Sri SAI RAM ENGINEERING COLLEGE
INSTITUTE OF TECHNOLOGY
West Tambaram, Chennai - 44

Sairam INSTITUTIONS

SAIRAM DIGITAL RESOURCES

YEAR II

SEM III

EC8394

ANALOG AND DIGITAL COMMUNICATION

UNIT NO 1

ANALOG COMMUNICATION

1.4:THEORY OF FREQUENCY AND PHASE MODULATION

ELECTRONICS & COMMUNICATION ENGINEERING

4 QUALITY EDUCATION

ANGLE MODULATION

FREQUENCY MODULATION(FM)

Frequency of the carrier is varied in accordance with message signal

PHASE MODULATION(PM)

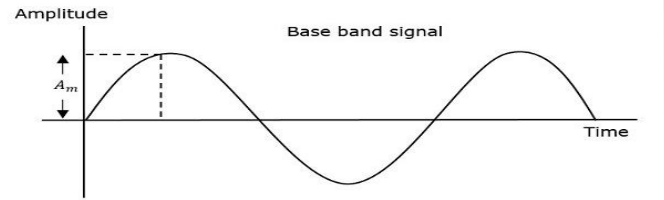
Phase angle of the carrier is varied in accordance with message signal

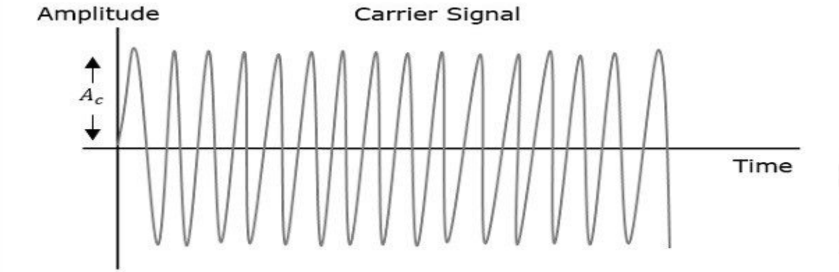
- Frequency modulation as well as phase modulation are forms of angle modulation .
- Angle modulation has several advantages over the amplitude modulation such as noise reduction, improved system fidelity and more efficient use of power.
- The standard equation of the angle modulated wave is $s(t)=A_c\cos\theta_i(t)$
- Where, A_c is the amplitude of the modulated wave, which is the same as the amplitude of the carrier signal
- $\theta_i(t)$ is the angle of the modulated wave

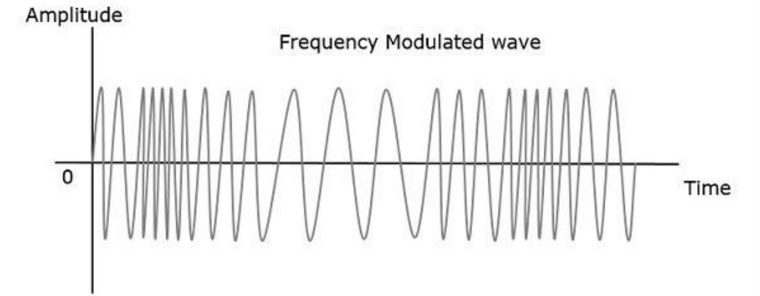
Angle modulation may be defined as the process in which the total phase angle of a carrier wave is varied in accordance with the instantaneous value of the modulating or message signal, while amplitude of the carrier remain unchanged.
Let the carrier signal be expressed as:
c(t) = ACos(2π fc t+θ)
Where 2 f t c φ = π +θ → Total phase angle
θ → phase offset

$f_c \rightarrow$ carrier frequency

So So in-order to modulate the total phase angle according to the baseband signal, it can be done by either changing the instantaneous carrier frequencyor by changing the instantaneous phase offset angle .


Amplitude
Base band signal
A_m
Time


Amplitude
Carrier Signal
A_c
Time


Amplitude
Frequency Modulated wave
0
Time

Angle modulation

- Introduction
- What is angle modulation?
- What is the difference between amplitude and angle modulation?
- A sinusoidal carrier signal is given as $e_c = E_c \sin\left[\theta_c(t)\right]$

e_c = Instantaneous amplitude of the carrier signal

- E_c = Amplitude of carrier signal

$\theta_c(t)$ = Total phase angle of the carrier signal at a time instant, t

$$\omega_c = 2\pi f_c$$

- With reference to the carrier signal given by eqn assume that

Angle modulation

- The angular frequency is defined as the Rate of change of the total phase angle with respect to time . $\omega_c = \frac{d\theta_c(t)}{dt}$

$$\int_0^t \omega_c \, dt + \phi_0 = \int_0^t \frac{d\theta_c(t)}{dt} dt$$

- les

$$\theta_c(t) = \int_0^t \omega_c \, dt + \phi_0 \qquad \theta_c(t) = \omega_c t + \phi_0$$

$$e_c = E_c \sin(\omega_c t + \phi_0) \qquad e_c = E_c \sin(2\pi f_c t + \phi_0)$$

- Substituting in the 1st eqn e_c

Mathematical analysis:

- **Instantaneous phase deviation** (ϕ) **:** instantaneous change in the phase of the carrier at a given instant of time. It indicated how much the phase of the carrier is changing with respect to its reference phase.
- **Instantaneous phase** $\theta(t)$**:** precise phase of the carrier at a given instant of time.
- **Instantaneous frequency deviation** $\theta'(t)$**:** instantaneous change in the frequency of the carrier at a given instant of time. It is the first derivative of the instantaneous phase deviation.
- **Instantaneous frequency**(ωi) **:** precise frequency of the carrier at a given instant of time.

$$(\omega i(t)) = \frac{d}{dt}\phi(t) = \frac{d}{dt}[\omega c(t) + \theta(t)] = \omega c + \theta'(t)$$

$\theta'(t)$

Equation of an F.M wave

- Consider a modulating signal e_m given by equation which modulates the frequency of the carrier signal e_c as given by the eqn

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

$$e = E_c \sin \phi_i$$

$$e_c = E_c \sin \omega_c t$$

- The eqn of an FM signal is given as

$$\omega_i = \frac{d\phi_i}{dt}$$

- Integrating both sides of eqn
- Then the instantaneous freq and the instantaneous phase can be related

$$\phi_i = \int_0^t \omega_i \, dt$$

Equation of an F.M wave

- The instantaneous angular frequency is given by

$$\omega_i = \omega_c + k_f e_m \qquad \omega_i = \omega_c + k_f E_m \cos \omega_m t$$

- Substituting the eqn for e_m

$$\phi_i = \int_0^t \left[\omega_c + k_f E_m \cos \omega_m t\right] dt$$

- The instantaneous phase of the FM signal is obtained by substituting instantaneous freq in instantaneous phase

$$\phi_i = \omega_c t + k_f \frac{E_m}{\omega_m} \sin \omega_m t + \phi_1$$

Equation of an F.M wave

- The final expression of an FM wave is obtained by substituting instantaneous phase eqn in the eqn of e to obtain eqn of FM signal

$$e = E_c \sin \phi_i$$

$$e = E_c \sin\left[\omega_c t + k_f \frac{E_m}{\omega_m} \sin \omega_m t\right]$$

- which can be rewritten as

$$e = E_c \sin\left[2\pi f_c t + k_f \frac{E_m}{2\pi f_m} \sin 2\pi f_m\right]$$

Frequency deviation

- We know that the instantaneous angular frequency is given as

$$\omega_i = \omega_c + k_f E_m \cos \omega_m t$$

$$2\pi f_i = 2\pi f_c + k_f E_m \cos \omega_m t$$

- This eqn can be rewritten as

$$f_i = f_c + \frac{k_f E_m}{2\pi} \cos \omega_m t$$

- The frequency deviation in an unmodulated carrier frequency fc is given by

$$\frac{k_f E_m}{2\pi} \cos \omega_m t$$

Frequency deviation

- The freq deviation is defined as

$$f_i = f_c + f_d \cos \omega_m t$$

$$f_D = f_d \cos \omega_m t$$

$$f_d = \frac{k_f E_m}{2\pi}$$

- Substituting the above eqn in the instantaneous freq eqn

$$f_{i\,(\max)} = f_c + f_d; \quad \text{when } \cos \omega_m t = +1$$

$$f_{i\,(\min)} = f_c - f_d; \quad \text{when } \cos \omega_m t = -1$$

- The limiting frequency of an FM wave is obtained as
- The maximum freq deviation is positive when the positive peak amplitude of the modulating signal occurs
- The maximum freq deviation is negative when the negative peak amplitude of the modulating signal occurs

Modulation index

- Substituting the definition of freq deviation in the FM eqn obtained

$$e = E_c \sin\left[2\pi f_c t + k_f \frac{E_m}{2\pi f_m} \sin 2\pi f_m\right]$$

$$e = E_c \sin\left[2\pi f_c t + \frac{f_d}{f_m} \sin \omega_m t\right]$$

- Where the modulation index mf $m_f = \frac{f_d}{f_m}$

- from this eqn the freq deviation is given as $f_d = m_f f_m$

FM eqn is $e = E_c \sin\left[\omega_c t + m_f \sin \omega_m t\right]$

Deviation ratio

- The deviation ratio is given by the eqn

$$\text{Deviation Ratio, } D_f = \frac{\text{Maximum permissible frequency deviation}}{\text{Highest modulating frequency}}$$

$$D_f = \frac{\Delta f}{W}$$

$$m_f = \frac{f_d}{f_m}$$

Cont…

- PERCENTAGE MODULATION

  The percentage modulation is defined as the ratio of the actual frequency deviation produced by the modulating signal to the maximum allowable frequency deviation in percentage form

DEVIATION RATIO.

