Features and Weaknesses of Phantoms for CR/DR System Testing

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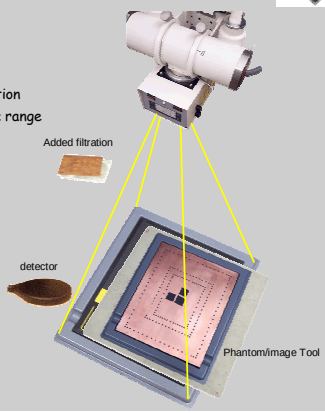
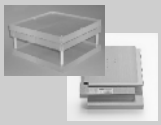
Physics testing of image detectors

- Parameters to test
  - Spatial resolution
  - Contrast resolution
  - Uniformity/geometric distortion
  - Dose response/signal dynamic range
  - Noise
- Experiments/testing methods
  - Direct measurements
  - Phantoms/image tools
    - Qualitative
    - Quantitative

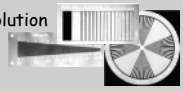


Phantom Types

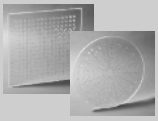
- Attenuation



- High Contrast/Spatial Resolution



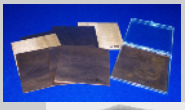
- Low Contrast/Contrast Sensitivity



- Anthropomorphic

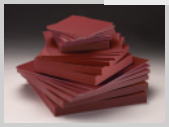
Attenuation test tools

- Metals
  - Aluminum, Copper, etc.



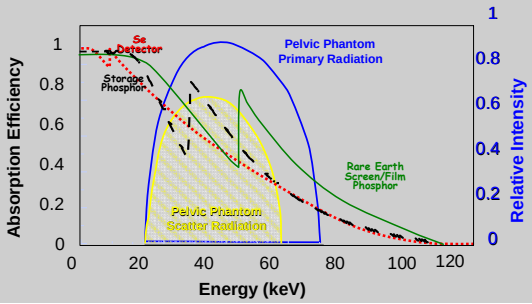
- Plastics/Composite Materials
  - Lucite, Tissue Equivalent, etc.

- Water/Equivalent



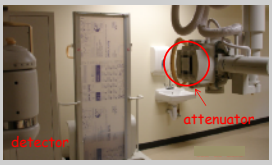
Detectors - Energy Sensitivity

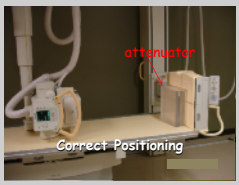
- Digital detectors can be significantly more sensitive to scatter radiation as compared to traditional phosphor screens
  - Scatter needs to considered at setup when testing systems



Attenuator positioning

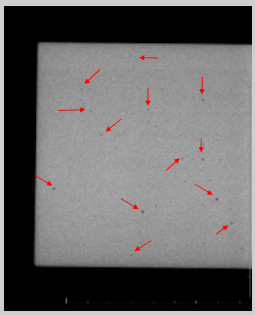
- Modifying beam quality
  - Position attenuators far from detector to minimize scatter contribution in measurement
- Simulating patient attenuation
  - Position close to detector in same location as patient





Attenuator Construction

- Attenuator "purity" may not be acceptable for the measurement
  - Measurement of mammography HVL requires attenuators that are at least 99.9% Aluminum
- Tissue equivalent materials may not be uniform

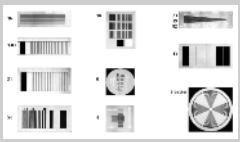


Attenuation test tools

- Easy to use
- Placement of attenuator needs to be considered based on the test
- Purity or Uniformity of material may not be adequate for some tests

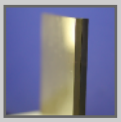
High Contrast/Spatial Resolution Test tools

