Understanding Imaging-System Performance: Quantum Sinks and the Detective Quantum Efficiency

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An important aspect of imaging science is understanding the fundamental physics and engineering principles that determine image quality. This understanding is particularly important for medical physicists involved with the design, evaluation or testing of x-ray imaging systems. In the first of this two-part presentation, metrics developed to describe image quality were introduced, including the modulation transfer function (MTF), Wiener noise-power spectrum (NPS), and detective quantum efficiency (DQE). In this second part, the relationship between system design and image quality (in terms of the DQE) is described using a linear-systems Fourier approach.

While it has been known since the work of Albert Rose in the 1940s that image quality is directly tied to the number of quanta used to create an image, the Rose approach is too simplistic to use in many situations of practical importance. More recently, Fourier-based methods of describing image signal and noise have been adapted from foundations laid out by scientists and engineers studying communications theory and are now widely used. In this presentation, principles of linear-systems theory used in the analysis of medical-imaging systems to describe signal and noise transfer are described. The link is made to metrics of image and system quality including the MTF, noise-equivalent number of quanta (NEQ), quantum sinks, and the DQE. The theoretical bases for the NPS of digital-imaging systems is presented, including a description of noise aliasing. It is shown how noise aliasing can degrade the DQE of digital systems. Examples are given showing how the theoretical principles presented can be applied to the analysis of several types of imaging systems including x-ray image-intensifier based systems and the new active-matrix flat panel digital systems.

Educational Objectives

1. Understand methods used to predict the DQE for particular system designs.
2. Understand the effect of primary and secondary quantum sinks as a function of spatial-frequency.
3. Understand the importance of noise aliasing on the DQE of digital imaging systems.