Module - I

Analog Communication (8)

- Block diagram of commⁿ s/m, analog & digital s/m, need for modlⁿ.
- Amplitude Modlⁿ, model & spectrum & index of modlⁿ
- DSB-SC and SSB modlⁿ, SSB txⁿ & rxⁿ.
- FM & PM Mode of FM, Spectrum of FM s/l.

→ Introduction to communication

- The term communications refers to the sending, receiving and processing of information by electronic means. Communication is the process of passing or transmitting information from one point to another. The electronic s/m used for conveying the information from the source to destination is called the commⁿ s/m.

→ Elements of a communication s/m.

The basic elements of a communication s/m are

1. The source of information or message signal.
2. Transmitter: The device that sends the s/l.
3. Channel: The medium on which the signal is carried.
4. Receiver: The device that recieves the transmitted s/l from the channel.
5. Destination: Final block which receives the message signal.

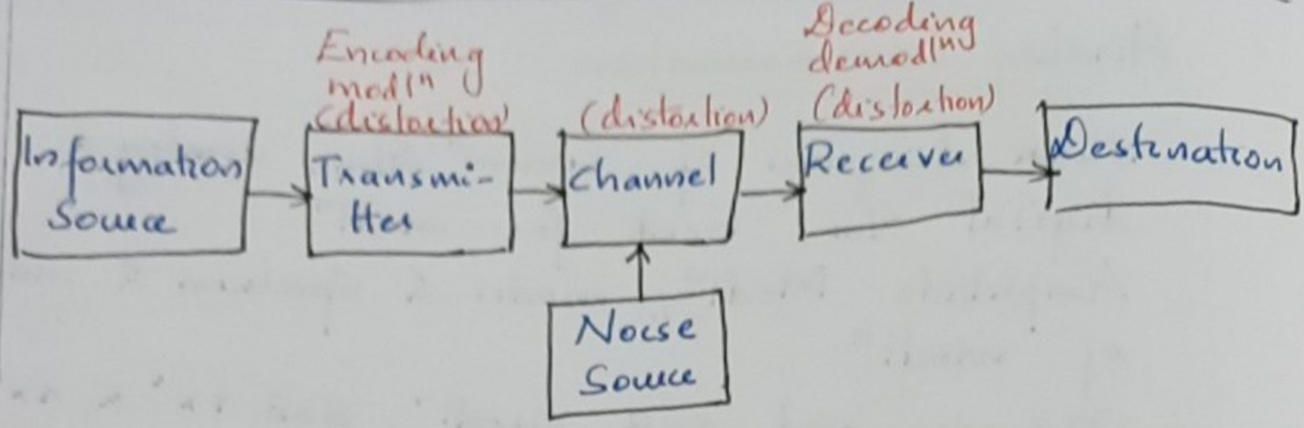


Fig 1: Block diagram of a communication system.

The fig:1 shows the block diagram of a communication system. Any communication system will have five blocks, including information source or message (msg) signal (s/l) and destination blocks. In the case of practical design cases, we are interested only in the other three blocks namely transmitter, channel and receiver.

1. Information Source: The information comes from the information source is converted into electrical signal convert a non-electrical signal into an electrical signal suitable. transducer are used. Transducer is a device which converts energy in one form to other. The electrical version of the message signal is the actual input to the transmitter block of the communication system.

2. Transmitter: The objective of the transmitter
block is to collect the incoming message
signal and modify it in a suitable manner
(if needed). In this block the information
modulates the carrier is superimposed on a
high-frequency signal (eg: sine wave). The
actual method of modulation varies from one
system to another. Modulation may be high
level or low level and the system itself may
be amplitude modulation, frequency modulation,
pulse modulation or any variation or combin-
ation of these, depending on the requirements

3. Channel: A channel or communication channel
refers the physical medium which connects the
transmitter and the receiver.. The physical
medium includes copper wire, coaxial cable,
optical fiber cables, waveguide and free space
or atmosphere. The choice of a particular
channel depends on the feasibility and also
the purpose of communication system.

4. Receiver: The receiver block receives the
incoming modified version of the message
signal from the channel and processes it to
recreate the original (non-electrical) form of
the message signal. Demodulation is the most
important one which converts the message
signal available in the modified from to
the original electrical version of the message.

5 Destination: The destination is the final block in the communication system which receives the message signal and processes it to comprehend the information present in it.

→ Analog and digital signals

The analog signal is that type of signal which varies smoothly and continuously with time. This means that analog signals are defined for every value of time and they take on continuous values in a given time interval.

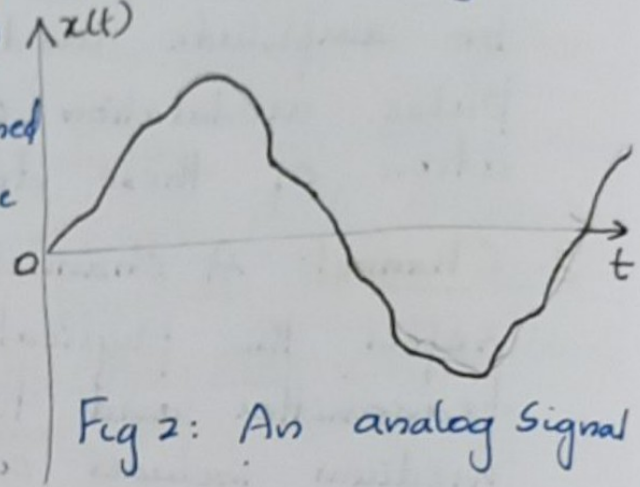
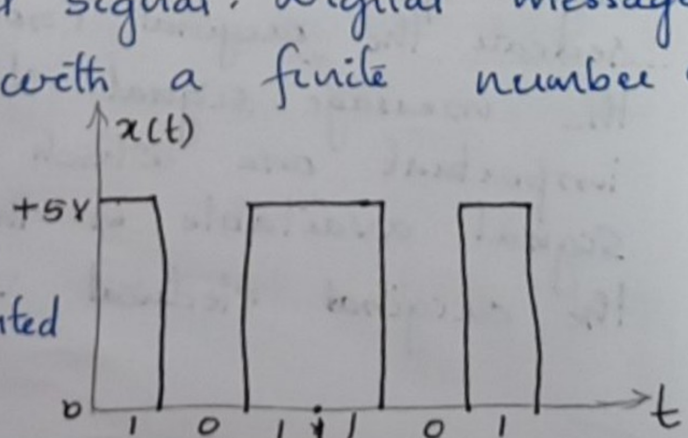


Fig 2: An analog signal

eg. Temperature, the atmospheric pressure, speech s/g etc.

An alternative form of signal representation is that of a sequence of no:s, each number representing the signal magnitude at an instant of time. The resulting signal is called a digital signal. Digital messages are constructed with a finite number of symbols.

Since a digital signal is represented only by digits,



therefore binary no: s/m is used to represent a digital signal.

→ Analog & Digital System.

Analog and digital signals are used to transmit information (such as any audio or video), usually through electric signals. In digital technology, translation of information is into binary format (either 0 or 1) and information is translated into electric pulses of varying amplitude in analog technology

- Comparison between digital system & analog system:

	Parameter	Digital System	Analog System
1	Signal	Uses discrete signals as on/off representing binary format. Off is 0, ON is 1	Uses continuous signals with varying magnitude.
2	Wave type	Square waves	Sine waves.
3	Technology	Digital s/m first transform the analog waves to limited set of numbers and then record them as digital square waves.	Analog s/ms records the physical waveforms as they are originally generated.
4	Transmission	Digital transmission is easy and can be made noise proof with no loss at all.	Analog signals are affected badly by noise during transmission
5	Flexibility	Digital s/m hardware can be easily modulated as per the requirements.	Analog s/m's hardware are not flexible

	Parameter	Digital S/m	Analog S/m
6	Bandwidth	Needs more bandwidth to carry same information	Requires less bandwidth
7	Memory	Digital data is stored in form of bits	Analog data is stored in form of waveform signals
8	Power requirement	Needs low power as compare to its analog counterpart	Consume more power than digital systems.
9	Best suited for / Uses	Computing and digital electronics	Audio and Video transmission.
10	Cost	Cost is high	Cost is low
11	Example	Digital S/m are Computer, CD, DVD	Analog electronics, Voice in air ie radio using AM

→ <u>Need for modulation</u>

1. Reduce the height of antenna
2. Avoids mixing of signals
3. Increases the range of communication
4. Allows multiplexing of signals.
5. Allows adjustments in the bandwidth
6. Improves quality of reception
7. Narrow banding
8. To overcome equipment limitations
9. Modulation for frequency assignment

10. Modulation to reduce noise and interference.

1. Reduce the height of the antenna

The height of an antenna required for transmission and reception of radio waves in radio transmission is a function of wavelength of the frequency used.

The minimum height of the antenna is given as $\lambda/4$ ------→ (1)

But, $\lambda = c/f$ →(2) where c - Velocity of light, f - frequency of radio wave

Height of antenna, $h = \frac{\lambda}{4} = \frac{c}{f \times 4} = \frac{c}{4f}$ →(3)

From eqn (3) it can be easily noticed that ~~at the~~ low frequency (wavelength is very high) the height of the antenna is high.

