Amplitude Modulated Systems

- Communication is process of establishing connection between two points for information exchange.
- Channel refers to medium through which message travels e.g. wires, links, or free space.
- Information is called baseband signal/modulating signal.
  Example: **A**udio signal30 Hz to 20 KHz
  Tone – single frequency
- Modulation is the requirement of communication systems. It is a process by which some characteristic of carrier signal is varied according to instantaneous value of modulating signal.

Types of Modulation:

- **Continuous wave (CW) modulation:**-Carrier waveform is continuous.
- Example :Amplitude and Angle modulations,
- **Pulse modulation:** Carrier is pulse type:
  - ➤ Pulse Analog Modulation: PAM, PWM, PPM
  - ➤ Pulse Digital modulation: PCM, DM, DPCM
- **Digital Modulation Schemes:** Used for data transmission; ASK, FSK, PSK

Need for Modulation?

(i)   **Multiplexing:** Simultaneous transmission of multiple messages. If transmitted without modulation they will interfere.

(ii)   **Size of antenna:** audio frequency: 30Hz – 20 KHz

    (a)   For 30Hz,λ = 10,000 KM, Antenna size λ /4 = 2500 Km (Impractical)

    (b)   For 1 MHz carrier, λ = 300m, Antenna λ/4 = 75m (Big)

    (c)   For 100 MHz carrier, λ = 3m, Antenna (λ/4) = 7.5m (Practical).

(iii)   **Narrow banding:** If baseband signal (50 Hz-20 KHz) is transmitted directly one needs very wide band antenna. Frequency translation improves a lot typical 1:200 ratio of band edge reduces to 1:1.01for frequency range of 1 MHz.

Amplitude Modulation (Conventional AM)

- Amplitude of carrier is changed with respect to modulating signal.
- It is linear modulation.

Carrier wave $e_c = E_c \cos \omega_c t$

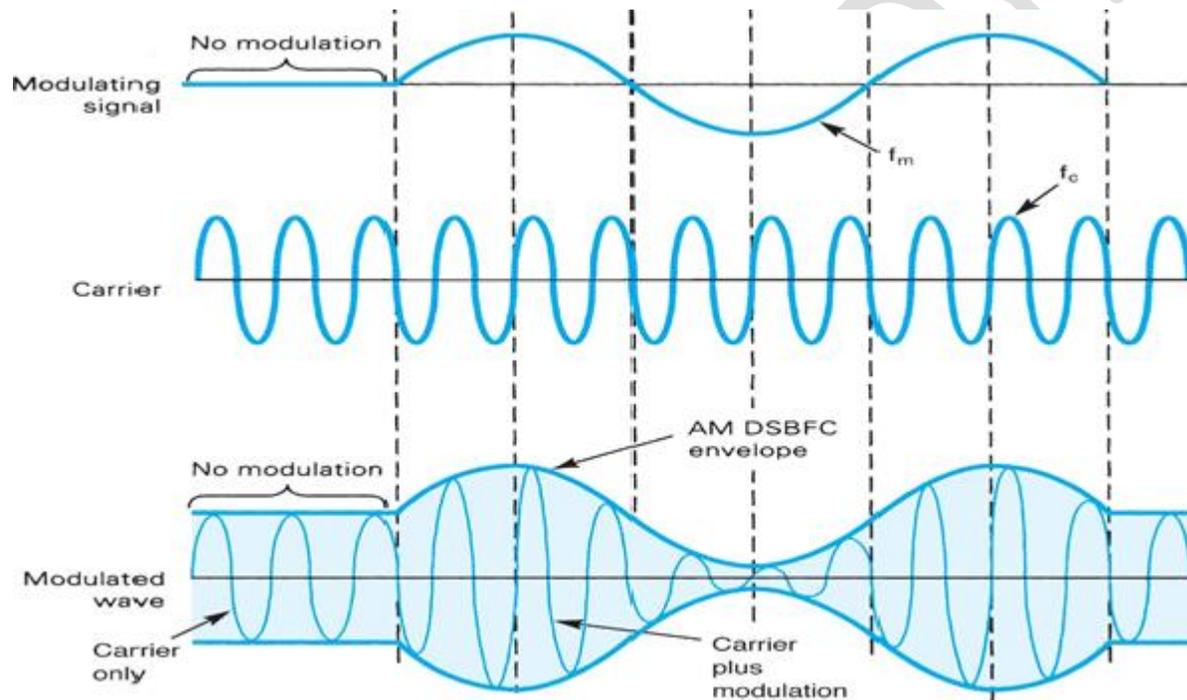Modulating signal $e_m = E_m \cos \omega_m t$

