IAT 1 Scheme and Solution
BEC402 Principles of Communication Systems

Department of ECE, CMRIT

CMR INSTITUTE OF TECHNOLOGY

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Internal Assessment Test - I

Sub:	Principles of Communication Systems							Code:	BEC402
Date:	03/ 06/ 2024	Duration:	90 mins	Max Marks:	50	Sem:	4th	Branch:	ECE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1.	Define standard form of amplitude modulation, derive its equation and explain each term. Derive the Spectral equation of AM wave and hence draw and explain the AM spectrum for a generic message signal having frequency components from 0-W.	[10]	CO2	L2
2.	Explain in detail the working of square modulator with the help of necessary diagrams, waveforms and derivations.	[10]	CO2	L2
3.	With necessary diagrams, waveforms and equations explain the working of Lattice modulator.	[10]	CO2	L2
	An audio frequency signal, $2cos\ (2\pi 2 * 10^3 t)$, is used to amplitude modulate a carrier signal $200cos\ (4\pi 10^6 t)$, Assume modulation index of 0.6. Find i) Sideband frequencies ii) Bandwidth required iii) Total transmitted power iv) Efficiency	[10]	CO2	L3
5.	With the help of necessary diagrams, waveforms and derivations explain high-level collector AM modulator	[10]	CO2	L2
6	Derive the time domain representation of single-tone modulated narrow band FM signal. Plot the spectrum for the same.	[10]	CO2	L2
7	a) Define frequency deviation and modulation index with regard to FM scheme. b) A sinusoidal modulating wave of amplitude 5v and frequency 1kHz is applied to a FM modulator with frequency sensitivity 50Hz/Volt and carrier frequency is 100kHz. Calculate frequency deviation and Modulation index	[10]	CO2	L3

1. **Define standard form of amplitude modulation, derive its equation and explain each term. Derive the Spectral equation of AM wave and hence draw and explain the AM spectrum for a generic message signal having frequency components from 0-W.**

Definition: Amplitude modulation is the process of varying the amplitude of a periodic waveform, called the carrier signal, in proportion to the instantaneous amplitude of the modulating signal that typically contains information to be transmitted (1M)

The standard form of AM in the time domain:(4M)

Signals are defined as follows

Message: m(t)

Carrier: $c(t) = Vc\text{Sin}\ (2\pi f_c t)$

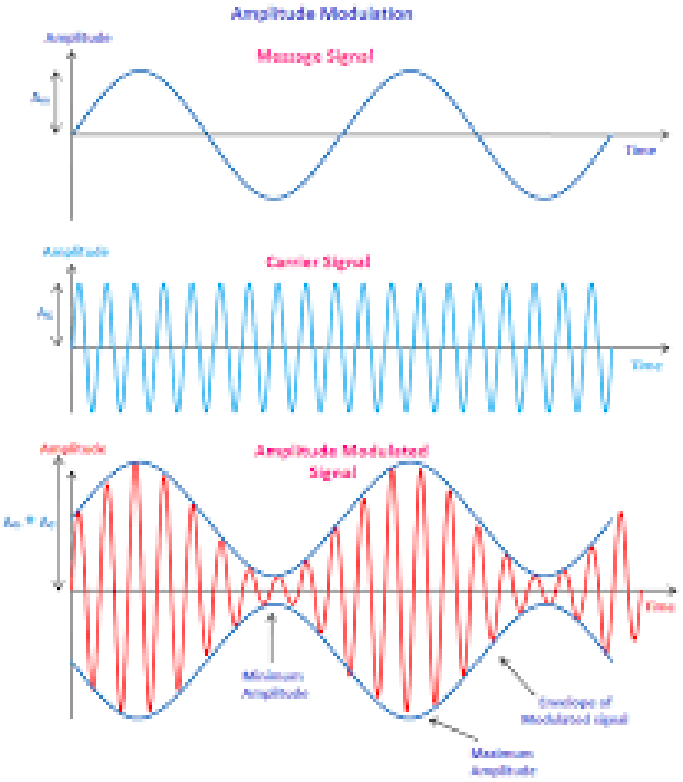
Modulated Signal: The amplitude of the carrier signal changes proportional to m(t) and frequency and phase remain the same, which can be mathematically expressed as

