Analog and Digital Communication

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Advantages and Disadvantages of Amplitude Modulation

Amplitude Modulation is easier to implement.	**When it comes to power usage it is not efficient.**
Demodulation can be done using few components and a circuit.	**It requires a very high bandwidth that is equivalent to that of the highest audio frequency.**
The receiver used for AM is very cheap.	**Noise interference is highly noticeable.**

Amplitude Modulation

Double Sideband Full Carrier Signal (DSBFC)

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

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

Transmission Power

$$P_t = P_c\left[1 + \frac{\mu^2}{2}\right]$$

Transmission Efficiency

$$\eta = \frac{P_{SB}}{P_t}$$

An Audio frequency signal 10sin 2π 500t is used to amplitude modulate a carrier of 50 sin $2\pi 10^5 t$. Assume modulation index =0.2 calculate A) Total Transmission power delivered to the load of 600Ω B) Carrier Power C) Sideband power D) Efficiency

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

Double Sideband Suppressed Carrier Signal (DSBSC)

If the carrier in AM system is suppressed and the saved power is distributed to the two sidebands, then such a process is called as **Double Sideband Suppressed Carrier** system

Equation of DSBSC

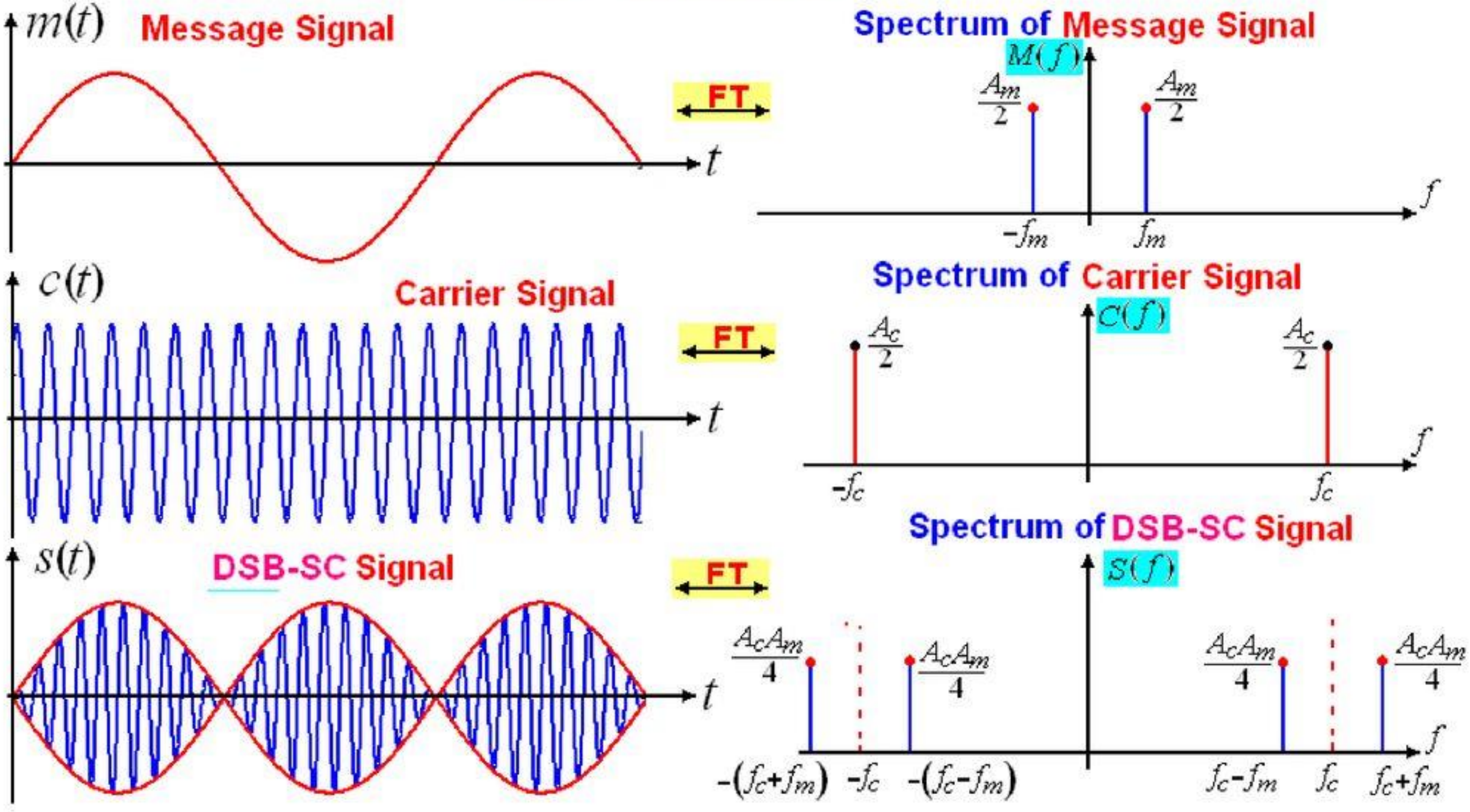
Bandwidth of DSBSC

Power Calculations of DSBSC

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

$$P = \frac{{v_{rms}}^2}{R} = \frac{\left(v_m\sqrt{2}\right)^2}{R}$$

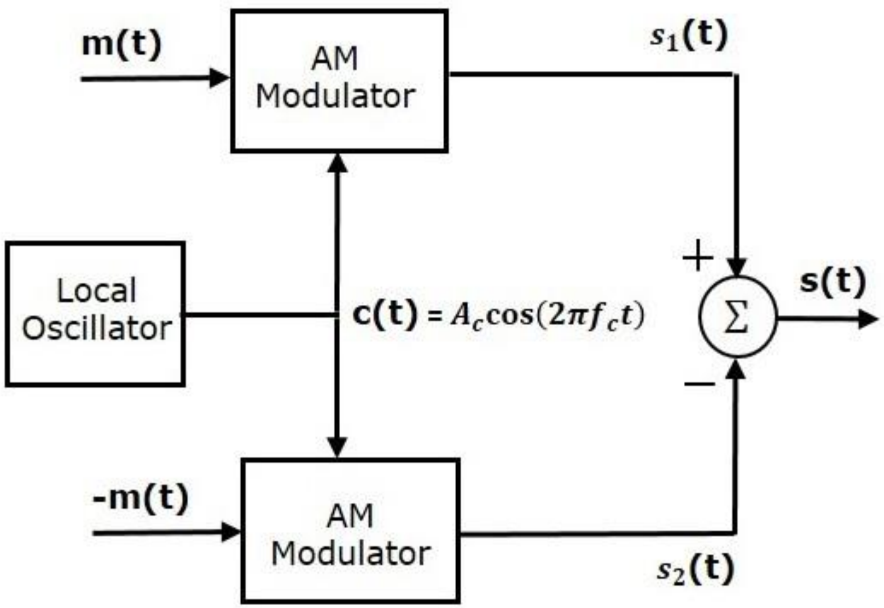
Single Tone DSB-SC Modulation and its Spectrum