Eg: Consider a baseband signal with f = 1 KHz, then height of antenna, $h = \frac{c}{4f} = \frac{3 \times 10^8}{4 \times 1 \times 10^3} = \underline{75000 m}$.

This height of a vertical antenna is unthinkable and impracticable. On the other hand consider a modulated signal with 1 MHz frequency in the broadcast band, then height of the antenna, $h = \frac{c}{4f} = \frac{3 \times 10^8}{4 \times 1 \times 10^6} = \underline{75 m}$

This height of antenna is practical and such antenna can be installed.

2. Avoids mixing of signals

All sound signals are concentrated within the range 20 Hz to 20 KHz. The transmission of baseband signals from various sources causes the mixing of signals and then it is difficult to seperate at the receiver end.

∴ Modulating different signal sources by different carrier frequencies avoid mixing of signals.

3. Increases the range of communication

At low frequencies radiation is poor and signals gets highly attenuated. Therefore baseband signals cannot be transmitted directly over long distances. Modulating effectively increases the frequency of the signal to be radiated and thus increases the distance over which signals can be transmitted faithfully.

4. Allows multiplexing of signals

Multiplexing is a process in which two or more signals can be transmitted over the same communication channel simultaneously. With the advent of modulation technique the sharing of a common channel for the transmission of various or multiple base band signals is possible, thus multiplexing is possible. The multiplexing allows the same channel to be used by many signals. Hence, many TV channels can use the same frequency range, without getting mixed with each other or different frequency signals can be transmitted at the same time.

5. Improves Quality of Reception

With ~~the~~ modulation techniques like FM. and digital communication techniques such as PCM, the effect of noise can be reduced to a great extent. This improves quality of reception.

6. Allows adjustments in the bandwidth

Bandwidth is the total range of ~~frequency~~ frequency required to pass a specific signal that has been modulated to carry data without distortion or loss of data. The ideal bandwidth allows the signal to pass under conditions of maximum AM or FM adjustment. Too narrow a bandwidth will result in loss of data.

→ Amplitude Modulation (AM)

AM is the process of varying the amplitude of the high frequency signal (carrier signal) with the instantaneous amplitude of a low frequency signal (message signal). Amplitude modulation is a relatively inexpensive, low quality form of modulation that is used for commercial broadcasting of both audio and Video signals.

The carrier wave is expressed as,

$$e_c(t) = E_{c\,max} \sin(2\pi f_c t + \phi_c) \longrightarrow (4)$$

The message wave is expressed as,

$$e_m(t) = E_{m\,max} \sin(2\pi f_m t + \phi_m) \longrightarrow (5)$$

In amplitude modulation a voltage proportional to the modulating signal is added to the carrier amplitude and the added component of voltage be represented in functional notation as $e_m(t)$, then the modulated carrier wave is given by,

$$e(t) = \left[(E_{c\,max} + e_m(t)) \cos(2\pi f_c t + \phi_c)\right] \longrightarrow (6)$$

The term $[E_{c\,max} + e_m(t)]$ describes the envelope of the modulated wave.

- Advantages of AM

1. It is simple to implement.
2. It can be demodulated using a circuit consisting of very few components.
3. AM receivers are very cheap as no specialised components are needed.

- Disadvantages of AM

1. It is not efficient interms of its power usage.

2. It is not efficient interms of bandwidth.
3. It is sensitive to noise.

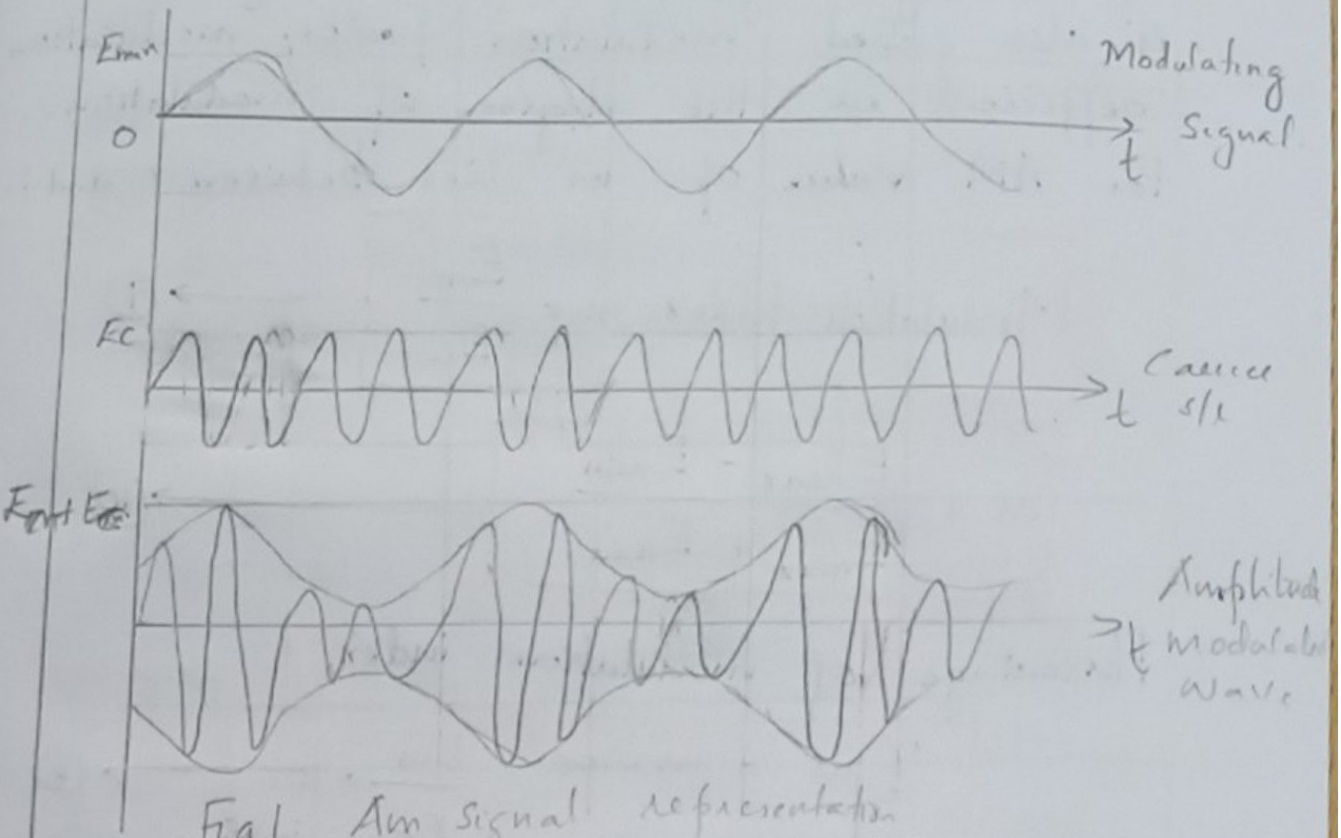


Fig 1 AM signal representation

- Modulation Index for AM (m)

For sinusoidal AM, the modulating waveform is of the form

$$e_m(t) = E_{m\,max} \cos(2\pi f_m t + \phi_m) \cong E_m \cos\omega_m t \longrightarrow (7)$$

The carrier is expressed as,

$$e_c(t) = E_{c\,max} \cos(2\pi f_c t + \phi_c) \cong E_c \cos\omega_c t \longrightarrow (8)$$

Amplitude modulation is independent of these phase angles ϕ_m and ϕ_c which may be therefore be set equal to zero to simplify the algebra and trigometry used in the analysis.

* Modulation Index is the ratio of amplitudes of message signal to carrier signal. It is also called modulation factor, modulation coefficient or the degree of modulation. For AM value of m lies between 0 and 1.

$$\boxed{\text{Modulation Index, } m = \frac{E_m}{E_c}} \longrightarrow (9)$$

$$\boxed{m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}} \longrightarrow (10)$$

Percentage of modulation index,

$$\boxed{\% m = m \times 100 = \frac{E_m}{E_c} \times 100} \longrightarrow (11)$$

- Mathematical expression for AM...

Let the modulating signal, $e_m = E_m \cos \omega_m t$

carrier signal, $e_c = E_c \cos \omega_c t$

where E_m: Maximum amplitude of the message s/l.

E_c: Maximum amplitude of the carrier s/l.

ω_m: Frequency of modulating signal,

$\omega_m = 2\pi f_m$.

ω_c: Frequency of carrier signal,

$\omega_c = 2\pi f_c$

The amplitude modulated wave

$$E_{AM} = E_c + e_m \qquad \rightarrow 12$$

$$= E_c + E_m \cos \omega_m t$$

The instantaneous value of amplitude modulated wave is given by

$$e_{AM} = E_{AM} \cos \omega_c t$$

$$= \left[E_c + E_m \cos \omega_m t\right] \cos \omega_c t$$

$$= E_c \left[1 + \frac{E_m}{E_c} \cos \omega_m t\right] \cos \omega_c t$$

$$= E_c \left[1 + m \cos \omega_m t\right] \cos \omega_c t \qquad \rightarrow 13$$

$$\boxed{e_{AM} = E_c \left[1 + m \cos 2\pi f_m t\right] \cos 2\pi f_c t}$$

- Frequency spectrum of Sinusoidal AM

Although the modulated waveform contains two frequencies f_c and f_m the modulation process generates new frequencies that are the sum and differencies of these frequencies.

