (boosting at transmitter side) and de-emphasis (attenuating at receiver side)circuits.

7. A carrier signal is frequency modulated by a sinusoidal signal of 5 V_{pp} and 10 kHz. If the frequency deviation constant is 1 kHz/V, determine the maximum frequency deviation and state whether the scheme is narrowband FM or wideband FM. (MAY/JUNE – 2016)

   Solution:

   Given $E_m = 5\ V_{pp}$

   Where V_{pp} denotes peak to peak amplitude. Then the maximum positive amplitude is given by $E_m = 5/2 = 2.5$ V,

   $k_f = 1$ kHz/V = 1000 Hz = 1×10^3 Hz , $f_m = 10$ kHz = 10×10^3 Hz.

   Maximum frequency deviation, $\delta = E_m \times k_f$

   $= 2.5 \times 1 \times 10^3 = 2500$ Hz.

   $$\text{Modulation index, } m_f = \frac{\delta}{f_m} = \frac{2500}{10 \times 10^3} = 0.25$$

   Since modulation index is less than 1, then this is Narrowband FM.

8. If the maximum phase deviation in a phase modulation system when a modulating signal of 10 V applied is 0.1 radian, determine the value of phase deviation constant. (MAY/JUNE – 2014)

   Solution:

   Given $\theta(t) = 0.1$ radian and $e_m(t) = 10$ V

   For Phase Modulation, $\theta(t) = k_p e_m(t)$

   $$k_p = \frac{\theta(t)}{e_m(t)} = \frac{0.1}{10} = 0.01\ \frac{\text{rad}}{\text{volts}}.$$

9. Why is frequency modulation preferable for voice transmission? (MAY/JUNE – 2014)

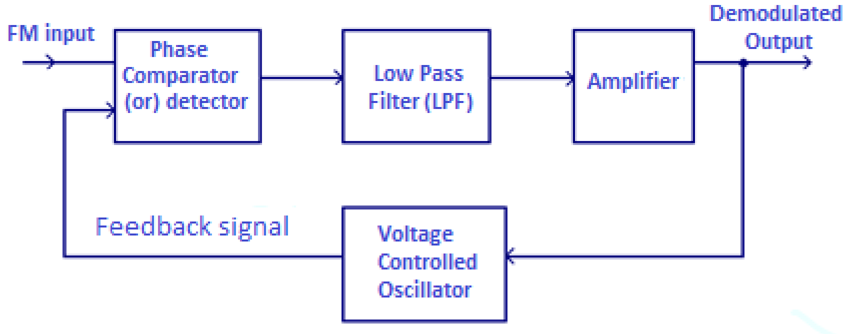
Frequency modulation is preferred for voice transmission because of two reasons:

- The bandwidth needed for voice signal is less.
- Ability to transfer quality sound.
- Noise interference is low.
- Ability to modulate 2 separate signals for stereo.

10. How is the narrowband FM converted into wideband FM? (NOV/DEC – 2012, NOV/DEC – 2011)

The narrowband FM signal can be converted into wideband FM signal by simply passing it through a non–linear device with power P. Both the carrier frequency and frequencydeviation Δf of the narrowband signal are increased by a factor P.

11. Draw the simple schematic of a PLL demodulator and name the blocks of PLL. (NOV/DEC – 2013)



PLL consists of following blocks:

Phase Comparator: It generates the voltage which is proportional to difference between the FM signal and Voltage Controlled Oscillator (VCO) output.

LPF and Amplifier: The voltage of phase comparator is low pass filtered and then amplified.

VCO: The amplified output is given to VCO. It generates the FM signal proportional to output of the amplified output. The VCO output is given as one of the input to thecomparator.

12. A carrier is frequency modulated by a sinusoidal modulating frequency 2 kHz, resulting in a frequency deviation of 5 kHz. What is the bandwidth occupied by the modulated waveform?

Solution:

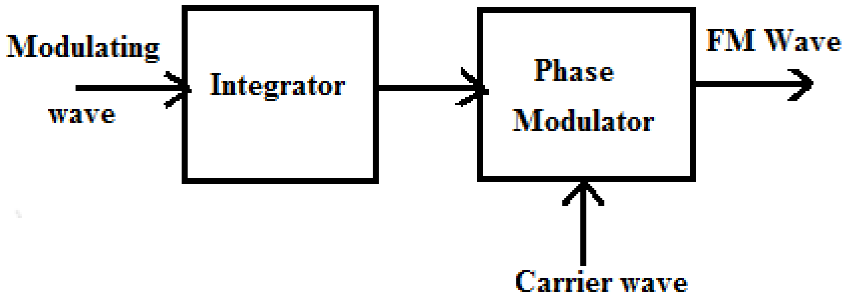
Given f_m (or) $f_{m\,(max)}$= 2 kHz, δ = 5 kHz

Bandwidth = $2(\delta + f_{m\,(max)})$ = 2 (5+2) kHz = 14 kHz.

13. Illustrate the relationship between FM and PM, with block diagrams. (MAY/JUNE – 2012, NOV/DEC - 2010)

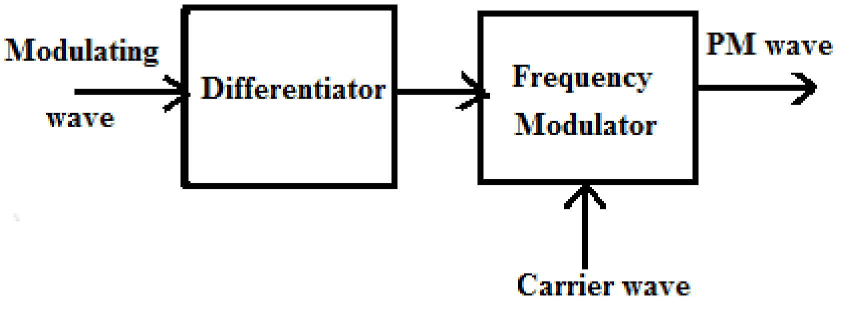
FM

- Phase angle varies linearly with integral of modulating signal.
- The modulating signal is integrated and then applied to the phase modulator. Thus, FM can be obtained from PM.



