Sistemi di Acquisizione e Ricostruzione in Tomosintesi, Dosi e Controllo di Qualità

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System	GE Essential	Hologic Selenia Dimensions	IMS Giotto TOMO	Philips MicroDose	Planned Nuance Excel DBT	Siemens MAMMOMAT Inspiration
Detector type	Full field—indirect	Full field—direct (a-Se)	Full field—direct (a-Se)	Linear slit scan–spectral photon counting (Si)	Full field—direct (a-Se)	Full field—direct (a-Se)
Detector size (cm)	24 × 30	24 × 29	24 × 30	21 line detectors, each 24 cm long	24 × 30	24 × 30
Detector pixel size (μm)	100	70 (binned 2 × 2)[a]	85	50 (perpendicular to motion)	85	85
Detector motion	Static	Rotating	Static	Continuous slit scan	Rotating during exposure[b]	Static
X-ray tube target	Mo or Rh	W	W	W	W	W
X-ray tube filtration	0.03 mm Mo or 0.025 mm Rh	0.7 mm Al	0.05 mm Rh or 0.05 mm Ag	0.5 mm Al	0.075 mm Ag or 0.06 mm Rh	0.05 mm Rh
X-ray tube motion	Step-and-shoot	Continuous	Step-and-shoot	Continuous	Continuous	Continuous
Angular range (deg)	25	15[c]	40	11	30	50[d]
Number of projections	9	15	13[e]	21	15	25
Scan time (s)	7	3.7	12	3–10	20	25[d]
Source to detector distance (cm)	66	70	68	66	65	65.5
Detector to center of rotation distance[f] (cm)	4	0	2	−40	4.37	4.7
Air gap (cm)	2.2	2.5	2.2	0.4–2.4	2.38	1.7
Reconstruction method	Iterative	FBP	Iterative with total variation regularization	Iterative	Iterative	FBP
Development stage[g]	Prototype	Commercial system	Commercial system[h]	Prototype	Prototype	Commercial system[h]
References	16, 31	16	32–35	26, 27, 36	37	16, 38–40

I Sechopoulos, Med Phys 40 (2013)

Confronto tra sistemi clinici

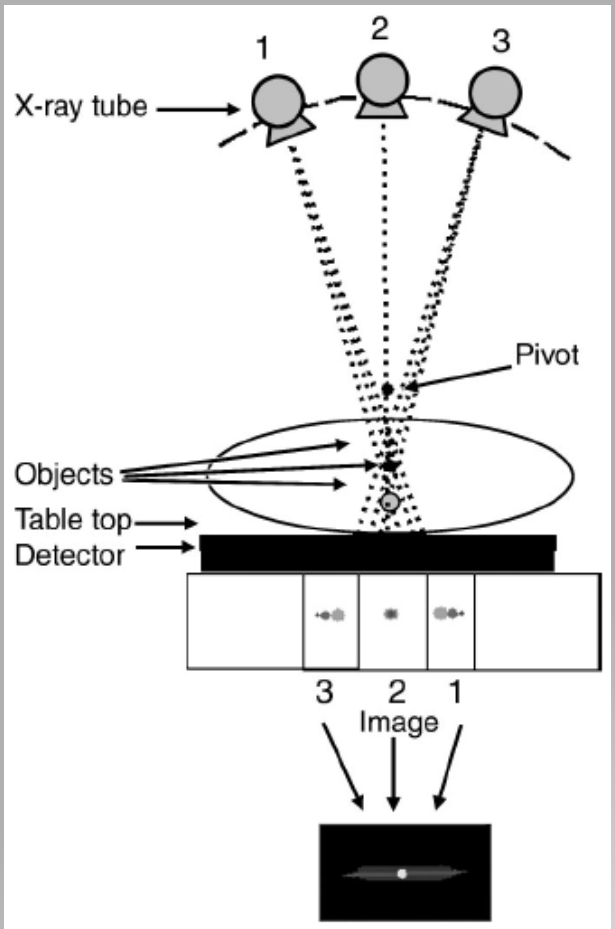
	GE Healthcare	Fujifilm	Hologic	IMS	Siemens
Pixel Size (µm)	100	50/100 (HR) 100/150 (ST)	70 (2x2 bin.)	85	85
Detector	CsI	a-Se (HCP)	a-Se	a-Se (Anrad)	a-Se (Anrad)
Anode	Mo / Rh	Tungsten	Tungsten	Tungsten	Mo / Tungsten
Angular Range	25°	15° (ST) 40° (HR)	15°	40°	50°
Projections	9	15	15	13	25
Scan time	< 7 seconds	~ 4 seconds	< 4 seconds	< 10 seconds	15 ÷ 25 sec.
Scan mode	Step & Shoot	Continuous	Continuous	Step & Shoot	Continuous
Geometry	Uniform, CT style	Uniform, CT style	Uniform, CT style	Variable angles & dose	Uniform, CT style
Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo



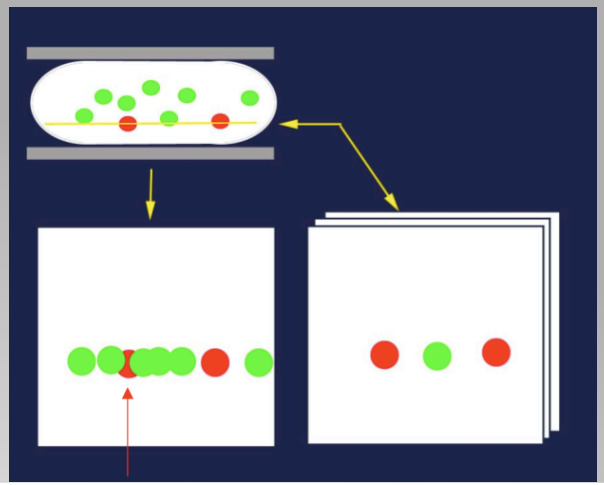


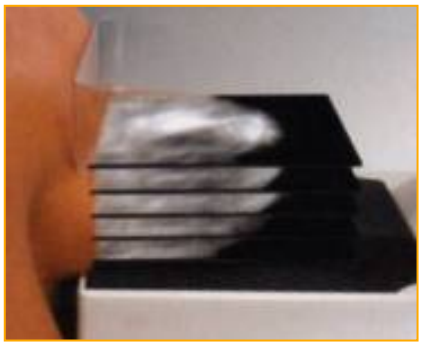

SIEMENS
SIEMENS
SIEMENS

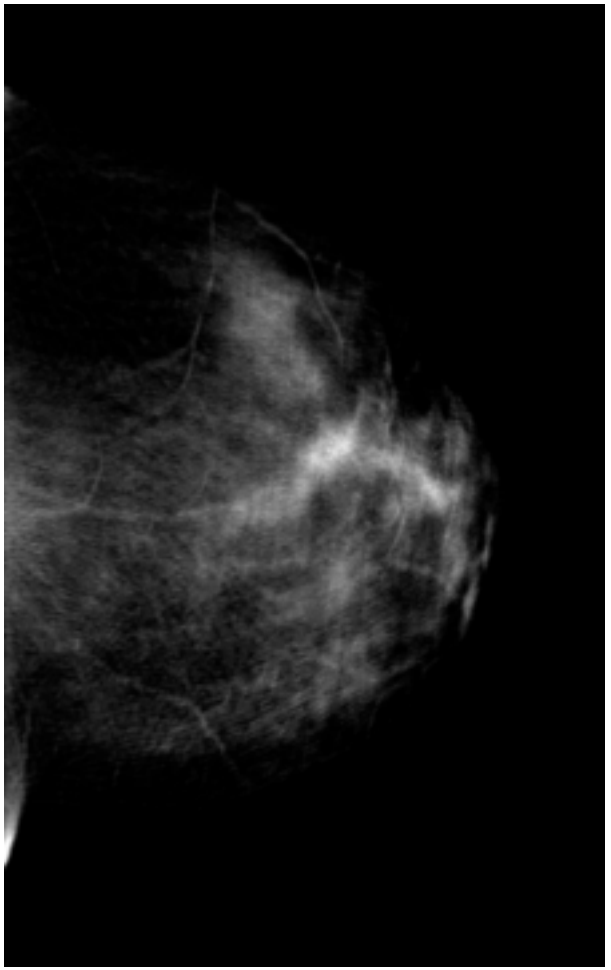
Tomosynthesis = limited-angle cone-beam Tomography



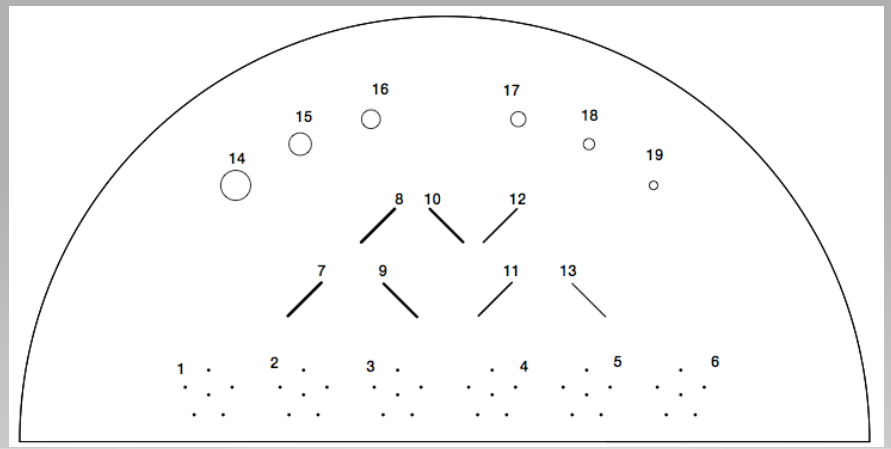
Attraverso una serie di radiografie (2D) del seno effettuate a bassa dose ruotando il tubo a raggi X, si ricostruiscono tomogrammi (3D) per ridurre le sovrapposizioni anatomiche



