$$\frac{G_v(f)}{G_v(1\text{ Hz})} = \left(\frac{f}{1\text{ Hz}}\right)^2$$

or

$$10\log\left(\frac{G_v(f)}{G_v(1\text{ Hz})}\right) = 20\log\left(\frac{f}{1\text{ Hz}}\right)$$

or

$$[G_v(f)]\text{ dB} = 20\log f \tag{10.18.1}$$

The noise spectral density is seen to increase at the rate of 6 dB per octave. The low noise levels at low frequencies show why the signal-to-average noise power for FM is inherently better than AM, for which the noise spectral density is constant. However, a disadvantage arises in that, for speech, the clarity of speech (or what is termed the articulation efficiency) depends on the high-frequency content of the speech waveform, and the rising noise characteristic of FM tends to mask this.

The situation can be improved by including a *de-emphasis* network following the FM detector, which attenuates the noise at the rate of 6 dB per octave. Since the network will also attenuate the modulating signal spectrum in a similar fashion, it is necessary to include a compensating network at the transmitter that pre-emphasizes the modulating spectrum by 6 dB per octave, and naturally this is known as a *pre-emphasis network*. For broadcast applications it is essential that manufacturers work to a common pre-emphasis/de-emphasis set of characteristics. Figure 10.18.1 shows typical pre-emphasis and de-emphasis networks, along with their relative responses. The values used in calculating the response curves are given in Problems 10.60 and 10.62.

10.19 FM Broadcast Receivers

FM commercial broadcasting in North America takes place in the VHF band between 88 and 108 MHz. Within this band, allotted frequencies are spaced 200 kHz apart and are allowed a maximum frequency deviation of ±75 kHz around the carrier frequency. Propagation at VHF is restricted to line of sight, and coverage is usually only for a radius of about 50 miles around the transmitter location. The programs broadcast on these channels in the past have been mostly music, and the basic modulating frequency bandwidth is 15 kHz, as opposed to the 5 kHz used on AM stations.

Figure 10.19.1(a) shows the block schematic of a typical FM broadcast receiver of the monaural or single-channel variety. It is a superheterodyne circuit, with a tuned RF amplifier so that maximum signal sensitivity is typically between 1 to 10 μV. The RF-stage-tuned circuits and the local oscillator are tuned by a three-ganged variable capacitor controlled from a panel knob. The oscillator frequency can be varied from 98.7 to 118.7 MHz, yielding an intermediate frequency (IF) of 10.7 MHz.

The IF amplifier section is comprised of several high-gain stages, of which one or more are amplitude limiters. The schematic shown here has one high-gain nonlimiting input stage, followed by one amplitude-limiting stage. All stages are tuned to give the desired band-pass characteristic, which is shown in

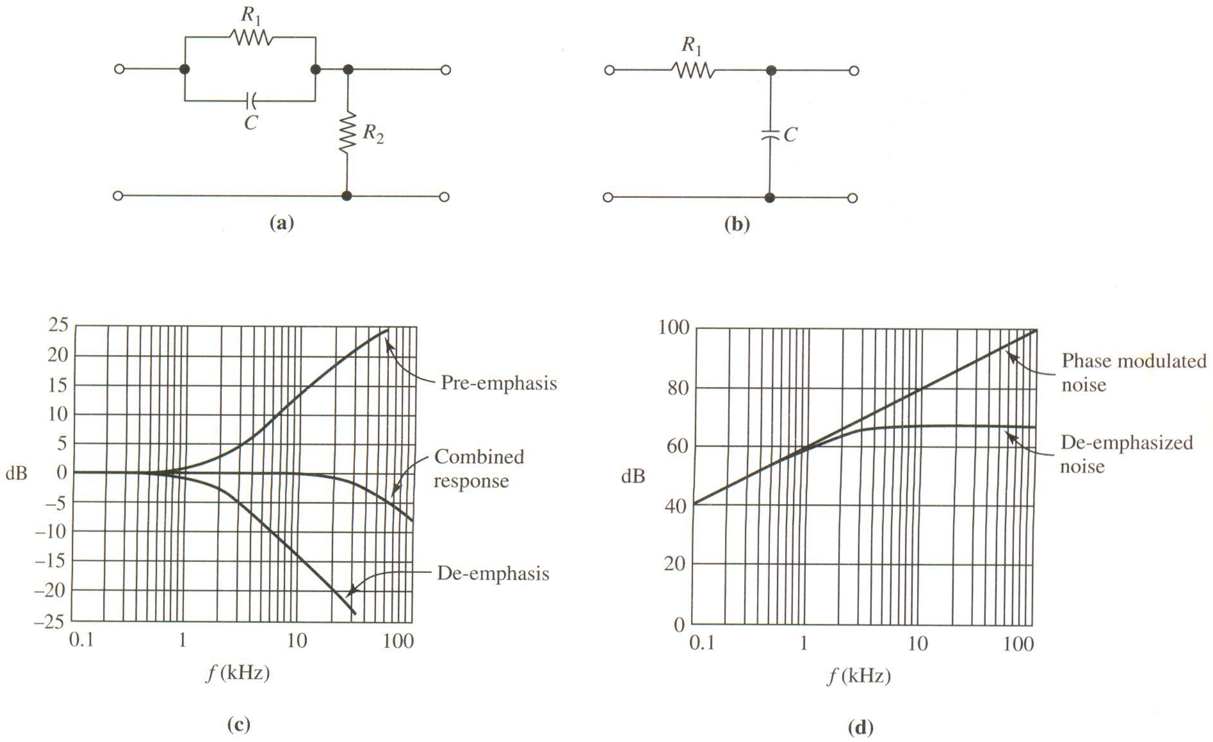

Figure 10.18.1 (a) Standard preemphasis network having a lower corner frequency of 2.12 kHz and (b) a typical de-emphasis network. (c) Preemphasis and deemphasis curves and the combined response. (d) Noise before and after de-emphasis. All curves are referenced to their 1-Hz values.

Fig. 10.19.1(b). This is centered on 10.7 MHz and has a 180-kHz bandwidth to pass the desired signal. Amplitude limiting is usually arranged to have an onset threshold of about 1 mV at the limiting-stage input, corresponding to the quieting level of input signal, which may be set at 10 μV or lower.

The FM detector may be any one of several types of FM detectors described in Section 10.14, perhaps incorporating automatic frequency control as described in Section 10.15.

AGC is not usually supplied in less expensive FM receivers. These receivers have sufficient amplifier gain so that the last stage operates in saturation for most signals to obtain the necessary amplitude limiting for good detection. AGC may be provided to control the RF and early IF stages so that saturation of the nonlimiting IF stages does not occur on strong signals.

Figure 10.19.1 shows the block diagram of an FM receiver that uses AGC. In this case, a sample of the IF signal is extracted just before the input to the limiting IF amplifier. This sample is applied to a special detector used only to obtain the AGC signal and is a peak amplitude detector similar to that in Fig. 7.9.1. The derived AGC signal is applied to control the RF preamplifier and the first IF amplifier. Its time constant is similar to that used in AM receivers.