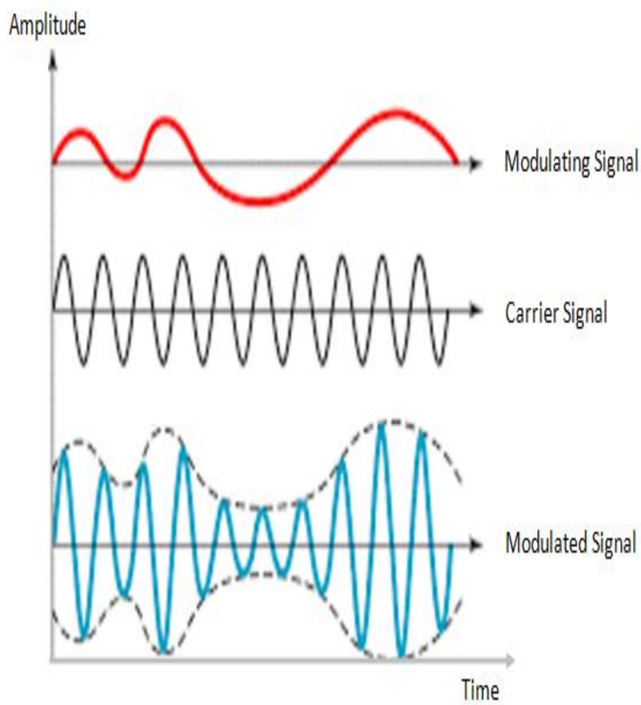
$s(t) = \left[V_c\ + x * m(t)\ \right] Sin\ (2\pi f_c t)$; typical value x=1. The expression can be rewritten as

$s(t) = Vc[1 + k_a m(t)\ ]\text{Sin}\ (2\pi f_c t)$

- k_a *is a constant, Amplitude sensitivity*
- $k_a\ |m(t)|_{max}$ *is termed as Modulation index/ factor,* μ/m
- m=μ = Vm/Vc or $k_a\ |m(t)|_{max}$ or k_a Vm

Graphical representation: single tone and generic modulating signal: (1M)





Frequency Domain Representation: (2M+2M)

To arrive at frequency domain representation, take the Fourier transform of s(t)

$$S(f) = \int_{-\infty}^{\infty} s(t)e^{-j2\pi ft}\ dt$$

$$S(f) = F(V_c\,[1 + k_a m(t)]Sin\ (2\pi f_c t))$$

$$S(f) = F[A_c\,Sin\ (2\pi f_c t)] + F[A_c\,k_a m(t) Sin\ (2\pi f_c t)]$$ --------*(1)*

Note: magnitude spectrum is considered

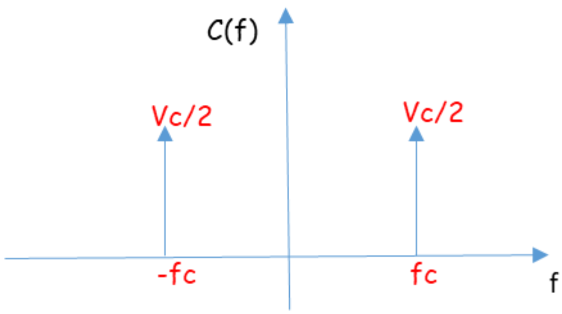
By applying Fourier results

$F\big(Sin(\ 2\pi f_c t)\big) = \frac{1}{2}[\delta(f - f_c) + \delta(f + f_c)]$ and $e^{j2\pi ft} g(t) \leftrightarrow G(f - f_c)\ given\ g(t) \leftrightarrow G(f)$

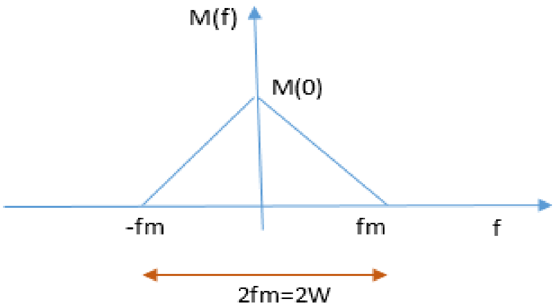
Equation 1 can be rewritten as

$S(f) = \frac{A_c}{2}[\delta(f - f_c) + \delta(f + f_c)] + \frac{A_c k_a}{2}[M(f - f_c) + M(f + f_c)]$, magnitude spectrum

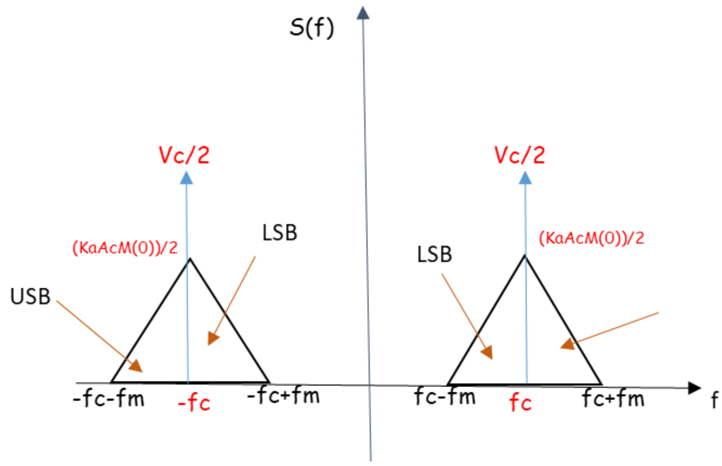
Spectrum of carrier signal



Assuming M(f), the spectrum of the modulating signal to be

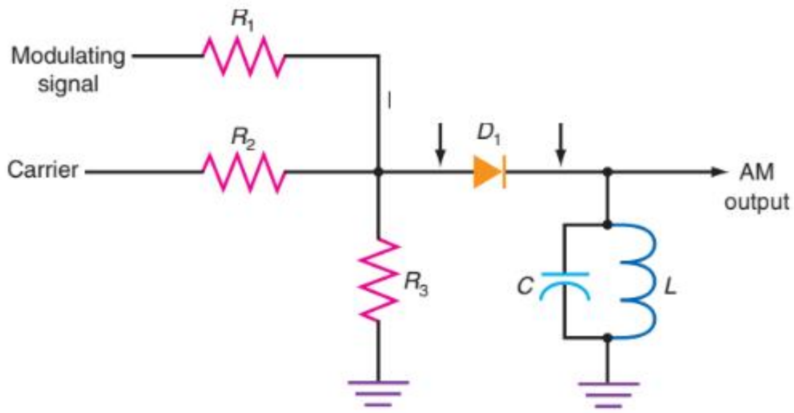


Spectrum of S(t)



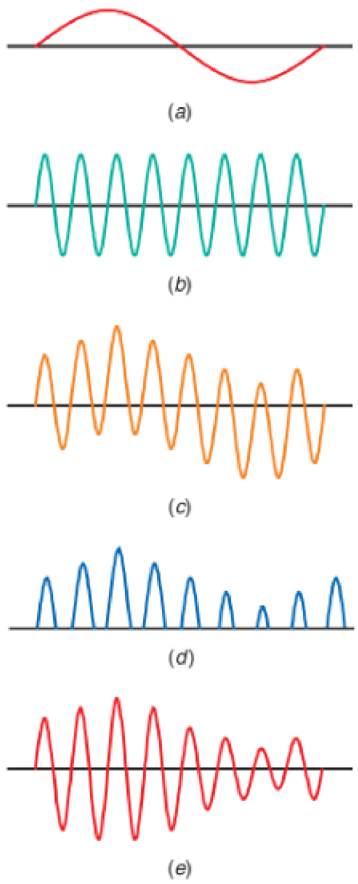
2. **Explain in detail the working of the square Law modulator with the help of necessary diagrams, waveforms, and derivations.**

   The circuit diagram of the diode-based modulator is shown below. (Circuit, explanation-3M, Waveforms-2M)



   The resistor network provides an algebraic sum of the carrier and message signals. The combined signal is applied to the diode, which conducts only during the positive cycles of the composite signal. This pulsating current through the diode varies in proportion to the instantaneous amplitude of the message signal. This pulsating signal is applied to a tuned circuit with a resonance frequency the same as that of carrier frequency. The filter works as a resonator which produces positive and negative oscillations proportional to the message amplitude. The waveforms at different points in the circuit are given below.

Waveforms in the diode modulator. (*a*) Modulating signal. (*b*) Carrier. (*c*) Linearly mixed modulating signal and carrier. (*d*) Positive-going signal after diode D_1. (*e*) Am output signal.



Mathematical analysis of square law modulator: (5M)

Diode in the nonlinear operating region can be modeled by,

$$i = av + bv^2$$

Where i,v specifies diode current and voltage
From the modulator diagram, the input voltage to the diode is algebraic sum of carrier,Vc and message Vm,
V=Vc+Vm
Applying the square law device model for the diode,

$$v = v_c + v_m$$

The diode current in the resistor is

$$i = a(v_c + v_m) + b(v_c + v_m)^2$$

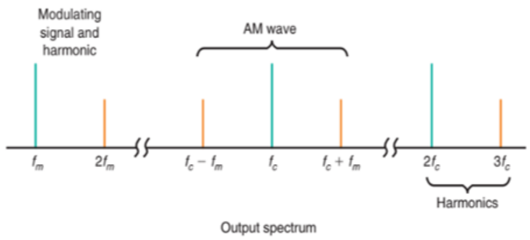
Expanding, we get

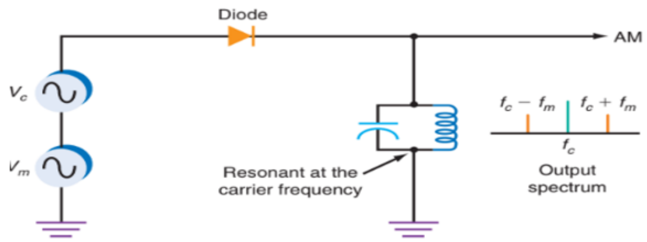
$$i = a(v_c + v_m) + b(v_c^2 + 2v_c v_m + v_m^2)$$

Substituting carrier and message signal time domain expressions, we get

$$i = aV_c \sin \omega_c t + aV_m \sin \omega_m t + bV_c^2 \sin^2 \omega_c t + 2bV_c V_m \sin \omega_c t \sin \omega_m t + bv_m^2 \sin^2 \omega_m t$$

Compared with standard AM expression, term 2,3,5 are unwanted components, representing message frequency, DC components, and harmonics of carrier frequency. The AM signal can be recovered, if the bandpass filter in the circuit is tuned to carrier frequency with approximate AM bandwidth,





3. **With necessary diagrams, waveforms and equations explain the working of the Lattice modulator.**
4. An audio frequency signal, $2cos\,(2\pi 2 * 10^3 t)$, is used to amplitude modulate a carrier signal $200cos\,(4\pi 10^6 t)$, Assume modulation index of 0.6. Find i) Sideband frequencies ii) Bandwidth required iii) Total transmitted power iv) Efficiency -------(4*2.5M)

Given
Fc=2MHz
Fm=2kHz
Vc=200
Vm=2
m=0.6
i)Side Band:

LSB=Fc-Fm=1.998MHz
USB=Fc+Fm= 2.002MHz
ii)Bandwidth=2Fm=4KHz
iii)Power

$$P_T = P_c\left(1 + \frac{m^2}{2}\right)$$

$$Pc = \frac{V_c^{\ 2}}{2} = 20KW$$

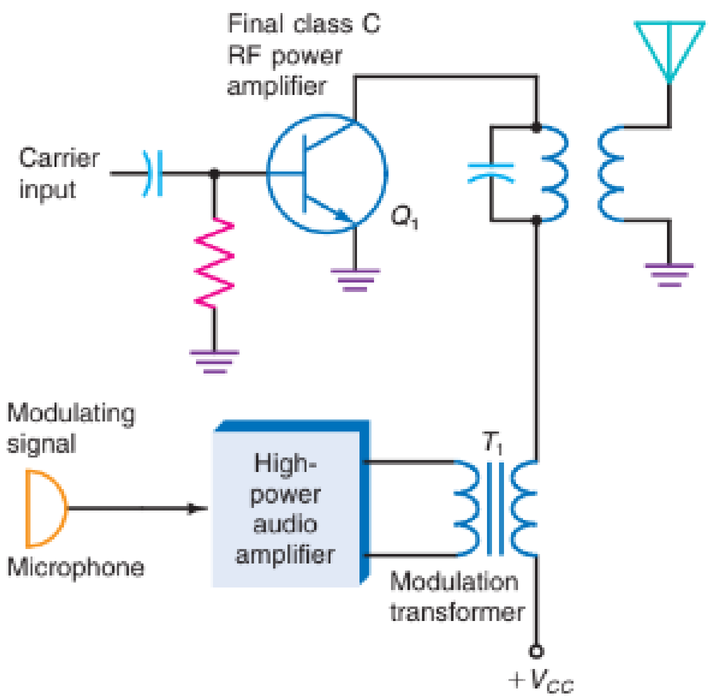
$$PT = \frac{V_c^{\ 2}}{2}\left(1 + \frac{m2}{2}\right) = 23.6kW$$

iv)Efficiency

$$\%efficiency = \left(\frac{m2}{2 + m2}\right) * 100 = 15.25\%$$

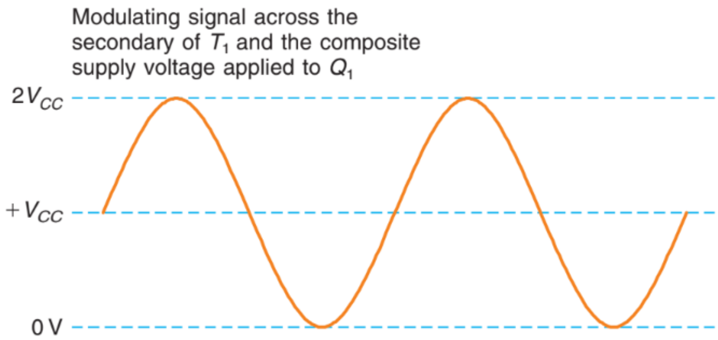
5. **With the help of necessary diagrams, waveforms and derivations explain high-level collector AM modulator**
Circuit-3M, Q point graph-2M,Explanation-5M

The high-level modulator varies the voltage and power in the final RF amplifier stage of the transmitter. The result is high efficiency in the RF amplifier with high-quality performance. The circuit diagram of the transistor-based high-level modulator is as follows. The carrier signal is applied to the base of a high-power class C-tuned amplifier. The modulating signal is coupled using a transformer and is superimposed with the collector supply.



With a zero-modulation input signal, there is zero-modulation voltage across the secondary of T1, the collector supply voltage is applied directly to the class C-amplifier, and the output carrier is a steady sine wave.
When the modulating signal occurs, the AC voltage of the modulating signal across the secondary of the modulation transformer is added to and subtracted from the DC collector supply voltage. This varying supply voltage is then applied to the class C amplifier, causing the amplitude of the current pulses through transistor Q1 to vary. As a result, the amplitude of the carrier sine wave varies with

the modulated signal. When the modulation signal goes positive, it adds to the collector supply voltage, thereby increasing its value and causing higher current pulses and a higher amplitude carrier. When the modulating signal goes negative, it subtracts from the collector supply voltage, decreasing it. For that reason, the class C amplifier current pulses are smaller, resulting in a lower-amplitude carrier output. Thus the output amplitude varies in proportion to the message signal, or in other words the circuit produces AM,



A major disadvantage of collector modulators is the need for a modulation transformer that connects the audio amplifier to the class C amplifier in the transmitter. The higher the power, the larger and more expensive the transformer. for 100 percent modulation, the power supplied by the modulator must be one-half the total class C amplifier input power.

