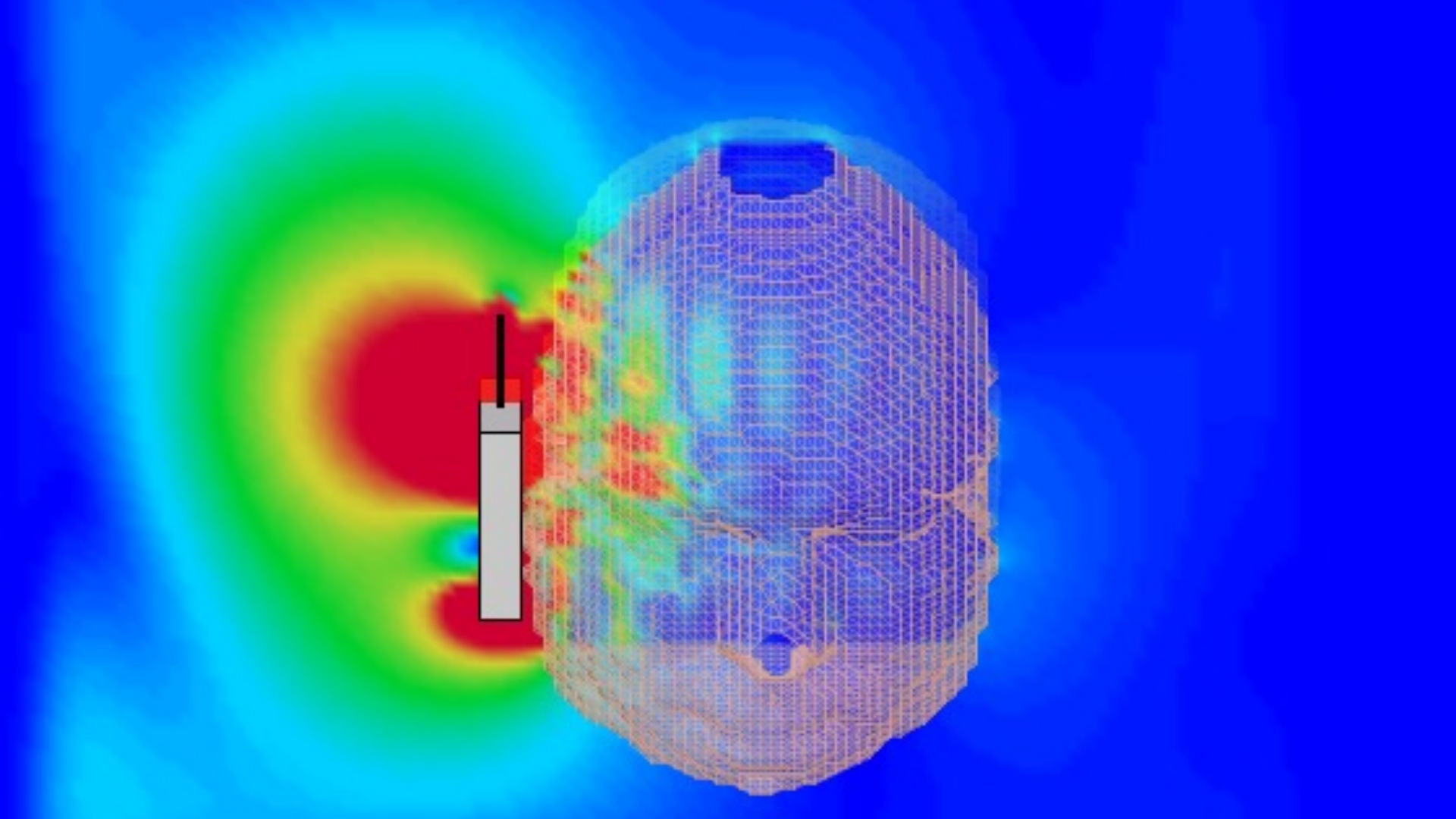
Microwave technology enables safer breast cancer diagnostics

Andreas Fhager,
Biomedical Electromagnetics Research Group,
Chalmers University of Technology