- Deviation ratio is a ratio of maximum peak frequency deviation divided by the maximum modulating signal freq

$$\boxed{DR = \frac{\Delta f_{(max)}}{f_{m(max)}}}$$

$$\text{Deviation Ratio (DR)} = \frac{\text{Maximum peak frequency deviation (hertz)}}{\text{Maximum modulating signal frequency (hertz)}}$$

Frequency spectrum of an fm system

- Thus the final expression obtained in FM $e = E_c \sin\left(\omega_c t + m_f \sin \omega_m t\right)$
- Substituting Ec=1 in the above eqn we get

$$e = \sin\left(\omega_c t + m_f \sin \omega_m t\right)$$

- This eqn can be expanded as below using the trigonometric ident $\sin(A + B) = \sin A \cos B + \cos A \sin B$

$$A = \omega_c t$$

$$B = m_f \sin \omega_m t$$

$$e = \underbrace{\sin \omega_c t \cos\left(m_f \sin \omega_m t\right)}_{\text{Constituent I}} + \underbrace{\cos \omega_c t \sin\left(m_f \sin \omega_m t\right)}_{\text{Constituent II}}$$

$$\text{Constituent I} = \sin \omega_c t \cos\left(m_f \sin \omega_m t\right)$$

$$\text{Constituent II} = \cos \omega_c t \sin\left(m_f \sin \omega_m t\right)$$

FM&PM (Bessel function)

Thus, for general equation:

$$v_{FM}(t) = V_C \cos(\omega_C t + m_f \cos\omega_m t)$$

$$\cos(\alpha + m\cos\beta) = \sum_{n=-\infty}^{\infty} J_n(m)\cos\left(\alpha + n\beta + \frac{n\pi}{2}\right)$$

$$m(t) = V_C \sum_{n=-\infty}^{\infty} J_n(m)\cos\left(\omega_c t + n\omega_m t + \frac{n\pi}{2}\right)$$

$$v(t)_{FM} = V_C\{J_0(m_f)\cos\omega_C t + J_1(m_f)\cos\left[(\omega_C+\omega_m)t + \frac{\pi}{2}\right] - J_1(m_f)\cos\left[(\omega_C-\omega_m)t - \frac{\pi}{2}\right]$$
$$+ J_2(m_f)\cos[(\omega_C + 2\omega_m)t] + J_2(m_f)\cos[(\omega_C - 2\omega_m)t] + \ldots J_n(m_f)\ldots\}$$

It is seen that each pair of side band is preceded by **J** coefficients. The order of the coefficient is denoted by subscript m. The Bessel function can be written as

$$J_n(m_f) = \left(\frac{m_f}{2}\right)^n \left[\frac{1}{n} - \frac{(m_f/2)^2}{1!(n+1)!} + \frac{(m_f/2)^4}{2!(n+2)!} - \ldots\right]$$

n = number of the side frequency

m_f = modulation index

Frequency spectrum of an fm system

- The two constituents obtained are

$$\text{Constituent I} = \sin \omega_c t \cos (m_f \sin \omega_m t)$$
$$\text{Constituent II} = \cos \omega_c t \sin (m_f \sin \omega_m t)$$

- Consider the factor of constituent 1. Expand using Fourier series

$$\cos (m_f \sin \omega_m t) = J_0(m_f) + 2J_2(m_f)\cos 2\omega_m t + 2J_4(m_f)\cos 4\omega_m t + \dots + 2J_{2n}(m_f)\sin 2n\omega_m t + \dots$$

- Consider the factor of constituent 2. Expand using Fourier series

$$\sin(m_f \sin \omega_m t) = 2J_1(m_f)\sin \omega_m t + 2J_3(m_f)\sin 3\omega_m t + \dots + 2J_{2n-1}(m_f)\sin(2n-1)\omega_m t + \dots$$

Frequency spectrum of an fm system

- Substitute the expanded eqn in the corresponding constituent 1 and 2

$$\text{Constituent I} = \sin\omega_c t \begin{bmatrix} J_0(m_f) + 2J_2(m_f)\cos 2\omega_m t + 2J_4(m_f)\cos 4\omega_m t + \ldots. \\ + 2J_{2n}(m_f)\cos 2n\omega_m t + \ldots \end{bmatrix}$$

$$\text{Constituent I} = J_0(m_f)\sin\omega_c t + 2J_2(m_f)\left[\sin\omega_c t \cdot \cos 2\omega_m t\right] + 2J_4(m_f)\left[\sin\omega_c t \cdot \cos 4\omega_m t\right] + \ldots. + 2J_{2n}(m_f)\left[\sin\omega_c t \cdot \cos 2n\omega_m t\right] + \ldots$$

$$\text{Constituent I} = J_0(m_f)\sin\omega_c t + 2J_2(m_f)\left[\sin\omega_c t \cdot \cos 2\omega_m t\right] + 2J_4(m_f)\left[\sin\omega_c t \cdot \cos 4\omega_m t\right] + \ldots. + 2J_{2n}(m_f)\left[\sin\omega_c t \cdot \cos 2n\omega_m t\right] + \ldots$$

- The above obtained eqn can be further expanded using the trignometric identity

Frequency spectrum of an fm system

- Similarly for constituent 2

$$\text{Constituent II} = 2J_1(m_f)\cos\omega_c t\sin\omega_m t + 2J_3(m_f)\cos\omega_c t\sin 3\omega_m t + \dots + 2J_{2n-1}(m_f)\cos\omega_c t\sin(2n-1)\omega_m t + \dots$$

- Can be further expanded using the trignometric identity

$$\text{Constituent II} = 2J_1(m_f)\left[\frac{1}{2}\sin(\omega_c+\omega_m)t - \frac{1}{2}\sin(\omega_c-\omega_m)t\right] + 2J_3(m_f)\left[\frac{1}{2}\sin(\omega_c+3\omega_m)t - \frac{1}{2}\sin(\omega_c-3\omega_m)t\right] + \dots + 2J_{2n-1}(m_f)\left[\frac{1}{2}\sin(\omega_c+(2n-1)\omega_m)t - \frac{1}{2}\sin(\omega_c-(2n-1)\omega_m t)\right] + \dots$$

Frequency spectrum of an fm system

- By substituting constituent 1 and 2

$$
\begin{aligned}
e = {} & J_0(m_f)\sin\omega_c t + J_1(m_f)[\sin(\omega_c+\omega_m)t - \sin(\omega_c-\omega_m)t] \\
& + J_2(m_f)[\sin(\omega_c+2\omega_m)t + \sin(\omega_c-2\omega_m)t] \\
& + J_3(m_f)[\sin(\omega_c+3\omega_m)t - \sin(\omega_c-3\omega_m)t] \\
& + J_4(m_f)[\sin(\omega_c+4\omega_m)t + \sin(\omega_c+4\omega_m)t] \\
& + \ldots \\
& + J_{2n-1}(m_f)[\sin(\omega_c+(2n-1)\omega_m)t - \sin(\omega_c-(2n-1)\omega_m)t] \\
& + J_{2n}(m_f)[\sin(\omega_c+2n\omega_m)t + \sin(\omega_c-2n\omega_m)t] \\
& + \ldots
\end{aligned}
$$

