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LECTURE # 17 PART (III)

3.4 (i) AM & FM TRANSMITTER (MODULATORS)

(ii) AM & FM RECEIVER (DEMODULATORS or DETECTORS)

Transmitter Block main function → Modulation & Frequency Translation.

Receiver Block main function → Demodulation or Detection & Reverse Frequency Translation.

Amplitude Modulator or Mixer : An AM transmitter can be based on different types of modulation techniques to carry out modulation e.g DSB-Full Carrier, DSB-SC, SSB-SC & VSB modulation. The name of the circuit that carries out the process of Amplitude Modulation is called a Mixer. Therefore Mixer/Amplitude Modulator output is a DSB-Full carrier signal. See Figure:1.

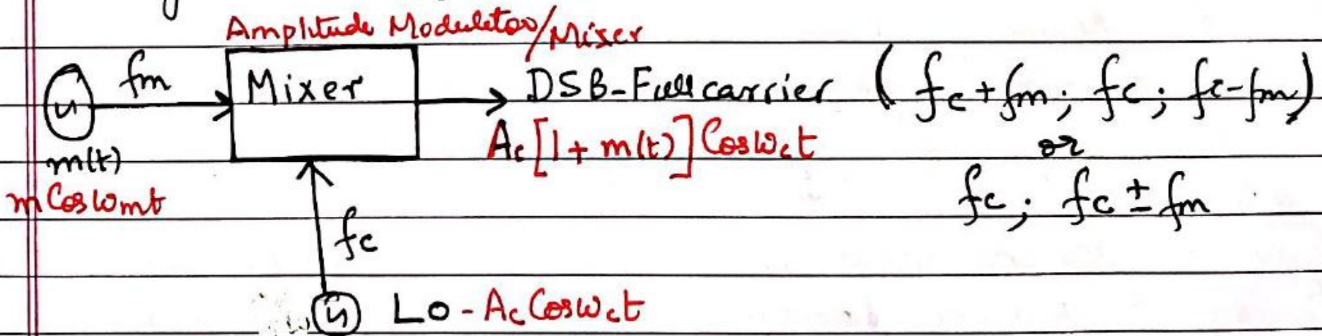


Figure: 1 : Mixer is another name for Amplitude Modulator that mixes baseband signal m(t) and Local Oscillator Signal (f_c) to produce at output a DSB-full Carrier which has three components in the Spectrum — f_c, $f_c \pm f_m$

Balanced Modulator or Multiplier The name of the circuit that carries out the process of DSB-SC modulation is called a Balanced Modulator. It is also called a multiplier because when baseband signal m(t) and LO signal carrier (f_c) is fed to a balanced modulator, it simply multiplies the two inputs to produce only two spectral components $f_c + f_m$ & $f_c - f_m$.

See Figure: 2 below:

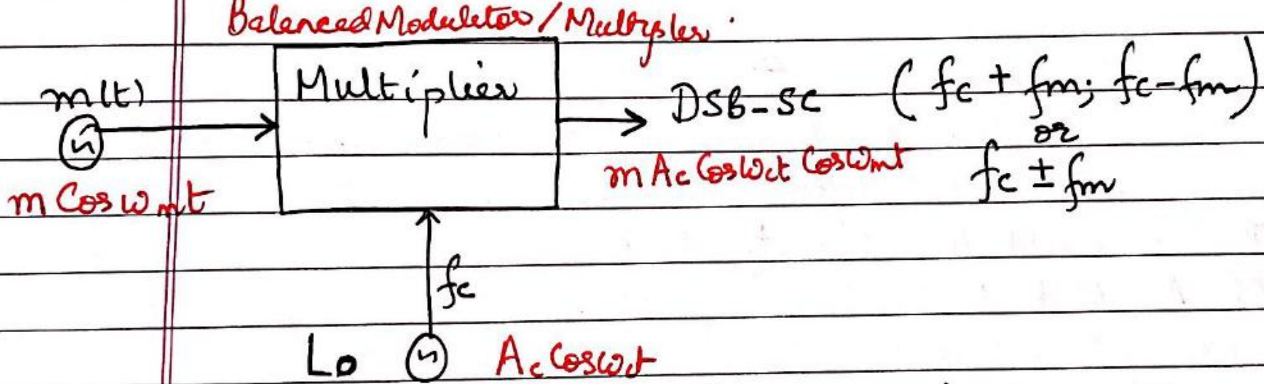


Figure: 2 The Balanced Modulator/Multiplier simply multiplies two inputs causing Frequency Translation of smaller frequency (f_m) around higher frequency (f_c) while suppressing the higher frequency (f_c) itself.

As was discussed in previous lectures the DSB-Full Carrier or DSB-SC outputs can further be passed through filters or processed in different types of circuits to result in SSB-SC & VSB-SC or VSB-Full carrier.

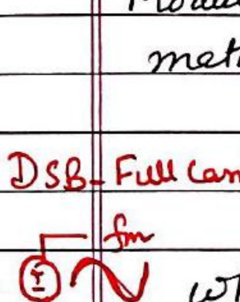
Q. Briefly describe a circuit that performs the function of Amplitude Modulation (DSB- Full carrier).

or

Write a Short note on the Circuit Realization of a Mixer / Amplitude Modulator producing a DSB-Full carrier Signal.

Ans: A Mixer Circuit is used for the Generation of an Amplitude Modulated Signal with full carrier. Such a signal is mathematically represented as

DSB- Full carrier $$V_{AM}(t) = A_c [1 + m(t)] \cos \omega_c t$$



where m(t) is the baseband modulating (information) signal at frequency fm.