6. Derive the time domain representation of single-tone modulated narrow band FM signal. Plot the spectrum for the same.

The standard representation of FM signal (7M)

$c(t) = Vc\text{Sin}\ (2\pi f_c t)$

$m(t) = Vm\text{Sin}\ (2\pi f_m t)$

$s(t) = V_C\ \text{Sin}(2\pi f_c t - \beta\ cos(2\pi f_m t))$ use $\sin(A - B) = \sin A \cos B - \cos A \sin B$

$s(t) = V_C\ \text{Sin}\big(2\pi f_c t) \cos(\beta \cos(2\pi f_m t)) - V_C \cos(2\pi f_c t) \sin(\beta \cos(2\pi f_m t))$---------------(A)

Narrow band FM:

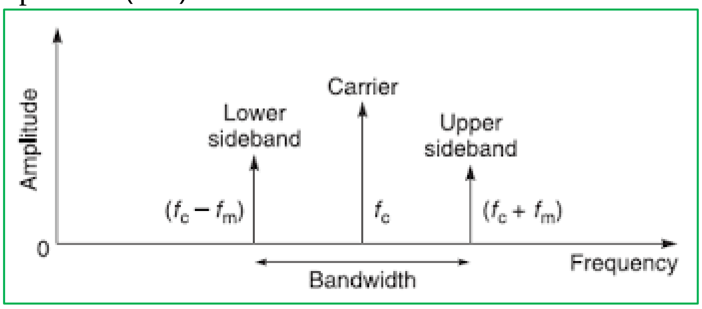
In narrow band FM, $\beta \ll 1rad$

In equation (A), applying trigonometric results, $\cos(\text{theta}) = 1, theta \ll and \sin(theta) = theta, if\ theta \ll$

$s(t) \approx V_C \sin(2\pi f_c t) * 1 - A_C \cos(2\pi f_c t)\beta \cos(2\pi f_m t)$

$$s(t) \approx V_C \sin(2\pi f_c t) - V_C\beta \left[\frac{Cos(2\pi(f_c - f_m)t) + Cos(2\pi(f_c + f_m)t)}{2}\right]$$

Spectrum(3M)



7. a) Define the frequency deviation and modulation index of the FM scheme.

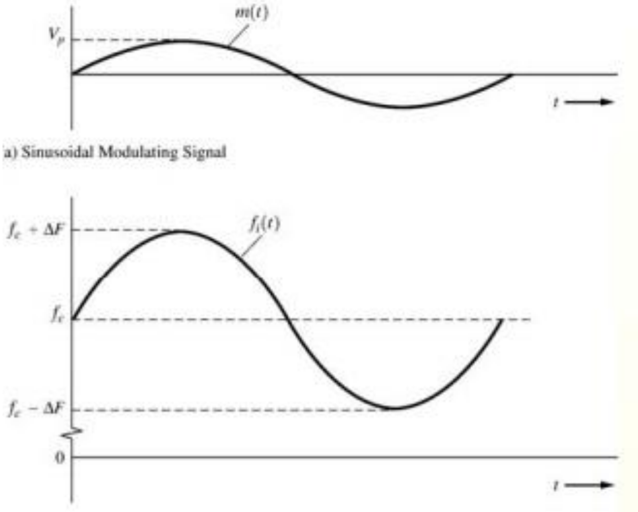
b) A sinusoidal modulating wave of amplitude 5v and frequency 1kHz is applied to a FM modulator with frequency sensitivity 50Hz/Volt and carrier frequency is 100kHz. Calculate frequency deviation and Modulation index

a)

Frequency Deviation: Maximum departure of the frequency of FM signal from the carrier. frequency. The deviation is proportional to the amplitude of the modulating signal and not related to frequency of the modulating signal (3M)

Frequency Deviation= kf*Vm

The carrier frequency swing for single-tone FM is depicted below,



Modulation Index: It shows the depth of modulation. This is the ratio of deviation and bandwidth of the message signal (2M). The bandwidth of FM is majorly defined by beta.

Beta=(kf*Vm)/fm

b) Given

Vm=5V

Fm=1kHz

Fc=100kHz

kf=50

Frequency Deviation= kf*Vm= 50*5=250 (2.5M)

Beta=(kf*Vm)/fm = 0.25 (2.5 M)