Sri SAI RAM ENGINEERING COLLEGE

INSTITUTE OF TECHNOLOGY

West Tambaram, Chennai - 44

SAIRAM DIGITAL RESOURCES

YEAR II

SEM III

EC8394

ANALOG AND DIGITAL COMMUNICATION

UNIT NO 1 ANALOG MODULATION

INTRODUCTION TO COMMUNICATION

AMPLITUDE MODULATION

ELECTRONICS & COMMUNICATION ENGINEERING

4 QUALITY EDUCATION

Introduction to communication

What is modulation?

- Modulation is performed at the transmitting end of the communication system.
- At the receiving end of the system we usually require the original baseband signal to be restored, this is usually accomplished by using a process known as demodulation

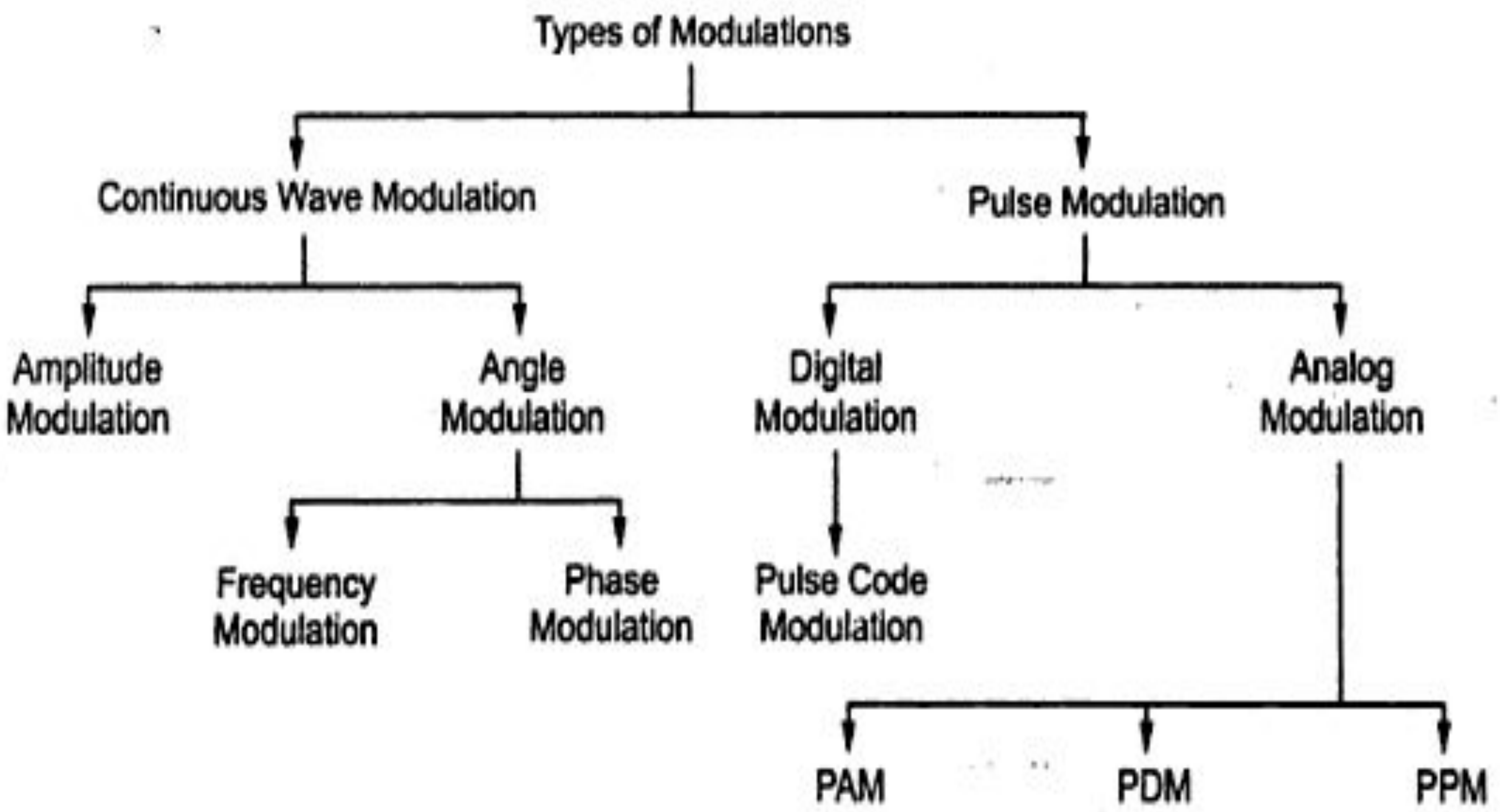
- In basic signal processing terms, we thus find that the transmitter of an analog communication system consists of a modulator and the receiver consists of a demodulator.
- Message signal
- Carrier signal-modulated to convey information