Frequency spectrum of an fm system

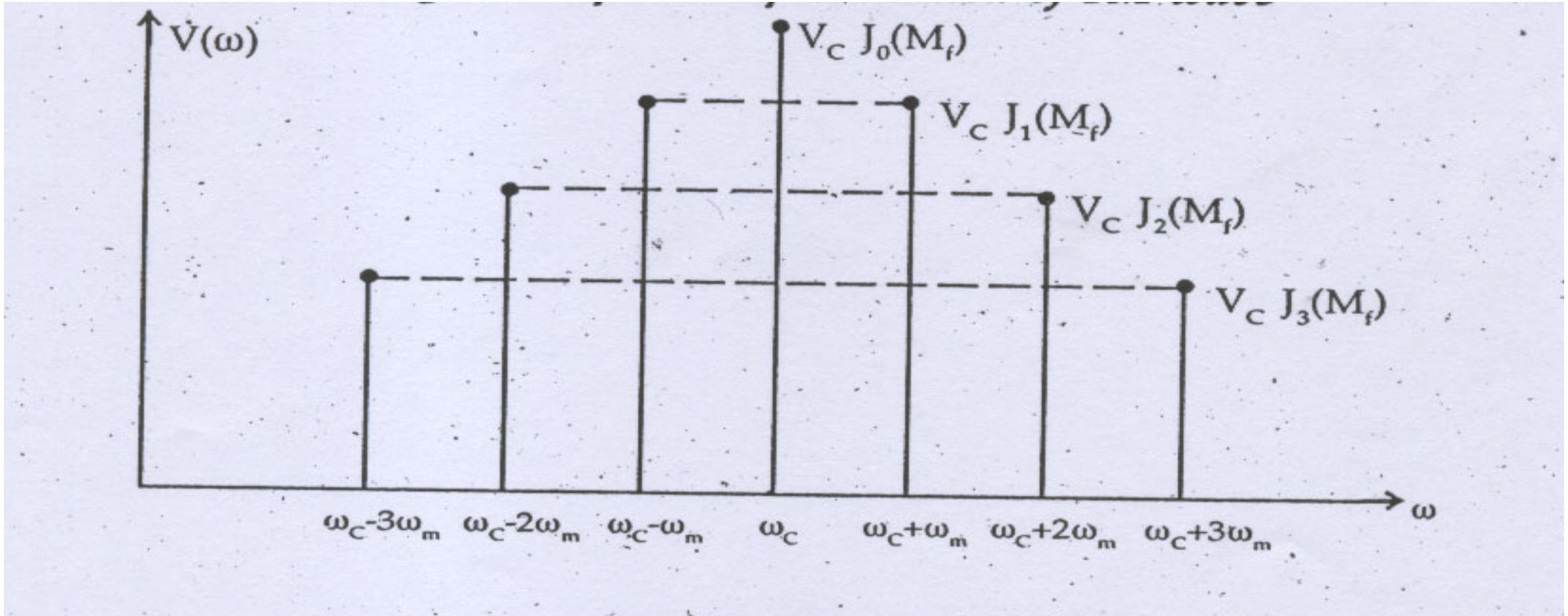


Fig. 2. Phasor representation of FM

FM Bandwidth

- Theoretically, the generation and transmission of FM requires infinite bandwidth. Practically, FM system have finite bandwidth and they perform well.
- The value of modulation index determine the number of sidebands that have the significant relative amplitudes
- If n is the number of sideband pairs, and line of frequency spectrum are spaced by fm, thus, the bandwidth is:

$$B_{fm} = 2nf_m$$

For n≥1

Estimation of transmission b/w;

$$B_{fm} = 2(\Delta f + f_m)........(1)$$

Carson’s Rule

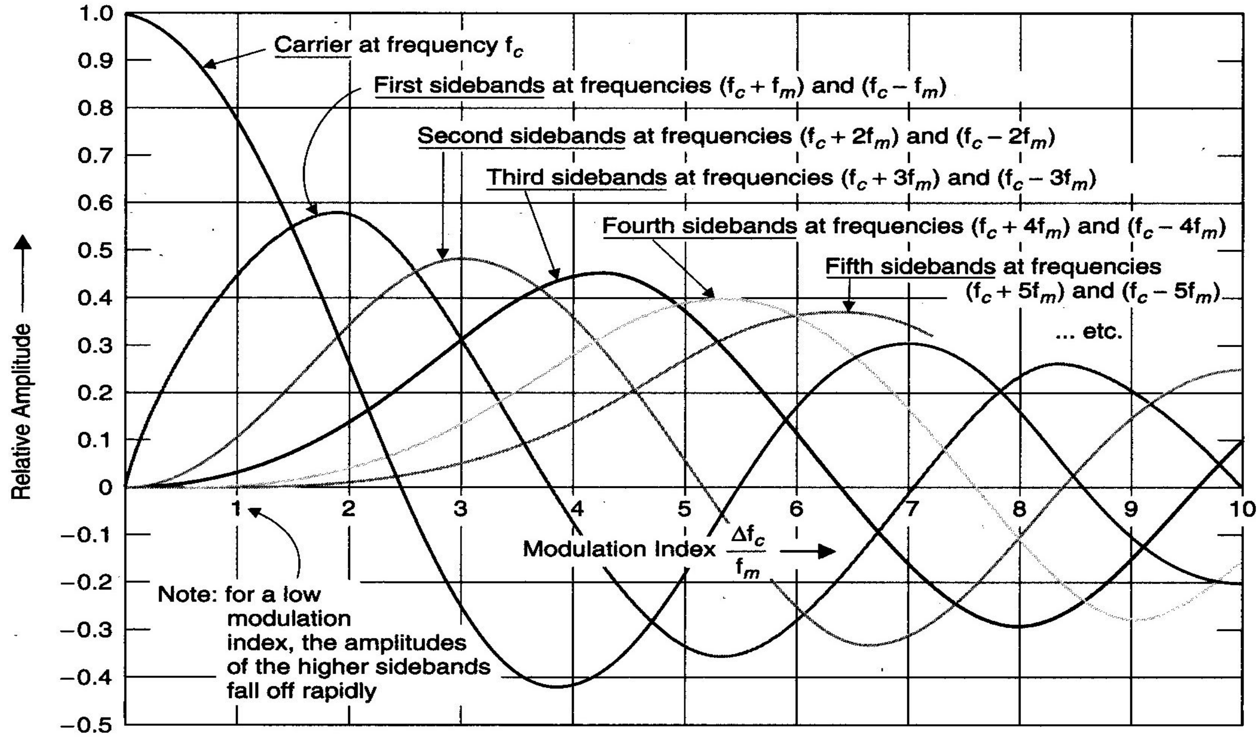
It provides a rule of thumb to calculate the bandwidth of a single-tone FM signal.

$$Bandwidth = 2(\Delta f + f_m) = 2(1 + m_f) f_m$$

If baseband signal is any arbitrary signal having large number of frequency components, this rule can be modified by replacing f m by deviation ratio D.

$$D = \frac{Peak\ Frequency\ deviation\ corresponding\ maximum\ possible\ amplitude\ of\ m(t)}{Maximum\ frquency\ component\ present\ in\ the\ modulating\ signal\ m(t)}$$

Then the bandwidth of FM signal is given as: Bandwidth = 2(1+ D) fmax


Carrier at frequency f_c
First sidebands at frequencies $(f_c + f_m)$ and $(f_c - f_m)$
Second sidebands at frequencies $(f_c + 2f_m)$ and $(f_c - 2f_m)$
Third sidebands at frequencies $(f_c + 3f_m)$ and $(f_c - 3f_m)$
Fourth sidebands at frequencies $(f_c + 4f_m)$ and $(f_c - 4f_m)$
Fifth sidebands at frequencies $(f_c + 5f_m)$ and $(f_c - 5f_m)$
... etc.
Relative Amplitude
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
1
2
3
4
5
6
7
8
9
10
Modulation Index $\frac{\Delta f_c}{f_m}$
Note: for a low modulation index, the amplitudes of the higher sidebands fall off rapidly

Modulation Index	Carrier	Side Frequency Pairs													
m	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}
0.00	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.25	0.98	0.12	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	0.94	0.24	0.03	—	—	—	—	—	—	—	—	—	—	—	—
1.0	0.77	0.44	0.11	0.02	—	—	—	—	—	—	—	—	—	—	—
1.5	0.51	0.56	0.23	0.06	0.01	—	—	—	—	—	—	—	—	—	—
2.0	0.22	0.58	0.35	0.13	0.03	—	—	—	—	—	—	—	—	—	—
2.4	0	0.52	0.43	0.20	0.06	0.02	—	—	—	—	—	—	—	—	—
2.5	−0.05	0.50	0.45	0.22	0.07	0.02	0.01	—	—	—	—	—	—	—	—
3.0	−0.26	0.34	0.49	0.31	0.13	0.04	0.01	—	—	—	—	—	—	—	—
4.0	−0.40	−0.07	0.36	0.43	0.28	0.13	0.05	0.02	—	—	—	—	—	—	—
5.0	−0.18	−0.33	0.05	0.36	0.39	0.26	0.13	0.05	0.02	—	—	—	—	—	—
5.45	0	−0.34	−0.12	0.26	0.40	0.32	0.19	0.09	0.03	0.01	—	—	—	—	—
6.0	0.15	−0.28	−0.24	0.11	0.36	0.36	0.25	0.13	0.06	0.02	—	—	—	—	—
7.0	0.30	0.00	−0.30	−0.17	0.16	0.35	0.34	0.23	0.13	0.06	0.02	—	—	—	—
8.0	0.17	0.23	−0.11	−0.29	−0.10	0.19	0.34	0.32	0.22	0.13	0.06	0.03	—	—	—
8.65	0	0.27	0.06	−0.24	−0.23	0.03	0.26	0.34	0.28	0.18	0.10	0.05	0.02	—	—
9.0	−0.09	0.25	0.14	−0.18	−0.27	−0.06	0.20	0.33	0.31	0.21	0.12	0.06	0.03	0.01	—
10.0	−0.25	0.05	0.25	0.06	−0.22	−0.23	−0.01	0.22	0.32	0.29	0.21	0.12	0.06	0.03	0.01

FM Power Distribution

- As seen in Bessel function table, it shows that as the sideband relative amplitude increases, the carrier amplitude, J_0 decreases.
- This is because, in FM, the total transmitted power is always constant and the total average power is equal to the unmodulated carrier power, that is the amplitude of the FM remains constant whether or not it is modulated.
- In effect, in FM, the total power that is originally in the carrier is redistributed between all components of the spectrum, in an amount determined by the modulation index, m_f, and the corresponding Bessel functions.
- At certain value of modulation index, the carrier component goes to zero, where in this condition, the power is carried by the sidebands only.

