JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA
KAKINADA – 533 001 , ANDHRA PRADESH

GATE Coaching Classes as per the Direction of
Ministry of Education
GOVERNMENT OF ANDHRA PRADESH

Analog Communication

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Presentation Outline

Angle Modulation:

- Comparison of NBFM with WBFM
- Generation of FM waves
- Demodulation of FM waves
- Problems

Learning Outcomes

- At the end of this Session, Student will be able to:
- LO 1 : Demonstrate the generation and demodulation of angle modulated waves
- LO2 : Pre-emphasis and De-emphasis
- LO 2 : Compare NBFM with WBFM

Angle Modulation

Definition:

The modulation in which, the angle of the carrier wave is varied according to the baseband signal.

- An important feature of this modulation is that it can provide better discrimination against noise and interference than amplitude modulation.
- An important feature of Angle mod. is that it can provide better discrimination against noise and distortion
- Complexity Vs. Noise and interference Tradeoff
- Two types:
- Phase modulation
- Frequency Modulation

Angle Modulation

- The angle modulated wave can be expressed as

$$s(t) = A_c cos[\theta_i(t)] \qquad (1)$$

where $\theta_i(t)$ denotes the angle of a modulated sinusoidal carrier and A_c is the carrier amplitude. A complete oscillation occurs whenever $\theta_i(t)$ changes by 2π radians.

- If $\theta_i(t)$ increases monotonically with time, the average frequency in Hertz, over an interval from *t* to *t*+ *Δt*, is given by

$$f_{\Delta t}(t) = \frac{\theta_i(t+\Delta t) - \theta_i(t)}{2\pi\Delta t} \qquad (2)$$

- We may therefore define the instantaneous frequency of the angle modulated signal *s(t)* as follows

$$f_i(t) = \lim_{\Delta t \to 0} f_{\Delta t}(t)$$

$$= \lim_{\Delta t \to 0} \frac{\theta_i(t+\Delta t) - \theta_i(t)}{2\pi\Delta t} \qquad (3)$$

$$= \frac{1}{2\pi}\frac{d\theta_i(t)}{dt}$$

- Thus according to the equation (1), we may interpret the angle modulated signal s(t) as a rotating phasor of length *Ac* and angle $\theta_i(t)$
- The angular velocity of such a phasor is $\frac{d\theta_i(t)}{dt}$ measured in radians per second, in accordance with equation (3).
- In the simple case of an unmodulated carrier, $A_c cos2\pi f_c t$

  the angle $\theta_i(t)$ is

$$\theta_i(t) = 2\pi f_c t + \emptyset_c$$

and the corresponding phasor rotates with a constant angular velocity equal to $2\pi f_c$

The constant $\emptyset_c$ is the value of $\theta_i(t)$ at t=0.

- There are an infinite number of ways in which the angle $\theta_i(t)$ is varied in some manner with the message (baseband) signal. However, we shall consider two commonly used methods.

i. Phase Modulation (PM)

ii. Frequency Modulation (FM)

i. Phase Modulation (PM):

PM is that form of angle modulation in which the angle $\theta_i(t)$ is varied linearly with the message signal m(t), as shown by

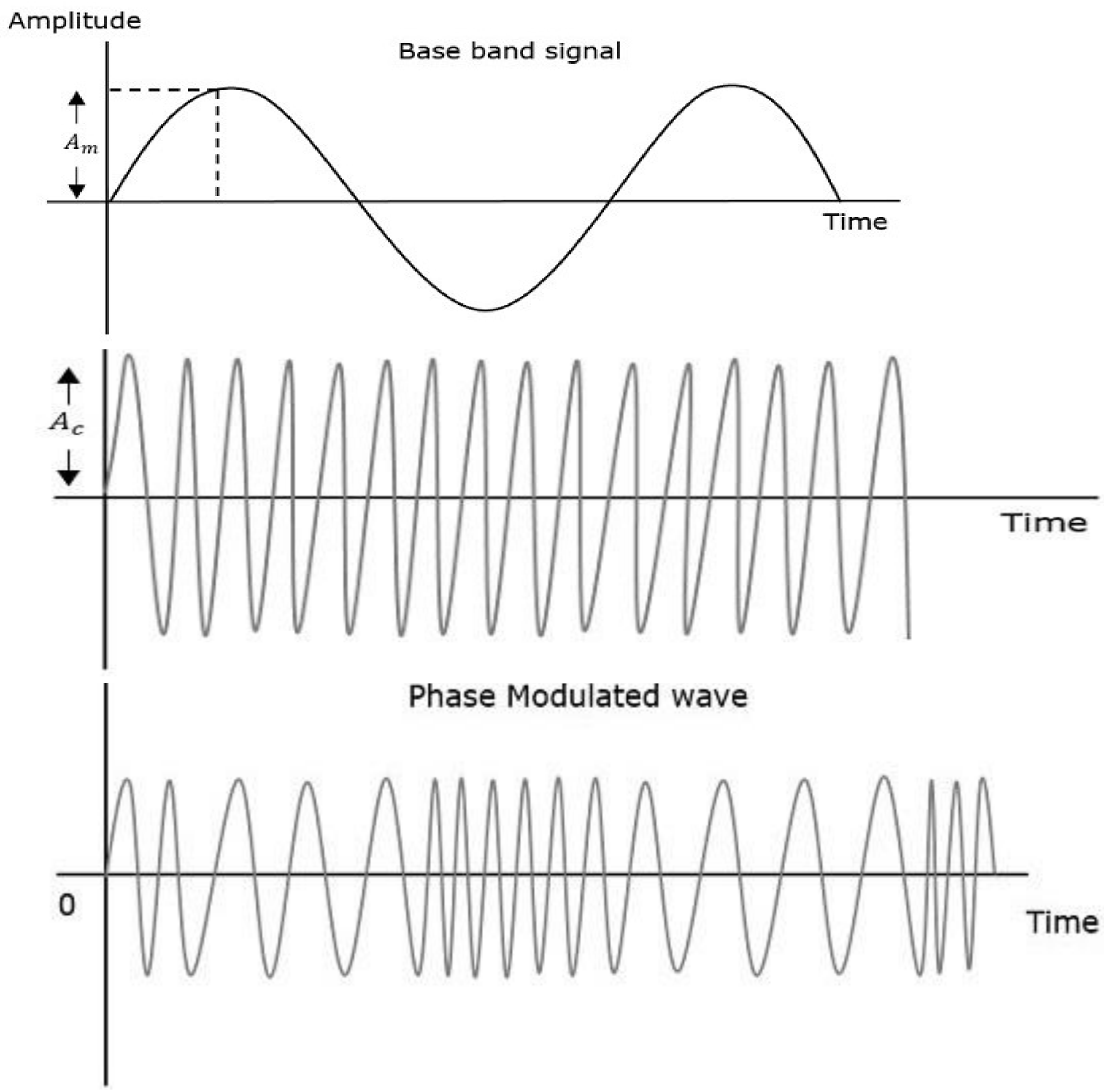
$$\theta_i(t) = 2\pi f_c t + k_p m(t)$$

- The term $2\pi f_c t$ represents the angle of the unmodulated carrier and the constant k_p represents the phase sensitivity of the modulator , rad/V.

- The phase modulated signal s(t) is thus described in the time domain by

$$s(t) = A_c cos[2\pi f_c t + k_p m(t)]$$

Phase Modulation (PM)



ii. Frequency Modulation:

FM is that form of angle modulation in which the instantaneous frequency $f_i(t)$ is varied linearly with the message signal m(t), as shown by

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

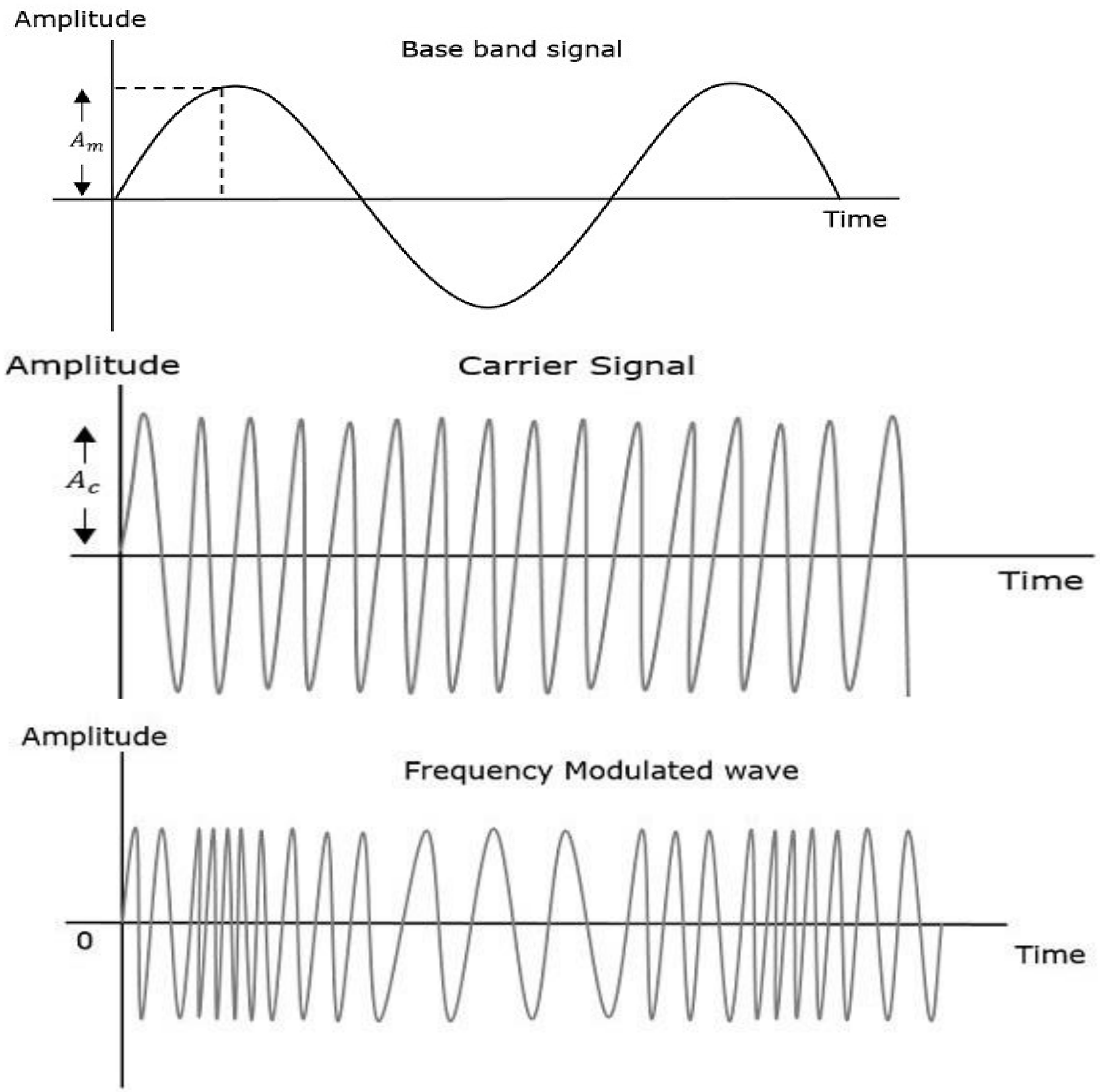
The term $f_i(t)$ represents the frequency of the unmodulated carrier and the constant k_f represents the frequency sensitivity of the modulator, Hz/V.

