RADIOLOGY RESEARCH

CR/DR Image Noise – Part 2

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AAPM 2011
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MO-A-110-2

Learning Objectives

- 1. To understand the roll of measuring the Noise Power Spectrum (NPS) of a digital radiography detector in acceptance testing or routine QA
- 2. To understand the methodology and challenges of measuring the NPS of a digital radiography detector in a clinical setting
- 3. To become familiar with the NPS measurement's sensitivity to the acquisition technique and beam conditions

Outline

- Motivation
- Setup of Beam Conditions for NPS measurement
- Acquisition and Export of data for NPS analysis
- Use of NPS Analysis software
- Examples of acquired NPS data

Motivation

- Measurement of NPS provides a robust and reliable metric of digital detector performance as part of a Quality Control and Assurance Program
- NPS is more sensitive than visual assessment of Contrast Detail Phantoms (*Rivetti et al., Med Phys V 37(2)*) or the use of the Standard Deviation of the image noise (Part 1 of this session)
- NPS is easily repeatable and allows comparison amongst different detector systems

Motivation

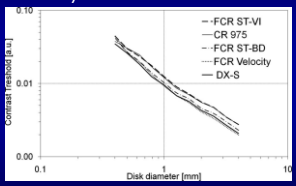
- Regular Acquisition of NPS over time:
  - Allows monitoring of performance of detector from acceptance through end of life
  - Normalizing NPS to the exposure at detector allows direct comparison of data from different time points
  - Failure modes of digital detectors can be observed through documentation and monitoring of NPS

Motivation

- NPS vs. Contrast Detail Analysis or Standard Deviation of Noise for QC
  - The square of the Standard Deviation of noise is integral of NPS over frequency and cannot differentiate between different noise textures
  - Contrast Detail analysis is subjective and not repeatable (same conditions can never be truly replicated as observer changes over time)
  - Contrast Detail analysis does not provide as clear a visualization of differences between systems as NPS

Motivation

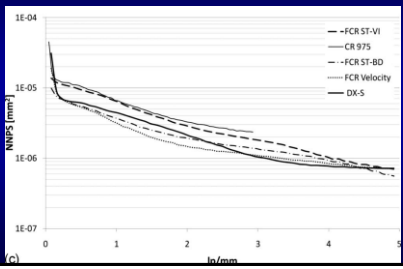
- Plot of Contrast Detail Curve for Multiple Detector Systems



Rivetti et al. Med Phys 37(2)

Motivation

- Plot of NPS for Same Detector Systems allows better visualization of differences



Rivetti et al. Med Phys 37(2)

Setup of Beam Conditions for NPS measurement

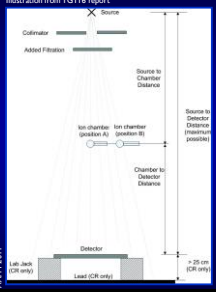
- Beam Conditions for NPS of Radiographic Units are AAPM Exposure Index Conditions defined in TG 116 (*Sheppard et al. Med Phys 36(7)*)
  - Well established approach to reach equivalent HVL of 6.8 mm Al for data acquisition using:
    - 66-74 kVp at 0.5 mm Cu + 0-4 mm Al
  - Commercial products available to assist in achieving Standard Beam Conditions
  - Radiography III (WE-A-110-1) and Part I of this session discusses beam conditions further
- Use of same beam conditions as EI allows for easy acquisition of NPS data at acceptance of unit

Setup of Beam Conditions for NPS measurement

- Setup of Standard Beam Conditions for Radiography Systems
  - Standard Beam Condition produce relatively flat output of photons per mR vs. kVp
  - Adjust each system to get same HVL at Standard Beam Conditions so same Quanta per mR can be used for normalization
  - Adjust kVp to reach 6.8 mm Al HVL as last resort (add Al to 0.5 mm Cu as first step)
  - Precise positioning (and measurement) of ion chamber location is very important for calculation of exposure at detector
  - Removal of Anti-Scatter Grid is required