Modulated signal $s(t) = E_c \left[1 + \frac{E_m}{E_c} \cos \omega_m t \right] \cos \omega_c t$

Where, modulation index $(\mu) = \dfrac{E_m}{E_c}$

$$s(t) = E_c \cos \omega_c t + \frac{\mu E_c}{2} \cos(\omega_c - \omega_m)\, t + \frac{\mu E_c}{2} \cos(\omega_c + \omega_m)\, t$$

Three components

      (i) Carrier frequency with amplitude E_c

      (ii)   Upper sideband $(\omega_c + \omega_m)$ *with amplitude* $\frac{\mu E_c}{2}$

      (iii)   Lower side band $(\omega_c - \omega_m)$ *with amplitude* $\frac{\mu E_c}{2}$

No modulation

Modulating
signal

f_m

f_c

Carrier

AM DSBFC
envelope

No modulation

Modulated
wave

Carrier
only

Carrier
plus
modulation

Experimental Determination of Modulation Index (μ):

Minimum amplitude of AM wave $V_{min} = (E_c - E_m)$

Maximum amplitude of AM wave $V_{max} = (E_c + E_m)$

So, $\mu = \dfrac{(V_{max} - V_{min})}{(V_{max} + V_{min})}$ (From the waveform on CRO)

Power in AM wave:

(a) Conventional AM (DSB FC)

$$P_{AM} = \frac{E_{car}^2}{R} + \frac{E_{LSB}^2}{R} + \frac{E_{USB}^2}{R} \quad \text{where all voltages in}$$

RMS and R is resistance of antenna

$$E_c = \frac{E_c}{\sqrt{2}}$$

$$P_{LSB} = P_{VSB} = \frac{E_{SB}^2}{R} = \frac{\left(\frac{\mu\, E_c/2}{\sqrt{2}}\right)^2}{R} = \frac{\mu^2 E_c^2}{8R}$$
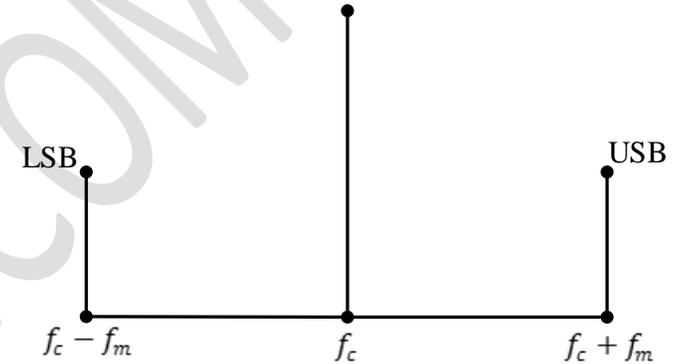
$$P_{AM} = \frac{E_c^2}{2R} + \frac{\mu^2}{4}\frac{E_c^2}{2R} + \frac{\mu^2}{4}\frac{E_c^2}{2R} \quad (\textit{Resistance R can be taken as unity})$$

$$\frac{P_{AM}}{P_c} = \frac{P_T}{P_c} = \left(1 + \frac{\mu^2}{2}\right) \quad OR \quad P_{DSBFC} = \left(1 + \frac{\mu^2}{2}\right)P_c \quad \& \quad \eta = \frac{P_{SB}}{P_T} = \frac{\mu^2}{(2 + \mu^2)}$$

For $\mu = 1$, $\eta = 33.3\%$

If modulated by several tones then overall modulation index is given by

$$\mu_t = \sqrt{\mu_1^2 + \mu_2^2 + \text{-----}}$$

LSB · · USB

$f_c - f_m$ f_c $f_c + f_m$

(b) Double side band suppressed carrier system (DSBSC)

Most of the power in conventional AM is contained in carrier.

Major saving of carrier in this systems.