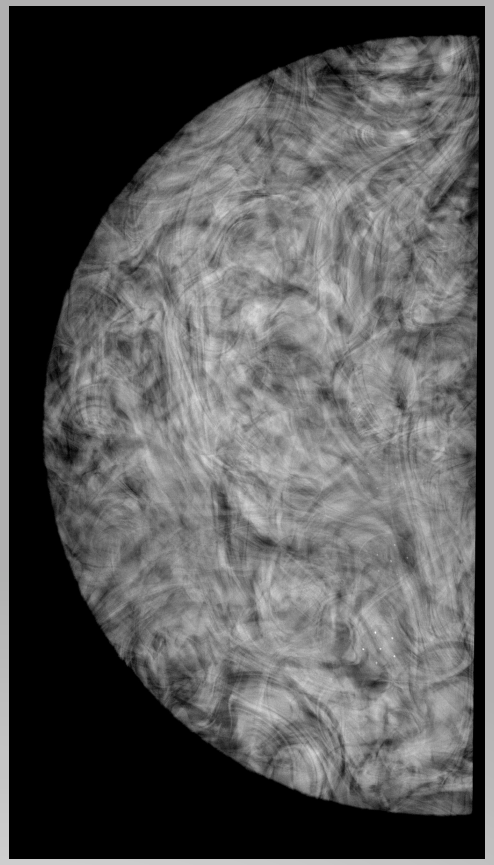




CIRS Mammography Phantom

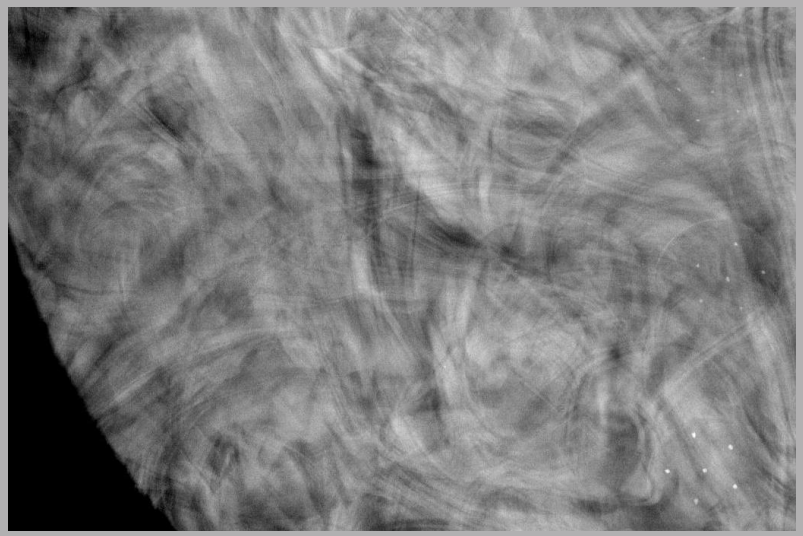


DBT vs Mammo

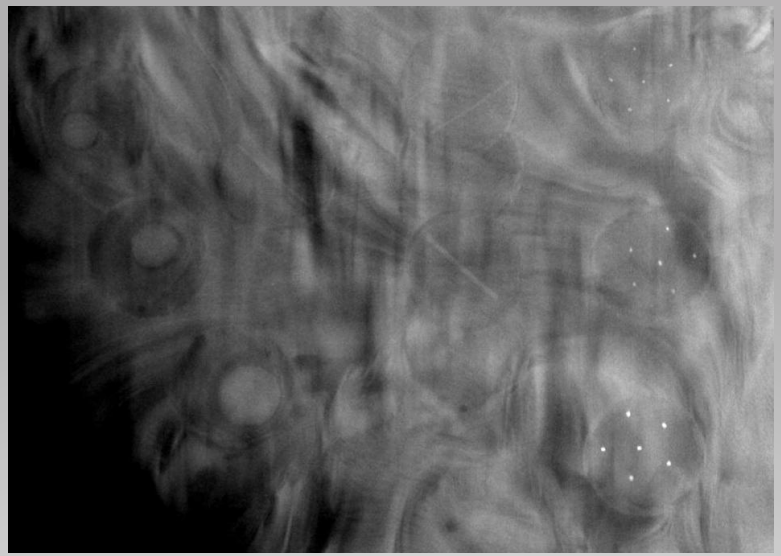


Vecchio *et al*, Eur Rad 21, 2011

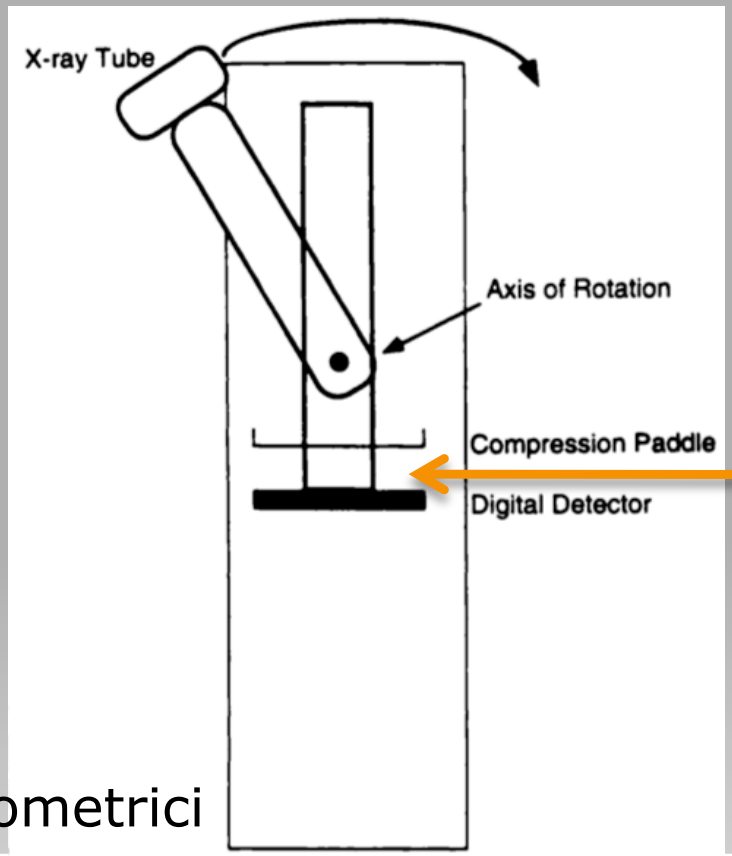
MAMMO



DBT



Il Mammografo



Potter

- Problemi geometrici
- Riduzione del livello di esposizione, aumento della dose, rumore elettronico …

	GE Healthcare	Fujifilm	Hologic	IMS	Siemens
Pixel Size (µm)	100	50/100 (HR) 100/150 (ST)	70 (2x2 bin.)	85	85
Detector	CsI	a-Se (HCP)	a-Se	a-Se (Anrad)	a-Se (Anrad)
Anode	Mo / Rh	Tungsten	Tungsten	Tungsten	Mo / Tungsten
Angular Range	25°	15° (ST) 40° (HR)	15°	40°	50°
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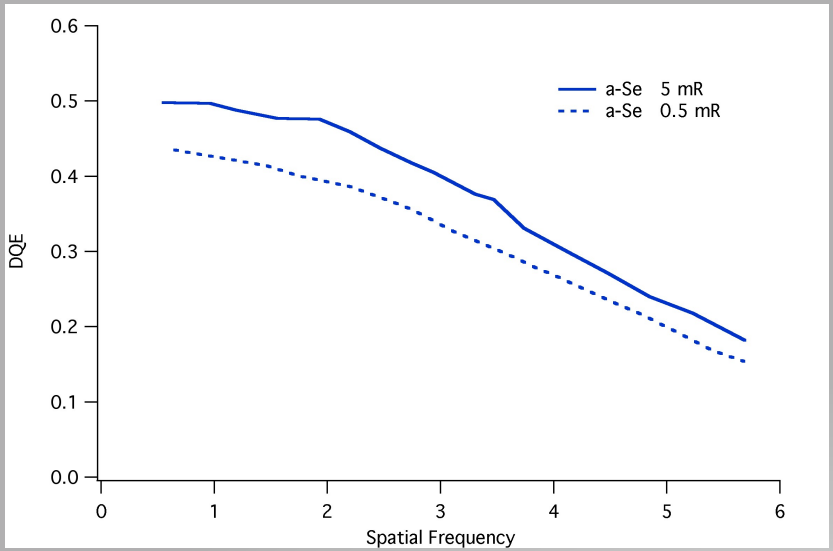
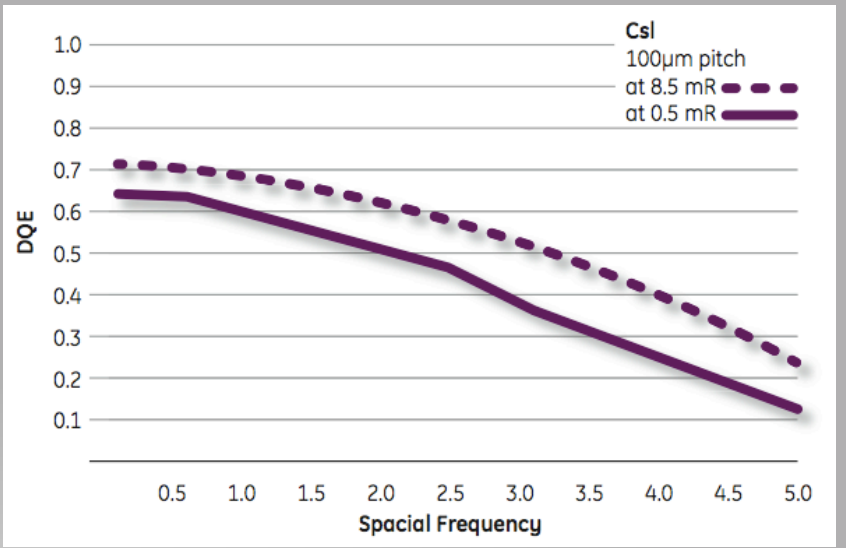
Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo

Detector performance vs Dose





Pixel size

Pixel *binning*:

- Riduce i tempi di acquisizione/ricostruzione
- Migliora il SNR

Ma … attenti alla risoluzione spaziale!

