Paper Code: AS-2798
B.Sc. (Electronics) : V Semester
Paper I: Analog Communication

Section-I

1. (i) The unit of modulation index is:
   (a) volt (b) ampere (c) Hz **(d) no unit**

   (ii) If a periodic function f(t) of period T satisfies $f(t) = -f(t + T/2)$, then in its Fourier series expansion,
   (a) the constant term will be zero.
   (b) there will be no cosine terms.
   (c) there will be no sine terms.
   (d) there will be no even harmonics.

   (iii) In modulation, carrier wave contains the voltage :
   (a) of resultant wave
   (b) of speech voltage to be transmitted
   (c) with constant frequency - phase or amplitude
   (d) for which frequency, phase or amplitude is varied

   (iv) The ratio of modulating power to total power at 100% modulation:
   (a) 1:3 (b) 2:3 (c) 1:2 (d) 3:2

   (v) In a low level AM system, amplifiers following the modulated stage must be
   (a) a linear devices
   (b) harmonic devices
   (c) class C amplifiers
   (d) non-linear devices

   (vi) Which of the following noise become of great importance at high frequencies:
   (a) shot noise (b) random noise
   (c) impulse noise **(d) transit-time noise**

   (vii) A carrier is simultaneously modulated by to sine waves with modulation indices of 0.3 and 0.4, the total modulation index is

   (a) 1.0 **(b) 0.5** (c) 0.7 (d) 2.0

   (viii) In the spectrum of a frequency-modulated wave
   (a) the carrier frequency disappears when the modulation index is large
   (b) the amplitude of any sideband depend on the modulation index
   (c) the total number of sideband depend on the modulation index
   (d) the carrier frequency cannot disappears

   (vi) The condition for the reactance modulator to be pure inductive using RC network is
   (a) Xc >> R **(b) Xc << R**
   (c) Xc = R (d) Xc = 2R

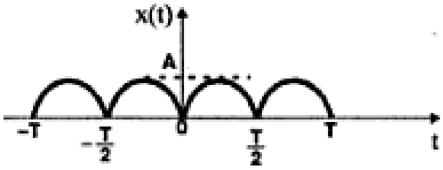
   (x) According to Carson's rule, the bandwidth required to pass an FM wave is

(a) $2f_m$ (b) $2\Delta f$

(c) $2(\Delta f + f_m)$ (d) $(\Delta f + f_m)$

Section – II

2. Determine the trigonometric form of Fourier series of the full wave rectifier sine wave as shown in figure:



Ans: The waveform shown in fig. is the output of full wave rectifier. The equation of the half sine wave is

$$f(t) = A \sin\left(\frac{\omega t}{2}\right)$$

It has even symmetry i.e. f(t) = f(-t) *t*herefore, f(*t*) is even and $b_n = 0$.

$$a_n = \frac{4}{T}\int_0^{\frac{T}{2}} f(t)\cos n\omega t\, dt = \frac{4A}{T}\int_0^{\frac{T}{2}} \sin\left(\frac{\omega t}{2}\right)\cos n\omega t\, dt = \frac{2A}{T}\int_0^{\frac{T}{2}} 2\sin\left(\frac{\omega t}{2}\right)\cos n\omega t\, dt$$

$$= \frac{2A}{T}\int_0^{\frac{T}{2}}\left[\sin\left(n+\frac{1}{2}\right)\omega t - \sin\left(n-\frac{1}{2}\right)\omega t\, dt\right]$$

$$= \frac{2A}{\omega T}\left[-\frac{\cos\left(n+\frac{1}{2}\right)\omega t}{\left(n+\frac{1}{2}\right)} + \frac{\cos\left(n-\frac{1}{2}\right)\omega t}{\left(n-\frac{1}{2}\right)}\right]_0^{\frac{T}{2}}$$

$$= \frac{A}{\pi}\left[-\frac{\cos\frac{1}{2}(2n+1)\pi - 1}{\frac{1}{2}(2n+1)} + \frac{\cos\frac{1}{2}(2n-1)\pi - 1}{\frac{1}{2}(2n-1)}\right]$$

$$= \frac{A}{\pi}\left[\frac{1}{2n+1} - \frac{1}{2n-1}\right] = \frac{4A}{\pi\,(1-4n^2)}$$

$\therefore$ $$a_0 = \frac{4A}{\pi}$$

$\therefore$ $$f(t) = \frac{4A}{\pi} + \frac{4A}{\pi}\sum_{n=1}^{\infty}\frac{\cos n\omega t}{1-4n^2}$$

3. What is modulation and explain why we need modulation. Derive the expression for amplitude modulated carrier wave.

Ans: Modulation

Modulation is the process of placing the message signal over some carrier to make it suitable for transmission over long distance.

