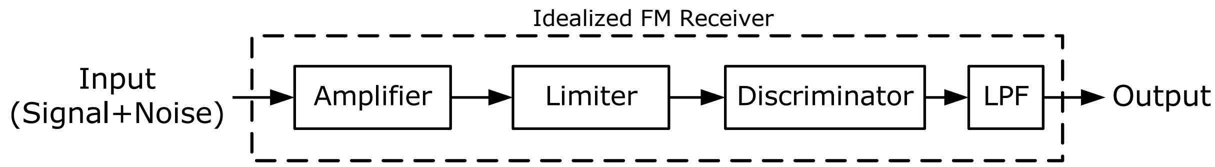
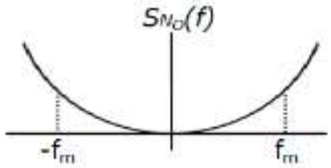
## 4.8 NOISE IN FM SYSTEMS




In FM signals, $s_I(t) = A\cos\theta$, where $\theta = \omega_c t + k\int_0^t m(\tau)d\tau$, and $s_o(t) = \frac{d\theta}{dt} - \omega_c = km(t) \Leftrightarrow$ $S_o = \overline{s_o^2(t)} = k^2\overline{m^2(t)}$. The PSD of output noise of FM demodulator is $S_{N_o} = \frac{\eta}{A^2}f^2$.




Since it has a parabolic spectrum, therefore, the effect of noise in FM for higher frequency components is much higher than the effect of noise on lower frequency.

Assuming LPF cutoff frequency (or $B$) = $f_m$, the output noise power from the LPF is:

$$N_o = \int_{-f_m}^{f_m} S_{N_o}(f)df = \int_{-f_m}^{f_m} \frac{\eta}{A^2}f^2 df = \frac{\eta f^3}{A^2}$$

The output signal power $S_o = k^2 P_M$, where $P_M$ is the average power of $m(t)$. So:

$$\frac{S_o}{N_O} = \frac{3k^2A^2P_M}{2\eta f_m^3}$$

But $\beta = \frac{k\max|m(t)|}{f_m}$ and $S_I = \frac{A^2}{2}$ and $N_I = \eta f_m$ .

This yields:

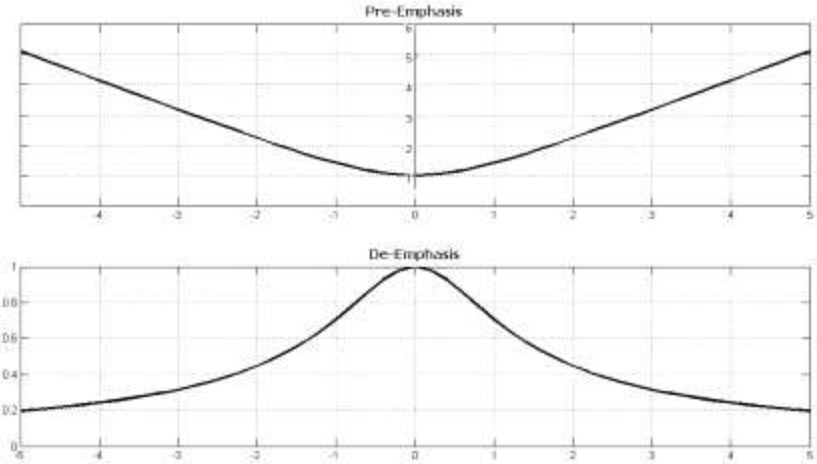
$$\frac{S_o}{N_o} = \frac{3\beta^2 P_M}{[\max|m(t)|]^2}$$

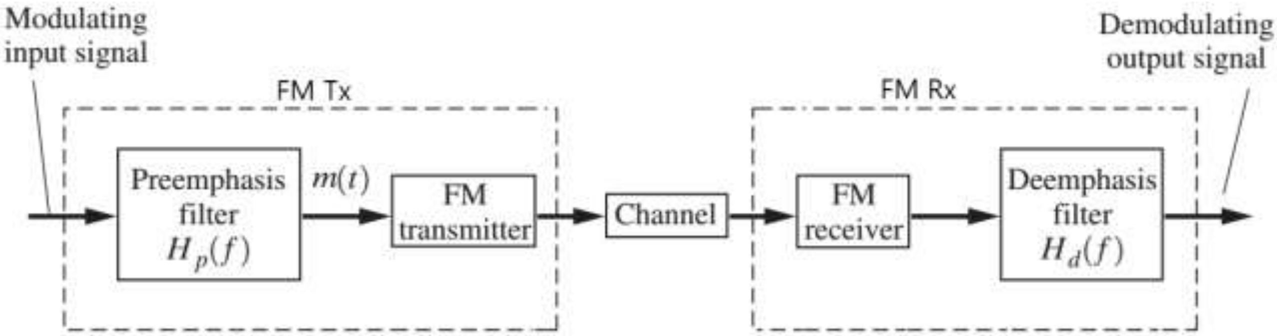
and in case of $m(t) = \cos(\omega_m t)$ we get:

$$\frac{S_O}{N_O} = \frac{3\beta^2}{2}\frac{S_I}{N_I}$$

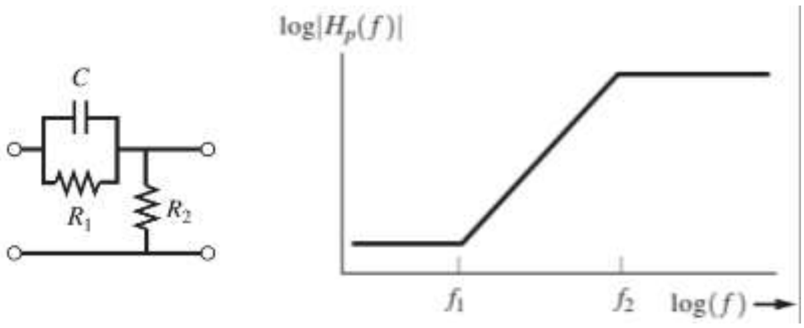
**SNR Improvement in FM using Pre-emphasis/De-emphasis**

The audio signals have most of the energy at the lower frequency (300 → 3300)Hz. And as in the output of the FM demodulator the noise PSD rises parabolically with the frequency, that means: the noise PSD is largest in the frequency range where the signal PSD is smallest. To remedy this situation, we emphasize the high-frequency components in the input signal at the transmitter. At the output of the FM demodulator in the receiver the inverse operation is performed. The signal spectrum is restored to its original shape but the noise which was added after the pre-emphasis is now reduced.




Preemphasis Filter:




Deemphasis Filter: