Signals & Communication Systems

CO-3 Question Bank.

1) Write any two pratical applications of AM?

Radio Broadcasting - AM is used for long distance audio broadcasts on AM radio bands.

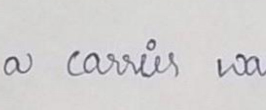
Aircaft Communication - AM is used in VHF transmissions for pilot - ATC communications.

2) Explain the phenomenon of amplitude modulation with neat sketchs.

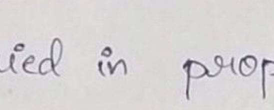
Amplitude Modulation is a modulation technique where the amplitude of a carrier wave is varied in proportion to the instantaneous amplitude of the message signal. This is done to superimpose the information contained in the message signal onto the carrier wave for transmission,

1) message signal (modulating signal)

This is the signal containing the information to be transmitted. It can be an audio, video or any other type.



message signal.



carrier wave

2) Carrier signal

This is a high frequency wave that acts as a carrier for the message signal. It has constant amplitude & frequency.

Process - Combining these two signal in accordance with the instantaneous amplitude.

Mathematical representation,

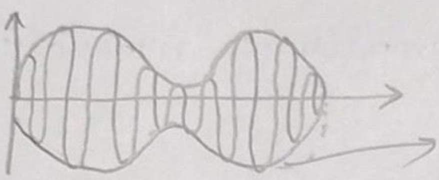
$$s(t) = A_c (1 + m(t)) \cos 2\pi f_c t$$

where,

A_c = carrier wave amplitude

$m(t)$ = message signal.

f_c = carrier wave frequency.



Applications:

① Air carft communication

② AM radio broadcasting.

③ Discuss the methodology of modulation & demodulation in a communication system.

Modulation & demodulation are essential processes that enable efficient & reliable transmissions over long distances.

Modulation:

It's the process of modifying message signal with carrier signal to transmit over longer distances.

Types

1) Amplitude
2) Phase
3) Frequency

Demodulation:

It's the reverse process of modulation, where the original message signal is extracted from the modulated carrier wave. Briefly saying recovering the underlying information.

Techniques:

1) Frequency discriminator
2) Envelope detection
3) Phase locked loop (PLL)

Why demodulation, modulation are essential?

Efficient transmission, allows the message signal to be transmitted at a higher frequency, which reduces signal attenuation and interference. Long distance transmissions are also possible without degradation. Multiple signal transmission simultaneously over a single channel.

4) Derive the expression for amplitude modulated wave and hence obtain the efficiency, power, current relations.

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

$$c(t) = A_c \cos(2\pi f_c t)$$

$$\cancel{s(t) = A_m + A_c} \qquad A_0 = A_c + m(t)$$

$$s(t) = (A_c + A_m \cos(2\pi f_m t)) \cos(2\pi f_c t) \quad \text{--- (1)}$$

$$s(t) = (A_c + A_m \cos(2\pi f_m t)) \cos(2\pi f_c t)$$

$$\Rightarrow s(t) = A_c \left[1 + \frac{A_m}{A_c} \cos(2\pi f_m t) \right] \cos(2\pi f_c t) \quad \text{--- (2)}$$

$$s(t) = A_c \cos(w_c t) + A_m \cos(w_m t) \cos(w_c t)$$

$$\cos A \cos B = \frac{1}{2}(\cos(A+B) + \cos(A-B))$$

$$\Rightarrow s(t) = A_c \cos(w_c t) + \frac{A_m}{2}[\cos(w_c + w_m)t + \cos(w_c - w_m)t]$$

η = efficiency

$$\eta = \frac{A_m^2/2}{A_c^2 + A_m^2/2} = \frac{A_m^2}{2A_c^2 + A_m^2}$$

Power $\Rightarrow P_T \propto A_c^2 + \frac{A_m^2}{2}$.

5) Explain the significance & advantages of modulation process & explain any two types of modulation with neat diagrams & expressions.

Significance & Advantages of modulation process:

1) Efficient transmission
2) Improved signal quality
3) multiplexing
4) Bandwidth utilization.

