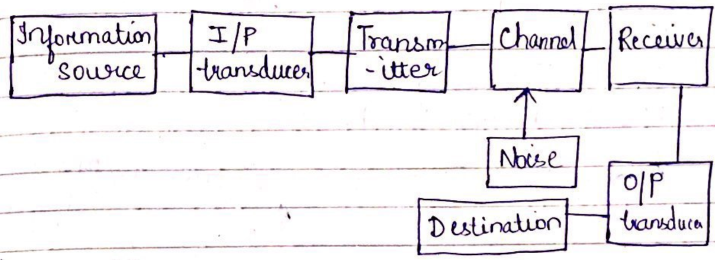
25/07/18

UNIT-1

Communication is simply the process of conveying the message at a distance or it is the process of transmission of information from a source to destination.

Eg:- Radar comm, mobile comm, TV broadcasting

Block diagram of communication process or system



Information source

Message or a information originates from a source in the form of words, group of words, codes, ~~[illegible]~~ sound signals, symbols.

I/P transducer :→

It is a device which converts the information or a data into a electrical signal.

Eg: Microphones.

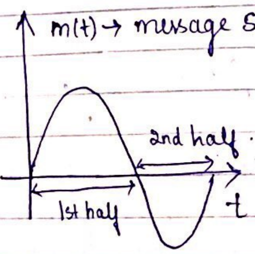
Transmitter →

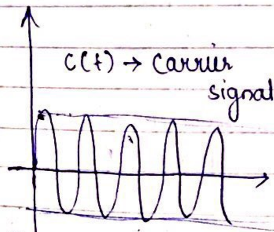
The main function of a transmitter is modulation.

In a long distance, radio comm, signal amplification is necessary before modulation. (Amplification means increase the power of a signal to make a signal stronger).

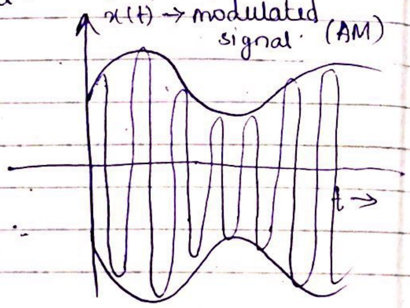
In modulation the message signal is superimposed on a high frequency carrier signal.

Types of modulation:–
~~The modulation~~ AM, FM, PM
AM → Amplitude mod.
FM → Frequency mod.
PM → Phase mod.



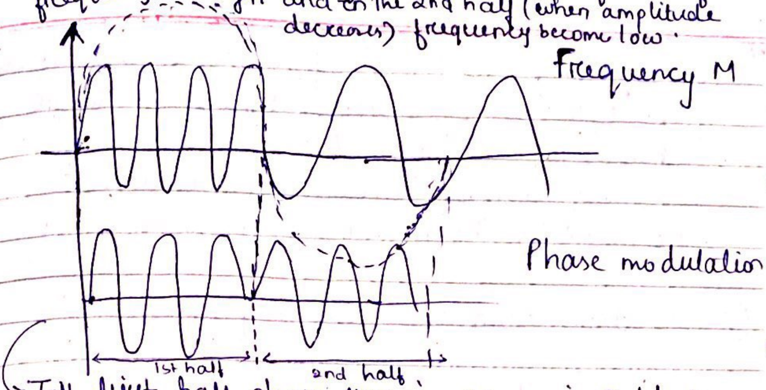


Here amplitude is same

(Superimposing m(t) & c(t))


Here we superimpose Msg S/N and carrier S/N to vary the amplitude. Here in b/w M/g S/N there is carrier S/N.

In FM we change the frequency. Till the first half frequency is high and in the 2nd half (when amplitude decreases) frequency become low.



→ Till first half phase remains same, in 2nd half phase changes.

Without a modulation long distance communication is not possible.

Why we need modulation?

① Reducing the antennae height.
(Antennae converts electrical signal to EM wave and resulting wave will travel with the velocity of light).

$$f = \frac{c}{\lambda} \; ; \; h = \frac{\lambda}{4} \; ; \; h = \frac{c}{4f}$$

h → height of antennae.

Modulation is the process of increasing the frequency of the signal to reduce the antennae height.

Scanned with CamScanner

② Multiplexing :- It is the process of transmission of multiple no:- of signals through a single channel at the same time.
In wired communication, modulation is required for the purpose of multiplexing.

③ It also avoid the mixing of the signal.

Channel and noise.

Channel is the physical connection or a medium through which signal propagates from one place to anothers.
There are 2 types of channel :-
① Point to point. ② Broadcast channel.
Eg:- Wirelines, wireless, microwave links, optical fibres.
* In wirelines we send guided EM waves.
* In microwave links we send EM waves in a free space.
* Optical fibres :- ~~Has~~ least distortion in this.

Noise - It is the unwanted signal which tends to interfere with the required signal and noise is random in nature. It enters in the required signal at any point in the communication system.

* Distortion happens internally while noise happens externally (by temp. pressure, etc).

Receiver :- The main function of a receiver is demodulation.

Demodulation is the process in which the original signal is generated from the received signal.

O/P transducer :-
It is used to reproduce the message signal from the electrical signal.
Eg:- speakers.

Source of information.

① Speech ② TV ③ facsimile ④ PC

Speech :- It is the primary method for a human communication. ~~in a com~~
In a communication system, transfer of info. from a speaker to a listener ~~can~~ which takes place in a 3 successive stages :-
① Production. ② Propagation.
③ Preception.

TV :- ~~In a TV~~ TV refers to transmission of pictures in motion by means of electrical signal. In this we communicate through satellite

Facsimile :- It transmits still pictures over a comm. channel. (Telephone lines). It is highly popular facility for the transmission of handwritten or a printed text from one point to another.

→ Image sensor is used to convert light to electrical signal.

PC :- These are used for the electronic Mails, exchange of S/W and sharing of resources.

→ Texts are encoded using ASCII code

→ ASCII → American standard code for Information Interchange.

ASCII code is the first code developed specifically for computer communication

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Representation of signals & systems.

Signal is a function of an independent variable that carry some information.

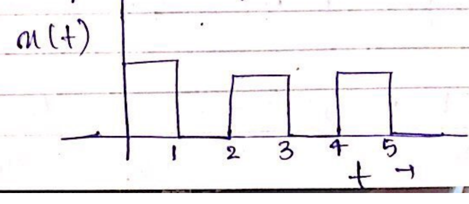
Eg: current characteristic, voltage characteristic, etc.

Types of signals :-

1. Periodic & Aperiodic.
2. Even & Odd signals.
3. Energy & Power signals.
4. Deterministic & random signals.
5. Causal ~~&~~, Non-causal & Anti-causal signals.

→ Periodic & Aperiodic signals :-

Periodic signals are the signals which are repeated after some time.



Condition (For periodic signal)

$x(t=T) = x(t)$

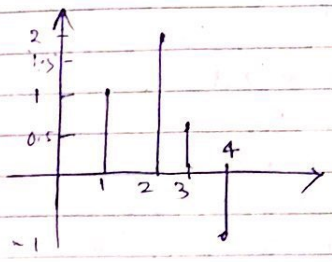
where $T = 2$ for this eg;

T = fundamental periodic

Fundamental period is a minimum time period after a minimum time in which signal repeats.

$x[n + Mn] = x[n]$ (discrete signals)

$x(t = T) = x(t)$ (continuous signal)



Step to check conditions

① When more than one signal are evolved in addition or subtraction

② Identify the period individually of signals.

eg; $\underset{T_1}{x_1(t)} + \underset{T_2}{x_2(t)} + \underset{T_3}{x_3(t)} + \underset{T_4}{x_4(t)}$

③ Calculate T_1/T_2, T_1/T_3, T_1/T_4

④ If the ratio of the step ③ is rational number then signal is periodic

⑤ Calculate the LCM of denominator of step ③ and denoted as x.

⑥ $T = x \cdot T_1$ (Fundamental period $= xT_1$)

Q. $x(t) = \sin\left(\frac{2\pi t}{3}\right)\cos\left(\frac{4\pi t}{5}\right)$

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

$= \frac{1}{2}\left[\sin\left(\frac{22\pi}{15}\right)t + \sin\left(\frac{2\pi}{15}\right)t\right]$

$= T_1 = \frac{2\pi}{\frac{22\pi}{15}}$. $T_2 = \frac{2\pi}{2\pi/15}$

$T_1 = \frac{15}{11}$ $T_2 = 15$.

$\frac{T_1}{T_2} = \frac{1}{11}$

L.C.M of 11 = 11

$x = 11$

Fundamental period $= x T_1$

$= 11 \cdot \frac{15}{11} = 15$ → Ans

So this is a periodic signal.

→ Even and odd signal.

Even signal $= x(-t) = x(t)$

Odd signal $= x(-t) = -x(t)$

$$x_e(t) = \frac{x(t) + x(-t)}{2}$$

$$x_o(t) = \frac{x(t) - x(-t)}{2}.$$

For continuous

$x[-n] = x[n]$

$x[-n] = -x[n]$

for discrete.

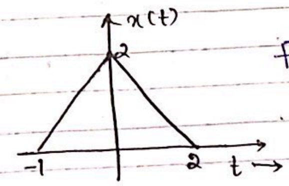
When given a function we do the following in order.

① Shifting
② Scaling.
③ Reversal.

Eg:- $x(-3t+5)$

① $x(t+5)$
② $x(+3t+5)$
③ $x(-3t+5)$

Q



Find even & odd signals.

→ Energy and Power signals.

$$\text{Energy} = \lim_{T\to\infty} \int_{-T}^{T} |x(t)|^2 dt.$$

$$\text{Power} = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 dt.$$

Energy signal: $E \to$ finite, $P = 0$.

Power signal: $P =$ finite, $E = \infty$.

