Unit 2

(2)

Analog Communication - FM Modulators

In this chapter, let us discuss about the modulators which generate NBFM and WBFM waves. First, let us discuss about the generation of NBFM.

Generation of NBFM

We know that the standard equation of FM wave is

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\,dt\right)$$

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

For NBFM,

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

We know that $\cos\theta \approx 1$ and $\sin\theta \approx 1$ when θ is very small.

By using the above relations, we will get the **NBFM equation** as

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

The block diagram of NBFM modulator is shown in the following figure.

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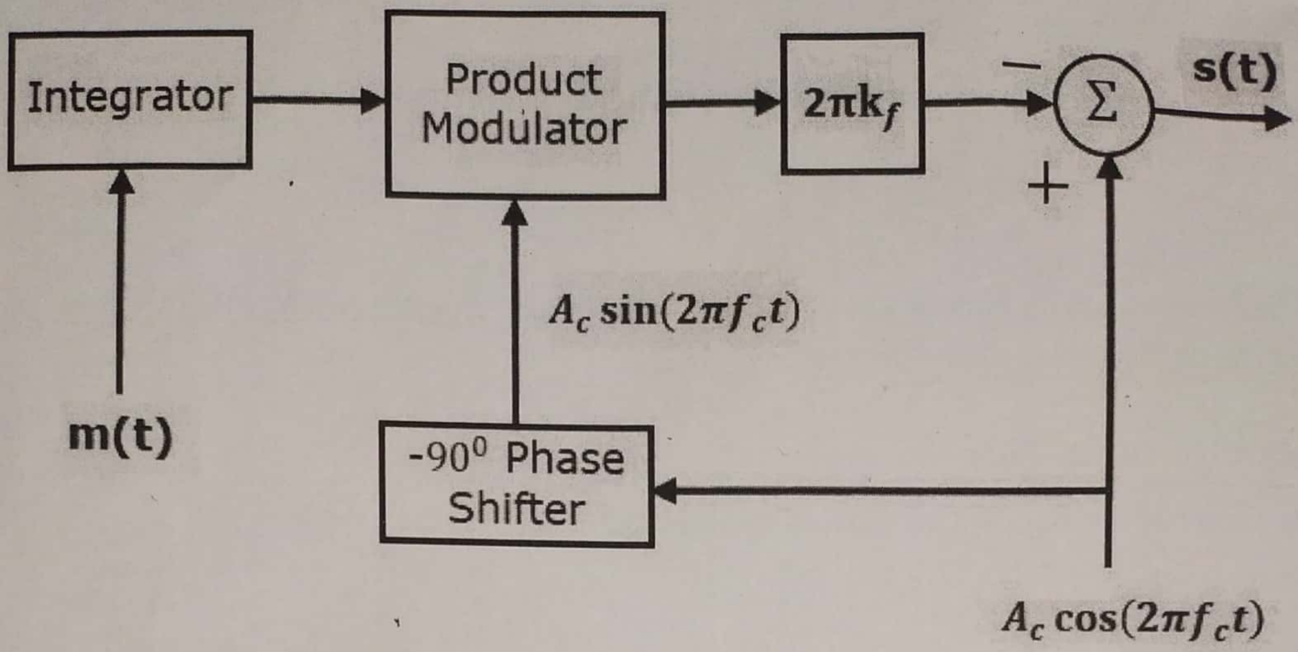


Here, the integrator is used to integrate the modulating signal $m(t)$. The carrier signal $A_c \cos(2\pi f_c t)$ is the phase shifted by -90^0 to get $A_c \sin(2\pi f_c t)$ with the help of -90^0 phase shifter. The product modulator has two inputs $\int m(t)\,dt$ and $A_c \sin(2\pi f_c t)$. It produces an output, which is the product of these two inputs.

This is further multiplied with $2\pi k_f$ by placing a block $2\pi k_f$ in the forward path. The summer block has two inputs, which are nothing but the two terms of NBFM equation. Positive and negative signs are assigned for the carrier signal and the other term at the input of the summer block. Finally, the summer block produces NBFM wave.

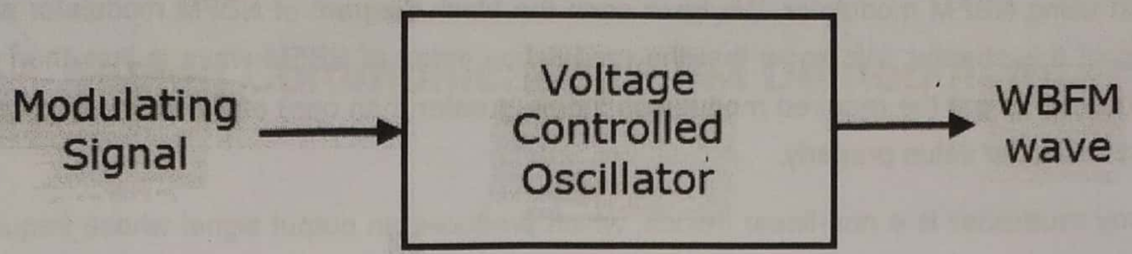
Generation of WBFM

The following two methods generate WBFM wave.

- Direct method
- Indirect method

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 is shown in the following figure.



Here, the modulating signal $m(t)$ is applied as an input of Voltage Controlled Oscillator (VCO). VCO produces an output, which is nothing but the WBFM.

$$f_i \; \alpha \; m(t)$$

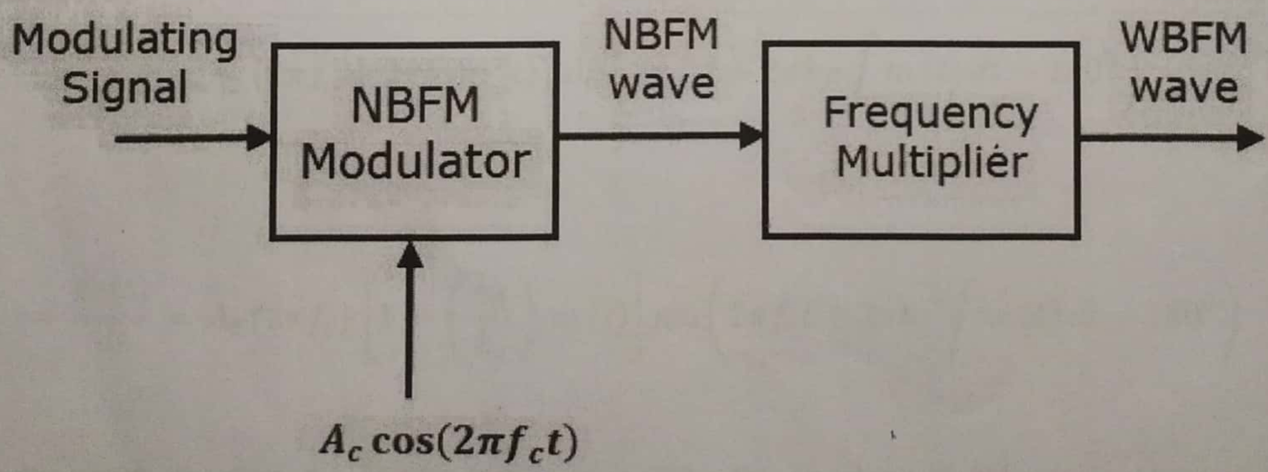
$$\Rightarrow f_i = f_c + k_f m(t)$$

Where,

f_i is the instantaneous frequency 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 have seen the block diagram of NBFM modulator at the beginning of this chapter. 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.

Frequency multiplier is a non-linear device, which produces an output signal whose frequency is 'n' times the input signal frequency. Where, 'n' is the multiplication factor.