Types of modulation - Amplitude Modulation
Frequency Modulation

Amplitude modulation is carrier wave is varied in accordance with instantaneous amplitude of modulating signal.

$$s(t) = [A_c + m(t)] \cos(2\pi f_c t)$$

Frequency modulation is carrier wave is varied in accordance with instantaneous frequency of modulating signal.

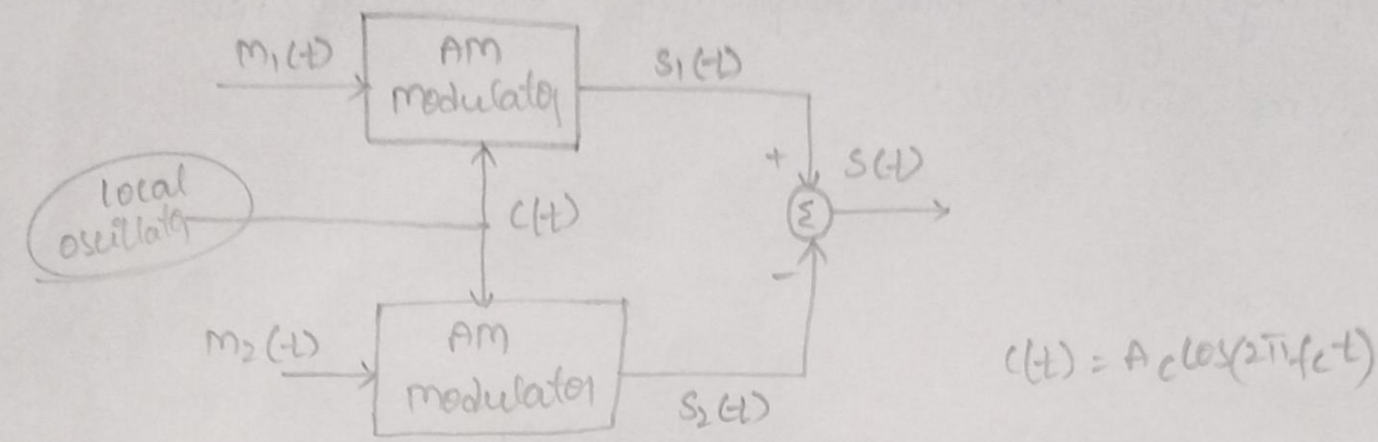
$$s(t) = A_c \cos(2\pi f_c t + K_f m(t))$$

6) Explain the concept of balanced modulator with a neat diagram?

There are two types of modulators that generate DSBSC waves

1) Balanced Modulator

2) Ring modulator.



A balanced modulalator is an electronic device designed to combine two input signals - typically a carrier signal & a modulating signal - to produce an output that product while suppressing the carrier component.

The carrier signal $c(t) = A_c \cos(2\pi f_c t)$ is applied as one of the inputs of these two AM modulators.

Output of upper modulator,

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

Output of lower modulator,

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

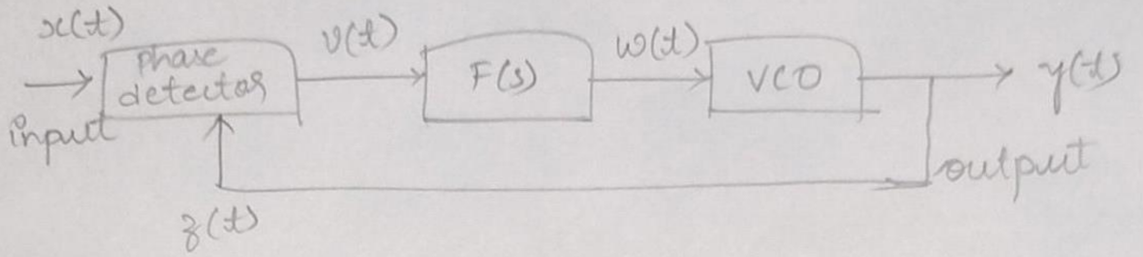
$$\Rightarrow S(t) = S_2(t) - S_1(t)$$

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

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

7) Explain the concept of first order PLL

PLL means phase locked loop, is a feedback system that utilizes a voltage controlled oscillator (VCO) to generate an output signal that tracks the phase of an input reference signal. It's like a self adjusting clock that keeps itself synchronized with a reference time source.



