FM SIGNAL GENERATION

They are two basic methods of generating frequency-Modulated signals

- Direct Method
- Indirect Method

DIRECT FM

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

In a direct FM system the instantaneous frequency is directly varied with the information signal. To vary the frequency of the carrier is to use an Oscillator whose resonant frequency is determined by components that can be varied. The oscillator frequency is thus changed by the modulating signal amplitude.

INDIRECT FM

$$x(t) = A_c \cos(2\pi f_c t + \theta(t))$$

$$\theta(t) = 2\pi k_p m(t)$$

$$\theta(t) = 2\pi k_f \int_0^t m(\tau)d\tau$$

Angle modulation includes frequency modulation FM and phase modulation PM.

FM and PM are interrelated; one cannot change without the other changing. The information signal frequency also deviates the carrier frequency in PM.

Phase modulation produces frequency modulation. Since the amount of phase shift is varying, the effect is that, as if the frequency is changed.

Since FM is produced by PM , the later is referred to as indirect FM.

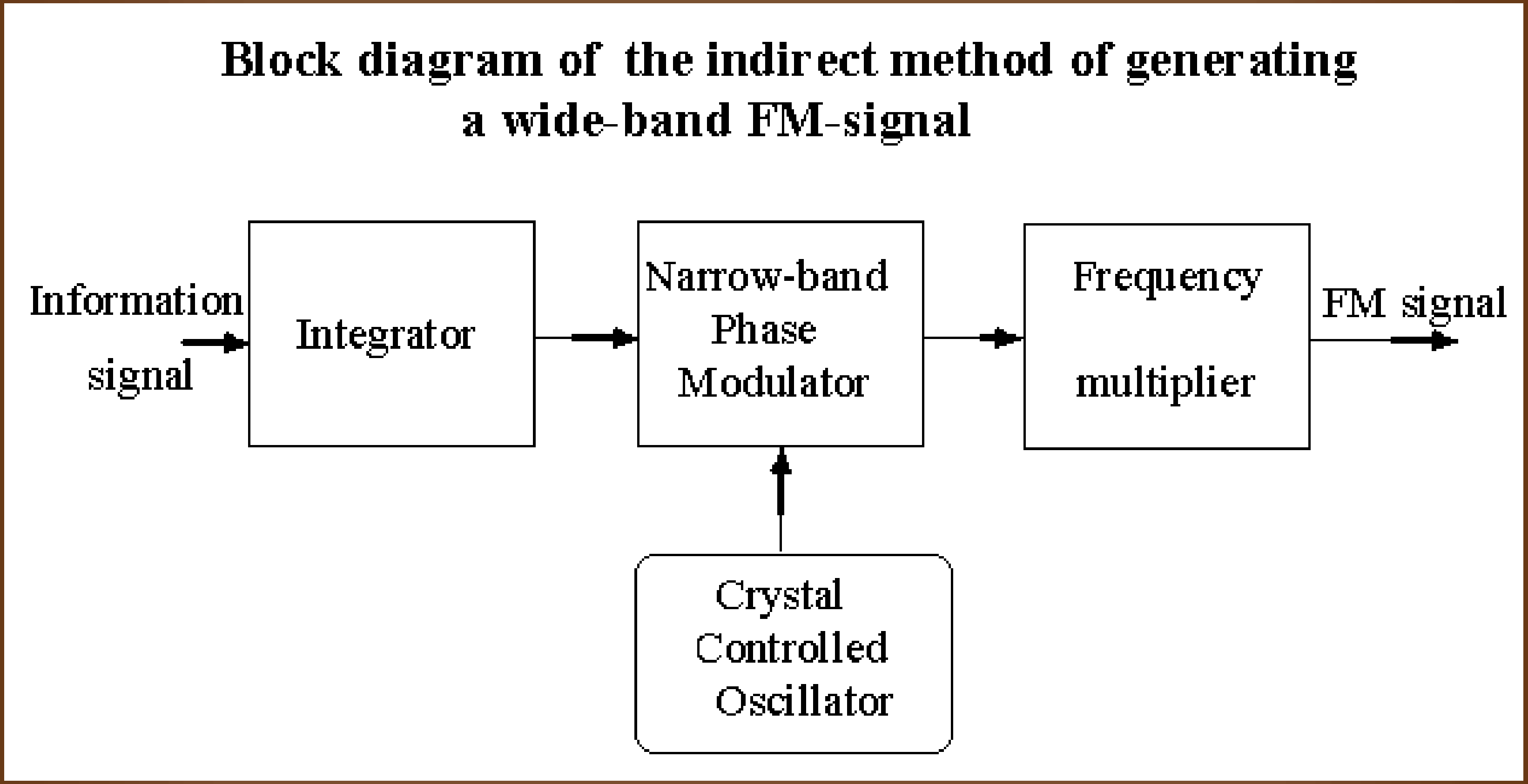
The information signal is first integrated and then used to phase modulate a crystal-controlled oscillator, which provides frequency stability.