Generation of DSB-SC Wave

Balanced Modulator

It consists of two identical AM modulators. These two modulators are arranged in a balanced configuration in order to suppress the carrier signal. Hence, it is called as Balanced modulator.



synchronous Detection

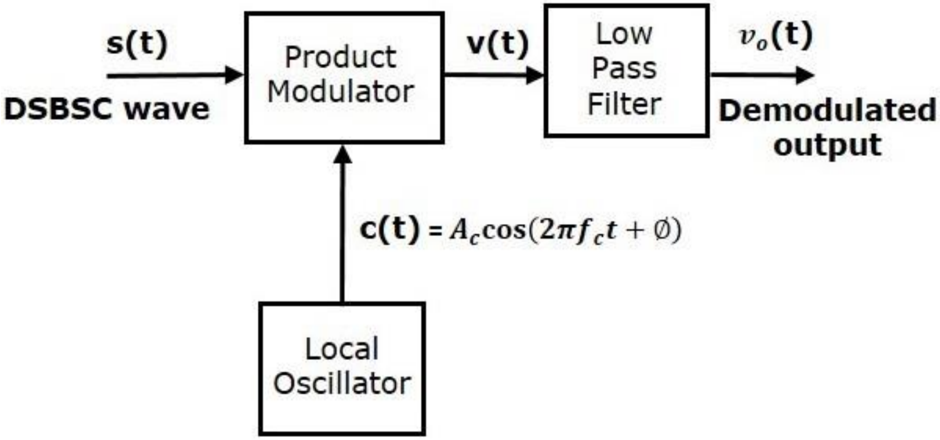
Here, the same carrier signal (which is used for generating DSBSC signal) is used to detect the message signal. Hence, this process of detection is called as **coherent** or **synchronous detection**.

$$s\left(t\right) = A_c \cos(2\pi f_c t) m\left(t\right)$$

$$c\left(t\right) = A_c \cos(2\pi f_c t + \phi)$$

$$v\left(t\right) = A_c \cos(2\pi f_c t) m\left(t\right) A_c \cos(2\pi f_c t + \phi)$$

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



$$v_0 t = \frac{{A_c}^2}{2} \cos\phi m\left(t\right)$$

Double Sideband Full Carrier Signal (DSB-FC) – AM Signal

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

Double Sideband Suppressed Carrier Signal (DSB-SC) – DSB Signal

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

Single Sideband Suppressed Carrier Signal (SSB-SC) – SSB Signal

Single Sideband Suppressed Carrier Signal (SSB-SC) – SSB Signal

The process of suppressing one of the sidebands along with the carrier and transmitting a single sideband is called as **Single Sideband Suppressed Carrier** system.

Bandwidth =fm

$$P_t = P_c \left[\frac{\mu^2}{4}\right]$$

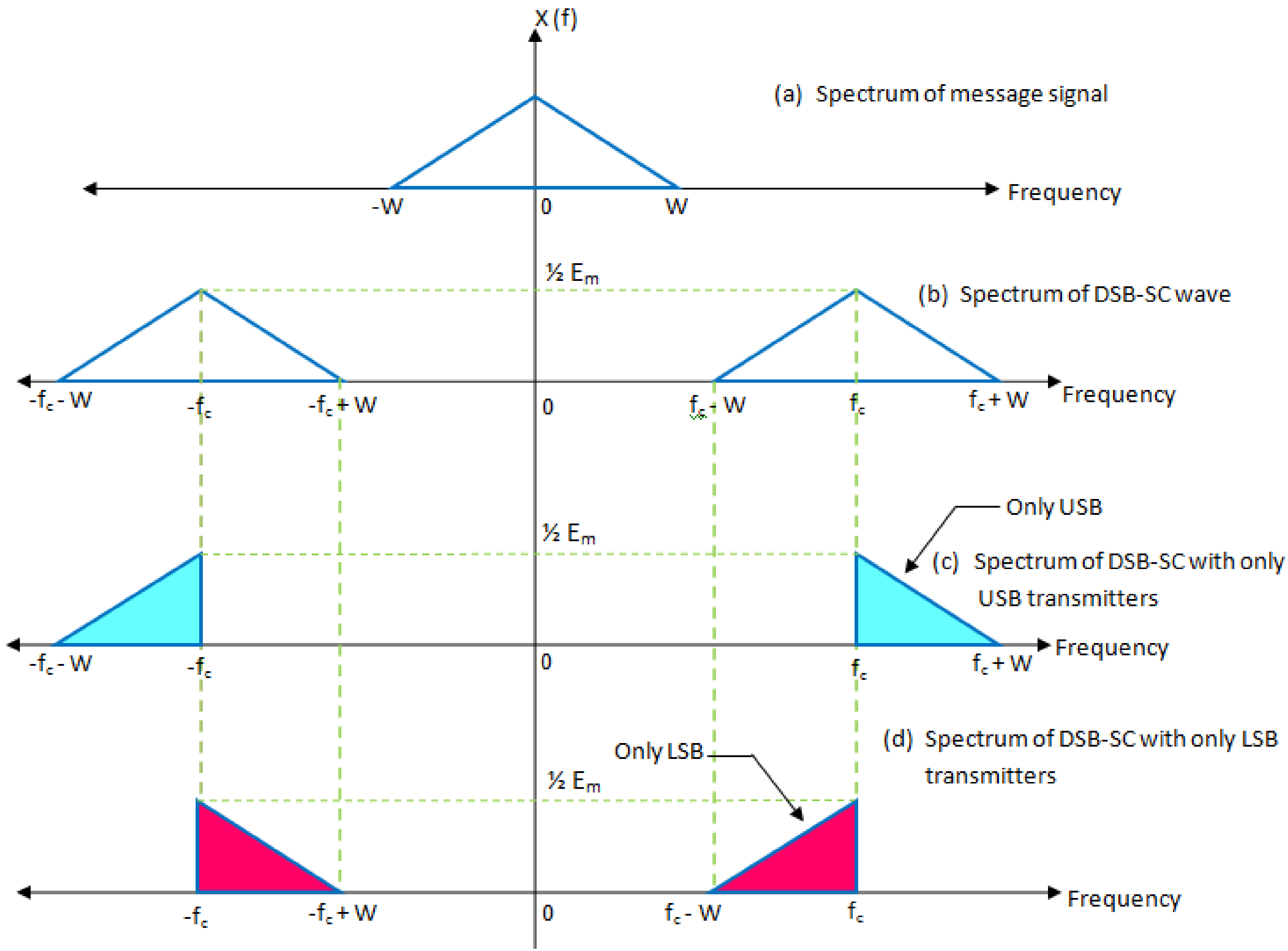
Single Sideband Suppressed Carrier Signal (SSB-SC) – SSB Signal