What are the reasons for modulation?

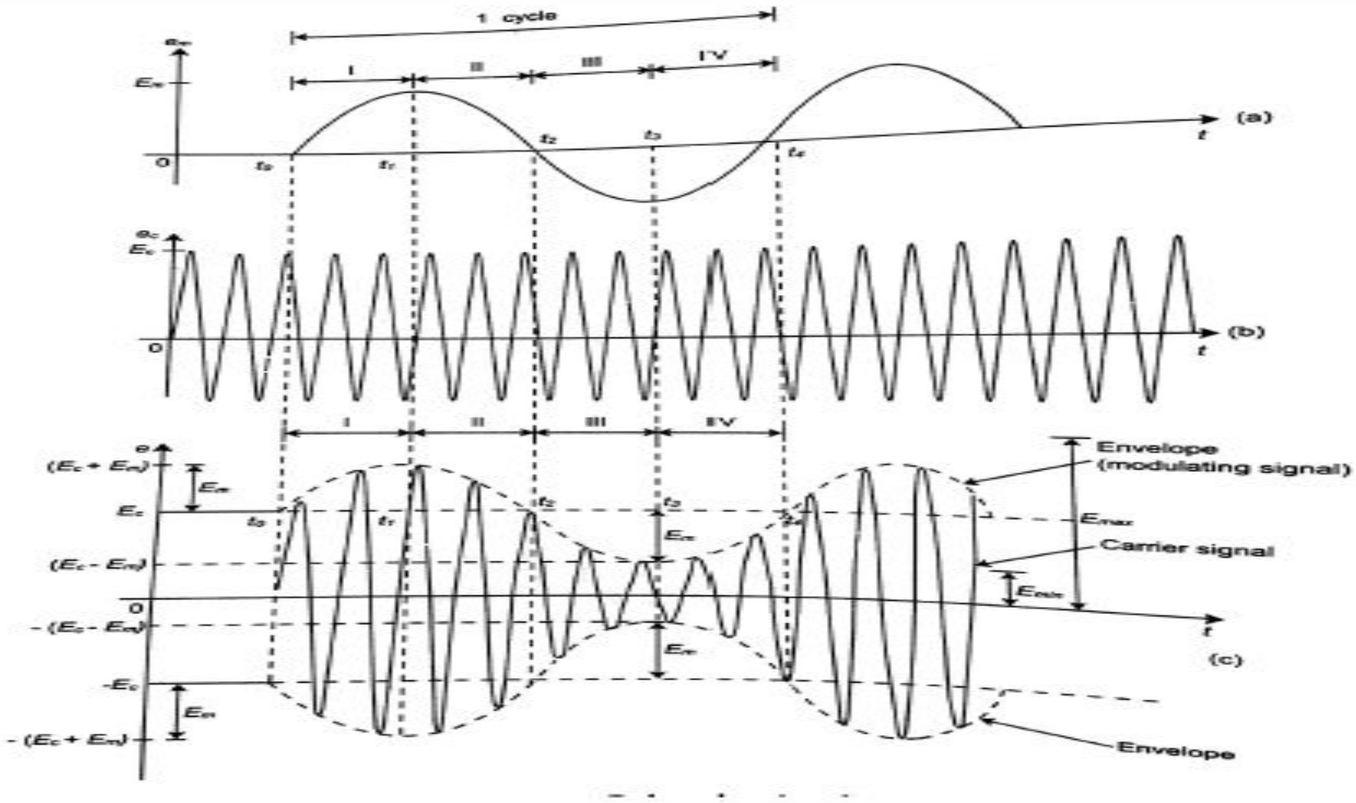
If modulation is not employed however, the system designer could confront the following problems:

- Antenna Height
- Narrow Banding
- Poor radiation and penetration
- Diffraction angle
- Multiplexing
- To overcome equipment limitations
- To reduce noise and interferences

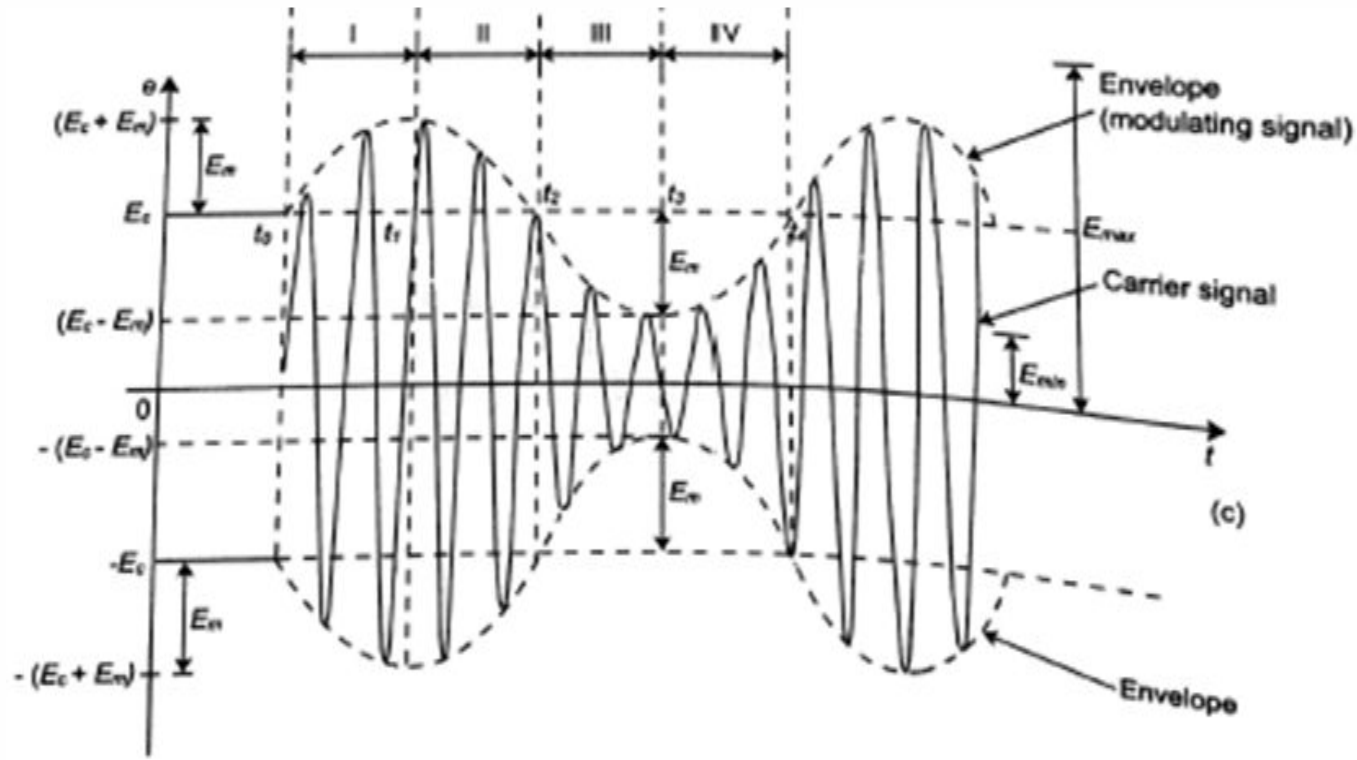
What are the Different Modulation Methods?