$V_c(t)$ is the high frequency Carrier at freq. fc

Working:- $V_c(t)$ carrier is generated by a Local Oscillator such as Hartley or Collpit. The Oscillators are highly preferred to be Stable. This implies that if the oscillator is meant to generate a frequency of fc, there should be no fluctuation of neither Amplitude (A_c) nor the frequency (f_c). Otherwise any amplitude fluctuations or frequency fluctuations at the Tx itself will introduce distortion in the DSB-Full Carrier modulated output even before transmission over communication channel.

Figure : 3 Shows the circuit diagram of a Mixer using P-n junction diode.

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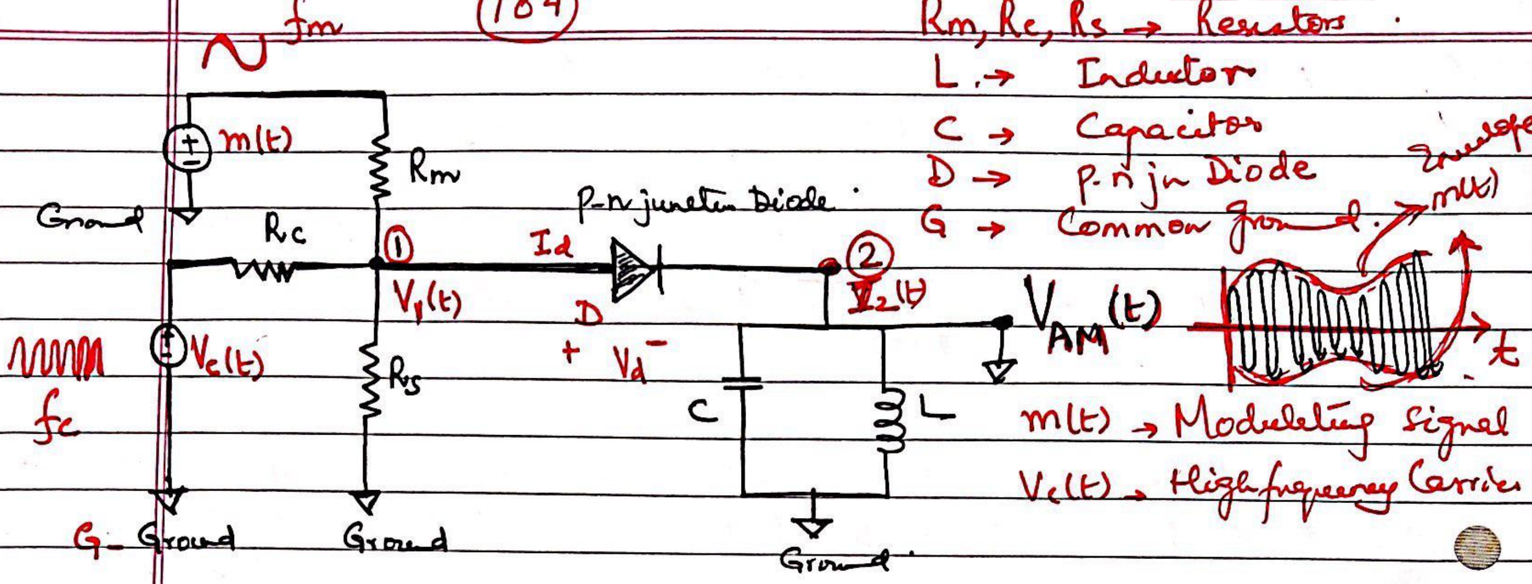

Rm, Rc, Rs → Resistors.
L → Inductor
C → Capacitor
D → p-n jn Diode
G → Common ground.

m(t) → Modulating signal
Vc(t) → High frequency Carrier

Figure: 3 Circuit Diagram of a Mixer Using p-n junction diode

Position ① V_1 Attatching the two Sources m(t) and $V_c(t)$ to a common node adds the voltage together. However it has to be understood that $V_{AM}(t)$ – DSB-Full carrier signal represented as $A_c[1+m(t)]\cos\omega_c t$ is not mere sum of two signal. ie Mixer does not perform the function of addition. Mixing is not Addition. But mixing is when three components will be generated ie $f_c - f_m$; f_c; $f_c + f_m$. That is why we have additional circuitry even beyond position ①.

So far at position ① the voltage produced is a linear sum of m(t) and $V_c(t)$. as shown in Figure

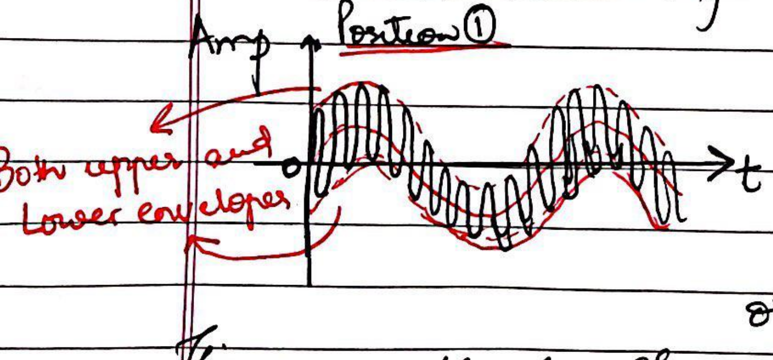

Figure: 4 Position ① potential is Linear Sum of $V_c(t)$ and m(t). ie

Position ① potential $\propto [V_c(t) + m(t)]$

or position ① Potential (V_1) $= k\,[V_c(t) + m(t)]$

This means the sum of m(t) and $V_c(t)$ will look like Figure: 4 at position ①.

