Better Insight with Wide-Angle Tomosynthesis

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Disclosure & Disclaimer

Dr. Steffen Kappler is full-time employee of SIEMENS Healthcare GmbH, Forchheim, Germany. In addition, Steffen is private stake-holder of SIEMENS AG and Siemens Healthineers AG.

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Outline

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Wide-angle Digital Breast Tomosynthesis
System Design & Image Reconstruction
Synthetic Mammograms (2D & 3D)
Grid-less Applications
TiCEM Dual-Energy Technique
Tomosynthesis-guided Biopsy
Short Outlook to the Future
Conclusion
Introduction
Image Quality in Breast Cancer Screening

Basic Image Quality Requirements:
- Highest spatial resolution (details, µCalc)
- Excellent contrast reproduction (tumors, ...)
- Standardized (but region-specific) image appearance
- Efficient suppression of scatter radiation effects
- Lowest possible radiation dose

Challenges in X-ray Breast Imaging:
- High resolution measurement system
- Complex image processing of large high-resolution image matrices
- Scatter compensation

Reading challenge: Huge amount of anatomical background!

Introduction
Anatomical Background Reduction: Digital Breast Tomosynthesis

FFDM vs. DBT
Introduction

Anatomical Background Reduction: Digital Breast Tomosynthesis

Wide-Angle Digital Breast Tomosynthesis: 40° vs. 20° Experiment

Stronger reduction of tissue overlap with wider acquisition angles

Experiment: Phantom with two 1.0 mm steel balls, 6 mm apart in z-direction

Learning: Wider scan angles significantly increase depth resolution!

Wide-Angle Digital Breast Tomosynthesis

Stronger reduction of tissue overlap with wider acquisition angles

Illustration: Probability Maps of Lesion Location

Learning: Wider scan angles significantly increase depth resolution!
Wide-Angle Digital Breast Tomosynthesis
Improved low-contrast lesions detection

Comparison Study: Narrow- and Wide-angle DBT

Part 1: Simulation study using a cascaded linear system model (CLSM)
Results: reduced in-plane breast structural noise and increased in-plane detectability of masses with wide-angle DBT

Part 2: Clinical pilot study comparing mass conspicuity
Results: masses are more conspicuous in wide-angle DBT

→ Detection of mass lesions in dense breasts can be improved by increasing the angular range in DBT


Learning: Better depth resolution improves detection of tumor masses and low-contrast lesions!

Clinical Case: Definitive Finding with Wide-Angle Tomo
Ultrasound-confirmed, invasive ductal carcinoma grade 2

Note: Ultrasound clearly demonstrates a lesion with malignant appearance.
Guiding Principle

“Deliver better insight with wide-angle tomosynthesis”

Wide-Angle System Design: MAMMOMAT Revelation

Overview

- 50° wide-angle tomosynthesis
- Insight 2D and 3D
- TiCEM – Titanium Contrast Enhanced Mammography
- PRIME Technology
- Insight BD – Breast Density Assessment
- Personalized Soft Compression
- BIRADS® – Breast Imaging Reporting and Data System
- InSpect – Integrated Specimen Tool
- PREP Technology
- Breast screening

Technical Specifications

- X-ray tube: Tungsten anode, 1 mm inherent beryllium filtration
- X-ray beam filter: Anode/filter combinations: W/Rh, W/Ti
- Anti-scatter grid: Grid ratio 5:1, 51 lines/cm
- Detector technology: Amorphous Selenium (aSe, 85µm pixels)
- Detector size: 24 cm x 30 cm (9.5” x 12”)
- System swivel range: +180° to -180°
- Tomo mode swivel range: -25° to +25° (with 25 projections)
- Source-image distance: 65 cm (25.6”)
- Height adjustment: 69 cm (27.2”) to 150 cm (59.1”) (object table)

Note: This document is a Siemens Healthineers product brochure, providing information on their mammography systems.
Wide-Angle System Design: MAMMOMAT Revelation
High-Performance X-ray Measurement System

X-ray generator & tube
- Tungsten anode, 1 mm inherent beryllium filtration
- kV range: 23…35 kV / 45…49 kV for Dual-Energy
- Inks range at 25 kV: 2.1.2 times in mks mode, 7.715 times in AEC mode
- Exposure times: 10 ms to 4 (large focus) / 60 ms to 6 (small focus)
- Focal spot size (IEC 60336): 0.3 mm (large) / 0.15 mm (small)

X-ray beam filter
- Anode/filter combinations: W/Rh, W/Ti

Anti-scatter grid
- Grid ratio 5:1, 31 lines/cm

Flat detector
- Amorphous selenium (aSe)
- Pixel size: 85 μm x 85 μm squared
- Detector size: 24 cm x 30 cm (9.5" x 12")
- Image matrix: 2816 x 3584

Wide-Angle Tomosynthesis Image Reconstruction: EMPIRE
Algorithm Outline

Enhanced Multiple Parameter Iterative Reconstruction

EMPIRE Main Processing Steps
- Super-resolution reconstruction (0.2 mm) using FBP with statistical artifact reduction
- Slab calculation (2.0 mm, 50% overlap) for better visualization of calc clusters and smoother scrolling
- Iterative noise reduction

EMPIRE Image Flavors
- BT – soft breast tissue contrast enhancing
- CT – standard reconstruction

Study on Image Quality
100 patients, 4 readers (standard FBP vs. EMPIRE), better overall image quality, contrast, and visibility of calcifications