In order to minimize the distortion in the phase modulator, the modulation index is kept small, thereby is resulting in a ***narrow-band FM-signal***

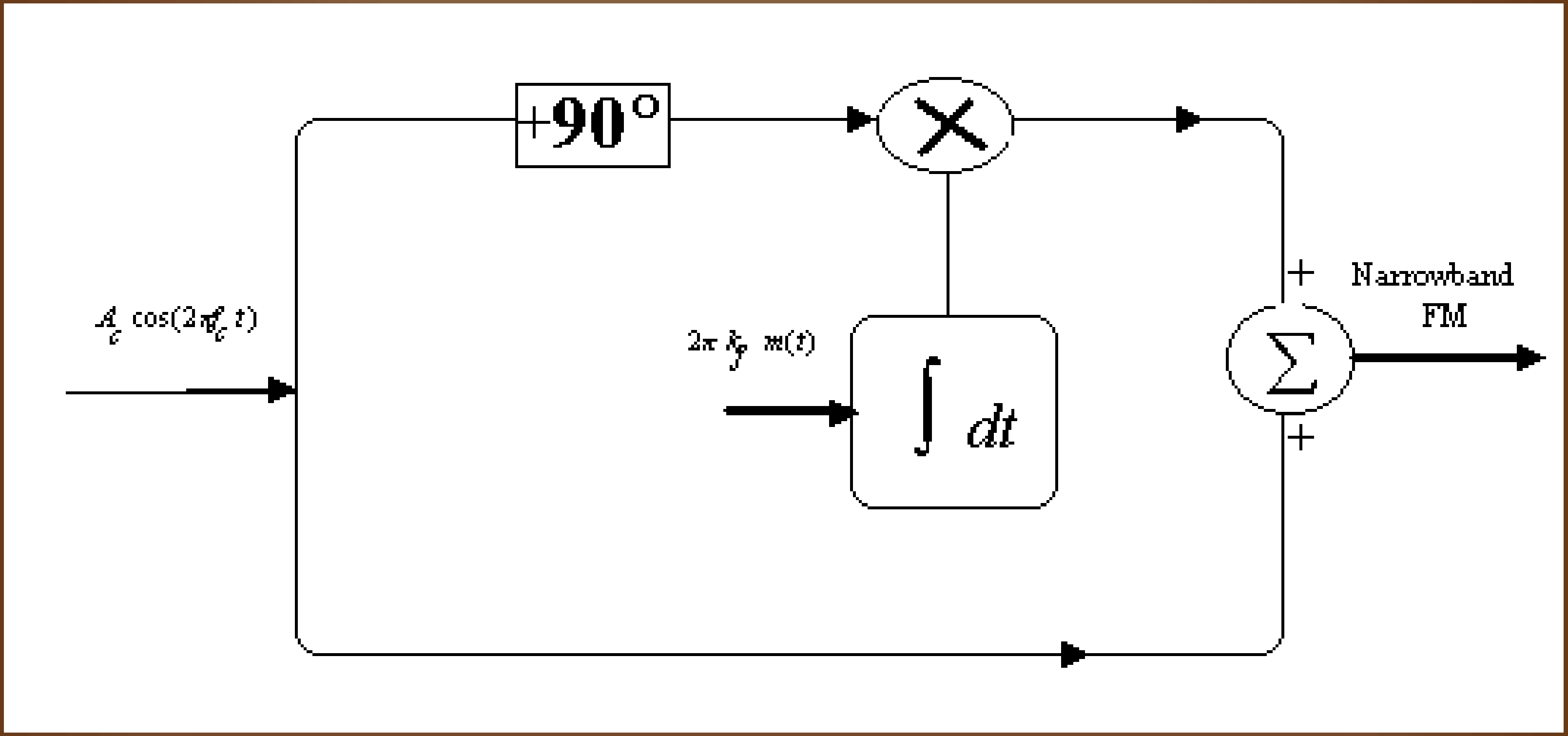
The narrow-band FM signal is multiplied in frequency by means of frequency multiplier so as to produce the desired wide-band FM signal.