Advantages

- Bandwidth
- Power
- Lesser Noise

Applications

- Point to Point Communication
- Television
- Military Communication
- Radio Navigation


X (f)
(a) Spectrum of message signal
Frequency
-W
0
W
½ Em
(b) Spectrum of DSB-SC wave
-fc - W
-fc
-fc + W
0
fc - W
fc
fc + W
Frequency
Only USB
½ Em
(c) Spectrum of DSB-SC with only USB transmitters
-fc - W
-fc
0
fc
fc + W
Frequency
(d) Spectrum of DSB-SC with only LSB transmitters
Only LSB
½ Em
-fc
-fc + W
0
fc - W
fc
Frequency

Percentage of power saved in SSB

When Compared With AM System

$$\% \text{ Power Saved} = \frac{P_{AM} - P_{SSB}}{P_{AM}}$$

When Compared With DSB System

$$\% \text{ Power Saved} = \frac{P_{DSB} - P_{SSB}}{P_{DSB}}$$

An AM transmitter of 1kW power if fully modulated. Calculate the power transmitted if it is transmitted as SSB.

$$P_t = P_c\left[1 + \frac{\mu^2}{2}\right]$$

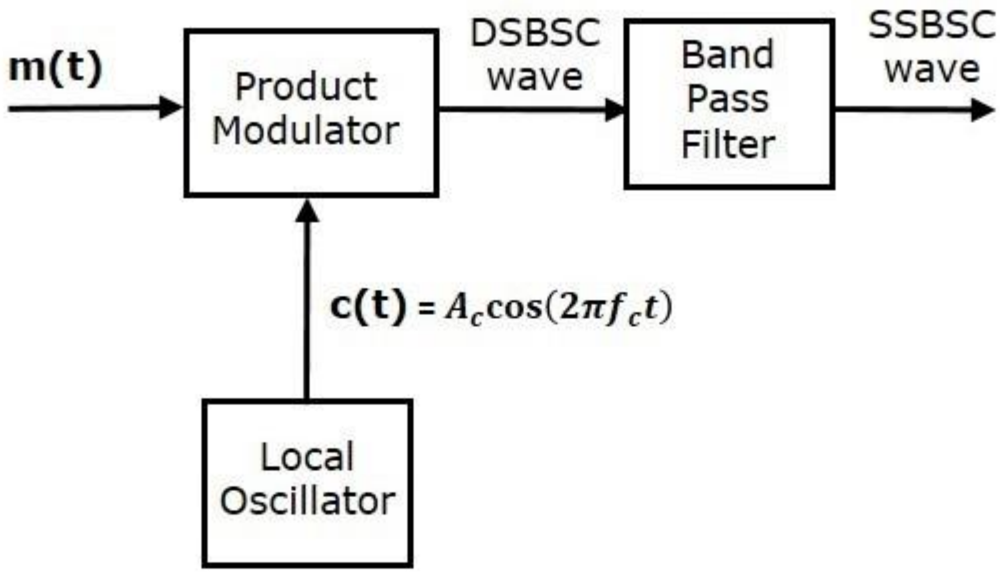
Calculate the percentage power saving when the carrier and one of the side bands are suppressed in AM wave modulated to a depth of a) 100% b) 50%

