UNIT-3

NOISE IN ANALOG MODULATION:

- Signal to noise ratio: AM
- Receiver model
  - DSBSC Receiver
  - SSB Receiver
  - FM Receiver Model
- Noise in FM Reception,
  FM threshold Effect
  Pre-Emphasis, De-Emphasis, in FM

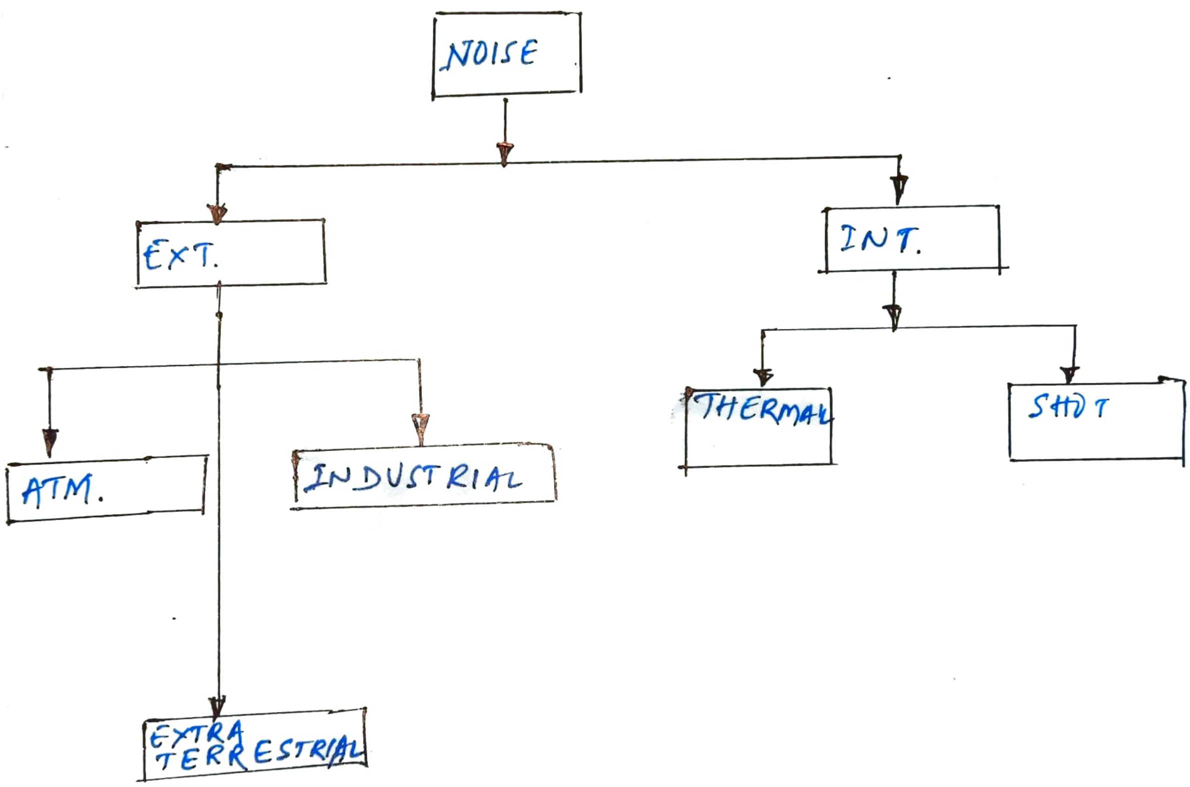
NOISE IN COMMUNICATION SYSTEMS:

Noise: It is an unwanted signal which tends to interfere with modulating signal.

Types of noise:

Noise is basically divided into,

1. External Noise
2. Internal Noise



1. External Noise:

- Atmospheric Noise: Radio noise caused by natural atmospheric processes, primarily lightening discharges in thunder storms.
- Extraterrestrial Noise: Radio disturbances from sources other than those related to the Earth.

- Cosmic Noise: Random noise that ~~originate~~ originates outside the Earth's atmosphere.
- Solar Noise: Noise .... " from the Sun.

- Industrial Noise: " ignition, aircraft, electrical motors, switch gear, Welding etc.,

2. Internal Noise:

Shot Noise: Random motion of electrons in the semiconductor devices.