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This can be proved as below:-

As observed in figure: 3, $m(t)$ and $V_c(t)$ are fed through resistors R_m & R_c. In order to find node voltage we use superposition theorem and KVL theorems.

Let $R_m = R_c = R_s = R$

Suppose at position ① potential $V_1 = (\text{Voltage})_1 + (\text{Voltage})_2$ ①

where $(\text{Voltage})_1 = \left(\frac{m(t)}{2R}\right) R = \frac{m(t)}{2}$ ②.

$(\text{Voltage})_2 = \left(\frac{V_c(t)}{2R}\right) R = \frac{V_c(t)}{2}$ ③.

By Superposition theorem using eqn ② & ③ in ①

At position ①, $V_1 = (\text{Voltage})_1 + (\text{Voltage})_2$

∴ At position ①, $V_1 = \frac{1}{2}\left[m(t) + V_c(t)\right]$ implying sum (Linear) of $m(t)$ + $V_c(t)$.

that will look like Figure 4.

This figure: 4 shows that $m(t)$ shape is present on both upper and lower envelope of the carrier. We use a higher value of A_c of carrier amplitude as compared to the $m(t)$ amplitude.

Position ② (V_2 or I_2). Closer inspection of potential V_1 at Position ① as illustrated in Figure 4 resembles AM. However the envelope is varied on both upper as well as lower side of the zero reference. We need to get rid of the lower part. This is achieved by clipping one portion of potential V_1. The clipping can be accomplished with a non-linear device.

A linear device is a device that has linear transfer characteristics eg. a diode, a transistor (BJT), an Op-Amp etc. An Op-Amp has no cut-in voltage problem but the output is in the form of voltage and not current. This is a disadvantage because we need a current for replicating the (clipped) upper half in following circuitry later. So a better choice is the use of the Linear Transfer characteristics of a diode or BJT. In Figure 3, the device employed for Clipping or rectification is a diode D. (p-n diode)

When signal $V_1(t)$ at position (1) is passed through diode D then diode acts as a half wave rectifier. It clips the negative half of each of cycle of Figure(4). This means that the negative cycle of $V_1(t)$ is clipped off because the diode D is reverse biased for the negative cycles of $V_1(t)$. See the operation in Figure 5

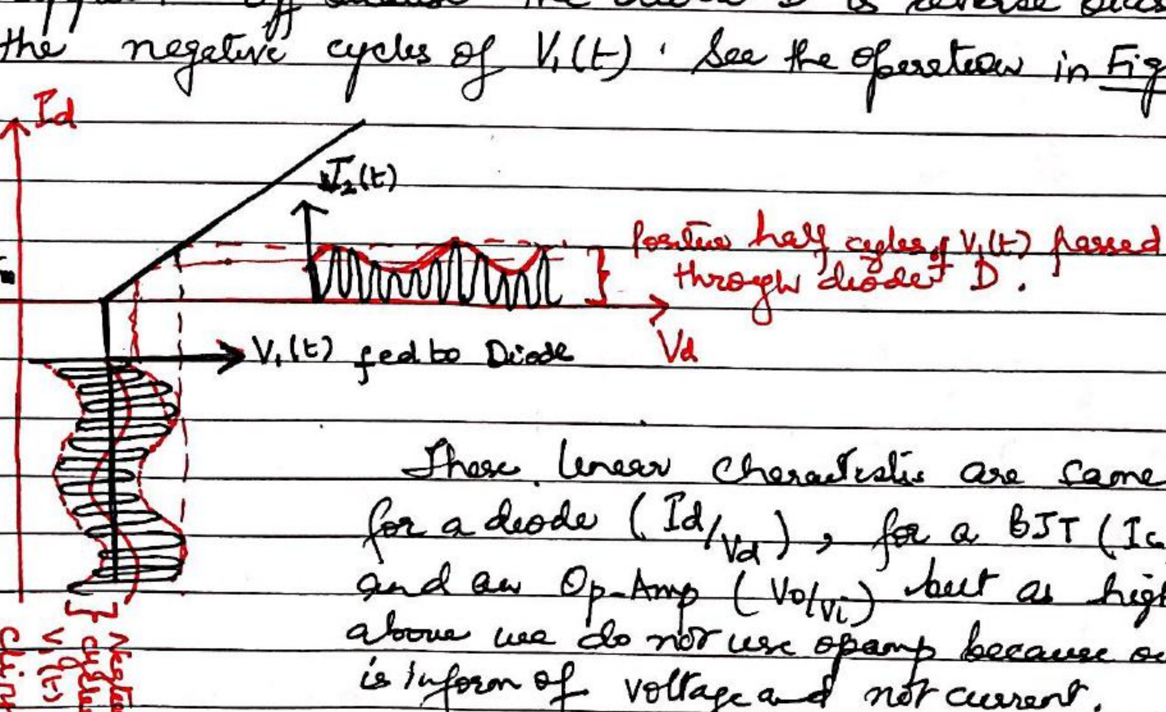

Figure 5:- Diode Characteristics that rectifies negative half of $V_1(t)$.

These linear characteristic are same for a diode (Id/Vd), for a BJT (Ic/V_{BE}) and an Op-Amp (Vo/V_i) but as highlighted above we do not use opamp because output is in form of voltage and not current.