Average Power

The average power in unmodulated carrier $$P_c = \frac{V_c^2}{2R}$$

- The total instantaneous power in the angle modulated carrier.

$$P_t = \frac{m(t)^2}{R} = \frac{V_c^2}{R}\cos^2[\omega_c t + \theta(t)]$$

$$P_t = \frac{V_c^2}{R}\left\{\frac{1}{2} + \frac{1}{2}\cos[2\omega_c t + 2\theta(t)]\right\} = \frac{V_c^2}{2R}$$

- The total modulated power

$$P_t = P_0 + P_1 + P_2 + .. + P_n = \frac{V_c^2}{2R} + \frac{2(V_1)^2}{2R} + \frac{2(V_2)^2}{2R} + .. + \frac{2(V_n)^2}{2R}$$

Frequency spectrum of an fm system

- The points observed from this frequency spectrum
- The total transmitting power of an FM signal

$$P_T = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R}$$

$$P_T = \frac{E_c^2}{2R}$$

$$P_T = \frac{E_c^2}{2}$$

Types of Frequency Modulation

- ➔ High frequency deviation =>High Bandwidth=> High modulation index=>Wideband FM
- ➔ Small frequency deviation =>Small Bandwidth=> Small modulation index=>Narrowband FM

Classification of FM:

Based on the modulation index value the FM are classified as

- Narrowband FM ma<1
- Wide band FM ma >1

WIDEBAND FM PARAMETERS :

1. modulation index : Greater than 1
2. maximum deviation: 75 kHz
3. range of modulating frequency: 30 Hz to 15 kHz
4. maximum modulation index: 5 to 2500
5. bandwidth : large,about 15 times higher than BW of narrowband FM
6. applications : entertainment broadcasting
7. pre-emphasis and de-emphasis : is needed.

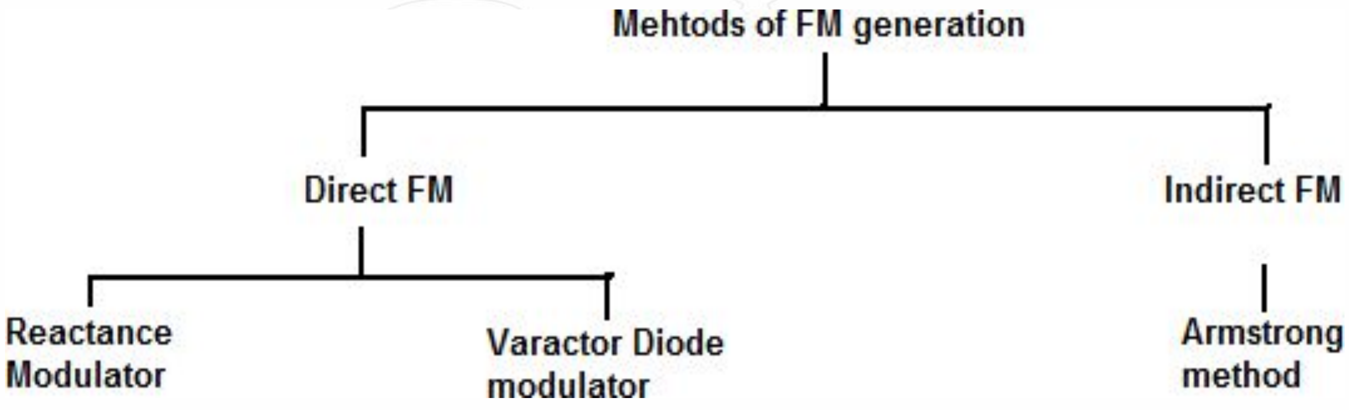
NARROWBAND FM PARAMETERS :

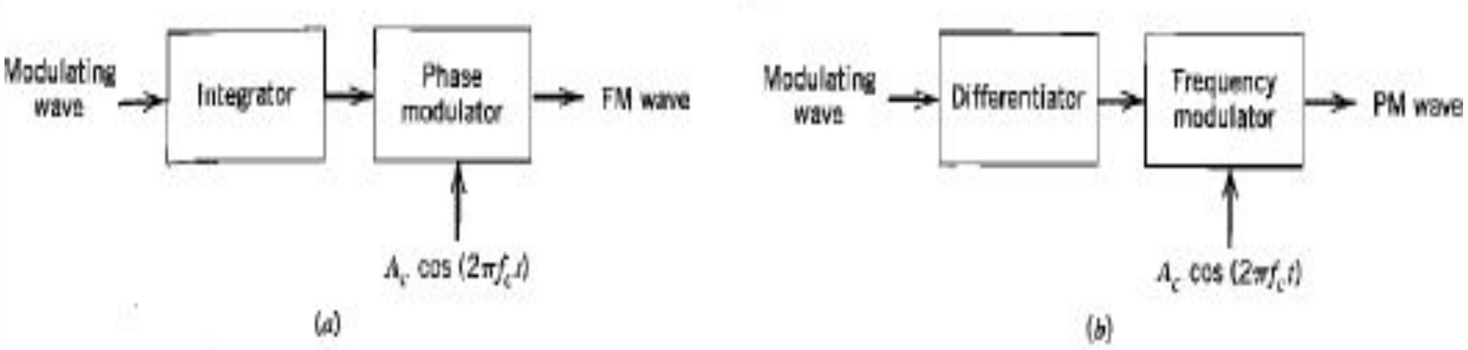
1.modulation index: less than or slightly greater than 1
2. maximum deviation: 5kHz
3. range of modulating frequency : 30 Hz to 3 kHz
4. maximum modulation index : slightly greater than 1
5. bandwidth : small.approximately same as that of AM
6. applications: FM mobile communication like police wireless,ambulance etc
7. pre-emphasis and de-emphasis : is needed

Generation of FM waves:

Fm Modulators: There are 2 types of FM modulators.

1. Direct Method 2. Indirect Method

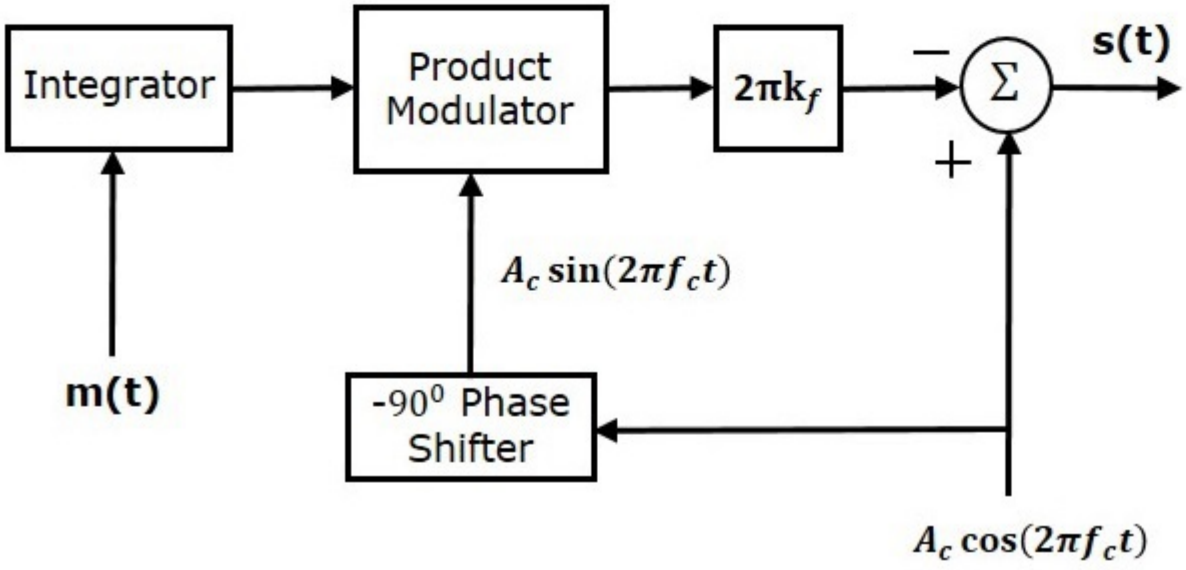




llustration of the relationship between FM and PM
Fig (a) Generation of FM using PM
Fig (b) Generation of PM from FM

Narrow band FM:

The block diagram of NBFM modulator



Methods of Generating FM wave

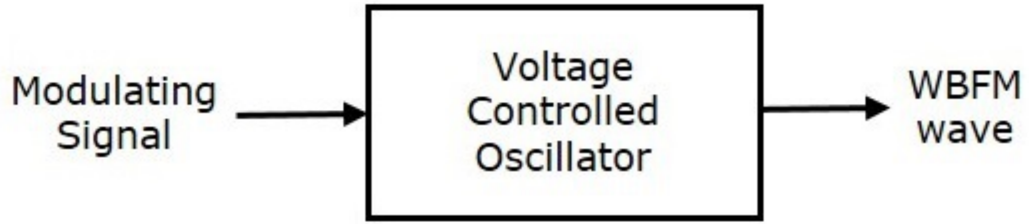
Direct FM: In this method the carrier frequency is directly varied inaccordance with the incoming message signal to produce a frequency modulated signal.

Indirect FM: This method was first proposed by Armstrong. In thismethod, the modulating wave is first used to produce a narrow-band FMwave, and frequency multiplication is next used to increase thefrequency deviation to the desired level.

Direct Method

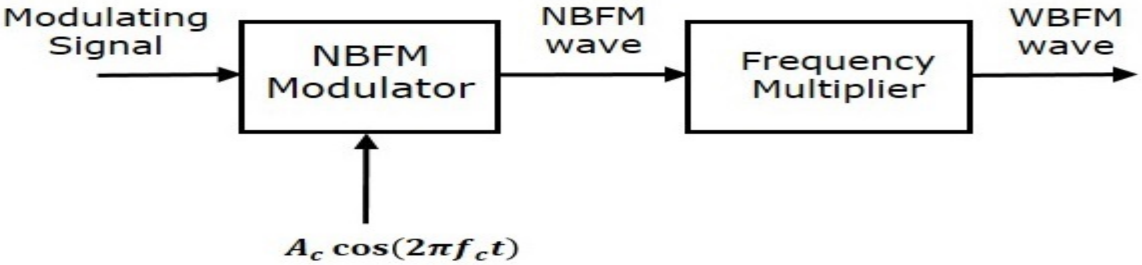
- This method is called as the Direct Method because we are generating a wide band FM wave directly.
- In this method, Voltage Controlled Oscillator (VCO) is used to generate WBFM.
- VCO produces an output signal, whose frequency is proportional to the input signal voltage. This is similar to the definition of FM wave.

The block diagram of the generation of WBFM wave



Indirect Method

- This method is called as Indirect Method because we are generating a wide band FM wave indirectly.
- This means, first we will generate NBFM wave and then with the help of frequency multipliers we will get WBFM wave.
- The block diagram of generation of WBFM wave is shown in the following figure.



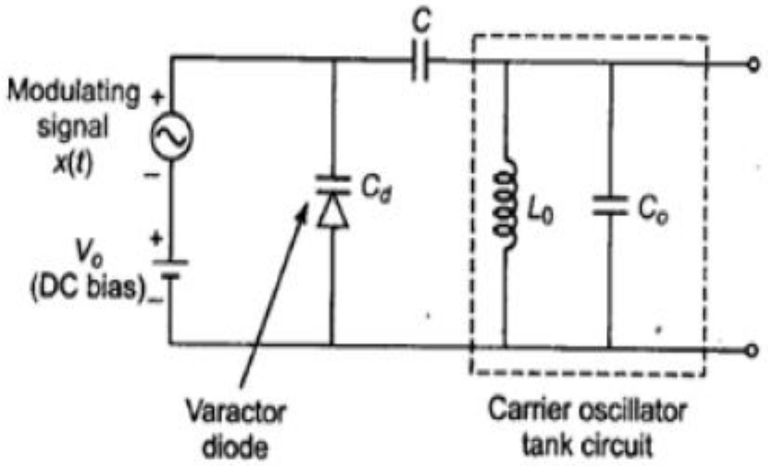
- This block diagram contains mainly two stages. In the first stage, the NBFM wave will be generated using NBFM modulator.
- We know that the modulation index of NBFM wave is less than one.
- Hence, in order to get the required modulation index (greater than one) of FM wave, choose the frequency multiplier value properly.

Direct Method or Parameter Variation Method

In this method, the baseband or modulating signal directly modulates the carrier. The carrier signal is generated with the help of an oscillator circuit. This oscillator circuit uses a parallel tuned L-C circuit. Thus the frequency of oscillation of the carrier generation is governed by the expression:

$$\omega_c = \frac{1}{\sqrt{LC}}$$

The carrier frequency is made to vary in accordance with the baseband or modulating signal by making either L or C depend upon to the baseband signal. Such an oscillator whose frequency is controlled by a modulating signal voltage is called as Voltage Controlled Oscillator. The frequency of VCO is varied according to the modulating signal simply by putting shunt voltage variable capacitor (varactor/varicap) with its tuned circuit. The varactor diode is a semiconductor diode whose junction capacitance changes with dc bias voltage. The capacitor C is made much smaller than the varactor diode capacitance C_d so that the RF voltage from oscillator across the diode is small as compared to reverse bias dc voltage across the varactor diode.



Varactor diode method for FM generation

$$C_d = \frac{k}{\sqrt{v_D}} = k(v_D)^{-\frac{1}{2}}$$

$$v_D = V_o + x(t)$$

$$\omega_i = \frac{1}{\sqrt{L_o(C_o + C_d)}}$$

$$\Rightarrow \omega_i = \frac{1}{\sqrt{L_o\left(C_o + k v_D^{-\frac{1}{2}}\right)}}$$

- The capacitance of the varactor diode depends on the fixed bias set by R
- Either R1 or R2 is made variable.
- The radio frequency choke [RFC] has high reactance at the carrier frequency to prevent carrier signal from getting into the modulating signal.
- At +ve going modulating signal adds to the reverse bias applied to the varactor diode D, which decreases its capacitance & increases the carrier frequency.
- A –ve going modulating signal subtracts from the bias, increasing the capacitance, which decreases the carrier frequency.

Drawbacks of direct method of FM generation:

- Generation of carrier signal is directly affected by the modulating signal by directly controlling the tank circuit and thus a stable oscillator circuit cannot be used. So a high order stability in carrier frequency cannot be achieved.
- The non-linearity of the varactor diode produces a frequency variation due to harmonics of the modulating signal and therefore the FM signal is distorted.

Indirect method or Armstrong method of FM generation

- ➔ A very high frequency stability can be achieved since in this case the crystal oscillator may be used as a carrier frequency generator. In this method, first of all a narrowband FM is generated and then frequency multiplication is used to cause required increased frequency deviation.
- ➔ The narrow band FM wave is then passed through a frequency multiplier to obtain the wide band FM wave. Frequency multiplication scales up the carrier frequency as well as the frequency deviation.
- ➔ The crystal controlled oscillator provides good frequency stability. But this scheme does not provide both the desired frequency deviation and carrier frequency at the same time. This problem can be solved by using multiple stages of frequency multipliers and a mixer stages.

FM Demodulators / Detectors

FM demodulator must satisfy the following requirements

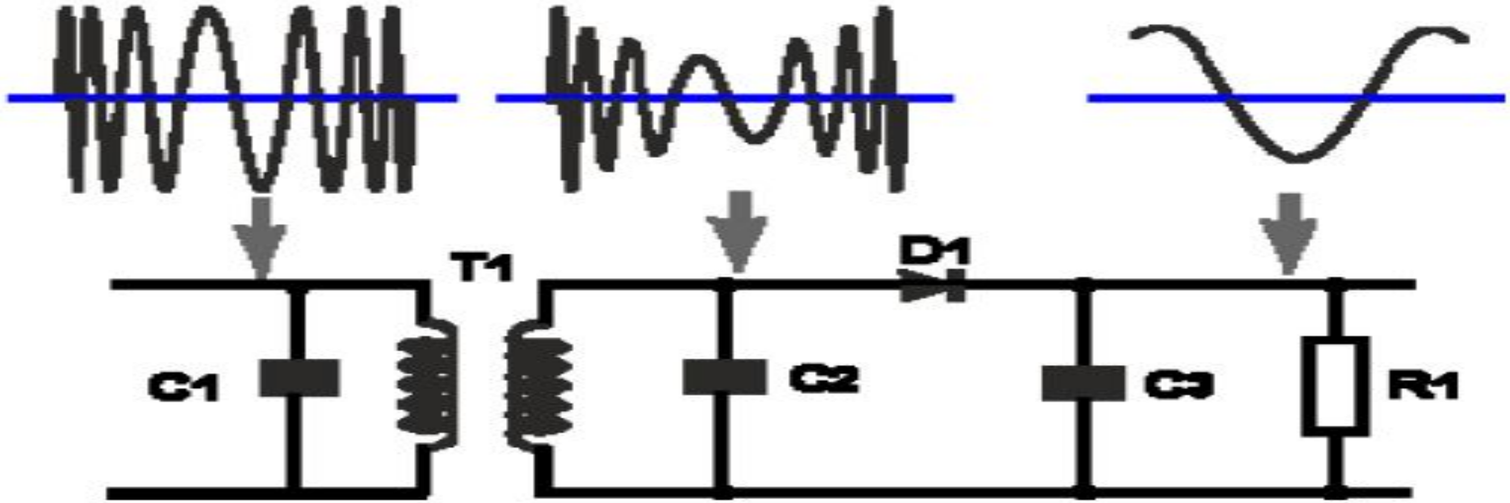
- It must convert the frequency variations into amplitude variations
- This conversion must be linear and efficient.
- The demodulator circuits must be insensitive to amplitude changes.
- It should not be too critical in its adjustment and operation.