Setup of Beam Conditions for NPS measurement

Illustration from TG116 report



Setup of Beam Conditions for NPS measurement

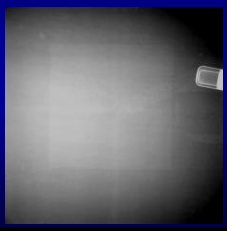
- Required equipment for NPS measurements on Radiography Systems
  - Ion Chamber and kVp meter and R/O box
  - At least 7 mm of Al for HVL determination under Standard Beam Conditions
  - 0.5 Cu + 0-4 mm Al (or equivalent) to reach Standard Beam Conditions
- Mammography Systems
  - 40 mm of Breast Tissue Equivalent material used to establish beam conditions of NPS measurement

Acquisition and Export of data for NPS analysis

- Analysis of NPS requires acquisition and exporting of images with "For Processing" Image Values as defined in TG 116
- Gain and offset corrections and flat field corrections should be applied to produce For Processing images that can be analyzed
- Relationship between Image values and exposure is different for different manufacturers
  - Linear vs. Log relationship of pixel values to exposure

Acquisition and Export of data for NPS analysis

- "Raw" data exported without corrections: Not Useable for NPS analysis – also includes possible lag artifacts



Acquisition and Export of data for NPS analysis

- Acquisition Steps
  - Setup Beam Conditions
  - Determine average exposure at the center of the beam
  - Determine exposure with ion chamber at the edge of the beam (setup for image acquisition)
  - Acquire 5-10 images at detector exposures ranging from ~ 0.1 to 10 mR
    - Detector exposure determined by geometric correction of ion chamber placed at edge of field

Acquisition and Export of data for NPS analysis

- Approach for each system to allow for export of for processing data (and in what form) must be defined and supplied by vendors for implementation of NPS (and MTF) analysis for QC
- Some systems require service level access to set up for processing export
- Some systems can be setup once in service mode and tech access can export data
- Radiography III (WE-A-110-1) includes information on image export

Acquisition and Export of data for NPS analysis

- Challenges to acquiring data for NPS analysis
  - Pixel values saturate if exposure is too high
  - Gain/offset and flat field corrections not applied to exported raw data
  - Must correct for Image Values that have log relationship to exposure (discussed in Part 1)
  - Small changes in setup geometry can significantly adjust calculated detector exposure and affect normalization
    - Solution: for repeated measurements on same system, use average exposure value for same mAs
  - Setup of system for export of For Processing Images

Acquisition and Export of data for NPS analysis

- Exporting For Processing Images:
  - AGFA required Service Access to set up export, tech access to export once set up
  - Philips required Service Access to set up and export
  - Lorad requires tech level access to export
    - Exported raw
  - GE Mobile unit required Physics I, uncorrected imageevel access to export
    - Exported raw, uncorrected image

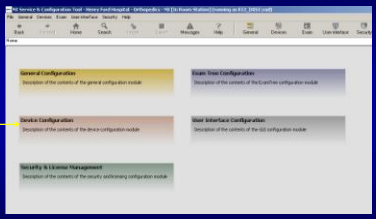
Acquisition and Export of data for NPS analysis

AGFA DXS Example

Of Steps to Export For Processing Images

Export Procedure for AGFA: 1. Go to Main Menu – select Service & Configuration Tool

Export Procedure for AGFA: 2. Select Device Configuration



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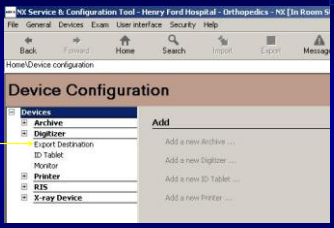
21

Export Procedure for AGFA: 3. Select Export Destination



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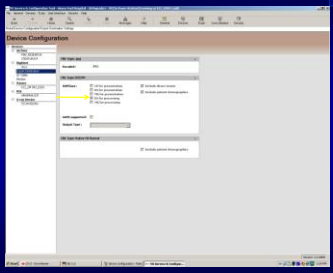
22