} Conditions

Q $x(t) = e^{-at} u(t)$

Unit impulse — **Unit step function**

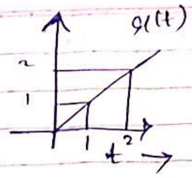
$$\delta(t) = \begin{cases} 1 & ; t = 0 \\ 0 & ; t \neq 0 \end{cases}$$

$$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

Unit ramp f^n:

$$r(t) = \begin{cases} At & t \geq 0 \\ 0 & t < 0 \end{cases}$$

if $A = 1$ then unit ramp f^n, else ramp f^n.



$x(t) = e^{-at} u(t)$.

$$\text{Power} = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} \left| e^{-at} u(t) \right|^2 dt$$

$$= \lim_{T \to \infty} \frac{1}{2T} \times \left[\int_0^{\infty} e^{-2at} \, dt \right]$$

$$= \frac{1}{2 \times \infty} \times \frac{1}{2a}$$

$$= 0 \times \frac{1}{2a}$$

$$= 0.$$

$$\text{Energy} = \lim_{T\to\infty} \int_{-T}^{T} \left| e^{-at} u(t) \right|^2 dt .$$

$$= \int_0^{\infty} e^{-2at} dt .$$

$$= \left| \frac{e^{-2at}}{-2a} \right|_0^{\infty}$$

$$= 0 + \frac{1}{2a} = \frac{1}{2a} .$$

$$\text{Power} = \lim_{T\to\infty} \frac{1}{2T} \left[\frac{1}{2a} \right]$$

$$= \frac{1}{2a} \times 0 = 0 .$$

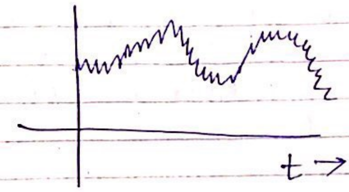
$E \to$ finite
$P \to 0$ } So this is energy signal.

→ Deterministic and Random signal.

Deterministic signal → A signal whose O/P can be determined or predicted at a given instant of time.
eg :- sin(t) ; cosine(t)

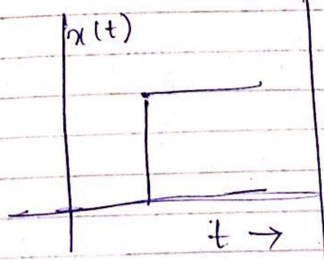
Random signal → It is a non-deterministic signal i.e, O/P can't be predicted at a given point of time.

Eg :- noise.

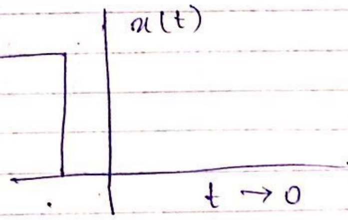


Random signal.

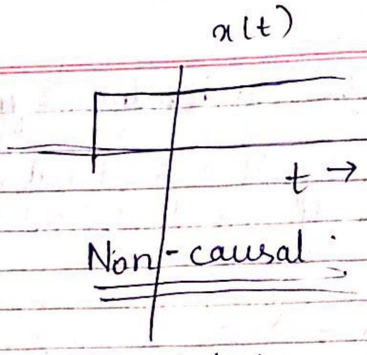
→ Causal, Anti-causal and non-causal.



Causal



anti-causal.



Non-causal :

→ A signal is said to be causal if it exists for +ve value of time domain (t).

→ A signal is said to be anti-causal if it exists for −ve value of t.

→ A signal is said to be non-causal if it exist for both +ve and −ve value of t.

Systems :

A system is any process that produces an O/P in response to an input signal.

Types of system :-

1. Linear and non-linear.
2. Static and dynamic.
3. Causal and non-causal or anticausal.
4. time variant and time invariant.

① **Linear** –

$$x_1(t) \longrightarrow \boxed{h(t)} \longrightarrow y_1(t)$$

$$x_2(t) \longrightarrow \boxed{h(t)} \longrightarrow y_2(t)$$

$y_3(t) = y_1(t) + y_2(t)$. (Separately we will give & find).

Now when we give input $x_1(t) + x_2(t)$ then we get an O/P $y_4(t)$.

If $y_4(t) = y_3(t)$ then our system is linear.

e.g.: $y(t) = e^{x(t)}$

$y_1(t) = e^{x_1(t)}$

$y_2(t) = e^{x_2(t)}$

$y_3(t) = y_1(t) + y_2(t) = e^{x_1(t)} + e^{x_2(t)}$

$y_4(t) = e^{x_1(t) + x_2(t)}$

$= e^{x_1(t)} \cdot e^{x_2(t)}$

$y_4(t) \neq y_3(t)$ [non-linear].

Time variant and time invariant system

→ If its I/P O/P characteristics doesnot change with time then system is called time invariant.

Replace $t \to t - t_0$.
Replace $y(t) \to y(t - t_0)$
then replace $x(t) \to x(t - t_0)$.

eg. $y(t) = t\,x(t)$ (Continuous eg).

$y(t-t_0) = y_1(t) = (t - t_0)\,x(t - t_0)$ ①

② $y_2(t) = t\,x(t - t_0)$.

$y_1(t) \neq y_2(t)$

then it is time variant.

eg:- $y[n] = x[n] - x[n-1]$

$y_1[n] = x[n - n_0] - x[(n - n_0) - 1]$

$y_2[n] = x[n - n_0] - x[(n - n_0) - 1]$

$y_1[n] = y_2[n]$ (time invariant).

Causal and non-causal or anti-causal

same

→ In a causal system, O/P depends upon present or past input, ~~value~~ output values and doesn't depend upon future values.

eg; $y(t) = x(t+1)$

$y(0) = x(1)$

At time = 0 value depends on $t = 1$
so this is a non-causal system.

Static & Dynamic system

↓ (memory less) ↓ (memory required)

→ All the static system are causal systems and vice-versa is not true.

→ Static system → only on present value not on past or future.
(depends written above "only")

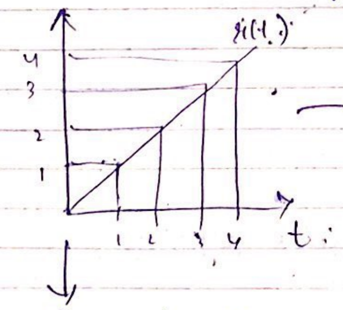
→ dynamic system → can depends on past, present or future.

Stable and Unstable system:

Condition 1 – Check bounded input or ~~[illegible]~~ bounded O/P.
i.e, input & O/P should be finite then the system is stable.

Condition 2:

$$\int_{-\infty}^{\infty} |h(t)|\, dt < \infty \quad (\text{finite values})$$



→ as there is no output bound so this is an unstable system.

Ramp function.

Communication channel.

→ The transmission of info. across a communication n/w is accomplished in a physical layer by means of communication channel.

→ Two basic groups of communication channel are based on :- guided propagation and free propagation.

guided → eg, telephone channels, optical fibres, coaxial cables.

free :- eg; mobile radio channels, broadcast channels, satellite channels.

Telephone channels:

Telephone channels uses circuit switching to establish an end to end communication link on a temporary basis.
The primary purpose of the n/w to ensure that telephone transmission b/w a speaker at the one end of the link & listener at the other end is an acceptable substitute for face to face conversation.

The telephone channel is bandwidth limited channel.

→ Voice signal – 300Hz to 3.5KHz
Audio " – 20Hz to 20 KHz
Video " – 0Hz to 4.5 MHz.

Coaxial cables.
It consist of an inner conductor and outer conductor separated by a dielectric insulating material. The inner conductor is made up of copper wires and outer conductor is made up of copper or copper coated steel.
Coaxial cable can operate as a multiple access medium.

Optical fibre.

Optical fibre is a dielectric wave guide that transports light signal from one place to another place.
It consist of a central core within which propagating EM field and which is surrounded by a cladding layer which is itself surrounded by a thin protective jacket.
The core & cladding are both made up of pure silica glass whereas the protective jacket is made up of plastic.

→ Optical fibre offers a following unique characteristics:
- Low transmission losses.
- Immunity to EMI (EM Interference)
- Small size & weight.
- Flexibility

Wireless broadcast channel.

It supports the transmission of radio & TV signals.
Transmission originates from an antennae that act as the transition unit between the source of modulated signal & EM waves in a free space.
At the receiver end an antennae is used to pick up the radiated waves and then recovering the original info. with the help of detector.

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Mobile radio channels.

Mobile Radio channels extends the capability of public telecommunication network. There is no line of sight for the communication rather Radio propagation takes place mainly by the way of scattering from the surface of surrounding and by the diffraction over and around them. The end result is that energy reaches the receiving antennae via more than one path.

Satellite channel.

Satellite channel provides broad area coverage. Satellite communication offers the following unique system capabilities.

1. Broad area coverage.
2. Reliable transmission links.
~~3. Transmission links.~~
3. Wide transmission bandwidth.

Base band and band pass signals.

Base band signal:
The message signal generated from the information source is known as base band signal. This base band signal may be the combination of two or more message signals.
If the base band signal is transmitted directly then it is known as base band transmission.
Base band transmission can be of 2 types ① Analog ② Digital transmission

The base band transmission doesn't use modulators and demodulators.
This transmission is preferred at low frequency and for short distance.

Band pass signals:
If the modulated signal is transmitted over the channel, it is known as band pass transmission.
The modulated signal has fixed band of frequencies around carrier frequency.
Band pass transmission is generally used at high frequencies & for long

distance.

Amplitude modulation.

Amplitude modulation is defined as the process in which amplitude of carrier wave is varied about a mean value, linearly with the base band signal.