- The frequency modulated signal s(t) is thus described in the time domain by

$$\theta_i(t) = 2\pi \int_0^t f_i(t)\,dt$$

$$s(t) = A_c cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)\,dt\right]$$

Frequency Modulation (FM)



Relationship between Phase Modulation (PM) and Frequency Modulation (FM)

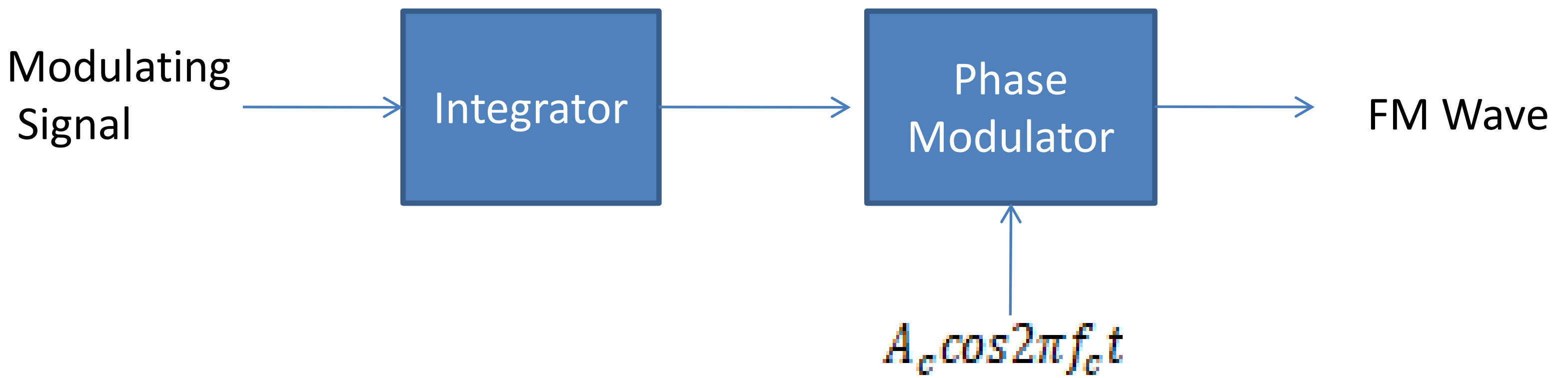


Fig (a): FM wave generation using Phase Modulator

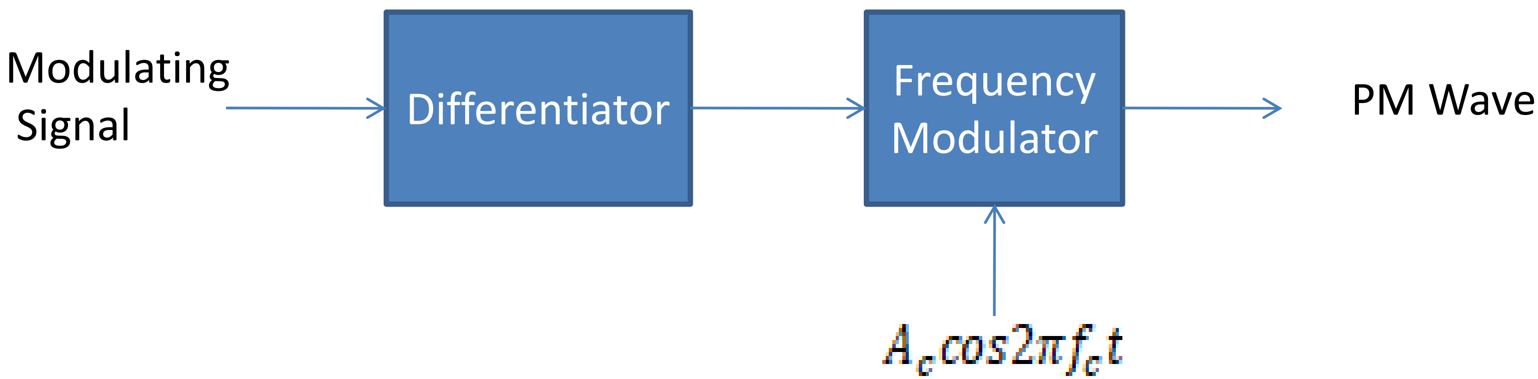


Fig (b): PM wave generation using Frequency Modulator

Single tone FM:

Consider a sinusoidal modulating signal defined by

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

The instantaneous frequency of the FM signal is

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

$$f_i(t) = f_c + k_f A_m cos 2\pi f_m t$$

$$= f_c + \Delta f \, cos 2\pi f_m t$$

where $\Delta f = k_f A_m$

The quantity Δf is called frequency deviation , representing the maximum departure of the instantaneous frequency of the FM signal from the carrier frequency f_c

- The angle $\theta_i(t)$ of the FM signal is

$$\theta_i(t) = 2\pi \int_0^t f_i(t)dt$$

$$= 2\pi f_c t + \frac{\Delta f}{f_m} \sin(2\pi f_m t)$$

- The ratio of frequency deviation Δf to the modulating frequency is commonly called as modulation index of the FM signal. We denote it by β

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

$$\theta_i(t) = 2\pi f_c t + \beta \sin(2\pi f_m t)$$

So, The FM wave is

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

Frequency Modulation

- Depending on the value of β, we may distinguish two cases of FM:

  i. Narrowband FM, for which β is small

  ii. Wideband FM, for which β is large

- $s(t)=A_c\cos(2\pi f_c t + \beta \sin(2\pi f_m t)$
- Single tone FM wave

i. Narrowband Frequency Modulation:

The expression for a narrowband FM signal is generated from

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

By simplifying the above equation , it can be written as

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

Which can be expressed in detailed form as

$$s(t) \simeq A_c cos(2\pi f_c t) + \frac{1}{2}\beta A_c\left[cos(2\pi(f_c+f_m)t)\right] - \frac{1}{2}\beta A_c cos(2\pi(f_c - f_m)t)\Big]$$

- The above expression for NBFM is similar to Single tone AM signal

Narrowband Frequency Modulation Contd.,

But the modulated signal produced by the narrowband modulator of above figure differs from this ideal condition in two fundamental respects;

1. The envelope contains residual amplitude modulation and , therefore, varies with time.
2. For a sinusoidal modulating wave, the angle $\theta_i(t)$ contains harmonic distortion in the form of third and higher order harmonics of the modulation frequency f_m.

- However, by restricting the modulation index to $\beta \leq 0.3$ radians, the effect of residual AM and harmonic PM are limited to negligible levels.
- The expression of NBFM is similar to corresponding one defining an AM signal, which is as follows

Narrowband Frequency Modulation Contd.,

$$s(t) = (A_c cos 2\pi f_c t) + \frac{1}{2}\beta A_c\{cos[2\pi(f_c + f_m)t] - cos[2\pi(f_c - f_m)t]\}$$ --- NBFM

$$s_{AM}(t) = A_c(cos 2\pi f_c t) + \frac{1}{2}\mu A_c\{cos[2\pi(f_c + f_m)t] + cos[2\pi(f_c - f_m)t]\}$$ --- AM

- In case of sinusoidal modulation, the basic difference between an AM signal and NBFM signal is that the algebraic sign of the lower side frequency in the NBFM is reversed. Thus a NBFM signal is essentially requires the same transmission bandwidth (i.e $2f_m$) as the AM signal.

i. Narrowband Frequency Modulation:

Generation of NBFM:

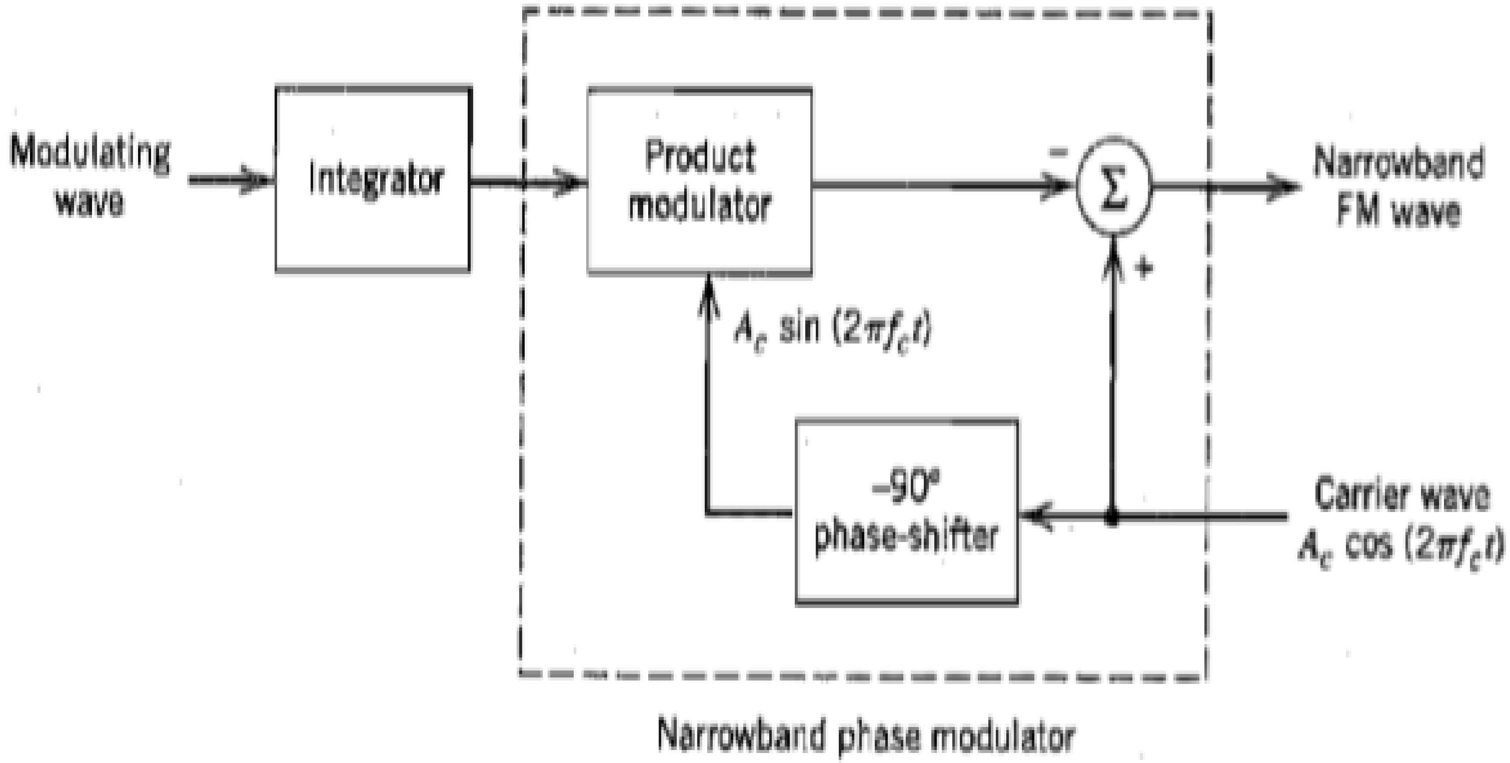


Figure: Block diagram of a method for generating a Narrow Band FM signal

Wide-band FM

- We can generate the spectrum of the single tone FM wave given by $s(t) = A_c \cos[(2\pi f_c t) + \beta \sin(2\pi f_m t)]$ for arbitrary values of 'β'
- In general, FM wave produced by sinusoidal modulating wave shown above is by itself is not periodic, unless the f_c is an integer multiple of f_m.
- By rewriting the above equation for FM wave and simplifying with the help of Fourier series representation and also by using Bessel function, the equation for WBFM wave is obtained.

ii. Wideband FM:

- From single tone FM wave given by
- s(t)=$A_c \cos(2\pi f_c t + \beta \sin(2\pi f_m t)$
- The Fourier Series rep. of FM is

$$s(t) = A_c \sum_{n=-\infty}^{\infty} J_n(\beta) \cos[2\pi(f_c + nf_m)t]$$

The expression for a Wideband FM signal is

$$S(f) = \frac{A_c}{2} \sum_{n=-\infty}^{\infty} J_n(\beta)[\delta(f - f_c - nf_m) + \delta(f + f_c + nf_m)]$$

The discrete spectrum of s(t) is obtained by taking Fourier Transform of both sides of above equation ; we thus have

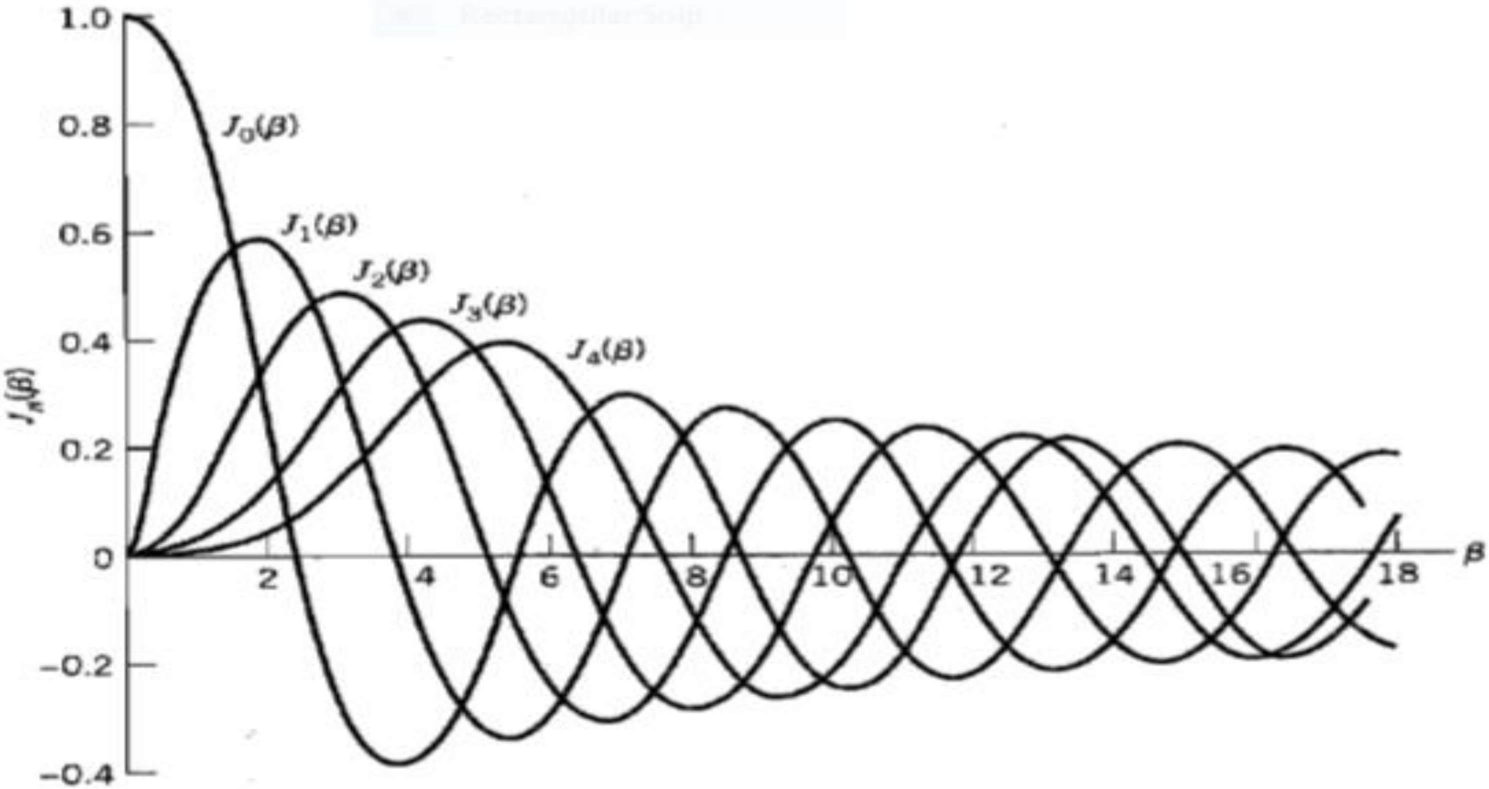


Figure: Plots of Bessel functions of the first kind for varying orders

WBFM Contd.,

Bessel function properties:

1. $J_n(\beta) = (-1)^n J_{-n}(\beta)$ for all n, both positive and negative
2. For small values of modulation index β, we have

$$J_0(\beta) \cong 1$$

$$J_1(\beta) \cong \frac{\beta}{2}$$

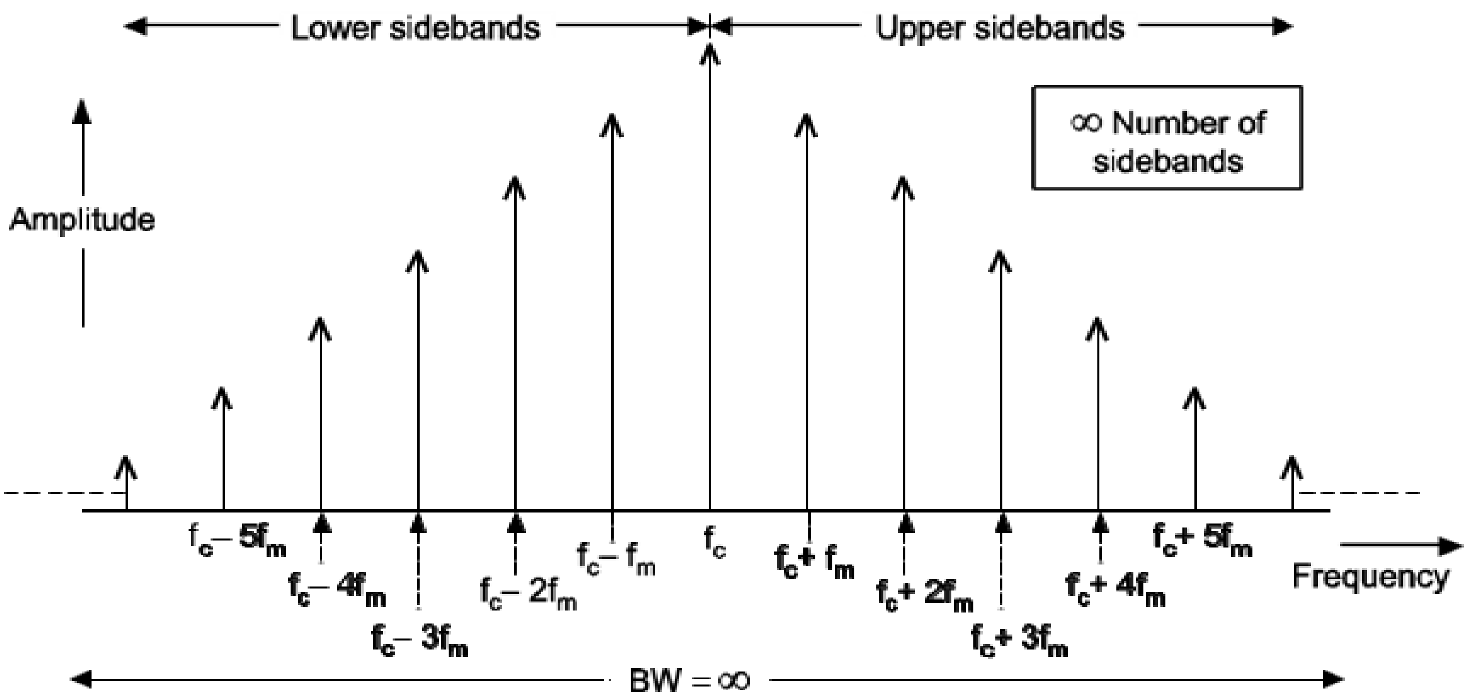
$$J_n(\beta) \cong 0, n > 2$$

3. $\displaystyle\sum_{n=-\infty}^{\infty} {J_n}^2(\beta) = 1$

WBFM Contd.,

- The spectrum of an FM signal contains a carrier component and an infinite set of side frequencies located symmetrically on either side of the carrier at frequency separations of f_m, $2f_m$,…

  In this respect, the result is unlike that which prevails in an AM system, since in an AM system a sinusoidal modulating signal gives rise to only one pair of side frequencies.



WBFM Contd.,

- For the special case of β small compared with unity, only the Bessel coefficients $J_0(\beta)$ and $J_1(\beta)$ have significant values, so that the FM signal is effectively composed of a carrier and a single pair of side frequencies at $f_c \pm f_m$
- The amplitude of the carrier component varies with β according to $J_0(\beta)$. That is, unlike an AM signal, the amplitude of the carrier component of an FM signal is dependent on the modulation index β. The physical explanation for this property is that the envelope of an FM signal is constant, so that the average power of such a signal developed across a 1-ohm resistor is also constant, as shown by

$$P = \frac{1}{2} A_c{}^2$$

The average power of the FM signal is $P = \frac{1}{2} A_c{}^2 \sum_{n=-\infty}^{\infty} J_n{}^2(\beta)$

Comparison between NBFM and WBFM

S.No	Parameter	NBFM	WBFM
1	Modulation Index	Less than 1	Greater than 1
2	Maximum Deviation	5 kHz	75 kHz
3	Range of modulating frequency	20 Hz to 3 kHz	20 Hz to 15 kHz
4	Bandwidth	Small approximately same as that of AM BW = $2f_m$	Large and greater than that of NBFM. BW = $2(\Delta f+fm)$
5	Applications	FM mobile communication like police wireless, ambulance, short range ship to shore communication etc.	Entertainment broadcasting (can be used for high quality music transmission)

Generation of FM Signals

- There are essentially two basic methods of generating frequency modulated signals, namely

  i. Direct FM (Parameter Variation Method)

  ii. Indirect FM (Armstrong's)

- In the direct method the carrier frequency is directly varied in accordance with the input baseband signal, which is readily accomplished using a "Voltage Controlled Oscillator".

- In the indirect method, the modulating signal is first used to produce a narrowband FM signal, and frequency multiplication is next used to increase the frequency deviation to the desired level.

Methods of FM Generation

Direct Methods

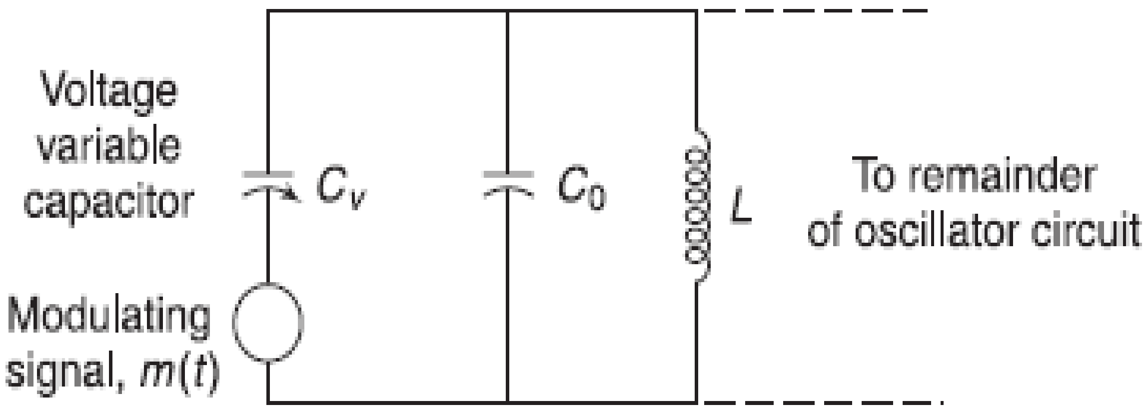
- Direct-FM Varactor Diode Modulator
- FM Reactance Modulator
- Frequency-stabilized Reactance FM Transmitter
- Crossby Direct FM Transmitter
- PLL Direct FM Modulator

Indirect Methods

- Armstrong Indirect FM Transmitter

Direct FM

Parameter Variation Method:



$$f = (2\pi\sqrt{LC})^{-1}$$

The principal difficulty here is to maintain a stable carrier frequency over extended period of time.

