NARROW BAND FM MODULATION:

Types of FM

The FM systems are basically classified into following two types :

Narrow band FM

Wide band FM / Broadband FM

Narrow Band FM

A narrow band FM is the FM wave with a small bandwidth , The modulation index mf of narrow band FM is small as compared to one radian . Hence, the spectrum of narrow band FM consists of the carrier and upper sideband and a lower sideband .

For small values of mf , the values of the j coefficients are as under :

$J0(mf) = 1$,

$J1(mf) = mf/2$

$Jn(mf) = 0$ for $n > 1$

Practically, the narrow band FM systems have mf less than 1 . The maximum permissible frequency deviation is restricted to about 5 kHz . This system is used in FM mobile communications such as police wireless, ambulances, taxicabs etc . This frequency modulation has a small bandwidth when compared to wideband FM. The modulation index β is small, i.e., less than 1.Its spectrum consists of the carrier, the upper sideband and the lower sideband. This is used in mobile communications such as police wireless, ambulances, taxicabs, etc.

Generation of Narrow band Frequency Modulated Wave (NBFM)

We know that the standard equation of FM wave is

$$s(t)=Accos(2\pi fct+2\pi kf\int m(t)dt) \qquad (1)$$

$$s(t)=Accos(2\pi fct)cos(2\pi kf\int m(t)dt) - Acsin(2\pi fct)sin(2\pi kf\int m(t)dt) \qquad (2)$$

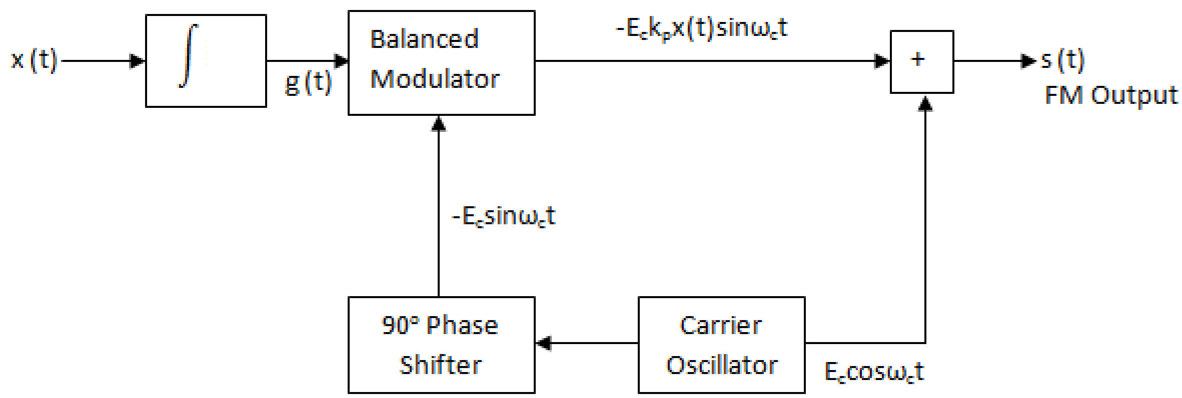

Figure 2.2.1 Generation of Frequency

Modulated Signal, Diagram Source Brain Kart

For NBFM,

$$|2\pi k_f \int m(t)dt| << 1 \qquad (3)$$

We know that cosθ≈1 and sinθ≈1 when θ is very small.

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

$$s(t)=A_c\cos(2\pi f_c t)-A_c\sin(2\pi f_c t)2\pi k_f \int m(t)dt \qquad (4)$$

The block diagram of NBFM modulator is shown in the following figure 2.2.1. Here, the integrator is used to integrate the modulating signal m(t)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 $\int m(t)dt \int m(t)dt$ 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 as shown in the figure 2.2.2.

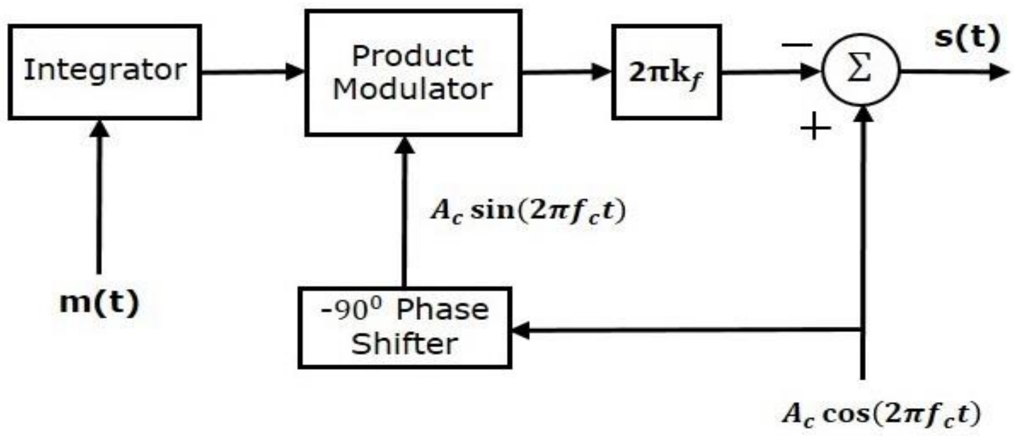

Figure 2.2.2 Generation of Frequency Modulated Signal

Diagram Source Brain Kart

Analysis of Narrow band FM

As we know, the expression for instantaneous frequency of FM wave is given as :

$$f_i = f_c + k_f x(t) \tag{5}$$

Where, x(t) is the modulating signal .