$C(t)$ = carrier signal

$= A_c \cos 2\pi f_c t$

$m(t)$ = message signal (base band signal)

$= A_m \cos 2\pi f_m t$.

where, $f_c \rightarrow$ carrier frequency

$f_m \rightarrow$ message frequency

$A_c \rightarrow$ Carrier signal amplitude.

$$S_{AM}(t) = A_c \left[1 + K_a m(t)\right] \cos 2\pi f_c t$$

$S_{AM}(t)$ ↳ amplitude modulated signal

K_a ↳ Amplitude sensitivity

* study trigonometry.

$$X(f) / X(\omega) / X(j\omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\omega t}\, dt.$$ fourier transform.

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\omega)\, e^{j\omega t}\, d\omega.$$

$$\boxed{\begin{aligned} \omega &= 2\pi f \\ d\omega &= 2\pi df. \end{aligned}}$$

$$x(t) = \int_{-\infty}^{\infty} X(f)\, e^{j2\pi f t}\, df.$$

Properties of fourier transform.

$x(t) \longleftrightarrow X(\omega)$

$x(t)\, e^{j\omega_c t} \longleftrightarrow X(\omega - \omega_c)$

$x(t)\, e^{-j\omega_c t} \longleftrightarrow X(\omega + \omega_c)$.

$1 \longleftrightarrow 2\pi\, \delta(\omega)$

↳ unit impulse function

$1 \cdot e^{j\omega_c t} \longleftrightarrow 2\pi\, \delta(\omega - \omega_c)$

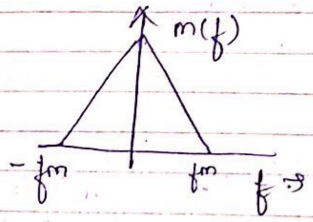
$e^{j2\pi f_c t}\, x(t) \longleftrightarrow X(f - f_c)$

$$S_{AM}(t) = A_c \cos 2\pi f_c t + K_a m(t) \cos 2\pi f_c t$$

$$= \frac{A_c}{2}\left(e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right) + \frac{K_a m(t)}{2}\left(e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right)$$

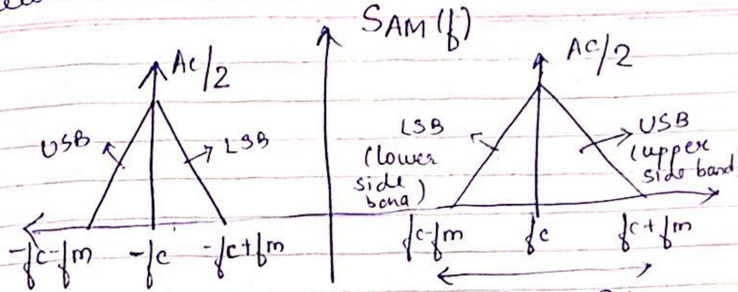
$$S_{AM}(f) = \frac{A_c}{2}\left\{2\pi\delta(f-f_c) + 2\pi\delta(f+f_c)\right\} + \frac{K_a}{2}\left[M(f-f_c) + M(f+f_c)\right]$$

Suppose we have,



Frequency spectrum of amplitude modulated signal!-

i.e. we convert our time domain in frequency domain because we cannot calculate noise in time domain, neither we can reduce the noise in time domain.



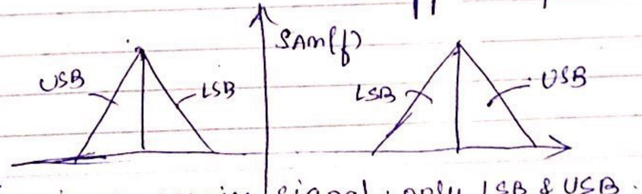
$B_W = 2f_m$.

Bandwidth (BW) $= 2f_m$

To decrease the power wasteage

1. First we have done amplitude modulation.
2. As our carrier signal is of no use, as we have to send message signal. so we will supress ~~Acp~~ carrier signal i.e, we will remove $A_c/2$.

It is called Double side band - Suppressed carrier

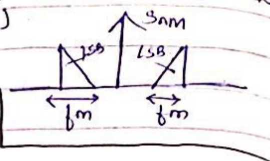


There is no carrier signal; only LSB & USB.

so total bandwidth now is still $2f_m$.

③ To reduce more power, then we will send only one side band (suppose LSB). Then the signal is known as SSB-SC (single side band suppressed carrier & then we will take the mirror image after receiving)

Now bandwidth $= f_m$.



$m(t)$ is of 2 types :- (message signal)

① Single tone.

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

(Only 1 message signal)

② Multiple tone.

$$m(t) = A_{m_1} \cos 2\pi f_{m_1} t + \cos 2\pi f_{m_2} t$$

(2 or more message signal together).

Power relation of amplitude modulation.

(For single tone)

$$S_{AM}(t) = A_c[1 + K_a m(t)] \cos 2\pi f_c t$$

$$= A_c \cos 2\pi f_c t + A_c \underbrace{K_a m(t)}_{\mu = \text{modulation index}} \cos 2\pi f_m t \cos 2\pi f_c t.$$

$K_a m(t) = \mu$ = modulation index.

★ Power of carrier signal :

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

$$= \frac{A_c^2}{2R} = \frac{A_c^2}{2} \quad (R = 1).$$

Power of carrier signal $= \boxed{\frac{A_c^2}{2}}$

$$S_{AM}(t) = A_c \cos 2\pi f_c t + \frac{A_c \mu}{2}\left[\cos 2\pi [f_c + f_m] t + \cos 2\pi (f_c - f_m) t\right]$$

$$\Downarrow$$

$$\underbrace{\frac{A_c^2}{2}}_{\text{Power of carrier signal}} + \underbrace{\frac{\left(\frac{A_c \mu}{2}\right)^2}{2}}_{\text{Power of LSB}} + \underbrace{\frac{\left(\frac{A_c \mu}{2}\right)^2}{2}}_{\text{Power of USB}}$$

$$= \frac{A_c^2}{2}\left[1 + \frac{\mu^2}{4} + \frac{\mu^2}{4}\right]$$

$$\boxed{= \frac{A_c^2}{2}\left[1 + \frac{\mu^2}{2}\right]}$$

Power of the amplitude modulated signal.

Total power of side bands

$$= \frac{(A_c \mu)^2}{8} + \frac{(A_c \mu)^2}{8}$$

$$\boxed{= \frac{A_c^2 \mu^2}{4}}$$

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Double tone

$$m(t) = A_{m_1} \cos 2\pi f_{m_1} t + A_{m_2} \cos 2\pi f_{m_2} t$$

$$\text{Power} = P_c\left(1 + \frac{\mu_T^2}{2}\right)$$

$$\Rightarrow \mu_T^2 = \mu_1^2 + \mu_2^2.$$

Bandwidth = 2 (Highest frequency)

If $f_{m_1} > f_{m_2}$

$BW = 2f_{m_1}$

else

$BW = 2f_{m_2}$

Transmission efficiency.

$$\eta = \frac{\text{Total sideband power}}{\text{Total power}}$$

$$= \frac{\frac{A_c^2 \mu^2}{4}}{\frac{A_c^2}{2} + \frac{A_c^2 \mu^2}{4}} \quad \text{(OR)} \quad \frac{P_c \frac{\mu^2}{2}}{P_c\left[1 + \frac{\mu^2}{2}\right]}$$

$$= \frac{\frac{\cancel{A_c^2}}{\cancel{2}}\left(\frac{\mu^2}{2}\right)}{\frac{\cancel{A_c^2}}{\cancel{2}}\left[1 + \frac{\mu^2}{2}\right]} = \boxed{\frac{\mu^2}{2 + \mu^2} \times 100\%}$$

↳ For single tone.

→ For double tone or multiple tone..

$$\boxed{\eta = \frac{\mu_T^2}{\mu_T^2 + 2} \times 100\%.}$$

Case 1 $- \mu = 0$.

$\eta = 0\%$.

Case 2 $\mu = \frac{1}{\sqrt{2}}$

$$\frac{\frac{1}{2}}{\frac{1}{2}+2} \times 100\%$$

$$= \frac{1}{5} \times 100\% = 20\%$$

Case 3 ⇒ $\mu = 1$

$$\frac{1}{3} \times 100\% = 33.33\%$$

$$\boxed{\approx 33\%}$$

→ generally we take $\mu = 1$ for comparison.

Current Relationship.

$$P = VI$$
$$= (IR)I$$
$$= I^2 R \quad \text{—— (1)}$$

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

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

$$\Rightarrow \boxed{I_t^2 = I_c^2\left(1 + \frac{\mu^2}{2}\right)}$$

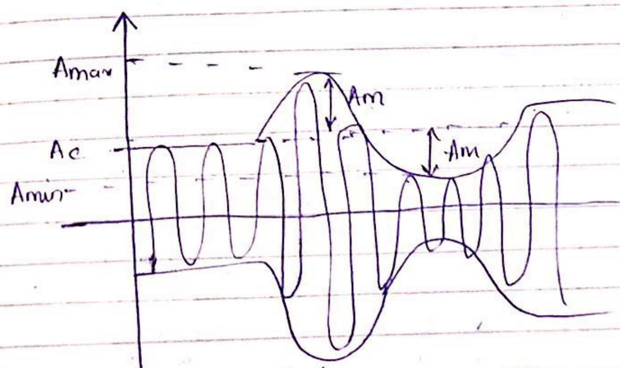
Voltage Relationship in Amplitude modulation (AM)

$$P = \frac{V^2}{R}$$

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

$$\Rightarrow \boxed{V_t^2 = V_c^2\left(1 + \frac{\mu^2}{2}\right)}$$

Time Domain Representation of AM.



$$A_{max} = A_c + A_m \longrightarrow (1)$$

$A_{min} = A_c - A_m \longrightarrow (2)$

$\mu = K_a A_m = \frac{A_m}{A_c} \longrightarrow (3)$

$A_{max} = A_c\left(1 + \frac{A_m}{A_c}\right) = A_c(1+\mu)$.

$A_{min} = A_c\left(1 - \frac{A_m}{A_c}\right) = A_c(1-\mu)$.