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Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo

Uno spettro più energetico

- Penetrazione obliqua del fascio
- Tomosintesi: mammelle dense …
- Lunghi tempi di esposizione
- Rumore elettronico
- “Limiti” di dose

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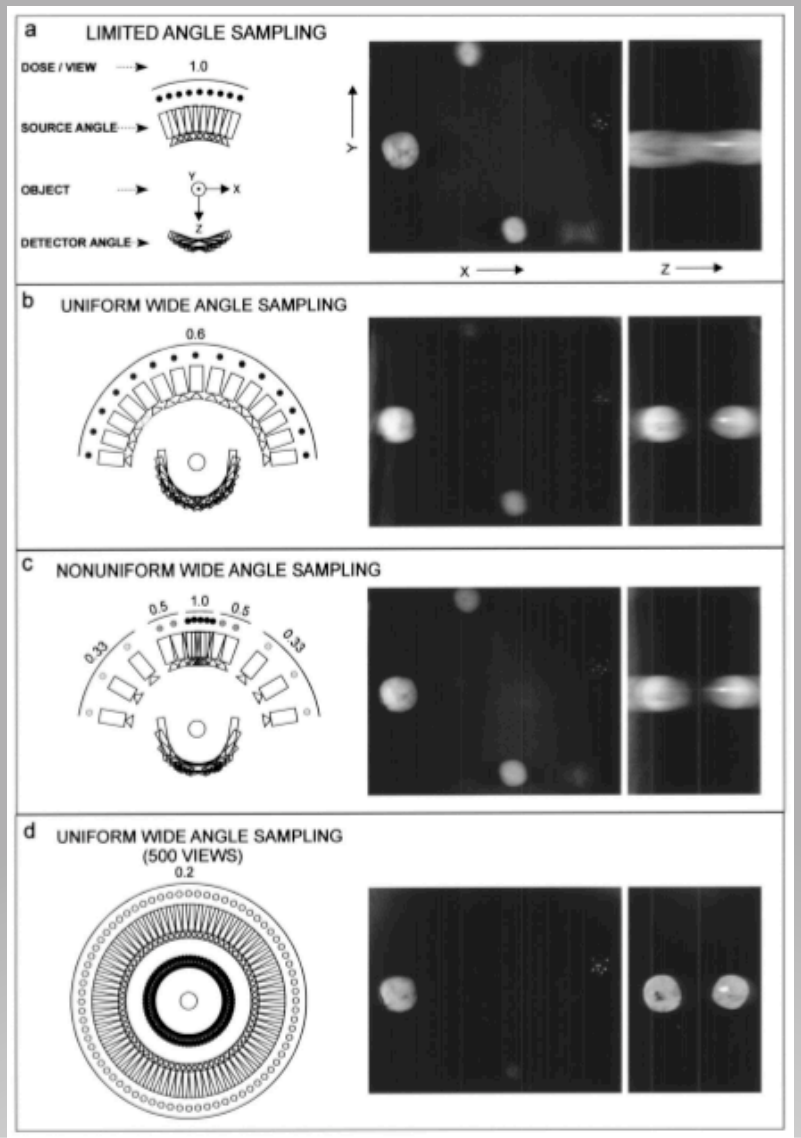
Parametri di acquisizione

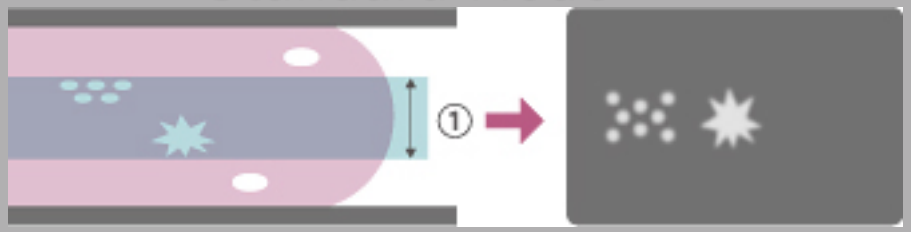
- Numero di proiezioni migliora la ricostruzione ma aumenta il tempo di acquisizione (e produce anche immagini a bassa statistica)
  10-25 proiezioni
- Apertura angolare migliora la risoluzione in profondità ma riduce quella planare
  15-50 gradi
- Dose totale simile alla mammografia (CC+MLO)