- Thermal or Jhonson Noise: Random motion of electronics in the resistors is called thermal noise.

$$V_n = K T_0 B R,$$

Where, K = Boltzmann const.
R = Resistance
T_0 = Abso. Temp.
B = Bandwidth

NOISE FIGURE: (F_n)

It is the ratio of output and input noise of an amplifier or network (Model). It is expressed as,

$$F_n = \frac{K T_0 B G + \Delta N}{K T_0 B G}$$

Where, Δ = Noise added by the amplifier or N/W (Process)
G = gain of the network.

Noise Figure (F_n) of cascaded Amplifier or Network:

$$F_n = F_1 + \frac{(F_2 - 1)}{G_1} + \frac{(F_3 - 1)}{G_1 \cdot G_2} + \cdots \frac{(F_n - 1)}{G_1 G_2 G_3 \cdots G(n-1)}$$

Where, F_1 = NF of 1st stage
G_1 = gain of 1st stage
F_2 = . . . G_n . . .

Noise equivalent bandwidth:

When white noise (flat spectrum of frequencies like white light) is passed through a filter having frequency response, some of the noise power rejected by filter and some is passed through the output.

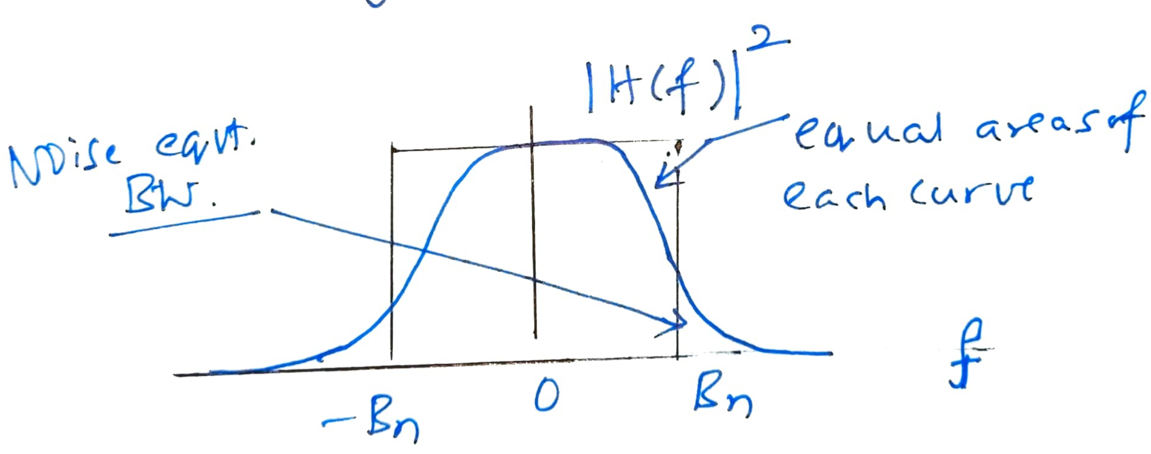


FIGURE OF MERIT: It is the ratio of output SNR to input SNR of a communication system.

$$\boxed{FOM = \frac{S_o/N_o}{S_i/N_i}}$$

Where, S_o = o/p signal power
N_o = o/p noise power
& S_i = i/p sig. power
N_i i/p noise power

Receiver Model for Noise Calculation:

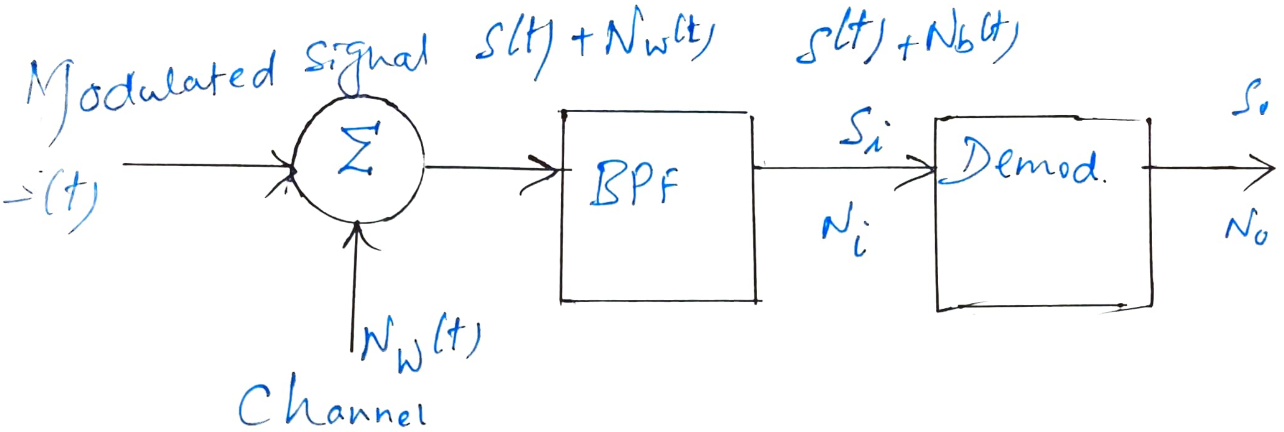
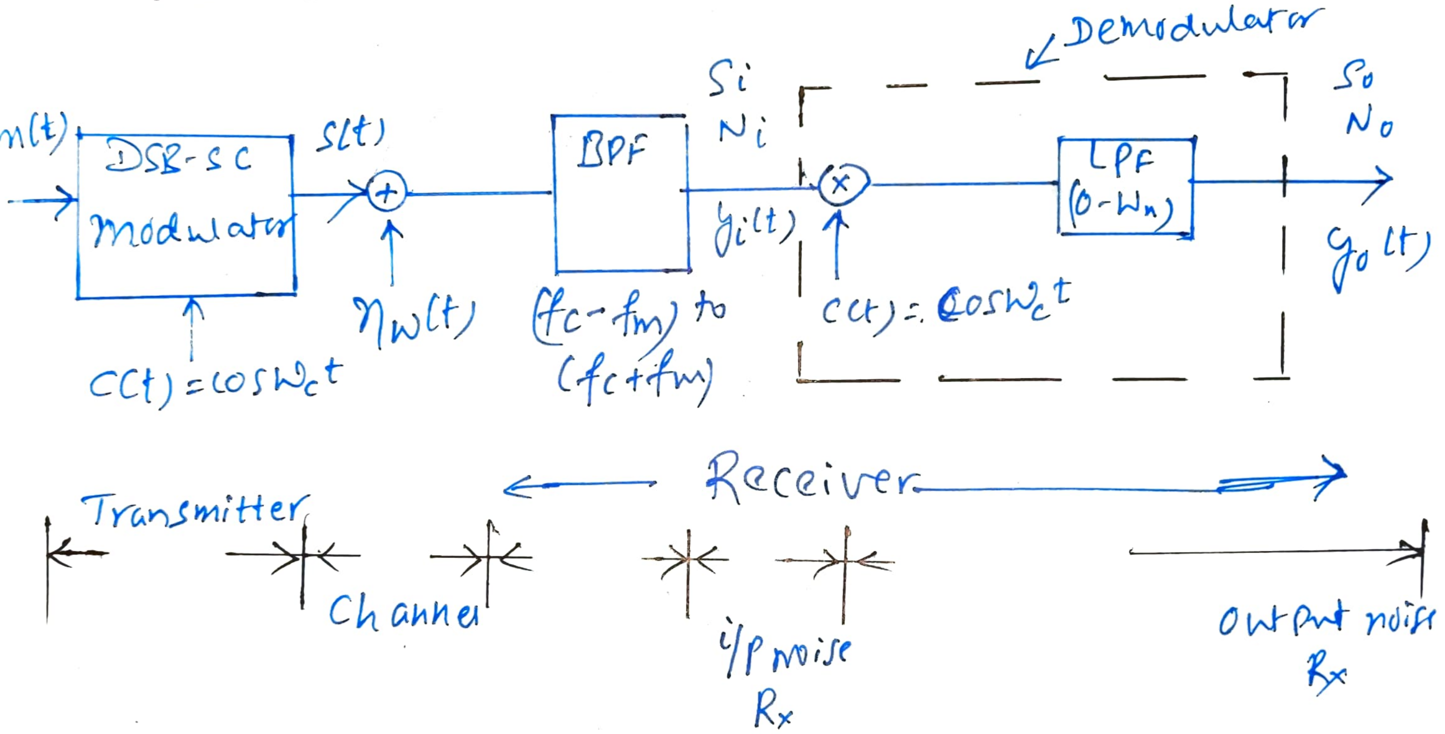


Figure of Merit calculation in DSB-SC



- Transmitter contains DSB-SC modulator

Whose output $s(t) = m(t) \cdot \cos W_c t \longrightarrow (*)$

OR $\Rightarrow s(t) = m(t) \cdot \cos(2\pi f_c t)$

- Noise generated by the channel is considered as white noise $\eta_w(t)$ with uniform noise power spectral density $\eta/2$.

