

Breast Tomosynthesis

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Outline

- ✓ Physics aspects of breast tomosynthesis
- ✓ Quality control of breast tomosynthesis

Limitation of 2D mammography

Performance of 2D Mammography

✓ Sensitivity: 83.55

Good but not ideal.

✓ Specificity: 90.9%

The root cause?

✓ The radiation dose ? No. wide dose range in use.

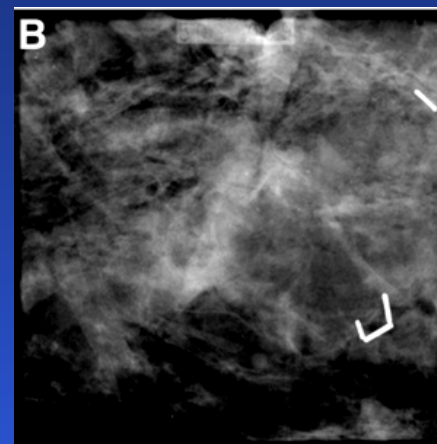
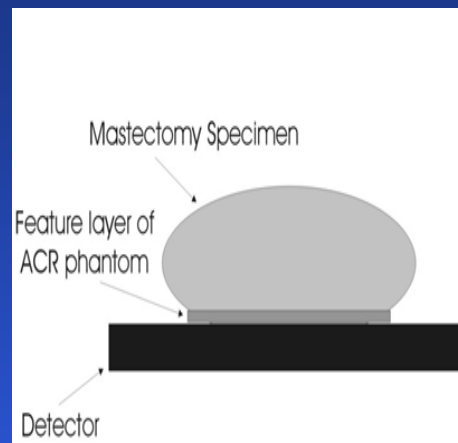
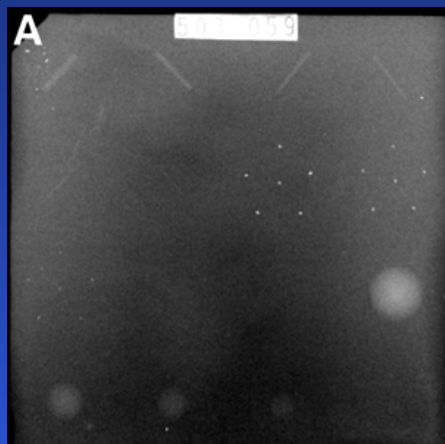
✓ The detector resolution ? No. SF resolution more than enough.

✓ The detector dynamic range? No. SF & DM difference small.