PM

- Phase angle varies linearly with modulating signal.
- The modulating signal is differentiated and then applied to the frequency modulator. Thus, PM can be obtained from FM.



14. What is meant by detection? Name the methods for detecting FM signals. (MAY/JUNE – 2012, MAY/JUNE – 2011)

Detection is the process of obtaining modulating signal back from modulated signal. The detection is performed at the receiver.

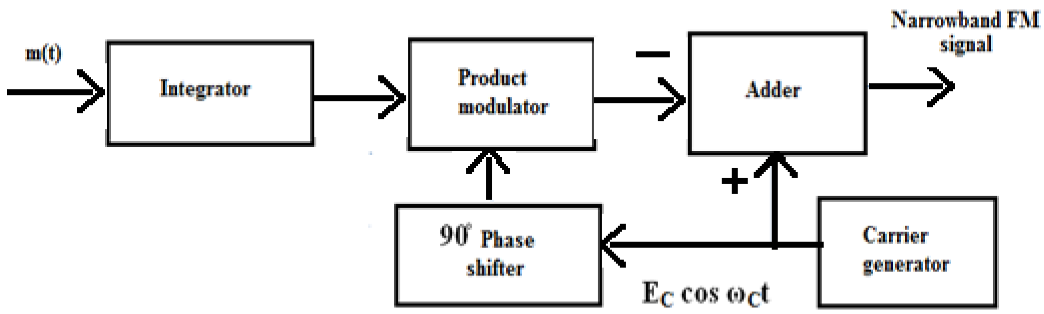
Methods of FM detection:

i. Balanced slope or frequency discriminator
ii. Foster – Seeley or phase discriminator
iii. Ratio detector
iv. PLL demodulator

15. What are the advantages of ratio detector? (NOV/DEC – 2011)

- Ratio detector has wider bandwidth.
- Provides a good level of immunity to amplitude noise.
- Very good linearity due to linear phase relationship between primary and secondary windings.

16. Draw the block diagram of a method for generating a narrowband FM signal. (MAY/JUNE – 2010)



17. A carrier wave of frequency 100 MHz is frequency modulated by a signal.

$X(t) = 20 \sin (200\pi \times 10^3 t)$

What is the bandwidth of FM signal if the frequency sensitivity of the modulator is 25 kHz per volt? (MAY/JUNE – 2010)

Solution:

Given $X(t) = 20 \sin (200\pi \times 10^3 t)$ and $k_f = 25$ kHz/V $= 25 \times 10^3$ Hz/V

Compare the given equation with $E_m \sin (2\pi f_m t)$

We get, $E_m = 20$ V, f_m(or)$f_{m(max)} = 100$ kHz

Maximum frequency deviation $\delta = E_m \times k_f$

$= 20 \times 25 \times 10^3 = 500$ kHz.

Bandwidth of FM signal, BW = $2(\delta + f_{m(max)})$ Hz

$= 2(500$ kHz $+ 100$ kHz$) = 1200$ kHz or 1.2 MHz.

18. Obtain the bandwidth of the FM signal. (MAY/JUNE – 2009)
$c(t) = 10 \cos [\ 2 \times 10^7\pi t + 8 \cos (1000\pi t)]$

Solution:

Given $c(t) = 10 \cos [\ 2 \times 10^7\pi t + 8 \cos (1000\pi t)]$

Compare the given FM signal equation with standard FM signal,

$c(t) = E_C\cos (\omega_c t + m_f\cos\omega_m t)$

Here, $m_f = 8$, $\omega_m = 1000\pi$

Hence $2\pi f_m = 1000\pi$

f_m (or) $f_{m(max)} = 500$ Hz

We know that, modulation index of FM $(m_f) = \delta/f_m$

Hence $\delta = m_f f_m = 8 \times 500$ Hz $= 4000$ Hz.

Bandwidth of FM signal $= 2(\delta + f_{m(max)})$

$= 2\ (4000 + 500) = 9000$ Hz or 9 kHz.

19. What do you understand by FM stereo multiplexing? (MAY/JUNE – 2009)
Stereo multiplexing is a form of frequency division multiplexing designed to transmit two separate signals via the same carrier. It is widely used in the FM radio broadcasting to send two different elements of a program.

The two important factors that influence the FM stereo transmission are:

- The transmission has to operate within the allocated FM broadcast channels.
- It has to be compatible with the monophonic receivers.

20. What is the purpose of limiter in FM receiver?

Limiter is present before demodulator in FM receiver. The purpose of the limiter is to provide a constant level of signal to the FM demodulator, thus reducing the effect of signal level changes in the output. For instance, if two or more signals are received at the same time, a high performance limiter stage can greatly reduce the effect of the weaker signals onthe output. The limiter also reduces the effect of noise spikes.

21. Write the advantages and disadvantages of Foster-Seeley discrimination method.

Advantages:

a. Easier to design.
b. Only two tuned circuits are necessary and they are tuned to same frequency.
c. Linearity is better.

Disadvantages:

a. It requires Amplitude limiting circuit.

22. Write the disadvantages of FM.

a. FM has infinite number of sidebands.
b. Bandwidth requirement of FM is much higher.
c. FM equipments are more complex and hence costly.
d. Area covered by FM is limited, to line of sight area.

23. Distinguish between FM and PM.

S. No.	Frequency Modulation	Phase Modulation
1.	Frequency of the carrier is varied according to amplitude of modulating signal.	Phase of the carrier is varied according to amplitude of modulating signal.
2.	The maximum frequency deviation depends upon the amplitude of modulating signal and modulating frequency.	The maximum phase deviation depends only the amplitude of modulating signal.
3.	Modulation index for FM $m_f = (k_f E_m)/f_m$ wherek_f is frequency deviation constant of FM, E_m is the voltage of modulating signal and f_m is the frequency of modulating signal.	Modulation index for PM $m_p = k_p E_m$ wherek_p is frequency deviation constant of PM and E_m is the voltage of modulating signal.