From eq. (1) and (2)

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

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

Put in eq (3)

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

* Possible ques → If time domain of AM is given then find A_{min}, A_{max}, μ, etc.
Remember A_{min} will be the one above because down is the mirror image.

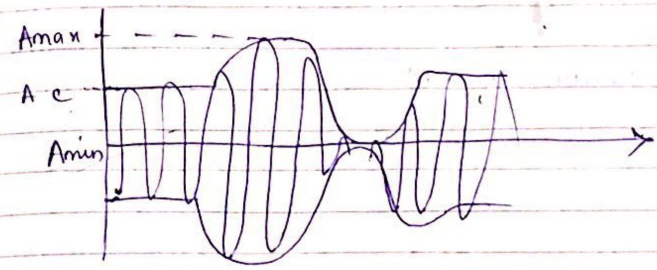
(I) $\mu < 1$ (Under modulation)

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

$\Rightarrow A_m < A_c$. so $A_c - A_m$ will be positive. A_m will be +ve (i.e, above x-axis)

Time domain Same as previous.

(II) $\mu = 1$ (Critical modulation).



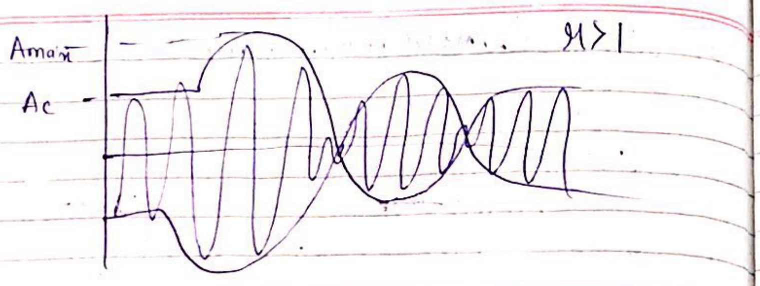
$A_m = A_c$.

So $A_{min} = 0$; i.e, its touching x-axis.

(III) $\mu > 1$ (Over modulation)

$A_m > A_c$.

$A_c - A_3 < 0$ (so it will go below x-axis)



* We can recover message signal from μ<1 and μ=1 but maximum recovery is done in μ<1 case. So we generally prefer μ<1 for AM.

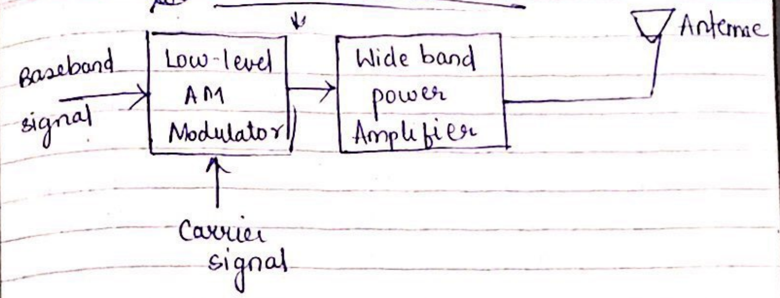
Generation of AM.

Depending upon power level of carrier at which modulation takes place, there are 2 methods of AM generation:-

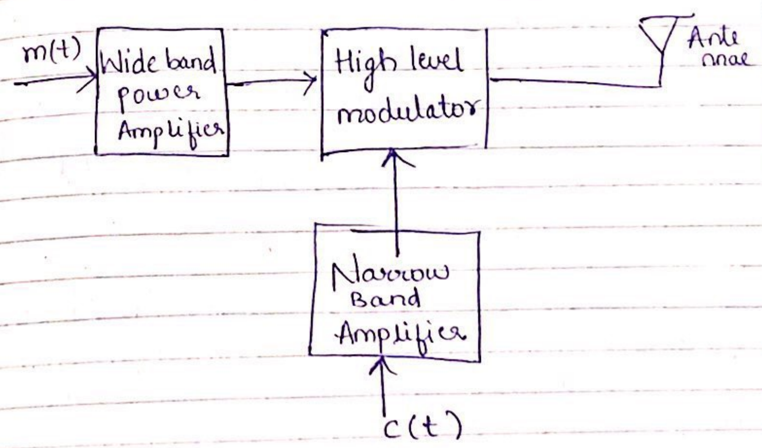
1. low level modulation.
2. high level modulation.

* In low level modulation, we will pass carrier & msg signal through modulator and then amplify them, but in HLM we will do vice-versa.

low level modulation.



High level modulation.



Low-level modulation.

In a low level modulation system, the modulation is done at low power level. At a low power levels a very small

★ after modulation modulating signal is known as modulated signal.

power is associated with carrier signal and message signal.
Because of this, O/P power of modulation is low.
The power amplifiers are required to boost the amplitude modulated signals upto the desired output level.

High level modulation

In a high level amplitude modulation system, the modulation is done at high power level.
The modulating signal and carrier signal are first power amplified and then applied to AM high level modulator.

For a modulating signal ~~the~~ wide band power amplifier is required just to preserve all the frequency component present in modulating signal.

For a carrier signal, the narrow band power amplifier is required because it is a fixed frequency signal.

Liner devices → Having linear VI characteristics
eg- Resistor, etc.

Non-linear devices → Having non-linear VI characteristic
eg:- Diode, FET, transistors, etc.

Square-law Diode modulation

★ Linear relation.

$V = iR$

$i = \frac{1}{R} \times V$

$\text{Or } i = G\,v \quad (\text{or}) \quad i = bv$

$\boxed{\text{Or } i = a + bv}$ where a and b are constants.

★ Non-linear relation:

$$\boxed{i = a + bv + cv^2 + dv^3 \cdots}$$

where a, b, c, d ·· are constants.

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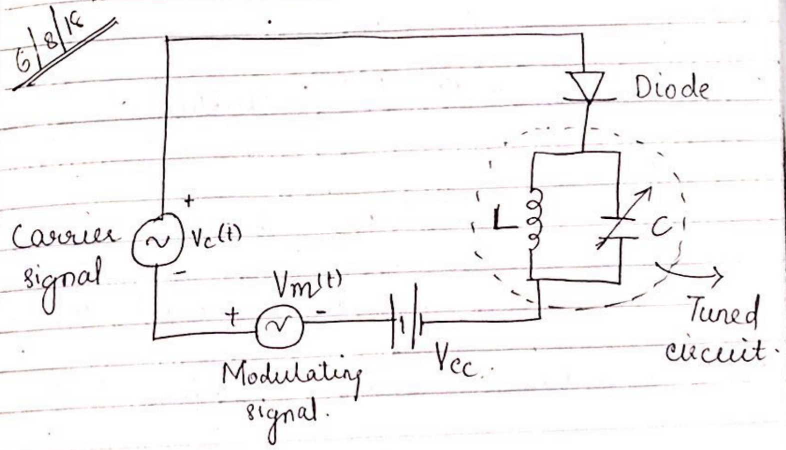


$V_s = V_c + V_m$ (total voltage across the diode).

$= A_c \cos \omega_c t + A_m \cos 2\pi f_m t$

$i = a + bV_s + cV_s^2$

$i = a + b(V_c + V_m) + c(V_c + V_m)^2$

$= a + bV_c + bV_m + cV_c^2 + cV_m^2 + 2cV_cV_m$

$= a + bV_c + bV_m + c(A_c^2 \cos^2 \omega_c t + A_m^2 \cos^2 \omega_m t$

$+ 2A_cA_m \cos \omega_c t \cos \omega_m t)$

$\cos^2\theta = \frac{1+\cos 2\theta}{2}$

$= a + b(V_c + V_m) + c\left(A_c^2\left(\frac{1+\cos 2\omega_c t}{2}\right) + A_m^2\left(\frac{1+\cos 2\omega_m t}{2}\right) + 2A_cA_m \cos \omega_c t \cos \omega_m t\right)$

$= a + b(V_c + V_m) + c\left(A_c^2\left(\frac{1+\cos 2\omega_c t}{2}\right) + A_m^2\left(\frac{1+\cos 2\omega_m t}{2}\right) + \right.$

$2A_cA_m[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$

carrier term, modulating term, DC value

$= \underbrace{bV_c}_{\text{carrier term}} + \underbrace{bV_m}_{\text{modulating term}} + \underbrace{a + c\left(\frac{A_c^2}{2} + \frac{A_m^2}{2}\right)}_{\text{DC value}} +$

$\left(\frac{cA_c^2 \cos 2\omega_c t}{2} + \frac{cA_m^2 \cos 2\omega_m t}{2}\right)$ → harmonics of carrier & modulating signal

$+ (2A_cA_m[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t])$

upper side band & low side band

After passing through tuned circuit, which is tuned to ω_c, the terms whichever be left are:-

$= bA_c \cos \omega_c t + \frac{cA_c^2 \cos 2\omega_c t}{2} +$

$2A_cA_m[\cos(\omega_c + \omega_m)t + \cos(\omega_c - \omega_m)t]$

Detection of AM wave:-

The recovery of baseband signal from the modulated signal is known as demodulation or detection of wave.

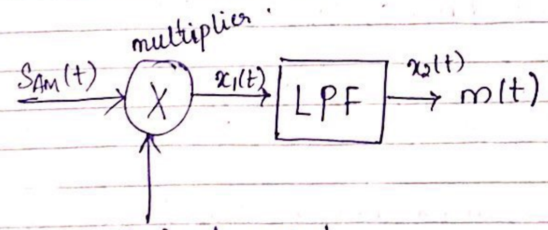
there are 3 methods:-

(1) Coherent detector.

② Square law detector.
③ Envelope detector.

① Coherent detection.

Case 1 – Perfect synchronisation.
Case 2 – Imperfect synchronisation.



$C(t) = A_c \cos\omega_c t$.
(Perfect).

Imperfect $c(t) = A_c \cos(\omega_c t + \phi)$.