- Line pair patterns

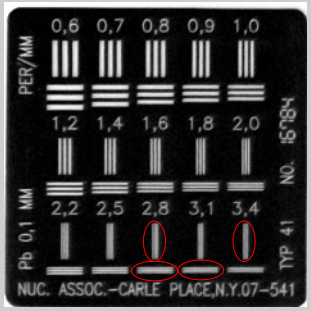


- Mesh patterns

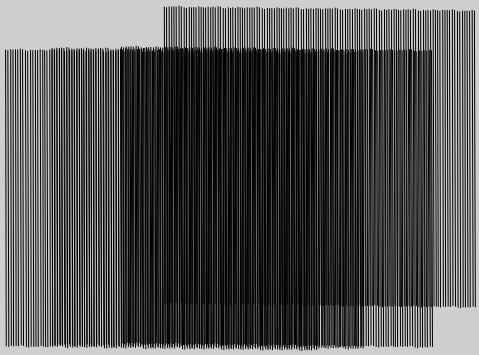
- Edge phantoms



Line pair patterns



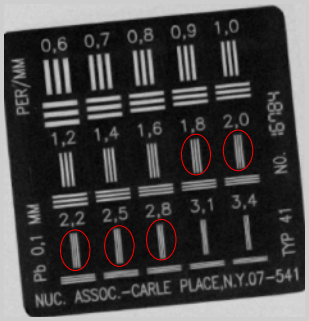
Aliasing and Moiré Effect



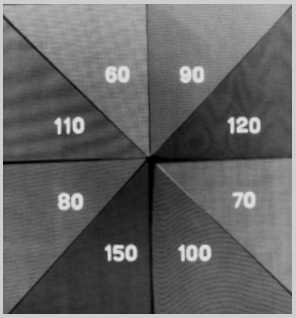
Line pair pattern

Detector Pitch

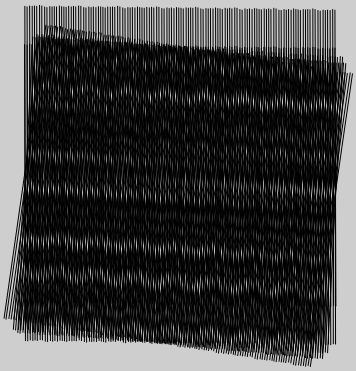
Line pair patterns



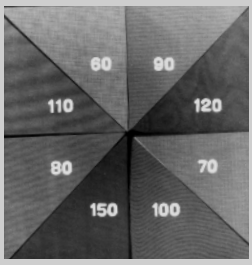
Mesh Patterns

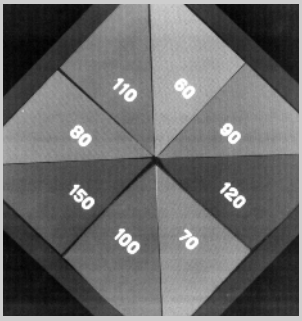


Moiré Effect



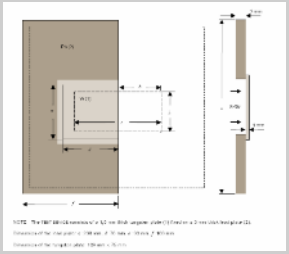
Mesh Patterns





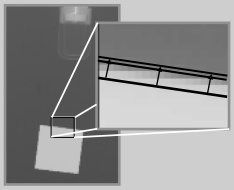
MTF/DQE Measurement

- IEC 62220-01 (2003)
  - Method for determining Detective Quantum Efficiency (DQE) of digital imaging systems
  - Defines specifications for a test device required to make these measurements

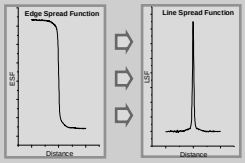


MTF/DQE Measurement Issues

- Requires Pre-processed image values that are "linear" with exposure
- Determination of edge response
  - Need to bin pixel data along edge
  - Phantom positioning critical for consistent results

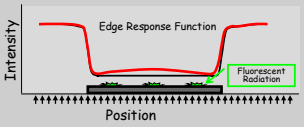


- Smoothing/fitting of edge response curves to allow utilization of Fourier Analysis
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements

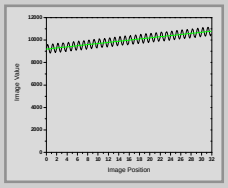


MTF/DQE Measurement Issues

- Fluorescent radiation
  - Only issue at high kVp
  - Important if comparing to other MTF/DQE measurements

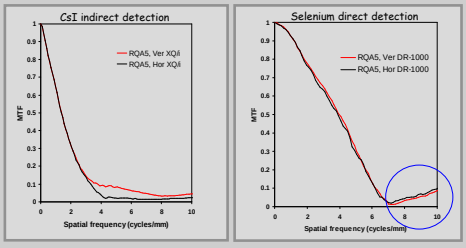


- Noise Power Spectrum (NPS) determination
  - Need to remove effects of trends associate with heel effect, etc.
  - Variations in method used may produce different results
  - Important to standardize if comparing to other MTF/DQE measurements



MTF Measurements

- Quantitative results
- Good indication of changes
- Subtleties in the measurement and analysis of data can make comparisons between measurements by different tests inaccurate
- Need to understand artifacts in results due to aliasing, etc.

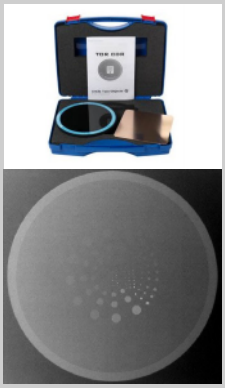


High Contrast/Spatial Resolution Test tools

- Line pair patterns
  - Subjective
  - Need to consider detector pitch in relation to resolution pattern
- Edge Phantoms
  - Objective
    - MTF Determination
  - Valid for determining if changes have occurred over time if performed "consistently"
    - Requires standardization of methods used *if* comparison between systems or results from different physicists is desired
    - Would benefit from development of "standardized" software package to do the calculations
      - Task Group No. 162 "Research Software for 2D Image"

Low Contrast/Contrast Sensitivity test tools

- Contains objects of varying size and attenuation
- Requires observers to determine which objects are visible
  - Subjective

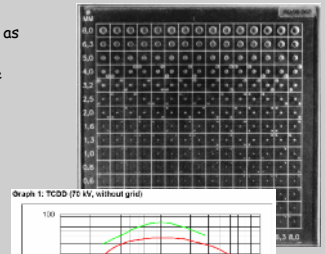


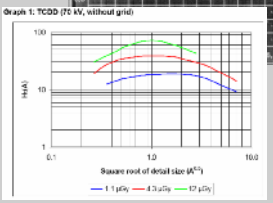
Threshold Contrast Detail Detection index (TCDD)

- TCDD gives an indication of the lowest contrast detectable (C_T) as a function of the detail size
- given in terms of square root of the object area ($A^{\frac{1}{2}}$)
- Can be quoted in terms of the threshold detection index (H_T)

$$H_T(A) = 1/[C_T * A^{\frac{1}{2}}]$$

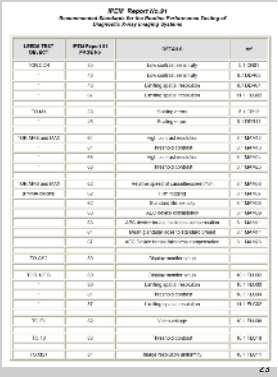
- High value for $H_T(A)$ indicates good visibility





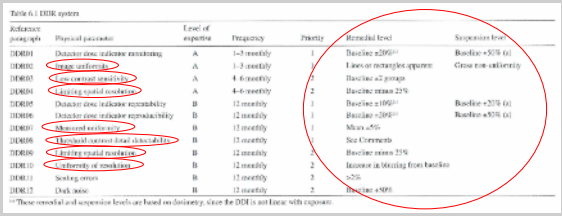
Institute of Physics and Engineering in Medicine (IPEM)

- Goals:
  - Improving standards in clinical practice
  - Providing advice on scientific and engineering issues in healthcare to other healthcare professionals, ***government*** and the public.
- Develops Reports and other publications to achieve these goals
  - Owns several journals:
    - Physics in Medicine and Biology
    - Physiological Measurement
    - Medical Engineering and Physics
  - Report 91 Recommended Standards for the Routine Performance Testing of Diagnostic X-Ray Imaging Systems
    - Specifies the use of phantoms throughout the testing procedures

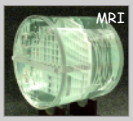


IPEM Criteria (example)

- Most results are subjective !