If NBFM wave whose modulation index β is less than 1 is applied as the input of frequency multiplier, then the frequency multiplier produces an output signal, whose modulation index is 'n' times β and the frequency also 'n' times the frequency of WBFM wave.

Sometimes, we may require multiple stages of frequency multiplier and mixers in order to increase the frequency deviation and modulation index of FM wave.

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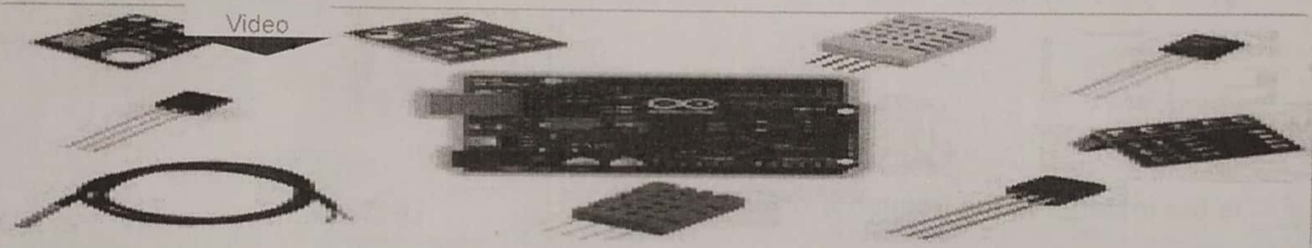

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Analog Communication - FM Demodulators

In this chapter, let us discuss about the demodulators which demodulate the FM wave. The following two methods demodulate FM wave.

- Frequency discrimination method
- Phase discrimination method

Frequency Discrimination Method

We know that the equation of FM wave is

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt\right)$$

Differentiate the above equation with respect to 't'.

$$\frac{ds(t)}{dt} = -A_c \left(2\pi f_c + 2\pi k_f m(t)\right) \sin\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt\right)$$

We can write, $-\sin\theta$ as $\sin(\theta - 180^0)$.

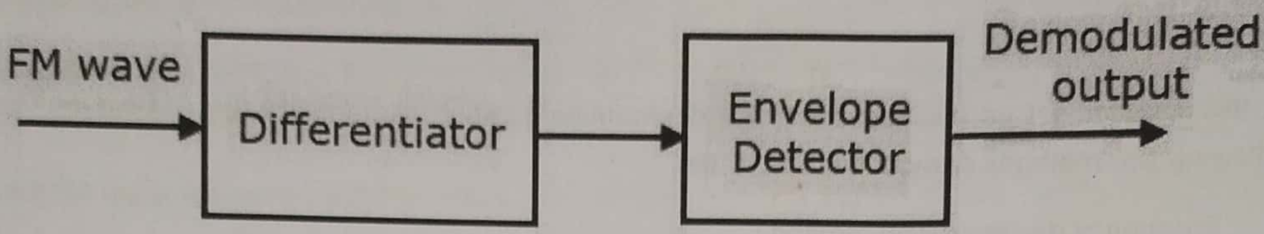
$$\Rightarrow \frac{ds(t)}{dt} = A_c \left(2\pi f_c + 2\pi k_f m(t)\right) \sin\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt - 180^0\right)$$

$$\Rightarrow \frac{ds(t)}{dt} = A_c (2\pi f_c) \left[1 + \left(\frac{k_f}{k_c}\right) m(t)\right] \sin\left(2\pi f_c t + 2\pi k_f \int m(t)\, dt - 180^0\right)$$

In the above equation, the amplitude term resembles the envelope of AM wave and the angle term resembles the angle of FM wave. Here, our requirement is the modulating signal $m(t$

Hence, we can recover it from the envelope of AM wave.