- Band Pass filter's bandwidth is equal to modulated signal bandwidth
- BPF allows DSB-SC signal and converts White noise into color noise or band Pass noise $n_B(t)$.

Therefore, o/p of the BPF is

$$y_i(t) = s(t) + n_B(t)$$

- Synchronous detector is used to extract modulating signal m(t) which contain multiplier followed by LPF.

i/p signal Power is,

$$S_i = m^2(t)/2$$

i/p noise Power,

$$N_i = \eta \cdot 2f_m$$

output signal Power is,

$$S_o = [m^2(t)/2]^2$$

output noise power is,

$$N_o = \eta \cdot f_m/2$$

Substituting values in FOM,

$$FOM = (S/N)_o / (S/N)_i$$

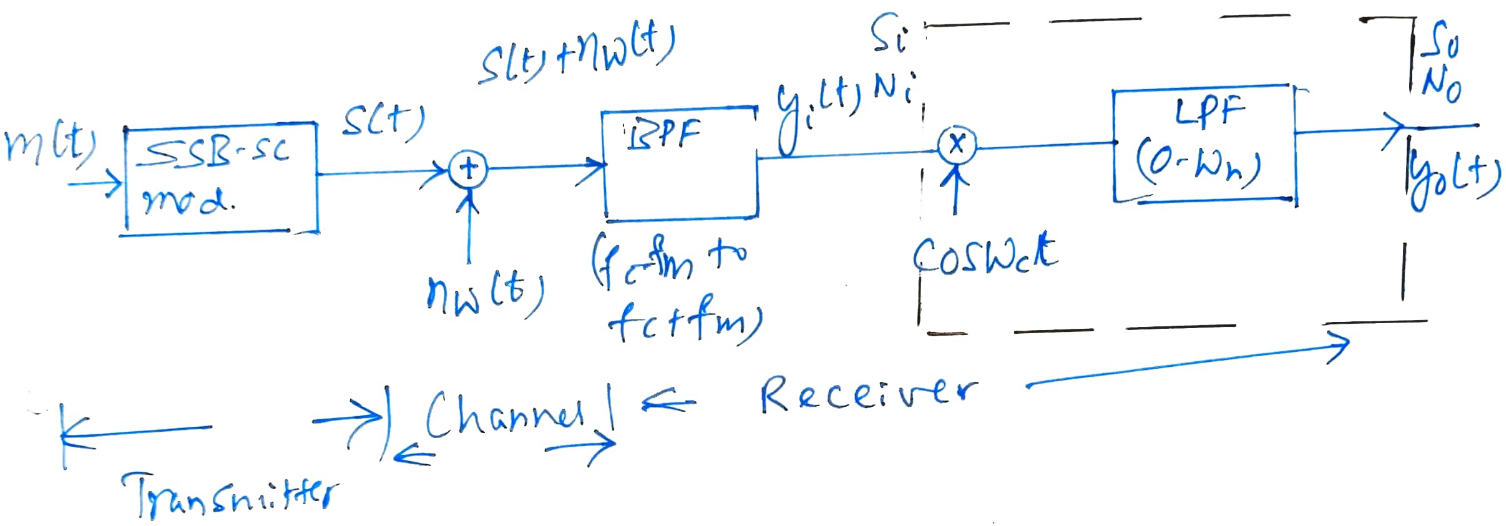
$$\boxed{FOM = \frac{S_o/N_o}{S_i/N_i} = 2}$$

Figure of Merit Calculation in SSB-SC:

SSB-SC Signal, $s(t) = m(t)\cos\omega_c t \pm m_h(t)\sin\omega_c t$

Output of BPF, $y_i(t) = s(t) + n_B(t)$

Bandpass noise, $n_B(t) = n_i(t)\cos\omega_c t \; n_q(t)\sin\omega_c t$



Input signal power is,

$$S_i = m^2(t)$$

input noise power,

$$N_i = \eta \cdot f_m$$

Output Signal Power,

$$S_o = m^2(t)/4$$

Output noise Power

$$N_o = \eta \cdot f_m/4$$

Substituting these values,

$$\boxed{FOM = \frac{S_o/N_o}{S_i/N_i} = 1}$$

Noise calculation in FM System:

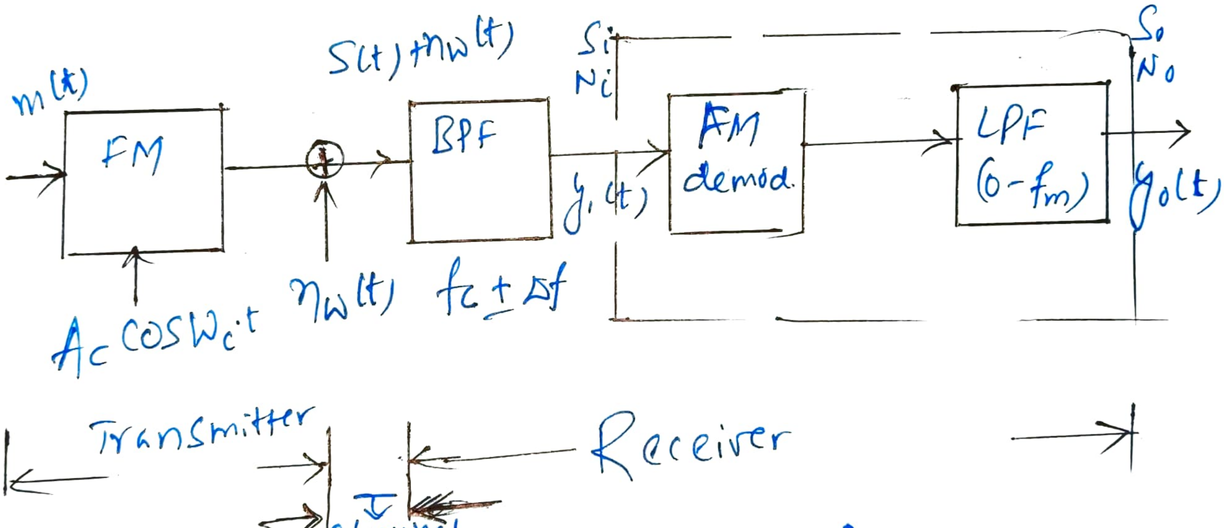
Frequency modulated signal

$$s(t) = A_c \cos[W_c t + K_f \int m(t) \cdot dt]$$

Output of BPF is

$$y_i(t) = s(t) + n_B(t)$$

$$= A_c \cos[W_c t + K_f \int m(t) \cdot dt] + n_B(t)$$



input signal power is, $S_i = A_c^2/2$,

Input noise power, $N_i = 2\eta \cdot \Delta f$

Output signal power, $S_o = \gamma^2 K_f^2 m^2(t)$

Substituting these values,

$$FOM = \frac{S_o/N_o}{S_i/N_i}$$

$FOM = (3/4\pi^2) f_m^3$, where $m_f = \Delta f / f_m$

$$\boxed{FOM = \frac{3}{4\pi^2} m^3 \cdot f}$$

Threshold effect:

~~At first,~~

In low power applications, it is desirable to lower the value of the predetection signal-to-noise ratio at which threshold occurs in FM systems.

Several techniques have been developed for lowering this value and these schemes use some form of feedback demodulation.

The analysis of noise performance of feedback demodulator is rather involved and simply note that feedback demodulators lower the threshold by as much as 7dB.

The PLL lowers the threshold by about 2 to 3dB.

Even a 2dB power savings is particularly important in low power digital applications such as in space communications.