Export Procedure for AGFA: 4. Set DX for Processing – this allows export of For Processing Images to CD Writer



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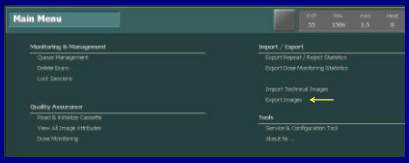
23

Export Procedure for AGFA: 5. Select export images from main menu and export desired images to CD as For Processing



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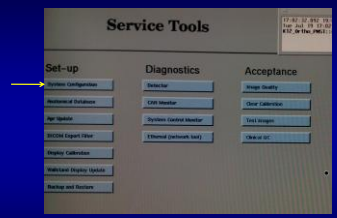
24

Acquisition and Export of data for NPS analysis

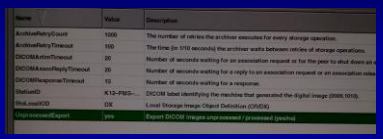
Philips Pixium Example

Of Steps to Export For Processing Images

Export Procedure for Philips: 1. Enter Service Mode and Select System Configuration

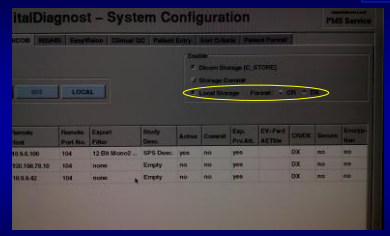


Export Procedure for Philips: 2. Under "Unstructured Items" tab change *Unprocessed Export* to "yes".

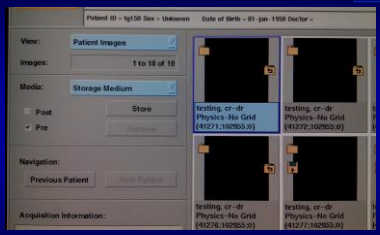


Name	Value	Description
ArchiveRetryCount	1000	The number of retries the archiver executes for every storage operation.
ArchiveRetryTimeout	100	The time (in 1/10 second) the archiver waits between retries of storage operations.
DICOMAcrtimTimeout	20	Number of seconds waiting for an association request or for the peer to shut down an a
DICOMAssocReplyTimeout	20	Number of seconds waiting for a reply to an association request or an association relea
DICOMResponseTimeout	15	Number of seconds waiting for a response.
StationID	K12-PIIS-...	DICOM label identifying the machine that generated the digital image (0008,1010).
SharedOID	DX	Local Storage Image Object Definition (OIUDX)
UnprocessedExport	yes	Export DICOM images unprocessed / processed (yes/no)

Export Procedure for Philips: 3. Under "DICOM" tab Enable *Local Storage* of DX images



Export Procedure for Philips: 4. After saving changes and restarting application, export images to "Storage Medium" as "Pre".



Acquisition and Export of data for NPS analysis

Lorad Selenia:

Select Output as -

Cdrw Raw to Export Raw Images (uncorrected) to CD

Acquisition and Export of data for NPS analysis

GE AMX 700:

Select Raw processing option to allow Export of Raw Images (uncorrected) to PACS system

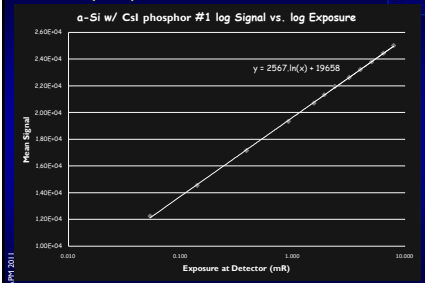
Use of NPS Analysis Software

- Requires DICOM input
- Define following system specific parameters described further in Part I of this session
  - Block analysis size
  - Area to analyze NPS over
  - Pixel size
  - Correction factor for systems with log image value to exposure relationship
- Outputs following analysis are
  - 2D NPS image
  - Data and plots of 1D NPS data

