

Noise in Analog Communication Systems

- Noise is unwanted signal that affects wanted signal
- Noise is random signal that exists in communication systems
- Noise
 - Internal
 - External

Internal:

- It is due to random movement of electrons in electronic circuits
- Major sources are resistors, diodes, transistors etc.
- Thermal noise or Johnson noise and shot noise are examples.

External:

- Man- made and natural resources
- Sources over which we have no control
- Examples are Motors, generators, atmospheric sources.

Noise level in system is proportional to

- Temperature and bandwidth
- Amount of current
- Gain of circuit

- Resistance of circuit

Effect of noise

- Degrades system performance (Analog and digital)
- Receiver cannot distinguish signal from noise
- Efficiency of communication system reduces

Types of noise

- Thermal noise/white noise/Johnson noise or fluctuation noise
- Shot noise
- Noise temperature
- Quantization noise

Thermal Noise: This noise is generated due to thermal motion (Brownian motion) of electrons inside resistor. This noise is zero at absolute zero degree Kelvin and generated when temperature rises, also called thermal noise. Also called Johnson noise who invented it.

Thermal noise also referred as '**White noise**' since it has uniform spectral density across the EM Spectrum.

PSD of thermal noise $S_n(f)$ is

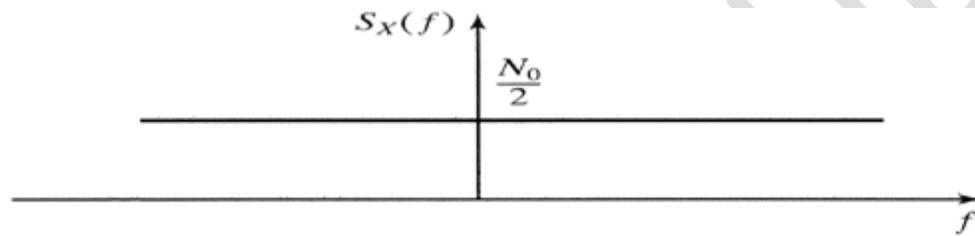
$$S_n(f) = \frac{kT}{2}$$

(where k is Boltzman's constant and T is temperature)

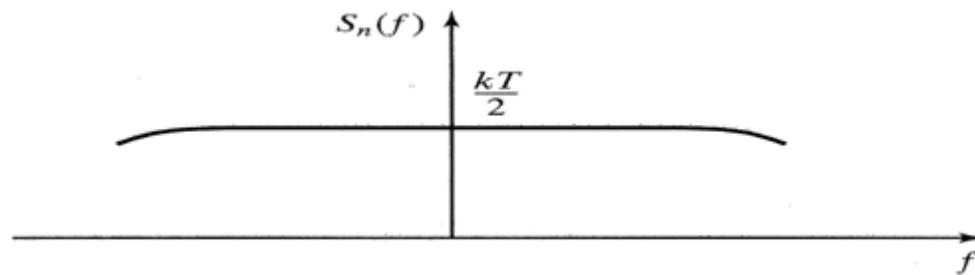
kT is denoted by N_0

Then

$$S_n(f) = \frac{N_0}{2}$$



Power spectrum of a white process.



Power spectrum of thermal noise.

Work of Johnson and Nyquist gave the expression for noise power

$$P_n = \bar{v}_n^2 = 4kTBR \text{ volt}^2$$

Where,

k = Boltzman constant

T = Absolute temp. (Kelvin)

B = Bandwidth (Hz)

R = Resistance (ohms)

Where \bar{v}_n is mean noise voltage.

SHOT NOISE

It is electronic noise that occurs when there are finite number of particles that carry energy such as electrons or photons.

Due to analogy of lead shots called shot noise.

It has uniform spectral density like thermal noise.

Determination of Noise level

Signal to noise level ratio (SNR)

$$\frac{S}{N} = \frac{\text{Power of useful signal voltage}}{\text{Power of noise voltage}}$$

$$\text{Noise Figure} = \frac{\text{Signal to noise ratio at input}}{\text{Signal to noise ratio at output}} = \frac{S_i/N_i}{S_o/N_o}$$

Noise figure is always > 1

Noise temperature

Equivalent noise temperature is not the physical temperature of amplifier, but a theoretical construct, that is an equivalent temperature that produces that amount of noise power

$$T_e = T(F - 1)$$

Noise figure of cascaded stages

FRIIS formula for calculating total noise factor of several cascaded amplifiers

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \dots$$

F_1, F_2, \dots & G_1, G_2, \dots etc are Noise figure and gains of different stages in cascade.

Note that noise figure is mainly dominated by first two stages.

Effect of Noise on AM Systems:

The channel introduces additive noise in message and thus message received becomes corrupted.

Figure of merit is defined

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

Modulation system with higher γ has better noise performance.