FM Pre-emphasis and De-emphasis

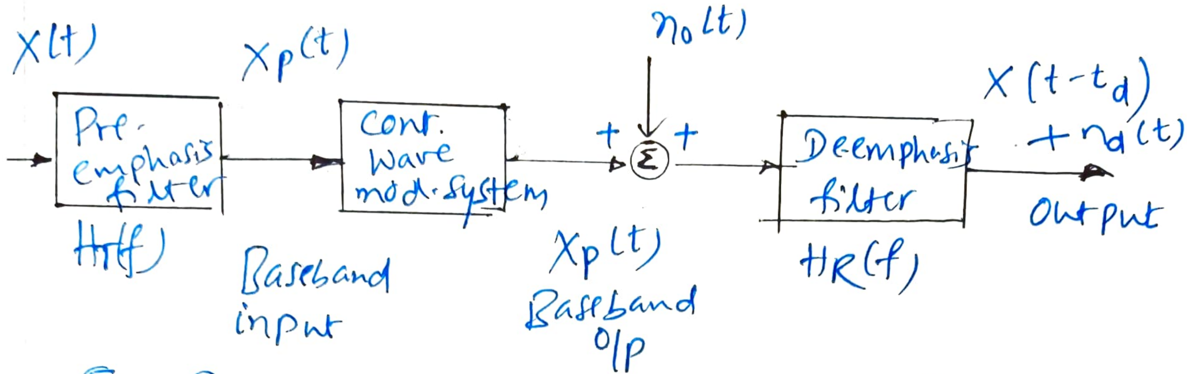
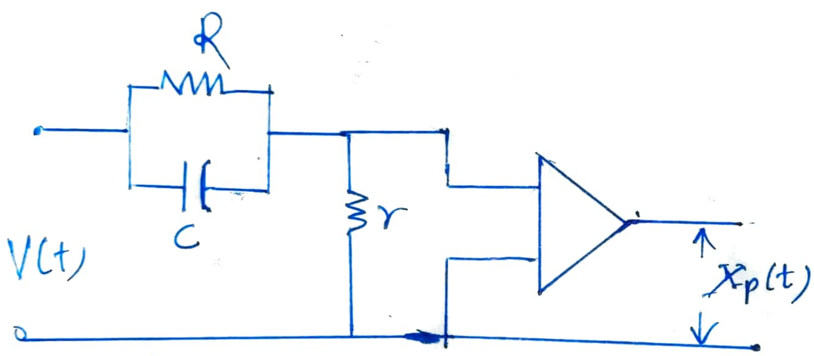
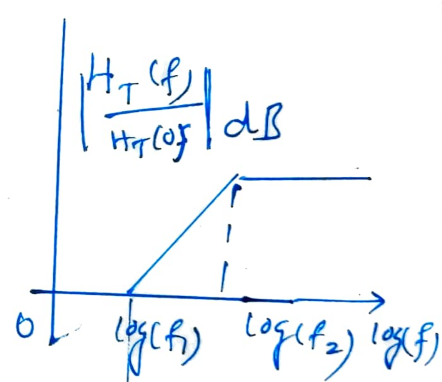


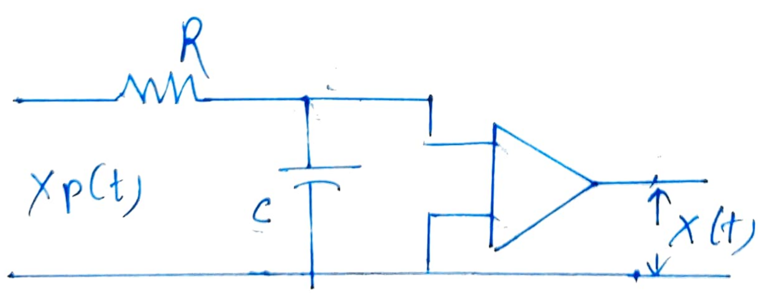
Fig. Preemphasis | deemphasis filtering CW communication systems.

$$H_T(f)H_R(f) = \exp(-j2\pi t_d)$$

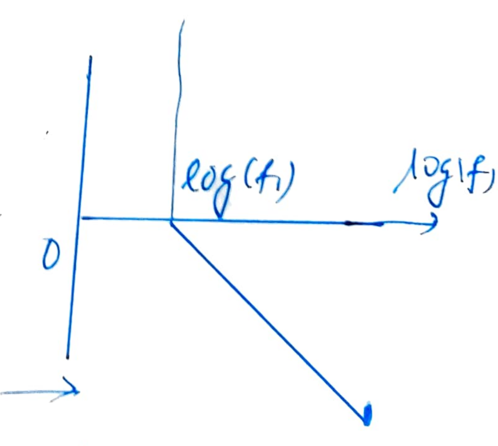


Pre-emphasis





Deemphasis



$G_{no}(f) = k_1\eta$, for $|f| < f_x$ →

$G_{no}(f) = k_2\eta f^2$, for $|f| < f_x$ →

Continuous Wave (CW) modulation systems for improving the output SNR.