4.	It has infinite number of sidebands.	It has only two sidebands like AM.

24. Write the expression for spectrum of a single tone FM signal.

When the carrier is frequency modulated by a modulating signal $\cos\omega_m t$, then the FM signal is represented using Bessel functions as follows:

$$e_{FM}(t) = E_c \{J_0 \sin \omega_c t + J_1 [\sin (\omega_c + \omega_m) t - \sin (\omega_c - \omega_m) t]$$
$$+ J_2 [\sin (\omega_c + 2\omega_m) t + \sin (\omega_c - 2\omega_m) t]$$
$$+ J_3 [\sin (\omega_c + 3\omega_m) t - \sin (\omega_c - 3\omega_m) t]$$
$$+ J_4 [\sin (\omega_c + 4\omega_m) t + \sin (\omega_c - 4\omega_m) t] + \dots\}$$

Here $J_0, J_1, J_2, \dots$ are the Bessel functions and E_c is the amplitude of carrier signal.

Above equation shows that the side bands are

Frequency of sidebands	Amplitude
$\omega_c \pm \omega_m$	$E_c J_1$
$\omega_c \pm 2\omega_m$	$E_c J_2$
$\omega_c \pm 3\omega_m$	$E_c J_3$
⋮	⋮

25. Give the frequency spectrum of narrowband FM.

The narrowband FM equation is given as,

$$e_{FM}(t) = E_c \cos (2\pi f_c t) + \frac{mE_c}{2} \{\cos 2\pi(f_c + f_m) t - \cos 2\pi(f_c - f_m) t\}$$

Above equation shows that there is a carrier frequency (f_c) of amplitude E_c, upper sideband $f_c + f_m$ of amplitude $\frac{mE_c}{2}$ and lower sideband $f_c - f_m$ of amplitude $\frac{mE_c}{2}$.

26. What is modulation index of FM?

The modulation index (m_f) is defined as the ratio of maximum frequency deviation (δ) to the modulating frequency (f_m).

$$m_f = \frac{\delta}{f_m} = \frac{\text{Maximum frequency deviation}}{\text{Modulating frequency}}$$

27. What are the advantages of FM over AM?

- All the transmitted power in FM is useful, while in AM most of the transmitted power is in carrier which contains no information.
- The noise in FM can be further reduced by increasing the deviation, which is not in AM.
- Noise in FM is reduced to a large extent by employing amplitude limiters to remove the amplitude variations caused by noise. However these amplitude limiters cannot be used in AM, as information is contained in the amplitude variations of the signal. Thus FM reception is immune to noise than AM reception.
- FM broadcast operates in the upper Very High Frequency (VHF) and Ultra High Frequency (UHF) range, where noise effects are minimal. While on the other hand, AM broadcast operates in the Medium Frequency (MF) and High Frequency (HF) which are easily affected due to noise.

28. What are the applications of phase locked loop?

- Phase locked loops are used for various purposes in AM and FM communication.
- Automatic frequency correction in FM transmitter uses PLL to keep carrier frequency constant.
- PLL is used in direct FM Transmitter to generate wideband FM signals.
- PLL is also used in FM demodulators.

UNIT III RANDOM PROCESS

1. State Central Limit Theorem. (Nov/Dec – 2017, Nov/Dec – 2016, May/June – 2016)
   When infinitely large number of identically and independently distributed random variables is added, the resultant is Gaussian distributed.

2. What is meant by ergodic process? (Nov/Dec – 2017)
   A random process is called ergodic process if time averages are equal to ensemble averages. Thus for ergodic process, $m_X(t) = m_x(T)$ and $R_X(t_1, t_2) = R_x(\tau,T)$

   Where $m_X(t)$ is ensemble mean, $m_x(T)$ is time mean, $R_X(t_1, t_2)$ is ensemble autocorrelaion and $R_x(\tau,T)$ is time autocorrelation.

3. List the necessary and sufficient conditions for the process to be WSS. (MAY/JUNE – 2017)

A process X(t) is Wide-Sense Stationary (WSS) if the following conditions are satisfied:

- Mean of random process is equal to the expected value of random process.

$$m_X(t) = E[X(t)] \text{ is independent of t.}$$

- Autocorrelation $R_X(t_1, t_2)$ depends only on the time difference $\tau = t_1 - t_2$ and not on t_1 and t_2 individually.

4. Define WSS.

A random process is said to be Wide Sense Stationary or Weak Sense Stationary (WSS), if it's mean and autocorrelation functions are independent of shift of time origin.

5. State Wiener – Khintchine (W-K) theorem. (MAY/JUNE – 2017) (or) Write Einstein – Wiener – Khintchine relation. (NOV/DEC – 2016)

Wiener – Khintchine theorem states that for a stationary random process X(t), the power spectral density S(f) is the Fourier transform of autocorrelation function R(τ). (i.e.,)

$$\text{Thus } S(f) = F[R(\tau)]$$

$$\text{where } S(f) = \int_{-\infty}^{\infty} R(\tau)e^{-j2\pi f\tau}\, d\tau \text{ and } R(\tau) = \int_{-\infty}^{\infty} S(f)e^{j2\pi f\tau}\, d\tau$$

6. Define autocorrelation function.(MAY/JUNE – 2016)

The autocorrelation function is defined as the expectation of the product of two random variables which are obtained by observing the random process at different times. Let the random process be observed at t_1 and t_2. The corresponding random variables are $X(t_1)$ and $X(t_2)$. The autocorrelation function will be,

$$R_X(t_1, t_2) = E[X(t_1)X(t_2)] = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2 f_{X(t_1)X(t_2)}(x_1, x_2)\, dx_1 dx_2$$

Here $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x_1 x_2 f_{X(t_1)X(t_2)}(x_1, x_2)$ is the second order Probability Density Function of random process.

7. Define a random variable. Specify the sample space and the random variable for a coin tossing experiment. (NOV/DEC – 2012, MAY/JUNE – 2012, NOV/DEC - 2010)

Random variable:

A function which takes on any value from the sample space and its range is some set of real numbers is called a random variable of the experiment.

Sample space and random variable for coin tossing:

S = {H, T}

Here H – head and T – tail.

Let $X = \begin{cases} 1 \text{ for } S = H \\ -1 \text{ for } S = T \end{cases}$

Then 1 and -1 will be random variables.