Varactor Diode Modulator

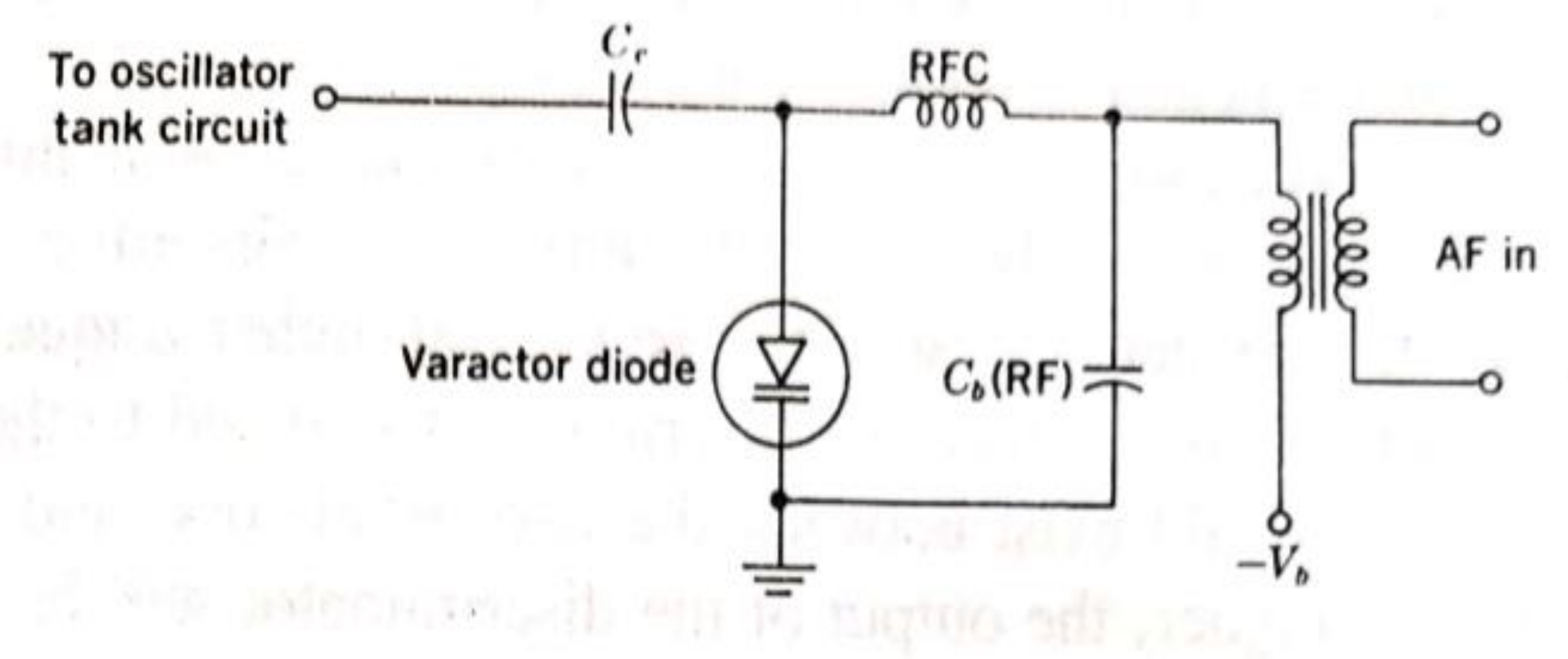


Figure: Varactor Diode Modulator

Basic Reactance Modulator

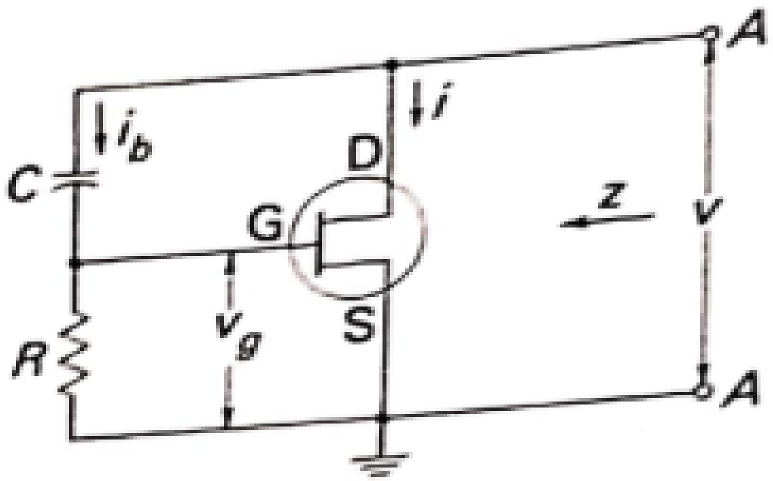


Figure: Basic reactance modulator

- The FET reactance modulator behaves as a three terminal reactance that may connected across the tank circuit of the oscillator to be frequency modulated.
- The value of the reactance is proportional to the transconductance of the device, which can be made to depend on the gate bias and its variations.

Basic Reactance Modulator Contd.,

- The following should be noted from $C_{eq} = g_m RC$

1. This equivalent capacitance depends on the transconductance and can therefore be varied with the bias voltage.
2. The capacitance can be originally adjusted to any value by varying the components R and C.

- In practice the gate-to-drain impedance is 5 to 10 times the gate-to-source impedance. Let Xc = nR

$$X_c = \frac{1}{\omega C} = nR$$

$$C = \frac{1}{\omega n R} = \frac{1}{2\pi f n R}$$

$$C_{eq} = g_m RC = g_m R \frac{1}{2\pi f n R} = \frac{g_m}{2\pi f n}$$

Basic Reactance Modulator Contd.,

- The impedance z, as seen at the input terminals A-A is almost entirely reactive.

$$z = -j\frac{X_c}{g_m R}$$

- This impedance is quite clearly a capacitive reactance, which may written as

$$X_{eq} = \frac{X_c}{g_m R} = \frac{1}{2\pi f g_m R C} = \frac{1}{2\pi f C_{eq}}$$

- From the above equation, it is seen that under such conditions the input impedance of the device is a pure reactance and is given by

$$C_{eq} = g_m R C$$

Basic Reactance Modulator Contd.,

TABLE 5-3

NAME	Z_{gd}	Z_{gs}	CONDITION	REACTANCE FORMULA
RC capacitive	C	R	$X_C \gg R$	$C_{eq} = g_m RC$
RC inductive	R	C	$R \gg X_C$	$L_{eq} = \frac{RC}{g_m}$
RL inductive	L	R	$X_L \gg R$	$L_{eq} = \frac{L}{g_m R}$
RL capacitive	R	L	$R \gg X_L$	$C_{eq} = \frac{g_m L}{R}$