Technological base

Microwave components

Widely available computer resources in compact form



Research Group in Biomedical Engineering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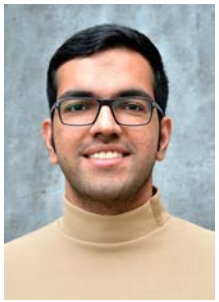
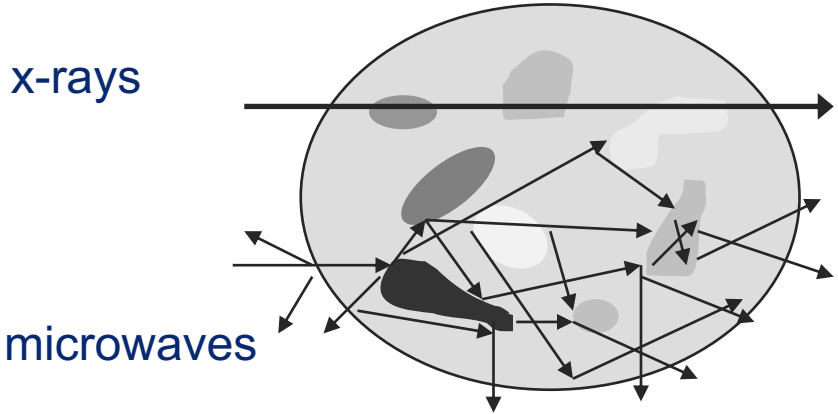
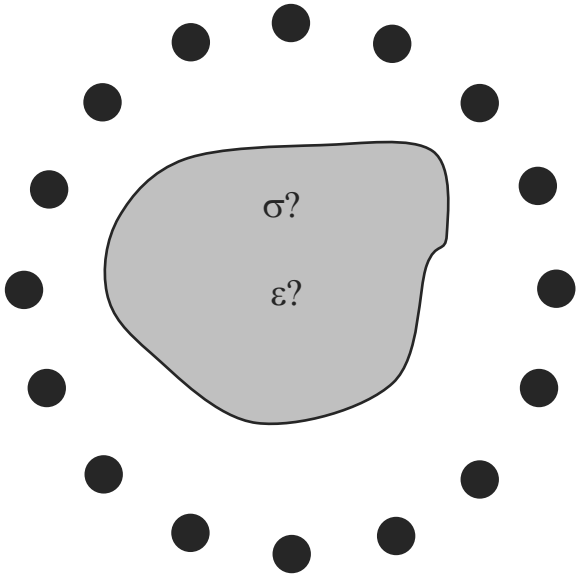

Seyed Moein Pishnamaz


Mattia de Lazzari

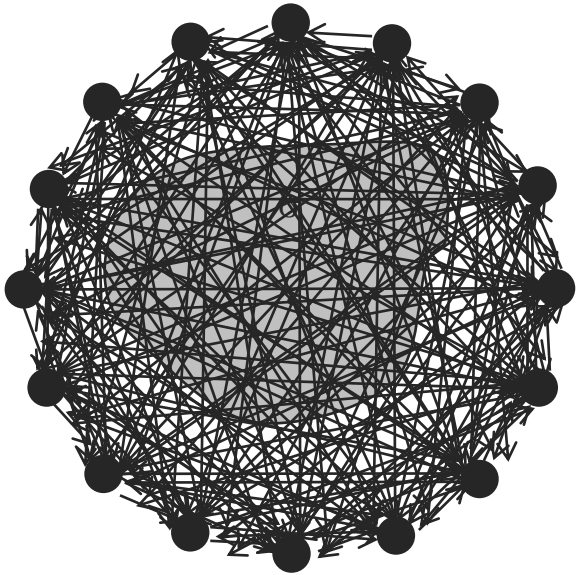
Analysing microwaves is challenging



The basis of diagnosing based on microwave data



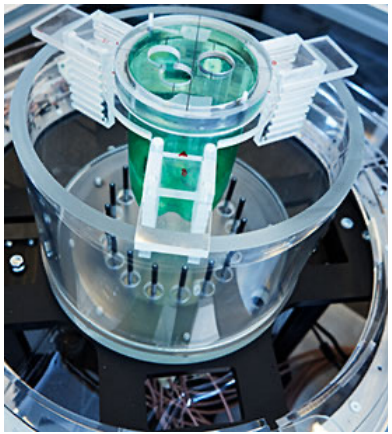
Scattering measurements of several antenna combinations

