Purpose: With the development of RT treatment planning systems that use the relationship between CT number and Electron Density (ED), rather than the Linear Attenuation Coefficient (LAC) of a given material, a number of authors have pointed out the divergence between the linearity of CT numbers vs. LAC in the diagnostic range compared to the relationship between the CT number and ED. This paper will review the differences and similarities, and describe a new set of phantom test objects and automated software that can be used to automatically assess both scales. In particular the relative importance of atomic number (Z) and the relative impact of Coherent vs. Incoherent effects at high Z levels will be evaluated.

Methods: A newly developed phantom (Catphan® 700) has an expanded set of sensitometric samples of known density, electron density, and chemical composition (Z effective). CT scans of the phantom were obtained at various energies (kVp) and the measured CT numbers were compared to the known physical characteristics mentioned above. Regressions between measured CT numbers, linear attenuation coefficients (with and without coherent scattering effects), and electron density for the materials were performed. Effects of different materials and the inclusion of coherent scattering on linearity scale and effective energy were established.

Results: The linearity scale and effective energy are shown to be dependent on the selection of materials scanned and the inclusion/exclusion of coherent scattering effects in the linear attenuation coefficients. Electron density deviates significantly from a linear relationship with CT number.

Conclusions: Caveats accompanying high Z materials are reinforced regarding application to the RT relationship between CT number and electron density. Interesting results were obtained for the influence of coherent vs. incoherent scattering, which appears to be important as the number of slices and scanning volume increases in CT.

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