The Preemphasis/deemphasis filter arrangement is shown

We obtain the T/F of these filter

$$|H_T(f)|^2 = K_1 \, G_{n0}^{1/2}(f) \,/\, G_x^{1/2}(f)$$

$$|H_R(f)|^2 = G_x^{1/2}(f) \,/\, K_1 \, G_{n0}^{1/2}(f)$$

$$H_T(f)\, H_R(f) = \exp(-j2\pi f t_d)$$

The const. K_1 is chosen to satisfy the constraint

$$\int_{f_x}^{-f_x} G_x(f) \cdot df = \int_{-f_x}^{f_x} G_x(f) \cdot |H_T(f)|^2 \cdot df$$

eqn. is normalised avg. power of the base band signal. $x(t)$ is the normalised Power of Preemphasized signal $x_p(t)$.

Constraint assure linear modulation and transmitted power is not altered by Preemphasis filtering.

BW of FM signals remains the same.

The SNR improvement that results from Preemphasis/deemphasis can be calculated as:

$$E\{n_o^2(t)\} = \int_{-f_x}^{f_x} G_{n_o}(f) \cdot df$$

With the deemphasis filter, the noise psd is given by

$$E\{n_d^2(t)\} = \int_{-f_x}^{f_x} G_{n_o}(f) \cdot |H_R(f)|^2 \cdot df$$

$$= \int_{-f_x}^{f_x} [G_{n_o}(f) \,/\, |H_T(f)|^2] \, df$$

The SNR improvement due to Preemphasis and deemphasis filtering is given by,

$$\gamma = \frac{E\{n_o^2(t)\}}{E\{n_d^2(t)\}} = \frac{\int_{-f_x}^{f_x} G_{n_o}(f) \cdot df}{\int_{-f_x}^{f_x} [G_{n_o}(f) \, |H_R(f)|^2]}$$

Where,

$f_1 = \frac{1}{2\pi RC}$, $f_2 = \frac{1}{2\pi rC}$

$f_2 >> f_1$

Problem:

\# Preemphasis/deemphasis filters in Commercial FM. $RC = 75\mu$ sec.

Assuming noise psd $G_{no} = k_2 f^2$ & the following psd

$$G_x(f) = \begin{cases} [1+(f/f_1)^2]^{-1}, & |f| < 15\,kHz \\ 0 & \text{elsewhere} \end{cases} \quad f_1 = 2.1\,kHz$$

Find SNR improvement

Soln:

$H_T(f) = \sqrt{k_1}\,(1 + jf/f_1)$ $\quad k_1$ - Power gain of filter

$$H_R(f) = \frac{1}{\sqrt{k_1}}(1 + jf/f_1)^{-1}$$

$$\int_{-f_x}^{f_x} \frac{df}{1+(f/f_1)^2} = \int_{-f_x}^{f_x} k_1\,df \quad \text{or} \quad k_1 = \frac{f_1}{f_x}\tan^{-1} f_x/f_1$$

$$\gamma = \frac{k_1 \int_{-f_x}^{f_x} k_2 f^2 \cdot df}{\int_{-f_x}^{f_x} k_2 f^2 \left[1 + (f/f_1)^2\right]^{-1} \cdot df}$$

$$= \tan^{-1}(f_x/f_1)\left[3\frac{f_1}{f_x}\left(1 - \frac{f_1}{f_x}\tan^{-1}\frac{f_x}{f_1}\right)\right]^{-1}$$

$f_x = 15\,kHz$, $f_1 = 2.1\,kHz$ Sub.

We obtain $\underline{\gamma \simeq 4}$,

or $\underline{\gamma = 6.0\,dB}$