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Tailoring Diagnostic Physics Performance Evaluation to the Imager Technology in Digital Roentgen-ray Imaging: Assessing Image Quality

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INTRODUCTION

In flat panel based Roentgen-ray imaging practice, it has been demonstrated [1] that various noise sources come into play at different image receptor incident air-kerma values stressing the image receptor specific dependence of these system characteristics. Electronic noise at low doses and fixed pattern noise associated with high doses are examples of ever present variances in digital imaging practice.

By choosing image receptor incident air-kerma value over which the digital detector behaves in a quantum limited fashion, one can minimize the influence of non-quantum noise sources listed above. Experimental methods involved do not require a new test or data acquisition procedure but rather a few additional exposures under the same test conditions as for detector characteristic response assessment is all it takes.

Testing low contrast detectability under detector dose conditions encompassing the AEC driven dose regime and functional limits can uniquely quantify low contrast performance according to the system. This test should be performed only after verifying the AEC calibration accuracy.

AIM

To develop a method to evaluate image quality based on design characteristics of a digital x-ray imaging system that aims to reduce the influence of non-quantum noise sources during flat detector image quality testing and allows for conforming the testing techniques to the system design characteristics. The two image quality metrics that can be tested while conforming to system parameters are:

A. Quantitative High Contrast Spatial Resolution
B. Low Contrast Detectability of digital detector

METHOD

a. Noise analysis was performed on a GE-Definium 8000 flat panel radiographic unit.
b. During acceptance/annual testing, under detector calibration SID or at a minimum SID of 150 cm, with RQA 5 beam conditons, measure air-kerma values at the position of the image receptor, over a range of mAs stations up-to maximum air-kerma values the detector can sustain without saturating.
c. Expose the detector to the same air-kerma values under FOR-PROCESSING settings.
d. Using a ROI of 2 cm x 2 cm, pixel values and standard deviation in the middle of the detector, for each image were determined.
e. Variance is calculated as the square of standard deviation and plotted against the air-kerma employed.
f. In MS Excel, fitting a power trend line with display equation option to the data provides you with the corresponding equation of the type: $y = aC^b$. Here a and b are constants and the range of air-kerma values for which b yields a value of close to 1 is the detector air-kerma value of interest.
g. The detector is exposed to deliver this dose with high contrast resolution pattern at a slight angle to the two axis as shown in the Figures 1 and 2 respectively.
h. This detector is designed with a linear characteristic response.
i. LCD was assessed on a Siemens Agile Max FD system using a commercially available Contrast Detail Phantom and visual inspection was performed to quantify low contrast.
j. For assessing low contrast detectability, the AEC calibration air-kerma values are verified for accuracy. Minimum and maximum values are based on the minimum user selectable detector dose value along with most negative and most positive density control selector settings. This way the entire AEC design spectrum of potential detector doses is covered and LCD is assessed at each value. Test is performed at SID corresponding to the grid focus, as specified by the grid manufacturer.

RESULTS

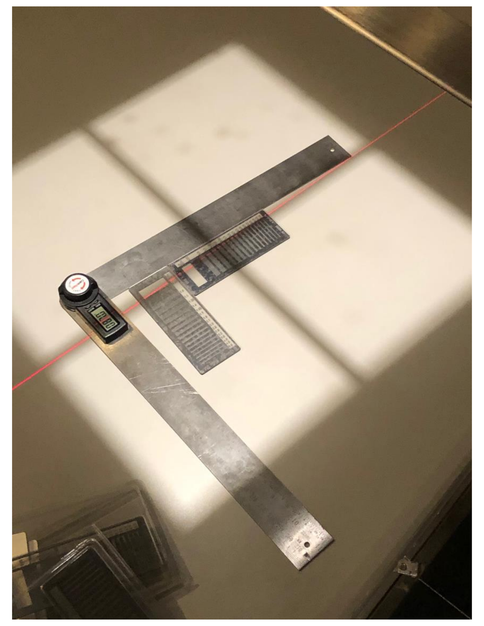

Figure 1. Precision high contrast resolution patterns positioned at three degree to the image receptor axis as shown in the picture.