$$P_{AM} = P_c\left[1 + \frac{\mu^2}{2}\right]$$

$$\%\ \text{Power Saved} = \frac{P_{AM} - P_{SSB}}{P_{AM}}$$

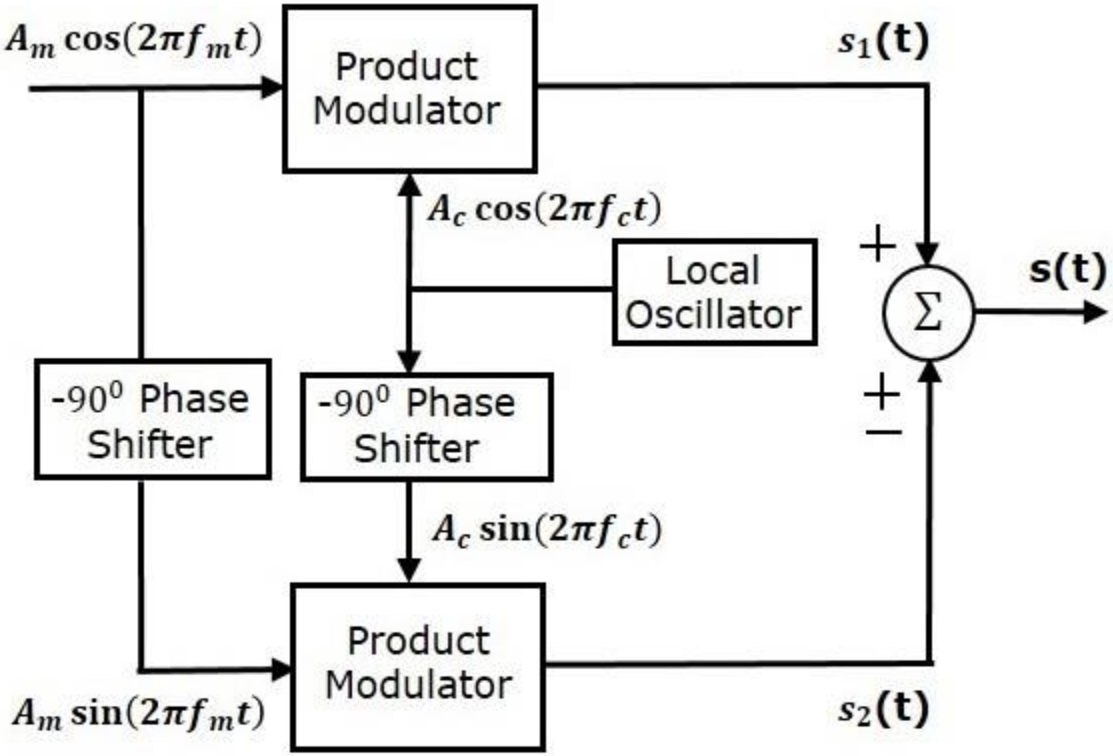
Generation of SSB wave

- Frequency Discrimination method

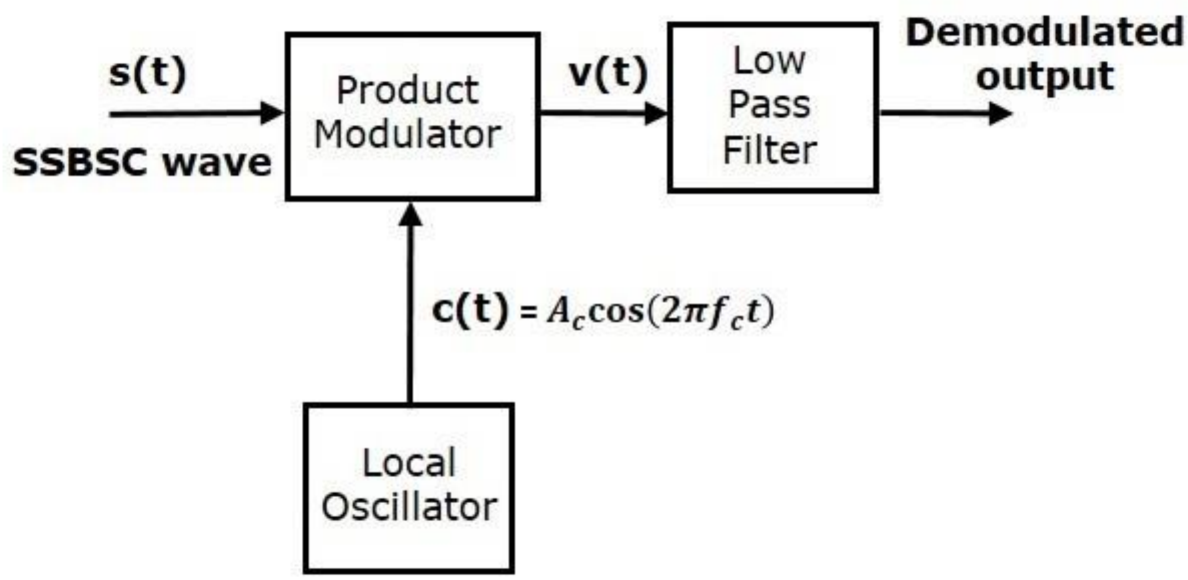


Generation of SSB wave

- SSB modulation by Phase shift

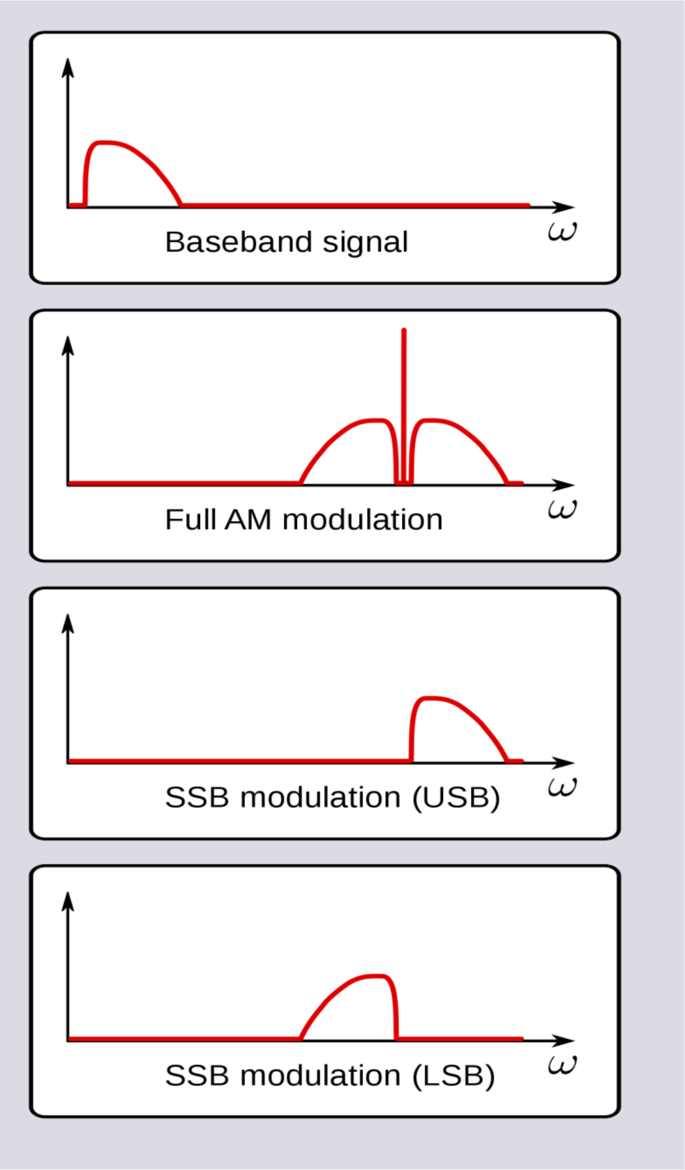


Demodulation of SSB wave



Disadvantages of SSB

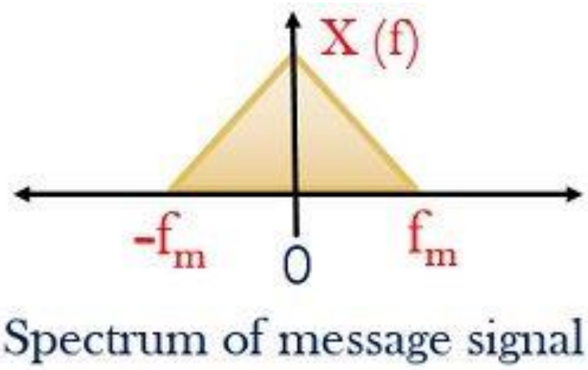
- The generation of SSB is **quite complex** as the suppression of one of the sidebands is difficult.
- The generation of SSB **requires sharp cut off** characteristics of the sideband suppression filter.
- SSB receivers require **more precise tuning than DSB**