We know that

$$e_{AM} = E_c \left[1 + m \cos 2\pi f_m t\right] \cos 2\pi f_c t$$

$$= E_c \cos 2\pi f_c t + m E_c \cos 2\pi f_m t \cos 2\pi f_c t$$

$$= E_c \cos 2\pi f_c t + \frac{m E_c}{2} \cos 2\pi (f_c - f_m) t + \frac{m E_c}{2} \cos 2\pi (f_c + f_m) t \qquad \rightarrow 14$$

$$\boxed{e_{AM} = \underbrace{E_c \cos 2\pi f_c t}_{1} + \underbrace{\frac{m E_c}{2} \cos 2\pi f_{LSB} t}_{2} + \underbrace{\frac{m E_c}{2} \cos 2\pi f_{USB} t}_{3}} \qquad \rightarrow 15$$

where f_{LSB} : Lower Side Band frequency,

$$\boxed{f_{LSB} = f_c - f_m} \longrightarrow 16$$

f_{USB} : Upper side Band frequency,

$$\boxed{f_{USB} = f_c + f_m} \longrightarrow 17$$

$\therefore$ The equation (15) of AM, e_{AM} consists of three components.

1^{st} term :- Carrier wave of amplitude E_c and frequency f_c

2^{nd} term :- Lower side frequency of amplitude $\frac{mE_c}{2}$ and frequency $f_c - f_m$

3^{rd} term :- Upper side frequency of amplitude $\frac{mE_c}{2}$ and frequency $f_c + f_m$

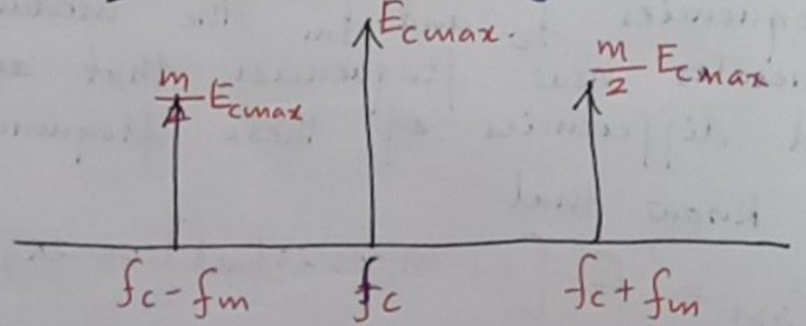


Fig 2 : Frequency spectrum of AM

- Power Relation in Modulated Wave

The average power in a sine (or cosine) voltage wave of peak value E_{max} developed across a resistor, R is $P = \frac{E_{max}^2}{R} \longrightarrow (18)$

The total average power, $P_t = P_c + P_{LSB} + P_{USB}$ $\longrightarrow$ (19)

$$P_t = \frac{E_c^2}{R} + \frac{E_{LSB}^2}{R} + \frac{E_{USB}^2}{R} \longrightarrow (20)$$

All voltages in equation (20) are rms values. The first term of eq^n (20) give the unmodulated carrier power:

$$P_c = \frac{E_c^2}{R} = \frac{\left(\frac{E_{c\,max}}{\sqrt{2}}\right)^2}{R} = \frac{E_c^2 max}{2R} \longrightarrow (21)$$

The second and third terms give the side band power.

As $P_{LSB} = P_{USB}$ the power of the side band is,

$$P_{LSB} = P_{USB} = \left(\frac{m E_{c\,max}/2}{\sqrt{2}}\right)^2 \div R$$

$$= \frac{m^2}{4} \cdot \frac{E_{c\,max}^2}{2R} = \frac{m^2}{4} \cdot P_c \longrightarrow (22)$$

$$\therefore P_t = P_c + P_{LSB} + P_{USB}$$

$$= \frac{E_c^2 max}{2R} + \frac{m^2}{4} \cdot \frac{E_c^2 max}{2R} + \frac{m^2}{4} \cdot \frac{E_c^2 max}{2R} \longrightarrow (23)$$

From eq^n 21 ie $P_c = \frac{E_c^2 max}{2R}$, we can write eq^n (23) as

$$P_t = P_c + \frac{m^2}{4} \cdot P_c + \frac{m^2}{4} \cdot P_c \longrightarrow (24)$$

$$P_t = P_c \left(1 + \frac{m^2}{4} + \frac{m^2}{4}\right)$$

$$\boxed{P_t = P_c \left(1 + \frac{m^2}{2}\right)} \longrightarrow (25)$$

$$\boxed{\frac{P_t}{P_c} = 1 + \frac{m^2}{2}} \longrightarrow (26)$$

For 100% modulation where, $m = 1$; the total power is $\boxed{P_t = 1.5\,P_c} \longrightarrow (27)$

* The ~~total~~ ratio of power in any one side frequency to the total power transmitted is therefore $1/6$.

HW Analyse sinusoidally modulated waveforms for different values of m and plot it

Sol^n: $m < 1$ - under modulated

$m = 1$ - fully modulated

$m > 1$ - over modulated.

- Effective voltage and current for Sinusoidal AM.

The effective or rms voltage E of the modulated wave is defined by the equation,

$$\frac{E^2}{R} = P_t \longrightarrow (28)$$

The effective or rms voltage E_c of the carrier component is defined by the equation,

$$\frac{E_c^2}{R} = P_c \longrightarrow (29)$$

We know that; $P_t = P_c\left[1 + \frac{m^2}{2}\right]$

$$\frac{E^2}{R} = P_c\left[1 + \frac{m^2}{2}\right]$$

$$= \frac{E_c^2}{R}\left[1 + \frac{m^2}{2}\right]$$

$$\boxed{E = E_c\sqrt{\left(1 + \frac{m^2}{2}\right)}} \longrightarrow (30)$$

A Similar argument applied to current yields,

$$\boxed{I = I_c\sqrt{1 + \frac{m^2}{2}}} \longrightarrow (31)$$

where I : rms current of modulated wave
I_c : rms current of unmodulated wave

The current equation provides are method of monitoring modulation index, by measuring the antenna current with and without modulation applied.

$$\boxed{m = \sqrt{2\left[\left(\frac{I}{I_c}\right)^2 - 1\right]}} \longrightarrow (32)$$

- Transmission efficiency of the AM Wave

Transmission efficiency of the AM wave is defined as the ratio of the transmitted power which contains the information (ie sum of lower side band and upper side band power) of the total transmitted power (P_t).

Transmission efficiency, $\eta = \dfrac{P_{LSB} + P_{USB}}{P_{Total}} \longrightarrow (33)$

$$\eta = \frac{\frac{m^2}{4} P_c + \frac{m^2}{4} P_c}{\left[1 + \frac{m^2}{2}\right] P_c}$$

$$= \frac{\frac{m^2}{2}}{\left[1 + \frac{m^2}{2}\right]}$$

$$\boxed{\eta = \frac{m^2}{2 + m^2}.} \longrightarrow (34)$$

The percentage transmission efficiency is given as,

$$\boxed{\% \, \eta = \frac{m^2}{2 + m^2} \times 100 \, \%} \longrightarrow (35)$$

- Bandwidth of AM Wave

Bandwidth is the range of frequencies over which modulation takes place. It is obtained by taking the difference between highest and lowest frequencies.

$$\text{BW of AM} = f_{USB} - f_{LSB}$$
$$= f_c + f_m - (f_c - f_m)$$
$$\boxed{BW = 2f_m} \longrightarrow (36)$$

Thus the bandwidth of AM signal is twice the maximum frequency of modulating signal.

Qn: 1 A carrier wave of frequency 10 MHz and peak value 10V is amplitude modulated by a 5 KHz sine wave of amplitude 6V. Determine the modulation index and draw the amplitude spectrum.

Qn: 2 The rms antenna current of an AM radio transmitter is 10A when unmodulated and 12A when ~~Sma~~ Sinusoidally modulated. Calculate the modulation Index.

Qn: 3 A 460W carrier is modulated to a depth of 65%. Calculate total power of modulated wave.

Qn: 4 A 320W carrier is simultaneously modulated by two audio waves with modulation % of 45 and 60 respectively. What is the sideband power radiated?