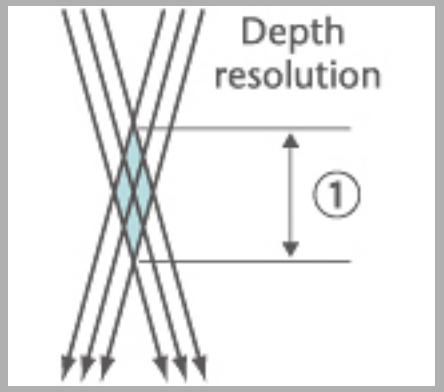


Wu *et al*, Med. Phys. 30, 2003

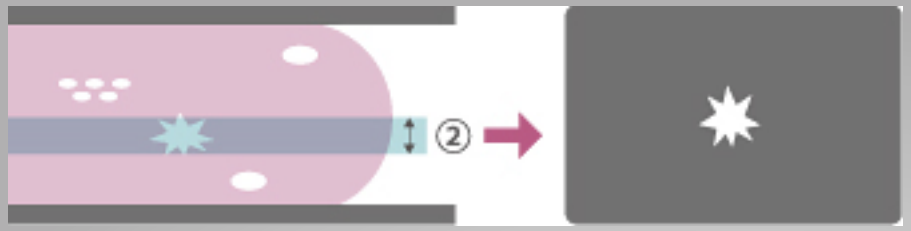
Doppia modalità di acquisizione

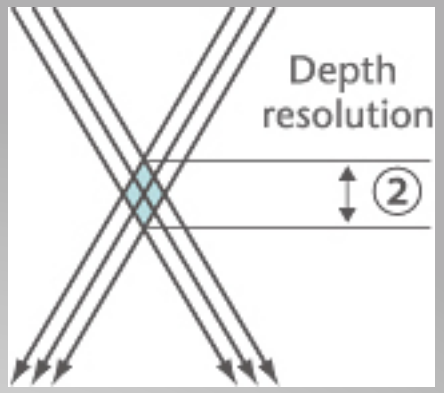
Standard Mode





High Resolution Mode





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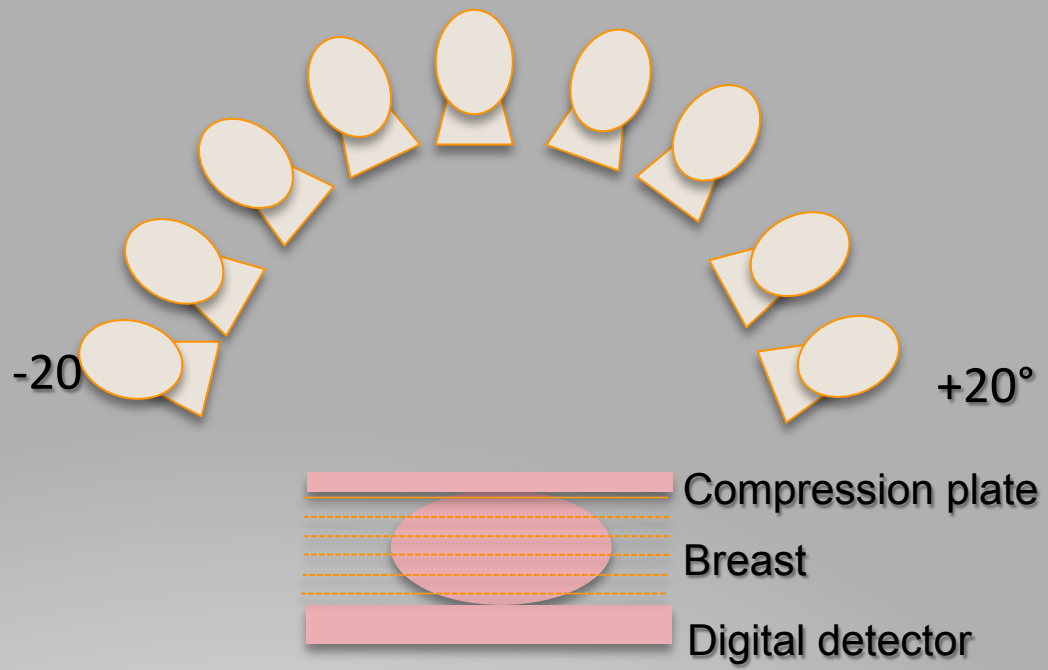
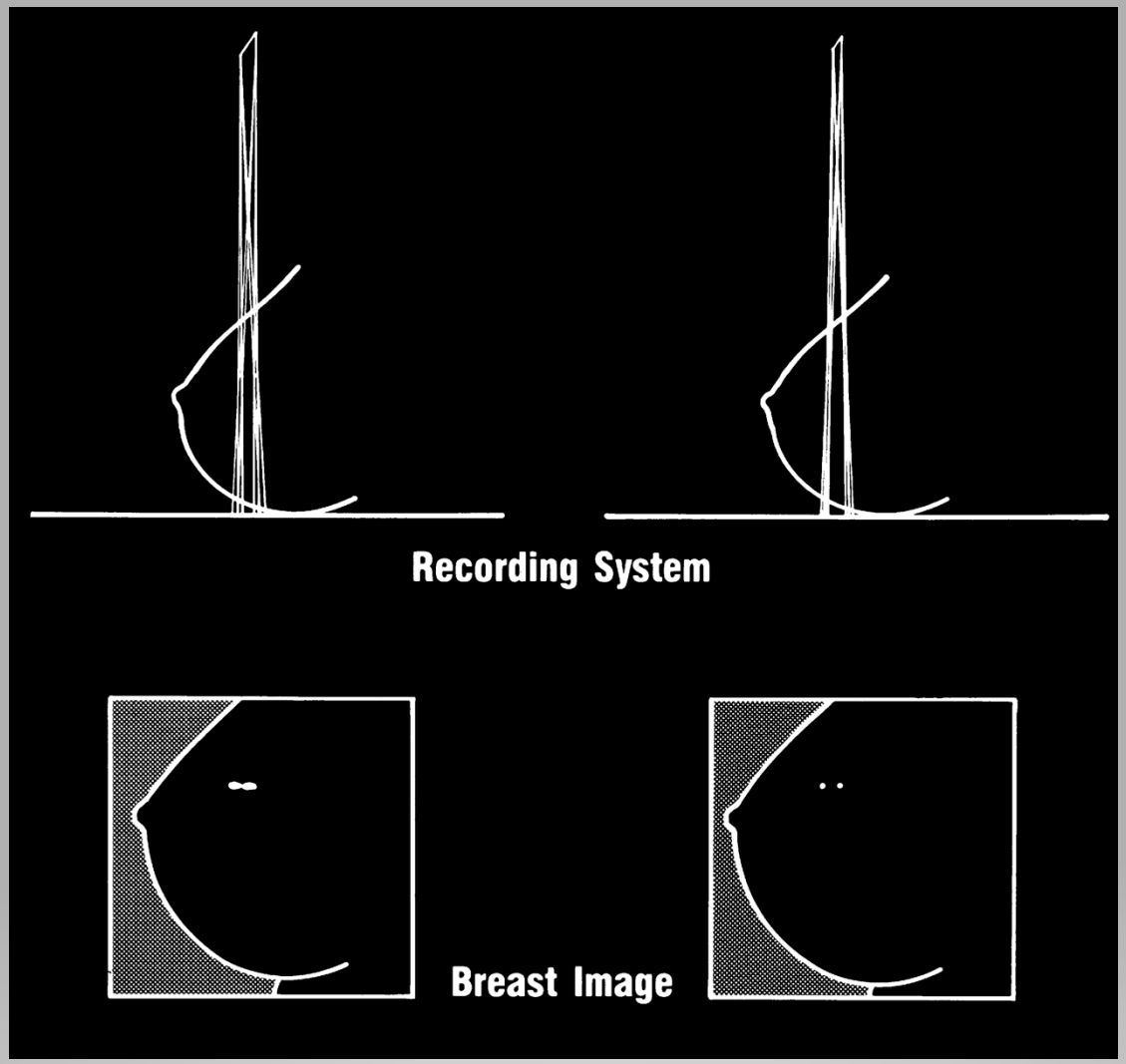
Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo

Step & Shoot vs Continuous

- Il tubo RX si muove rapidamente lungo un arco fermandosi ad ogni esposizione per una frazione di secondo




Recording System
Breast Image

	GE Healthcare	Fujifilm	Hologic	IMS	Siemens
Pixel Size (µm)	100	50/100 (HR) 100/150 (ST)	70 (2x2 bin.)	85	85
Detector	CsI	a-Se (HCP)	a-Se	a-Se (Anrad)	a-Se (Anrad)
Anode	Mo / Rh	Tungsten	Tungsten	Tungsten	Mo / Tungsten
Angular Range	25°	15° (ST) 40° (HR)	15°	40°	50°
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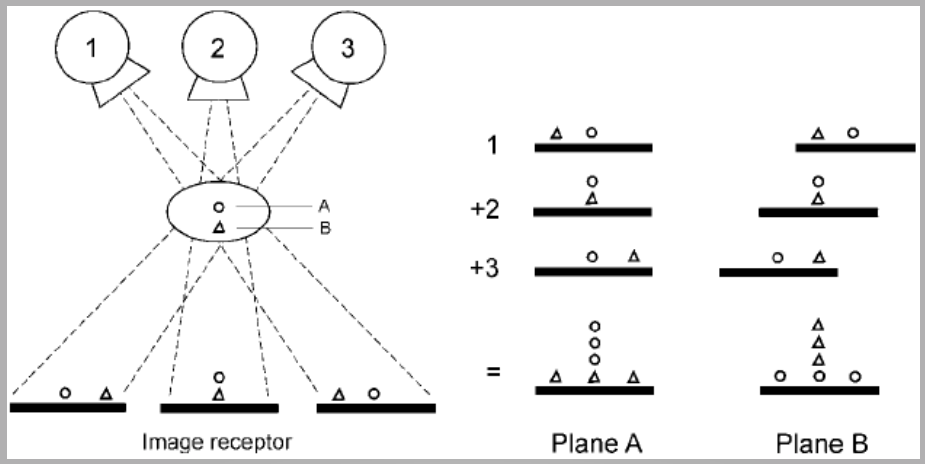
Geometry	Uniform, CT style	Uniform, CT style	Uniform, CT style	Variable angles & dose	Uniform, CT style
Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo

Metodi di Ricostruzione in DBT

- Algoritmo “shift & add” semplice e veloce ma …
  ogni strato contiene traccia del resto del volume!



- Riduzione del contrasto globale dell’immagine …

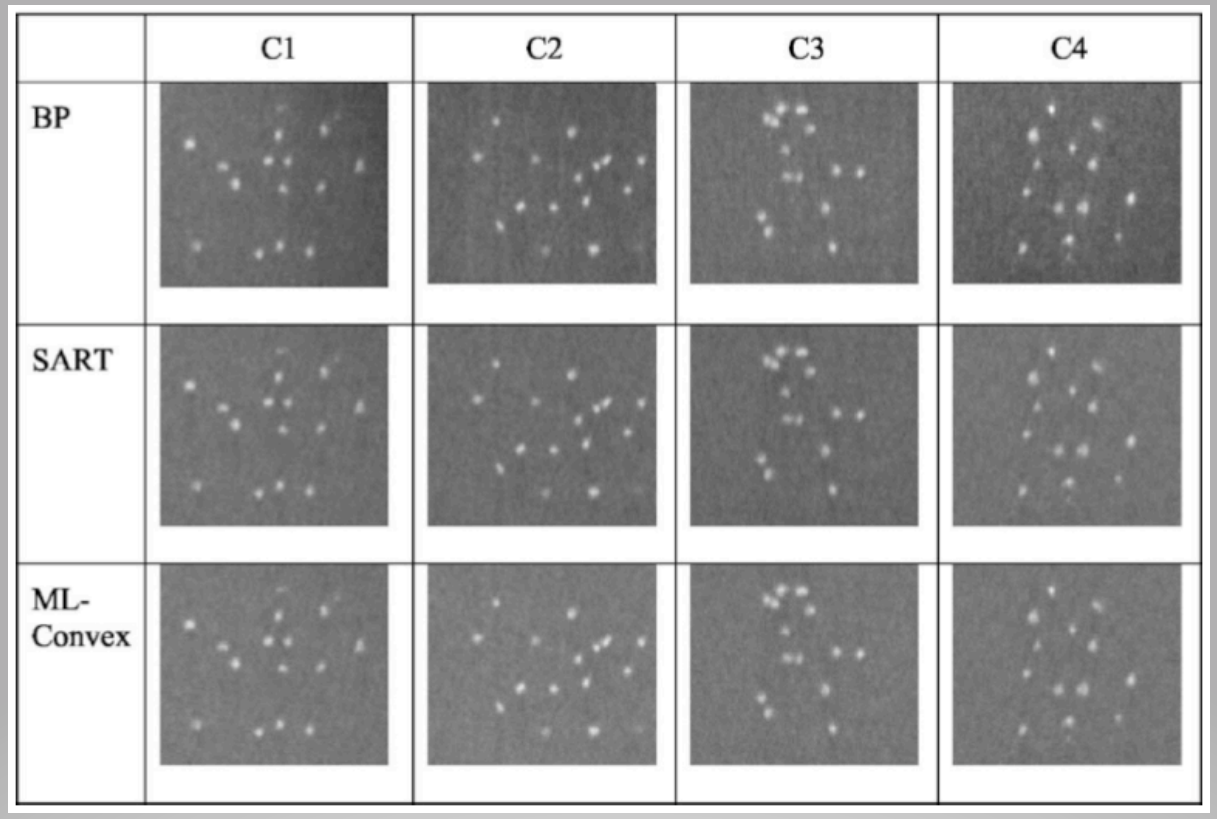
- E’ necessario ricorrere a metodi di soppressione delle strutture (sfuocate) appartenenti agli altri piani

Dobbins & Godfrey, Phys. Med. Biol. 48, 2003

Algoritmi di Ricostruzione

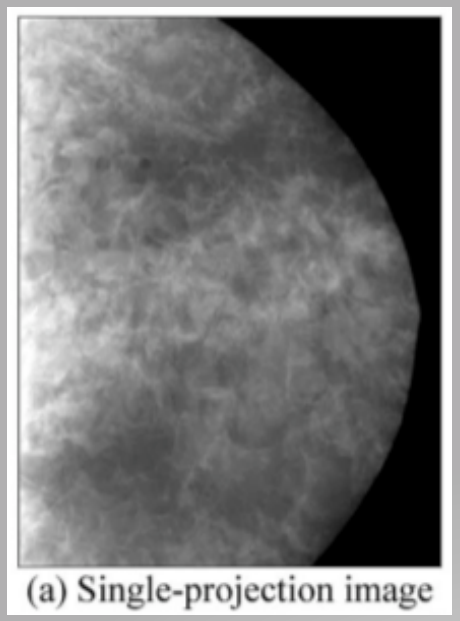
- Mathematic method of geometric transformation
  - SAA (Shift-And-Add)
  - BP (Back-Projection)
- Mathematic method of Fourier Transformation
  - FBP: Filtered Back-Projection
- Statistical reconstruction algorithms
  - MLEM: Maximum-Likelihood Expectation-Maximization
- Algebraic reconstruction algorithms:
  - SART: Simultaneous Algebraic Reconstruction Tech.