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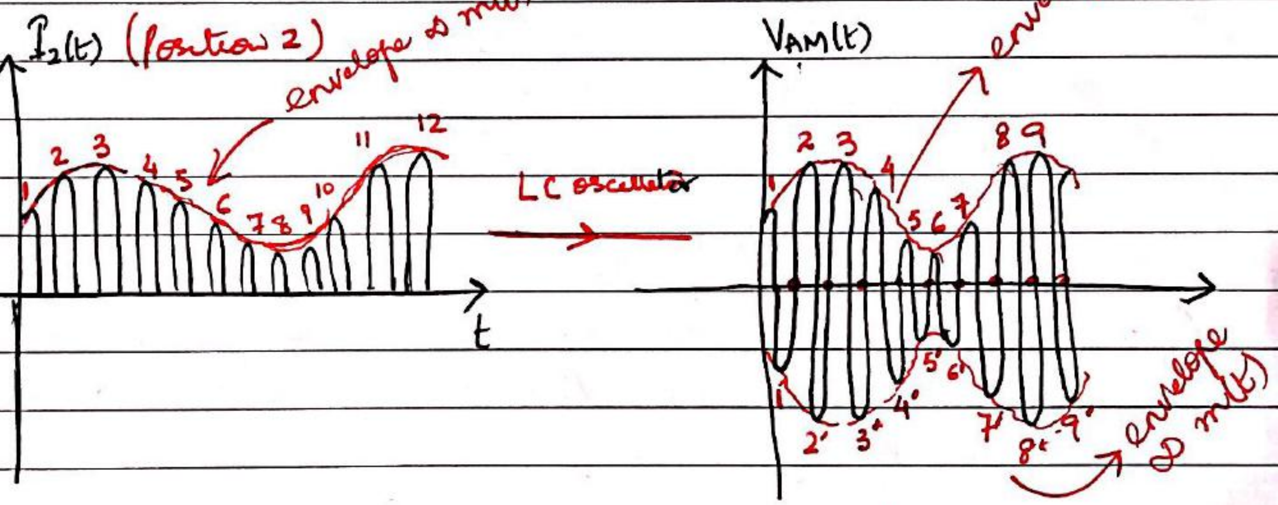
LC Oscillator Function The next objective is to reflect the waveform at position 2 ($I_2(t)$) along x-axis. This can be done by using an LC oscillator with the resonant freq. $f_{res} = f_c$ equal to Carrier frequency.

For each half cycle of $I_2(t)$ it generates a full cycle of sinusoidal wave. The output is a potential $V_{AM}(t)$ as shown below in Figure 6

Figure 6: Generation of AM wave from current pulses at position ②.



In order to generate AM wave (DSB-Full carrier) from the rectified current pulses at position ②, these pulses (rf half cycles 1, 2, 3, 4 - - - -) are fed to the LC tuned circuit. The oscillations would have any initial amplitude proportional to the size of the size of the current pulse and a decay rate dependent on the time constant of the circuit. However here a train of pulses (1, 2, 3, 4, - - - -) is fed to the tuned circuit where each pulse has got Varying Amplitude. Each pulse will cause a complete sinewave of amplitude as that of (same) that of the initiating current pulse. Hence pulse 1 get completed followed by pulse 2 getting completed so on.

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Hence the successive pulses are of varying amplitude. This process is also known as the flywheel effect of tuned circuit.

A good approximation of an AM wave results since the original current pulses fed to LC circuit at position ② are having amplitude / envelope proportional to m(t) modulating signal

∴ Output of LC circuit.

$$V_{AM}(t) = A_c\left[1 + m(t)\right]\cos\omega_c t$$

which is an amplitude modulated wave of form or scheme namely DSB - Full carrier.

Q. Briefly describe a circuit that performs the operation or function of Amplitude modulation with suppressed carrier (DSB - SC).

or

Write a Short note on the Circuit Realization of a Multiplier / Balanced Modulator producing DSB-SC Signal.

Ans: A multiplier circuit is used for the generation of DSB_SC. It is the balanced modulator which when fed with baseband signal m(t) and LO carrier f_c ($A_c\cos\omega_c t$) produces at output

$$V_{DSB-SC} = m(t)\, A_c \cos\omega_c t$$

as shown in Figure 2 on page 182.

Balanced Modulator or Multiplier — A simple circuit implementation for a balanced Modulator is a Ring Modulator which consists of 2 centre tapped transformers and 4 diodes. In the circuit shown below in Figure 7, m(t) is given as V_{in} and we use a Square wave generator (Voltage controlled oscillator-VCO). The VCO generates a square wave which has same frequency as that of a sinusoidal carrier.