Need of Modulation

There are several important reason which are given below to modulate the original signal :

i) To increase the bandwidth of the signal i.e. large frequency range is transmitted.
ii) To multiplex the signals i.e. different kinds of signal can be transmitted simultaneously
iii) By modulating the signals in different proportion and different frequency range the interference can be reduced, in other words, reduce the complexity of the transmission system
iv) To decrease antenna height.

The expression for amplitude modulated carrier wave

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

$$e_m = E_m \sin\omega_m t$$

and the carrier signal by e_c

$$e_c = E_c \sin\omega_c t$$

The expression for amplitude modulated wave can be given as

$$E_{AM} = E_c + e_m$$

$$= E_c + E_m \sin\omega_m t$$

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

$$e_m = E_{AM} \sin\theta = E_{AM} \sin\omega_c t$$

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

$$= E_c \sin\omega_c t + E_m \sin\omega_c t \sin\omega_m t$$

$$= E_c \sin\omega_c t + \frac{E_m}{2}[\cos(\omega_c - \omega_m) - \cos(\omega_c + \omega_m)]$$

4. Explain the following term with suitable expression.

(i) Signal to noise ratio

Signal to noise ratio is calculated in communication systems. It is used for bandwidth, transmission rate, etc. calculations. It is defined as

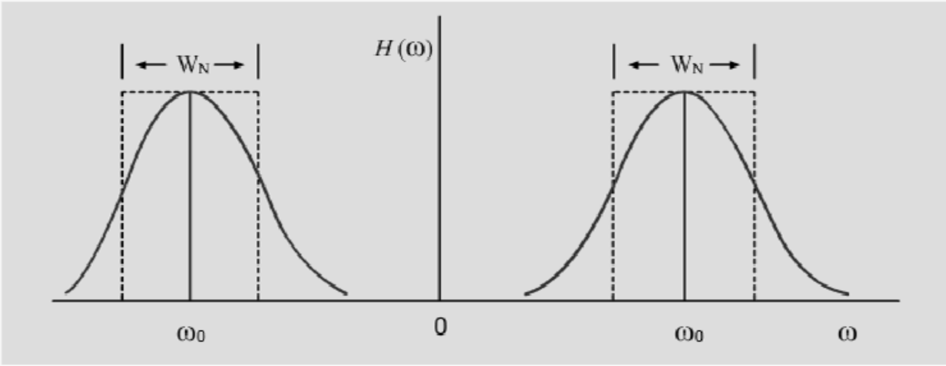
$$\frac{S}{N} = \frac{signal\ power}{noise\ power}$$

$$\frac{S}{N} = \frac{V_s^2/R}{V_n^2/R} = \left[\frac{V_s}{V_n}\right]^2$$

where, V_s is the signal voltage and V_n is the noise voltage

(ii) Noise bandwidth

Noise Bandwidth is defined as the frequency span of a noise power curve with an amplitude equal to the. actual peak value, and with the same integrated area.



Noise Bandwidth

For example, if the real filter with transfer $H(\omega)$ centered at ω_0 is used, we can consider an equivalent rectangular filter centered at ω_0 with a bandwidth W_N passing the same noise power. W_N is called the noise bandwidth of the real filter.

(iii) Noise temperature

The noise can also be represented by what is known as equivalent noise temperature. This representation is more convenient at microwave frequencies in connection with the noise at the receiver input.

If the noise power due to amplifier, having a noise factor F, is

$P_{na} = (F-1)kTB$

If T_e represents equivalent noise temperature representing noise power, then

$P_{na} = kT_eB$, as per definition

$kT_eB = (F-1)kTB$

$T_e = (F-1)T$

Equivalent noise temperature is just an alternative way of representing noise factor.