8. When a random process is called deterministic? (NOV/DEC – 2011, MAY/JUNE – 2010)

When future values of any sample function can be predicted from the knowledge of past values, then the random process is called deterministic random process.

9. Write the Rayleigh and Rician probability density functions. (MAY/JUNE – 2011)

Probability Density Function for Rayleigh distribution is given by

$$f_R(r) = \frac{r}{\sigma^2} e^{\frac{-r^2}{2\sigma^2}}$$

Probability Density Function for Rician distribution is given by:

$$f_R(r) = \frac{r}{\sigma^2} e^{\frac{-(r^2 + A_C^2)}{2\sigma^2}} I_0\left(\frac{rA_C}{\sigma^2}\right)$$

Here σ^2 is variance of the signal, r is the magnitude or envelope, A_C is the amplitude of constant amplitude sine wave. $I_o(\ )$ is modified Bessel function of the first kind.

10. When the random process is said to be strict sense or strictly stationary? (MAY/JUNE – 2011)

The random process is said to be strict sense or strictly stationary when

i. All the statistical properties do not change with shift of time origin.
ii. A truly stationary process should start at t = -∞ and should not stop till t = +∞.

11. When a random process is called stationary? (MAY/JUNE – 2010)

When the statistical properties of a random process do not change with time, then it is called stationary random process.

12. Define non-stationary process.

A process is said to be non-stationary if the statistical properties are function of time.

13. State the properties of autocorrelation function.

- The autocorrelation function is an even function of τ. (i.e.,) $R_X(\tau) = R_X(-\tau)$
- The autocorrelation function has its maximum value of $\tau = 0$ (i.e.,) $|R_X(\tau)| \leq R_X(0)$
- The autocorrelation function shows conjugate symmetry.

$$R_X(\tau) = R_X^*(-\tau)$$

- The autocorrelation function $R_x(\tau)$ and energy spectral density $\psi(f)$ form a Fourier transform pair.

$$R_X(\tau) \text{ ① } \dagger(f)$$

14. State the properties of Gaussian process.

- If a Gaussian process is applied at the input of stable linear filter, then the output is also Gaussian.
- Let the Gaussian process be sampled at times $t_1, t_2, \ldots, t_n$. Then the set of random variables is obtained $X(t_1), X(t_2), \ldots, X(t_n)$ due to sampling. This set of random variablesis jointly Gaussian for any n.
- If the Gaussian process is stationary, then Gaussian process is also strictly stationary.
- If the random variables obtained due to sampling, the Gaussian process are uncorrelated, then they are statistically independent.

15. List out the properties of Power Spectral Density (PSD).

- Autocorrelation function $R(\tau)$and Power Spectral Density S(f) form a Fourier transform pair. (i.e.,) $R(r)$ ① $S(f)$
- The area under the Power Spectral Density function S(f) gives average power (P) of the signal. (i.e.,)

$$P = \int_{-\infty}^{\infty} S(f)df$$

- If $|H(f)|^2$ is the power gain of linear time invariant system, the output Power Spectral Density $S_o(f)$ and input Power Spectral Density $S_i(f)$ are related by

$$S_o(f) = |H(f)|^2 S_i(f)$$

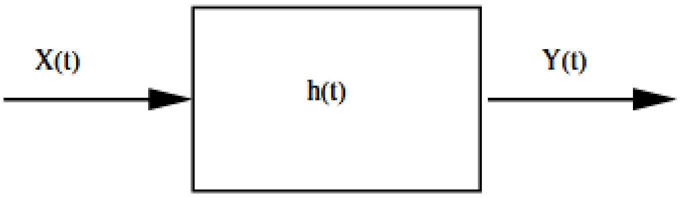
- The Power Spectral Density is even function of frequency (i.e.,) S(f) = S(-f)

16. Define random process.

A Random process X(s,t) is a function that maps each element of a sample space into a time function called sample function. Random process is a collection of time functions.

17. Define transmission of a random process through a LTI filter.

When the stationary random process X(t) with mean m_x and autocorrelation function $R_x(\tau)$ is passed through a Linear Time – Invariant (LTI) filter of impulse response h(t), producing a new random process Y(t) at the filter output.



18. Difference between random variable and random process.

S. No.	Random variable	Random process
1.	A random variable is a mapping from the sample space to the set of real numbers.	A Random process X (s,t) is a function that maps each element of a sample space into a time function called sample function.
2.	It is not the function of time.	It is the function of time.
3.	Random variables are not further classified.	Random processes can be stationary or ergodic.
4.	Only ensemble averages can be calculated.	Ensemble as well as time averages can be calculated.

19. Define Probability Density Function (PDF).

The derivative of Cumulative Distribution Function (CDF) with respect to some dummy variable is called as Probability Density Function (PDF).

PDF is denoted by $f_X(x)$. Therefore, it is given as,

$$f_X(x) = \frac{d}{dx} F_X(x)$$

Here x is the dummy variable.

20. Write the properties of Probability Density Function (PDF).

- PDF is nonzero for all values of x.

$$f_X(x) \geq 0 \text{ for all } x.$$

- The area under the PDF curve is equal to 1.

$$\int_{-\infty}^{\infty} f_X(x)dx = 1$$

- Cumulative Distribution Function (CDF) is obtained by integrating PDF.

$$F_X(x) = \int_{-\infty}^{x} f_X(x)dx$$

21. State Baye's rule. (NOV/DEC-2015)

Statement: Let $B_1, B_2, B_3, \ldots, B_n$ be mutually exclusive events and event A occurs only when any one of $B_1, B_2, B_3, \ldots, B_n$ occurs. Then,

$$P(B_i/A) = \frac{P(B_i)P(A/B_i)}{\sum_{i=1}^{n} P(B_i)P(A/B_i)}$$

22. Define Gaussian process. (NOV/DEC-2011)

The random process X(t) is said to be Gaussian distributed if every linear functional of X(t) is a Gaussian random variable.

The linear functional of X(t) is given as,

$$Y = \int_{0}^{T} g(t)X(t)dt$$

Here Y is the random variable called linear functional of X(t).

g(t) is some weighting function. For every g(t), Y must be Gaussian distributed. T is called the observation period of a random process.