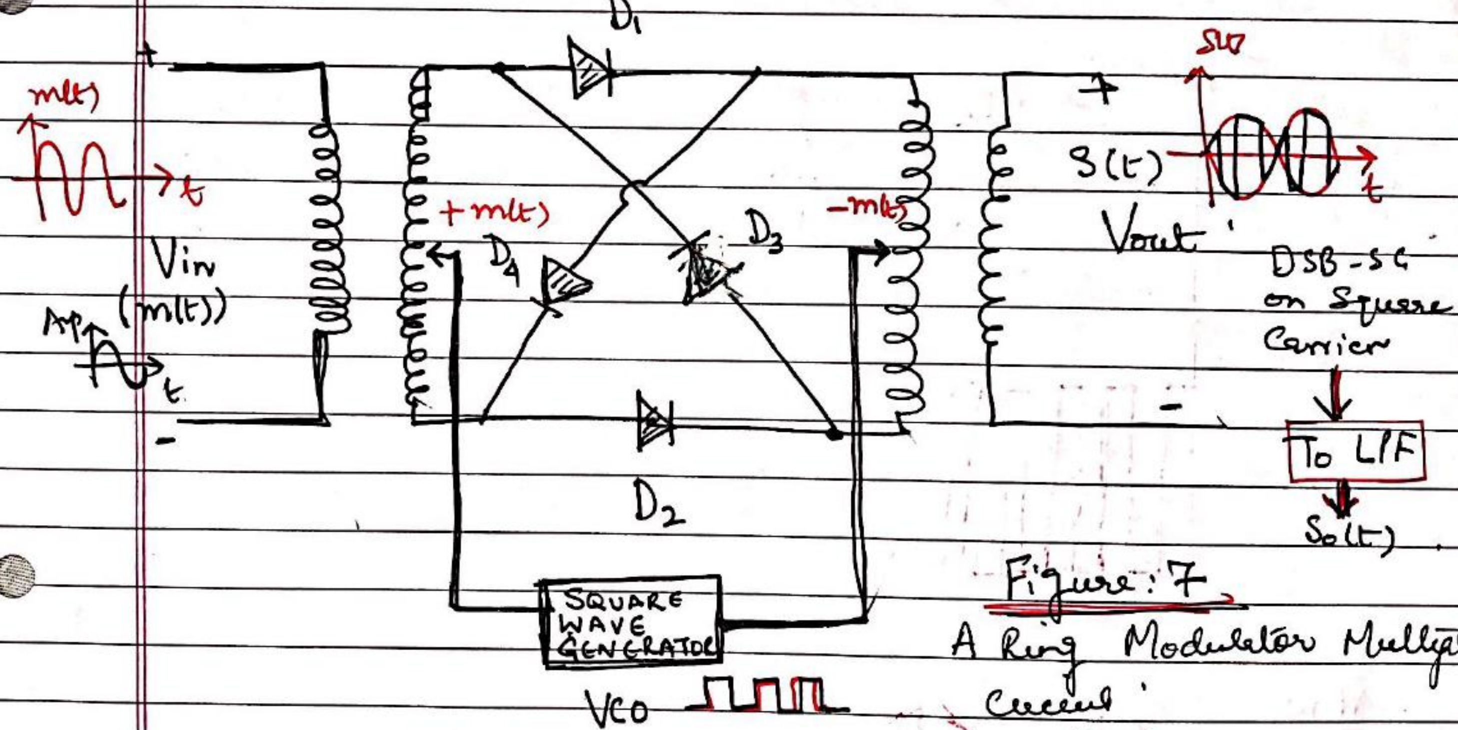


Figure: 7
A Ring Modulator Multiplier Circuit

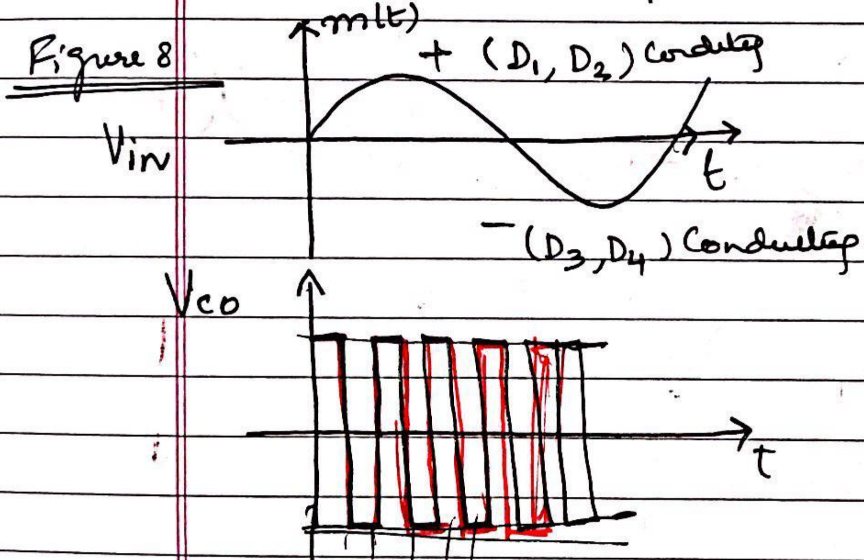
When m(t) wave is in positive half cycle, then diodes D_1 and D_2 are forward biased, Then positive levels of input m(t) are transferred to the output because D_3 and D_4 are reverse biased.

During negative half cycle of m(t) only D_3 and D_4 diodes are Forward biased and conducting while D_1 and D_2 diodes are non-conducting. Since connection of transformer has changed then we get -m(t) appears at output.