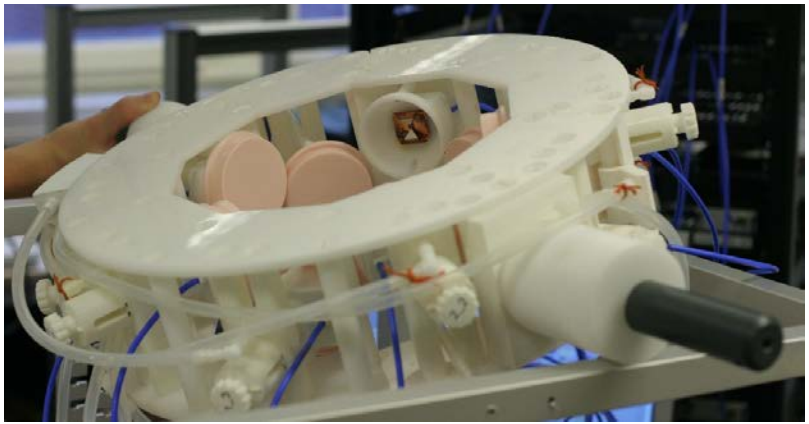


Opportunities in microwave diagnostics and treatment

Diagnostics of stroke and trauma, breast cancer, internal bleedings, pneumothorax, haemothorax, muscle ruptures.

Hyperthermia for cancer treatment in head and neck, children's brains cancer.





Our research focuses on antennas and antenna systems solutions, algorithms, and (miniaturized) systems.