The frequency multiplier is used to perform narrow band to wideband conversion.

The frequency deviation of this new waveform is “*M*” times that of the old, while the rate at which the instantaneous frequency varies has not changed


Block diagram of the indirect method of generating
a wide-band FM-signal
Information
signal
Integrator
Narrow-band
Phase
Modulator
Frequency
multiplier
FM signal
Crystal
Controlled
Oscillator

Modulator for Narrowband FM



FM Demodulation(복조기)

(1) Indirect: These types of demodulator use a phase-locked loop(PLL) to match a local oscillator to the modulated carrier frequency.

(2) Direct: This methods employ discriminators, which are devices, that discriminate one frequency from another by transforming frequency changes into amplitude changes.

Phase-locked Loop (위상고정 루프)

PLL is a negative feedback system, which can be used for indirect frequency demodulation. This important circuit finds application both in analog and digital communication.

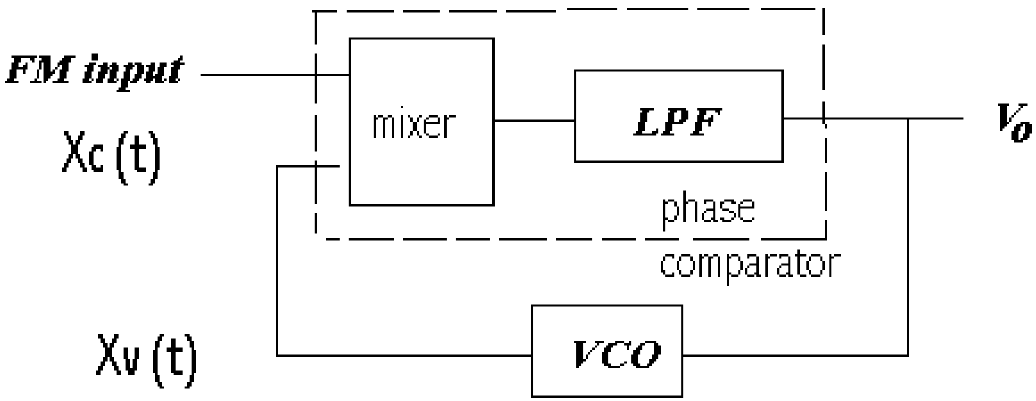


Fig. Phase-locked loop FM detector

See p.329
for eqns.

The loop compares the phase of the input signal to the phase of the signal at the output of the VCO.

The simplest method of phase comparison consists of a mixer followed by a low pass filter.

Feedback circuits are used to reduce the error term towards zero.

DISCRIMINATOR (분별기)

Slope Discriminator (그림 7.19)

1 . The ideal FM discriminator consists of a slope circuits (differentiator) followed by an envelope detector.

2. In order to ensure that the amplitude of the input signal is constant,

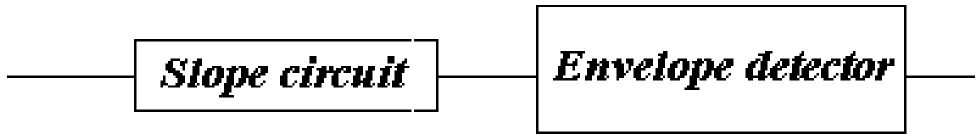
a limiter is placed before the differentiator.