The term kf x(t) represents the frequency deviation . The constant kf will control the deviation . For small values of kf , the frequency deviation is small and the spectrum of FM signal has a narrow band . Hence, it is called as the narrow band FM .

Let us consider the expression for FM wave as under :

$$s(t) = E_c \cos\,[2\pi f_c t + 2\pi k_f \int x(t)\,dt]$$

Expressing it in terms of ω, we have

$$s(t) = E_c \cos\,[\omega_c t + 2\pi k_f \int x(t)\,dt]$$

We can represent this in the exponential manner as under:

$$s(t) = E_c \cos\theta(t) = E_c e^{j\theta(t)}$$

This has been written by considering only the real part of $E_c e^{j\theta(t)}$

Therefore,

$$s(t) = E_c e^{j\theta(t)} = E_c e^{j[cos\omega_c t + k_f \int x(t)dt]}$$

Let $\int x(t)dt = g(t)$

Thus,

$$s(t) = E_c e^{j[cos\omega_c t + k_f\, g(t)]}$$

If $k_f g(t) << 1$ for all values (which is the case for narrow band FM), then, the expression for FM will be

$$\hat{s}(t) = E_c[1 + jk_f g(t)]e^{j\omega_c t}$$

Also,

$$s(t) = R_c[\hat{s}(t)] = \underbrace{E_c \cos\omega_c t}_{\text{Carrier}} - \underbrace{E_c k_f g(t) \sin\omega_c t}_{\text{Side band}} \quad (6)$$

This is the expression for narrow band FM

Mathematical Expression for Single-tone Narrow Band FM

As we know the expression for instantaneous frequency of FM wave is given by :

$$f_i = f_c + k_f\, x\,(t) \quad (7)$$

where, x (t) is the modulating signal and the term kf x (t) represents the frequency deviation.The constant kf will control the deviation. For small values of kf, the frequency deviation is small and the spectrum of FM signal has a narrow band. Hence, it is called as the narrow band FM.

Let us consider the expression for FM wave as under:

$$s(t) = E_c \cos\left[2\pi f_c\, t + 2\pi k_f \int x(t)\, dt\right] \tag{8}$$

Expressing it in terms of ω, we have:

$$s(t) = E_c \cos\left[\omega_c\, t + 2\pi k_f \int x(t)\, dt\right] \tag{9}$$

We can represent this in the exponential manner as under:

$$s(t) = E_c \cos\theta(t) = E_c\, e^{j\theta(t)}$$

This has been written by considering only the real part of Ec ejθ(t)

Therefore,

$$s(t) = E_c\, e^{j\theta(t)}. = E_c\, e^{j[\cos\omega_c t + k_f\, x(t)\, dt]} \tag{10}$$

Let

$$\int x(t)\, dt = g(t)$$

Thus,

$$s(t) = E_c e^{j[\cos\omega_c t + k_f\, g(t)]} \tag{11}$$

If kf g (t) < < 1 for all values (which is the case for narrow band FM), then, the expression for FM will be

$$\hat{s}(t) = E_c\left[1 + jk_f\, g(t)\right]e^{j\omega_c t}$$

Also,

$$s(t) = R_c\left[\hat{s}(t)\right] = \underbrace{E_c \cos\omega_c t}_{\text{carrier}} - \underbrace{E_c k_f\, g(t)\sin\omega_c t}_{\text{side band}}$$

This is the expression for narrowband FM. Hence, a narrow band FM wave can be expressed mathematically as under, The (-) sign associated with the LSB represents a phase shift of 180o.

$$e_{FM}(t) = s(t) = \underbrace{E_c sin\omega_c t}_{\text{Carrier}} + \frac{m_f E_c}{2}\sin\underbrace{(\omega_c + \omega_m)}_{\text{USB}}t - \frac{m_f E_c}{2}\sin\underbrace{(\omega_c - \omega_m)}_{\text{LSB}}t \qquad (12)$$

Narrowband FM Applications:

This frequency modulation has a small bandwidth when compared to wideband FM. The modulation index β is small, i.e., less than 1. Its spectrum consists of the carrier, the upper sideband and the lower sideband. This is used in mobile communications such as police wireless, ambulances, taxicabs, etc.