COMMUNICATION
Third stage
Electrical Power & Machines Engineering Department
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Lecture 7

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Noise in Analog Communication System

Thermal noise and additive white Gaussian noise

Noise in Communication Systems:

Noise is an unwanted signal which interferes with the original message signal and corrupts the parameters of the message signal.

Source of noise:

1- External Source: This noise is produced by the external sources which may occur in the medium or channel of communication. Such as:

- Atmospheric noise (due to irregularities in the atmosphere).
- Extra-terrestrial noise, such as solar noise and cosmic noise.

2- Industrial Source: This noise is produced by the receiver components while functioning. The components in the circuits, due to continuous functioning, may produce few types of noise. Such as:

- Thermal (Resistor) noise (Johnson noise or Electrical noise).
- Shot noise (due to the random movement of electrons and holes).
- Transit-time noise (during transition).

Thermal noise and additive white Gaussian noise

Resistor (Thermal) Noise:

It has been determined experimentally that the noise voltage Vn(t) that appears across the terminals of a resistor R is: additive, white, Gaussian Noise (AWGN), and has root mean square voltage, in a narrow freq. df, equal to

$$\boxed{Vn = \sqrt{4KTRdf}}\ \text{V} \quad \text{or} \quad \boxed{In = \sqrt{4KTGdf}}\ \text{A}$$

K= Botzman's constant = $1.37 * 10^{-23}$ Joule/k

T= temperature

T_o= room temperature

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Example 1: An amplifier has a bandwidth of 4MHz with 10kΩ as the input resistor. Calculate the RMS noise voltage at the input to this amplifier if the room temperature is 25° c?

Solution:

Bw=4M, R=10kΩ , T=25° c

T=25+273= 298 K

K= Botzman's constant = $1.37 * 10^{-23}$ Joule/k

$$Vn = \sqrt{4KTRdf}$$

$$Vn = \sqrt{4\ (1.37 * 10^{-23}) * (298) * (10 * 10^{3}) * (4 * 10^{6})}$$

$$Vn = 25.6\mu V$$

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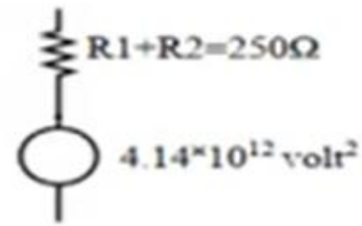
Example 2: calculate the RMS noise voltage arising from thermal noise in two resistors 100 & 150 resp. at T= 300°K within a bandwidth of 1MHz if:

- a- The resistors are connected in series.
- b- The resistors are connected in parallel.



Solution:

a) $Vn = \sqrt{4KT\ df\ (R1\ +\ R2)}$

$= \sqrt{4 \cdot 1.37 \cdot 10^{-23} \cdot 300 \cdot 10^{6} \cdot 250} = \sqrt{4.14 \cdot 10^{-12}}\ V$

Vn= 2.03 μ volt.

b) $i(t) = \sqrt{4KTdf(G1 + G2)}$

$= \sqrt{4 \cdot 1.37 \cdot 10^{-23} \cdot 300 \cdot 10^{6} \cdot (0.0167)} = \sqrt{2.76 \cdot 10-16}\ A$

= 0.0166 μ A.

$Vn(t) = In(t)$ Req. = 0.0166 * 10^{-16} * 60 = 0.997 μv.

Thermal noise and additive white Gaussian noise

Example 3: repeat Ex.2 with that the 100 resister is at a temp. of 600k.

Example 4: Determine the value of the noise voltage developed in a 1 k Ω resistor which is in a circuit that must be capable of carrying a bandwidth of 10 kHz at a temperature of 17°?

$T = 273 + 17 = 290\ K$

$$Vn = \sqrt{4KT\ Rdf}$$

$$Vn = \sqrt{4 \times (1.37 \cdot 10^{-23}) \times 290 \times 10^{4} \times 10^{3}}$$

$$Vn = \sqrt{1.6 \times 10^{-13}}$$

$= 0.4\ \mu V$

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Spectral Density and Correlation:

Energy Spectral Density (ESD): It shows the distribution of energy at each frequency component of nonperiodic signal.