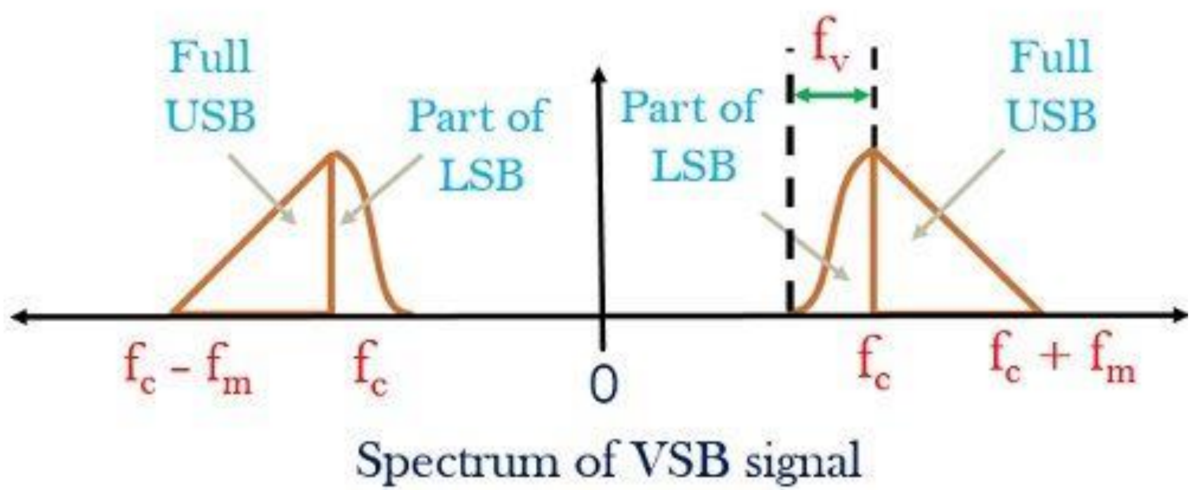


VSB Modulation

Vestigial Sideband Modulation or **VSB Modulation** is the process where a part of the signal called as **vestige** is modulated, along with one sideband.

Bandwidth= fm+fv





Comparison of Amplitude Modulation Techniques

Parameters	Standard AM	DSB-SC	SSB	VSB
Power	High	Medium	Less	Less than DSB-SC, Greater than SSB
Bandwidth	2fm	2fm	fm	fm<BW<2fm
Carrier Suppression	NO	YES	YES	NO
Sideband Suppression	No	No	One sided Completely	One sideband suppressed partly
Receiver Complexity	Simplex	Complex	Complex	Simplex
Application	Radio Communication	Point To Point Communication	Point To Point Comm (Long Distance)	Television Broadcasting