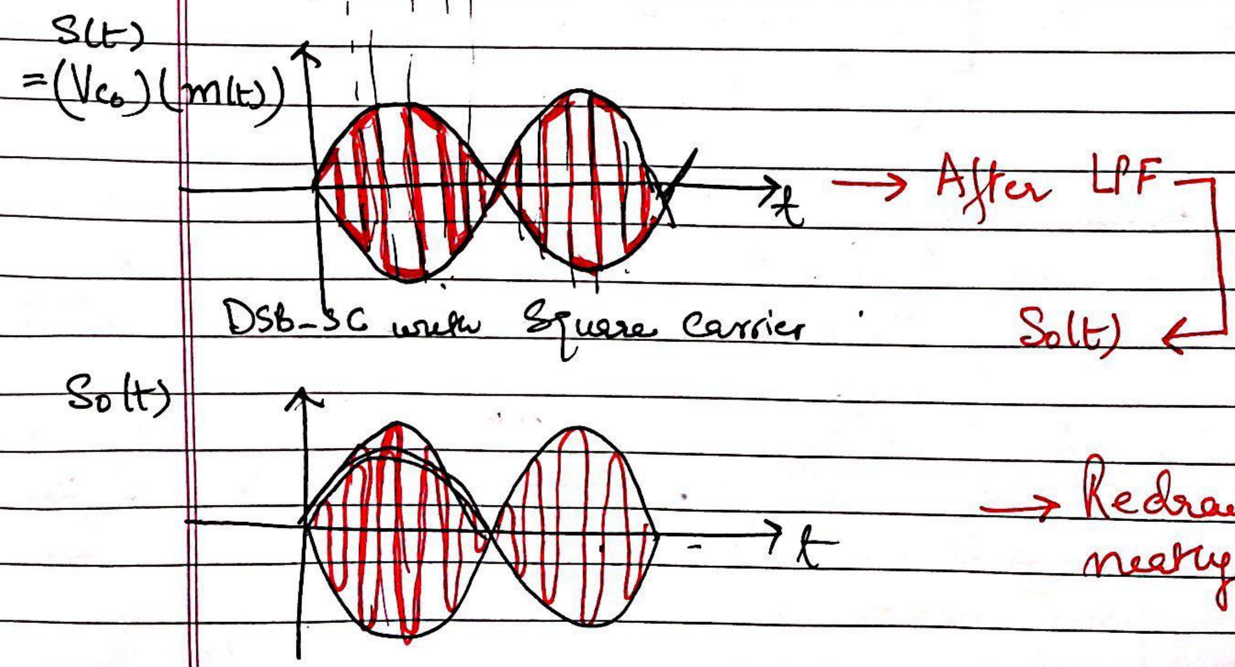
S(t) is a DSB-SC signal which in essence is a waveform equal to product of m(t) and Square wave. S(t) is finally passed through a LowPass filter that blocks all the high frequency components that result is Square carrier cycles. Result will be So(t) which is now DSB-SC where is carrier cycles are not Square but they are Sinusoidal cycles.