✓ The structure noise due to tissue overlaps? **Yes**

Limitation of 2D systems and solutions

Effects of structure noise

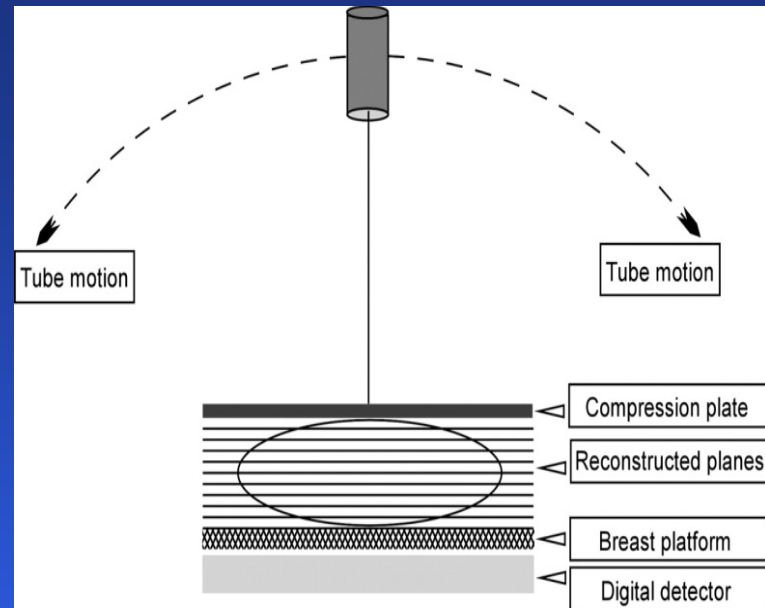
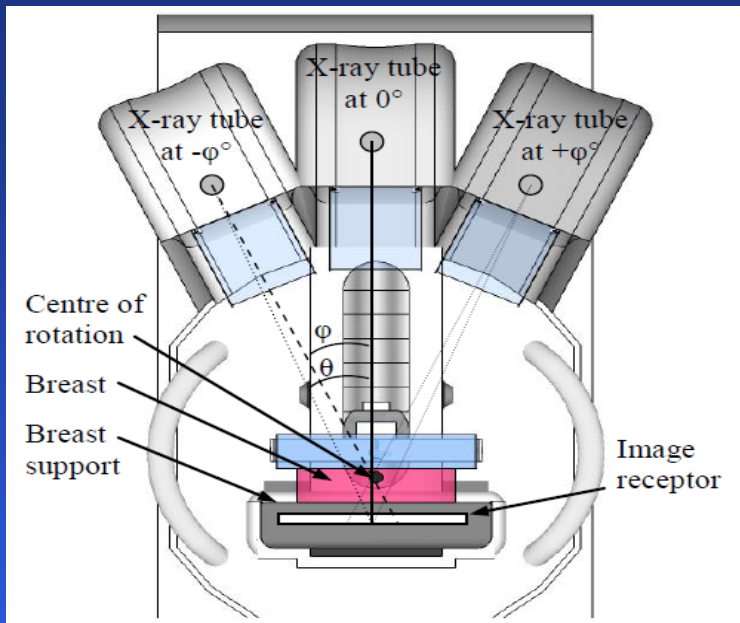


Solution: Tomographic imaging

- Digital Breast Tomosynthesis (DBT)
- Breast CT (BCT)
- Breast MRI
- ...

For a screening modality, it must be low cost, low dose, fast, efficient ... DBT may be the only option

Digital Breast Tomosynthesis



Scan: N projections

Reconstruction: M slices

New variable affecting IQ

New variable affecting IQ

- tube/detector/patient motion
- range of rotation
- number of projections
- scatter intensity

- incomplete data in f space
- selection of recon kernel
- geometric calibration

DBT Performance

Resolution:

x-y plane: \llsim DM (motion/pixel binning/geo calibration/recon)

z-direction: \sim 1 mm (limited data in f space)

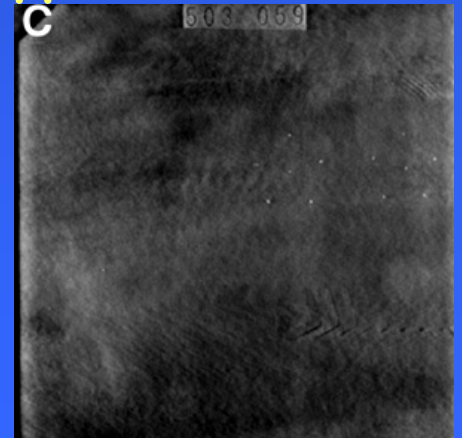
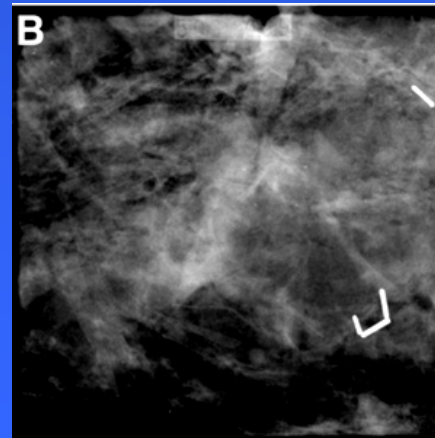
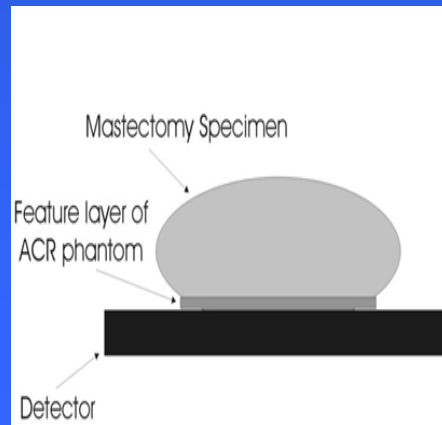
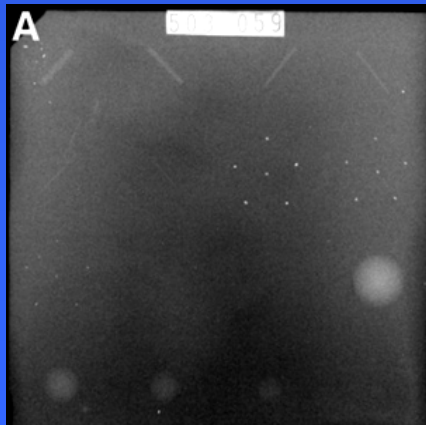
Calcification detection:

Conflicting reports (DBT better if no detector pixel binning)

2D image is required for Hologic for better cal. visualization

Mass detection:

sensitivity and specificity improved, recall rate dropped



DBT Performance

Artifacts:

High density objects in multiple slices (due to limited sampling)

Dose (ACR phantom, Hologic DBT):

Combo (DBT+2D) acquisition: $\sim 2.2 \times DM$

DBT acquisition with synthetic 2D: $\sim 1.2 \times DM$

Workflow:

$\sim DM$, reading time longer

Cost:

$\sim 2 \times DM$ + cost for more storage

Characteristics of DBT Systems

	GE Essential	Hologic Selenia Dimensions	IMS Giotto TOMO	Planmed Nuance Excel DBT	Siemens MAMMOMAT Inspiration	Philips MicroDose
X-ray tube target	Mo/Rh	W	W	W	W	W
X-ray tube filters	Mo/Rh	Al	Rh/Ag	Rh/Ag	Rh	Al
X-Ray Tube motion	Step&shoot	Continuous	Step&shoot	Continuous	Continuous	Continuous
Detect type	CsI-Si	a-Se	a-Se	CsI-a-Si	a-Se	Si, photon C
Detector size (cm)	24x30	24x29	24x30	24x30	24x30	21-slit
Detector pixel (µm)	100	70/140	85	85	85	50
Detector motion	Static	Rotating	Static	Rotating	Static	Rotating
Air gap (cm)	2.2	2.5	2.2	2.38	1.7	0.4-2.4
Grid	Trial	None	None	None	None	None
Angular range (deg)	25	15	40	30	50	11
Number of projections	5	15	13	15	25	21
Scan time (s)	7	3.7	12	20	25	3 - 10
Reconstruction						

Optimization of DBT System

Phantoms:

- Uniform background with embedded features (ACR)
- Anthropomorphic phantom (CIRS)
- Mathematic phantom

Figure of Merit (FOM):

- MTF/DQE
- CNR, CNR/MGD, CNR/ASF_w
- Signal difference noise ratio (SDNR)

Optimization of DBT

X-Ray sources:

- Target: Mo/Rh/W, more systems with W
- Filter: Mo/Rh/Ag/Al
- kVp: up to 49 (> DM)

High output is desirable for short acquisition time and contrast is enhanced by structure noise reduction, for same breast thickness, higher kVp is used in DBT

X-Ray Detectors:

- Material: CsI-Si (indirect), a-Se (direct)
- Minimal lag and ghosting
- Fast reading time
- May be running in the binning mode to speed up data acquisition

X-Ray Grid

- Not use with most DBT, GE is developing one for DPT
- Primary ray may be cutoff
- Dose may be double

Optimization of DBT

X-Ray tube motion:

- Step-and-Shoot: no focal spot motion blurring, but longer t
- Continuous: focal spot motion blurring, but short t

Angular range: α

- Large α \rightarrow better z-resolution,
- Large incident angle \rightarrow lower detector MTF and DQE for high f signal
- Large incident angle \rightarrow more attenuation
- Optimal: 45 - 60 degree