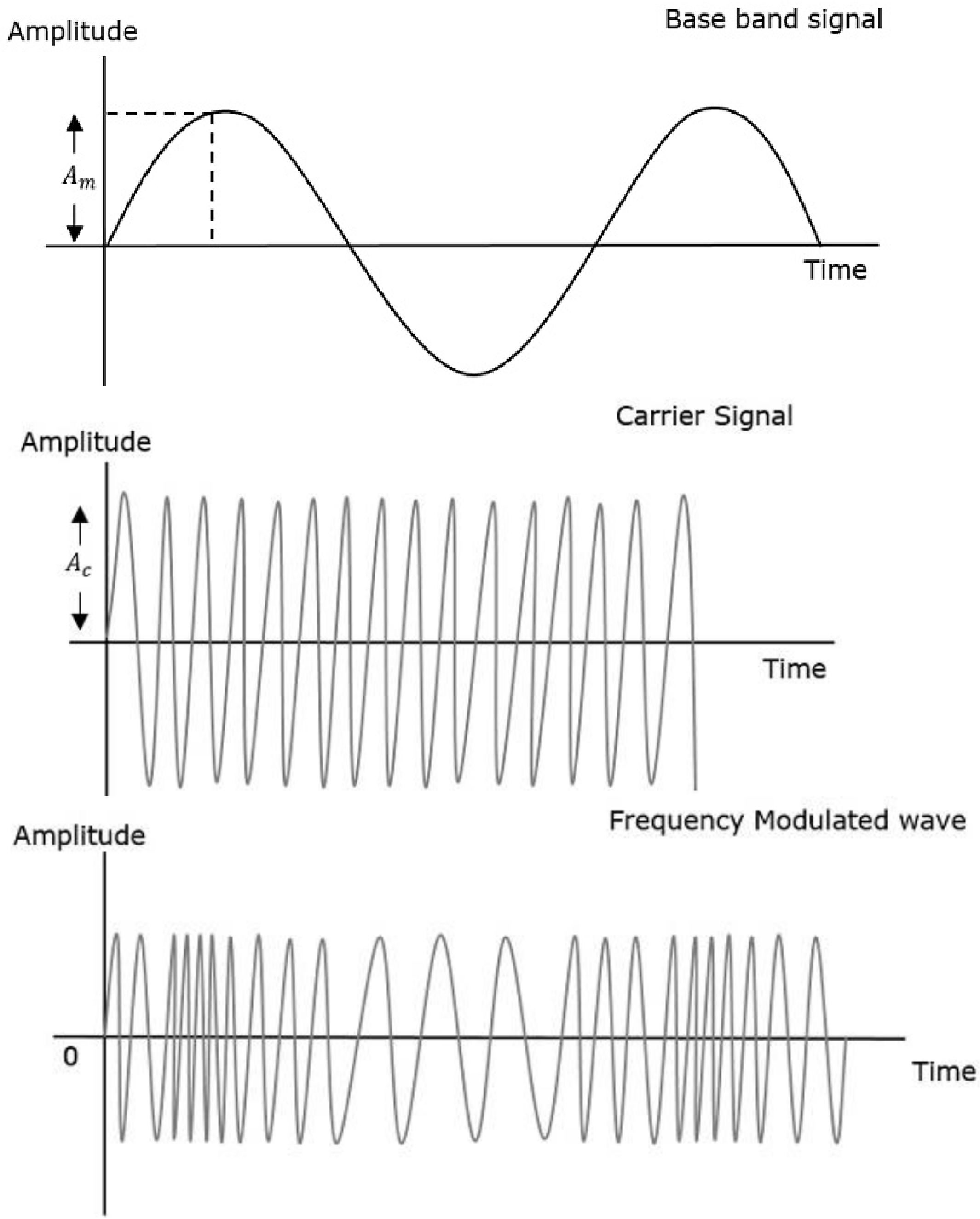
Angle Modulation

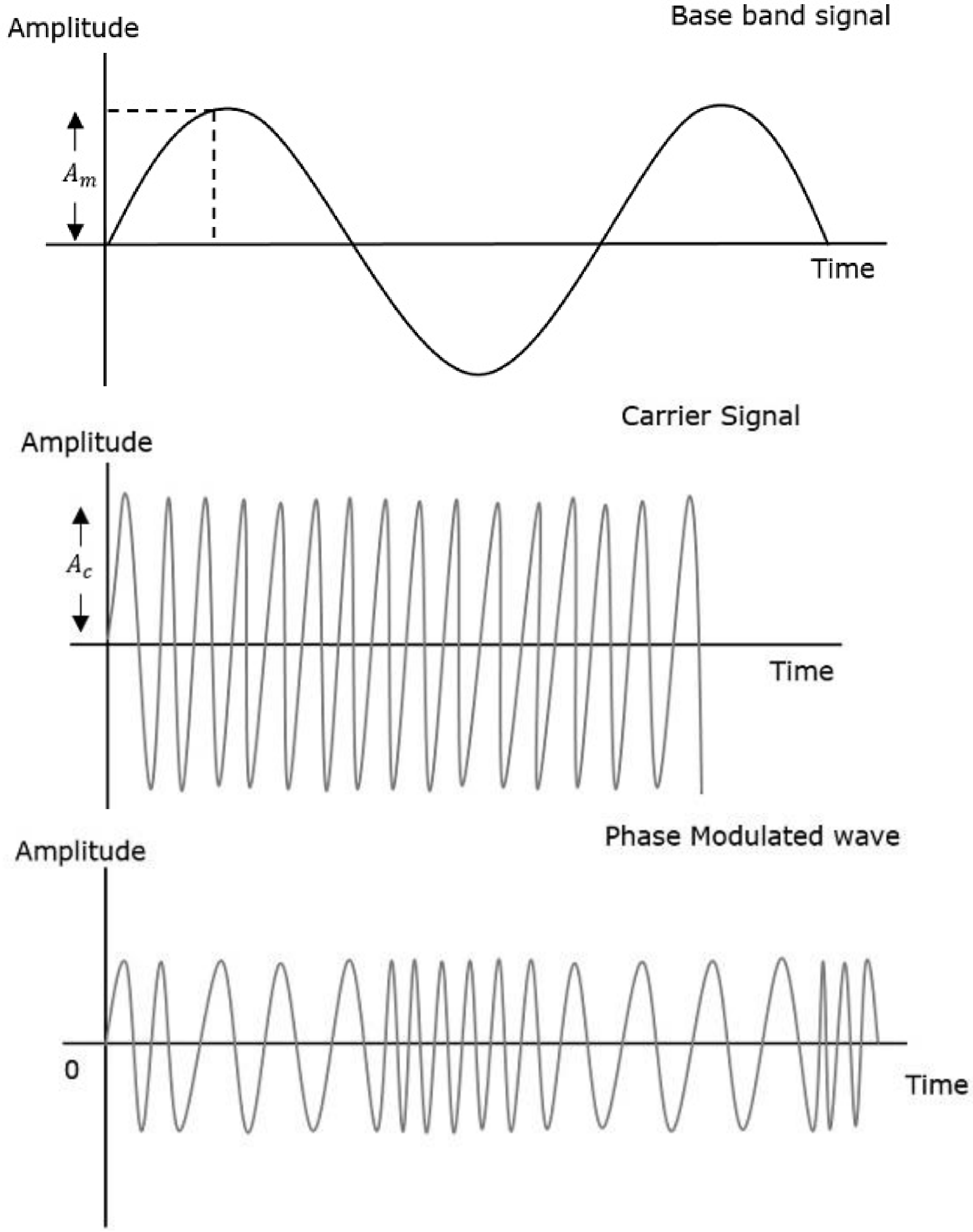
Angle Modulation is the process in which the frequency or the phase of the carrier varies according to the message signal.

$$S(t) = A_c \cos(W_c t + \varphi_c)$$

1. **Frequency Modulation** is the process of varying the frequency of the carrier signal linearly with the message signal.

2. **Phase Modulation** is the process of varying the phase of the carrier signal linearly with the message signal.


Amplitude
Base band signal
A_m
Time
Carrier Signal
Amplitude
A_c
Time
Frequency Modulated wave
Amplitude
0
Time

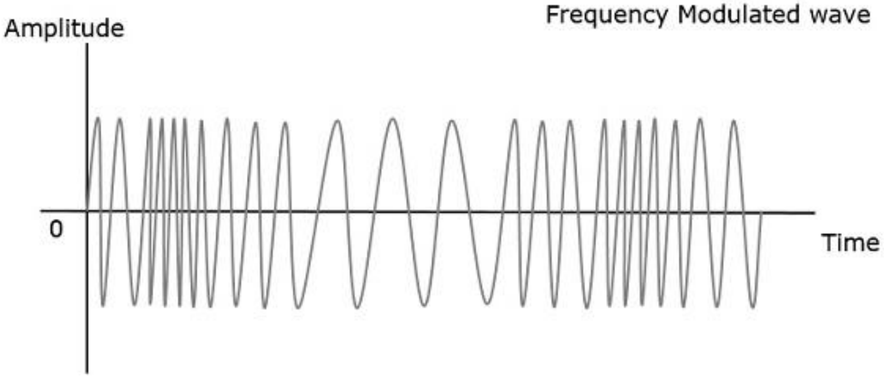

Amplitude
Base band signal
A_m
Time
Carrier Signal
Amplitude
A_c
Time
Amplitude
Phase Modulated wave
0
Time

Frequency Modulation

carrier frequency =$\mathbf{f_c}$

The frequency at maximum amplitude of the message signal = $\mathbf{f_c + \Delta f}$

The frequency at minimum amplitude of the message signal = $\mathbf{f_c - \Delta f}$



Frequency Deviation (Δf)=

FM modulated frequency -Normal frequency

Carrier Swing=The deviation of the frequency of the carrier signal from high to low or low to high