Breast Cancer

Clinical background

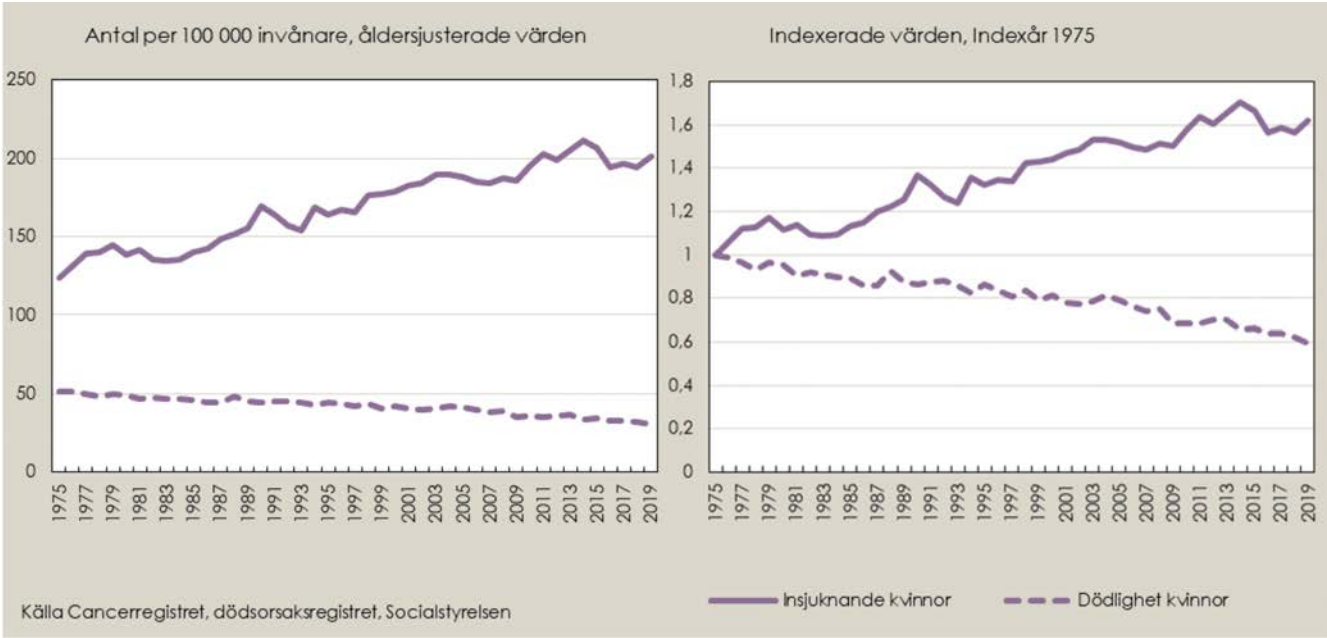
WHO statistics from 2020

2.3 million women diagnosed with breast cancer

685 000 deaths

Source: https://www.who.int/news-room/fact-sheets/detail/breast-cancer

Breast cancer statistics in Sweden



2019

8300 cases diagnosed

1353 deaths

Source: Dataanalyser av cancer 1975–2019, Socialstyrelsen
https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2021-3-7285.pdf

5-year Overall Survival of breast cancer by Stage

Stage	Classification	5-year overall survival
0	In situ	100%
I	Cancer formed	100%
II	Lymph nodes	93%
III	Locally advanced	72%
IV	Metastatic	22%

https://www.cancer.org/cancer/breast-cancer/understanding-a-breast-cancer-diagnosis/breast-cancer-survival-rates.html

Mammography images

Healthy breast

Image provided by
M.D. PhD Ingvar Andersson, Malmö

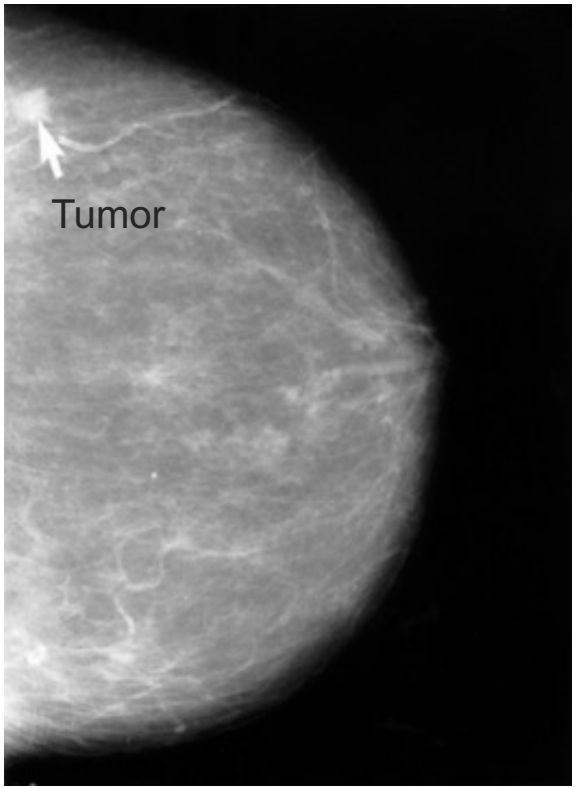
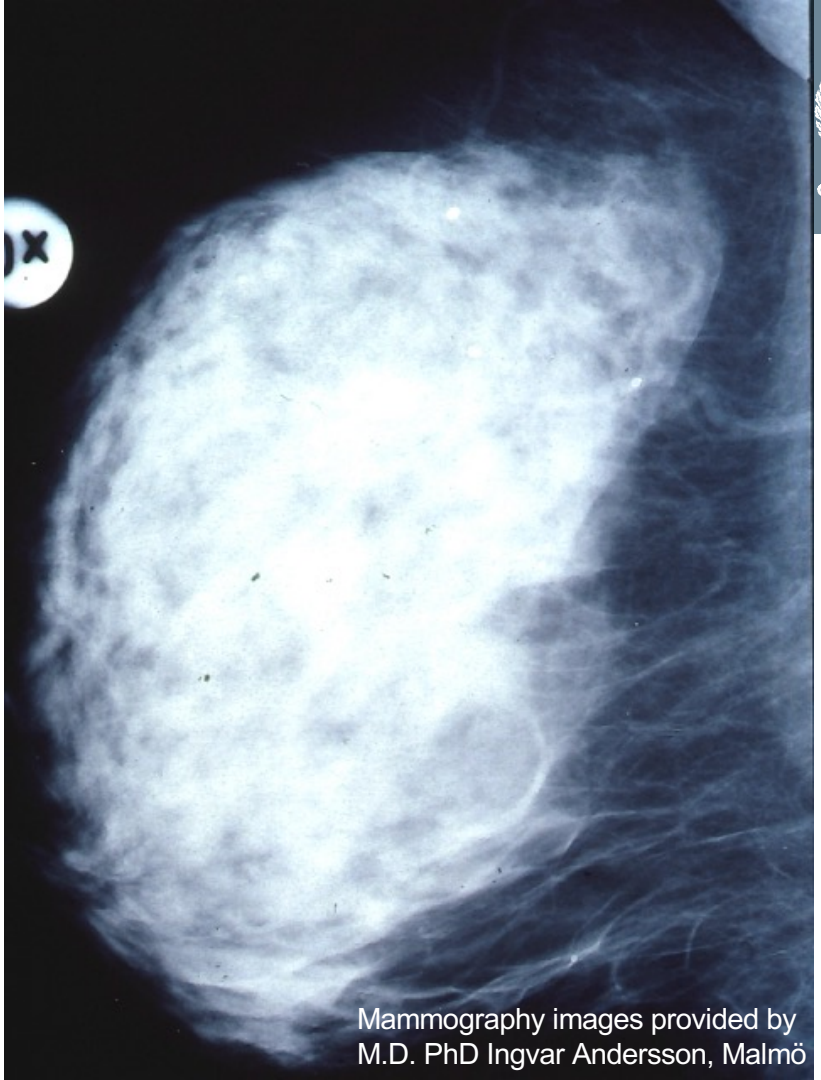