23. Define jointly Wide Sense Stationary processes.

The two processes X(t) and Y(t) are called jointly Wide Sense Stationary if each of X(t) and Y(t) is Wide Sense Stationary (WSS) and their cross-correlation depends only upon time difference τ. (i.e.,)

$$R_{XY}(t, t+\tau) = E[X(t)\, Y(t+\tau)] = R_{XY}(\tau)$$

Where $R_{XY}(t, t+\tau)$ and $R_{XY}(\tau)$ are crosscorrelation functions.

24. Define mean of random process.

The mean of random process is denoted by $m_X(t)$. The mean value is basically expected value of random process X(t).

Mean is given by

$$m_X(t) = E[X(t)] = \int_{-\infty}^{\infty} x\, f_{X(t)}(x)\, dx$$

Here $f_{X(t)}(x)$ is the first order probability density function of a random process.

25. Difference between SSS and WSS processes.

S. No.	Strict Sense Stationary (SSS) process	Wide Sense Stationary (WSS) process
1.	All statistical properties do not change with time.	Mean and autocorrelation do not change with time.
2.	Ideally, this process does not have start and end.	This process does have start and end at finite times.
3.	Such processes are not physically possible.	Such processes are physically possible.
4.	It appears stationary at all the times.	It appears stationary over certain period of time.

UNIT IV NOISE CHARACTERIZATION

1. Define the term noise equivalent temperature. (Nov/Dec – 2017)

   The equivalent noise temperature of a system is defined as the temperature at which a noisy resistor has to be maintained such that, by connecting the resistor to the input of a noiseless version of the system; it produces the same available noise power at the system output as that produced by all the sources of noise in the actual system. Noise Equivalent Temperature is denoted by T_e. Thus, $T_e = (F – 1) T$

   Where F is the noise factor and T is the temperature in Kelvin

2. List the external sources of noise. (Nov/Dec – 2017)

   There are number of external sources of noise. These are grouped into three categories,

   - ➢ Atmospheric noise i.e., Natural noise
   - ➢ Extraterrestrial noise i.e., Natural noise
     - ✓ Solar noise
     - ✓ Cosmic noise
   - ➢ Industrial noise i.e., Manmade noise

3. Define threshold effect in AM receiver. (NOV/DEC – 2011, NOV/DEC – 2010)

   In AM receiver, when the carrier to noise ratio reduces below certain value, the message information is lost. The performance of AM receiver deteriorates rapidly. It means that the input signal to noise ratio is below a certain level called threshold level and this effect is called threshold effect.

4. Comment the role of pre-emphasis and de-emphasis circuit in SNR improvement. (MAY/JUNE – 2017)

   Pre-emphasis

   It is the process of artificially boosting of high frequency component of message signal inorder to improve the overall Signal-to-Noise Ratio (SNR) by minimizing the noise present in the signal. Pre-emphasis is done in the transmitter side before frequency modulation.

   De-emphasis

   It is the process of decreasing the strength of high frequency component of message signal to get back the original transmitted message signal in order to improve the overall Signal-to-

Noise Ratio (SNR) by minimizing the noise present in the signal. De-emphasis is performed in the receiver side after demodulation.

Thus pre-emphasis and de-emphasis produces a more uniform SNR throughout the message signal frequency spectrum.

5. Two resistors of 20 kΩ, 50 kΩ are at room temperature (290 K). For a bandwidth of 100 kHz, calculate the thermal noise voltage generated by the two resistors in series. (NOV/DEC – 2016, NOV/DEC - 2011)

   Solution:

   Given R_1 = 20 kΩ, R_2 = 50 kΩ, T = 290 K

   B = 100 kHz, k = 1.38 x 10^{-23} J/K

   Equivalent series resistance will be, R = $R_1 + R_2$ = 20 + 50 = 70 kΩ

   Thermal noise voltage will be

   $E_n = \sqrt{4kTBR} = \sqrt{4 * 1.38 * 10^{-23} * 290 * 100 * 10^3 * 70 * 10^3} = 10.58\ \mu V$

6. Define noise figure. (NOV/DEC – 2016, MAY/JUNE – 2016, MAY/JUNE – 2015, MAY/JUNE – 2014, MAY/JUNE – 2013, MAY/JUNE - 2012)

   The noise factor F of an amplifier, or any other network, is defined as

$$\text{Noise Factor (F)} = \frac{\text{Available } \frac{S}{N} \text{ power ratio at the input}}{\text{Available } \frac{S}{N} \text{ power ratio at the output}}$$

   If the noise factor is expressed in decibel, then it is known as Noise Figure.

   Noise Figure = (Noise Factor) dB = 10 log [F]

7. Define capture effect in FM. (MAY/JUNE – 2016, MAY/JUNE – 2015, MAY/JUNE – 2012)

   When the noise interference is stronger than FM signal, then FM receiver locks to interference. This suppresses FM signal. When the noise interference as well as FM signals is of equal strength, and then the FM receiver locking fluctuates between them. This phenomenon is called capture effect.

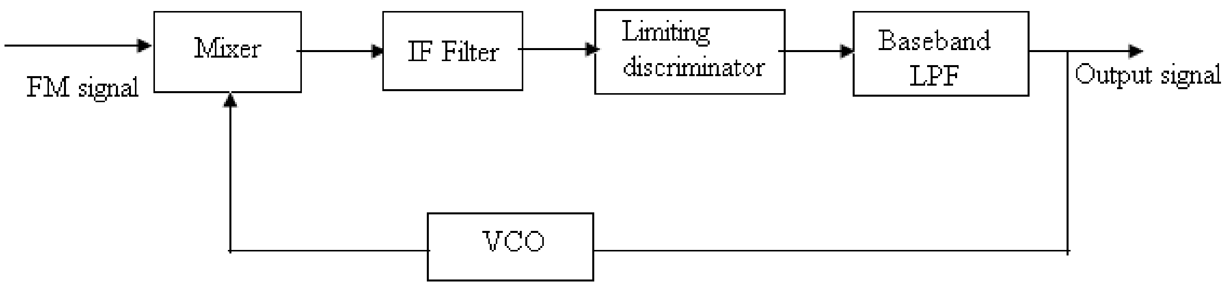
8. Define SNR. (MAY/JUNE – 2015)

Signal to Noise Ratio (SNR) is defined as the ratio of average signal power to average noise power.

$$\text{SNR} = \frac{\text{Average Signal Power}}{\text{Average Noise Power}}$$

9. What are the methods to improve FM threshold reduction? (MAY/JUNE – 2015, MAY/JUNE – 2011, MAY/JUNE – 2010)

Threshold reduction can be improved with the help of negative feedback in FM demodulator. It is achieved in Frequency Modulation Feedback (FMFB) demodulator method.