Q... The tuned circuit of the oscillator in a simple

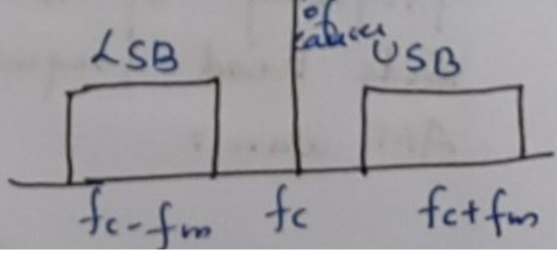
- Types of AM

1. DSB FC (A_3E) : Double Side Band Full Carrier
2. DSB SC : Double Side Band Suppressed carrier
3. SSB FC : Single Side Band Full carrier
4. SSB SC : Single Side Band Suppressed carrier
5. SSB RC : Single Side Band Reduced Carrier
6. ISB : Independent Side Band
7. VSB : Vestigal Side Band (used in TV broadcasting).

→ Double Sideband Suppressed Carrier (DSB-SC)s/m:

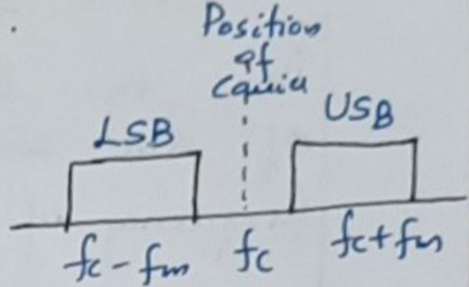
In the process of AM, the modulated wave consists of the carrier wave and two side bands. The modulated wave has the information only in the side bands. Side band is nothing but a band of frequencies, containing power, which are the lower and higher frequencies of the carrier frequency (f_{LSB} & f_{USB}).

The transmission of a signal, which contains a carrier along with two sidebands can be termed as Double Side Band Full Carrier system or simply DSBFC.



However, such a txm is inefficient. Because, 2/3 of the power is being wasted in the carrier, which carries no information.

If this carrier is suppressed and the saved power is distributed to the two sidebands, then such a process is called Double Sideband Suppressed Carrier system or simply DSBSC.



- Mathematical Expressions

Let modulating signal,

$$e_m(t) = E_m \cos(2\pi f_m t) \longrightarrow 37$$

Carrier signal, $e_c(t) = E_c \cos(2\pi f_c t) \longrightarrow (38)$

Mathematically we can represent the eq^n of DSBSC wave as the product of modulating and carrier signals.

$$s(t) = e_m(t)\, e_c(t) \longrightarrow (39)$$

$$\Rightarrow s(t) = E_m E_c \cos(2\pi f_m t) \cos(2\pi f_c t) \longrightarrow (40)$$

- Bandwidth of DSBSC Wave

Bandwidth, $BW = f_{max} - f_{min}$

Consider the eq^n of DSBSC modulated wave.

$$s(t) = E_m E_c \cos(2\pi f_m t) \cos(2\pi f_c t)$$

$$\Rightarrow s(t) = \frac{E_m E_c}{2} \cos[2\pi(f_c + f_m)t] + \frac{E_m E_c}{2} \cos[2\pi(f_c - f_m)t] \longrightarrow (41)$$

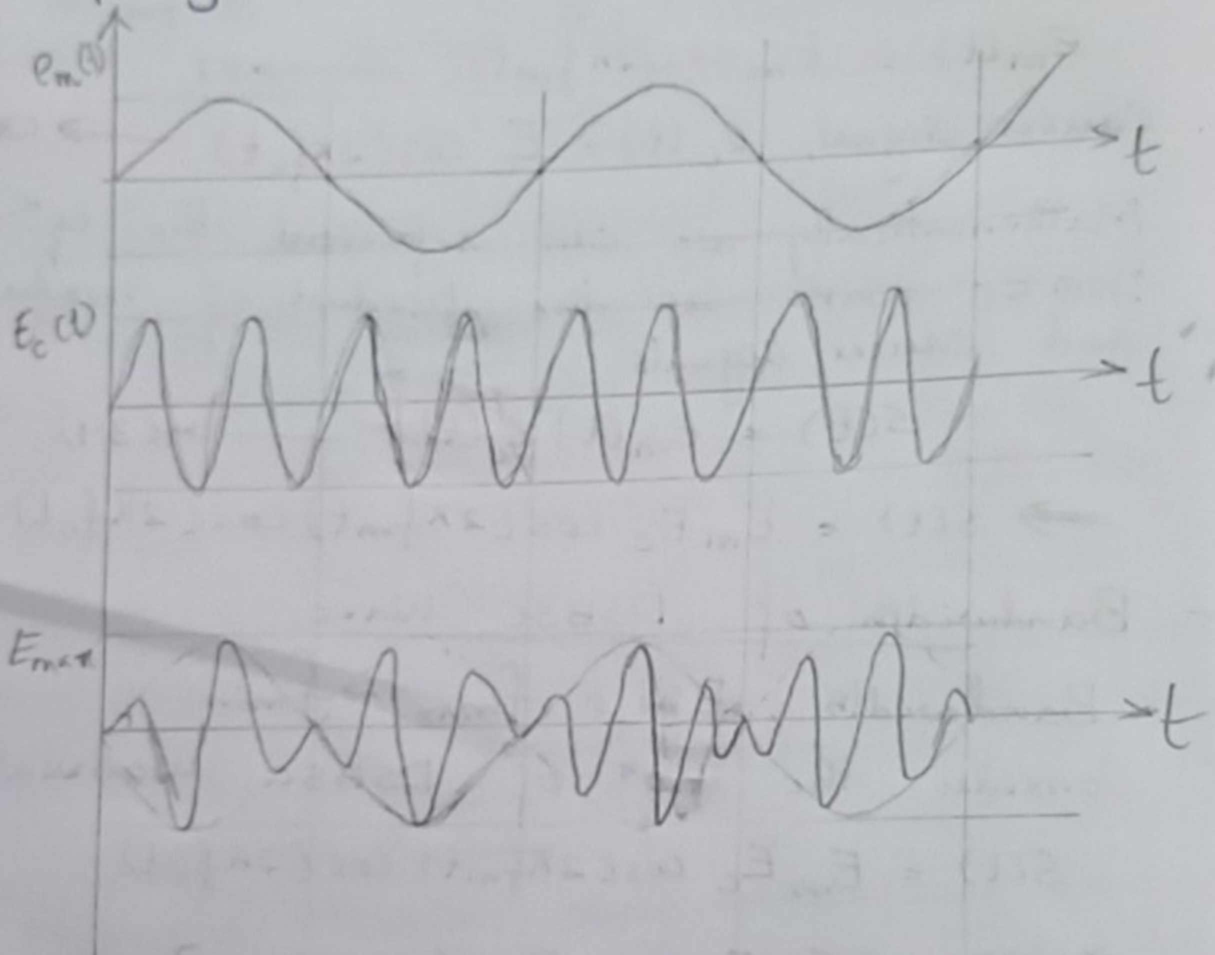
The DSBSC modulated wave has only 2 frequencies. So, the maximum and minimum frequencies are $f_c + f_m$ and $f_c - f_m$ respectively.

ie $f_{max} = f_c + f_m$ and $f_{min} = f_c - f_m$
Substitute f_{max} and f_{min} values in the BW formula.

$$BW = (f_c + f_m) - (f_c - f_m)$$

$$BW = 2f_m \longrightarrow 42$$

Thus the BW of DSBSC wave is same as that of AM wave and it is equal to twice the frequency of modulating signal.



Few points

(1) It is obvious from the fig, that the DSBSC signal exhibits phase - reversal at zero crossings ie whenever the base-

band signal $x(t)$ crosses zero. Because of this, the envelope of a DSB-SC modulated signal is different from the message signal. This is unlike the case of an AM wave signal.

(2) From fig, it is also clear that the impulses at $\pm \omega_c$ are missing which means that the carrier term is suppressed in the spectrum and only two sideband terms, USB and LSB are left. Therefore, it is called double sideband suppressed carrier (DSB-SC) system.

(3) In fig, considering only positive side the upper side band frequency is $\omega_c + \omega_m$ whereas the lowerside band frequency is $\omega_c - \omega_m$. The difference of these two is equal to the transmission bandwidth of a DSB-SC signal i.e,

Bandwidth, $B = (\omega_c + \omega_m) - (\omega_c - \omega_m) = 2\omega_m$.

Note that BW of DSBSC is same as that of AM wave.

→ Single Sideband Suppressed - Carrier (SSB-SC)

If the two side bands carry same information, DSB signal is redundant i.e in DSB, the basic information is transmitted twice, once in each side band. So one sideband may be suppressed. The carrier and one side band is completely suppressed. When only one side band is transmitted, the modulation is refered to as Single Side band modulation. It is also called as SSB or SSB-SC modulation.

The AM modulated signal from balanced modulator is given by

$$e(t) = K\, e_m(t) \cos \omega_c t \longrightarrow (43)$$

where K - multiple constant

$e_m(t)$ - modulating signal $E_m \cos \omega_m t$

$$\therefore\ e(t) = K E_m \cos \omega_m t \cos \omega_c t$$

$$= \frac{K E_m}{2} \left[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t \right]$$

$$e(t) = E_{max} \left[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t \right] \rightarrow (44)$$

where $E_{max} = \frac{K E_m}{2}$

The upper side frequency (USF) signal is given by,

$$e_{USF} = E_m \cos(\omega_c + \omega_m)t \longrightarrow (45)$$

The lower side frequency (LSF) s/l is given by,

$$e_{LSF} = E_m \cos(\omega_c - \omega_m)t \longrightarrow (46)$$

One of these side band frequencies can be removed by filtering.