FM Demodulators

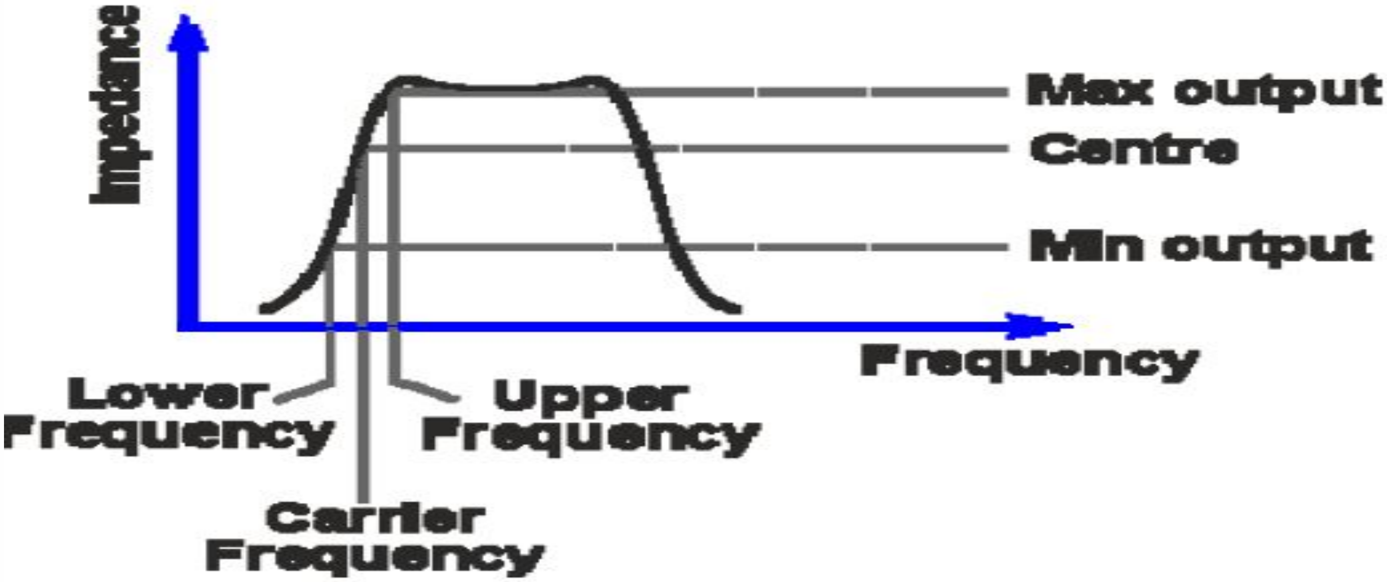
Generally a FM demodulator is composed of two parts:

- ➔ **Discriminator and Envelope Detector.**
- ➔ **Discriminator is a frequency selective network which converts the frequency variations in an input signal in to proportional amplitude variations. Hence when it is input with an FM signal, it can produce an amplitude modulated signal. But it does not generally alter the frequency variations which were there in the input signal. So the output of a discriminator is a both frequency and amplitude modulated signal.**
- ➔ **This signal can be fed to the Envelope Detector part of FM demodulator to get back the baseband signal**

SLOPE DETECTOR



FREQUENCY RESPONSE OF SLOPE DETECTOR

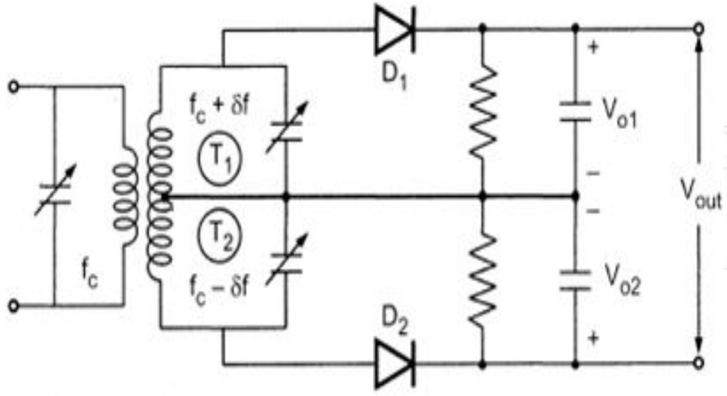


SLOPE DETECTOR

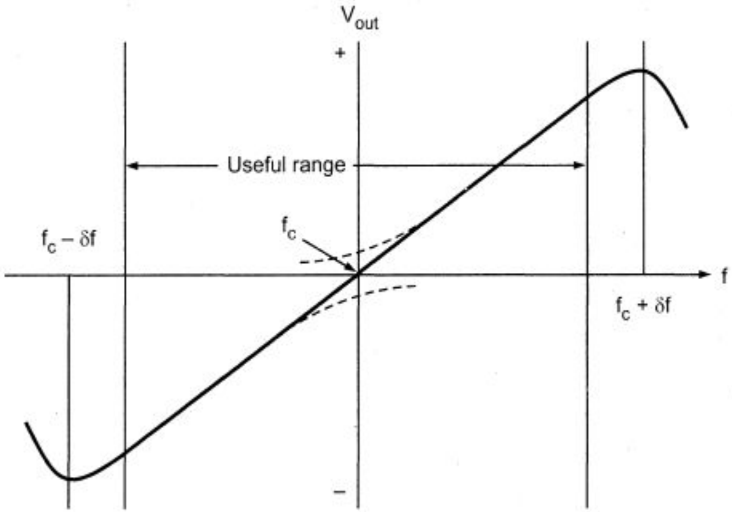
- ➔ Slope detector: A very simplest form of FM demodulation is known as slope detection or demodulation.

It consists of a tuned circuit that is tuned to a frequency slightly offset from the carrier of the signal.

- ➔ As the frequency of the signals varies up and down in frequency according to its modulation,so the signal moves up and down the slope of the tuned circuit. This causes the amplitude of the signal to vary in line with the frequency variations.
- ➔ In fact, at this point the signal has both frequency and amplitude variations.It can be seen from the diagram that changes in the slope of the filter, reflect into the linearity of the demodulation process.
- ➔ The linearity is very dependent not only on the filter slope as it falls away, but also the tuning of the receiver - it is necessary to tune the receiver frequency to a point where the filter characteristic is relatively linear



Balanced slope detector



Characteristic of balanced slope detector, or 'S'-curve

- Consists of 2 identical circuit connected back to back.
- FM signal is applied to the tuned LC circuit.
- Two tuned LC circuits are connected in series.
- The inductance of the secondary tuned LC circuit is coupled with the inductance of the primary LC circuit this forms a tuned transformer.
- Upper tuned circuit is T1 and Lower tuned circuit is T2

- I/P side LC is tuned to be

T_1 is tuned to f_c + □f - max freq fm.

T_2 is tuned to f_c - □f - max freq fm.

- Secondary of T_1 & T_2 are connected to diodes D_1 & D_2 with RC loads.

- The total o/p is equal to difference b/w Vo1 & Vo2.

- When i/p freq is fc, both T1 & T2 produce the same voltage hence o/p = 0

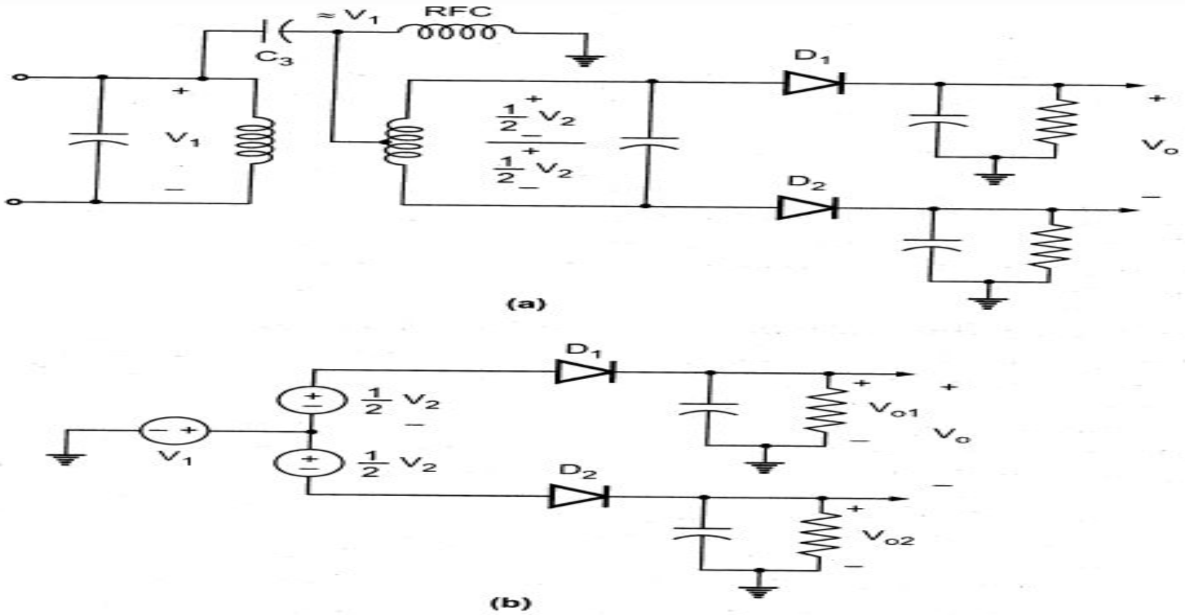
- When i/p freq is f_c + □f, the upper circuit T_1 produces maximum voltage since it is tuned to this freq.