- The Voltage Controlled Oscillator (VCO) frequency changes as per low frequency variations of output signal. In other words, VCO frequency does not depends upon high frequency variations of narrowband noise.
- Thus FMFB demodulator tracks only the slowly varying frequency of wideband FM waves.
- Hence, the receiver responds only to narrowband noise centered on instantaneous carrier frequency. This reduces the threshold of FMFB receiver.

10. Define white noise. Give its characteristics. (MAY/JUNE – 2014, MAY/JUNE – 2013, MAY/JUNE - 2011)

The noise which has Gaussian distribution and has flat spectral density over a wide range of frequencies is called white noise. The Power Spectral Density ($S_w(f)$) of white noise is given as,

$$S_w(f) = \frac{N_o}{2}$$

Where N_o is the amount of noise power.

Characteristics of white noise:

- White noise contains all frequency components in equal proportion.
- White noise contains frequencies from $-\infty$ to $+\infty$.
- White noise has a Gaussian distribution. Hence, any two samples of white noise are also statistically independent. Thus white noise samples are statistically independent as well as uncorrelated.

11. State the need for pre-emphasis and de-emphasis circuits in the field of communication. (MAY/JUNE – 2014, NOV/DEC – 2013, MAY/JUNE - 2013)

    The Power Spectral Density (PSD) of noise at the output of FM receiver usually increases rapidly at high frequencies but the PSD of message signal falls off at higher frequencies. This means the message signal doesn't utilize the frequency band in efficient manner. Thus, to utilize the frequency band in efficient manner and to improve noise performance can be obtained with the help of pre-emphasis and de-emphasis in FM.

12. When carrier to noise ratio is high, how will you get figure of merit of FM systems? (NOV/DEC – 2013)

    In case of high carrier to noise ratio, the transmission bandwidth B_T is increased. It provides the quadratic increase in the output signal to noise ratio or figure of merit of the FM systems.

$$\text{Figure of Merit} = \frac{(SNR)_o}{(SNR)_c} = \frac{3k_f^2 P}{W^2}$$

    k_f is the frequency sensitivity, P is the average power of message signal and W is message bandwidth.

13. How will you define the narrowband noise n(t) at the IF filter output in terms of its inphase and quadrature components? (NOV/DEC – 2013)

    The narrowband noise n(t) at the IF filter output in terms of inphase and quadrature components is,

    $n(t) = n_c(t) \cos(2\pi f_o t) - n_s(t) \sin(2\pi f_o t)$

    Here $n_c(t)$ and $n_s(t)$ are inphase and quadrature components.

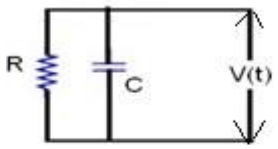
14. Determine the range of tuning of a local oscillator of a Super Heterodyne receiver when $f_{LO}>f_C$. The broadcast frequency range is 540 Hz to 1600 Hz. Assume f_{IF} = 455 kHz. (MAY/JUNE – 2012)

Solution: Given f_c = 540 Hz to 1600 Hz, f_{IF} = 455 kHz.

For $f_{LO}>f_C$ (High-side tuning), $f_{Lo}= f_c + f_{IF}$ = (540 Hz to 1600 Hz) + 455 kHz

= $(540 + 455 *10^3)$ to $(1600 + 455 *10^3)$ = (455.54 to 456.6) kHz.

15. Calculate thermal noise voltage across the simple RC circuit shown with R = 1 kΩ and C = 1 μF at T = 27°C. (NOV/DEC – 2012)



Solution: Given k =1.38×10^{-23} J/ °K, C = 1 μF, T = 27 + 273 = 300° K,

$$V_{no} = \sqrt{\frac{kT}{C}} = \sqrt{\frac{1.38 * 10^{-23} * 300}{1 * 10^{-6}}} = 0.06434\mu V.$$

16. Compare the noise performance of DSBSC receiver using coherent detection with AM receiver using envelope detection. (NOV/DEC – 2012, MAY/JUNE - 2011)

S. No.	Parameters	AM using Envelope detection	DSBSC using Coherent detection
1.	$(SNR)_O$ and $(SNR)_C$	$= \frac{1}{3}(SNR)_c$ for $m_a = 1$ Where m_a is the modulation index of AM	$(SNR)_o = (SNR)_c$
2.	Bandwidth	$2f_m$	$2f_m$
3.	Threshold effect	AM exhibits a threshold effect for lowsignal to noise ratio.	No threshold effect
4,	Noise performance	Poor	Better noise performance than AM

17. What is FM threshold effect?

As the carrier to noise ratio is reduced, clicks are heard in the receiver output. As the carrier to noise ratio reduces further, crackling or sputtering sound appears at the receiver output. Near the breaking point, the theoretically calculated output signal to noise ratio becomes large, but its actual value is very small. This phenomenon is called threshold effect.

18. What are the characteristics of superheterodyne receivers? (MAY/JUNE – 2010)

- It has wide range of tunable frequencies.
- It has good selection and rejection of adjacent channels.
- It provides good amplification.