Transistor Reactance Modulator

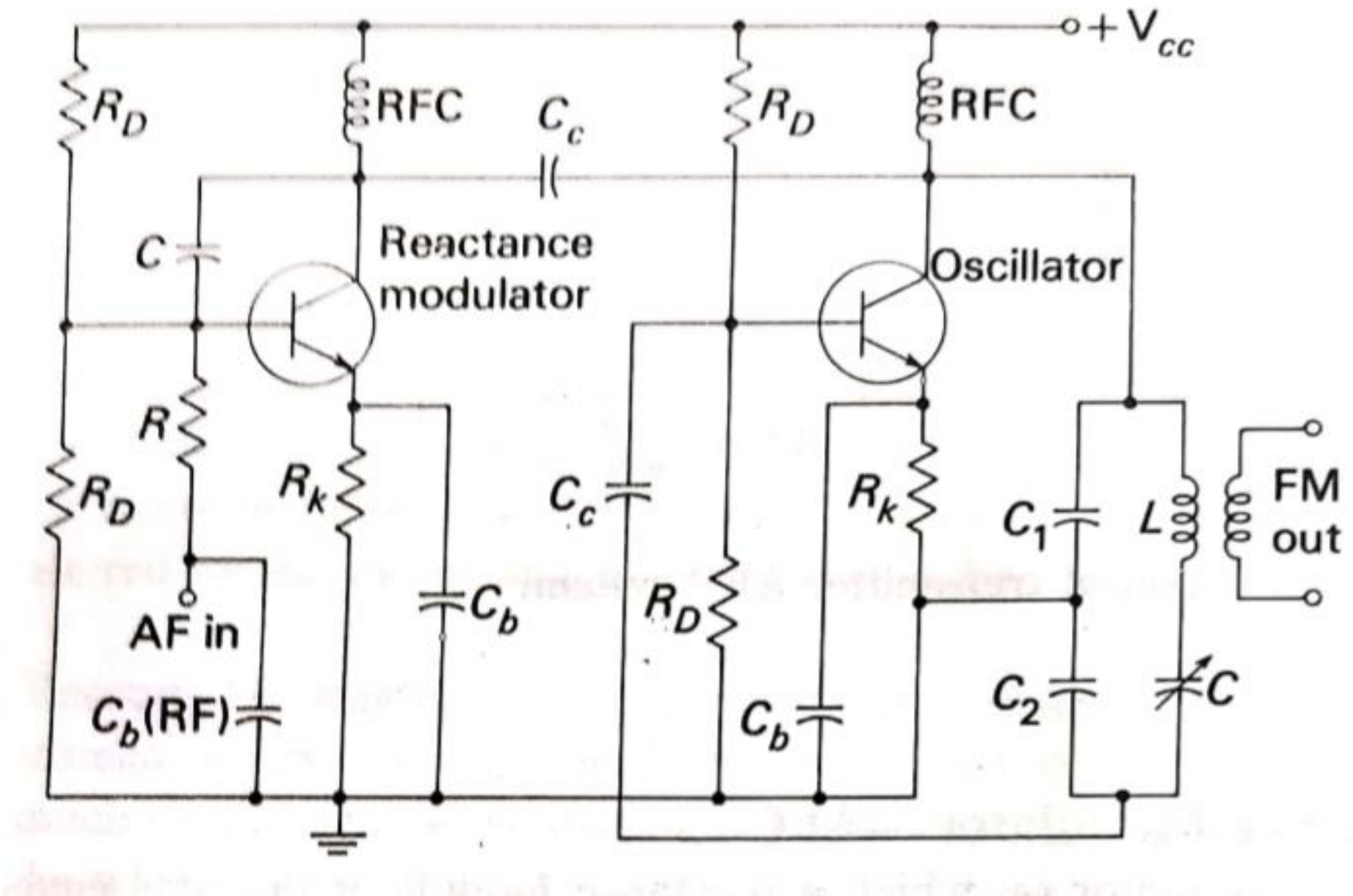


Figure: Transistor Reactance modulator

Indirect FM

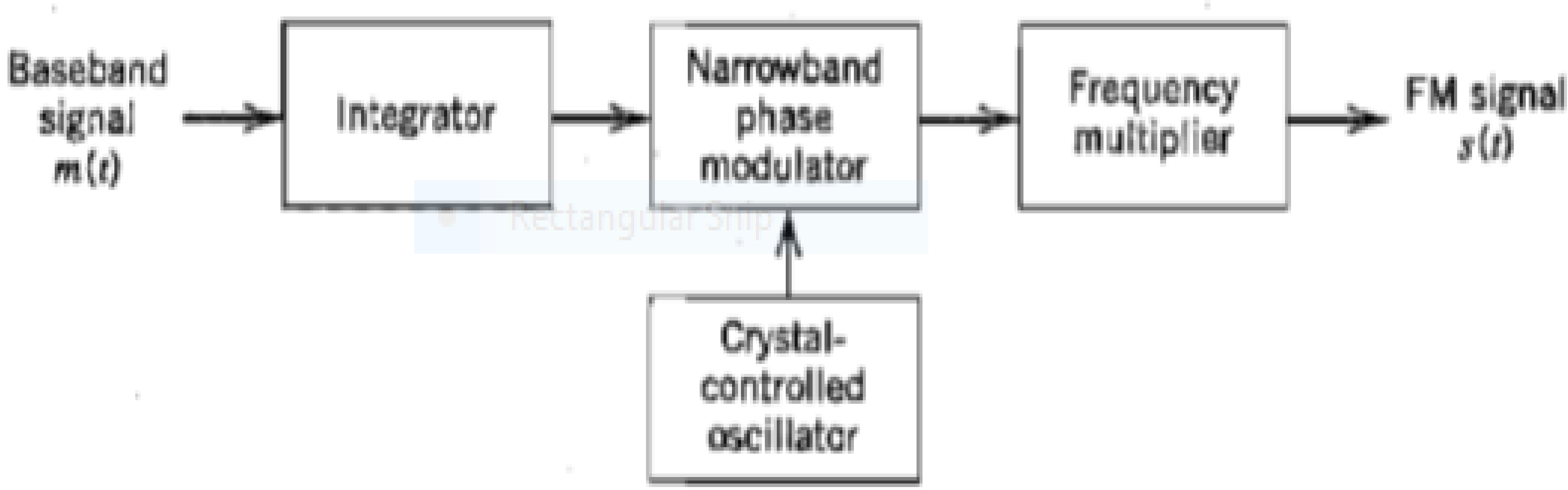


Figure: Block diagram of the indirect method generating a Wideband FM signal

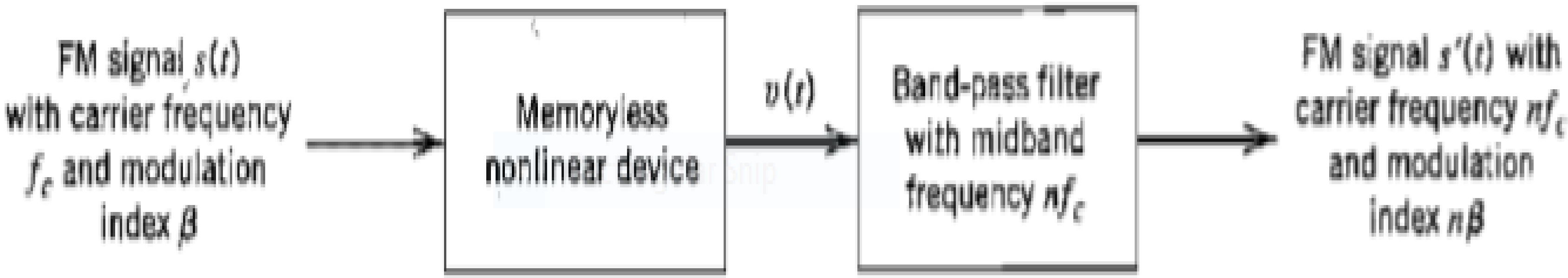
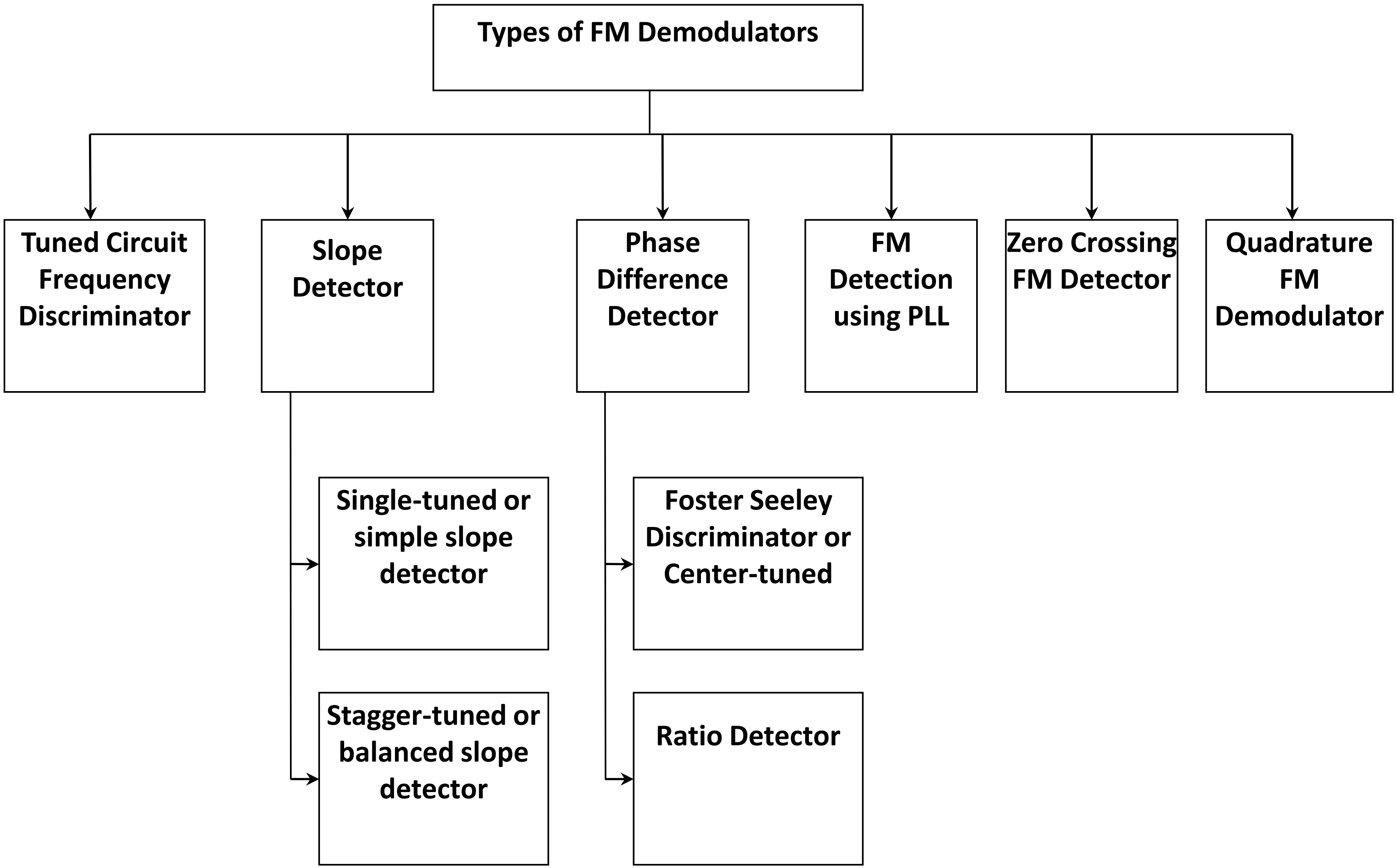


Figure: Block diagram of frequency multiplier

Demodulation of FM signals



Amplitude Limiting

- In order make full use of the advantages offered by FM, a demodulator must be preceded by amp. Limiter, any amplitude changes in the signal fed to the FM demodulators are spurious. They must be removed if distortion is to be avoided
- Since most FM demodulators react to amplitude changes as well as freq. changes
- The limiter is a form of clipping device, a circuit whose output tends to remain constant despite changes in the input signal.

Amplitude Limiter:

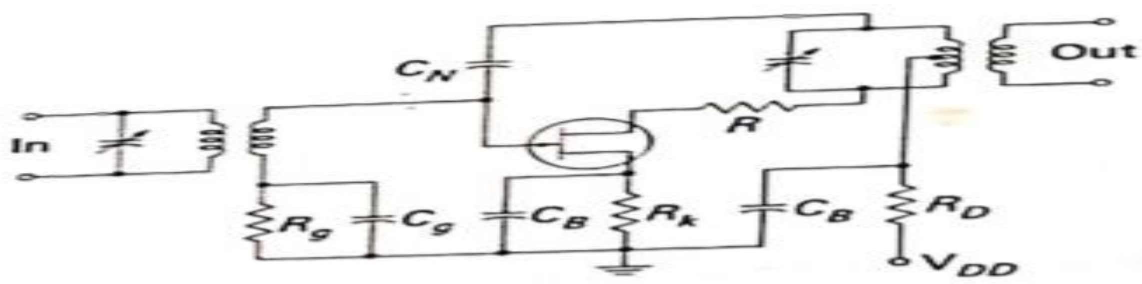


Figure: Amplitude Limiter

Amplitude Limiting Contd.,

- The Drain supply voltage has been dropped through resistor R_D
- The bias on the gate is leak type bias supplied by the parallel Rg-Cg combination.
- Finally, FET is neutralized by means of capacitor C_N , in consideration of the high frequency of operation.
- Leak type bias provides limiting, as shown in figure. When the input signal voltage rises, current flows in the Rg-Cg bias circuit, and a negative voltage is developed across the capacitor.
- The bias on the FET is increased in proportion to the size of the input voltage. As a result the gain of the amplifier is lowered, and the output voltage tends to remain constant.