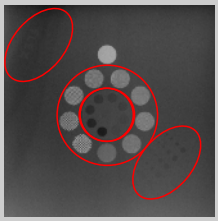


ACR Accreditation Phantoms



ACR Radiography/Fluoroscopy

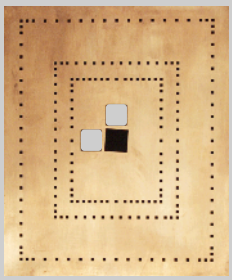
- Modules included
  - Chest
  - General
  - Fluoroscopy
- Phantom image
  - Radiography Chest/Abdomen
- ACR Discontinued Radiography/Fluoroscopy Accreditation Program in 2005

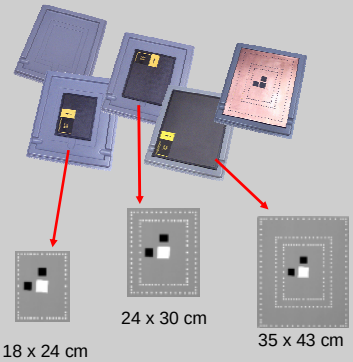


Original Equipment Manufacturer (OEM) Products

- Automated Image Quality Control Tool
  - Reproducible quantitative results
  - May detect sub-visible changes in image quality performance to initiate timely preventive maintenance
  - Highly automated procedure
  - Most provide data reporting in spreadsheet format

Test Phantom for Kodak (i.e. CareStream) DIRECTVIEW Total Quality Tool

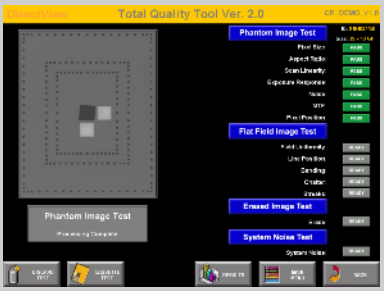




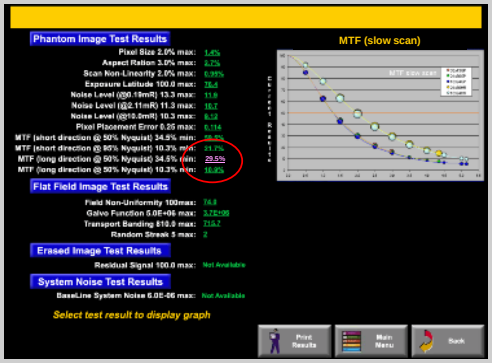
*Images provided by Eastman Kodak Company

KODAK User Interface

- Uniformity
- Noise
- Spatial frequency response (MTF)
- Exposure linearity
- Pixel size accuracy and aspect ratio
- Phantom image artifacts
- Laser Beam Function
- Residual signal erase



Kodak Test Result Details

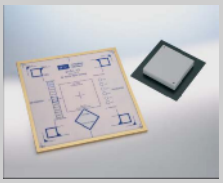


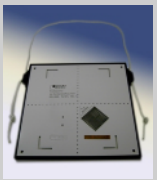
Test Limits

- Pre-set by OEM
- Basis for limit may not be justified in OEM literature
- If system fails a test, Service Engineer may not be educated how to correct problem
- AAPM Report 93: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems Recommends using vendor/manufacturer supplied phantom for Quality Control testing
  - Since each vendor/manufacturer system would be different, the Report could not specify exactly what to do or look for in the results

DIN 6868-58 (2001) and 6868-13 (2002)