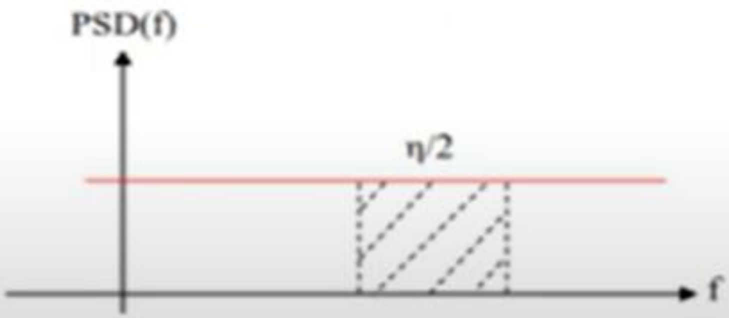
$ESD = |F(w)^2|$ Joule/Hz

$E = \frac{1}{2\pi}\int_{-\infty}^{\infty} ESD(f)df$ Joule

Power Spectral Density (PSD): It shows the distribution of power at each frequency component of periodic signal.

$PSD = 2\pi \sum_{n=-\infty}^{\infty} |cn|^2 \delta(f - nfo)$ Watt/Hz

$\overline{n^2} = \frac{1}{2\pi}\int_{-\infty}^{\infty} PSD(f)df$ Watt



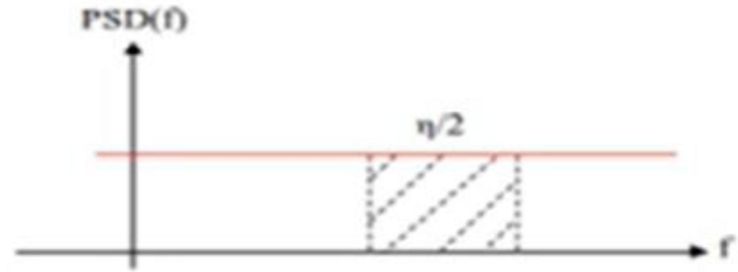
Note: Power spectral density exists for deterministic and random signals, such as noise.

Thermal noise and additive white Gaussian noise

White Noise:

A noise is said to be white if it has a flat spectrum at all frequency components, like the white light.

PSD= $\eta/2$ watt/Hz



Correlation:

1- Cross correlation: it is a measure of the similarity or relatedness between the waveforms suppose we have the two wave forms V1(t), V2(t) not necessarily periodic nor confined time interval.

The average cross correlation between them is defined.

$$R_{12}(\tau) = \lim_{T\to\infty} 1/T \int_{-T/2}^{T/2} v1(t)\, V2(t+\tau)\, dt$$

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If V1(t) and V2(t) are periodic with the same fundamental freq. fo

$$R_{12}(\tau)=\frac{1}{To}\int_{-To/2}^{To/2} V1(t)V2(t+\tau)dt$$

If V1|(t) and V2 (t) are non- periodic

$$R_{12}(T)=\int_{-\infty}^{\infty} V1(t)V2(t+\tau)dt$$

τ : is a searching or scanning parameter which may be adjusted to a proper time shift to reveal the relatedness or correlation between the function to the max. Extent possible when $R_{12}(\tau)= 0$ for all τ, the two function are uncorrelated.

Thermal noise and additive white Gaussian noise

2- Autocorrelation:

The correlation of a function with itself.

$$R(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} V(t) V(t+\tau)\, dt$$ For random signal

$$= \frac{1}{To} \int_{-T_o/2}^{T_o/2} V(t) v(t+\tau)\, dt$$ For periodic signal

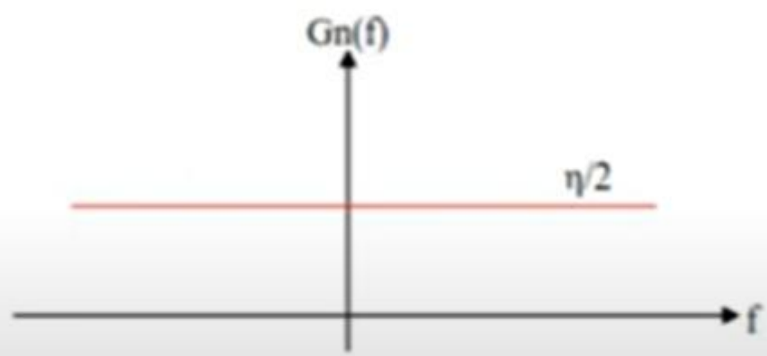
$$= \int_{-\infty}^{\infty} V(t) v(t+\tau)\, dt$$ For non- periodic signal

Thermal noise and additive white Gaussian noise

Noise in analog modulation systems:

Although the noise is assumed ransom so that the voltage values cannot be specified in advance, as a function of time, but we can assume that.