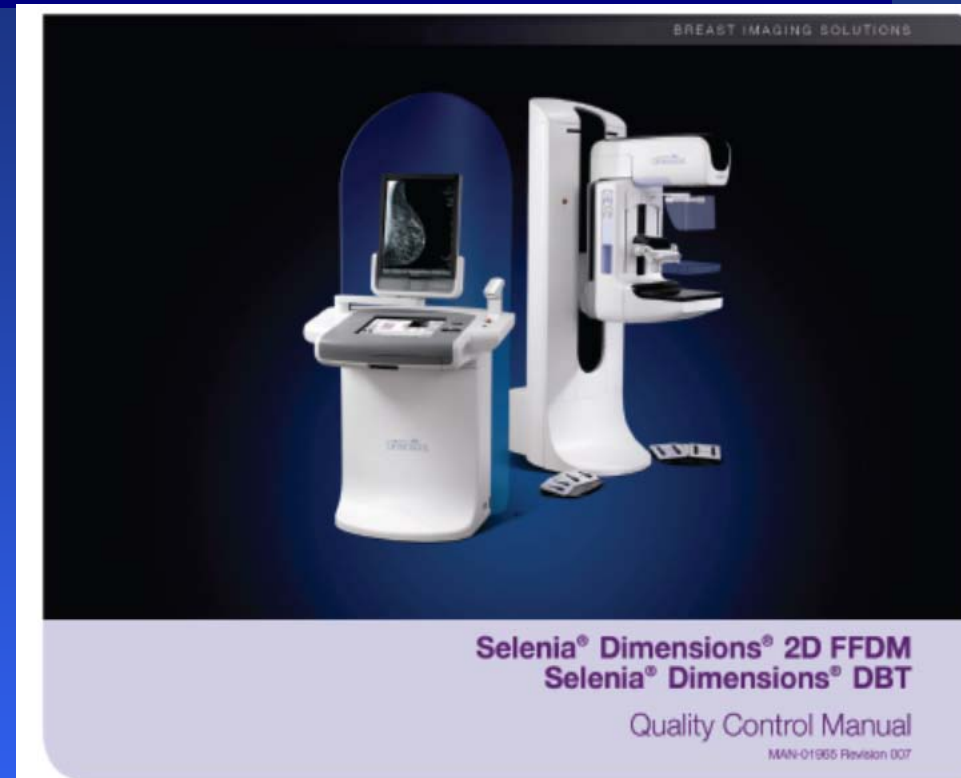
of projections: N

- For fixed α , IQ improves as N increases until N reaches a certain #
- High N \rightarrow higher noise in projection images
- optimal: 15-20

QC of DBT System

There is no QC standard for all DBT systems.

Follow Equipment Vendor's QC manual



The Hologic QC manual MAN-01965 covers:

- Selenia Dimensions 2D FFDM system
- Selenia Dimensions DBT system

SELENIA®
Dimensions®

HOLOGIC®

Selenia Dimensions: Image Acquisition Modes



2D Only



Combo: Tomo + 2D
under the same
compression



DBT Only

!AEC is calibrated independently for each mode

Selenia Dimensions: Specifications

Conventional 2D Imaging

- a-Se detector, 24×29 cm area
- 70 μm pixel size
- Rh and Ag filters
- HTC grid in contact mode;
No grid in magnification mode

DBT Imaging

- a-Se detector, 24×29 cm area
- 140 μm pixel size (2x2 binning)
- Al filter
- No anti-scatter grid
- Moving tube, 15° sweep
- Moving detector
- 15 projections
- 3-4 seconds acquisition
- FBP Reconstruction
 - ~100 μm pixel size
 - 1 mm slice spacing

Approved screening protocol for each breast:

One CC view DBT and one CC view 2D

One MLO view DBT and one MLO view 2D

Selenia Dimensions QC Tests (MP)