5. A complex modulating waveform consisting of sine wave amplitude 2V and frequency 2 kHz plus a cosine wave of amplitude 6V and frequency 4kHz amplitude modulates a 600 kHz and 12V peak carrier voltage. Plot the spectrum of modulated wave and determine the average power when the modulated wave is fed into 100Ω load.

Ans: The expression for amplitude modulated wave of the two wave forms represented by sine and cosine wave is given by

$$\begin{aligned} e_{AM} &= (E_c + E_{m1}\sin\omega_{m1}t + E_{m2}\cos\omega_{m2}t)\sin\omega_c t \\ &= E_c\sin\omega_c t + \frac{m_1 E_c}{2}\cos(\omega_c - \omega_{m1})t \\ &\quad - \frac{m_1 E_c}{2}\cos(\omega_c + \omega_{m1})t + \frac{m_2 E_c}{2}\sin(\omega_c + \omega_{m2})t \\ &\quad + \frac{m_2 E_c}{2}\sin(\omega_c - \omega_{m2})t \end{aligned}$$

Given, $E_c = 12$ V, $E_{m1} = 2$ V, $E_{m2} = 6$ V, $f_c = 600$ kHz, $f_{m1} = 2$ kHz, $f_{m2} = 4$ kHz

$m_1 = E_{m1}/E_c = 2/12 = 1.66$, $R = 100\ \Omega$

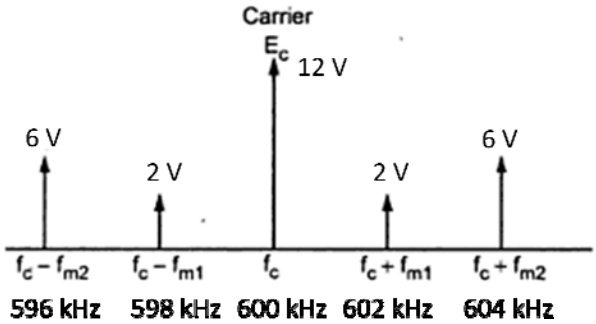
$m_2 = E_{m2}/ E_c \quad = 6/12 = 0.50$

The average power $P_{total} = \dfrac{E_c^2}{2R}\left(1+\dfrac{m_1^2}{2}+\dfrac{m_2^2}{2}\right)$

$$= \frac{12^2}{2\times 100}\left(1+\frac{(1.66)^2}{2}+\frac{(0.5)^2}{2}\right)$$

$= 1.8$ W

The spectrum of modulated wave is



6. Derive the following expression for the AM wave.

$$\frac{P_t}{P_c} = 1 + \frac{m^2}{2}$$

where, m is the modulation index, P_t is the total power of modulated wave and P_c is the power of carrier wave.

Ans: Let the V^2_{carr}, V^2_{LSB} and V^2_{USB} be the rms voltages of the carrier, lower side band and upper side band, respectively, then the total power of the modulated wave will be

$$P_t = P_c + P_{LSB} + P_{USB}$$

$$P_t = \frac{V_{carr}^2}{R} + \frac{V_{LSB}^2}{R} + \frac{V_{USB}^2}{R}(rms)$$

where R is the resistance in which power is dissipated.

$$P_c = \frac{V_{carr}^2}{R} = \frac{\left(V_c/\sqrt{2}\right)^2}{R} = \frac{V_c^2}{2R}$$

$$P_{LSB} = P_{USB} = \frac{V_{SB}^2}{R} = \left(\frac{mV_c/2}{\sqrt{2}}\right)^2 \div R = \frac{m^2V_c^2}{8R}$$