The received noise power could be computed if the noise power spectral density and transmission BW are known using



PSD= $\eta/2$ watt/Hz

Where η constant value

N=PSD*Bw
Noise power = power spectral density * bandwidth

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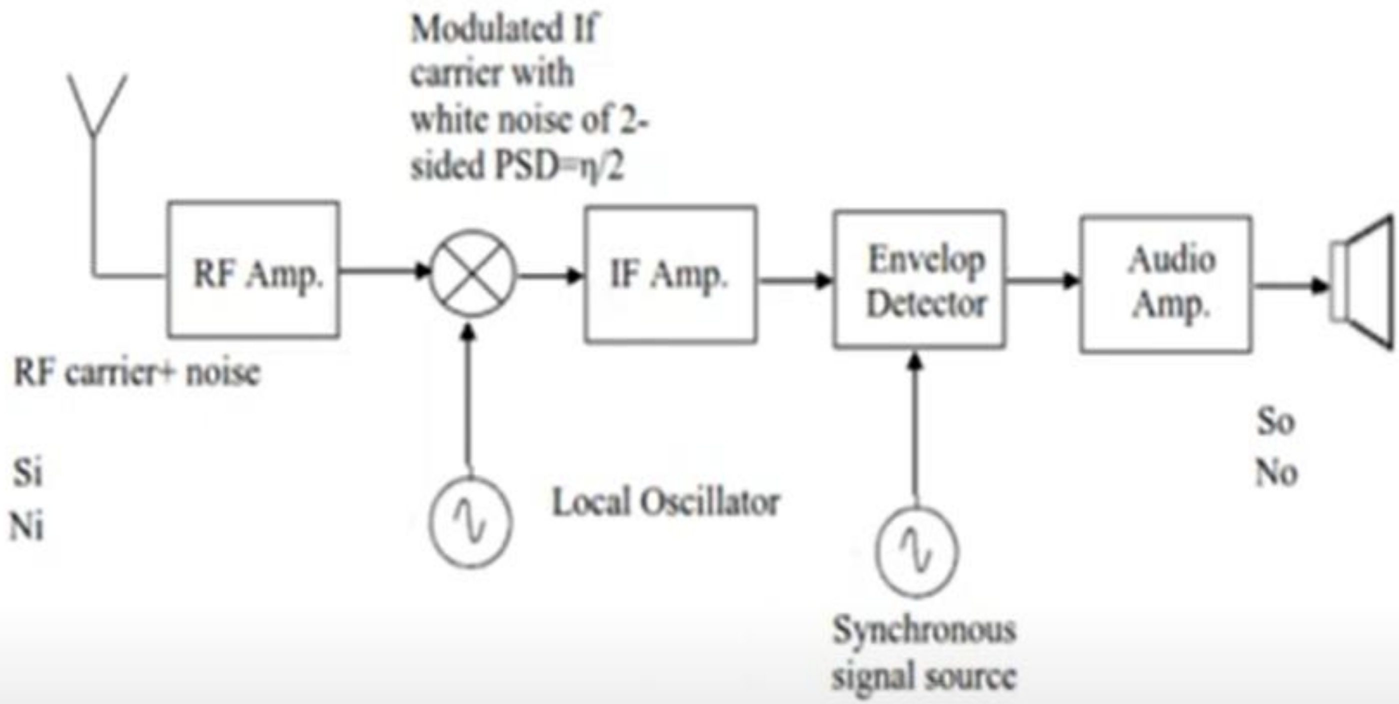

“Education is what remains after one has forgotten what one has learned in school.” Albert Einstein