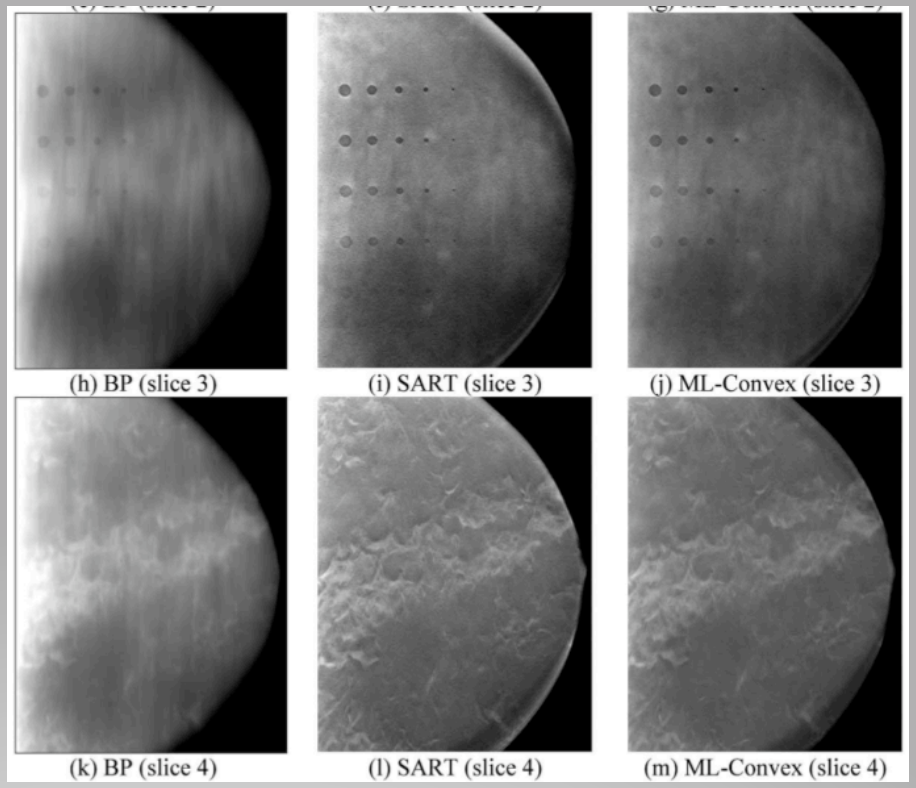
Confronto fra algoritmi (I)



Zhang *et al*, Med. Phys. 33, 2006

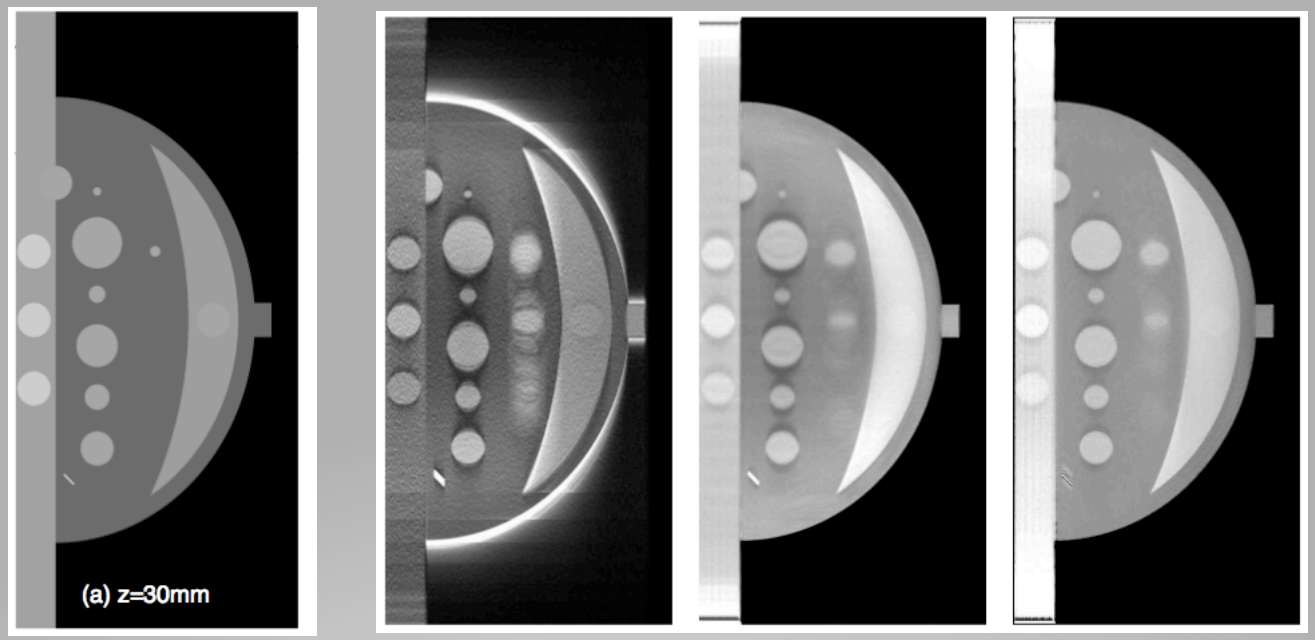
Confronto fra algoritmi (II)


(a) Single-projection image


(h) BP (slice 3) (i) SART (slice 3) (j) ML-Convex (slice 3)
(k) BP (slice 4) (l) SART (slice 4) (m) ML-Convex (slice 4)

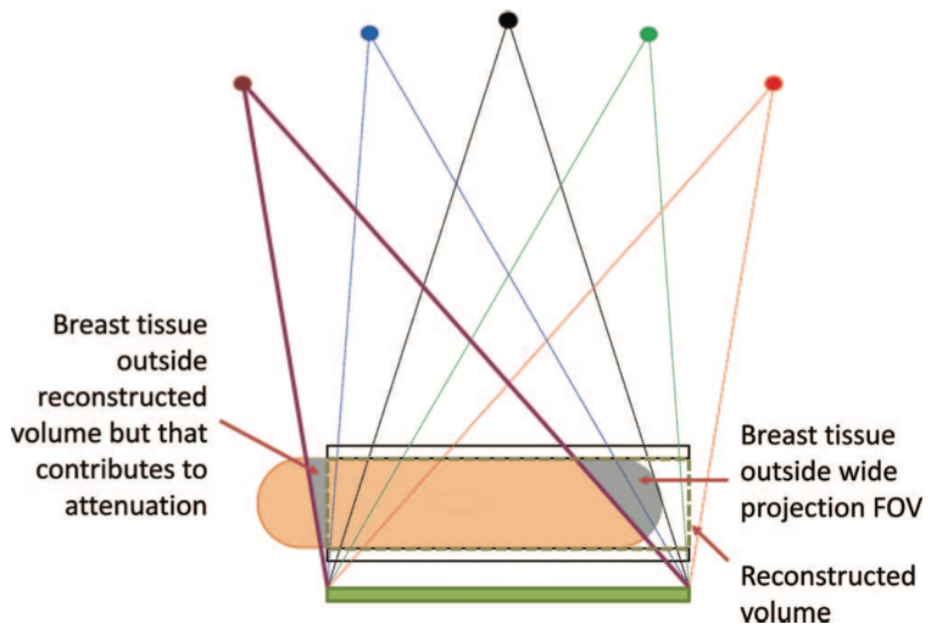
Zhang *et al*, Med. Phys. 33, 2006

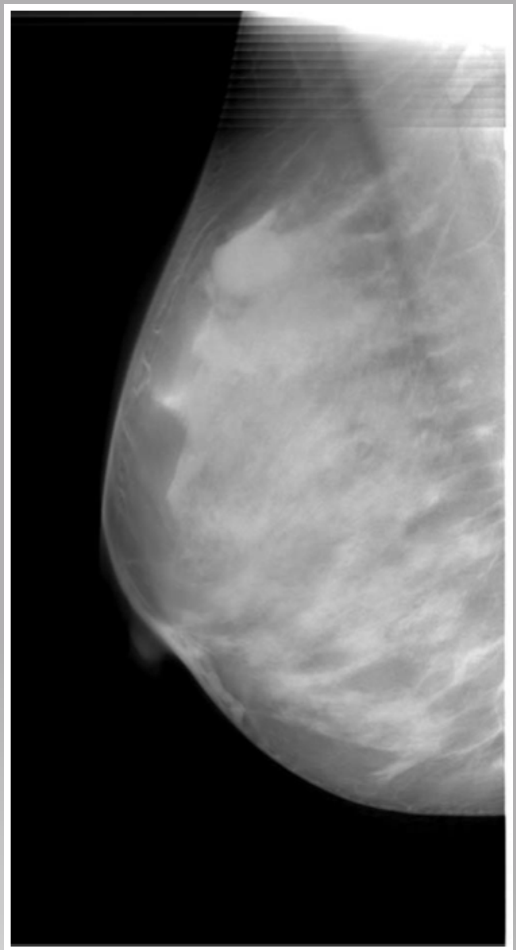
Iterative methods have been proposed as alternative to the common FBP methods in the case of limited number of x-ray projections so as to reduce streaking artifacts and to increase SNR