3. From the property of Fourier Transform,

$$F\left\{\frac{d}{dt}x(t)\right\} = j2\pi f X(f)$$

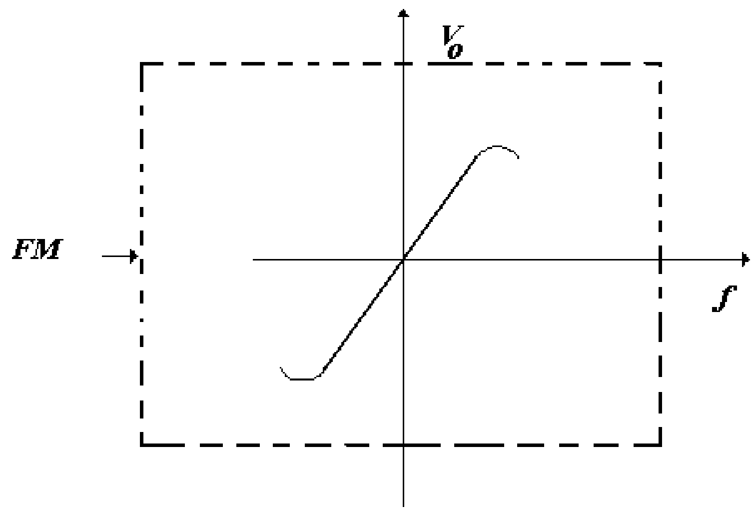
4. The transfer function of differentiator is,

$$H(f) = j2\pi f$$ **(그림 7.20)**



Frequency descriminator

Demodulator for FM



Frequency discriminator circuit symbol.

The slope discriminator is rarely used because of poor linearity.

The balanced slope detector

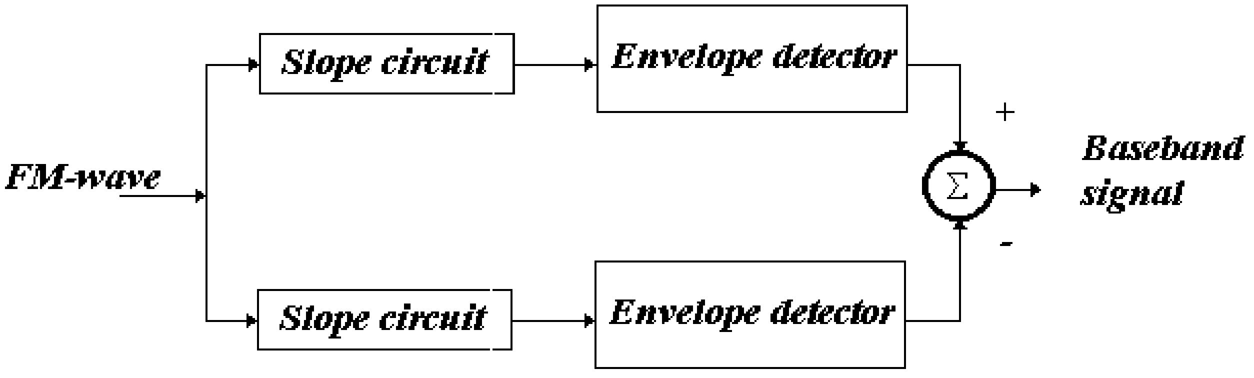


Fig. Balanced frequency discriminator

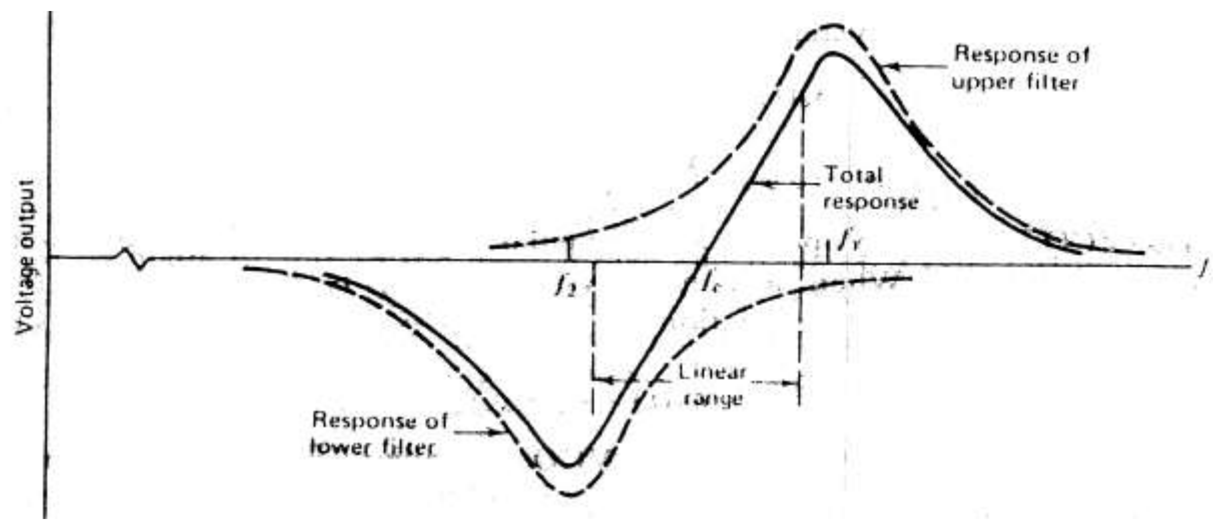
It provides better linearity than the single slope detector.