Efficiency of suppressed carrier (SC) system is 100%.

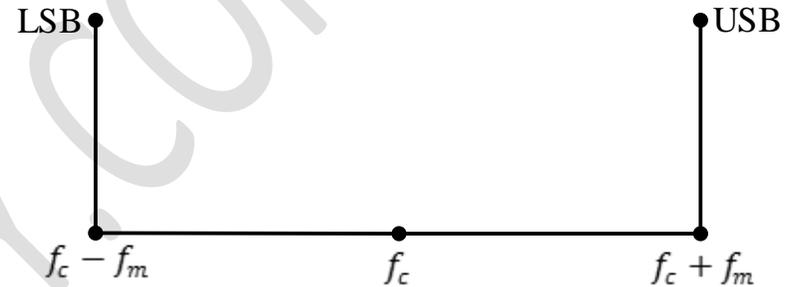It is at the cost of expensive and complex receiver

$$s(t) = m(t) \cos \omega_c t = \mu. E_c \cos \omega_m t \,.\cos \omega_c t$$

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

$$P_{USB} = P_{LSB} = \frac{\mu^2 E_c^2}{8R}$$

$$P_{DSBSC} = \frac{\mu^2 E_c^2}{4R} = \frac{\mu^2}{2} P_c$$

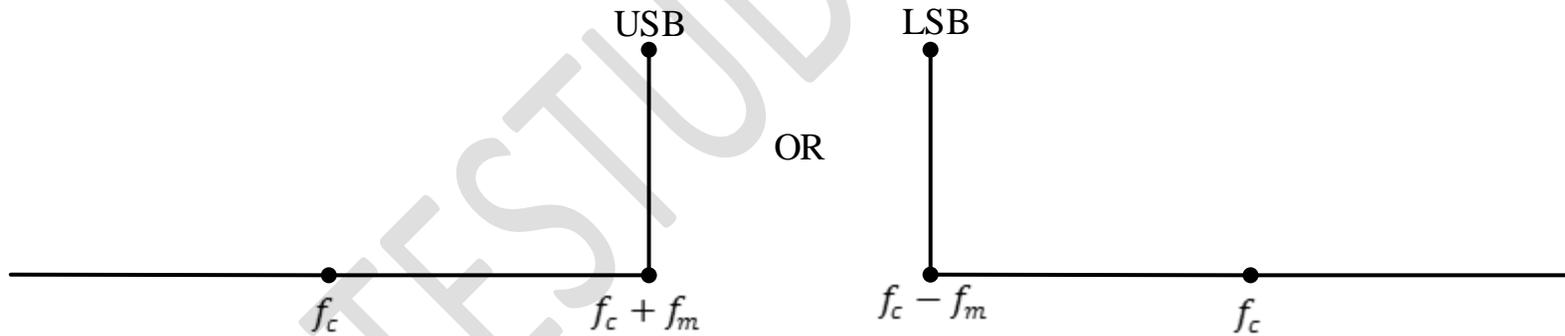Used in commercial radio broadcasting

(c)   Single sideband suppressed carrier (SSBSC)