Amplitude Limiting Contd.,

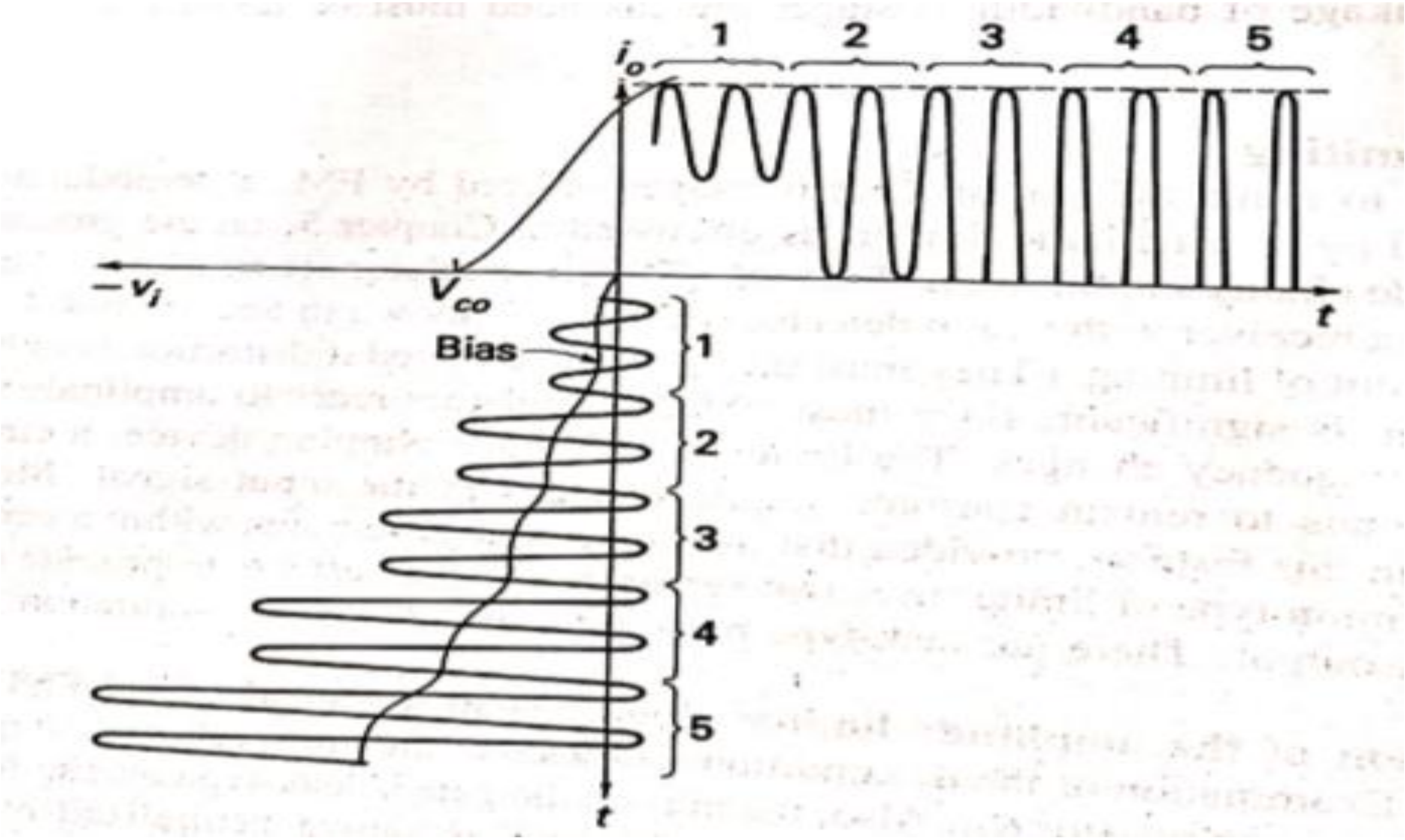


Figure: Amplitude Limiter Transfer Characteristics

Amplitude Limiting Contd.,

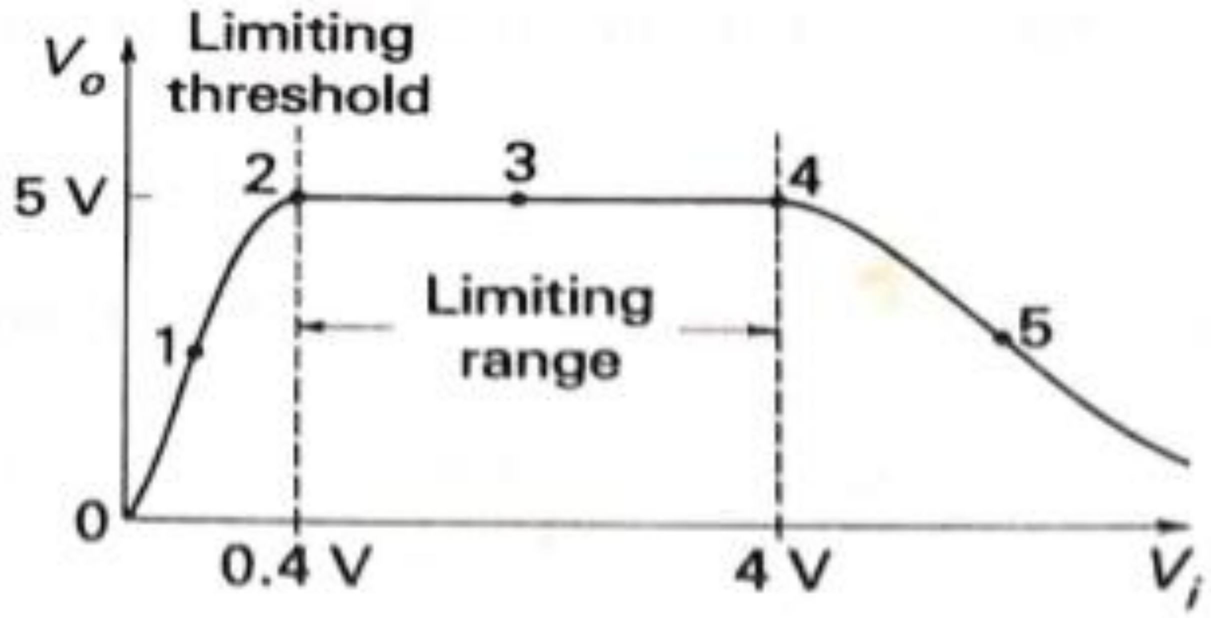


Figure: Typical Limiter response characteristics

Basic FM Demodulator Circuits

- The function of a frequency-to-amplitude changer, or FM demodulator, is to change the frequency deviation of the incoming carrier into an AF amplitude variation.
- In addition, the detection circuit should be insensitive to amplitude changes and should not be too critical in its adjustment and operation.
- Generally, this type of circuit converts the frequency-modulated IF voltage of constant amplitude into a voltage that is both frequency and amplitude-modulated. This latter voltage is then applied to the detector which reacts to amplitude change but ignores frequency variations
- It is necessary to devise a circuit which has an output whose amplitude depends on the frequency deviation of the input voltage

Slope Detection

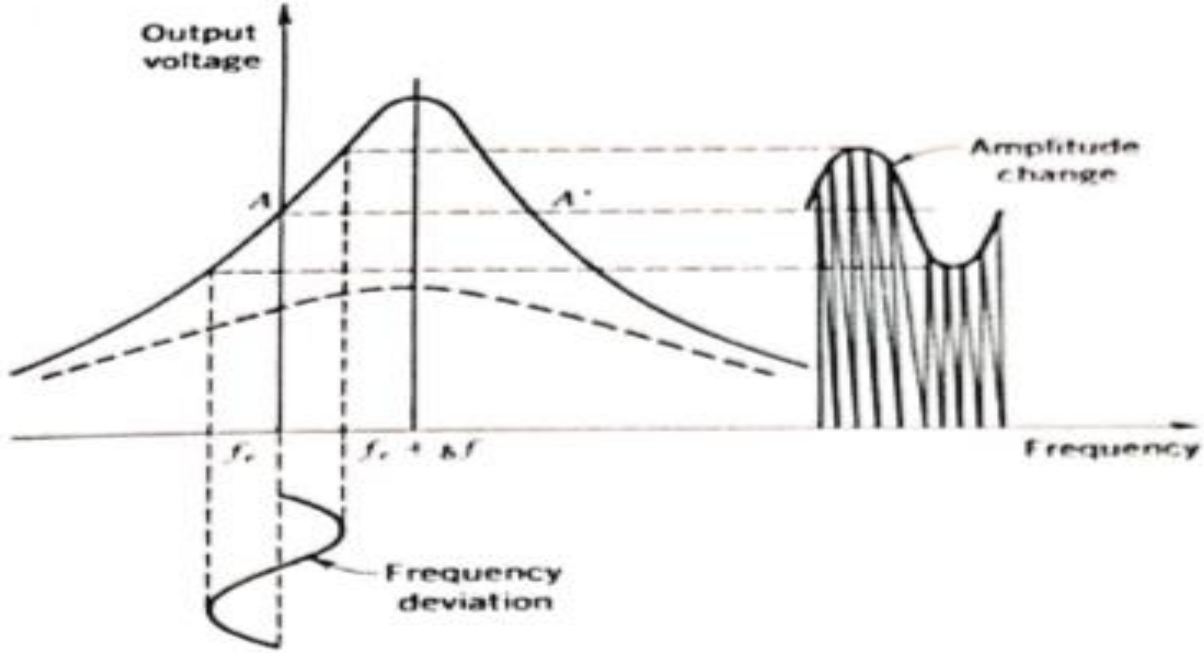


Figure: Slope Detector Characteristics Curve

- A frequency modulated signal fed to a tuned circuit whose resonant frequency is to one side of the center frequency of the FM signal.
- The output of this circuit will have an amplitude that depends on the frequency deviation of the input signal as illustrated in above figure

Slope Detection

- The circuit is detuned by an amount δf , to bring the carrier center frequency to point A on the selectivity curve .Frequency variation produces an output voltage proportional to the frequency deviation of the carrier.
- This output voltage is applied to a diode detector with an RC load of suitable time constant.

Disadvantages:

- It is linear only along a very limited frequency range
- It quite obviously reacts to all amplitude changes

Demodulation of FM signals Contd.,

i.Balanced Frequency Discriminator (Slope Detector)