Case 1 $x_1(t) = s_{AM}(t)\, c(t)$
$= \{A_c[1 + K_a m(t)]\cos 2\pi f_c t\}\, A_c \cos 2\pi f_c t$
$= A_c^2\cos^2 2\pi f_c t + A_c^2 K_a \cos^2 2\pi f_c t\, m(t)$

$x_1(t) = A_c^2\left[\frac{1+\cos 4\pi f_c t}{2}\right] + A_c^2 K_a m(t)\left[\frac{1+\cos 4\pi f_c t}{2}\right]$

$x_1(t) = \frac{A_c^2}{2} + \frac{A_c^2 \cos 4\pi f_c t}{2} + \frac{A_c^2}{2} K_a m(t)$
$+ \frac{A_c^2}{2} K_a m(t) \cos 4\pi f_c t$

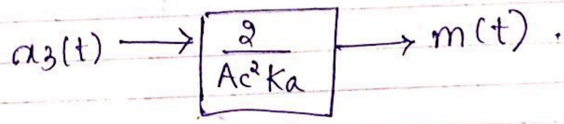
After passing through low pass filter.
(only const. and message signal will be left)

$x_2(t) = \frac{A_c^2}{2} + \frac{A_c^2 K_a m(t)}{2}$.

Pass this signal through capacitor.
(to remove the constant signal or DC value).

$x_3(t) = \frac{A_c^2 K_a m(t)}{2}$.

We will pass $x_3(t)$ through amplifier (so that only message signal is left).



Amplifier

After passing through amplifier we got $x_4(t)$

$$x_4(t) = x_3(t) \times \frac{2}{A_c^2 K_a}$$ (amplifier gain)

$$= \frac{\cancel{A_c^2 K_a}}{\cancel{2}}\, m(t) \times \frac{\cancel{2}}{\cancel{A_c^2 K_a}}$$

$$\boxed{= m(t)}$$

Finally we got the message signal.

Case 2 Imperfect synchronization

$$x_1(t) = S_{AM}(t)\, c(t)$$

$$= A_c\left[1 + K_a m(t)\right]\cos(2\pi f_c t)\, A_c \cos(2\pi f_c t + \phi)$$

$$= A_c^2 \cos 2\pi f_c t \cos(2\pi f_c t + \phi) + A_c^2 \cos 2\pi f_c t\, K_a m(t) \cos(2\pi f_c t + \phi)$$

$$= A_c^2\left[\frac{\cos(4\pi f_c t + \phi) + \cos\phi}{2}\right] + ''$$

$$= \frac{A_c^2 \cos\phi}{2} + \frac{A_c^2}{2}\cos(4\pi f_c t + \phi) + \frac{A_c^2}{2} K_a m(t) \cos\phi + \frac{A_c^2}{2} K_a m(t) \cos(4\pi f_c t + \phi)$$

After passing through low pass filter.

$$x_2(t) = \frac{A_c^2 \cos\phi}{2} + \frac{A_c^2}{2} K_a m(t) \cos\phi$$

After passing through capacitor.

$$x_3(t) = \frac{A_c^2}{2} K_a m(t) \cos\phi$$

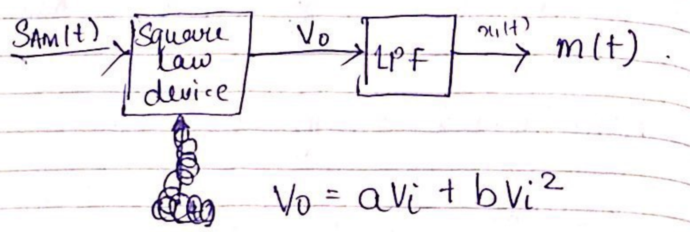
After passing through amplifier with gain $\frac{2}{A_c^2 K_a \cos\phi}$.

$$x_4(t) = \frac{\cancel{A_c^2}}{\cancel{2}} \cancel{K_a}\, m(t) \cancel{\cos\phi} \times \frac{\cancel{2}}{\cancel{A_c^2 K_a \cos\phi}}$$

$$\boxed{= m(t)}$$

Finally we got our message signal.

→ Square-law demodulation



$$V_0 = aV_i + bV_i^2$$

$$V_0 = a\left(A_c[1 + K_a m(t)]\cos 2\pi f_c t\right) + b\left(A_c[1 + K_a m(t)]\cos 2\pi f_c t\right)^2$$

$$= aA_c \cos 2\pi f_c t + aA_c K_a m(t)\cos 2\pi f_c t + bA_c^2 \cos^2 2\pi f_c t\left[1 + K_a^2 m^2(t) + 2K_a m(t)\right]$$

$$= aA_c \cos 2\pi f_c t + aA_c K_a m(t)\cos 2\pi f_c t + bA_c^2 \cos^2 2\pi f_c t + bA_c^2 \cos^2 2\pi f_c t\, K_a^2 m^2(t) + 2A_c^2 b K_a m(t)\cos^2 2\pi f_c t$$

$$= aA_c \cos 2\pi f_c t + aA_c K_a m(t)\cos 2\pi f_c t + bA_c^2\left[\frac{1 + \cos 4\pi f_c t}{2}\right] + bA_c^2 K_a^2 m^2(t)\left[\frac{1 + \cos 4\pi f_c t}{2}\right] + 2A_c^2 b K_a m(t)\left[\frac{1 + \cos 4\pi f_c t}{2}\right]$$

$$V_0 = aA_c \cos 2\pi f_c t + aA_c K_a m(t)\cos 2\pi f_c t + \frac{bA_c^2}{2} + \frac{bA_c^2}{2}\cos 4\pi f_c t + \frac{bA_c^2 K_a^2 m^2(t)}{2} + \frac{bA_c^2 K_a^2 m^2(t)}{2}\cos 4\pi f_c t + bA_c^2 K_a m(t) + A_c^2 b K_a m(t)\cos 4\pi f_c t$$

After passing through low pass filter we got:

$$x_1(t) = \frac{bA_c^2}{2} + \frac{bA_c^2 K_a^2}{2} m^2(t) + bA_c^2 K_a m(t)$$

Now after passing through capacitor:

$$x_2(t) = \frac{bA_c^2 K_a^2 m^2(t)}{2} + bA_c^2 K_a m(t).$$

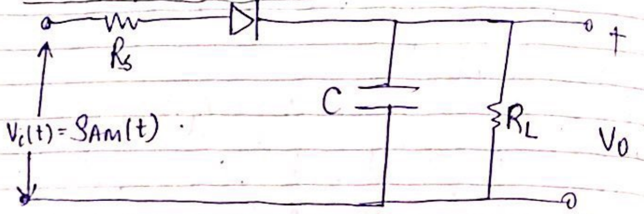
Now after passing through any tuned circuit tuned to $m(t)$, we got:

$$x_3(t) = bA_c^2 K_a m(t).$$

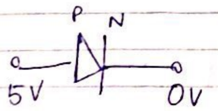
After passing through amplifier with gain $\frac{1}{bA_c^2 K_a}$; $x_4(t) = \frac{1}{bA_c^2 K_a} \times x_3(t) = m(t)$

we got $\boxed{m(t)}$ our original msg signal.

→ Envelope Detector



→ Ideal diode $V_0 = 0$.



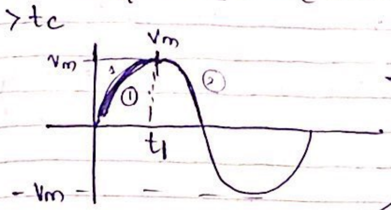
(forward - biased)

If $V_0 = 0$ then we will short-circuit the diode

In reverse bias, we will change in open circuit.

But if we have some V_0, then in forward bias case we will replace it with V_0 = some value.

R_s min ← $t_c = R_S C$ · (Charging time of diode)
R_L max ← $t_d = R_L C$ (Discharging " " ")
$t_d > t_c$

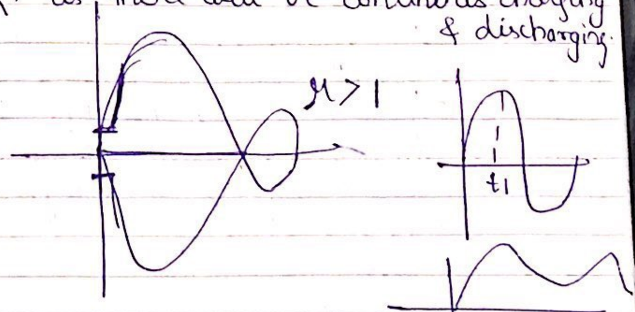


For +ve cycle only

→ In phase ① capacitor will charge and will be charged to V_m and will be forward bias.

→ In phase ②; it will discharge and will be reverse biased as charged will be pumped out.

→ For $\mu > 1$, envelope dector won't work, as there will be continous charging & discharging.



→ The positive envelope of applied signal is extracted and produced at the output.

→ For $\mu < 1$, the +ve envelope of AM signal will be message signal.

→ Envelope detector will fail for $\mu > 1$ because message signal will not be stored at positive envelope.

Case 1 :- At $t = 0$; positive diode will be forward biased and charging of capacitor $\tau_c = R_s C$. The value of R_s is small so that capacitor can quickly charge to the input voltage.

Case 2 :- At $t = t1$; diode is open circuit and discharging of capacitor with $t_d = R_L C$, the value of R_L should be high so that capacitor discharge very slowly.

Advantages & Disadvantages of Amplitude modulation

Ad.

① It is used for long distance communication.

② Demodulation is easier.

Disad

① Transmission power is wasting. Efficiency = 33%.

② Bandwidth is highest = $2f_m$.

③ It is highly affected by noise.

Double side band suppressed carrier

→ Carrier is supressed in double side band suppressed carrier because carrier doesn't affect the baseband signal.