$$P_{SSB} = \frac{E_{LSB}^2}{R} = \frac{E_{USB}^2}{R}$$

$$P_{LSB} = P_{USB} = \frac{E_{SB}^2}{R}$$

$$P_{SSB} = \frac{\mu^2}{4} \frac{E_c^{\,2}}{2R} = \frac{\mu^2}{4} \cdot P_c$$

USB   LSB

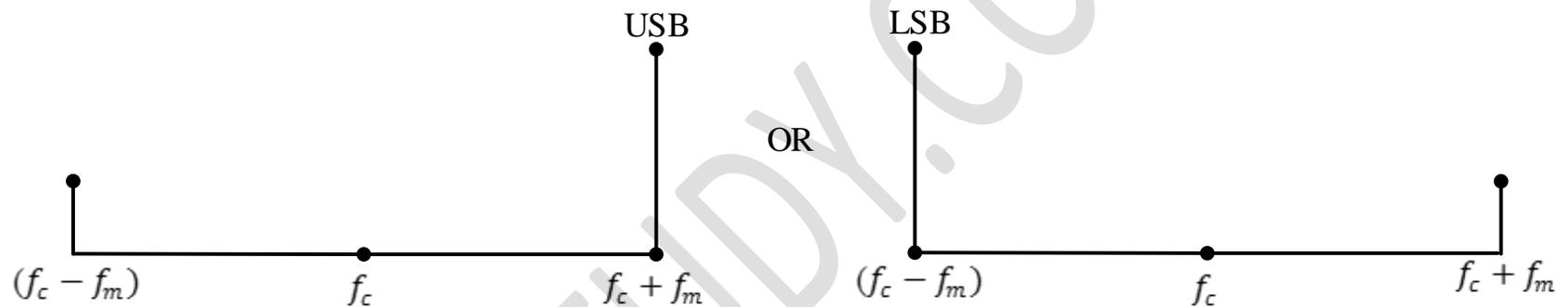OR

f_c $f_c + f_m$ $f_c - f_m$ f_c

Used in point to point communication

Vestigial Sideband (VSB):-

It is also called asymmetric sideband system. It is a clever compromise between DSB & SSB.

In VSB BW is $\approx 25\%$ higher than SSB.

An attractive option for TV broadcast. Total BW of TV channel is now 6 MHz instead of 9 MHz.

AM Modulators

- Modulation translates the message spectrum upward in frequency and demodulation is downward frequency translation
- Upward frequency translation achieved by multiplier.

Types of Modulators

- Multiplier Modulator: Using analog multiplier
- Nonlinear Modulators: Using nonlinear devices like diode
- Switching Modulator: Multiplication operation can be achieved by simple switching operation.
- Balanced Modulator or Ring Modulator: Used for generation of DSB-SC wave. It suppresses unwanted carrier.
- SSB generation: Using analog multiplier & BPF. It can be also be used for VSB

AM Demodulation or Detection: To extract baseband signal from conventional AM. DSB-SC and SSB modulation require coherent detection (complex in nature)

Two Types of AM Detectors

- **Square law detector:** For low level modulated signals (<1V), square law region of diode characteristic is used. This circuit gives distortion.
- **Linear diode detector or peak detector or envelope detector:** Extracts envelope of AM wave. It is simple and cheap (one diode, one capacitor) and one resistor

Operation of Envelope Detector

When AM wave amplitude increases capacitor voltage is increased. When input falls, capacitor voltage is reduced (discharged through R).

Choice of time constant

- To keep RC large compared to period of carrier wave to reduce fluctuations in detected envelope. If it is too high discharge curves is horizontal, the negative peak may be missing. This distortion is called **diagonal clipping**, so it is chosen as
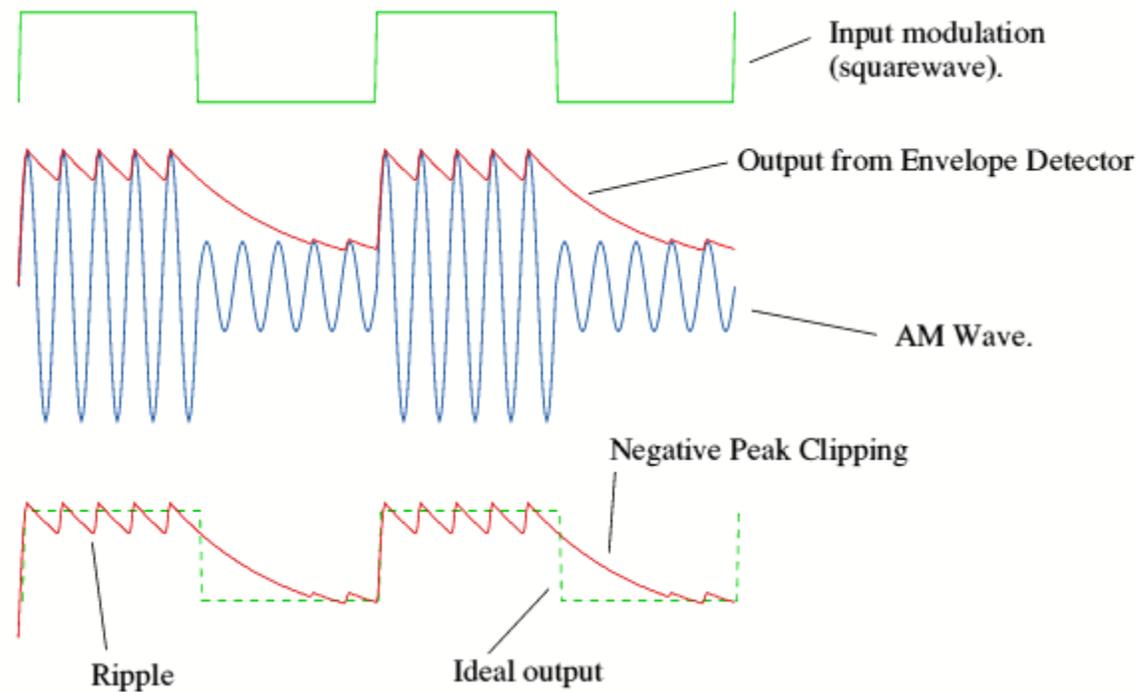
$$\frac{1}{fm} \gg \tau(RC) \gg \frac{1}{fc}$$