Each of these stages are shown below in figures 8

Figure 8

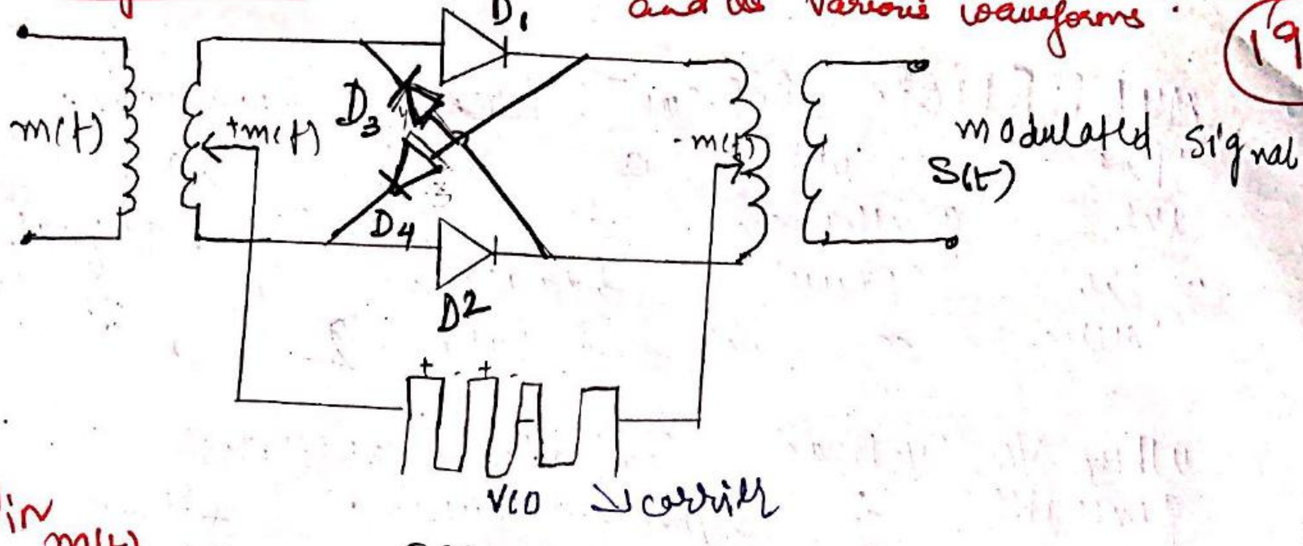


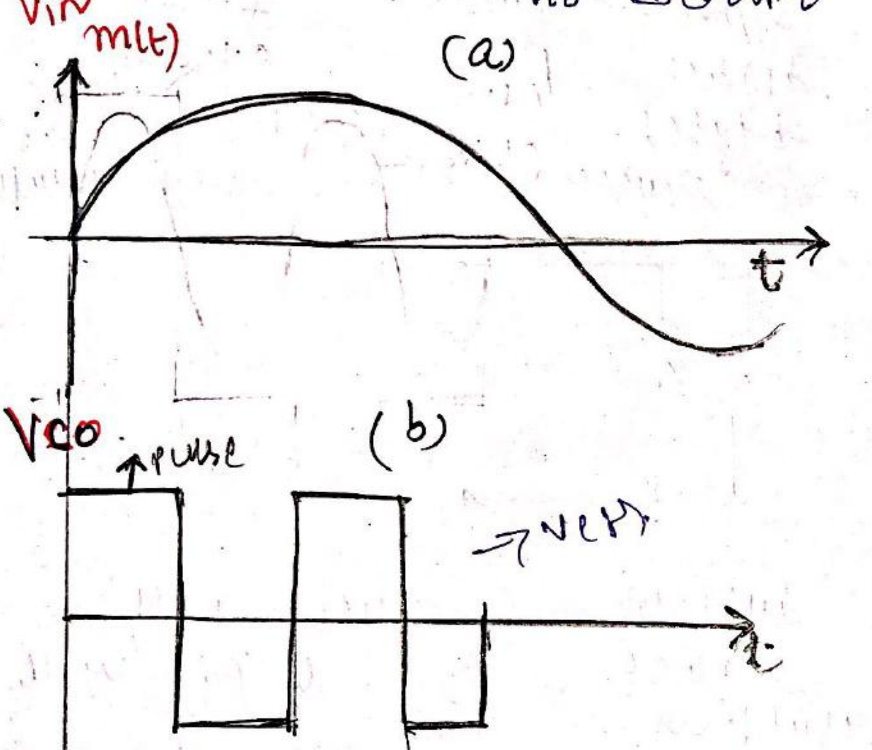
Low Pass filters cancel higher frequency components of Square wave and give us only sinwave low frequency component.

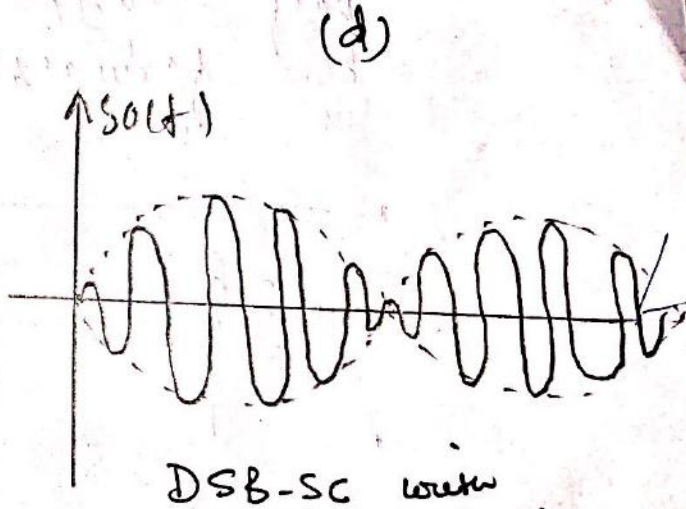


→ Redrawn more neatly on page 191

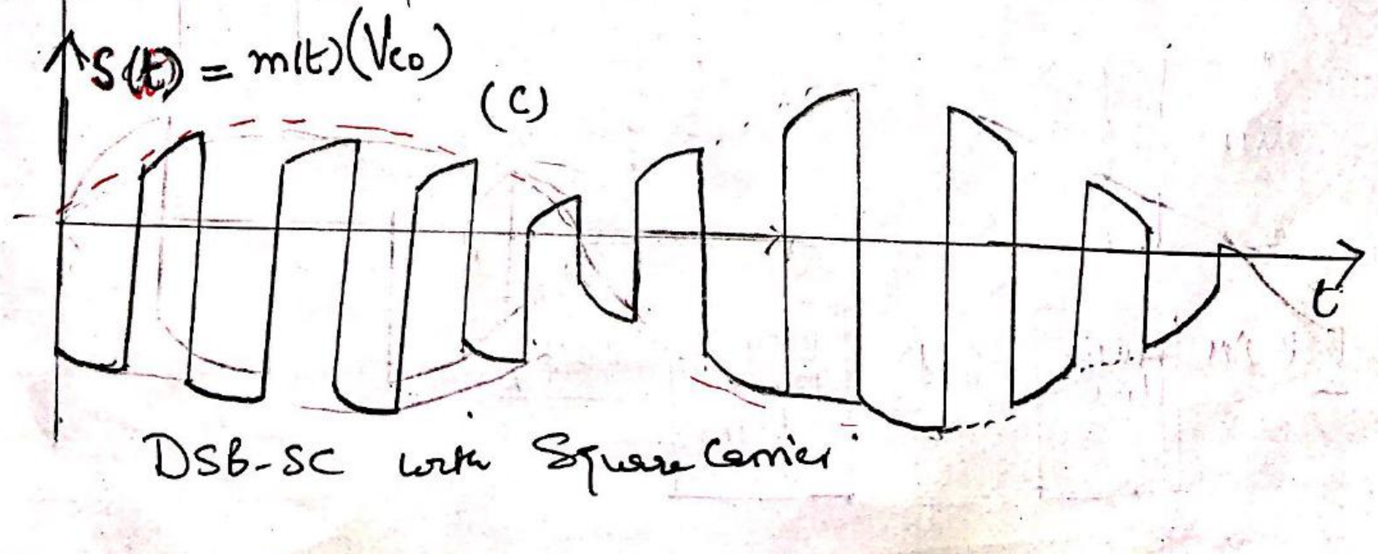
Figure 8 : Neat illustration showing circuit and its various waveforms.