→ The resulting signal obtained by the suppression of carrier from the modulated wave is called double side band suppressed carrier.

$$\boxed{s_{DSB-SC}(t) = c(t)\,m(t)}$$

$$= A_c \cos 2\pi f_c t \cdot A_m \cos 2\pi f_m t$$

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

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

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

$$= A_c\, m(t)\left[\frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2}\right]$$

$$= A_c\left[\frac{e^{j2\pi f_c t} m(t) + e^{-j2\pi f_c t} m(t)}{2}\right] \rightarrow (2)$$

Fourier transform

$$x(t) \longleftrightarrow X(f)$$

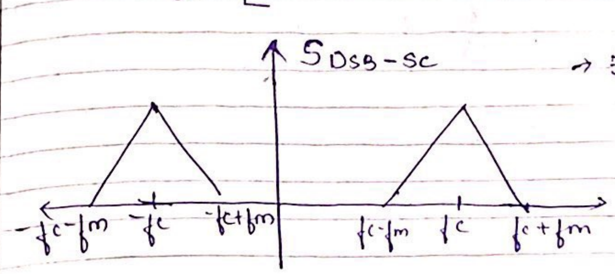
$$e^{j2\pi f_c t}\, x(t) \rightarrow X(f - f_c)$$

$$e^{-j2\pi f_c t}\, x(t) \rightarrow X(f + f_c)$$

$\rightarrow (3)$

From eq (2) and eq(3) :-

$$= \frac{A_c}{2}\left[M(f - f_c) + M(f + f_c)\right].$$



→ Frequency spectrum of DSB-SC

(There is no carrier)

Single tone DSB-SC

$$s_{DSB-SC}(t) = m(t)\,c(t)$$

= Same as equation (1) will come out.

$$\text{Total power} = \frac{\left(\frac{A_c A_m}{2}\right)^2}{2} + \frac{\left(\frac{A_c A_m}{2}\right)^2}{2}$$

$$= \frac{A_c^2 A_m^2}{4}$$

Bandwidth = $2f_m$.

$$\eta = \frac{\frac{A_c^2 A_m^2}{4}}{A_c^2 + \frac{A_c^2 A_m^2}{4}} \times 100 = \frac{\text{total sideband power}}{\text{total power}}$$

$= 100\%$.

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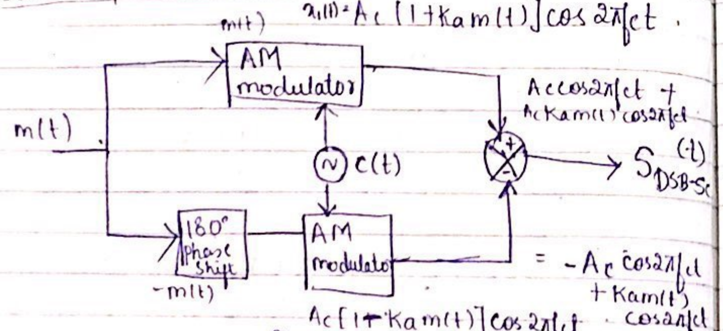
Generation of DSB-SC.

1. Balanced modulator.
2. Ring modulator.

1) Balanced modulator

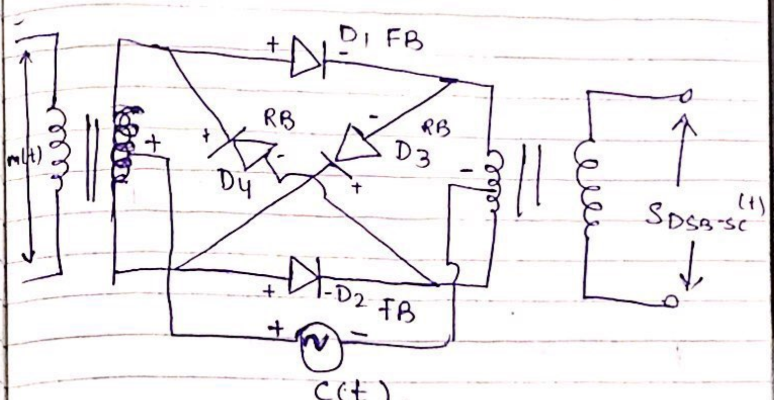


$$S_{DSB-SC}(t) = x_1(t) - x_2(t)$$

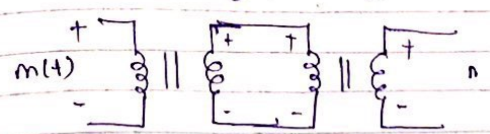
$$= 2K_a A_c m(t) \cos 2\pi f_c t.$$

In this 2AM modulators are connected in balanced to generate double side band-sc.

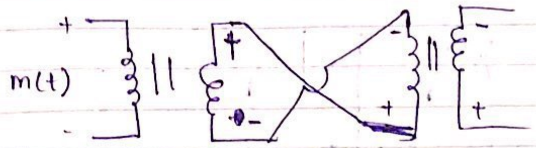
2. Ring modulator



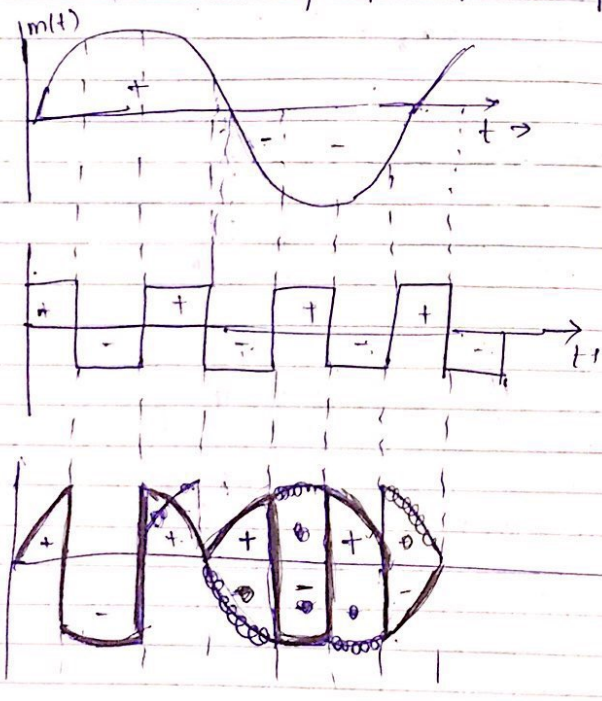
For +ve half cycle of c(t).



For −ve half cycle of c(t).



m(t)	c(t)	O/P	Diode (F.B)
+	+	+	D_1, D_2
+	−	−	D_3, D_4
−	+	−	D_2, D_1
−	−	+	D_3, D_4.



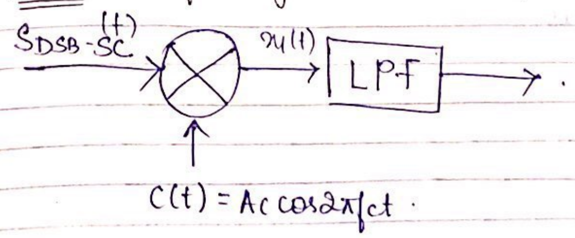
Case 1 –
During +ve half cycle of c(t) diode D_1 and D_2 are forward biased and D_3 and D_4 are reverse biased.

Case 2 –
During −ve half cycle, diode D_3 and D_4 are forward biased and diode D_1 and D_2 are reverse biased.

Demodulation of double-side band suppressed carrier.

① Coherent detector.

Case I → Perfect synchronisation.



$$x_1(t) = c(t)\, m(t) \cdot c(t)$$

$$= A_c^2 \cos^2 2\pi f_c t \; m(t)$$

$$= A_c^2 \left(\frac{1 + \cos 4\pi f_c t}{2} \right) m(t)$$

$$= \frac{A_c^2}{2} m(t) + \frac{A_c^2}{2} \cos 4\pi f_c t \; m(t)$$

After passing through low pass filter

we got $\frac{A_c^2}{2} m(t)$.

Then after passing through amplifier with gain $= \frac{2}{A_c^2}$

we got $\frac{A_c^2}{2} m(t) \cdot \frac{2}{A_c^2}$

$= m(t)$.

Thus, we got our message signal.

Case 2 :- Imperfect synchronisation.

$x_1(t) = c(t) m(t) c(t)$

$= A_c^2 \cos^2(2\pi f_c + \phi)t \; m(t)$

$= A_c^2 \left[\frac{1 + \cos(4\pi f_c + 2\phi)t}{2} \right] m(t)$

~~$= \frac{A_c^2}{2} m(t) + \frac{A_c^2}{2} \cos(4\pi f_c + 2\phi) t \, m(t)$~~

~~$= \frac{A_c^2}{2} m(t) +$~~

$= c(t) \; m(t) \; A_c \cos(2\pi f_c t + \phi)$

$= A_c^2 \cos 2\pi f_c t \; \cos(2\pi f_c t + \phi) \; m(t)$

$= \frac{A_c^2}{2} \left[\cos(4\pi f_c t + \phi) + \cos\phi \right] m(t)$

$x_1(t) = \frac{A_c^2}{2} \cos\phi \, m(t) + \frac{A_c^2}{2} \cos(4\pi f_c t + \phi) \, m(t)$

After passing through LPF.

we got $\frac{A_c^2}{2} \cos\phi \; m(t)$.

After passing through amplifier with gain $= \frac{2}{A_c^2 \cos\phi}$

we got $\frac{A_c^2}{2} \cos\phi \, m(t) \times \frac{2}{A_c^2 \cos\phi}$ $\boxed{= m(t)}$

Thus, we got our required message signal $m(t)$.

Advantages and Disadvantages of DSB-SC

Ad

① Efficiency is equal to 100%.

Disad

① Demodulation is complex.
② Bandwidth is equal to $2f_m$.

Single side band - suppressed carrier.