1.The upper and lower resonant filter sections of this circuit are tuned above and below the unmodulated carrier frequency f_c signal, f_1 and f_2.

2. Assume that both filters have a high Q-factor.

3. The quality factor or Q-factor of a resonant circuit is a measure of goodness of the whole circuit.

4.The linearity of the useful portion of the total response, centered at f_c, is determined by the separation of the two resonant frequencies.



LIMITER

1. If noise or other interference perturbs the amplitude of the carrier, then the carrier amplitude variations will cause distortion at the output.

2. This distortion can be removed by passing through a limiter prior to the differentiator.

3. The limiter output must then be converted to a sinusoid by passing it through a band-pass filter with center frequency and sufficient bandwidth to pass the varying fundamental.

4. The result is a constant amplitude sinusoid, which is differentiated and passed through the envelope detector to produce the desired signal.

NOISE IN FM SIGNAL

1. Noise is essentially amplitude variations. An FM signal, on the other hand, has a constant carrier amplitude.

2. Because of this, FM receivers contain limiter circuits that restrict the amplitude of the received signal.

3. Any amplitude variations occurring on the FM signal are effectively clipped off. This does not hurt the information content of the FM signal. Because of the clipping action of the limiter circuits, noise is almost completely eliminated.

INTERFERENCE (capture effect)

1. A major benefit of FM is that interfering signals on the same frequency will be effectively rejected. If the signal of one is more than twice the amplitude of the other, the stronger signal will "capture" the channel and will totally eliminate the weaker, interfering signal.

2. This is known as the *capture effect* in FM.

3. In FM, the capture effect allows the stronger signal to dominate while the weaker signal is eliminated.

4. However, when the strengths of the two FM signals begin to be nearly the same, the capture effect may cause the signals to alternate in their domination of the frequency.

계속 (capture effect)

5. Despite the fact that FM has superior noise rejection qualities, noise still interferes with an FM signal. This is particularly true for the high-frequency components in the modulating signal.

6. Since noise is primarily sharp spikes of energy, it contains a considerable number of harmonics and other high-frequency components.

7. These high frequencies can at times be larger in amplitude than the high-frequency content of the modulating signal.

8. This causes a form of frequency distortion that can make the signal unintelligible.

9. To overcome this problem Most FM system use a technique known as Pre-emphasis and De-emphasis.

Pre-emphasis and De-emphasis.

1. At the transmitter the modulating signal is passing through a simple network which amplifies the high frequency component more the low-frequency component. The simplest form of such circuit is a simple high pass filter.

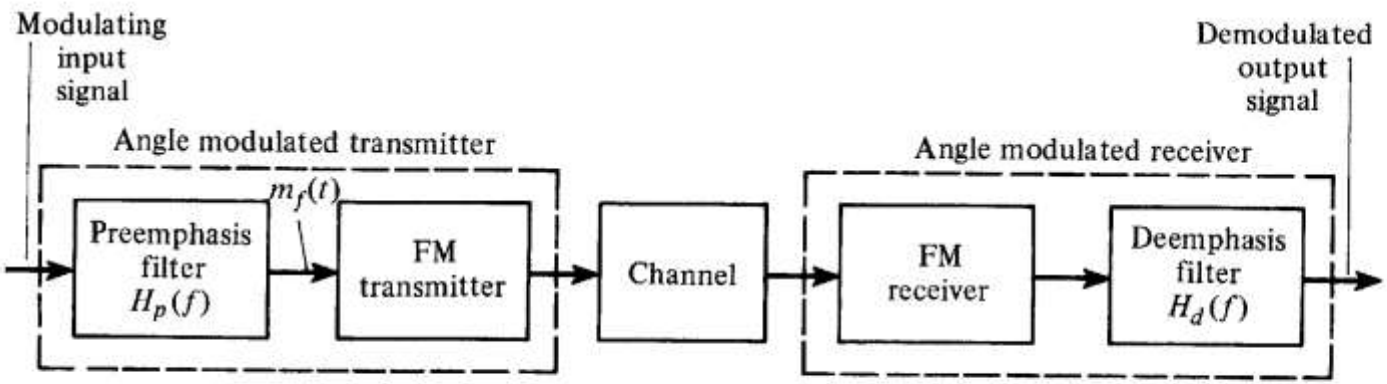
2. The pre-emphasis circuit increases the energy of the higher content of the higher-frequency signals so that will tend to become stronger than the high-frequency noise component. This improves the signal-to-noise ratio.

