# Fundamentals of Information Theory

A signal is a way of conveying information from one point to another. Our concern is to examine how much information is conveyed by a particular signal. Signals are simple in form if they do not carry much information. A mathematically correct sinusoidal varying voltage is described by the equation

$v = A \sin wt$

By definition this extends from $t=-\infty$ to $t=+\infty$ without any change in amplitude, A, or frequency, f (where $f= w/2\pi$).

## Information content in a wave

The most information we can retrieve by observing this wave is the value of its amplitude and frequency. We can, of course, obtain as many different measured values as we wish for the voltage at different times; however these are interdependent, and not really new information.

In general, for any signal which can be accurately described by a mathematical equation with n independent variables, the maximum information which the signal can carry is n values.

It follows that it is not practicable to describe fully any signal which is carrying useful amounts of information. The best we can do is to describe it's characteristics in general (statistical) terms.

A signal whose value can be evaluated at any time from a mathematical description of the signal is called deterministic. The more complicated signals whose value is not predictable in advance are referred to as non-deterministic, random, or stochastic signals.

## Measuring signals

In our consideration of the measurement of signals we are interested in answering two questions:

i) How precisely must we measure the signal?

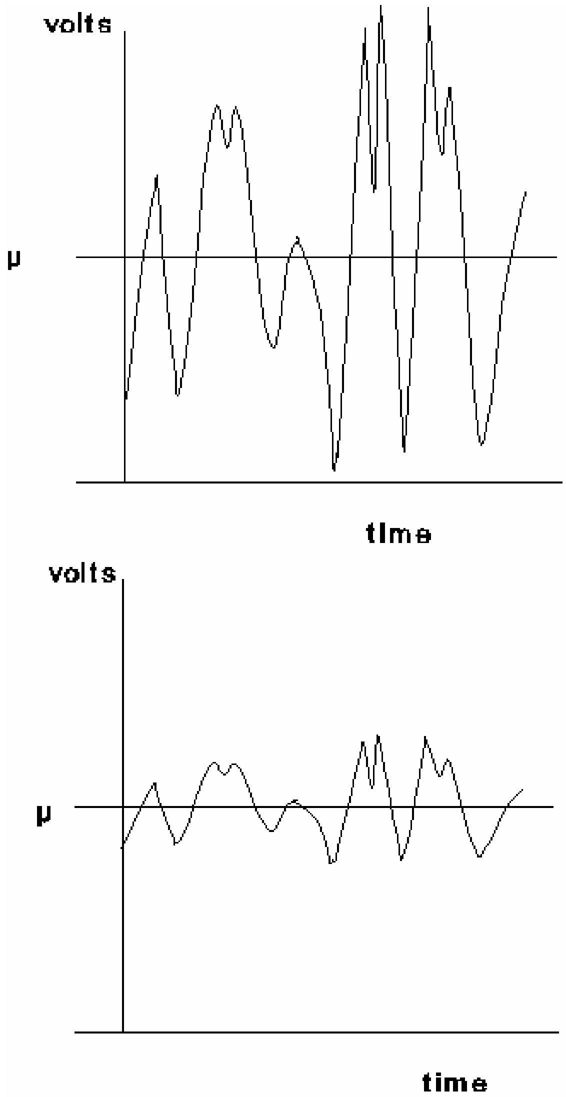
ii) How often must we measure the signal?

Our consideration of these questions must be guided by the amount of information present in the signal, and the amount of information we need to recover. In order to quantify these for our random signal we must examine its statistical characteristics.

## Statistical characteristics of a signal

Terms used to describe the characteristics of a stochastic signal include familiar measures such as mean, variance, and standard deviation, which describe the general behaviour. Less common terms are used to describe the way the signal varies - its spikiness (kurtosis figure) and also the `bigness' of the signal (root mean square value).

If our signal was truly random (i.e. with a Gaussian distribution) we could use the values for mean and standard deviation to determine the range of values which we would need to measure; and the kurtosis would give us an idea of the rate at which signals would need to be measured. Unfortunately this convenient situation is rarely the case, and we need to use more sophisticated techniques for describing the statistical behaviour of the signal.




Two signals with the same mean value, but with different RMS values

## Probability Density Distribution and Power Spectral Density

A more useful measure of the amplitude variation of the signal is the Probability Density Distribution ( PDD ). This simply gives the likelihood that the signal will be between two specified values at any instant it is measured.

The PDD is sometimes described as a Cumulative Probability Density distribution ( CPD ). This describes the likelihood that the signal will have a value less than some specified value at any instant.

In the same way that mean and standard deviation are inadequate to describe the amplitude characteristics of the signal, we also need a more precise way of describing the rate of changes in the signal. Any signal can be considered as being built up from a large number of sine waves. A process called spectral analysis allows us to discover the frequencies which are present in a particular signal. If we express our signal in this form, as a graph of RMS value (i.e. power) against frequency, we can analyse it to produce a `Power Spectral Density Distribution'   ( PSD ). This can help us to decide how often we need to measure the signal in order to obtain the information we are seeking.