- Acceptance testing and constancy checks of projection radiography systems with digital image receptors
  - German standard for testing of Storage Phosphor systems using a specially designed phantom to measure image quality parameters
  - Can purchase a phantom that will meet the requirements of this standard from several vendors

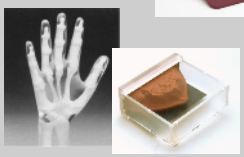




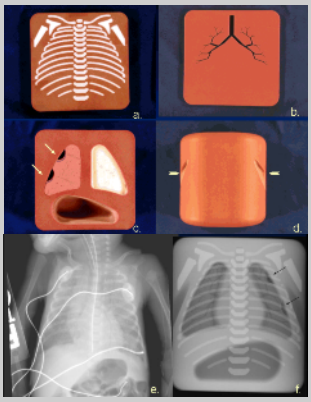
Anthropomorphic phantoms

- Shape "mimicking"

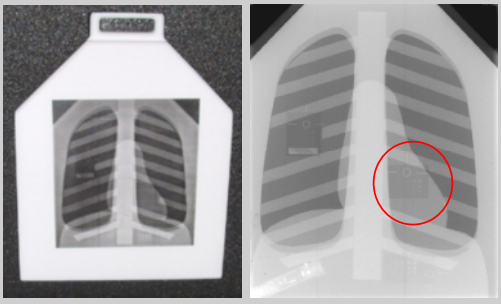
- Anatomically Accurate



Shape "mimicking"



Shape "mimicking"



Anatomically Accurate

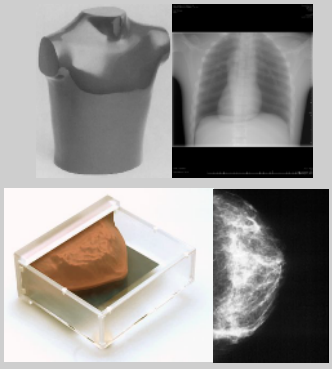
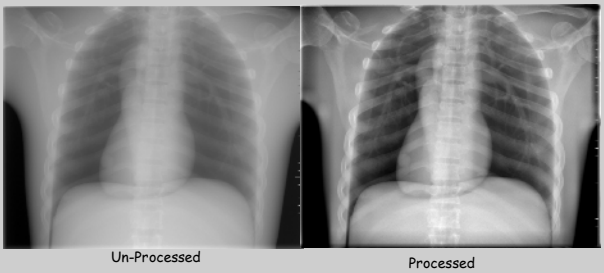


Image Processing



Un-Processed Processed

European Protocol for QC of … mammography Addendum on Digital Mammography

- It is acknowledged that at present it is not possible to get unprocessed images from some systems
- The image processing may introduce artifacts on phantom images and may be different from image processing for mammograms due to histogram or local texture based processing techniques
- Therefore care needs to be taken in interpretation of these processed images

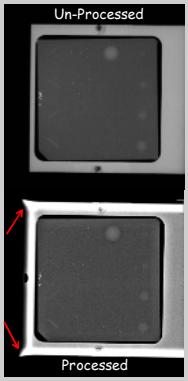
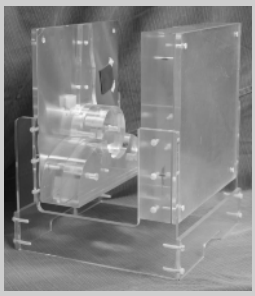


Image Processing

- To optimize image processing parameters the phantom would need to accurately mimic "true" anatomy
- At least one reference of a study attempting to accomplish this with a phantom for a specific vendor processing method*
- Impractical to do this for all Body Parts/Views and all vendor's image processing systems



*Moore CS, et al, "A method to optimize the processing algorithm of a computed radiography system for chest radiography", British Journal of Radiology, 80 (2007), 724-730

Phantom vs. Real Life

AAPM Report 93: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems

- Lists anthropomorphic phantoms in the recommended equipment list
  - Doesn't specify how to use the anthropomorphic phantoms in the Report

Government Phantom