The three major blocks are - Phase detector
Active low pass filter
Voltage controlled oscillator.

The phase detector produces a DC voltage, which is proportional to the phase difference between the input signal having frequency of finfin & feedback. phase detector is a multiplier & it produces two frequency components as its output - sum of the frequencies finfin & foutfout & difference b/w them. Active low pass filter produces a DC voltage at its output, after eliminating high frequency component present in the output. VCO produces a signal having a certain frequency, when no output applied. Frequency deviation is directly proportional to DC voltage present at the output of low pass filter. This happens only until the VCO frequency equals to input frequency signal.

Applications.

① Frequency synthesis ② FM demodulation.

8) Using the amplitude modulation process & perform modu with only sidebands without carriers.

In tradational method AM uses carries waves which produc two sidebands - upper & lower. To perform AM with sidebo only & not carriers we use (DSB-SC) double sideband suppressed carries.

DSB-SC modulation process:

① multiplication

message signal is multiplied with carrier signal. This shifts the frequency spectrum of message signal up & down by carrier frequency.

$$s(t) = m(t) * c(t)$$

② Carries suppression.

Instead of removing carries signals we use balance modulator to directly generate DSB-SC signal.

Demodulation process:

To recover the original message signal we involve multiplying the received signal with a locally generated carries wave that's synchronized in phase & frequency with original carries.

9) A modulating signal $10 \sin(2\pi \times 10^3 t)$ is used to modulate a carrier signal $20 \sin(2\pi \times 10^4 t)$. Then determine modulation index, percentage modulation, frequency of side band components and their amplitudes, bandwidth of modulated signal.

Given $m(t) = 10 \sin(2\pi \times 10^3 t)$

$V_m = 10$, $f_m = 10^3 = 1\,KHz$

$c(t) = 20 \sin(2\pi \times 10^4 t)$

$V_c = 20$, $f_c = 10^4 = 10\,KHz$

modulation index $(m) = \frac{V_m}{V_c} = \frac{10}{20} = 0.5$

Precentage modulation $= 0.5 \times 100$

$= 50\%$

Upper sideband frequency $= f_c + f_m = 10K + 1K$

$= 11\,KHz$

Lower side band frequency $= f_c - f_m = 10K - 1K$

$= 9\,KHz.$

Amplitude of each sideband $= \frac{m * V_c}{2} = \frac{0.5 * 20}{2} = \underline{5V}$

Bandwidth $= 2 * f_m$

$= 2 * 1K$, $= 2\,KHz.$

10) Calculate the upper & lower sideband frequencies in an AM communication system. Given the carrier frequency is 1MHz and the modulation index is 0.6.

Given

$f_c = 1MHz$ $\quad m = \frac{A_m}{A_c} = 0.6$

$f_{USB} = f_c + f_m$ $\quad f_m(t) = f_c + k \cdot m(t)$

$f_{LSB} = f_c - f_m$ $\quad m = \frac{\Delta f}{f_m}$ $\quad$ ~~f_m~~ $= 12 \times 10^3\,Hz$

(assume)

$\Rightarrow f_{USB} = (1 \times 10^6) + (12 \times 10^3)$

$= 1.012\,MHz$

$f_{LSB} = (1 \times 10^6) - (12 \times 10^3) = 0.988\,MHz.$

11) Calculate modulation index, discuss various possibilites of modulation index with neat sketches & hence determine modulation index.

Modulation index, often denoted by symbol μ, is a crucial parameter in amplitude modulation. It quantifies the extent to which the amplitude of carrier wave is altered by a modulating signal.

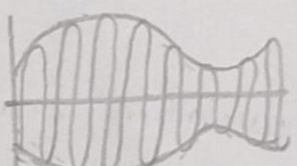
$$\mu = \frac{A_m}{A_c}$$

→ Undermodulation
→ Critical
→ Overmodulation

Undermodulation is when the modulating signal amplitude is less than amplitude of carrier wave. Here $\mu < 1$.