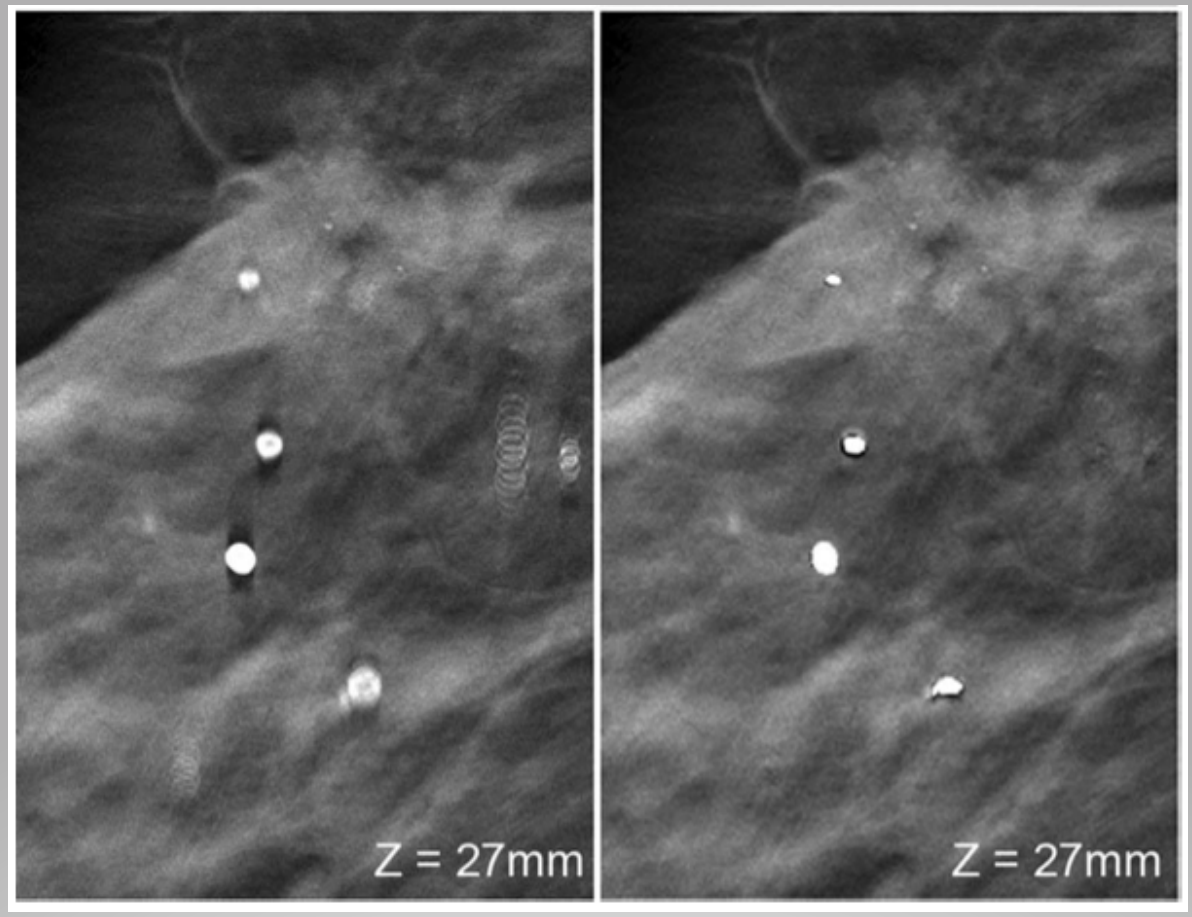
Reiser *et al*, arXiv, 2009

Artefatti in Tomosintesi (I)





Artefatti in Tomosintesi (II)



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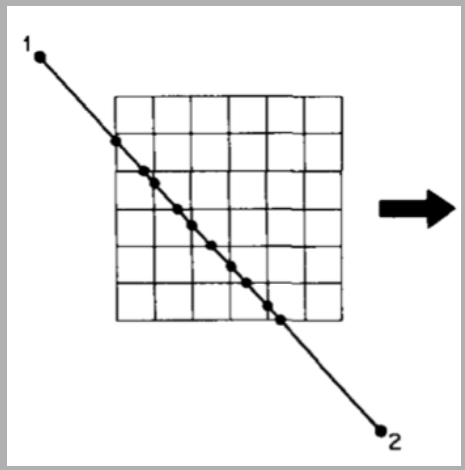
Reconstruction	Iterative	FBP	FBP	Iterative	FBP
Functions	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo (Sintetica)	Mammo/Tomo	Mammo/Tomo

DBT in screening?

- Tomosynthesis plus 2D significantly increase the cancer detection rate as compared with FFDM alone*
- Tomosynthesis with synthetic 2D images makes combined 2D and 3D possible with the same radiation dose as conventional FFDM
- The additional interpretation time for 3D + 2D as compared to 2D alone is acceptable for implementation in organized breast cancer screening

*Skaane et al, Radiology 267, 2013

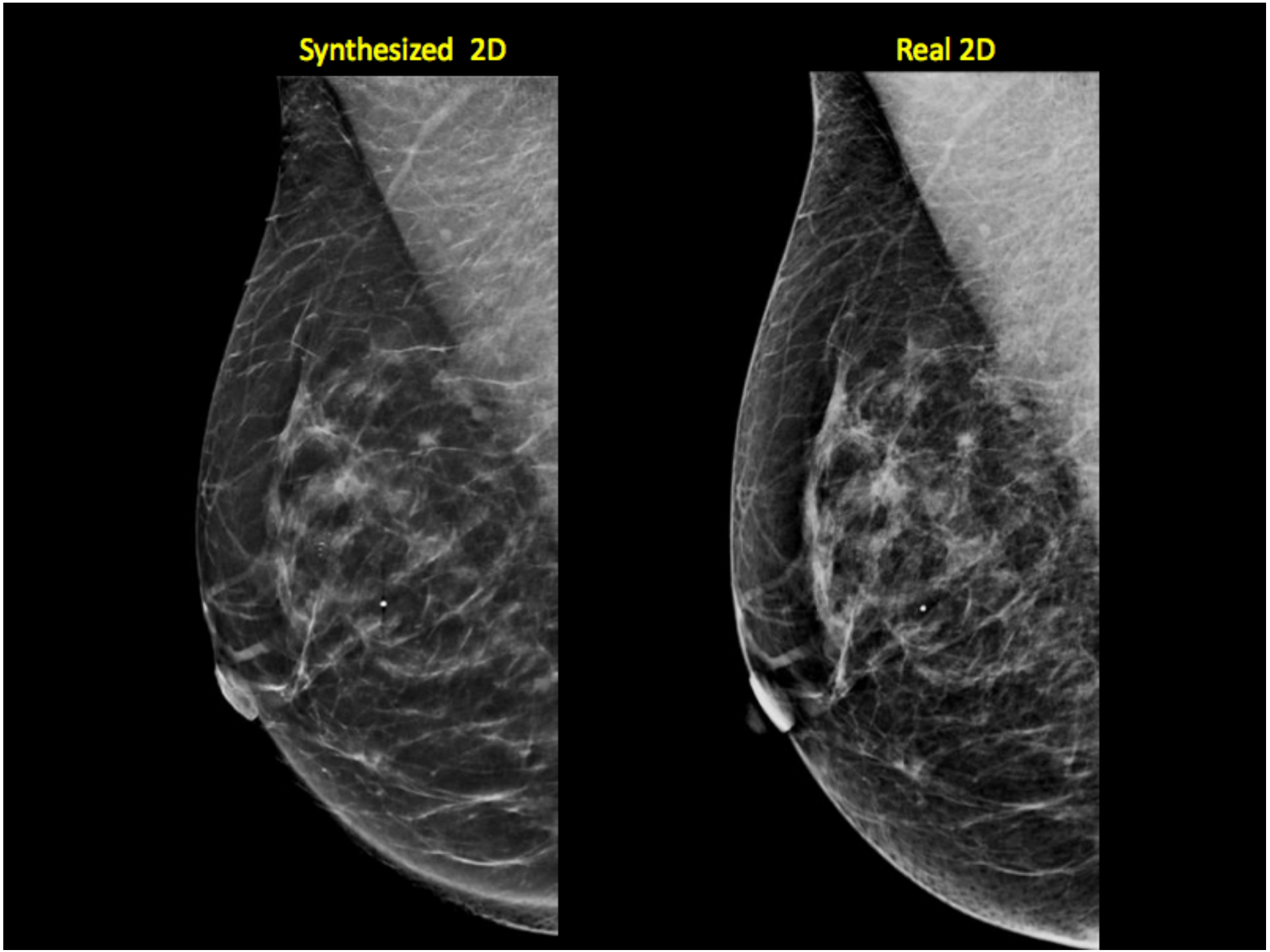
Volume re-projection



… Re-projection methods are well known in the field of image processing. A source point and image plane is chosen, on opposite sides of the image volume. Pixels are obtained by projecting the source point though the slice set to an image plane point. The pixel value is summed at each slice location by interpolating values in the original slices …