Total noise = Noise power spectral density \times Bandwidth

$$N = \frac{N_0}{2} \times W$$

Noise amplitude is having Gaussian distribution i.e. additive white Gaussian Noise (AWGN)

For AM-SC For both DSB and SSB $\gamma = 1$

Thus S/N ratios at input and output of detector are identical i.e. no improvement in S/N ratio

For conventional AM using envelope detector

$$\gamma = \frac{1}{3} \text{ for } \mu = 1$$

The maximum value of γ is 1/3 for modulation index of unity

Noise in Angle Modulated Systems

Like AM, noise performance of angle modulated systems is characterized by parameter γ

$$\gamma_{FM} = \frac{3}{2}\beta^2$$

If it is compared with AM

$$\frac{\gamma_{FM}}{\gamma_{AM}} = \frac{1}{2} \left(\frac{\omega_{FM}}{\omega_{AM}} \right)^2$$

Note if bandwidth ratio is increased by a factor 2, then γ_{FM}/γ_{AM} increases by a factor 4

This exchange of bandwidth and noise performance is an important feature of FM.

FM Threshold Effect

- In FM Systems, where signal level is well above noise ratio and demodulated signal to signal noise ratio are related by

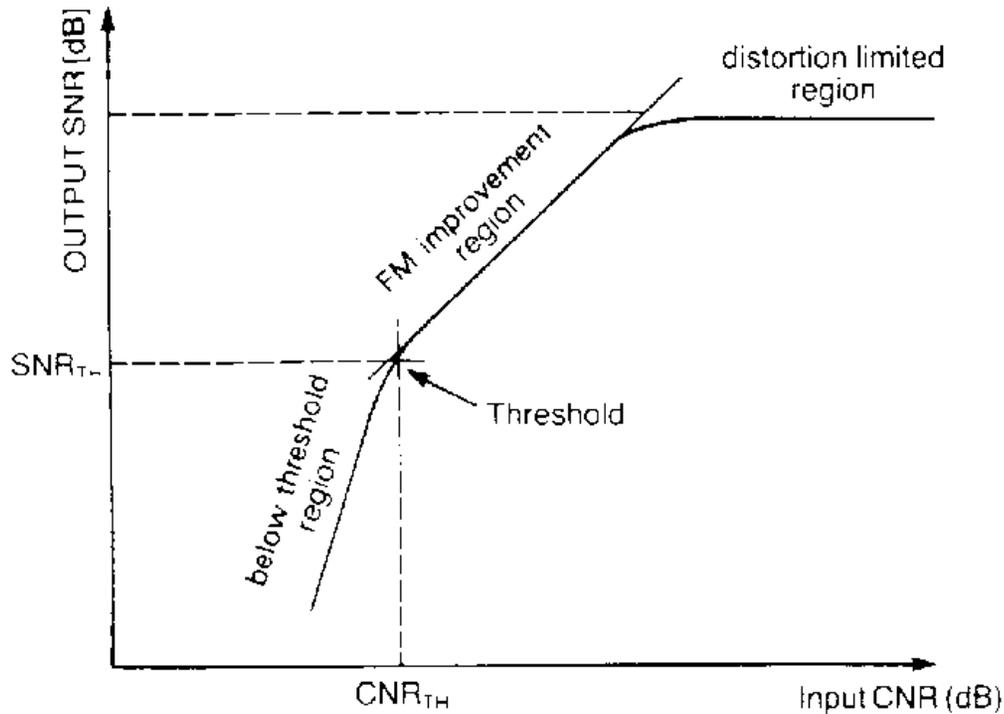
$$S/N = 3 \cdot \beta^2 \cdot C/N$$

S/N – Signal to noise ratio at output of demodulator

β – Modulation index

C/N – Carrier to noise ratio at input of demodulator

- Does not apply when S/N decreases below certain point called Threshold



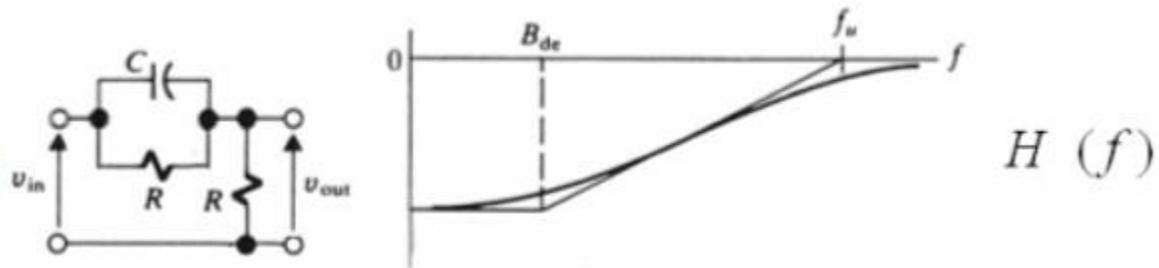
FM system is more susceptible to noise threshold as compared to AM.

Threshold improvement can be obtained by Pre-emphasis and De-emphasis

- Pre-emphasis: Improving signal to noise ratio by increasing the magnitude of high frequency signal with respect to lower frequency signals.
- A simple high pass filter can serve as transmitter's pre-emphasis circuit
- De-emphasis: Improving signal to noise ratio by decreasing the magnitude of high frequency signals with respect to lower frequency signals
- A simple low pass filter can operate as de-emphasis circuit in receiver.

The combined effect of these circuit is to increase signal to noise ratio for high frequency components during transmission, so that they are not masked by noise

transmitter filter



receiver filter