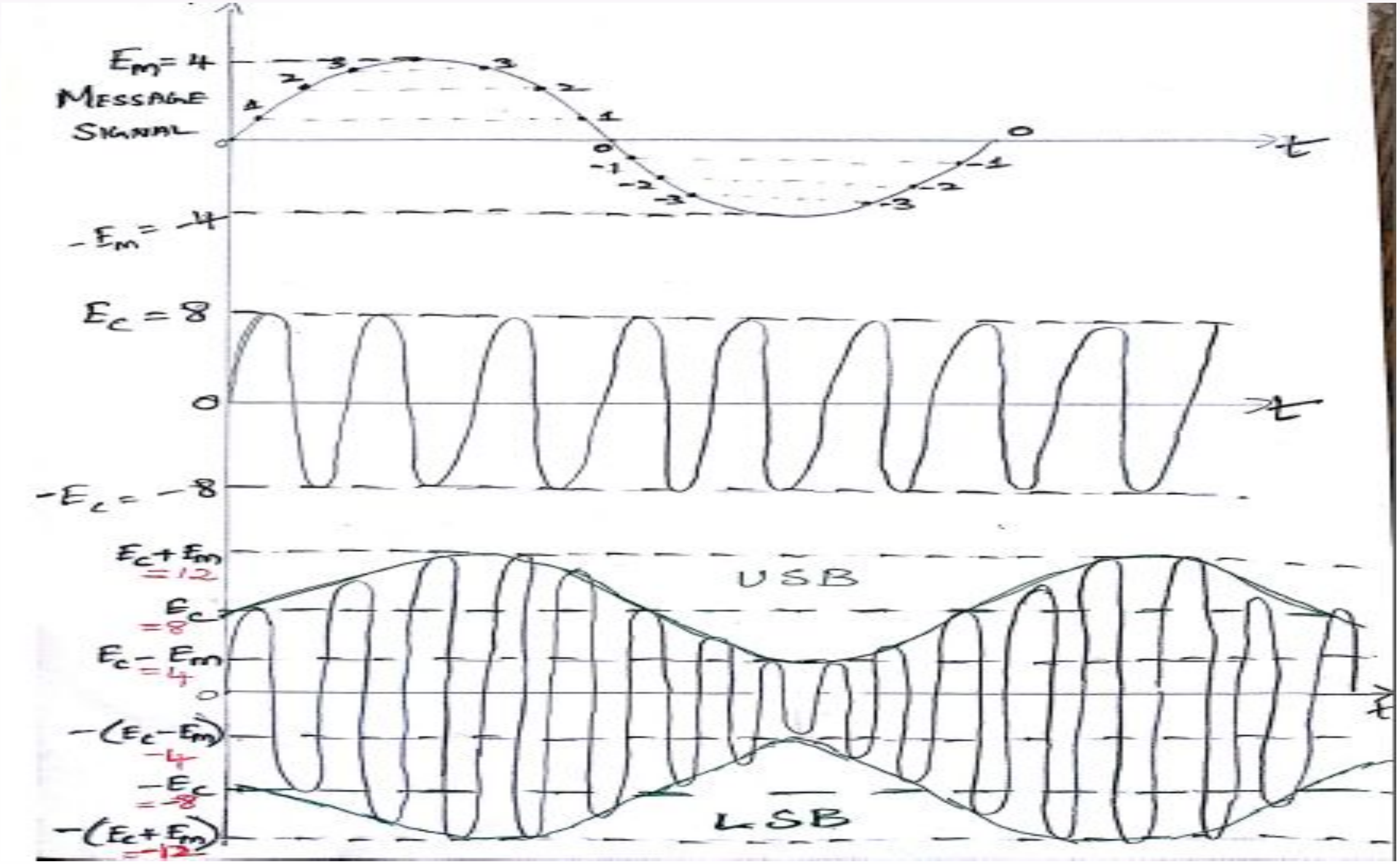


Baseband signal carrier signal & amplitude modulated wave

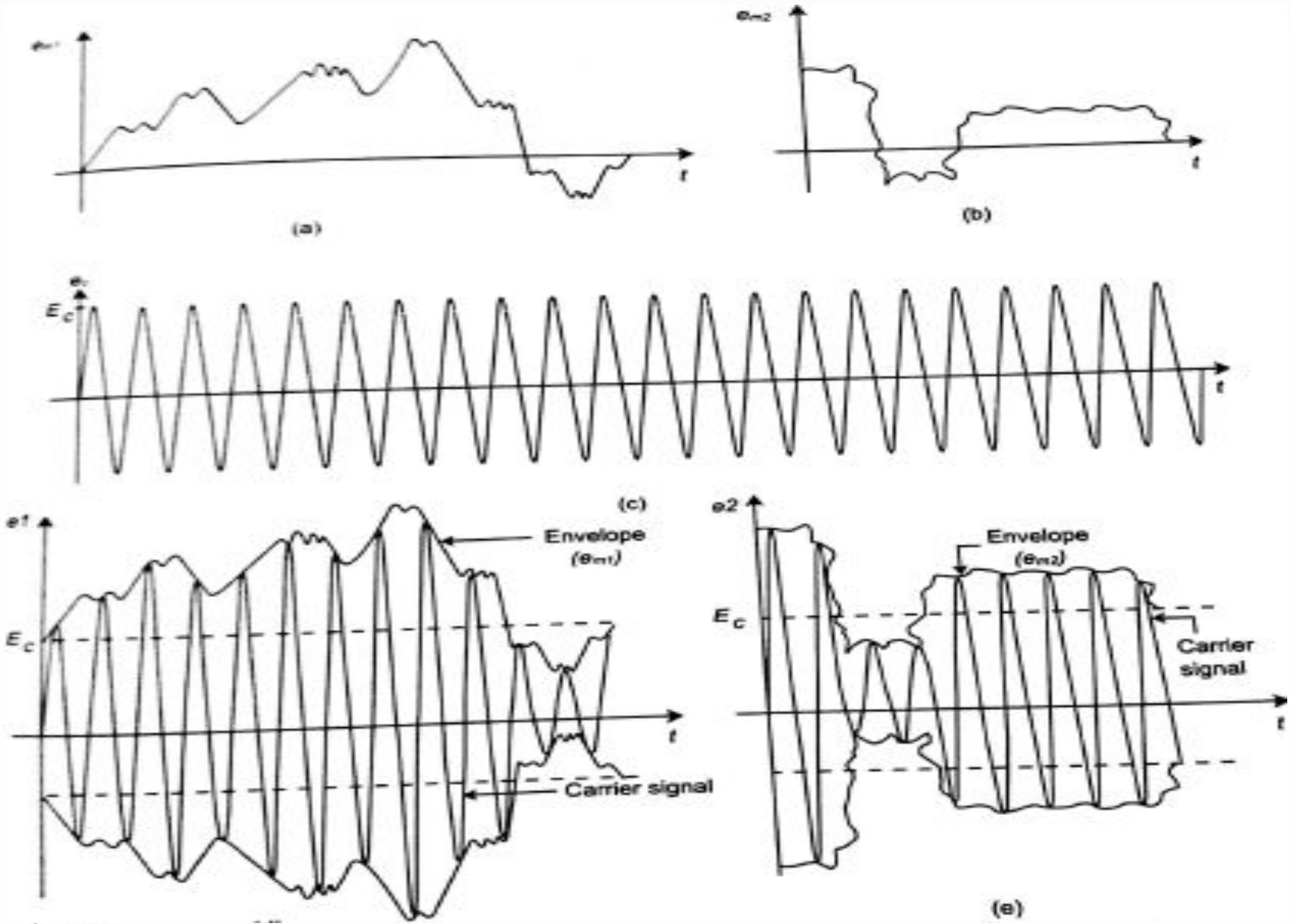


Am modulated wave




$E_m = 4$
MESSAGE SIGNAL
$-E_m = -4$
$E_c = 8$
0
$-E_c = -8$
$E_c + E_m = 12$
$E_c = 8$
$E_c - E_m = 4$
$-(E_c - E_m) = -4$
$-E_c = -8$
$-(E_c + E_m) = -12$
USB
LSB
t

Random variation



Equation of an am wave

The instantaneous value of modulating signal and carrier signal can be represented as given below

Instantaneous value of modulating signal

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

where e_m = instantaneous amplitude

E_m = maximum amplitude

$\omega_m = 2\pi f_m$ = angular frequency and

f_m = frequency of modulating signal

Instantaneous value of carrier signal

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

where e_c = instantaneous amplitude

E_c = maximum amplitude

$\omega_c = 2\pi f_c$ = angular frequency and

f_c = frequency of carrier signal

Equation of an AM Wave cont…

- Instantaneous value of amplitude modulated signal
- Using the above mathematical expression for modulating and carrier signals, we can create a new mathematical expression for the complete modulated wave, as given below

$$\begin{aligned} E_{AM} &= E_c + e_m \\ &= E_c + E_m \sin \omega_m t \end{aligned} \qquad \because e_m = E_m \sin \omega_m t$$