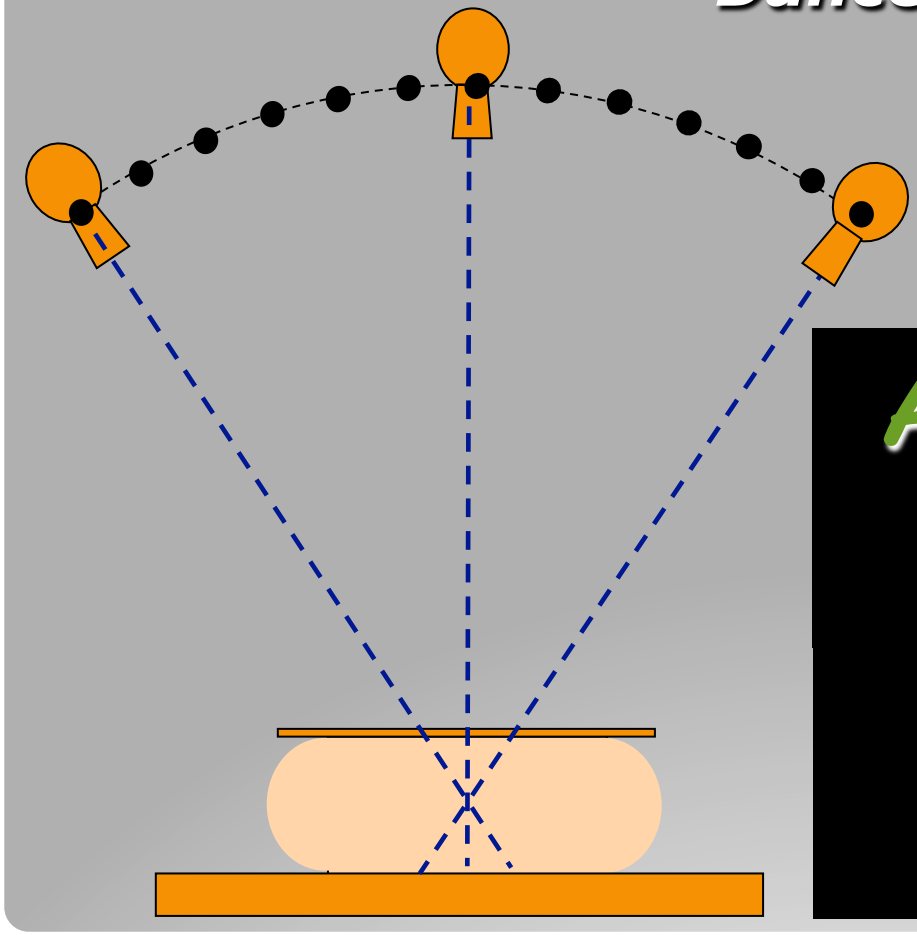
System and method for generating a 2D image from a tomosynthesis data set

US patent no. 7,760,924 B2, 2010


Synthesized 2D
Real 2D

Dosimetry for tomosynthesis

Dance et al PMB 2011



$$AGD = K\ gcs\ T$$

$$T=\Sigma a_i\ t(\Theta_i)$$

If same tube loading ...

$$T=(1/N)\ \Sigma\ t(\Theta_i)$$

K measured at 0 deg

Courtesy of Dr. D. Dance

Monte Carlo calculations of t(θ)

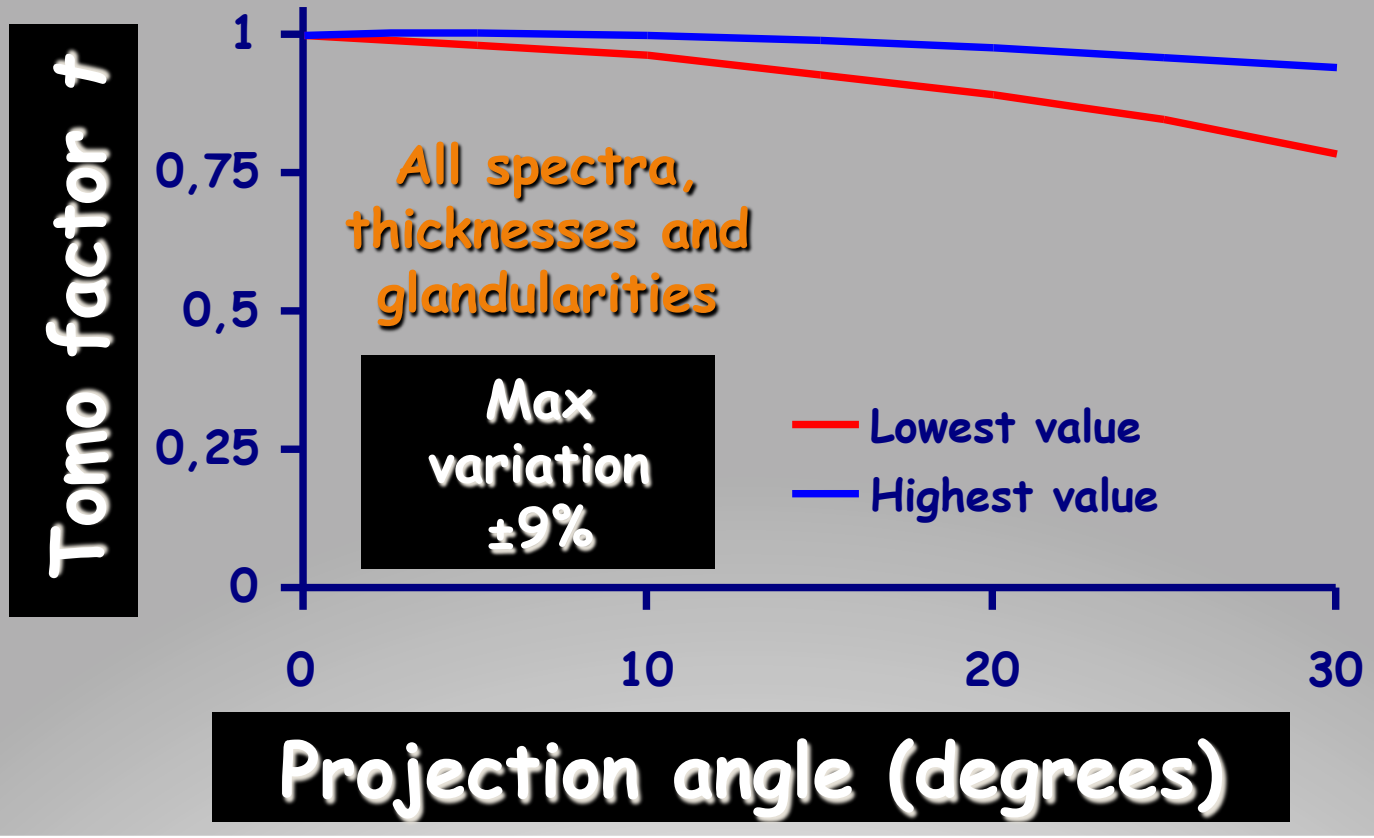
Spectra:
Mo/Mo, Mo/Rh, Rh/Rh,
W/Rh, W/Ag, W/Al
25-49 kV (depending on spectrum)

Breast thicknesses
2-11 cm

Breast glandularities
0.1 – 100%

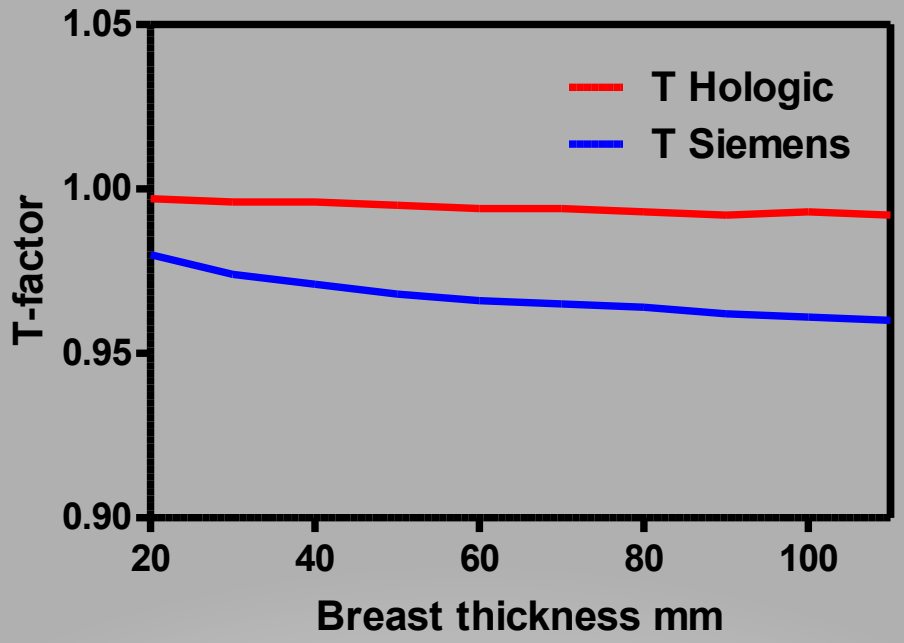
Courtesy of Dr. D. Dance

Overall variation of t(Θ) (CC view)