Carrier Swing = 2 × frequency deviation

= $\mathbf{2 \times \Delta f}$

Message Signal

$$m(t) = A_m Cos\, W_m t$$

Carrier Signal

$$C(t) = A_c Cos\, W_C t$$

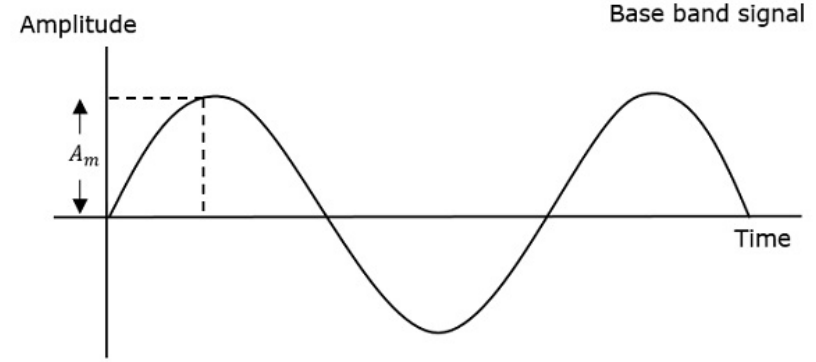
FM modulated Signal

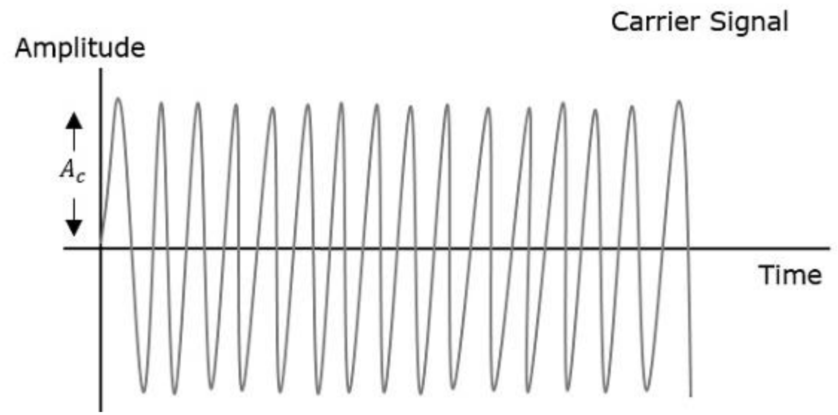
$$S(t) = A_c Cos\, (\theta)$$

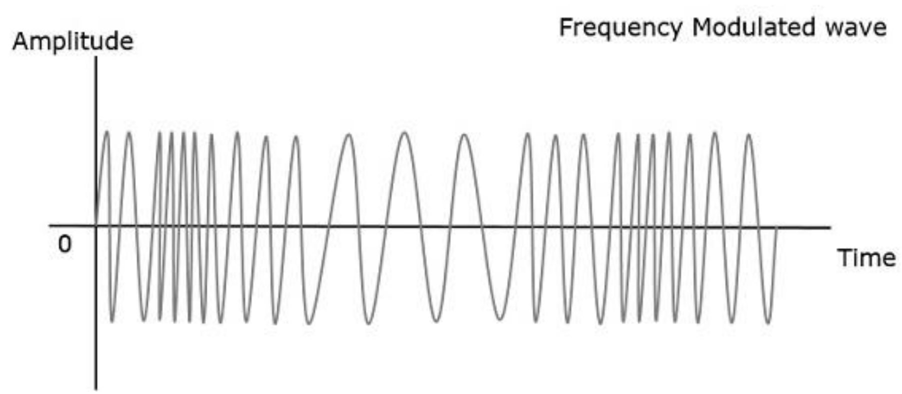
Instantaneous frequency

$$f_i(t) = f_c + k_f m(t)$$

k_f =**Frequency sensitivity**







$$S(t) = A_c Cos\,(\theta)$$

Instantaneous frequency $f_i(t) = f_c + k_f m(t)$

$$f_i(t) = \frac{1}{2\pi}\frac{d\theta}{dt} \qquad \theta(t) = \int 2\pi f_i(t)dt$$

$$S(t) = A_c Cos\left[2\pi f_c t + 2\pi k_f \int m(t)dt\right]$$

$$S(t) = A_c Cos\left[2\pi f_c t + 2\pi k_f \int m(t)dt\right]$$

$$m(t) = A_m Cos\, W_m t$$

$$S(t) = A_c Cos\left[2\pi f_c t + \frac{A_m k_f}{f_m}\, Sin\,(2\pi f_m t)\right]$$

$$S(t) = A_c Cos[2\pi f_c t + \beta\, Sin\,(2\pi f_m t)]$$

Modulation Index

$$\beta = \frac{A_m k_f}{f_m}$$

Modulation Index

$$\beta = \frac{A_m k_f}{f_m} = \frac{\Delta f}{f_m}$$

Frequency Deviation

$$\Delta f = A_m k_f$$

Carrier Swing = 2 × frequency deviation
= 2 × Δf

$$S(t) = A_c Cos\left[2\pi f_c t + 2\pi k_f \int m(t)dt\right] \quad S(t) = A_c Cos[2\pi f_c t + \beta\ Sin\ (2\pi f_m t)]$$

Narrow Band FM $\beta<1$ **, BW=** $2f_m$

Wide Band FM $\beta>1$**, BW =** $2(\beta+1)f_m$

A tone modulated FM signal is given by

$$\Phi_{FM}(t) = 4\cos(2\pi 10^6 t + 2\sin(2\pi 10^3 t)).$$

(1) What is the bandwidth of the FM signal in kHz?

(2) What is the power of the FM signal?