DSB-SC with Sinusoidal Carrier after LPF.



DSB-SC with Square Carrier

Q. With the help of a neat block diagram, explain the working of an AM Broadcast Transmitter.

Refer: Electronic Comm. System by George Kennedy.

Ans:-

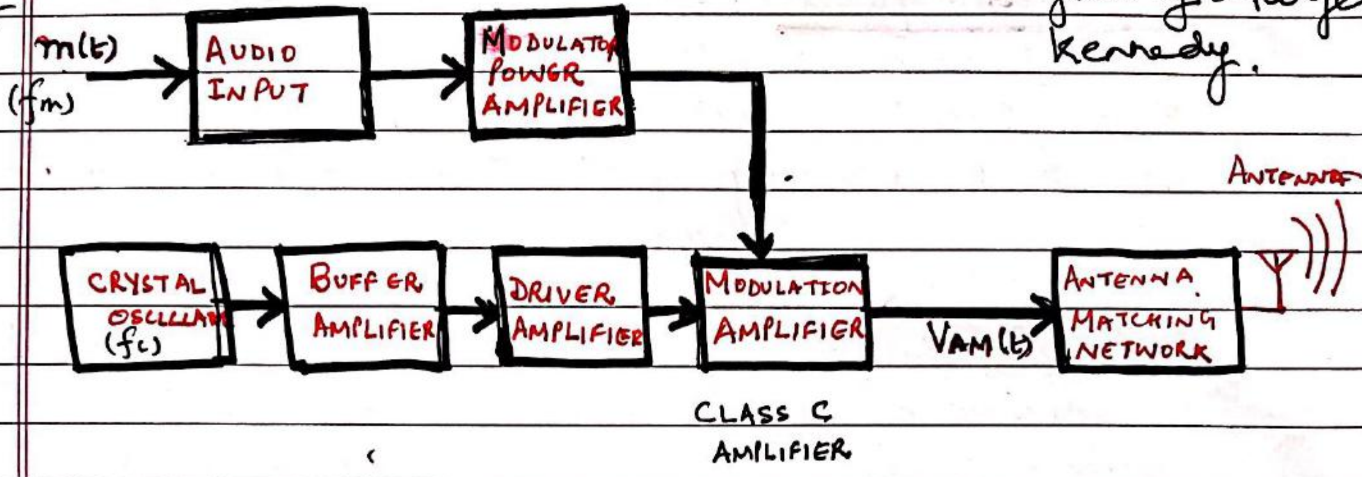


Figure: 8 Block diagram of a typical AM transmitter

Crystal Oscillator: The crystal oscillator is the source of carrier. The crystal oscillator is used to produce crystal controlled rf oscillations. The rf oscillations will serve as the carrier frequency f_c. Due to crystal, these oscillations are highly stable. If oscillations are not stable then the fluctuation in frequency or amplitude will cause unwanted distortion.

Buffer and Driver Amplifier: The crystal oscillator is followed by a tuned buffer amplifier and a tuned driver amplifier. Buffer is an isolating circuit between two circuits for impedance matching. The buffer usually has high input impedance and low output impedance. Example of buffer is Common Collector Emitter Follower. The driver is the circuit the provides the input for another circuit or controls the operation of that circuit.

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If required frequency multiplication is provided in one or more of these stages.

Modulation Amplifier : The modulation amplifier comprises mainly of a modulation circuit such as the mixer circuit as explained on page 184. If BJT is used then it is generally a class C power amplifier with collector modulated.

Audio Amplifier :- The audio signal is amplified by a chain of low level audio amplifiers and a power amplifier. Since this amplifier is controlling the power being delivered to final RF amplifier it must have sufficient power driving capability.

Impedance Matching Network : The output of final amplifier will be an AM signal. This signal is passed through an impedance matching network. This network includes the tank circuit of the final rf amplifier. The quality Q of this circuit must be low enough so that all the sidebands of signal are passed without amplitude and frequency distortion but at the same time must present an appropriate attenuation at the second harmonic of the carrier frequency. The required bandwidth is a standard 3db at ±5kHz around the carrier.

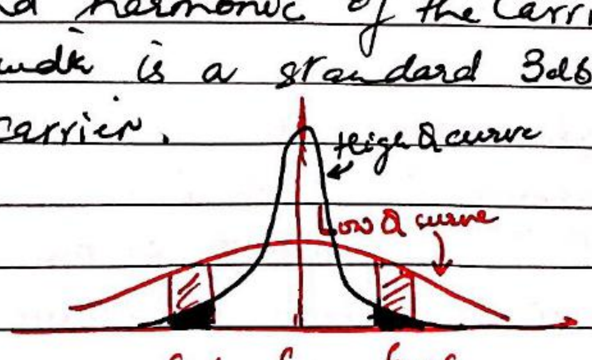

Figure shows high Q curve heavily attenuates USB & LSB around fc. Whereas low Q passes LSB & USB reasonably without attenuation

Q. What is High level and Low level modulation?

Ans. In an AM Tx, Amplitude Modulation can be generated at any point after the rf frequency carrier source. As a matter of fact even a crystal oscillator could be amplitude modulated except that this could be an unnecessary interference with its frequency stability. If a modulating baseband signal is applied at collector of the output ie the output stages of the Tx is collector modulated, the system is called high level modulation.

Lowlevel modulation is when modulation is applied at any other point including some other electrode of the output amplifier.

Sometimes modulation function is done in one of low level stages. This allows low power modulation and low level audio amplifier.