Demodulation of a SSB signal is achieved by multiplying it with a locally generated synchronous carrier signal. Detectors using this principle are called product detectors and balanced modulator circuits are used for this purpose.

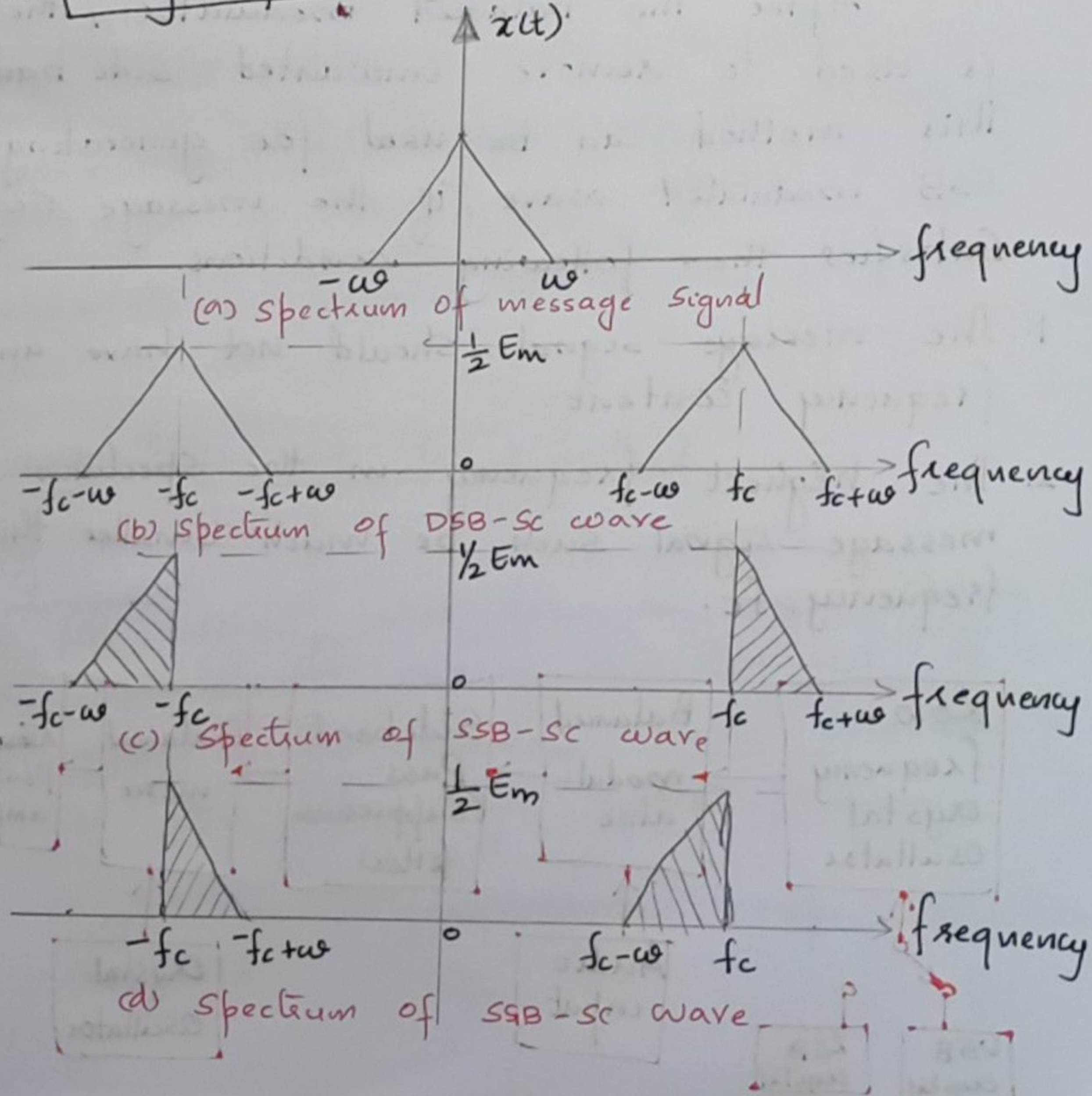
- Advantages of SSB-SC Modulation.

1. Reduction in transmission bandwidth.
2. Power saving since the high power carrier and one side band are not being transmitted.
3. Reduced Noise.

- Drawbacks of SSB-SC Modulation

1. It is expensive
2. Highly complex to implement.

- Frequency spectrum of SSB-SC



→ Methods for generating SSB-SC signal.

There are three practical methods to remove unwanted side band from the double side band signal to get the single side band signal.

They are

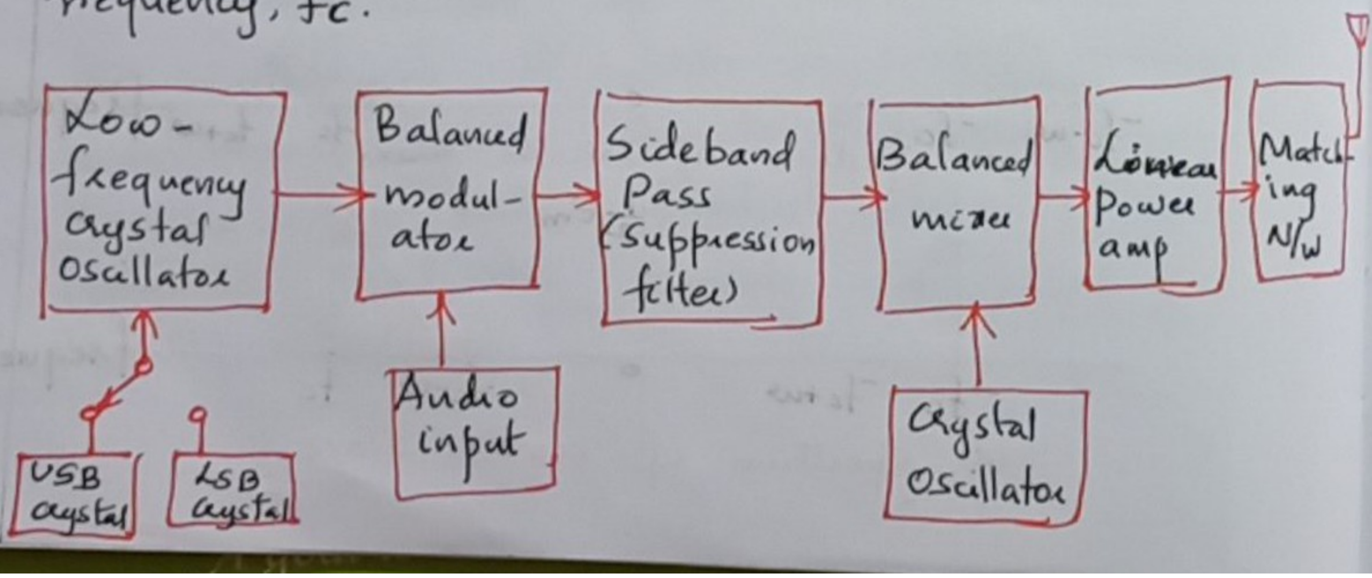
1. Filter Method (Frequency discrimination method)
2. Phase shift method (Phasing method)
3. The third method (Weaver's method)

1. Filter Method: (Frequency discrimination method)

After the balanced modulator, the filter is used to remove unwanted side band.

This method can be used for generating the SSB modulated wave, if the message signal satisfies the following conditions.

1. The message signal should not have any low frequency content.
2. The highest frequency in the spectrum of the message signal such be much smaller than carrier frequency, fc.



The balanced modulator is used to supress the carrier. Then filter suppresses one side band signal. The frequency of the generated single sideband signal is very low than the transmitter frequency. This frequency is boosted upto the transmitter frequency by the balanced mixer and crystal oscillator. The process of frequency boosting is also called up conversion. The sideband signal having frequency equal to the transmitter frequency is then amplified by the linear amplifier before transmission.