If the carrier and one of the side band are suppressed at the transmitter, no information is lost.
Modulation of this type which provides a single side band - with suppressed carrier is known as Single side band - suppressed carrier system

★ Hilbert transform of sin → −cos.

8/8/18

$$S_{DSB\text{-}SC}(t) = A_c A_m \cos 2\pi f_c t \cos 2\pi f_m t$$

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

$$S_{SSB\text{-}SC}(t) = \frac{A_c A_m}{2}\left[\cos 2\pi(f_c \pm f_m)t\right]$$

★ + for upper side band or − for lower side band.

$$= \frac{A_c A_m}{2}\left[\cos 2\pi f_c t \cos 2\pi f_m t \mp \sin 2\pi f_c t \sin 2\pi f_m t\right]$$

USB

LSB

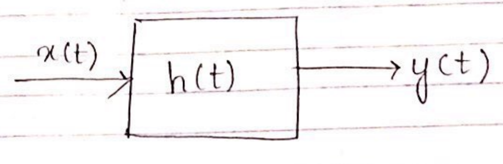
hilbert transform

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

$$\hat{m}(t) = A_m \sin 2\pi f_m t$$

$$= \frac{A_c}{2}\left[m(t)\cos 2\pi f_c t \mp \sin 2\pi f_c t\, \hat{m}(t)\right]$$

Hilbert transform.



convolution

$$y(t) = x(t) * h(t)$$

$$y(t) = \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\, d\tau$$

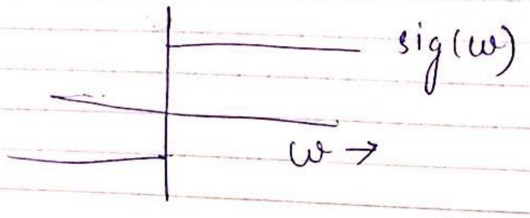
In hilbert transform ; $h(t) = \frac{1}{\pi t}$.

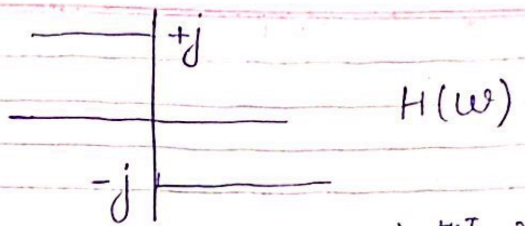
$$x(t) \longrightarrow \boxed{h(t) = \frac{1}{\pi t}} \longrightarrow y(t) = \hat{x}(t)$$

$$\left.\begin{aligned} Y(\omega) &= X(\omega) \cdot H(\omega) \\ Y(f) &= X(f) \cdot H(f) \end{aligned}\right\} \text{frequency domain.}$$

$$h(t) = \frac{1}{\pi t}$$

$$H(\omega) = -j\,\mathrm{sgn}(\omega) \quad [\mathrm{sgn} \to \text{signum}]$$





$$m(t) \xrightarrow{H.T} \hat{m}(t).$$

$$\boxed{A_m \sin 2\pi f_m t}$$

$$\hat{m}(t) \sin 2\pi f_c t$$

$$\hat{m}(t) \left[\frac{e^{j2\pi f_c t} - e^{-j2\pi f_c t}}{2j} \right]$$

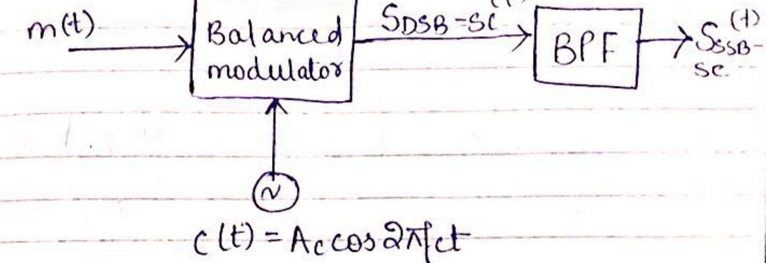
$$= \hat{m}(f - f_c) - \hat{m}$$

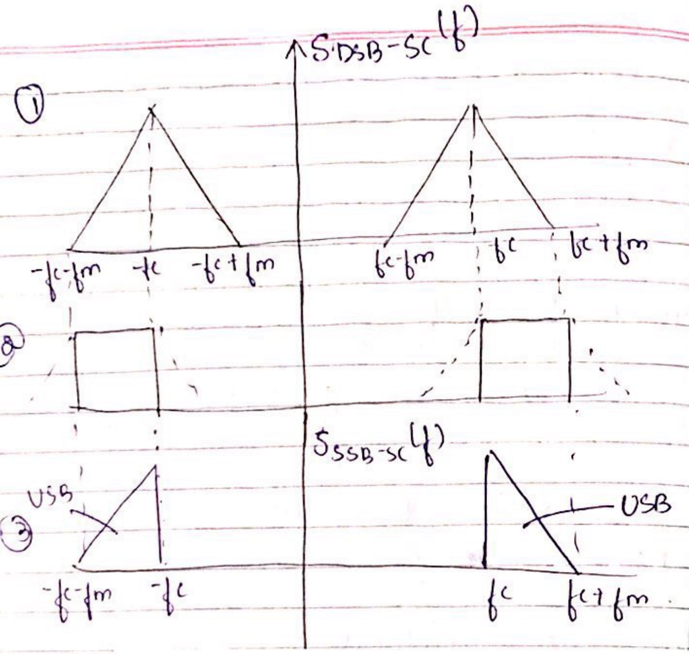
Generation of SSB-SC.

There are 2 methods:-

① Frequency discrimination.
② Phase discrimination.

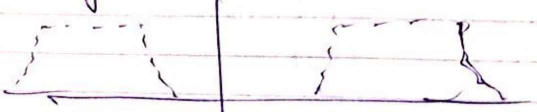
① Frequency discrimination





② After passing DSB-SC to BPF it will let the bands selected to pass through it and it will not let other bands to pass through it.

Practically, the BPF gives O/P like this.



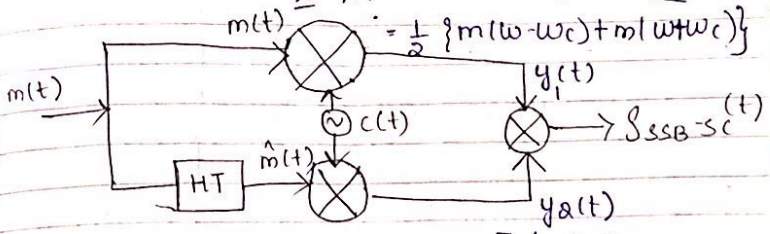
There is no sharp curve as shown in fig ②

so it will let some of the LB to pass through it. Thus, it is practically not possible.

~~Band~~ Drawback:

In case of frequency discrimination band pass filter should be as ideal as possible but ideal band pass filter is not possible.

Phase discrimination method



$= m(t)c(t) = m(t)\left[\frac{e^{j2\pi f_c t}+e^{-j2\pi f_c t}}{2}\right]$

$= \frac{1}{2}\{m(\omega-\omega_c)+m(\omega+\omega_c)\}$

$= \frac{1}{2j}\left[\hat{M}(\omega-\omega_c) - \hat{M}(\omega+\omega_c)\right]$

$\hat{m}(t)\sin 2\pi f_c t$

$y_1(t) = m(t)\cdot c(t)$

$= \cancel{\frac{A_c A_m}{2}\left[\cos 2\pi(f_c+f_m)t + \cos 2\pi(f_c-f_m)t\right]}$

$= \cancel{\frac{1}{2}[}$

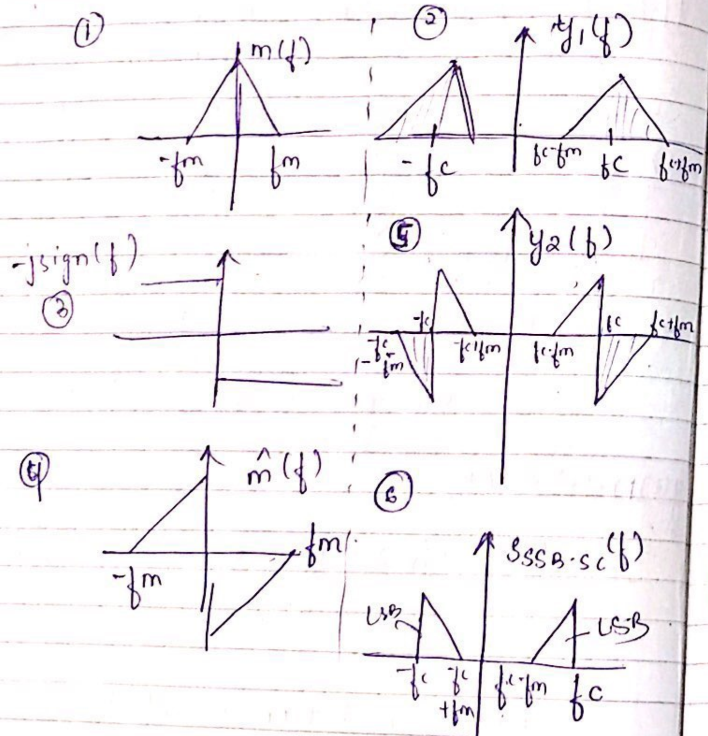
$= \cancel{A_c \cos 2\pi f_c t + A_m \cos 2\pi f_m t}$

$= \frac{m(t)}{2}\left[e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right] + \cancel{\frac{A_m}{2}\left[\cos 2\pi f_m t + e^{-j2\pi f_m t}\right]}$

$= \frac{Ac}{2}\, f2\pi = m(2\pi f - 2\pi f_c) + m(2\pi f + 2\pi f_c)$

$$\boxed{y_1(t) = m(\omega - \omega_c) + m(\omega + \omega_c)}$$

$\hat{m}(f) = m(f)\{-j\,\text{sign}(f)\}$



$$\boxed{\text{Now bandwidth} = f_m.}$$

$y_2(t) = \hat{m}(t) \cdot c(t)$

$= \hat{m}(t) \cdot \sin 2\pi f_c t$

$= \hat{m}(t) \left[\frac{e^{j2\pi f_c t} - e^{-j2\pi f_c t}}{2j}\right]$

$$\boxed{y_2(t) = \frac{1}{2j}\left[\hat{m}(\omega - \omega_c) - \hat{m}(\omega + \omega_c)\right]}$$

④ figure is the hilbert transform of our m(f) i.e, $m(f) \cdot \{-j\,\text{sign}(f)\}$

⑤ figure is the frequency spectrum of figure ④

⑥ adding $y_1(f) + y_2(f)$ gives us figure ⑥.