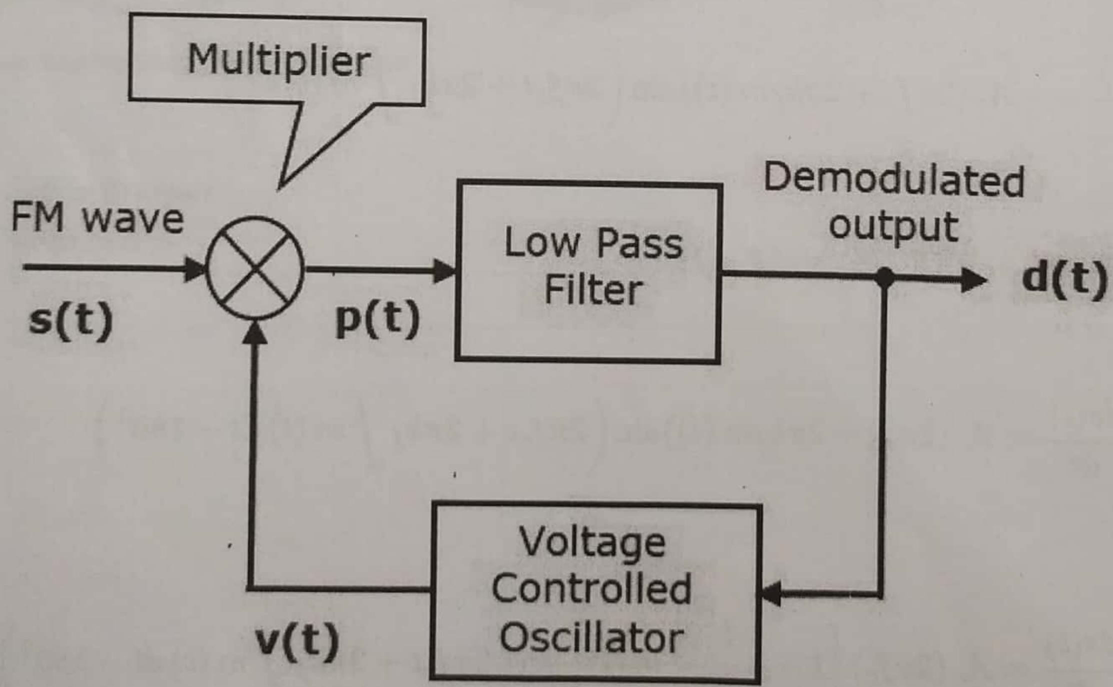
The following figure shows the block diagram of FM demodulator using frequency discrimination method.



This block diagram consists of the differentiator and the envelope detector. Differentiator is used to convert the FM wave into a combination of AM wave and FM wave. This means, it converts the frequency variations of FM wave into the corresponding voltage (amplitude) variations of AM wave. We know the operation of the envelope detector. It produces the demodulated output of AM wave, which is nothing but the modulating signal.

Phase Discrimination Method

The following figure shows the block diagram of FM demodulator using phase discrimination method.



This block diagram consists of the multiplier, the low pass filter, and the Voltage Controlled Oscillator (VCO). VCO produces an output signal $v(t)$, whose frequency is proportional to the nput signal voltage $d(t)$. Initially, when the signal $d(t)$ is zero, adjust the VCO to produce an output signal $v(t)$, having a carrier frequency and -90^0 phase shift with respect to the carrier signal.

FM wave $s(t)$ and the VCO output $v(t)$ are applied as inputs of the multiplier. The multiplier produces an output, having a high frequency component and a low frequency component. Low pass filter eliminates the high frequency component and produces only the low frequency component as its output.

This low frequency component contains only the term-related phase difference. Hence, we get the modulating signal $m(t)$ from this output of the low pass filter.

Numerical Problems 2

In the previous chapter, we have discussed the parameters used in Angle modulation. Each parameter has its own formula. By using those formulas, we can find the respective parameter values. In this chapter, let us solve a few problems based on the concept of Frequency Modulation.

Problem 1

A sinusoidal modulating waveform of amplitude 5 V and a frequency of 2 KHz is applied to FM generator, which has a frequency sensitivity of 40 Hz/volt. Calculate the frequency deviation, modulation index, and bandwidth.