Frequency Modulation

$$S(t) = A_c Cos[2\pi f_c t + \beta \, Sin\,(2\pi f_m t)]$$

$$S(t) = A_c Cos\left[2\pi f_c t + 2\pi k_f \int m(t)dt\right]$$

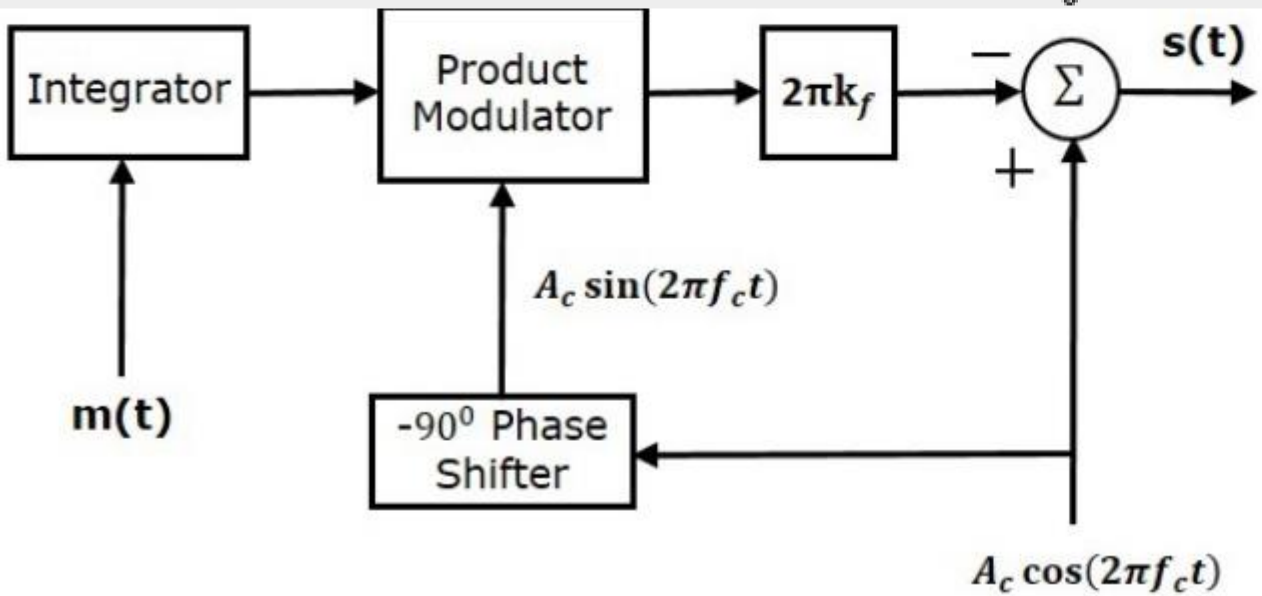
$$s\,(t) = A_c \cos(2\pi f_c t)\cos(2\pi k_f \int m\,(t)\,dt) - A_c \sin(2\pi f_c t)\sin(2\pi k_f \int m\,(t)\,dt)$$

For NBFM

$$\left|2\pi k_f \int m\,(t)\,dt\right| << 1$$

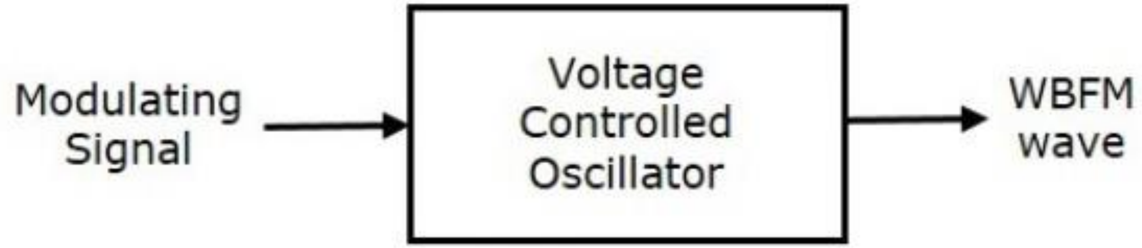
NBFM equation

$$s\,(t) = A_c \cos(2\pi f_c t) - A_c \sin(2\pi f_c t) 2\pi k_f \int m\,(t)\,dt$$

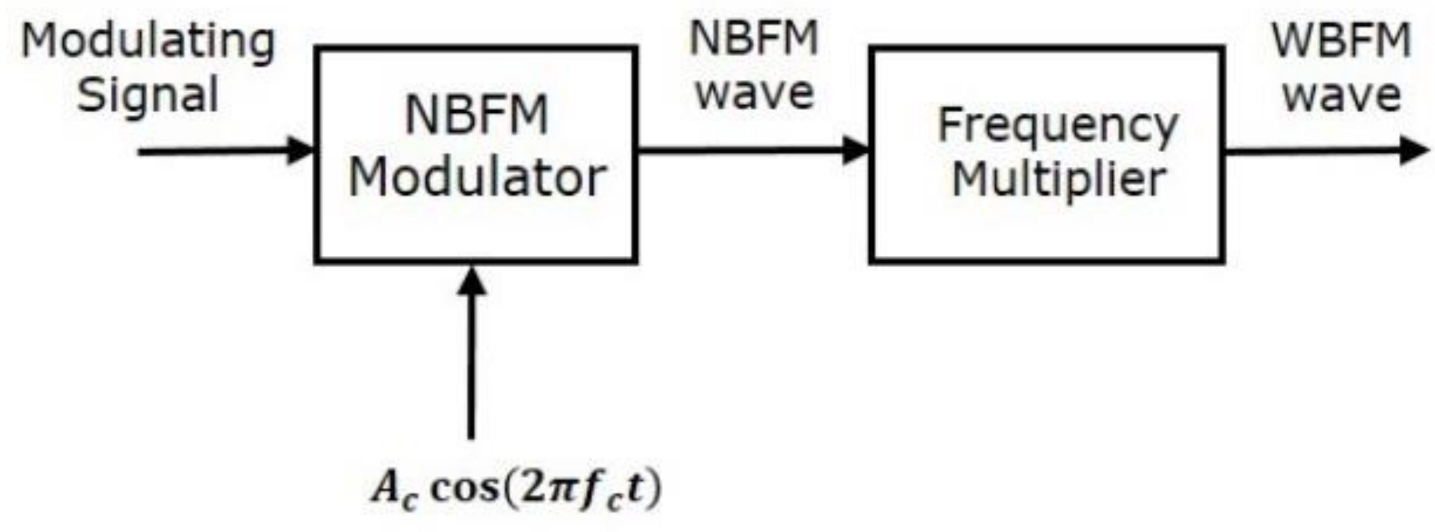


Generation of WBFM

Direct method



Indirect method



Phase Modulation

In frequency modulation, the frequency of the carrier varies. Whereas, in **Phase Modulation (PM)**, the phase of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.

Instantaneous phase

$$\phi_i = k_p m(t)$$

k_p is the phase sensitivity

$m(t)$ is the message signal

$$s(t) = A_c \cos(2\pi f_c t + \phi_i)$$

$$s(t) = A_c \cos(2\pi f_c t + \phi_i)$$

$$\phi_i = k_p m(t)$$

$$s(t) = A_c \cos(2\pi f_c t + \beta \cos(2\pi f_m t))$$

β = ***modulation index*** = $\Delta\phi = k_p A_m$

$\Delta\phi$ is phase deviation

Q.1. In PM the information is transmitted using ______ .

a. Change in frequency b. Change in amplitude c. Change in phase of the carrier

Q.2. With change in modulating frequency (fm), the modulation index mp of a phase modulated signal will ______.

a. increase b. decrease c. remain constant

Amplitude of PM wave ______

a. remain constant

b. change in proportion with the modulating voltage

c. change in proportion with the modulating frequency