- Advantages of filter method

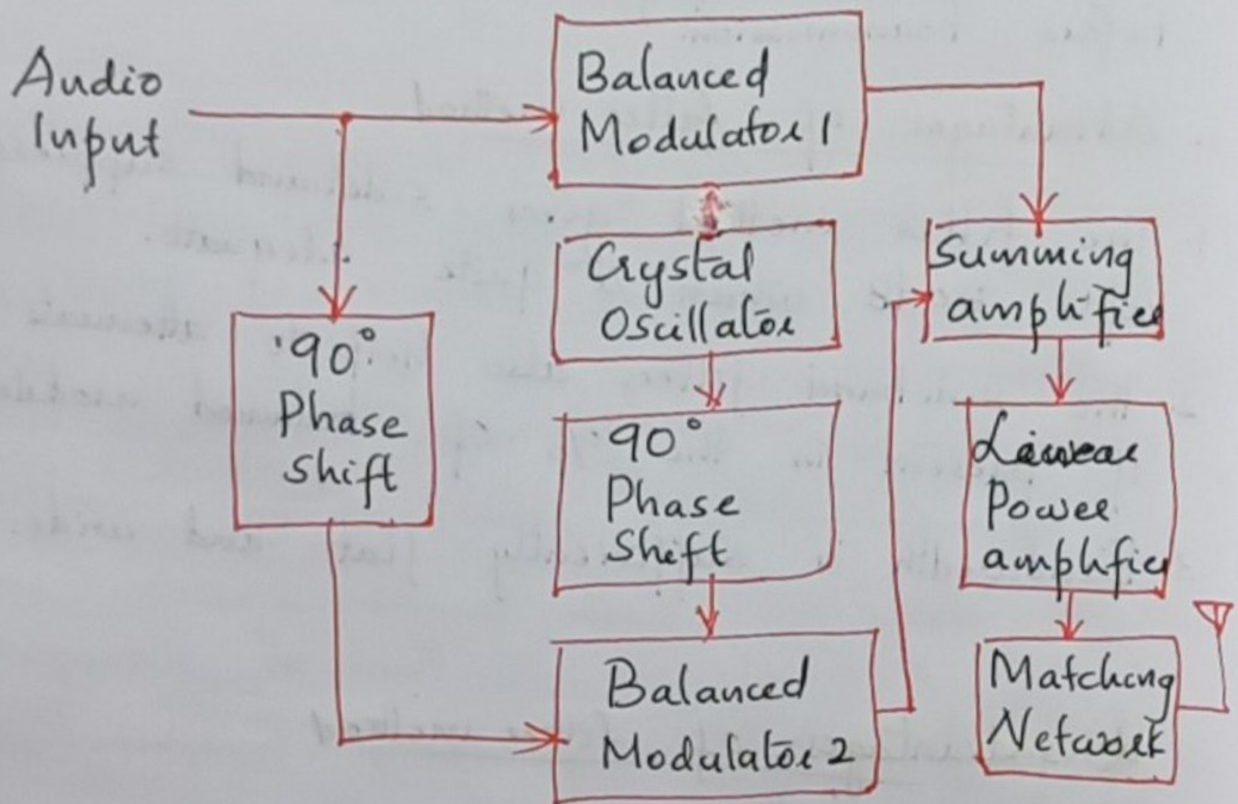
1. The filter method gives sideband suppression upto 50dB which is quite adequate.
2. The sideband filters also help to attenuate carrier if present in the o/p of balanced modulator.
3. Bandwidth is sufficiently flat and wide.

Disadvantages of filter method

1. They are bulky.
2. As modulation takes place at lower carrier frequency repeated mixing is required in conjuction with extremely stable oscillator to generate SSB at high radio frequencies.
3. At lower audio frequencies expensive filters are required.

2. Phase Shift Method (Phasing Method)

The phase shift method of SSB generation uses a phase shift technique that causes one of the sidebands to be cancelled out. The circuit doesnot have any sideband filters, and the primary modulation can be done at the transmitting frequency.



It relies on phase shifting and cancellation to eliminate the carrier and the unwanted sideband. This system uses two balanced modulators M_1 and M_2 and two 90° phase shifting ~~net~~ networks.

$$e_{LSF} = E_{Lmax} \cos(\omega_c - \omega_m)t \longrightarrow (47)$$

The standard trignometric identity for the difference of two angles gives

$$e_{LSF} = E_{Lmax} [\cos \omega_c t \cos \omega_m t + \sin \omega_c t \sin \omega_m t] \rightarrow (48)$$

but

$$\sin \omega_c t = \cos [\omega_c t - \pi/2] \longrightarrow (49)$$

$$\sin \omega_m t = \cos (\omega_m t - \pi/2] \longrightarrow (50)$$

Therefore,

$$e_{LSF} = E_{Lmax} [\cos \omega_c t \cos \omega_m t + \cos (\omega_c t - \pi/2) \cos(\omega_m t - \pi/2)] \rightarrow (51)$$

The first term of the above eq^n (51) is the result of balanced modulator1, which multiplies the two unshifted signals. The second term is the result of balanced modulator 2, which multiples the two signals each shifted by (-90°). The carrier signal is cancelled out in this circuit by both of the balanced modulators and the unwanted side bands cancel at the output of the summing amplifier.

If the two outputs are subtracted instead of adder the upper sideband will result.

$$e_{USF} = E_{umax} \cos(\omega_c + \omega_m)t$$

$$= E_{umax} [\cos \omega_c t \cos \omega_m t - \sin \omega_c t \sin \omega_m t) \rightarrow (52)$$

- Advantages of phase shift method

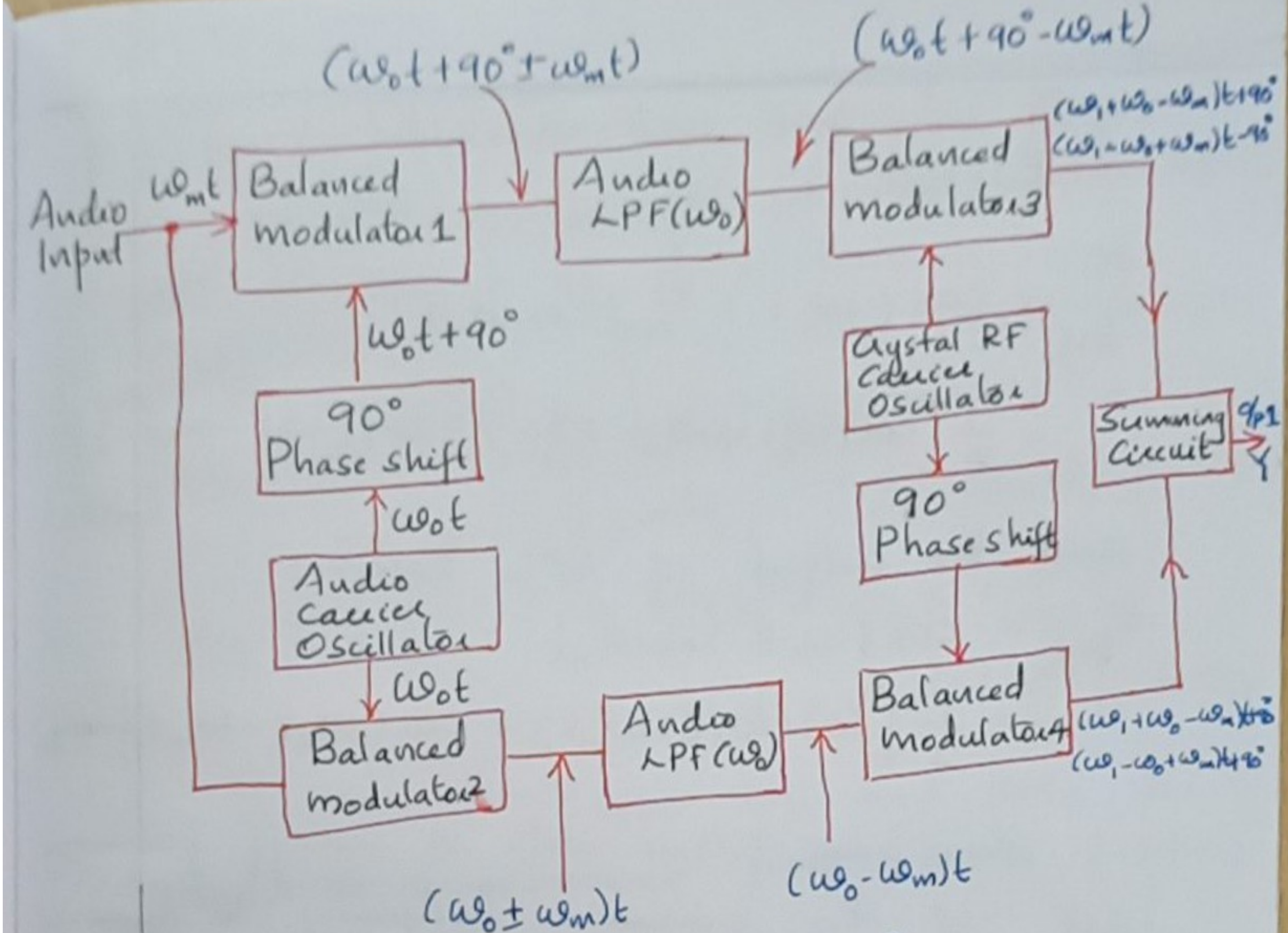
1. Bulky filters are replaced by small filters.
2. Low audio frequencies are used for modulation.
3. It can generate SSB at any frequency.
4. Easy switching from one side band to other side band is possible.

- Disadvantages

1. The design of the 90° phase shifting network for the modulating signal is extremely critical.
2. It requires complex AF phase shift network.
3. The output of two balanced modulators must be exactly same otherwise cancellation will be incomplete.