19. A receiver connected to an antenna of resistance of 50 Ω has an equivalent noise resistance of 30 Ω. Find the receiver noise figure. (MAY/JUNE – 2010)

Solution: Given $R_a = 50\ \Omega$, $R'_{eq} = 30\Omega$

$$\text{Noise Figure, } F = 1 + \frac{R_{eq}}{R_a} = 1 + \frac{30}{50} = 1.6$$

20. The power of a signal 10 mW and the power of the noise is 1 μW. What are the values of SNR and SNR_{dB}. (MAY/JUNE - 2009)

Solution: Given Signal Power = 10 mW, Noise Power = 1 μW

$$SNR = \frac{S}{N} = \frac{\text{Signal Power}}{\text{Noise Power}} = \frac{10\text{ mW}}{1\ \mu\text{W}} = \frac{10 * 10^{-3}}{1 * 10^{-6}} = 10000$$

$SNR_{dB} = 10 \log_{10} (10000) = 10 \log_{10} (10000) = 4*0 = 40$ dB.

21. Give the characteristics of Shot Noise. (MAY/JUNE - 2009)

- Shot noise is generated due to fluctuations in the number of electrons or holes.
- Shot noise has uniform spectral density.
- Mean square noise current depends upon direct component of current.
- Shot noise depends upon operating conditions of the device.

22. Define thermal noise. Give the expression for the thermal noise voltage across a resistor. (MAY/JUNE - 2015)

The electrons in a conductor possess varying amounts of energy. Small fluctuations in this energy produce small noise voltage in the conductor. These random fluctuations produced by thermal agitation of the electrons are called thermal noise.

Thermal noise voltage across a resistor is given as

$$E_n = \sqrt{4kTBR}$$

Where k is the Boltzmann's constant, T is the temperature of resistor,

B is the bandwidth and R is the resistor value.

23. Define noise equivalent bandwidth.

The noise equivalent bandwidth of the real filter is defined as the bandwidth of an ideal filter at which the noise power passed by real filter and ideal filter is same.

24. What is meant by figure of merit of a receiver?

The ratio of output signal to noise power $(SNR)_o$ to the channel signal to noise power $(SNR)_c$ is called figure of merit.

$$\text{Figure of merit} = \frac{(SNR)_o}{(SNR)_c} = \frac{S_o/N_o}{S_i/N_i}$$

25. What is a narrowband noise?

The signals of interest are usually passed through the filter and then given to the receiver. Such filter is narrowed and its midband frequency is large enough compared to bandwidth. The noise appearing at the output of such a filter is called narrowband noise.

26. Define figure of merit of AM receiver.

Figure of Merit of AM receiver is given as

$$\text{Figure of Merit} = \frac{k_a^2 P}{1 + k_a^2\, P}$$

Here k_a is percentage modulation and P is the average power of message signal.

27. Define flicker noise.

Flicker noise or 1/f noise is a form of electronic noise that dominates at low frequencies or low frequency offsets from oscillators. Flicker noise has a 1/f characteristic, or a "pink noise" power density spectrum. Flicker noise occurs in almost all electronic devices.

28. Compare the noise performance of AM and FM systems. (MAY/JUNE - 2009)

S. No.	Parameters	AM envelope detection (Nonlinear)	AM DSB-SC or SSB-SC linear detection	FM
2.	Bandwidth B_T	$2f_m$	$2f_m$ (DSB-SC) f_m (SSB-SC)	$8f_m$ for $m_f = 2$ $16f_m$ for $m_f = 5$
3.	Threshold effect	Present	Absent	Present
4.	Noise performance	Poor	Better	Good

UNIT-5

SAMPLING & QUANTIZATION

1. Define Dirac comb or ideal sampling function. What is its Fourier Transform?

Dirac comb is nothing but a periodic impulse train in which the impulses are spaced by a time interval of Ts seconds. The equation for the function is given by

$$\delta_{Ts}(t) = \sum_{n=-\infty}^{\infty} \delta(t - nTs)$$

The Fourier Transform of $\delta_{Ts}(t)$ is given by

$$F[\delta_{Ts}(t)] = f_s \sum_{m=-\infty}^{\infty} \delta(f - mf_s)$$

2. Give the interpolation formula for the reconstruction of the original signal.

The interpolation formula for the reconstruction of the original signal g(t) from the sequence of sample values {g(n/2W)}.

$$g(t) = \sum_{n=-\infty}^{\infty} g(n/2W)\ \text{sinc}(2Wt-n)$$

where 2W is the bandwidth

n is the number of samples.

3. State sampling theorem. (Madras Univ., Nov-97,Oct-98,Dec-06,08,09,May-07,09,12)

¾ If a finite –energy signal g(t) contains no frequencies higher than W hertz ,it is completely determined by specifying its co=ordinates at a sequence of points spaced 1/2W seconds apart.

¾ If a finite energy signal g(t) contains no frequencies higher than W hertz, it may be completely recovered from its co=ordinates at a sequence of points spaced 1/2W seconds apart.

¾ A band limited signal of finite energy, which has no frequency components higher than W Hz, may be completely recovered from the knowledge of its samples taken at the rate of 2W samples per second.

4. Define quadrature sampling.

Quadrature sampling is used for uniform sampling of band pass signals.

Consider $g(t) = g_I(t)\cos(2\Pi f_c t) - g_Q(t)\sin(2\Pi f_c t)$.

5. Define Nyquist rate. (Madras Univ, April-97)

Let the signal be band limited to W Hz. Then Nyquist rate is given as,

Nyquist rate = 2W samples/sec

Aliasing will not take place if sampling rate is greater than Nyquist rate.

6. What is meant by aliasing effect? (Madras Univ,April-97,Dec-05)

¾ Aliasing effect takes place when sampling frequency is less than Nyquist rate. Under such condition, the spectrum of the sampled signal overlaps with itself. Hence higher frequencies take the form of lower frequencies. This interference of the frequency components is called as aliasing effect.

¾ A band limited signal of finite energy, which has no frequency components higher than W Hz, may be completely recovered from the knowledge of its samples taken at the rate of 2W samples per second.

7. What is meant by PCM?

Pulse code modulation (PCM) is a method of signal coding in which the message signal is sampled, the amplitude of each sample is rounded off to the nearest one of a finite set of discrete levels and encoded so that both time and amplitude are represented in discrete form.. This allows the message to be transmitted by means of a digital waveform.

8. What are the two fold effects of quantizing process?

1. The peak-to-peak range of input sample values subdivided into a finite set of decision levels or decision thresholds
2. The output is assigned a discrete value selected from a finite set of representation levels are reconstruction values that are aligned with the treads of the staircase.