3. To return the frequency response to its normal level, a de-emphasis circuit is used at the receiver. This is a simple low-pass filter

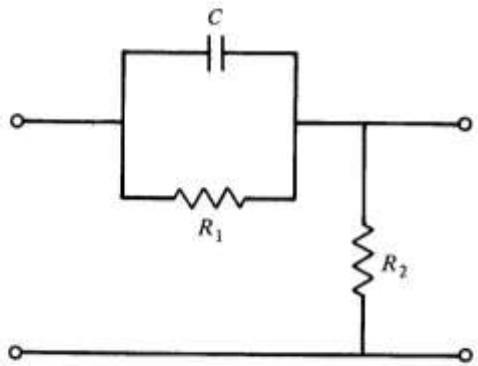
4. The de-emphasis circuit provides a normal frequency response.

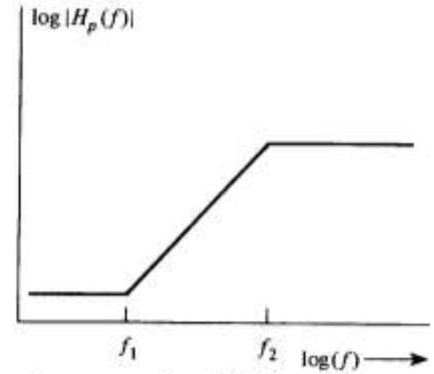
Pre-emphasis and De-emphasis.

The combined effect of pre-emphasis and de-emphasis is to increase the high-frequency components during the transmission so that they will be stronger and not masked by noise



(a) Overall Block Diagram

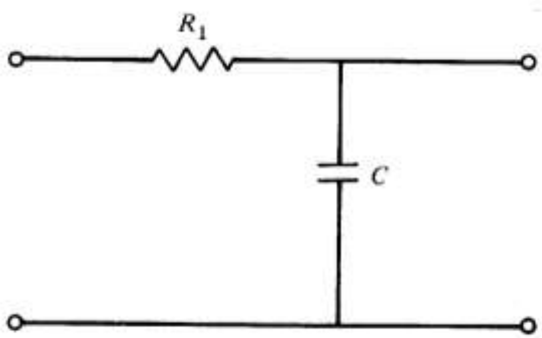


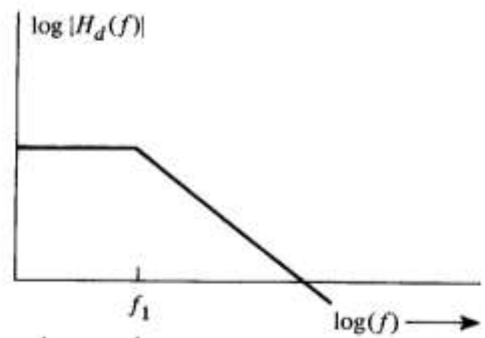


$$H_p(f) = K\,\frac{1 + j(f/f_1)}{1 + j(f/f_2)} \quad \text{where } f_1 = \frac{1}{2\pi\tau_1} = \frac{1}{2\pi R_1 C},\; f_2 = \frac{1}{2\pi\tau_2} = \frac{R_1 + R_2}{2\pi R_1 R_2 C}$$