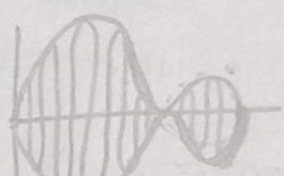
Critical modulation is when amplitudes of ~~amplitu~~ carrier wave & modulating signal. Here $\mu = 1$

Overmodulation is when the modulating signal amplitude exceeds the amplitude of carrier wave.



under modulation

$\frac{A_m}{A_c} < 1$



$\mu = \frac{A_m}{A_c} = 1$

Critical modulation

$\mu = \frac{A_m}{A_c} > 1$

critical modulation

$m(t) = A_m \cos \omega_m t$

$c(t) = A_c \cos \omega_c t$ ——— $A_0 = A_c + m(t)$ ———

$\Rightarrow y(t) = (A_c + A_m \cos \omega_m t) \cos \omega_c t$ —— ①

$y(t) = A_c \left(1 + \frac{A_m}{A_c} \cos \omega_m t\right) \cos \omega_c t$ —— ②

$\Rightarrow \frac{A_m}{A_c} = \mu$

$A_{max} = A_c + A_m$ —— ③ $\quad A_{min} = A_c - A_m$ —— ④

③ + ④

$A_{max} + A_{min} = 2A_c$

$A_c = \frac{A_{max} + A_{min}}{2}$ —— ⑤

−④ + ③

$A_{max} - A_{min} = 2A_m$

$A_m = \frac{A_{max} - A_{min}}{2}$ —— ⑥

⑤ | ⑥ $\quad \frac{A_m}{A_c} = \frac{A_{max} + A_{min}}{A_{max} - A_{min}}$

$\mu = \frac{A_m}{A_c} = \frac{A_{max} + A_{min}}{A_{max} - A_{min}}$

∴ Hence derived.

12) Explain the phenomenon of amplitude modulation using square law detector & switching modulator.

A square law detector utilizes a non linear device, typically a diode operation in its non linear region, to generate an output voltage proportional to the square of the i/p voltage.