Quality Control Test	2D	3D
Mammographic Unit Assembly Evaluation	Yes	
Collimation Assessment	Yes	Yes
Artifact Evaluation	Yes	Yes
kVp Accuracy and Reproducibility	Yes	
Beam Quality Assessment — HVL	Yes	Yes
Evaluation of System Resolution	Yes	Yes
Automatic Exposure Control (AEC) Function Performance	Yes	Yes
Entrance Exposure, AEC Reproducibility, and Dose	Yes	Yes
Radiation Output Rate	Yes	
Phantom Image Quality Evaluation	Yes	Yes
Signal-To-Noise and Contrast-To-Noise Measurements	Yes	
Diagnostic Review Workstation Quality Control	Yes	
Detector Ghosting (Troubleshooting Use Only)	Yes	

FDA approved screening protocol

For each breast:

One CC view DBT

One CC view 2D

One MLO view DBT

One MLO view 2D

2D image can be acquired

- In the combo mode
- Generated from DBT images with C-view software

QC Test: Dose

Objective:

To assess ESE and AGD

Test Method

- Measured ESE of ACR phantom in 2D or DBT or combo mode
- Calculate AGD using the ESE to AGD tables in the manual

Performance criteria:

2D: AGD < 3 mGy.

DBT: AGD < 3 mGy

Combo: AGD < 3 mGy (can be very close to 3 mGy!)

QC Test: Artifact Evaluation

Objective:

To assess the degree and the source of artifacts

Test Method:

- Acquire **projection** images with 4 cm acrylic block.
- Check artifacts in the **0 degree projection image**
- Artifacts due to reconstruction is not evaluated

Performance criteria:

Similar to DM

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QC Test: System Resolution

Objective:

To assess the limiting spatial resolution of the system

Test Method:

- Acquire 2D and DPT images of line pair pattern over 4 cm acrylic
- Determine the highest frequency line resolved in 2D image
- Determine the highest frequency line resolved in focal slice of DBT image set

Performance criteria:

2D: 7 lp/mm must be resolved

DBT: 3 lp/mm must be resolved.

QC Test: Phantom Image Quality

Objective:

To assess the quality and consistency of images

Test Method

- Acquire **ACR phantom** image in Combo or DBT mode
- Determine the score of fibers, specks and masses in 2D image
- Determine the score of fibers, specks and masses in the focal slice

Performance criteria:

Passing score:

2D: 5 fibers, 4 speck groups and 4 masses.

DBT: 4 fibers, 3 speck groups and 3 masses

For Hologic Dimensions DBT, the measured high contrast resolution in reconstructed slices is typically lower than that measured in 2D mode. Which one of the followings is not the possible reason?

0%

1. X-ray source motion

0%

2. Patient motion

0%

3. Detector pixel binning

0%

4. Al filter used in tomo mode

0%

5. Inaccurate geometric calibration

Answer: 4.

Al filter used in tomo mode

Explanation:

The filter will change the shape of x-ray spectrum, may affect HVL, dose and contrast, but not affect system resolution.

Reference:

1. J. A. Baker and J. Y. Lo, "Breast tomosynthesis: State-of-the-art and review of the literature," *Acad. Radio* l. 18, 1298-1310 (2011).

For fixed angle range and total mAs, too many projections may degrade the image quality, because

0%

1. Too many points will be in frequency space

0%

2. Acquisition time will be longer

0%

3. Dose will be higher

0%

4. Projection image will be very noisy

0%

5. X-ray tube will be too hot

Answer: 4

Projection image will be very noisy

Explanation:

If there are too many projections, mAs for each projection can be very low, the projection image will be very noisy.

Reference:

Sechopoulos I., A review of breast tomosynthesis. Part I. The image acquisition process. Med Phys. 2013 Jan;40(1)

For Hologic Dimensions, the total mean glandular dose to ACR mammographic Accreditation phantom in the combo mode (2D+DBT) must not exceed

0%

1. 6 mGy

0%

2. 3 mGy

0%

3. 4.5 mGy

0%

4. 2.5 mGy

0%

5. 3.5 mGy

Answer: 2

3 mGy

Explanation:

Specified in Selenia Dimensions QC manual

Reference:

Selenia Dimensions QC Manual MAN-01965,rev. 007 page 44

Other Optional Tests

- ✓ Ghosting
- ✓ Artifacts for reconstructed images
- ✓ Z-resolution
- ✓ ...

Thank You !