Hence this produces maximum votalge.

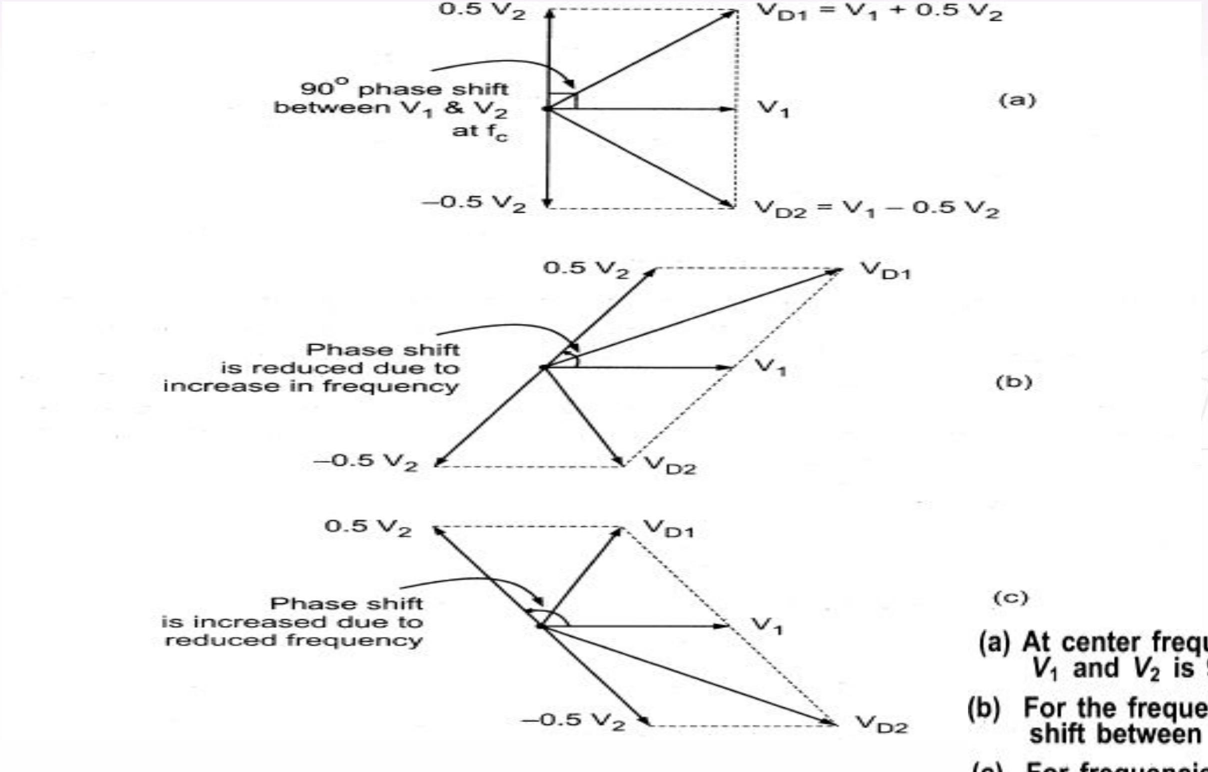
V_{01} is high compared to V_{02}.

Vout = V_{01} - V_{02} is positive for fc + □f.

Foster - Seeley Discriminator



(a) Basic Foster–Seeley discriminator
(b) Voltage generator equivalent circuit

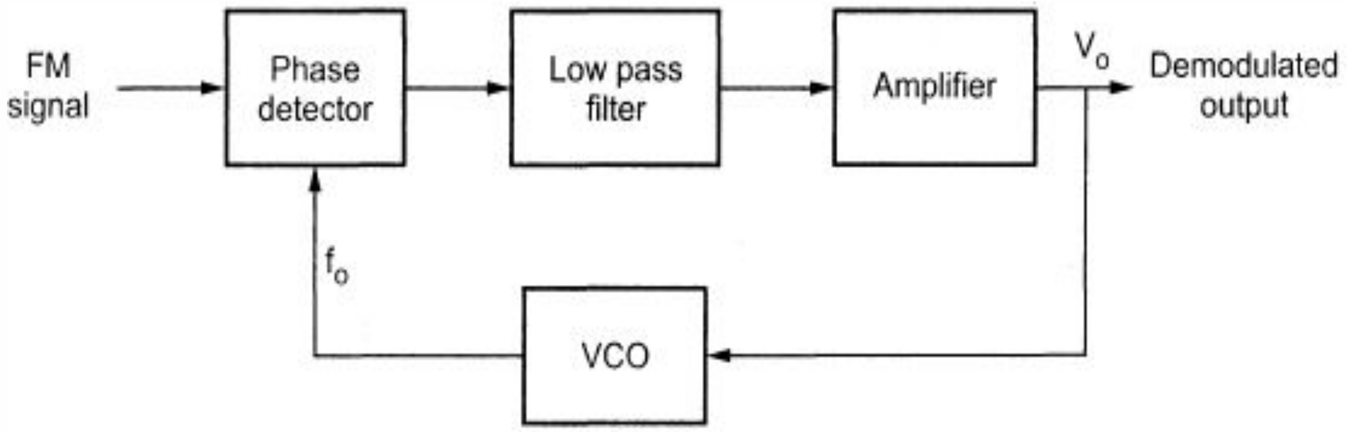


(a) At center frequency, phase shift between V_1 and V_2 is 90°. Hence $|V_{D1}| = |V_{D2}|$

(b) For the frequencies above center frequency, the phase shift between V_1 and V_2 is reduced. Hence $|V_{D1}| > |V_{D2}|$

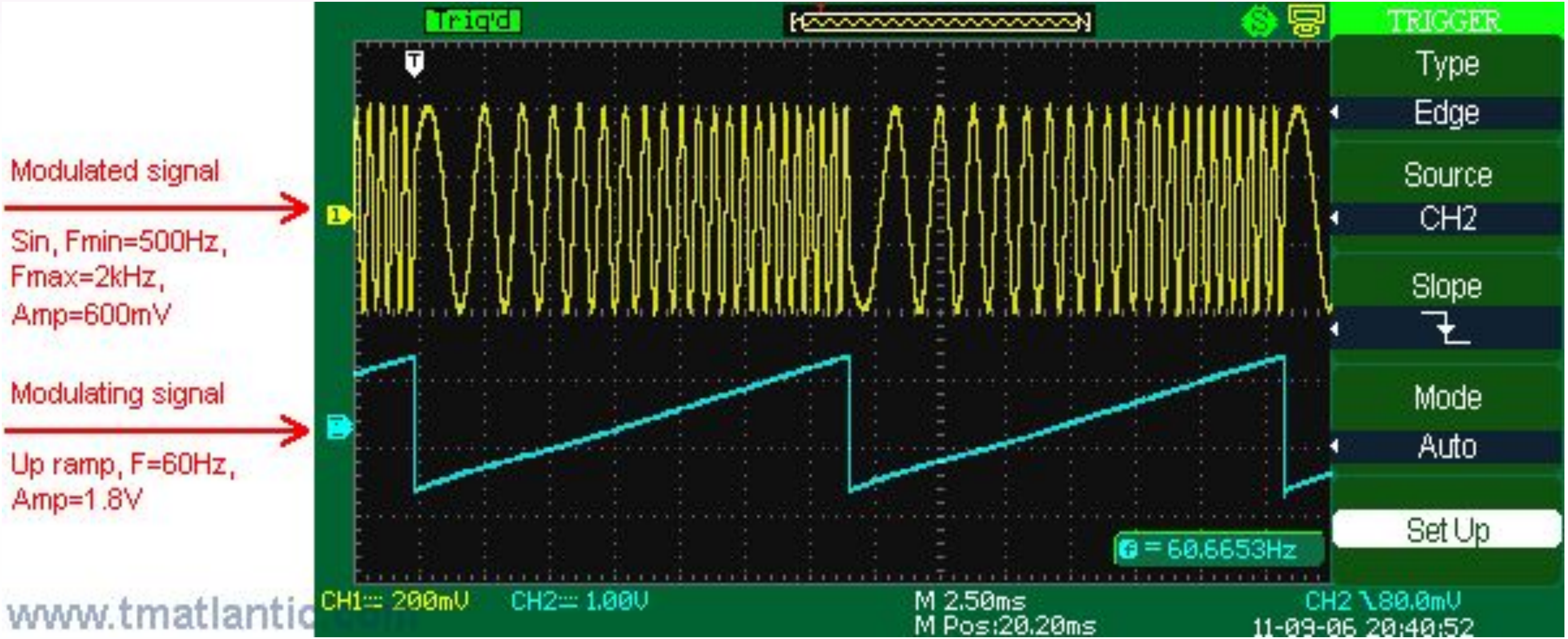
(c) For frequencies below center frequency, the phase shift between V_1 and V_2 is increased. This makes $|V_{D1}| < |V_{D2}|$