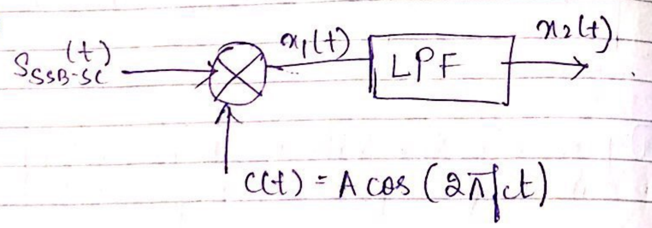
As f_c to $f_c + f_m$ are in opposite direction, on adding, they cancel out each other. Similarly from $-f_c$ to $-f_c - f_m$. Now we are left with only lower side band (LSB) and thus got single side band - suppressed carrier.

→ Demodulation of SSB-SC

→ Coherent detector :-

① Perfect synchronisation.
② Imperfect synchronisation.

①



$$\frac{A_c A_m}{2}\left[\cancel{\cos 2\pi f_c t \cos 2\pi} \cos 2\pi (f_c \pm f_m)t\right]$$

$$= \frac{A_c A_m}{2}\left[\cos 2\pi f_c t \cos 2\pi f_m t \mp \sin 2\pi f_c t \sin 2\pi f_m t\right]$$

$$= \frac{A_c}{2}\left[m(t)\cos 2\pi f_c t \mp \sin 2\pi f_c t\, \hat{m}(t)\right]$$

$$x_1(t) = A_c^2\left[m(t)\cos^2 2\pi f_c t \mp \sin 2\pi f_c t \cos 2\pi f_c t\, \hat{m}(t)\right]$$

$$= \frac{A_c^2}{2}\left[m(t)\left[\frac{1+\cos 4\pi f_c t}{2}\right] \mp \frac{\sin 4\pi f_c t}{2}\hat{m}(t)\right]$$

After passing through LPF.

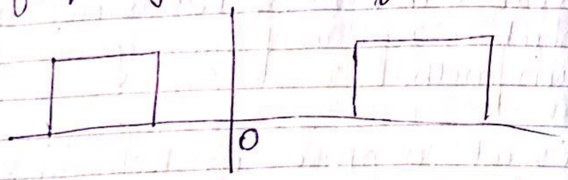
$$x_2(t) = \frac{A_c^2}{4} m(t).$$

After passing through amplifier with gain $\frac{4}{A_c^2}$

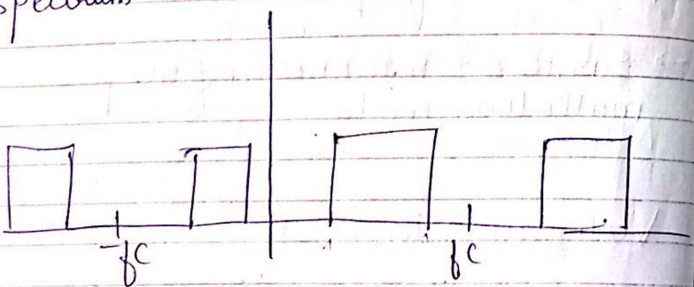
we get $m(t)$ (our message signal)

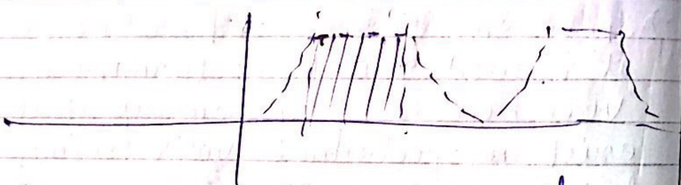
and LSB meet at carrier frequency.
This means use of SSB modulation is inappropriate for ~~the~~ transmission of such base band signal whose upper and lower side band is difficult to isolate.

→ This is our ~~frequency spectrum of~~ voice message



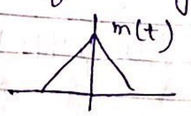
Shifting by fc we get our frequency spectrum.

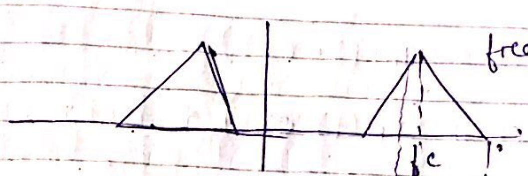




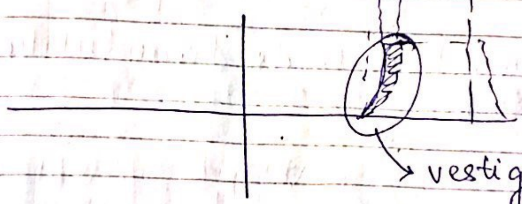
→ Here we can use SSB-SC but

in case of message signal (TV signal)





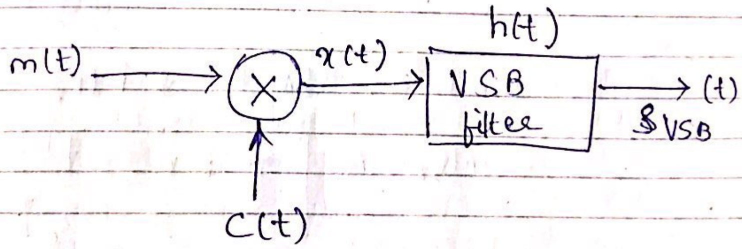
frequency spectrum



→ vestigial part.

→ So here we can use SSB-SC so we will use vestigial side band modulation.

VSB modulation:



impulse response of VSB.

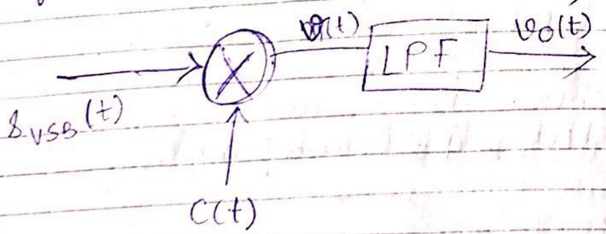
$$y(t) = x(t) * h(t)$$

$$Y(\omega) = X(\omega)\cdot H(\omega)$$

$$x(t) = m(t)\cdot c(t).$$

$$y(t) = (m(t)\cdot c(t)) * h(t).$$

Now we have to do demodulation of $s_{VSB}(t)$.



$$y(t) = (m(t)\cdot A_c\cos 2\pi f_c t) * h(t)$$

$$= m(t)\cdot A_c\left[\frac{e^{j2\pi f_c t}+e^{-j2\pi f_c t}}{2}\right]$$

$$X(f) = \frac{A_c}{2}\left[m(f-f_c) + m(f+f_c)\right]$$

$$\boxed{\underset{S_{VSB}(t)}{Y(f)} = X(f)\cdot H(f)}$$

$$v(t) = s_{VSB}(t)\cdot c(t)$$

$$= s_{VSB}(t)\cdot A_c\cos 2\pi f_c t$$

$$= s(t)\cdot\frac{A_c}{2}\left[e^{j2\pi f_c t}+e^{-j2\pi f_c t}\right]$$

$$V(f) = \frac{A_c}{2}\left[S(f-f_c) + S(f+f_c)\right]$$

$$V(f) = \frac{A_c}{2}\left[X(f-f_c)\cdot H(f-f_c) + X(f+f_c)\cdot H(f+f_c)\right]$$

$$= \frac{A_c}{2}\left[\frac{A_c}{2}\left[m(f-2f_c) + m(f)\right]\cdot H(f-f_c) + \frac{A_c}{2}\left[m(f) + m(f+2f_c)\right]\cdot H(f+f_c)\right]$$

After LPF:

$$V_0(t) = \frac{A_c^2}{4} m(f) H(f-f_c) + \frac{A_c^2}{4} m(f) H(f+f_c)$$

$$= \frac{A_c^2}{4} m(f) \left[H(f-f_c) + H(f+f_c) \right]$$

After passing through amplifier with gain $\frac{4}{A_c^2 [H(f-f_c) + H(f+f_c)]}$

$$\text{final} = \frac{\cancel{A_c^2}}{\cancel{4}} m(f) \cancel{\left[H(f-f_c) + H(f+f_c) \right]} \times \frac{\cancel{4}}{\cancel{A_c^2}} \cancel{\left[H(f-f_c) + H(f+f_c) \right]}$$

$$= m(f)$$

(This is our message signal)

Q. For AM wave maximum voltage was found 10V and minimum 5V. Find the modulation index η.

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

$$A_{max} = A_c + A_m$$

$$A_{min} = A_c - A_m$$

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

$$= 15V$$

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

$$= 5$$

$$\eta = \frac{5}{15} = \frac{1}{3} \longrightarrow \text{Ans}$$

Q. A message signal $m(t)$;

$$\boxed{m(t) = \frac{1}{2}\cos\omega_1 t - \frac{1}{2}\sin\omega_2 t}$$

$c(t)$ = Carrier signal.

ω_c = Carrier frequency

$$s_{AM}(t) = [1 + m(t)] \cos 2\pi f_c t$$

What is the power efficiency achieved by this modulation scheme?