3. Third method (Weaver's method)

And
Inp



$$Y\,(\text{o/p } 1) = (\omega_1 + \omega_0 - \omega_m)t + 90°$$

The third method of generating SSB-SC modulation is attributed to D.K Wearer and was developed during the 1950's. It is similar to the phase shifting method presenting previously, but it differs in that the modulating signal is first modulated on a low-frequency subcarrier which is then modulated onto frequency carrier.

Modulators BM_1 and BM_2 both have the unshifted modulating signal as inputs. BM_1 also takes the low-frequency subcarrier with a 90° shift introduced in it from the oscillator signal. BM_2 takes the subcarrier signal directly from the oscillator. Assuming unity magnitudes and sinusoidal single-freq. modulation, the o/p from BM_1 becomes,

$$e_{BM_1} = \cos(\omega_0 t + \pi/2) \cos \omega_m t$$

$$= \frac{1}{2}\left[\cos(\omega_0 t + \omega_m t + \frac{\pi}{2}) + \cos(\omega_0 t - \omega_m t + \frac{\pi}{2})\right] \rightarrow (53)$$

and the output of BM_2 becomes

$$e_{BM_2} = \cos \omega_0 t \cos \omega_m t$$

$$= \frac{1}{2}\left[\cos(\omega_0 t + \omega_m t) + \cos(\omega_0 t - \omega_m t)\right] \rightarrow (54)$$

Low pass filters with a cutoff frequency set at the subcarrier frequency to removes the sum (the first) term from each of the above signals, leaving only the second (difference) terms as inputs to BM_3 and BM_4. The signal applied to BM_3 is shifted by $+90°$ from that applied to BM_4. This process eliminates the need to provide a wide band $90°$ phase shifting network for the base band signals.

The o/p of BM_3

$$e_{BM_3} = \cos \omega_1 t \cos\left((\omega_0 - \omega_m)t + \frac{\pi}{2}\right) \rightarrow (55)$$

$$e_{BM_3} = \frac{1}{2}\left[\cos(\omega_1 t + ((\omega_0 - \omega_m)t + \pi/2)) + \cos(\omega_1 t - (\omega_0 - \omega_m)t + \pi/2)\right] \rightarrow (56)$$

$$e_{BM_3} = \frac{1}{2}\Big[\cos\big((\omega_1+\omega_0)t - \omega_m t + \tfrac{\pi}{2}\big) + \cos\big((\omega_1-\omega_0)t + \omega_m t - \tfrac{\pi}{2}\big)\Big] \rightarrow (57)$$

and the output of BM_4 becomes

$$e_{BM_4} = \cos\big(\omega_1 t + \tfrac{\pi}{2}\big)\cos(\omega_0 - \omega_m)t \rightarrow (58)$$

$$e_{BM_4} = \frac{1}{2}\Big[\cos\big((\omega_1 t + \pi/2) + (\omega_0 - \omega_m)t\big) + \cos\big((\omega_1 t + \pi/2) - (\omega_0 - \omega_m)t\big)\Big] \rightarrow (59)$$

$$e_{BM_4} = \frac{1}{2}\Big[\cos\big((\omega_1+\omega_0)t - \omega_m t + \tfrac{\pi}{2}\big) + \cos\big((\omega_1-\omega_0)t + \omega_m t + \tfrac{\pi}{2}\big)\Big] \rightarrow (60)$$

The outputs from BM_3 and BM_4 are added in a summing amplifier to produce the final output.

$$e_{out} = \cos\big((\omega_1 + \omega_0 - \omega_m)t + \tfrac{\pi}{2}\big) \rightarrow (61)$$

This is the lower side band on the carrier frequency $(f_1 + f_0)$.

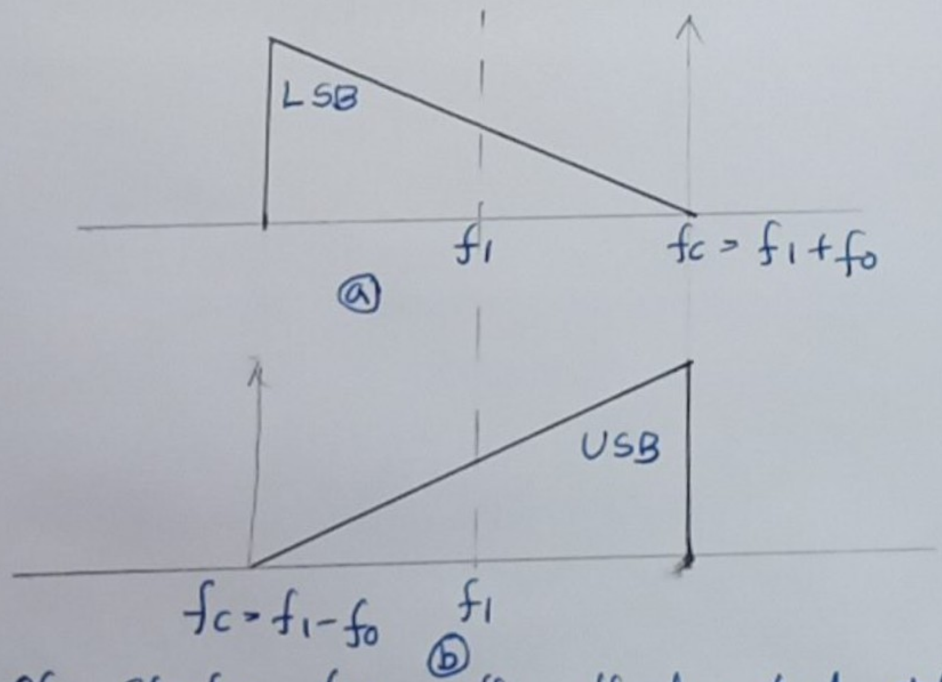


Fig o/p spectra for the third method ckt
(a) for LSB (b) for USB

→ SSB Reception

The received SSB signal is multiplied with a synchronous carrier and the result contains the original modulation signal as

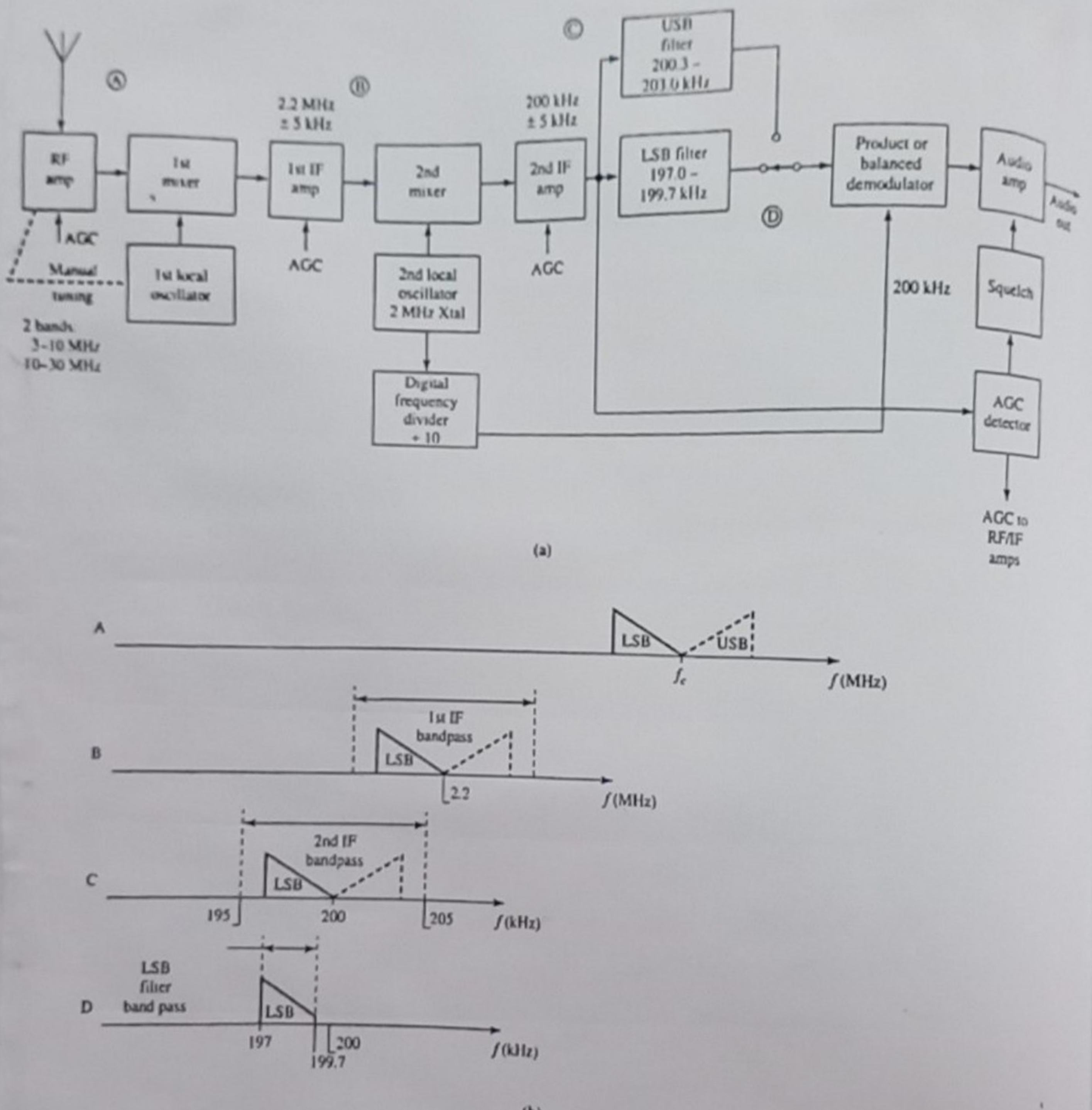


Figure 9.5.1 (a) Single-sideband HF receiver. (b) Spectra in the HF receiver for an LSB signal: Ⓐ, received RF signal; Ⓑ, output of first IF amp; Ⓒ, output of second IF amp; Ⓓ, output of LSB filter.

one component. Balanced or product modulators are used for demodulation. The carrier signal for the demodulator must be locally generated if the signals are true SSB signals with the carrier completely suppressed. This requires extreme stability for the local oscillator signals for demodulating and for the superheterodyne converters.