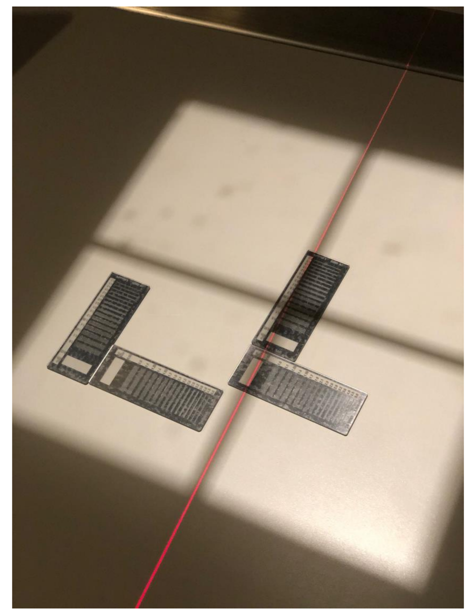

Figure 2. Demonstrating spatial resolution measurement in different areas of the image receptor.

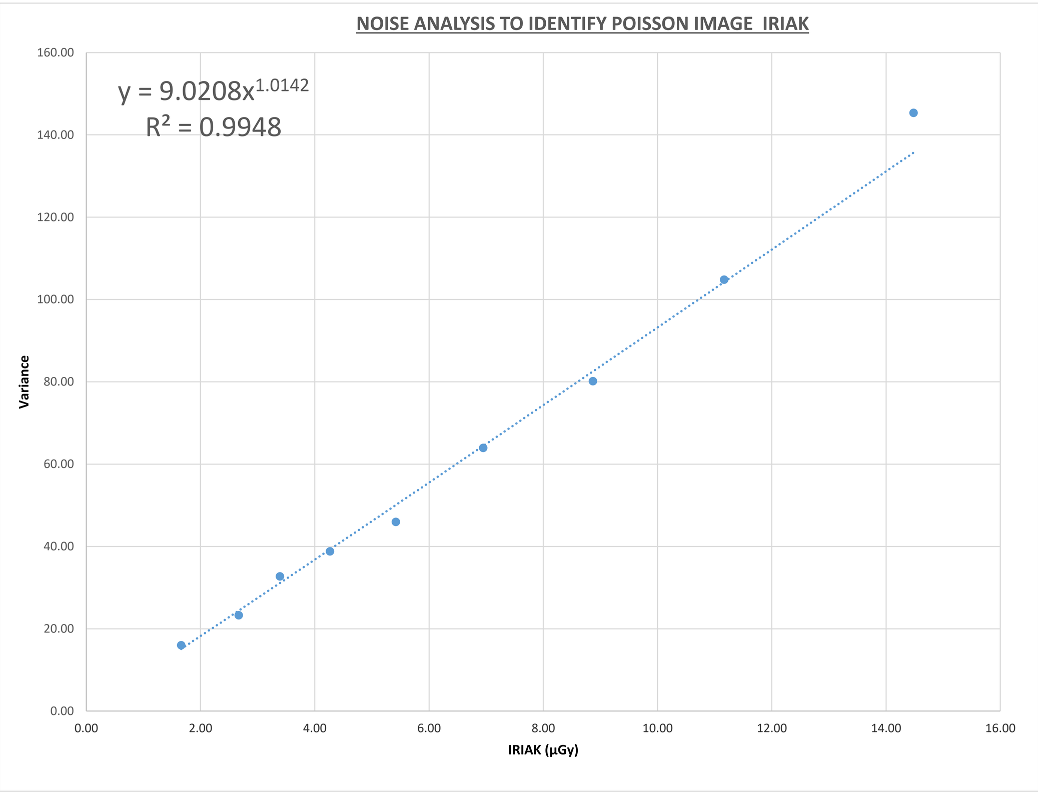

Figure 3. Power fit to the variance-Detector Dose value provides with the air-kerma value of interest