- The instantaneous value of the amplitude modulated wave is given as

$$e_{AM} = E_{AM} \sin \theta$$

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

Frequency spectrum and bandwidth of A.M wave

- The modulated carrier has new signals at different frequencies, called side frequencies or sidebands which occur in the frequency spectrum directly above and below the carrier frequency

$$f_{USB} = f_c + f_m$$

$$f_{LSB} = f_c - f_m$$

$$e_{AM} = (E_c + E_m \sin \omega_m t) \sin \omega_c t \quad \dots (1)$$

- The expression for the instantaneous value of the amplitude modulated wave

We know that, $m = \dfrac{E_m}{E_c}$ $\qquad E_m = m E_c$

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

$$= E_c (1 + m \sin \omega_m t) \sin \omega_c t \quad \dots (2)$$

$$= E_c \sin \omega_c t + m E_c \sin \omega_m t \sin \omega_c t \quad \dots (3)$$

$$\left[\sin a \sin b = \frac{1}{2}[\cos (a-b) - \cos (a+b)]\right]$$

Frequency spectrum and bandwidth of A.M wave

$$e_{AM} = \underbrace{E_c \sin \omega_c t}_{\text{carrier}} + \underbrace{\frac{mE_c}{2} \cos(\omega_c - \omega_m)t}_{\text{Lower side band}} - \underbrace{\frac{mE_c}{2} \cos(\omega_c - \omega_m)t}_{\text{Upper side band}} \quad \ldots (4)$$

•Looking at eqn 4 we can say that 1st term represents unmodulated carrier and two additional terms represents two sidebands

•The frequency of the lower sideband (LSB) is fc – fm and the frequency of the upper sideband (USB) is fc+fm

BANDWIDTH OF AM WAVE

•We know bandwidth can be measured by subtracting lowest frequency of the signal from highest frequency of the signal

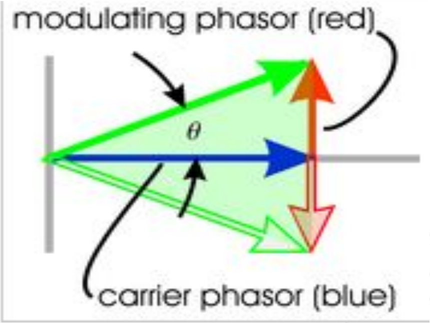
•For amplitude modulated wave it is given by

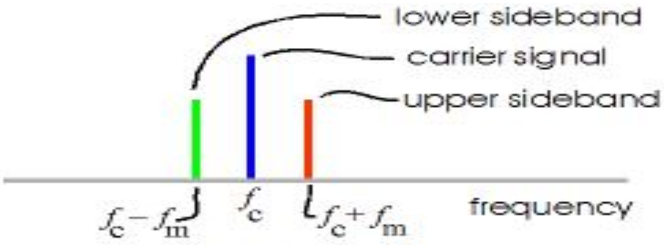
$$B_w = f_{USB} - f_{LSB}$$
$$= (f_c + f_m) - (f_c - f_m)$$
$$\boxed{B_w = 2 f_m}$$

•Therefore the bandwidth required for the amplitude modulation is twice the frequency of the modulating signal