$$P_t = \frac{V_c^2}{2R} + \frac{m^2V_c^2}{8R} + \frac{m^2V_c^2}{8R}$$

$$P_t = P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$$

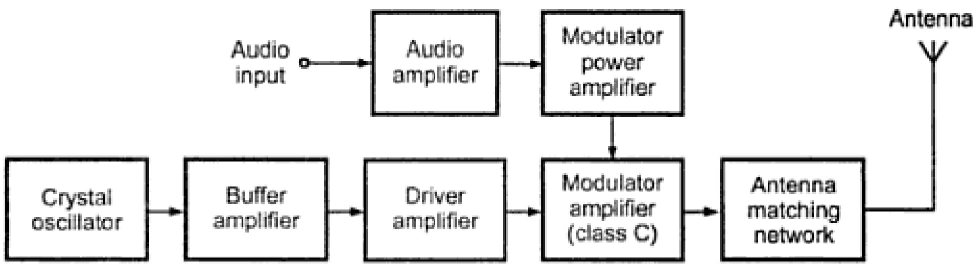
$$\frac{P_t}{P_c} = 1 + \frac{m^2}{2}$$

7. Draw a block diagram for AM transmitter which can be used as high or low level modulation system. Describe the function of each block. Compare high and low level modulation in AM transmitter.

Ans: AM Transmitters

High Level AM Transmitter

Fig. shows the block diagram of AM transmitter.



The crystal oscillator generates carrier frequency. The buffer amplifiers and driver amplifiers amplify the power level of the carrier to required value. The amplified carrier is given to class C modulator amplifier. The modulating signal is audio signal and given to audio amplifier. It is further amplified by audio power amplifier at a level suitable for modulation. The class C modulator amplifier modulates the carrier input according to modulating audio signal. The output of the class C modulating amplifier is AM and it is given to antenna through some antenna matching network. The antenna matching network is generally tuned LC circuit in collector circuit of modulator amplifier. In this AM transmitter, the modulator amplifier operates al high power levels and delivers power directly to the antenna. This is called High level modulated AM transmitter.

Low Level AM Transmitter

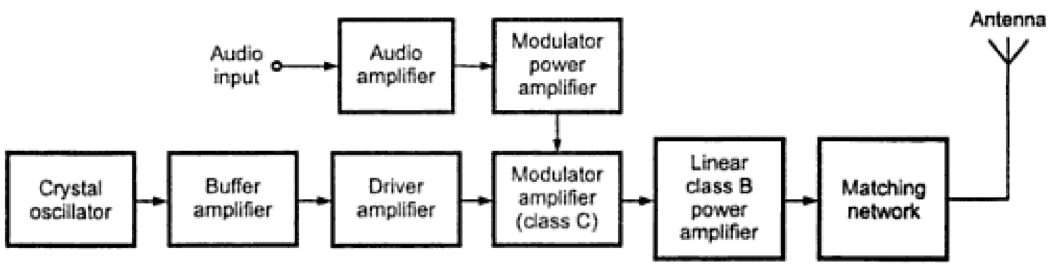


Fig. shows low level modulated AM transmitter block diagram. In this block diagram, observe that a linear class B power amplifier is used after class C modulator amplifier. The linear class B power amplifier performs the major power amplification and feeds the amplified AM signal to antenna. In this block diagram, the modulator amplifier performs modulation at relatively low power levels. Hence this is called low level modulated AM transmitter. The modulated AM signal is amplified by class B power amplifier to avoid distortion in the output.