Double conversion is often used in SSB receivers. Since very good adjacent channel selectivity must be provided since SSB signals are usually packed closely together in the frequency spectrum.

The first local oscillator and RF amplifier are manually tuned in two switched bands. The output of second crystal oscillator is divided by 10 in a digital counter to provide the carrier signal for the demodulator.

The output from the detector is passed through a gated audio amplifier that turns off the output to keep the noise down when the signal level drops below a preset threshold. This is called squelch. The amplified IF signal is rectified to provide the AGC voltage for the RF and IF amplifiers and for the squelch circuit.

The 2^{nd} IF amplifier is followed by two filters, USB and LSB filters. USB filter passes IF upperside band and rejects the lower side band. The LSB filter passes IF lower side band. The approximate sideband is selected by a switch that connects the o/p of the desired filter to the product detector.

One of the largest application of this type of SSB is multichannel citizen's band (CB) transceivers.

- Comparision between Phase shift method and Filter method

	Parameter	Filter Method	Phase Shift Method
1.	Method of cancelling unwanted side band.	Using filter	Using balance modulator and 90° phase shifter.
2.	Use of low modulating frequency	Not possible	Possible
3.	Need of up-conversion	Needed	Not needed
4.	Need of linear amplifier	Needed	Needed
5.	Possibility of SSB generation at any frequency	Not possible	Possible

Angle Modulation

In angle modulation, the information signal may be used to vary the carrier frequency, giving rise to frequency modulation or it may be used to vary the angle of phase lead or lag giving rise to phase modulation. Since both frequency and phase are parameters of the carrier angle, which is a function of time, the general term angle modulation covers both. There are 2 types of angle modulation.

→ Frequency Modulation (FM)

The modulating signal $e_m(t)$ is used to vary the carrier frequency. The type of modulation in which the frequency of the carrier signal varies in accordance with the modulating or baseband signal is called FM.

→ Phase Modulation (PM)

Information signal may be used to vary the carrier angle of phase.

PM is that type of angle modulation in which the phase angle ϕ is varied linearly with a baseband or modulating signal $x(t)$ about an unmodulated phase angle $(\omega_c t + \theta_0)$. This means that in PM, the instantaneous value of the phase angle is equal to the phase angle of the unmodulated carrier $(\omega_c t + \theta_0)$ plus a time-varying component which is proportional to modulating signal $x(t)$.

Mathematical Representation

The unmodulated carrier signal is expressed as $c(t) = A\cos(\omega_c t + \theta_0) = A\cos\phi \longrightarrow (62)$

where $\phi = \omega_c t + \theta_0$

Neglecting θ_0, we get total phase angle of unmodulated carrier is

$$\phi = \omega_c t \longrightarrow (63)$$

Now, according to PM, this phase angle 'ϕ' is varied linearly with a baseband or modulating signal $x(t)$.

Let the instantaneous value of phase angle be denoted by ϕ_i

Therefore, $\phi_i = \omega_c t + k_p \cdot x(t) \longrightarrow (64)$

where k_p is the proportionality constant and is known as phase sensitivity of the modulator. This is expressed in radians/volts.

Since, the expression for unmodulated carrier wave is

$$c(t) = A\cos\phi \longrightarrow (65)$$

$\therefore$ The expression for phase modulated wave will be

$$s(t) = A\cos\phi_i \longrightarrow (66)$$

Putting the value of ϕ_i in eq^n 66 from eq^n 64, we get

$$s(t) = A\cos[\omega_c t + k_p \cdot x(t)] \longrightarrow (67)$$

This is the mathematical expression for a phase modulated wave.

→ Frequency Modulation (FM)

FM is the type of modulation in which frequency of the carrier is varied in accordance with the instantaneous amplitude of the modulating signal. In FM amplitude remains constant. The new instantaneous frequency of modulated wave is given by,

$$f_i(t) = f_c + k_f\, e_m(t) \longrightarrow (68)$$

or interms of ω

$$\omega_i = \omega_c + k_f \cdot x(t)$$

where $e_m(t)$ – message or modulating signal

ie $e_m(t) = E_m \cos\omega_m t$

f_c – frequency of unmodulated carrier.

k_f – frequency deviation constant in hertz/volt.

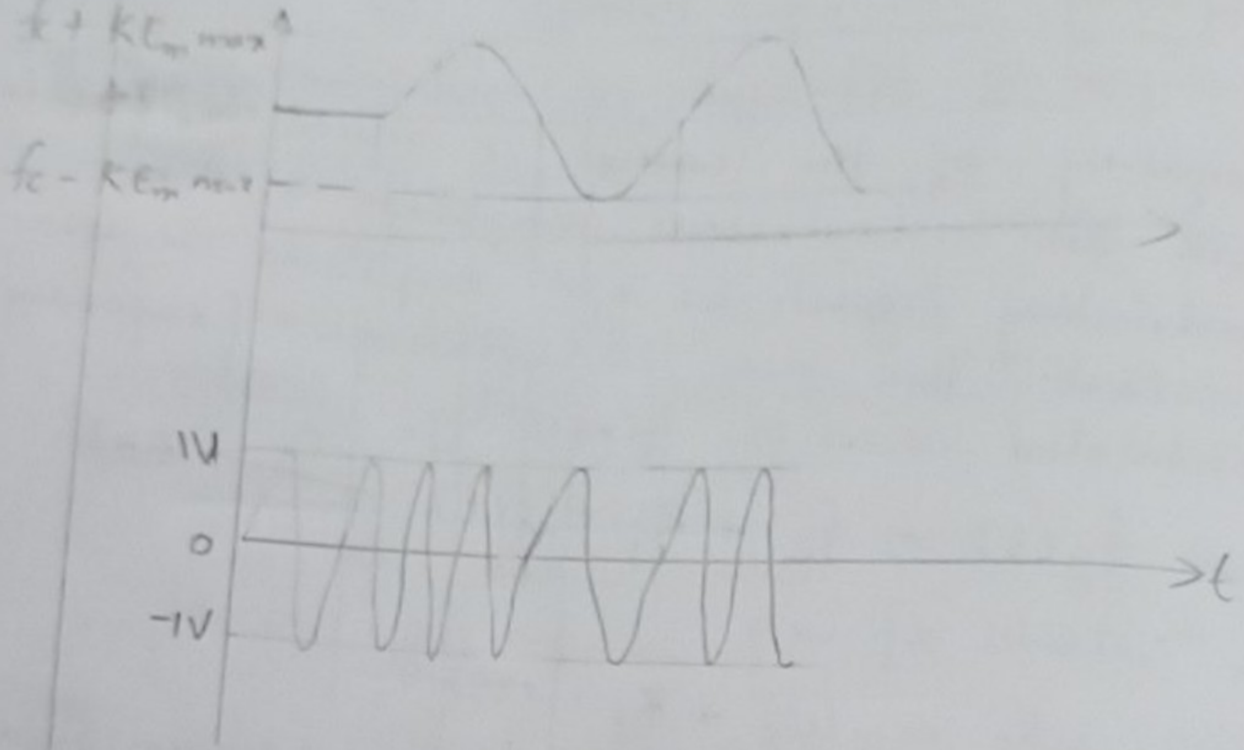
$$f_i(t) = f_c + k_f E_{m\,max} \cos 2\pi f_m t$$

$$= f_c + \Delta f \cos 2\pi f_m t \longrightarrow (69)$$

where the peak frequency deviation Δf is proportional to the peak modulating signal and is

$$\Delta f = kE_{m\,max} \quad \rightarrow (70)$$

The instantaneous frequency as a function of time is sketched in fig below.



- Modulation Index of FM

$$\beta = m_f = \frac{\text{Frequency deviation}}{\text{Modulating frequency}} = \frac{\Delta f}{f_m} \rightarrow (71)$$

For FM the modulation index is greater than 1 and hence the equation for the sinusoidally modulated wave becomes

$$e(t) = E_{c\,max} \cos\left(2\pi f_c t + \beta \sin 2\pi f_m t\right) \rightarrow (72)$$