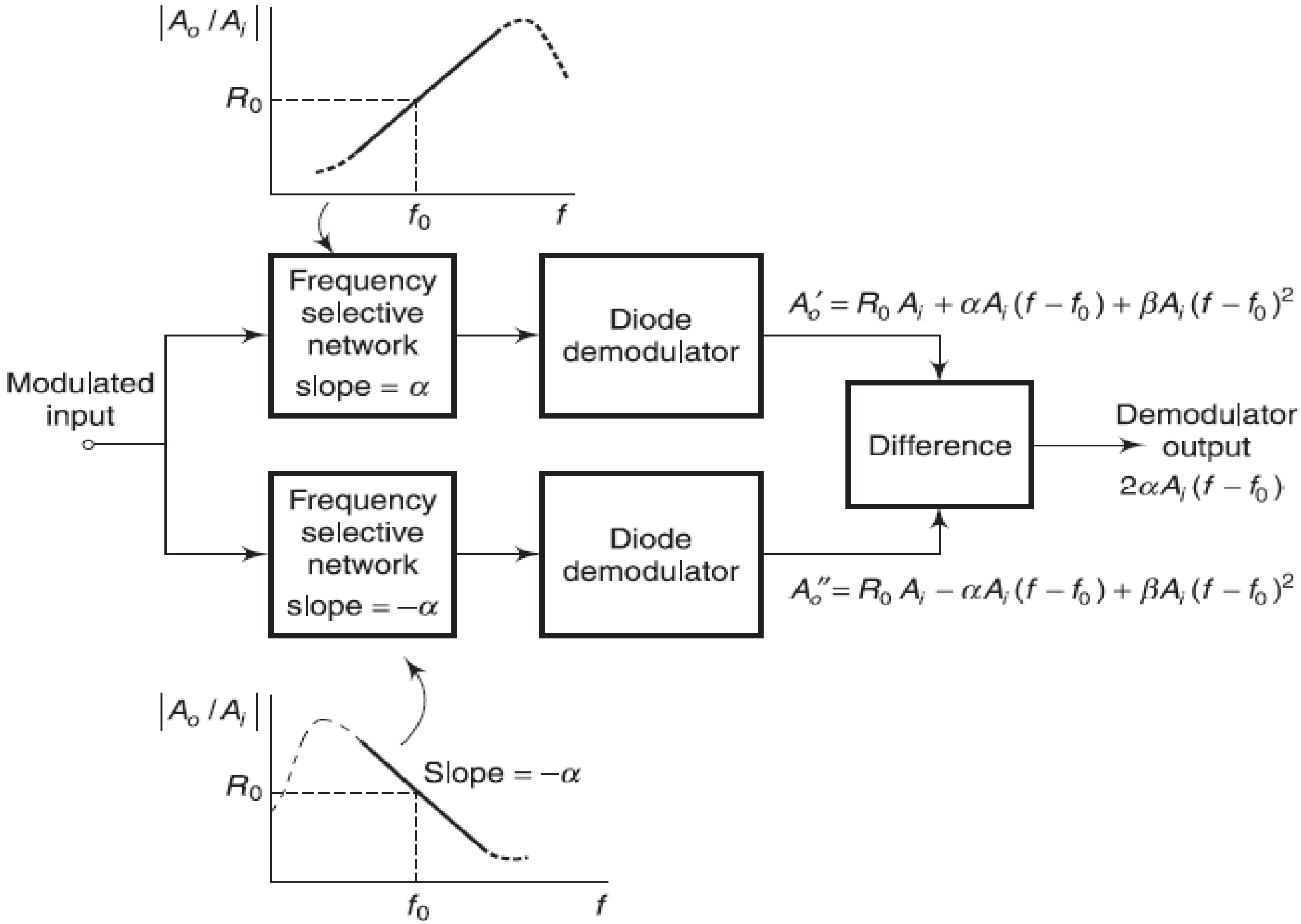
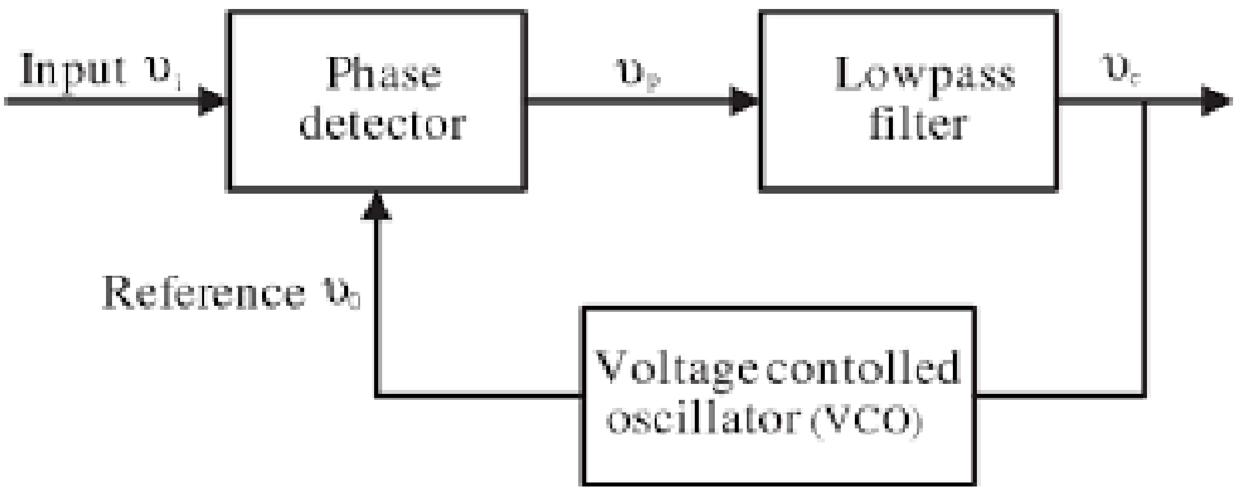


Figure: Block diagram of frequency discriminator

Demodulation of FM signals

ii. Phase Discrimination Method (PLL):



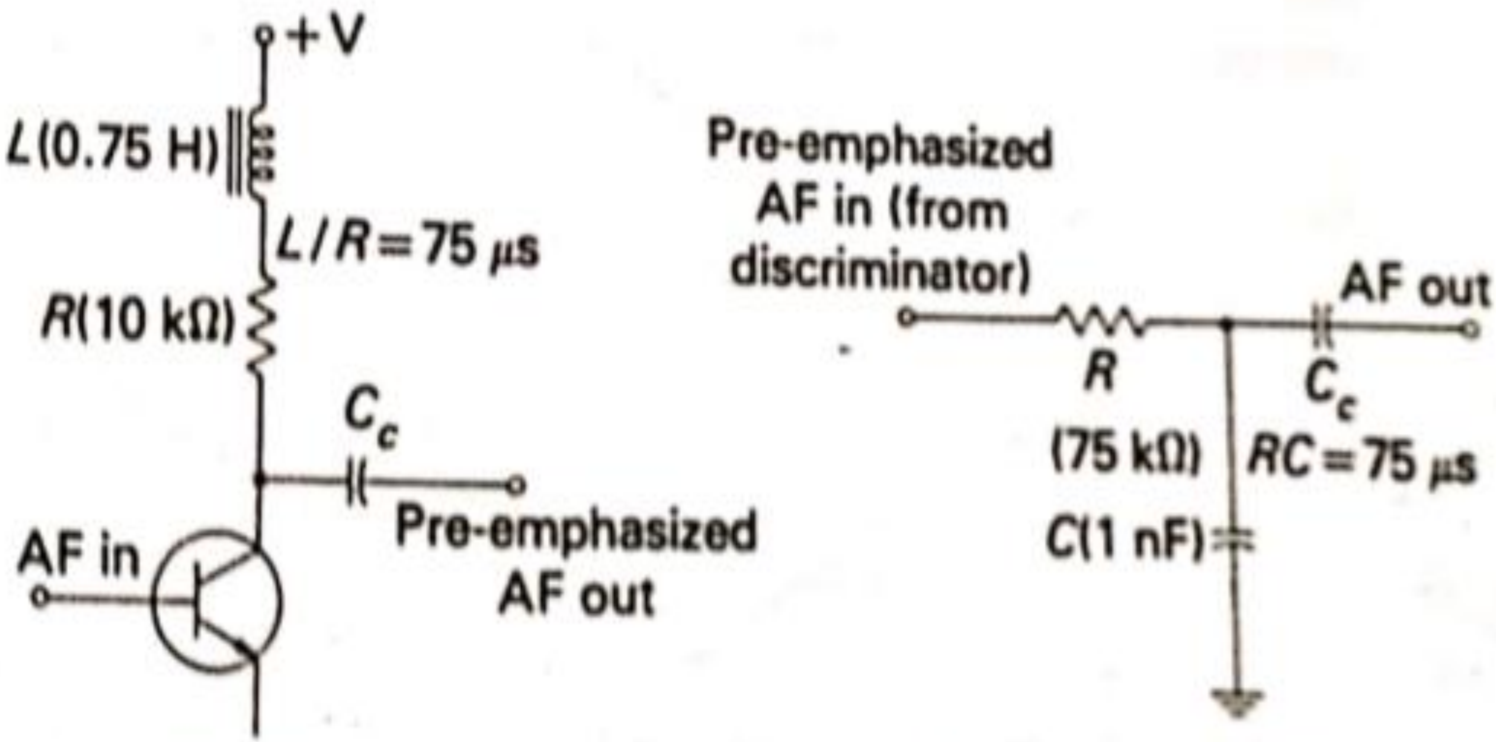
Comparison between AM and FM

S.No	Parameter	AM	FM
1	Definition	Amplitude of carrier is varied in accordance with amplitude of modulating signal keeping frequency and phase constant	Frequency of carrier is varied In accordance with the amplitude of modulating signal keeping amplitude and phase constant
2	Constant parameters	Frequency and phase	Amplitude and phase
3	Modulation Index	$\mu = Am/Ac$	$\beta = \frac{\Delta f}{f_m}$
4	Bandwidth	$BW = 2f_m$	$BW = 2(\Delta f + f_m)$
5	Number of Sidebands	Only two	Infinite and depends on β
6	Applications	MW, SW band broadcasting, video transmission in TV	Broadcasting FM, audio transmission in TV and analog cellular communications systems

Pre-emphasis & De-emphasis

- The noise has a greater effect on the higher modulating frequencies than on the lower ones. Thus, if the higher frequencies were artificially boosted at the transmitter and correspondingly cut at the receiver , an improvement in noise immunity could be expected, thereby increasing the **signal to noise ratio (SNR)**.
- The boosting of higher modulating frequencies, in accordance with a pre-arranges curve, is called **Pre-emphasis**, and the compensation at the receiver is called **De-emphasis**.
- The usage of microseconds for defining emphasis is standard.
- The amount of pre-emphasis in U.S FM broadcasing has been standardized as **75 microseconds** whereas in European and Australian broadcasing , it is **50 microseconds.**

Pre-emphasis & De-emphasis



(a) Pre-emphasis

(b) De-emphasis

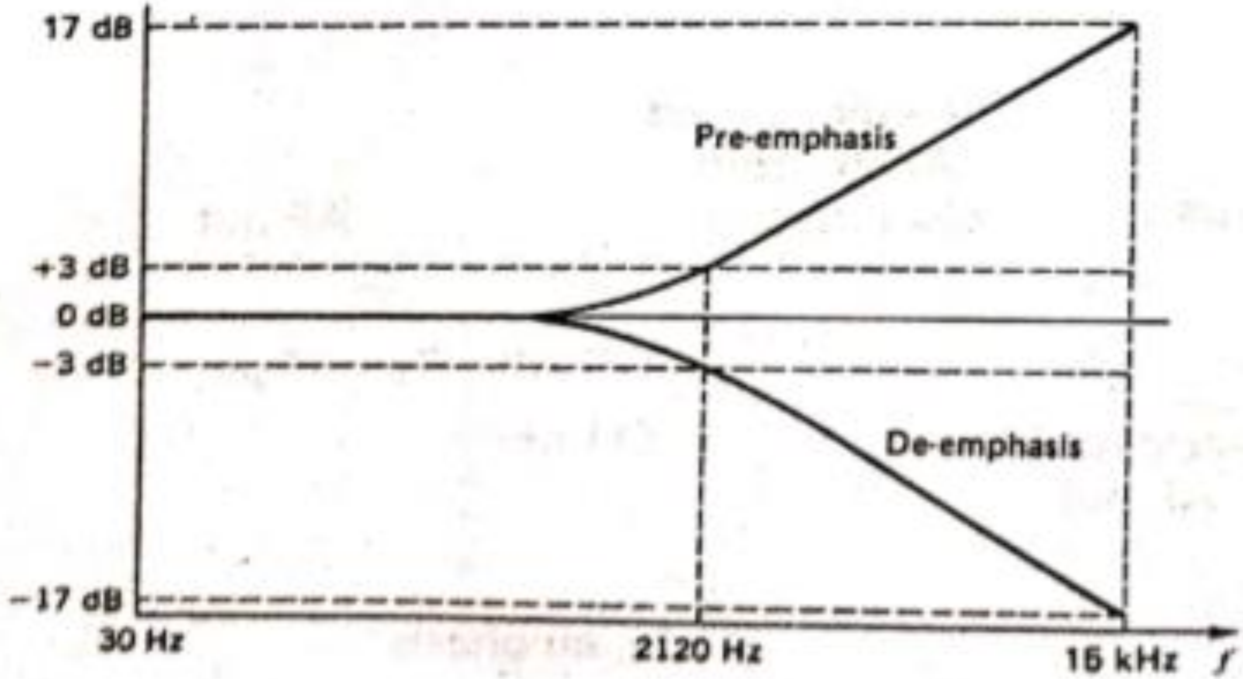


Figure: Pre-emphasis and De-emphasis curves for a 75 microseconds emphasis used in U.S

PROBLEMS ON FM

Question

In the stabilize reactance modulator AFC system,

a. the discriminator must have a fast time constant to prevent demodulation

b. the higher the discriminator frequency, the better the oscillator frequency stability

c. the discriminator frequency must not be too low, or the system will fail

d. phase modulation is converted into FM by the equalizer circuit

Solution

In the stabilize reactance modulator AFC system, the discriminator frequency must not be too low, or the system will fail

So Option C is Correct

Question

One of the following is an indirect way of generating FM. This is the

a. reactance FET modulator

b. varactor diode modulator

c. Armstrong modulator

d. reactance bipolar transistor modulator

Solution

Armstrong modulator is indirect way of generating FM.