Courtesy of Dr. D. Dance

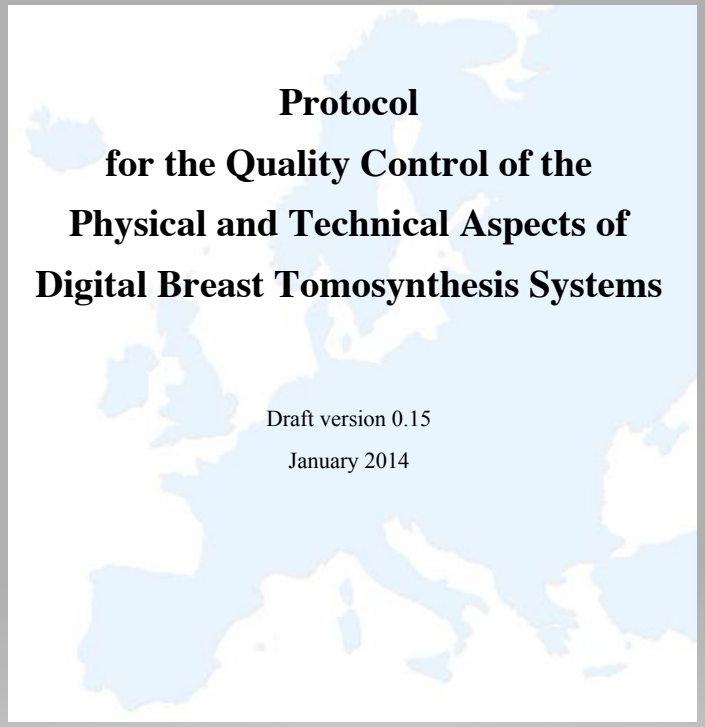
Variation of T with breast thickness



1. Data for both t(θ) and T can be specified in very compact tabulations, to be used for all spectra and breast glandularities
2. T close to 1

Courtesy of Dr. D. Dance

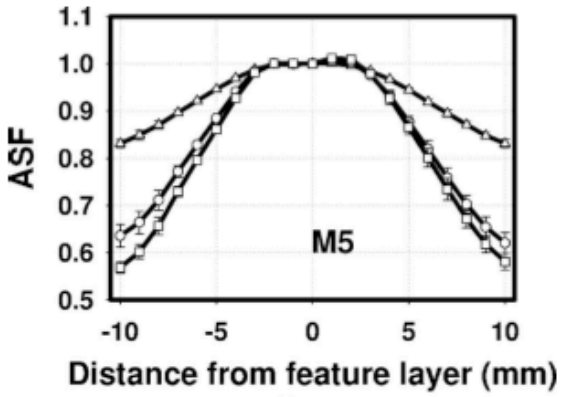
Controlli di Qualita' in DBT



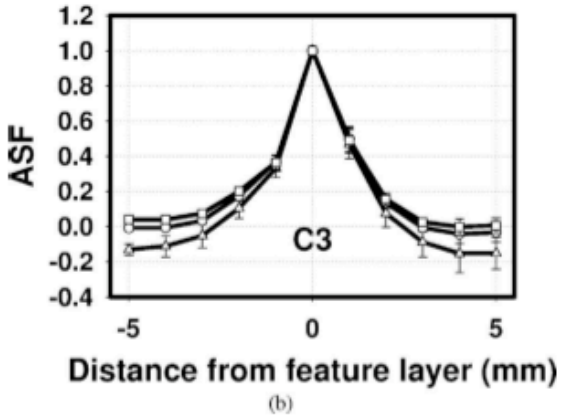
European Reference Organisation for Quality Assured Breast
Screening and Diagnostic Services

Controlli di Qualità in DBT

- AEC system
- Reproducibility and Homogeneity
- Image-quality (ASF, Ghost/Lag, ecc.)
- Dosimetry



(a)



(b)

FIG. 9. Comparison of ASF curves of the selected (a) mass (*M5*) and (b) microcalcification (*C3*) reconstructed with the BP (open triangles), SART (open circles), and ML-convex (open squares). Slices with positive distance are below the feature layer. The ASFs were obtained by averaging three repeated measurements and the error bars indicated the standard deviation of the measurements.

Zhang *et al*, Med. Phys. 33, 2006

Constancy Checking of Digital Breast Tomosynthesis Systems

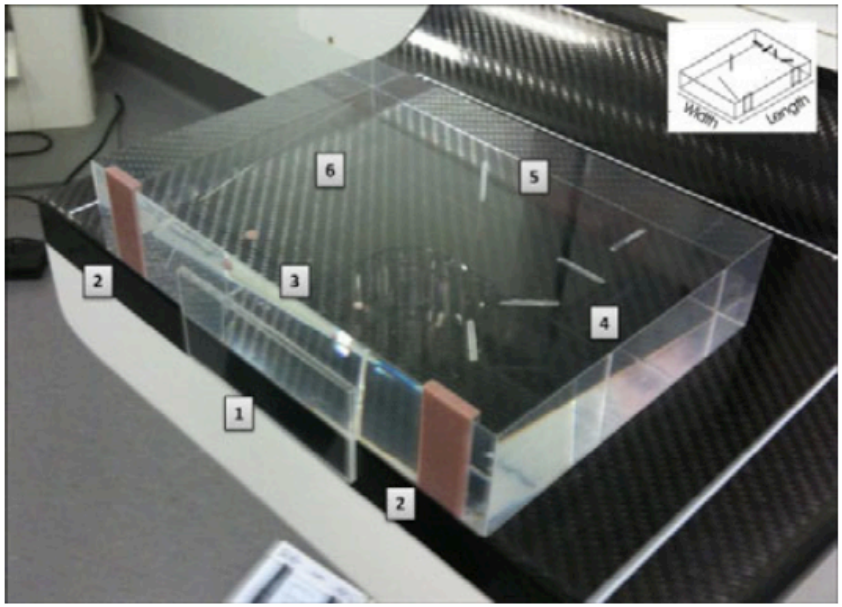
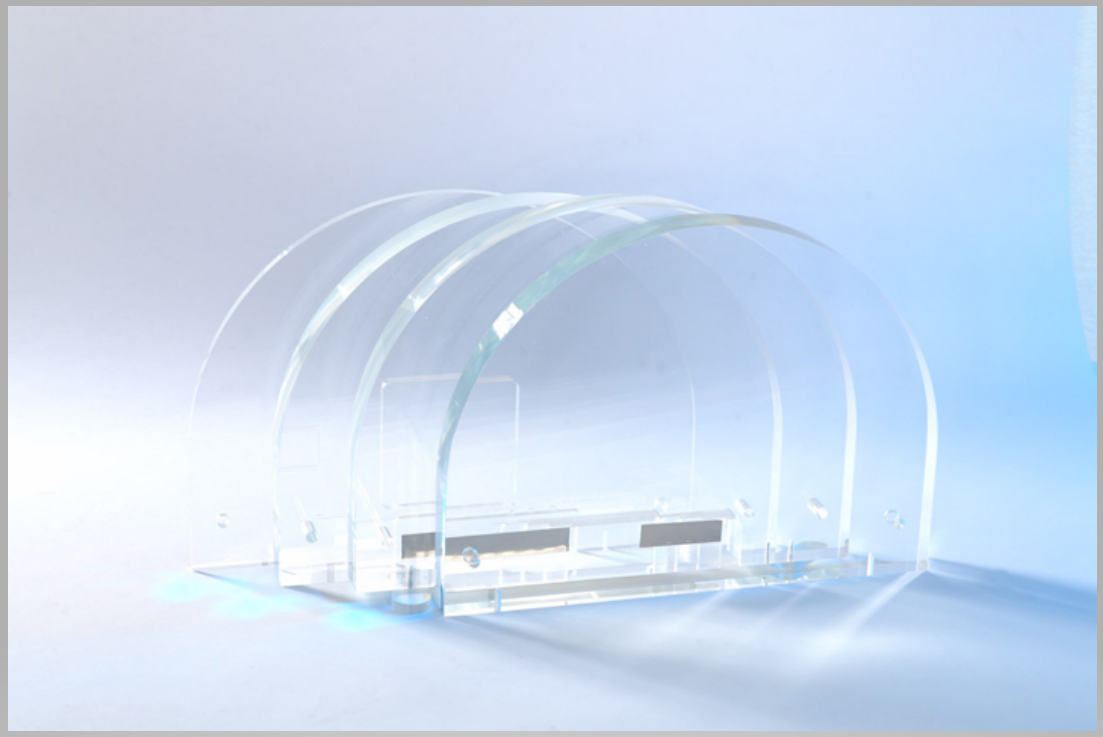


Fig. 7. Example of the *Agatha* phantom. This phantom consists out of: (1) phantom positioning aid; (2) cuboidal inserts to check for missing breast tissue; (3) low and high contrast spheres to check the artifact spread function (ASF) and to measure 3D MTF; (4) in-plane nylon wires to check the line object spread function (LOSF); (5) vertical wire to check for SDNR throughout the volume; (6) tilted Tungsten wire to check Z-direction sensitivity profile.

Jacobs *et al*, IWDM Proc. , 2010



http://quart.de/en/test-phantoms/mammography/g-quart-mamdigi-epqc.html

Lecture Notes in Computer Science Volume 7361, 2012, pp 284-291

Evaluation of Various Mammography Phantoms for Image Quality Assessment in Digital Breast Tomosynthesis

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Abstract

We investigated the appropriateness of four different mammography phantoms for image quality evaluation in Digital Breast Tomosynthesis (DBT). We tested the CIRS BR3D phantom, the ACR Prototype FFDM Accreditation Phantom, the Penn anthropomorphic breast phantom and the Quart mam/digi EPQC phantom. This work discusses the advantages and shortcomings of each phantom and concludes that none of them, in their current form, can be considered to be adequate as an image quality evaluation phantom for DBT.

Riassumendo …

- La DBT è una tecnica 3D *limited-angle* da ottimizzare in base a parametri "clinici":
  - ✓ Dose e Qualità dell'Immagine
  - ✓ Artefatti
  - ✓ Tempo di esposizione e tempo di ricostruzione
  - ✓ Modalità di visualizzazione
- Gli studi clinici serviranno a definire ulteriormente i parametri di acquisizione/ricostruzione
- I controlli di qualita' e i fantocci a disposizione non hanno ancora raggiunto il necessario livello di maturita' …