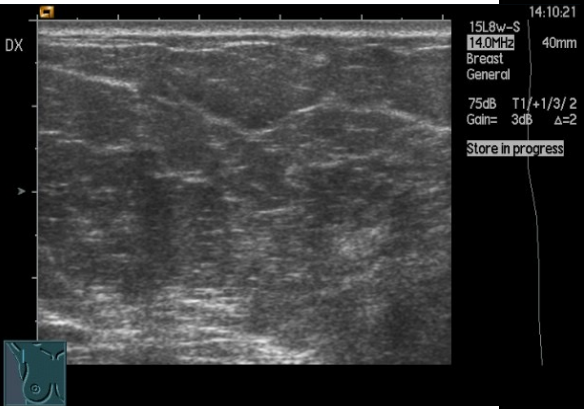
Image source: Wikipedia,
https://sv.wikipedia.org/wiki/Cancer

An image of a dense breast is a challenge

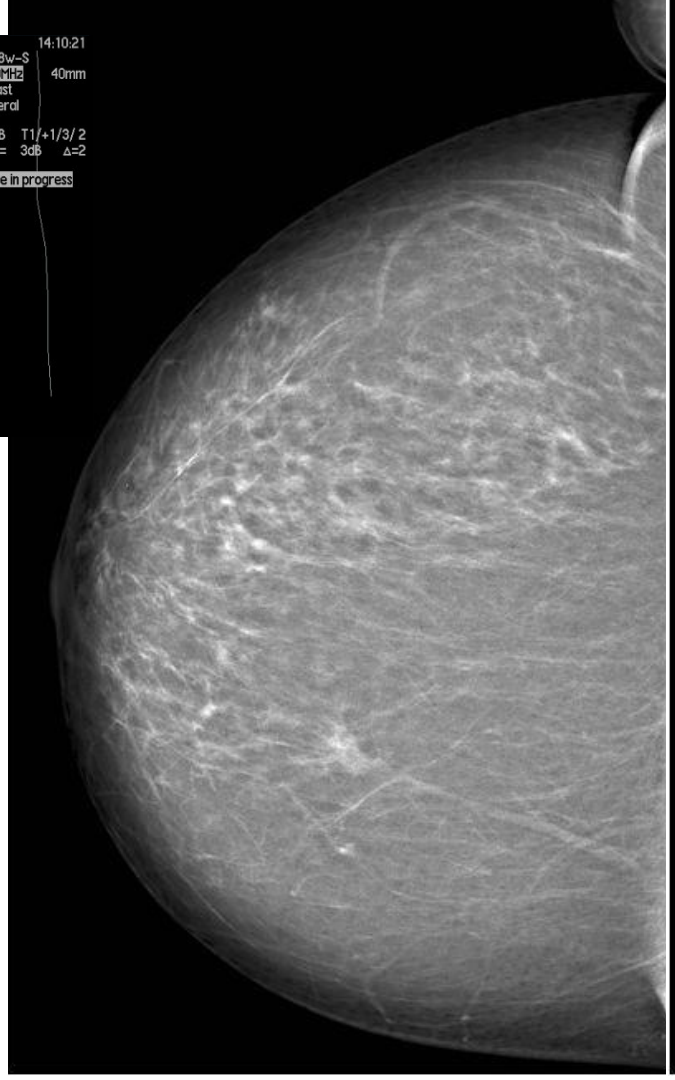
Large amounts of fibroglandular tissues makes it difficult to identify tumors in 2D mammographic images