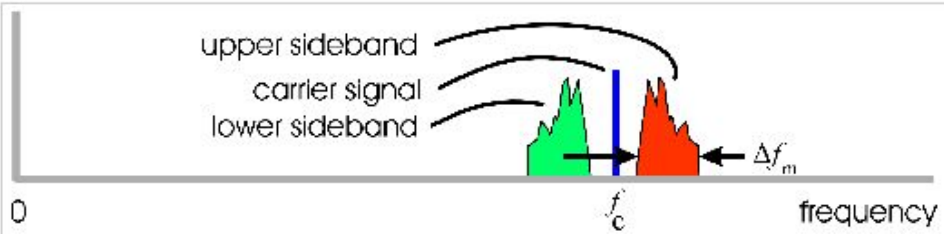
Sidebands

- **Phasor representation**

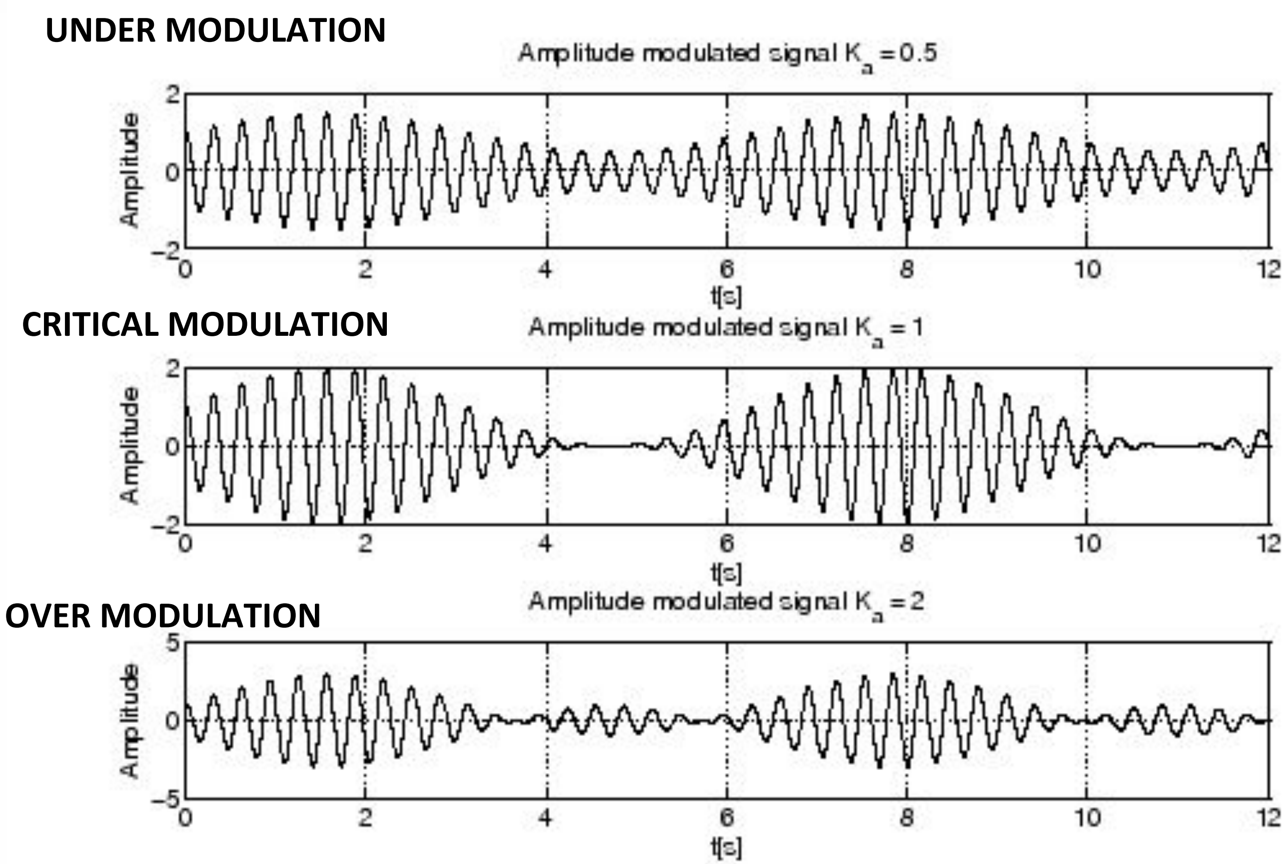




Spectrum of the resulting modulated signal



Degrees of modulation



Calculation of percentage of modulation

- Looking at the figure we can visualize that something unusual (distortion) will occur if Em is greater than Ec
- Therefore the modulating signal voltage Em must be less than the carrier voltage Ec for proper amplitude modulation
- This relationship between the amplitude of the modulating and carrier signals is important and it is expressed in terms of their ratio, commonly known as modulation index (m)
- It is also called **modulation factor, modulation coefficient or the degree of modulation**
- The m is the ratio of the modulating signal voltage to the carrier voltage
- The modulation index is a number lying between 0 and 1 and it is very often expressed as a percentage and called the percentage modulation