Above condition is possible only if $fc \gg fm$
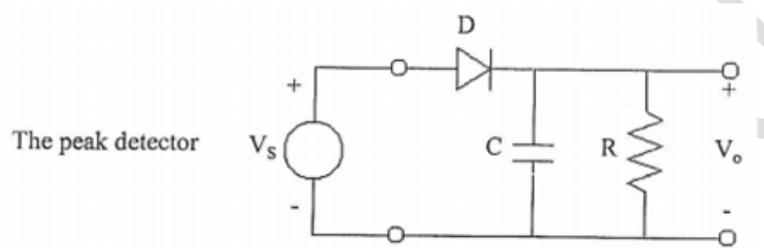
The peak detector

Output waveform for a peak detector driven by an AM wave:
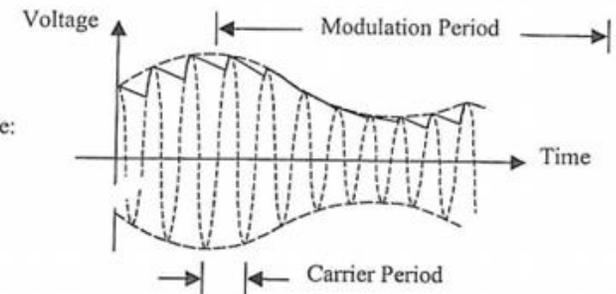
AM Receivers:

Tuned Radio Frequency Receivers (TRF):

➢ Cheap and simple
➢ Satisfactory at Medium frequency but poor at radio frequencies

Super heterodyne Receiver: Uses the principle of heterodyning (mixing)

Advantages:

➢ No variation in bandwidth
➢ High sensitivity and selectivity
➢ High adjacent channel rejection

Disadvantage: Suffers from image frequency problems

Image Signal

f_{ci} – Image frequency

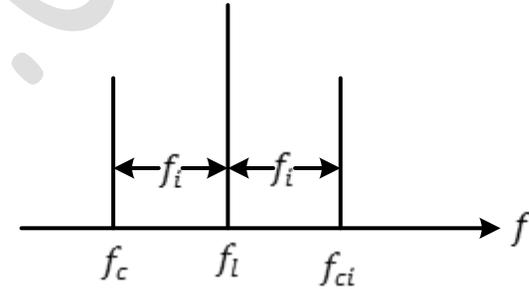f_c – Signal frequency

f_l - Local oscillator frequency

$f_l - f_c = f_i$

Or $f_c = (f_l - f_i)$

Image frequency $f_{ci} = (f_l + f_i)$

$$f_{ci} = f_c + f_i + f_i = (f_c + 2f_i)$$

Image signal should be rejected in RF stage only.

Comparison of AM Systems

Parameters	Conventional AM	DSBSC	SSB	VSB
1. Carrier suppression	No	Fully	Fully	No
2. Side band suppression	No	No	One sideband Completely	One side band suppressed partially
3. Bandwidth	2f	$2f_m$	f_m	$f_m < BW < 2f_m$ (between SSB and SSBSC)
4. Cost & complexity	Huge cost and complexity in transmitter low cost receivers	Simple Transmitter but costly receivers		
5. Use	Commercial Radio broadcast	Commercial radio broadcast	Point to point	TV