AM signal input,

$$s(t) = A_c(1+m(t))\cos(w_c t)$$

square law operation,

$$V_{out}(t) = K(s(t))^2$$

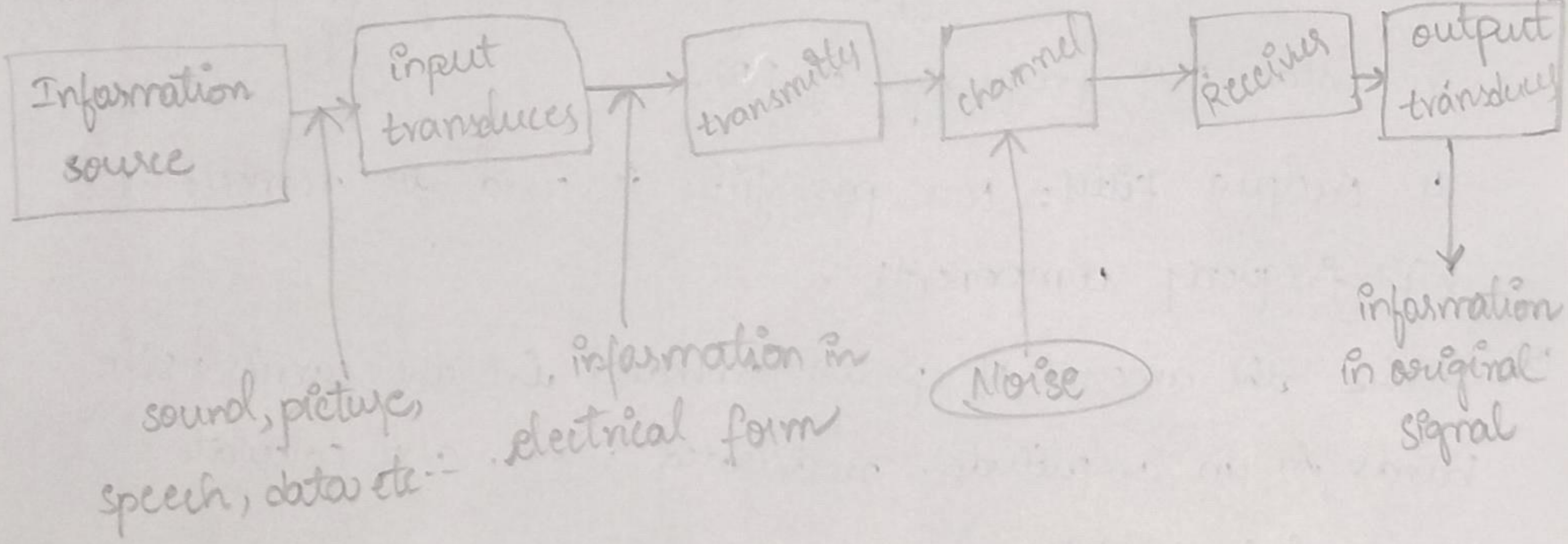
Expanding the square,

$$V_{out}(t) = K(A_c^2(1+2m(t)+m^2(t))\cos^2(w_c t))$$

$$\Rightarrow V_{out}(t) = \frac{K}{2}(A_c^2(t+2m(t)) + m^2(t))(1+\cos(2w_c t))$$

$$\Rightarrow V_{out}(t) = A_c(1+K_a m(t))\cos(2\pi f_c t)$$

13.) Discuss the electronic communication system with a simplified block diagram?



14) Explain the basic principle FM demodulation. With this principle how FM wave is demodulated using a single slope detector.

FM modulation is the process of extracting the original information signal from a frequency modulated (FM) carrier wave. The principle involves in converting FM to amplitude variations, achieved through a circuit has frequency dependent responses.

FM demodulation using a single slope detector:

It's a simple circuit where LC circuit is connected parallel with a diode & load resistor.

Working

① Tuned Circuit - It's designed to resonate at a frequency slightly above the centre frequency of FM signal.

② Slope detection - The slope of tuned circuits response curve is used to convert frequency variations into amplitude variation where both amplitude & frequency are directly proportional.

③ Diode detection - It rectifies the varying amplitude signal from the tuned circuit, producing a DC voltage proportional to instantaneous frequency of FM.

④ Output Filter: Low pass filter is used to remove the high frequency components.

15) Derive the amount of power embodied in the carrier, side bands in an amplitude modulated wave, also calculate transmission efficiency.

Power in Amplitude modulated wave.

$$s(t) = A_c[1+m(t)]\cos(\omega_c t)$$

$$P_c = \frac{A_c^2}{2R}, \quad P_S = \frac{\mu^2 A_c^2}{4R}$$

$$P_{sidebands} = 2 * P_S = \frac{\mu^2 A_c^2}{2R}$$

$$P_{total} = P_{carries} + P_{sidebands}$$

$$= \frac{A_c^2}{2R} + \frac{\mu^2 A_c^2}{2R}$$

$$P_t = \left(\frac{A_c^2}{2R}\right)\left(1+\mu^2\right)$$

$\longrightarrow$ transmission energy.

$$\eta = \frac{P_{SB}}{P_t}$$

$$\Rightarrow \eta = \frac{\frac{\mu^2 A_c^2}{2R}}{\left(\frac{A_c^2}{2R}\right)\left(1+\mu^2\right)}$$

$$\therefore \eta = \frac{\mu^2}{1+\mu^2}$$

16) Choose a linear diode & construct a demodulator for extracting information signal from the modulating signal.

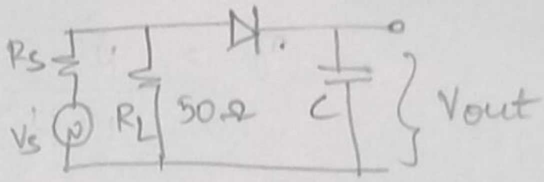
For AM modulation, we use low-barrier schottky diode. These exhibit excellent linearity at low level signals which is crucial for accurate recovery of the modulating signal.

Construction.

1) Diode should have low forward voltage drop & high frequency capability

2) Resistor value depends on desired bandwidth.

3) capacitor value determines the low pass filter's cutoff frequency



1) Diode rectifies the AM input signal allows only half cycle to pass.

2) Capacitor & Resistor forms a low pass filter. Capacitor charges as resistors discharges slowly through the circuit which smooths out the waveform, removes high frequency.

3) Output voltage across the resistor is demodulated, which is the original signal.