(b) Preemphasis Filter

(c) Bode Plot of Preemphasis Frequency Response





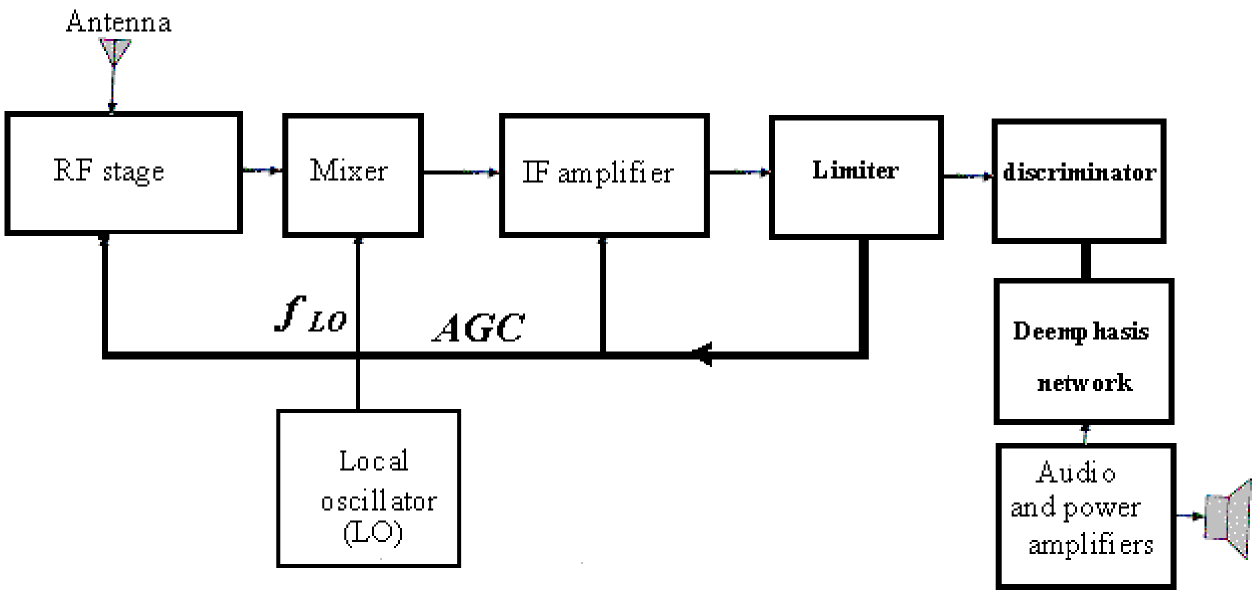
$$H_d(f) = \frac{1}{1 + j(f/f_1)} \quad \text{where } f_1 = \frac{1}{2\pi\tau_1} = \frac{1}{2\pi R_1 C}$$

(d) Deemphasis Filter

(e) Bode Plot of Deemphasis Characteristic

FM Superheterodyne Receiver

The FM Superheterodyne Receiver block diagram (see fig. below) has many similarities to that of the AM Superheterodyne receiver studied earlier. The only apparent differences are the use of the presence of *limiter-discriminator* circuit in place of envelope detector and the addition of a *de-emphasis network.*



FM ***Superheterodyne Receiver***

The universally standard IF frequency for FM is 10.7 MHz, as compared to 455 kHz for AM.

RF AMPLIFIERS

FM receivers function with a lower sensitivity, and are called upon to deal with input signals of 1 μV or less as compared with perhaps a 30-μV minimum input for AM. If a 1-μV signal is fed directly into a mixer, the high noise factor of an active mixer stage destroys the intelligibility of the 1-μV signal.

It is, therefore, necessary to amplify the 1-μ V level in a RF stage to get the signal up to at least 10 to 20 μV before mixing occurs. The FM system can tolerate 1 μ V of noise from a mixer on a 20 μV signal but obviously cannot cope with 1 μV of noise with a 1 μV signal.

This explains the abandonment of RF stages for the ever-increasing FM systems at the 1-GHz-and-above region. At these frequencies, transistor noise is increasing while gain is decreasing. The use of a RF amplifier reduces the image frequency problem.

Another benefit is the reduction in *local oscillator re-radiation* effects. Without a RF amp, the local oscillator signal can more easily get coupled back into the receiving antenna and transmit interference.

FM Stereo Receiver

All new FM broadcast receivers are being built with provision for receiving stereo, or two-channel broadcasts.

The left (L) and right (R) channel signals from the program material are combined to form two different signals, one of which is the left-plus-right signal and one of which is the left-minus-right signal.

The (L - R) signal is double-sideband suppressed carrier (DSBSC) modulated about a carrier frequency of 38 kHz, with the LSB in the 23- to 38-kHz slot and the USB in the 38- to 53-kHz slot. The (L + R) signal is placed directly in the 0- to 15-kHz slot, and a pilot carrier at 19 kHz is added to synchronize the demodulator at the receiver.