PLL Demodulator circuit



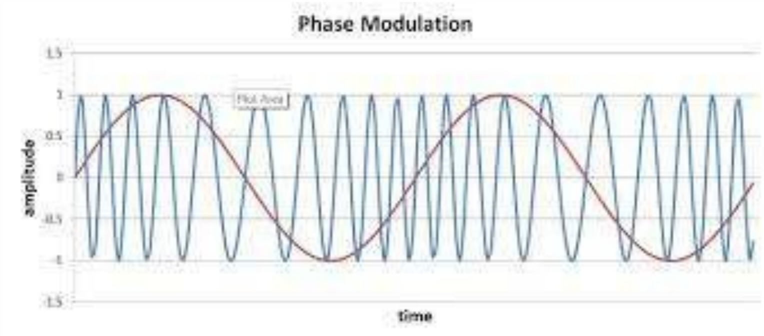
PLL FM demodulator / detector

- Fig. shows the block diagram of PLL FM demodulator.
- The output frequency of VCO is equal to the frequency of unmodulated carrier.
- The phase detector generates the voltage which is proportional to difference between the FM signal and VCO output.
- This voltage is filtered and amplified. It is the required modulating voltage.
- Here frequency correction is not required in VCO since it is already done at transmitter


Modulated signal
Sin, Fmin=500Hz, Fmax=2kHz, Amp=600mV
Modulating signal
Up ramp, F=60Hz, Amp=1.8V
www.tmatlantic.com
Trig'd
TRIGGER
Type
Edge
Source
CH2
Slope
Mode
Auto
Set Up
= 60.6653Hz
CH1 200mV
CH2 1.00V
M 2.50ms
M Pos:20.20ms
CH2 80.0mV
11-09-06 20:40:52

What is Phase Modulation

- Phase modulation, PM is sometimes used for analogue transmission, but it has become the basis for modulation schemes used for carrying data. Phase shoft keying, PSK is widely used for data communication.Phase modulation is also the basis of a form of modulation known as quadrature amplitude modulation, where both phase and amplitude are varied to provide additional capabilities.



Phase modulation basics

- A radio frequency signal consists of an oscillating carrier in the form of a sine wave is the basis of the signal. The instantaneous amplitude follows this curve moving positive and then negative, returning to the start point after one complete cycle - it follows the curve of the sine wave.

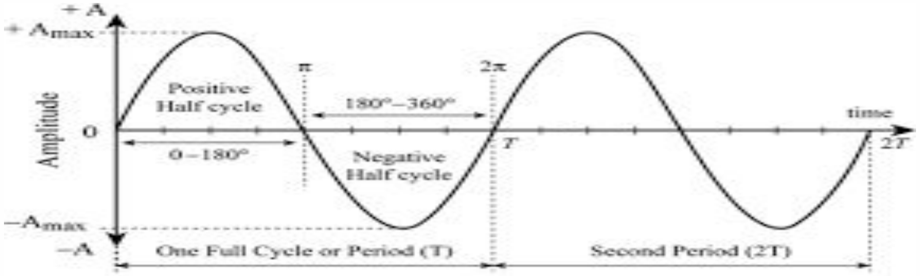
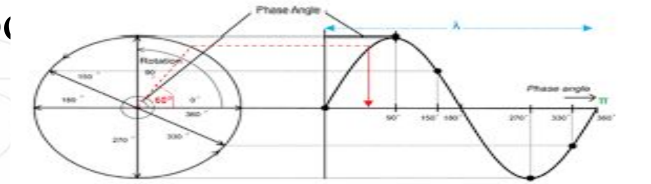


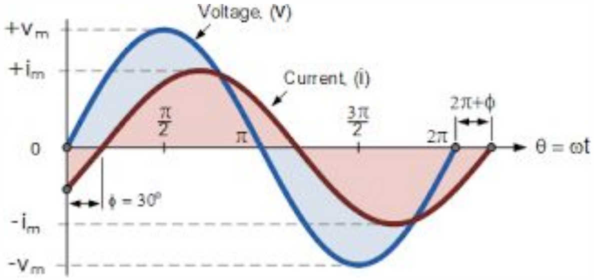
Figure 1

- The sine wave can also be represented by the movement of a point around a circle, the phase at any given point being the angle between the start pc form as shown.

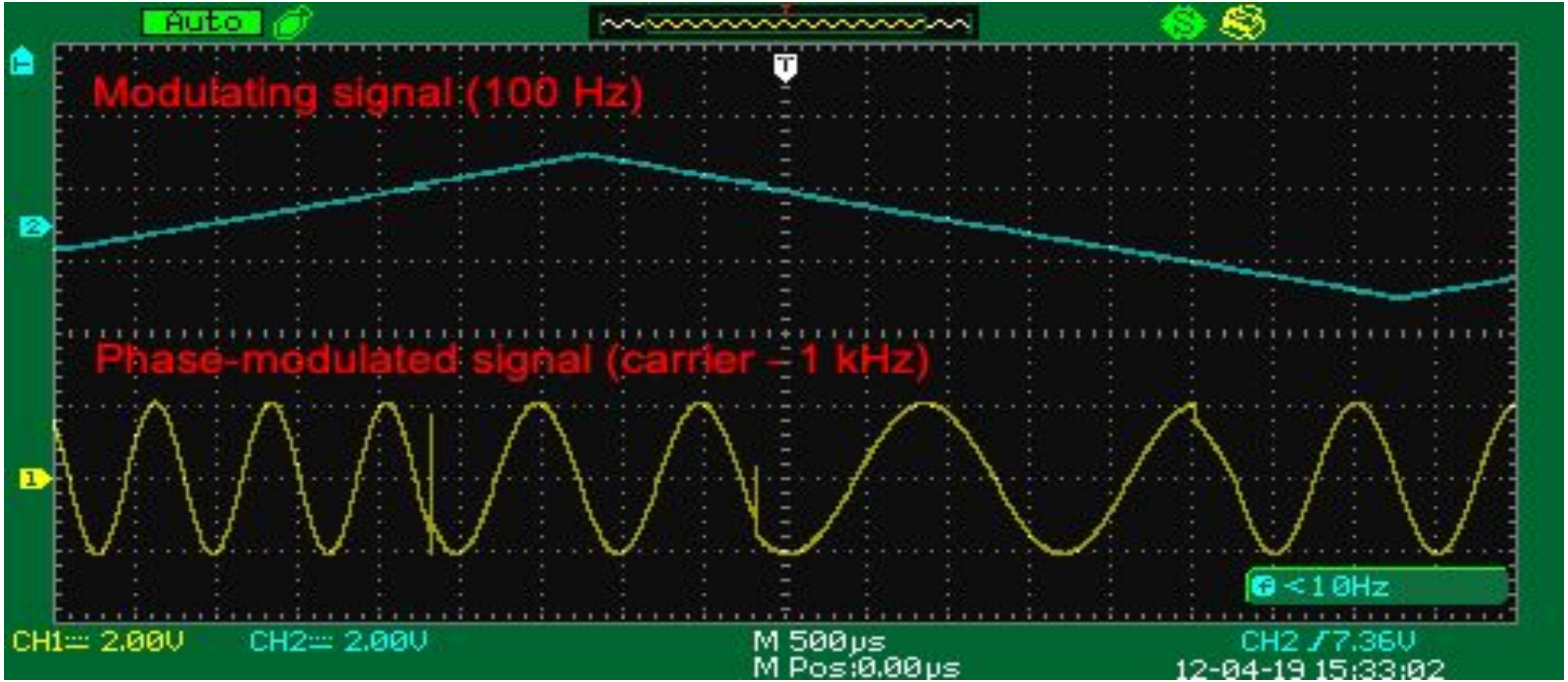


- Phase angle of points on a sine waveAlso the phase advances as time progresses so points on the waveform can be said to have a phase difference between them.

- Phase modulation works by modulating the phase of the signal, i.e. changing the rate at which the point moves around the circle. This changes the phase of the signal from what it would have been if no modulation was applied. In other words the speed of rotation around the circle is modulated about the mean value.



PHASE MODULATION



PHASE MODULATION

This makes the modulated signal

$$y(t) = A_c \sin(\omega_c t + m(t) + \phi_c)$$

This shows how m(t)modulates the phase –
the greater m(t) is at a point in time, the greater the phase shift of the modulated signal at that point.

It can also be viewed as a change of the frequency of the carrier signal, and phase modulation can thus be considered a special case of FM in which the carrier frequency modulation is given by the time derivative of the phase modulation.

PHASE MODULATION

- The mathematics of the spectral behavior reveals that there are two regions of particular interest:
- For small amplitude signals, PM is similar to amplitude modulation (AM) and exhibits its unfortunate doubling of baseband bandwidth and poor efficiency.
- For a single large sinusoidal signal, PM is similar to FM, and its bandwidth is approximately

$$2\,(h+1)\,f_M$$

- where $f_M = \omega_m/2\pi$ and h is the modulation index This is also known as Carson's Rule for PM.

VIDEO LINK OF FM MODULATION

https://youtu.be/qHd5eLD01zo

Thank You