Synthetic Mammograms
Motivation
**Synthetic Mammograms (insight2D)**

**Concept**
- Navigational tool with digital breast tomosynthesis
- Ideal for an easy comparison with prior FFDM and tomosynthesis exams
- 40% dose reduction as opposed to FFDM as an adjunct to tomosynthesis


**Rotating Synthetic Mammograms (insight3D)**

**Concept**
- Unique, rotating 3D display in breast tomosynthesis
- Faster reading of tomosynthesis exams
- Easier analysis of microcalcifications at a glance
- Comprehensive visualization of findings for surgeons, referring physicians, and patients


**Scatter Radiation Effects in X-ray Imaging**

**Brief Introduction to Scatter Radiation**
- Scattering processes destroy the intended absorption imaging geometry (i.e., straight lines from focal spot to detector)
- We distinguish 2 types of scattered radiation, from:
  - Tube or its vicinity → image blur
  - Patient or its vicinity → degrade image SNR
- Typically, scatter from the patient is dominant and does not contribute to the useful imaging process. However,
  - It produces a low-frequency background intensity
  - It reduces contrast
  - It increases quantum noise
Grid-less Applications for FFDM (PRIME)

Concept

Post-breast anti-scatter grids partially block primary radiation
Amount of scatter radiation scales with breast size
For small & mid-size breast grid removal enables full use of primary radiation
• significant dose reduction potential
• scatter modifies image quality and impression

Solution: Combination of automated breast-size dependent* grid removal, OpDose, adaptive AEC Algorithm and a scatter correction algorithm, where:
• software identifies scatter causing structures
• algorithm restores image quality and impression
*Note: grid is removed for compression thicknesses below 70 mm.

Grid-less Applications for FFDM (PRIME)

Results

1) Compared to grid-based acquisition with Mammomat Inspiration, depending on breast thickness
Images: Courtesy of MVZ Prof. Dr. Uhlenbrock & Partners, Dortmund, Germany
Without PRIME (68mAs)
With PRIME (45mAs)
- 30% dose

More Results

Grid-less mammography: excellent performance proven in screening routine
• Significant reduction of average dose (up to 30% less dose)
• Uncompromised image quality
• No negative impact on cancer detection rate
• Recall rate

<table>
<thead>
<tr>
<th>Number of Examinations</th>
<th>Recall rate</th>
<th>Cancer detection rate</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without PRIME (12 months)</td>
<td>&gt;50,000</td>
<td>2.59%</td>
<td>0.55%</td>
</tr>
<tr>
<td>With PRIME (5 months)</td>
<td>&gt;20,000</td>
<td>2.44%</td>
<td>0.55%</td>
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Grid-less Applications for FFDM (PRIME)

More Results

Reference: Siemens Healthineers
Contrast-enhanced Dual Energy Mammography

Dual Energy Iodine Imaging

- Mass attenuation coefficients of breast tissue and iodine contrast exhibit different characteristics
- Classical dual-energy technique for computation of an iodine-only material image applies
- Titanium filter applied to high-energy X-ray beam maximizes spectral separation
- Motion compensation and excellent scatter compensation are essential pre-requisites
- Iodine image by weighted subtraction of low (LE) and high (HE) energy images

Contrast-enhanced Dual Energy Mammography (TiCEM)

Titanium filter maximizes spectral separation

- BI-RADS 5, density category b
- CEM: Tumor with contrast enhancement

Titanium filter provides high X-ray yield, and enables consecutive exams without tube overheating

MAMMOMAT Revelation

Dedicated high energy 1.0 mm titanium X-ray filter with high X-ray yield
- Excellent spectral separation between low and high energy X-ray beams
- Up to 60% higher tube output compared to 0.3 mm Cu
- Enables consecutive examinations without tube overheating

Injection of iodinated contrast agent

Approx. 1.5–2 minutes waiting time

Patient positioning

Display of low-energy & combined image (Insight CEM) at the AWS

Acquisition of low & high-energy images

Repeat for additional views

Learning: Titanium filtration also provides high X-ray yield, and enables consecutive exams without tube overheating
Tomosynthesis-guided Biopsy (HD Breast Biopsy & InSpect)

50° tomo provide better depth resolution than 30° stereo

Short Outlook to the Future
Innovations in Mammography
State-of-the-Art High-End Systems provide:

- Fast workflow
- CC & MLO view for left & right breast
- Digital Mammography & Tomosynthesis
- Magnification mode
- Stereotactic biopsy
- Contrast-enhanced mammography

Conclusion
Wide-angle digital breast tomosynthesis significantly increases depth resolution and improves detection of tumor masses and low-contrast lesions.

To "deliver better insight" was guiding principle for the wide-angle system design of the MAMMOMAT Revelation

The EMPIRE Image Reconstruction was introduced to improve overall image quality, contrast, and visibility of calcifications.

The insight2D synthetic mammograms are great navigational tools and allow comparison with prior FFDM exams

The insight3D rotating synthetic mammograms enable easier analysis of micro calcifications and provide comprehensive visualization of findings.

The PRIME grid-less technique enables significant dose reduction for small & mid-size breast while maintaining high level of image quality.

The TiCEM dual-energy technique provides excellent spectral separation and the comparably high X-ray yield enables consecutive examinations without tube overheating.

Tomosynthesis-guided biopsy allows precise localization and targeting of suspicious tissue, the integrated specimen scanner allows instant specimen imaging.
Thank You.

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