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"Noise in classical and quantum measurements"

Abstract:

A common definition of noise relates to an unwanted or undesired signal or disturbance. In fact, design engineers often have to find ways to mitigate the deleterious effects noise has on measurement via techniques such as filtering and selective amplification. However, noise can be an ally in measurement and metrology. Einstein in 1905 recognized that the “noisy” motion of suspended particles on the surface of a fluid gave valuable information about the viscosity of the fluid. The analog in electrical systems was discovered by Johnson and explained by Nyquist in 1928. The role of noise in science and engineering has evolved from a nuisance to a subject of research. For example, in 2003 a primary temperature standard, built on a noisy source, measured accurately temperatures from ambient to near absolute zero. Quantum information sciences (quantum computing, storage and communication) rely on noisy sources to deliver what is expected to be a major disruptive technological shift later in this century. The mathematical foundation that describes noise has also evolved in scope and sophistication over the last 200 years. Applications of this formalism cover many areas of knowledge besides physical sciences including psychology, financial markets, biology and quality control. To give a valuable description of the general theory and its applications is beyond the time and space allotted for this tutorial. Instead, the tutorial will focus on concepts and applications that demonstrate the basic principles behind the theory and measurement of noise. This includes an introduction to the statistical description of random processes and some applications in electrical measurements in the classical and quantum realm. To benefit from this tutorial, the audience should be familiar with the basics of linear algebra and differential calculus. For those bringing computers equipped with mathematical toolboxes (statistics, algebra, and Fourier analysis) to the tutorial, program code examples will illustrate some practical aspects of the theory.