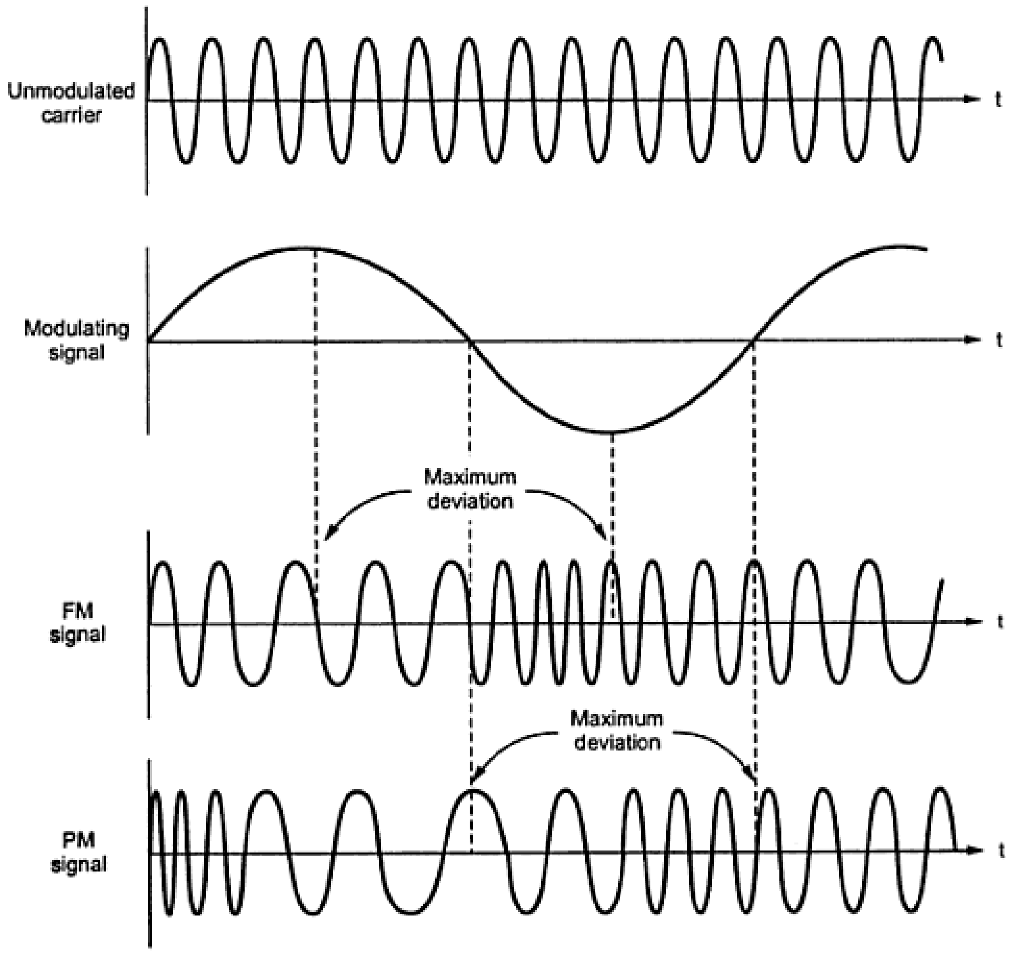
8. Describe frequency and phase modulation. Derive the formula for the instantaneous value of a FM voltage.

Ans:

We know that amplitude, frequency or phase of the carrier can be varied by the modulating signal. Amplitude is varied in AM. When, frequency or phase of the carrier is varied by the modulating signal. Then it is called angle modulation. There are two types of angle modulation.

1. **Frequency modulation**: When frequency of the carrier varies as per amplitude variations of modulating signal. Then it is called frequency modulation (FM). Amplitude of the modulated carrier remains constant.
2. **Phase modulation**: When phase of the carrier varies as per amplitude variation of modulating signal, then it is ca1led phase modulation (PM). Amplitude of the modulated carrier remains constant.

Figure below show the wave form of FM and PM.



From the figure the instantaneous frequency of the frequency modulated wave is given by

$f = f_c\,(1 + kV_m \cos \omega_m t)$

The maximum deviation or this particular signal will occur when the cosine term has its maximum value, ± 1. Under these conditions, the instantaneous frequency will be

$f = f_c\,(1 \pm kV_m)$

so that the maximum deviation δ will be given by

$\delta = kV_m f_c$

The instantaneous amplitude of the FM signal will be given by a formula of the form

$v = A\,\sin\theta$, where θ is the angle traced out by the vector A in time t. We can write the above equation as

$\omega = \omega_c\,(1 + kV_m \cos \omega_m t)$

$\theta = \int \omega\, dt = \int \omega_c\,(1 + kV_m \cos \omega_m t)\, dt = \omega_c \int (1 + kV_m \cos \omega_m t)\, dt$

$$= \omega_c\left(t + \frac{kV_m \sin \omega_m t}{\omega_m}\right) = \omega_c t + \frac{kV_m \omega_c \sin \omega_m t}{\omega_m}$$

$$= \omega_c t + \frac{kV_m f_c \sin \omega_m t}{f_m}$$

$$= \omega_c t + \frac{\delta \sin \omega_m t}{f_m}$$

The instantaneous value of the FM voltage

$$v = A \sin\left(\omega_c t + \frac{\delta \sin \omega_m t}{f_m}\right) \quad \text{or} \quad v = A \sin(\omega_c t + m_f \sin \omega_m t)$$

where, $m_f = \delta / f_m$ (modulation index for FM)