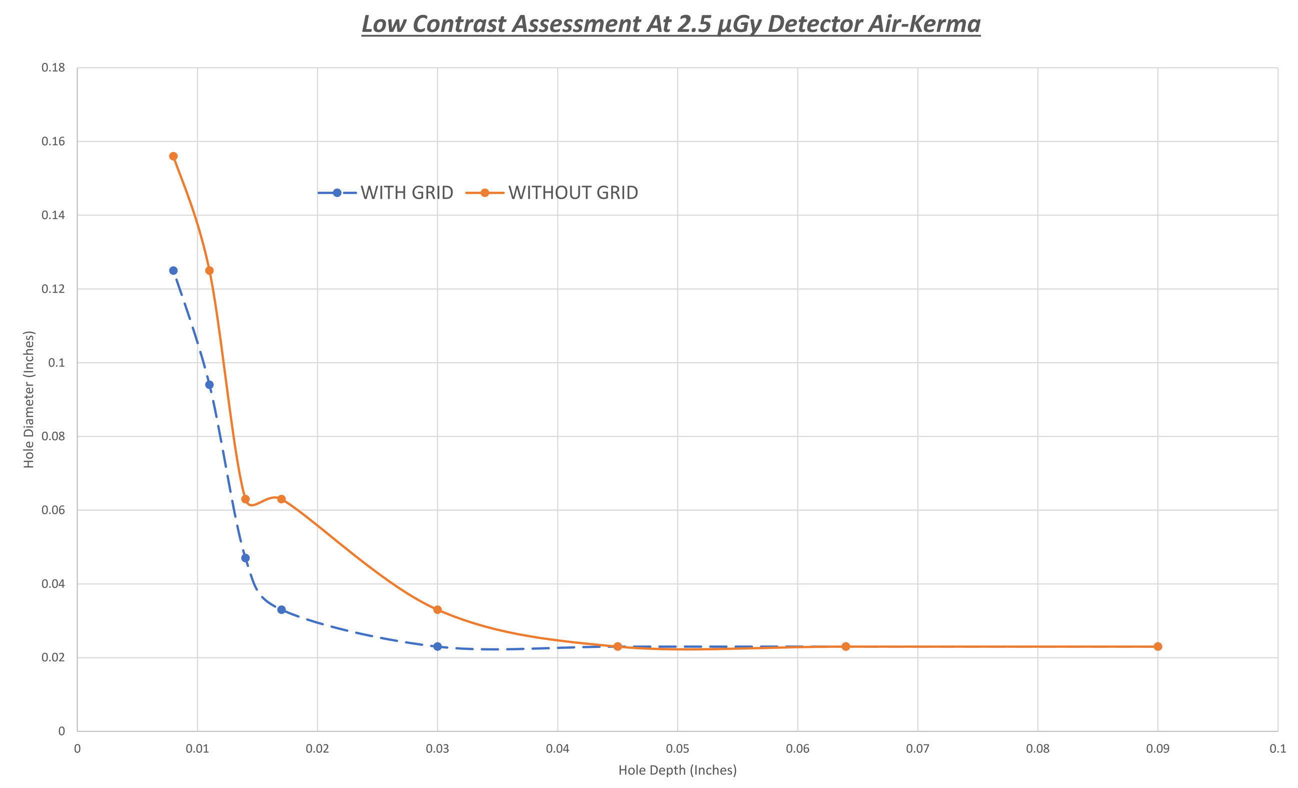

Figure 4. Low Contrast Detectability Assessment Results

Flat detector panel for use with radiographic units are usually composed of 4 detector elements stitched together, providing with one image receptor. High Contrast Spatial Resolution, therefore, can vary from one detector quadrant to the other. It is therefore important to assess resolution in the different quadrants along with the center of the image receptor.

User subjectivity related limitations of the commercially available contrast detail phantom make it undesirable to monitor routine imaging performance of the detector. This test, with appropriate tools can help assess grid performance in-terms of its scatter removing capabilities.

CONCLUSIONS

a. Quality control tests accounting for system characteristics can provide results that can improve performance monitoring, by providing unit design specific data.

b. It is recommended that image receptor dose is maintained below 30 µGy for quantitative high contrast resolution measurements as mentioned here.

c. Low contrast assessment using contrast detail phantoms without analysis software are difficult to use and the replication of results might be difficult over time and by different observers, particularly at clinically relevant low detector doses.

d. Use of the lowest AEC based air-kerma, along with the routinely used AEC calibration setting (0.4 µGy and 2.5 µGy, in our case) is recommended for routine quality control.

e. Lowest detector air-kerma image is most sensitive to system performance changes that may happen over time for the low contrast test.

f. The use of multi-purpose single shot phantoms for assessing a range of image quality parameters of DR system, such as low contrast sensitivity and high contrast spatial resolution is not a sound approach. Such phantoms are more appropriate for frequent and periodic quality control by radiographers.

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