9. What is meant by idle channel noise?

Idle channel noise is the coding noise measured at the receiver output with zero transmitter input.

10. What is meant by prediction error?

The difference between the actual sample of the process at the time of interest and the predictor output is called a prediction error.

11. Define delta modulation.

Delta modulation is the one-bit version of differential pulse code modulation.

12. Define adaptive delta modulation.

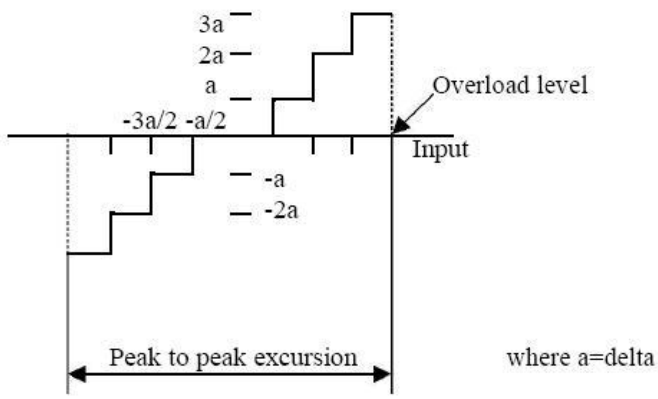
The performance of a delta modulator can be improved significantly by making the step size of the modulator assume a time- varying form. In particular, during a steep segment of the input signal the step size is increased. Conversely, when the input signal is varying slowly, the step is reduced, In this way, the step size is adapting to the level of the signal. The resulting method is called adaptive delta modulation (ADM).

13. Name the types of uniform quantizer?

1. Mid tread type quantizer.
2. mid riser type quantizer.

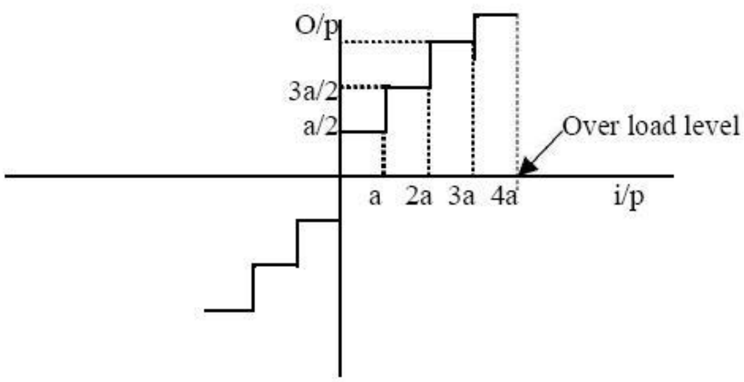
14. Define mid tread quantizer?

Origin of the signal lies in the middle of a tread of the staircase.



15. Define mid-riser quantizer?

Origin of the signal lies in the middle of a rise of the staircase



16. What is meant by quantization? (May-12)

While converting the signal value from analog to digital, quantization is performed. The analog value is assigned to nearest digital value. This is called quantization. The quantized value is then converted into equivalent binary value. The quantization levels are fixed depending upon the number of bits. Quantization is performed in every Analog to Digital Conversion.

17. The signal to quantization noise ratio in a PCM system depends on what criteria? (MAY-06)

The signal to quantization noise ratio in PCM is given as,

$$\mathbf{(S/N)}\ \boldsymbol{db} \leq \mathbf{(4.8+6}\boldsymbol{v}\mathbf{)dB}$$

Here v is the number of bits used to represent samples in PCM. Hence signal to quantization noise ratio in PCM depends upon the number of bits or quantization levels.

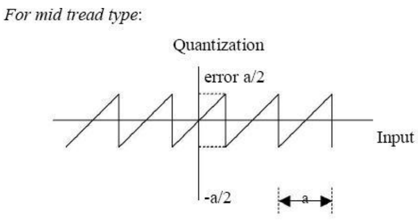
18. Define quantization error? (May-07)

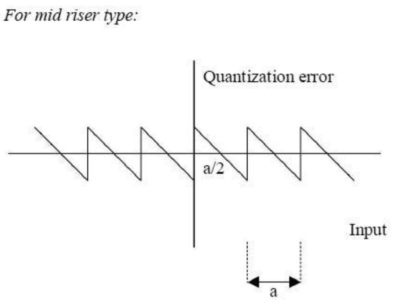
Quantization error is the difference between the output and input values of quantizer.

19. What you mean by non-uniform quantization? (May-08)

Step size is not uniform. Non-uniform quantizer is characterized by a step size that increases as the separation from the origin of the transfer characteristics is increased. Non-uniform quantization is otherwise called as robust quantization. .

20. Draw the quantization error for the mid tread and mid-rise type of quantizer?





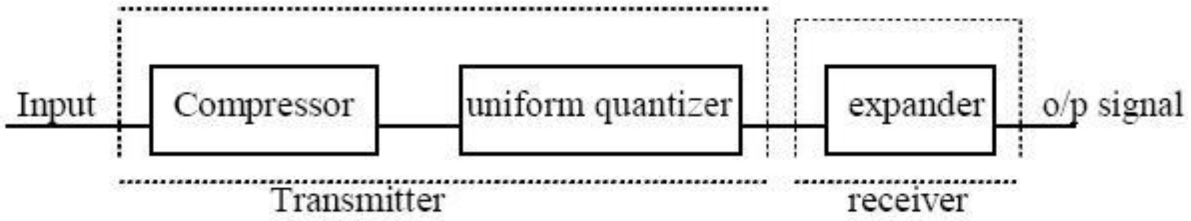
21. What is the disadvantage of uniform quantization over the non-uniform quantization?

SNR decreases with decrease in input power level at the uniform quantizer but non-uniform quantization maintains a constant SNR for wide range of input power levels. This type of quantization is called as robust quantization.

22. What do you mean by companding?

The signal is compressed at the transmitter and expanded at the receiver. This is called as companding. The combination of a compressor and expander is called a compander.

23. Draw the block diagram of compander? Mention the types of companding? Block diagram:



Types of companding:

1. A-law companding.
2. µ-law companding.