So option C is Correct

Question

The audio signal having frequency 500Hz and voltage 2.6V, shows a deviation of 5.2KHz in a Frequency Modulation system. If the audio signal voltage changes to 8.6V, calculate the new deviation obtained.

a. 17.2 KHz

b. 19.6 KHz

c. 25.6 KHz

d. 14.6 KHz

Solution

Deviation in FM is given by $\Delta f = k_f \ .A_m$

here, $k_f = \Delta f \ / \ A_m$

$= 5.2/2.6= 2$

When voltage changes to 8.6V = A_m

New frequency deviation $\Delta f = k_f \, A_m$

$= 2* 8.6$

$= 17.2$ KHz

So option A is correct

Question

In a FM system, a carrier of 100 MHz is modulated by a sinusoidal signal of 5 KHz. The bandwidth by Carson's approximation is 1MHz. If y(t) = (modulated waveform)^3, then by using Carson's approximation, the bandwidth of y(t) around 300 MHz and the spacing of spectral components are, respectively.

(a) 3 MHz, 5 KHz

(b) 1 MHz, 15 KHz

(c) 3 MHz, 15 KHz

(d) 1 MHz, 5 KHz

GATE 2000: 2 Marks

Question

Match List I with List II and select the correct answer using the codes given below the lists:

List I

A. Collector modulation

B. Phase shift method

C. Balanced modulator

D. Amplitude limiter

List II

1. FM generation
2. DSB generation
3. AM generation
4. SSB generation

Options:	**A**	**B**	**C**	**D**
	(a) 3	4	1	2
	(b) 4	3	1	2
	(c) 3	4	2	1
	(d) 4	3	2	1

Option C is Correct

Solution

In an FM signal, adjacent spectral components will get separated by modulating frequency
$\boldsymbol{f_m = 5KHz}$

$\boldsymbol{BW = 2(\Delta f + f_m) = 1MHz}$
$\boldsymbol{\Delta f + fm = 500\ KHz}$
$\boldsymbol{\Delta f = 495\ KHz}$

The nth order non-linearity makes the carrier frequency and frequency deviation increased by n-fold, with baseband frequency f_m unchanged.
$\boldsymbol{(\Delta f)_{new} = 3 \times 495 = 1485\ KHz}$

$\boldsymbol{New\ BW = 2(1485 + 5) \times 103 = 2.98\ MHz \approx 3\ MHz}$

So Option (a) is Correct

V(t)=5[cos$(10^6\pi t) - \sin(10^3\pi t)\sin(10^6\pi t)]$ $represents$

A. DSB suppressed signal
B. AM signal
C. SSB upper side band signal
D. Narrow band FM signal

Given signal is v(t)= 5[cos$(10^6\pi t) - \sin(10^3\pi t)\sin(10^6\pi t)]$

= 5cos$(10^6\pi t)$+5/2[cos$(10^6 + 10^3)\pi t$- cos$(10^6 - 10^3)\pi t]$

By observing the above equation we can conclude that

It is an Narrow band FM signal because a narrow band FM signal is represented by

$$s(t) = (A_c cos 2\pi f_c t) + \frac{1}{2}\beta A_c\{cos[2\pi(f_c + f_m)t] - cos[2\pi(f_c - f_m)t]\}$$

Therefore the given signal is an Narrow band FM signal

The signal $\cos w_c t + 0.5cosw_m t\ sinw_c t$ is

A. FM only

B. AM only

C. Both AM and FM

D. Neither AM nor FM

Solution: given signal is

$$\cos w_c t + 0.5cosw_m t\ sinw_c t$$

In order to become AM signal it should be in the form of

$$\cos w_c t + 0.5cosw_m t\ cosw_c t = (1 + 0.5\ cosw_m t\ )\ cosw_c t$$

Therefore it is not an AM signal

It is not an Narrow band FM signal by comparing with the standard FM signal

Therefore the answer is it is neither FM nor AM signal (option D)

The approximate transfer function of a frequency demodulator

$A. \frac{1}{j\pi f}$

$B. \frac{1}{j2\pi f}$

$C. \frac{1}{j2\pi f} + k$ for k$\ll$ 1

D. j$2\pi f$

Solution:

FM demodulators can be modelled as differentiator circuits ,
whose F.T is jw,
which acts as LOW pass filter
Options A, B,C are the transfer functions of integrators
Hence option D is the correct answer

An AM signal and a narrow band FM signal with identical carriers, modulating signals and modulation indices of 0.1 are added together. The resultant signal can be closely approximated by

A. Broad band FM
B. DSB-SC
C. SSB with carrier
D. SSB without carrier

SOLUTION:

$$V_{AM}(t) = Acosw_c t + \frac{0.1A}{2}\cos(w_c + w_m)\,t + \frac{0.1A}{2}\cos(w_c - w_m)$$

$$V_{NBFM}(t) = Acosw_c t + \frac{0.1A}{2}\cos(w_c + w_m)\,t - \frac{0.1A}{2}\cos(w_c - w_m)\,t$$

According to the condition given in the problem

Resultant signal= $V_{AM}(t)$+ $V_{NBFM}(t)$

$$= Acosw_c t + \frac{0.1A}{2}\cos(w_c + w_m)\,t + \frac{0.1A}{2}\cos(w_c - w_m)\,t + Acosw_c t + \frac{0.1A}{2}\cos(w_c + w_m)\,t - \frac{0.1A}{2}\cos(w_c - w_m)\,t$$

$$= 2Acosw_c t + 0.1\mathrm{A}\cos(w_c + w_m)\,t$$

Therefore it can be viewed as SSB with carrier (option C)

A frequency modulated signal is given by s(t)=10cos[$2\pi 10^6$t+$2\sin 2\pi 2000$t]. If the above signal is passes through a non liner device y=x^3, the carrier frequency and the modulation index for the FM wave at the output of the Non linear device is

Given FM Signal is

$$s(t)=10\cos[2\pi 10^6 t+2\sin 2\pi 2000t].$$

Comparing with general expression of single tone FM

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

The following can be extracted from the given input

$f_c = 10^6$, β=2

cos(nθ)

$\cos[2\pi f_c t+\Delta f]$ when applied to frequency multiplier the following changes will occur to an FM signal

$f_c \rightarrow$ **n** f_c

$\Delta f \rightarrow$ **n** Δf

$\boldsymbol{\beta} \rightarrow$ **n** $\boldsymbol{\beta}$

$\boldsymbol{f_m}$ $\boldsymbol{f_m}$ **(no change)** **[Concept to be remembered]**

Given that y(t)=$x^3(t)$,that implies n=3

Therefore $f_c' = \mathbf{3}\ \mathrm{f_c} = \mathbf{3}\ \boldsymbol{X}\ \mathbf{1}\ \boldsymbol{Mhz} = \mathbf{3}\boldsymbol{Mhz}$

β'=3 $\boldsymbol{\beta}$ **=3 x2=6**

A frequency Modulated signal is given by s(t)= cos[2π 10^7t+5cos2πf$_m$t]. if $J_5(5) \cong 0$.

The appropriate bandwidth to transmit s(t) is

s(t) can be expressed in terms of Bessel Functions

s(t)=$\sum_{n=-\infty}^{\infty} j_n(\beta)\cos(2\pi f_c \pm n f_m t)$

From the given expression it is clear that the spectrum of an FM signal contains a carrier component and an infinite set of side frequencies located symmetrically on either side of the carrier at frequency separations of $f_m, 2f_m, 3f_m$......

Given that $j_5(\beta) \cong 0$

Therefore we require four side bands to the left of f_c and four side bands to the right of f_c

Therefore bandwidth requires =4 f_m+4 f_m=8 f_m

C(t) and m(t) are used to generate an FM signal. If the peak frequency deviation of the generated FM signal is three times the transmission bandwidth of the AM signal ,then the coefficient term $5\cos[2\pi(1008\ X10^3 t)]$ in the FM signal(in terms of the Bessel coefficients)

(a) $5J_4(3)$

(b) $\frac{5}{2}J_8(3)$

(c) $\frac{5}{2}J_8(4)$

(d) $5J_4(6)$

Wide bend FM signal can be represented in terms of Bessel function

$$s(t)=A_c \sum_{n=-\infty}^{\infty} j_n(\beta) \cos(2\pi f_c \pm n f_m t)$$

Given that peak frequency deviation is three times the transmission bandwidth of the FM signal

$\Delta f = 3 * 2 * f_m = 6\ f_m$

The modulation index $\beta = \frac{\Delta f}{f_m} = \frac{6\ f_m}{f_m} = 6$

Given signal can be represented as $5\cos[2\pi(1008\ X10^3 t)] = 5$ $\cos[2\pi(1000 + 4 * 2)\ X10^3 t)$

By comparing with the wide band FM signal

We get n=4 and A_c=5

Therefore the coefficient can be written as

$5j_4(6)$ (option D)

A frequency modulated signal is given by s(t) $=10\sum_{n=-\infty}^{\infty} j_n(2)\cos(2\pi f_c \pm n f_m t)$.
The power of this frequency modulated signal is

Solution:

The given signal is of the form s(t)$=A_c\sum_{n=-\infty}^{\infty} j_n(\beta)\cos(2\pi f_c \pm n f_m t)$

Then the power can be computed as

We know that according to properties of Bessel function

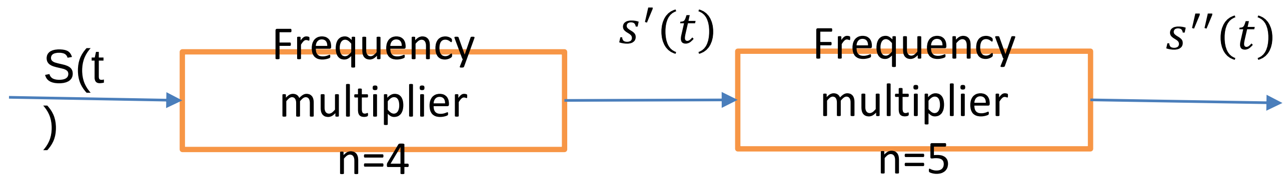
$$\sum_{n=-\infty}^{\infty} j_n^2(\beta) = 1$$

Therefore s(t) can be represented as

s(t)$=A_c\sum_{n=-\infty}^{\infty}\cos(2\pi f_c \pm n f_m t)$

$$=\frac{A_C^2}{2}=\frac{100}{2}=50\ W$$

An FM signal is s(t)= 10cos[2π 10^6t+0.2sin(2π $2X10^3$t)].It is passes through cascaded frequency multiplier of having multiplying constant of 4 and 5 respectively. Find all the parameters of FM signal at the output of each multiplier



Given signal

s(t)= 10cos[2π 10^6t+0.2sin(2π $2X10^3$t)].

Comparing with general expression of single tone FM

s(t)=$A_c$cos[2πf_ct+βsin2π$f_m t$]

A_c=10, f_c= 10^6

$\beta = 0.2$, f_m=2 kHz

$\Delta f = \beta f_m$=2*0.2=0.4Khz

first frequency multiplier , n=4

A_c=10

f_c= 10^6*4

$\beta = 0.2 * 4$

f_m=2 kHz , $\Delta f = \beta f_m$=1.6kHz

Second frequency multiplier , n=5

A_c=10

f_c= 10^6*4*5

$\beta = 0.2 * 4 * 5$

f_m=2 kHz, $\Delta f = \beta f_m$=8KHZ

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THANK YOU