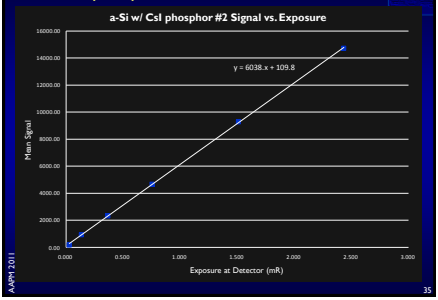
Use of NPS Analysis software

- Analysis of Data
  - Plot calculated average pixel value vs. exposure
  - Determine if pixel values have log or linear relationship to exposure
    - If log relationship, calculate gamma to use in NPS calculation

Use of NPS Analysis Software: Q Values with log relationship to exposure



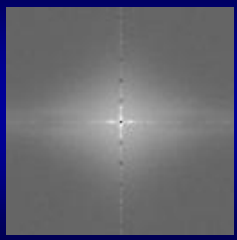
Use of NPS Analysis Software: Q Values with linear relationship to exposure



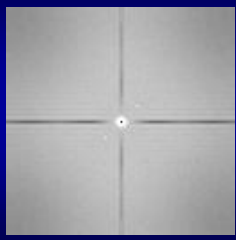
Use of NPS Analysis software

- Run NPS analysis using system specific parameters
- Examine 2D image of NPS to identify any NPS trends
- Choose representative 1D plots of data if desired
  - E.g. suppressed horizontal power vs. diagonal signal
- Normalize NPS data using ideal quanta per mR and calculated exposure at detector to get nNPS
  - Ideal Quanta per mR under Standard Beam Conditions for Radiographic systems ~ 255 photons
  - Ideal Quanta per mR for Mammography System w/ 40 mm breast equivalent in beam at 28 kV Mo/Mo ~ 45 photons

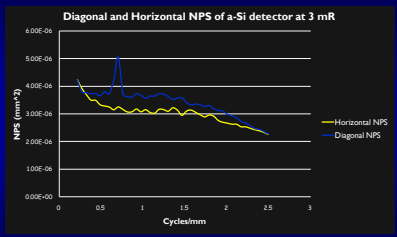
Storage Phosphor 2D NPS at ~ 4 mR Air Kerma



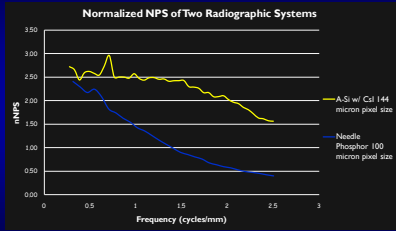
a-Si detector with CsI Scintillator 2D NPS at ~ 3 mR Air Kerma



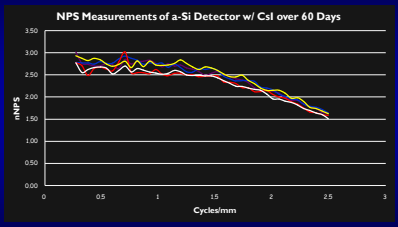
Examples of Acquired NPS Data



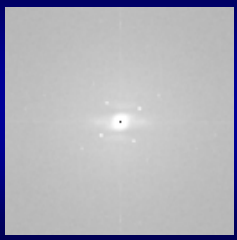
Examples of Acquired NPS Data



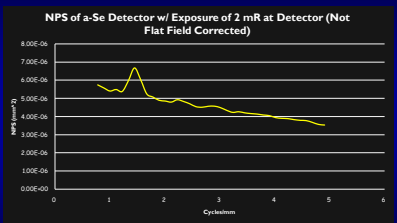
Examples of Acquired NPS Data



a-Se Detector 2D NPS at ~ 2 mR Air Kerma: Not Flat Field Corrected



Examples of Acquired NPS Data



Conclusion

- NPS analysis is a robust, reliable and repeatable assessment of detector noise performance as part of a Quality Assurance Program
- A challenge to widespread adoption of NPS as a regular QC metric is the difficulty in producing and exporting gain, offset and flat field corrected images with "for processing" image values
- Clear documentation and support from manufacturers to allow export of images that can be used for NPS analysis is vital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45