## 4.3 Generation of Angle Modulated Signals

### 4.3.1 Wideband Angle-Modulated Signals

There are two methods of generating wideband (WB) angle-modulated signals; the indirect method and the direct method.

#### *4.3.1.1 Indirect method*

In this method, a narrowband angle-modulated signal is produced as plotted in the figure below.

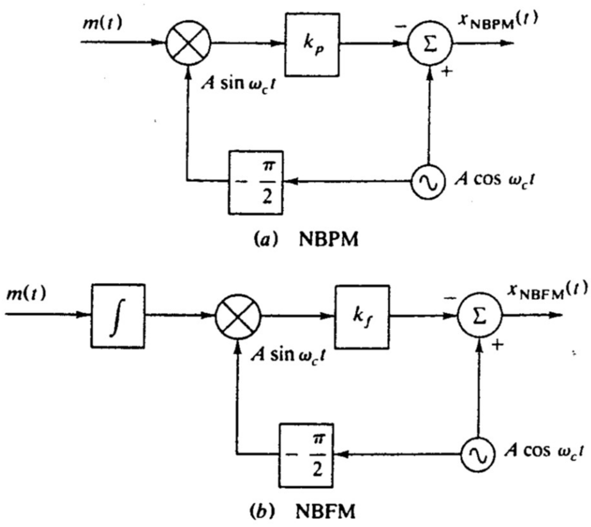



Figure: Generation of narrowband angle-modulated signals

The generated narrowband angle-modulated signal is then converted to a WB angle-modulated signal by using frequency multipliers as shown in the figure below.

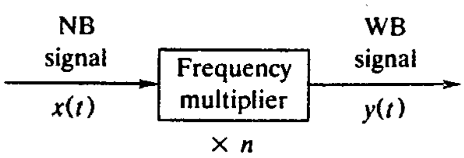



Figure: Frequency multiplier.

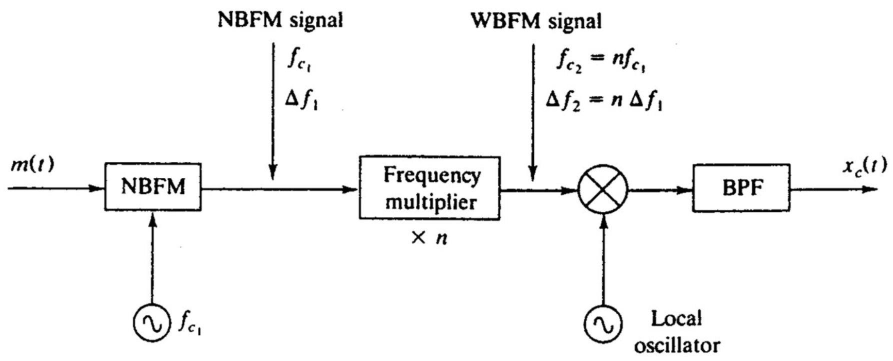
The frequency multiplier multiplies the argument of the input sinusoid by $n$. Thus, the input of a frequency multiplier is

$$x(t) = A\cos\left(2\pi f_c t + \phi(t)\right)$$

and the output of the frequency multiplier is

$$y(t) = A\cos\left(2\pi n f_c t + n\phi(t)\right)$$

Use of frequency multiplication normally increases the carrier frequency to an impractically high value. To avoid this, a frequency conversion, (using a mixer or DSB modulator) is necessary to shift the spectrum. The block diagram of narrowband-to-wideband conversion is given in the figure below.




### 4.3.1.2 Direct Method

In the direct method of generating an FM signal, the modulating signal directly controls the carrier frequency. A common method used for generating the FM directly is to vary the inductance or the capacitance of a tuned electric oscillator. Any oscillator whose frequency is controlled by the modulating signal voltage is called a *voltage controlled oscillator* (VCO). The main advantage of direct FM is that large frequency deviations are possible, and thus less frequency multiplication is required. The major disadvantage is that the carrier frequency tends to drift, so additional circuitry is required for frequency stabilization.

## 4.4 Demodulation of Angle Modulated Signals

Demodulation of FM signal requires a system that produces an output proportional to the instantaneous frequency of the input signal. Such system is called a *frequency discriminator*. If the input to an ideal discriminator is an angle modulated signal

$$u(t) = A\cos\big(2\pi f_c t + \phi(t)\big)$$

then the output of the discriminator is

$$y_d(t) = k_d \frac{d\phi(t)}{dt},$$

where $k_d$ is the discriminator sensitivity. The characteristics of an ideal frequency discriminator are shown in the figure below.

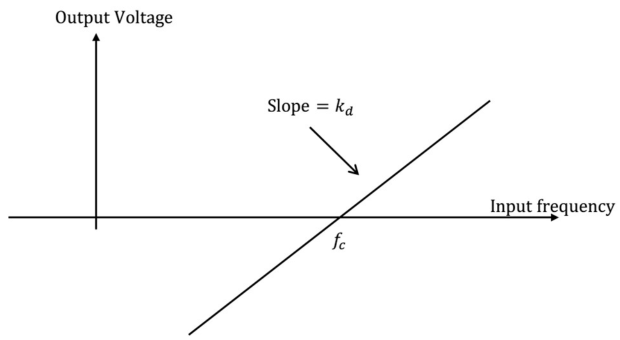



Figure: Input output characteristics of a discriminator.

For FM, $\phi(t)$ is given by

$$\phi(t) = 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau$$

so that the output of the discriminator becomes

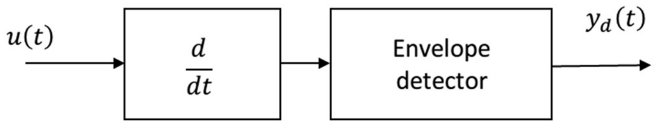
$$y_d(t) = 2\pi k_d k_f m(t)$$

The frequency discriminator can also be used to demodulate PM signals. For PM, $\phi(t) = k_p m(t)$. Therefore, the output of the discriminator is

$$y_d(t) = k_d k_p \frac{dm(t)}{dt}$$

Integration of the discriminator output yields a signal that is proportional to $m(t)$. A demodulator for PM therefore can be implemented as an FM demodulator followed by an integrator.

A simple approximation to the ideal discriminator is an ideal differentiator followed by an envelope detector, whose block diagram is shown below.




If the input to the differentiator is

$$u(t) = A\cos\big(2\pi f_c t + \phi(t)\big)$$

then the output of the differentiator is

$$u'(t) = \frac{d}{dt}u(t) = -A\left[2\pi f_c + \frac{d\phi(t)}{dt}\right]\sin\big(2\pi f_c t + \phi(t)\big)$$

The signal $u'(t)$ is both amplitude and angle modulated. The envelope of $u'(t)$ is

$$y_d(t) = A\left[2\pi f_c + \frac{d\phi(t)}{dt}\right]$$

For an FM signal, the output of the envelope detector would be

$$y_d(t) = A\big[2\pi f_c + 2\pi k_f m(t)\big]$$

and for a PM signal, the output of the envelope detector is

$$y_d(t) = A\left[2\pi f_c + k_p \frac{dm(t)}{dt}\right]$$