Solution

Given, the amplitude of modulating signal, $A_m = 5V$

Frequency of modulating signal, $f_m = 2KHz$

Frequency sensitivity, $k_f = 40Hz/volt$

We know the formula for Frequency deviation as

$$\Delta f = k_f A_m$$

Substitute k_f and A_m values in the above formula.

$$\Delta f = 40 \times 5 = 200Hz$$

Therefore, **frequency deviation**, Δf is $200Hz$

The formula for modulation index is

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

Substitute Δf and f_m values in the above formula.

$$\beta = \frac{200}{2 \times 1000} = 0.1$$

Here, the value of **modulation index**, β is 0.1, which is less than one. Hence, it is Narrow Band FM.

The formula for Bandwidth of Narrow Band FM is the same as that of AM wave.

$$BW = 2f_m$$

Substitute f_m value in the above formula.

$$BW = 2 \times 2K = 4KHz$$

Therefore, the **bandwidth** of Narrow Band FM wave is $4KHz$.

Problem 2

An FM wave is given by $s(t) = 20\cos\left(8\pi \times 10^6 t + 9\sin\left(2\pi \times 10^3 t\right)\right)$. Calculate the frequency deviation, bandwidth, and power of FM wave.

Solution

Given, the equation of an FM wave as

$$s(t) = 20\cos\left(8\pi \times 10^6 t + 9\sin\left(2\pi \times 10^3 t\right)\right)$$

We know the standard equation of an FM wave as

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

We will get the following values by comparing the above two equations.

Amplitude of the carrier signal, $A_c = 20V$

Frequency of the carrier signal, $f_c = 4 \times 10^6 Hz = 4MHz$

Frequency of the message signal, $f_m = 1 \times 10^3 Hz = 1KHz$

Modulation index, $\beta = 9$

Here, the value of modulation index is greater than one. Hence, it is **Wide Band FM**.

We know the formula for modulation index as

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

Rearrange the above equation as follows.

$$\Delta = \beta f_m$$

Substitute β and f_m values in the above equation.

$$\Delta = 9 \times 1K = 9KHz$$

Therefore, **frequency deviation**, Δf is $9KHz$.

The formula for Bandwidth of Wide Band FM wave is

$$BW = 2(\beta + 1) f_m$$

Substitute β and f_m values in the above formula.

$$BW = 2\,(9+1)\,1K = 20KHz$$

Therefore, the **bandwidth** of Wide Band FM wave is $20KHz$

Formula for power of FM wave is

$$P_c = \frac{{A_c}^2}{2R}$$

Assume, $R = 1\Omega$ and substitute A_c value in the above equation.

$$P = \frac{(20)^2}{2\,(1)} = 200W$$

Therefore, the **power** of FM wave is 200 **watts**.

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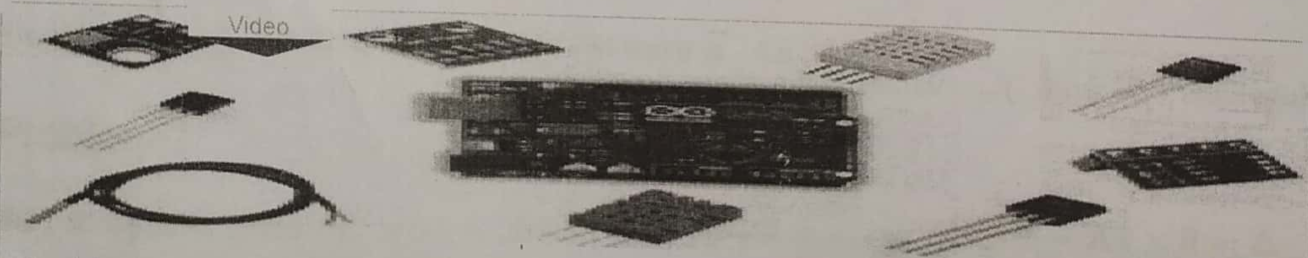

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