Calculating the modulation-index

- **Calculating the modulation index using AM wave**
- We know that $m = \frac{E_m}{E_c}$ with this relation we can calculate the modulation index from the modulated
- waveform . Hence we can write

$$E_m = \frac{E_{max} - E_{min}}{2}$$

- By substituting 1st eqn in 2nd eqn we ge

$$E_c = E_{max} - E_m = E_{max} - \left(\frac{E_{max} - E_{min}}{2}\right) = \frac{2E_{max} - E_{max} + E_{min}}{2}$$

- By diving 1st and 3rd eqn we get

$$m = \frac{E_m}{E_c} = \frac{(E_{max} - E_{min})/2}{(E_{max} + E_{min})/2}$$

$$m = \frac{E_m}{E_c} \qquad m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

Power distribution in an A.M wave

- We have seen that AM wave has three components :
- Unmodulated carrier
- Lower sideband
- Upper sideband
- Therefore the total power of AM wave is the sum of the carrier power Pc and Power in the two
- sidebands Pusb and Plsb. It is given as

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

$$\text{The average carrier power} = \frac{(A_c/\sqrt{2})^2}{R} = \frac{A_c^2}{2R}$$

- Where all three voltage represents r.m.s values and resistance R is a characteristic impedance of
- antenna in which the power is dissipated

Power distribution in an A.M wave

$$P_{LSB} = P_{USB}$$

$$= \left(\frac{\mu A_c / 2}{\sqrt{2}}\right)^2 \times \frac{1}{R}$$

$$= \frac{\mu^2 A_c^2}{8R}$$

The average total power, $P_{Total} = \frac{A_c^2}{2R} + \frac{\mu^2 A_c^2}{8R} + \frac{\mu^2 A_c^2}{8R}$

$$= \frac{A_c^2}{2R}\left(1 + \frac{\mu^2}{4} + \frac{\mu^2}{4}\right)$$

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

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

$$\frac{P_{Total}}{P_c} = 1 + \frac{\mu^2}{2}$$

Power distribution in an A.M wave

- CURRENT RELATION IN AM

We know that

$$\frac{P_{Total}}{P_c} = 1 + \frac{\mu^2}{2}$$

$$\frac{\mu^2}{2} = \frac{P_{Total}}{P_c} - 1$$

$$\mu^2 = 2\left(\frac{P_{Total}}{P_c} - 1\right)$$

$$\mu = \sqrt{2\left(\frac{P_{Total}}{P_c} - 1\right)}$$

Efficiency

- The total power is the sum of carrier power and the sideband power

$$\eta = \frac{P_{SB}}{P_T} \times 100\%$$

- Useful sideband power

$$P_{SB} = P_{LSB} + P_{USB}$$

- Total power in the AM Signal

$$P_T = P_C + P_{SB}$$

- The carrier power is the mean square value of the first term in the right hand side. For a
- sinusoid the root mean square value is given by the peak value divided by √2

$$P_C = \left(\frac{A_C}{\sqrt{2}}\right)^2 = \frac{A_C^2}{2}$$

Efficiency

- In the second and third term in the eqn the LSB and USB terms

$$P_{LSB} = P_{USB} = \left(\frac{A_c \mu}{2\sqrt{2}}\right)^2 = \left(\frac{A_c^2 \mu^2}{8}\right)$$

$$P_{SB} = P_{LSB} + P_{USB} = \left(\frac{A_c^2 \mu^2}{4}\right)$$

- Therefore modulation efficiency is given by

$$\eta = \frac{P_{SB}}{P_T} = \left[\frac{\left(\frac{A_c^2 \mu^2}{4}\right)}{\left\{\left(\frac{A_c^2}{2}\right) + \left(\frac{A_c^2 \mu^2}{4}\right)\right\}}\right]$$

- When simplified and expressed as a percentage yields

$$\eta = \left[\frac{\mu^2}{\mu^2 + 2}\right] \times 100\%$$

Efficiency

- Thus efficiency is given by

$$\eta = \left[\frac{\mu^2}{\mu^2 + 2}\right] \times 100\%$$

- If μ=1 (critical modulation) then
- %η= (1/3) x 100= 33.3%
- Only 33.3% of energy is used and remaining power is wasted by the carrier along with the sidebands