Signals and Communication II.

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Noise in communication systems

- Noise is a broad term referring to unwanted signals that interfere with the transmission of information signals.
- There are several sources of noise such as random motion of electrons and the discrete nature of charge
- Due to the random nature of noise, we use statistical techniques to characterise and analyse noise.

Statistical characterisation of noise

- Let $v_n(t)$ represent a noise voltage, the average value of this signal is zero and is given by

$$\overline{v_n}(t) = < v_n(t) > = \frac{1}{T} \int_T v_n(t) dt = 0 \qquad (1)$$

- The noise variance or equivalently the noise power is non zero.

$$\overline{v_n(t)^2} = \frac{1}{T} \int_T v_n^2(t) dt \neq 0 \qquad (2)$$

- The root mean square noise voltage is given by

$$v_{n,rms} = \sqrt{\overline{v_n(t)^2}} \qquad (3)$$

Power spectrum

- The power spectrum of noise characterises the noise power as a function of frequency.
- The power spectrum is related to the autocorrelation function of the noise signal
- Autocorrelation is a mathematical way of quantifying how similar nearby samples of a signal are.
- Signals can vary from totally unpredictable to constant

Correlation

- Noise signals are examples of random signals which cannot be predicted exactly at a given time
- We characterise them by self-similarity. Similarity between a sample at a time t and a time $t + \tau$

See Notebook for more details.

Thermal Noise

- The noise power generated by a resistor R is represented by a voltage source in series with the resistor. The mean square value of the resistor is

$$\overline{v_n^2} = 4k_B TRB \tag{4}$$

- Where k_B is Boltzmann's constant, T is the temperature in Kelvin and B is the bandwidth.
- This noise is characterised by a flat spectrum and is called 'white' noise. The autocorrelation function is a Dirac delta function.

Example

- Let $R = 10k\Omega$, $B = 10^6 MHz$ and $T = 20C$. Compute the RMS noise voltage.
- If we have two resistors in series, then the mean square noise voltage is

$$\overline{v_n^2} = 4k_B T(R_1 + R_2)B = \overline{v_{n1}^2} + \overline{v_{n2}^2} \tag{5}$$

- The noise powers add, NOT the noise voltages
- For general circuits we use the Thevenin's equivalent circuit to determine the noise voltage.

Example

- Determine $V_{T,s}$, R_T and $\overline{v_{Tn}^2}$