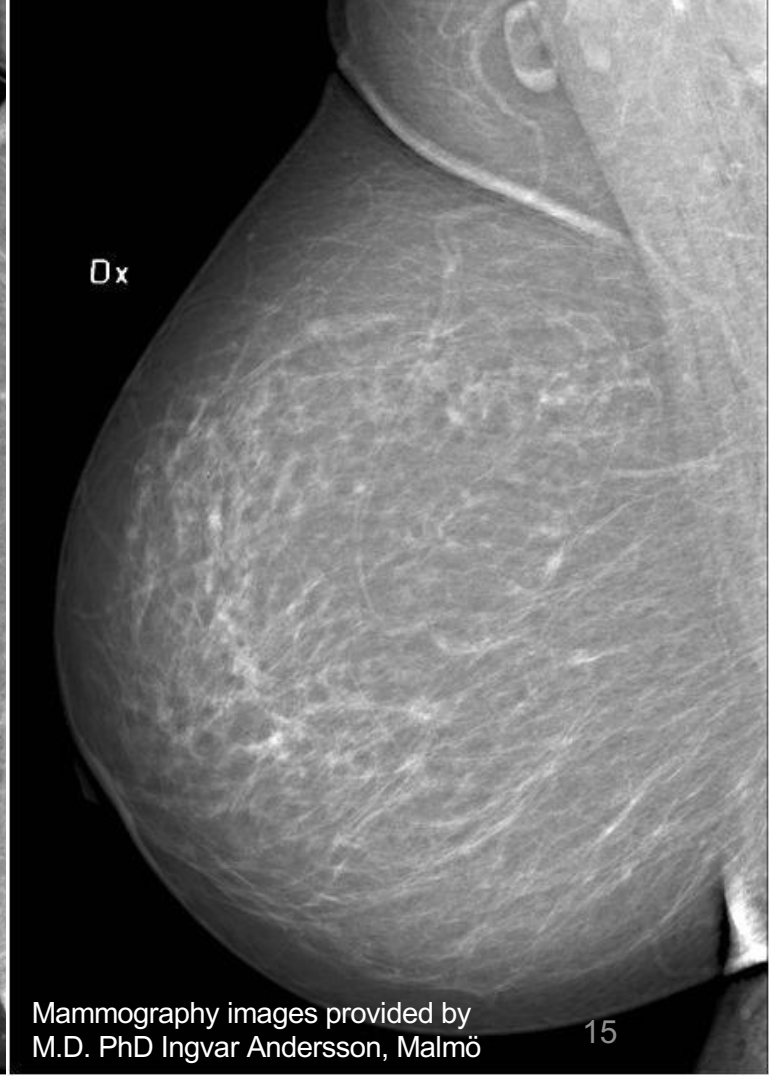


Mammography images provided by M.D. PhD Ingvar Andersson, Malmö



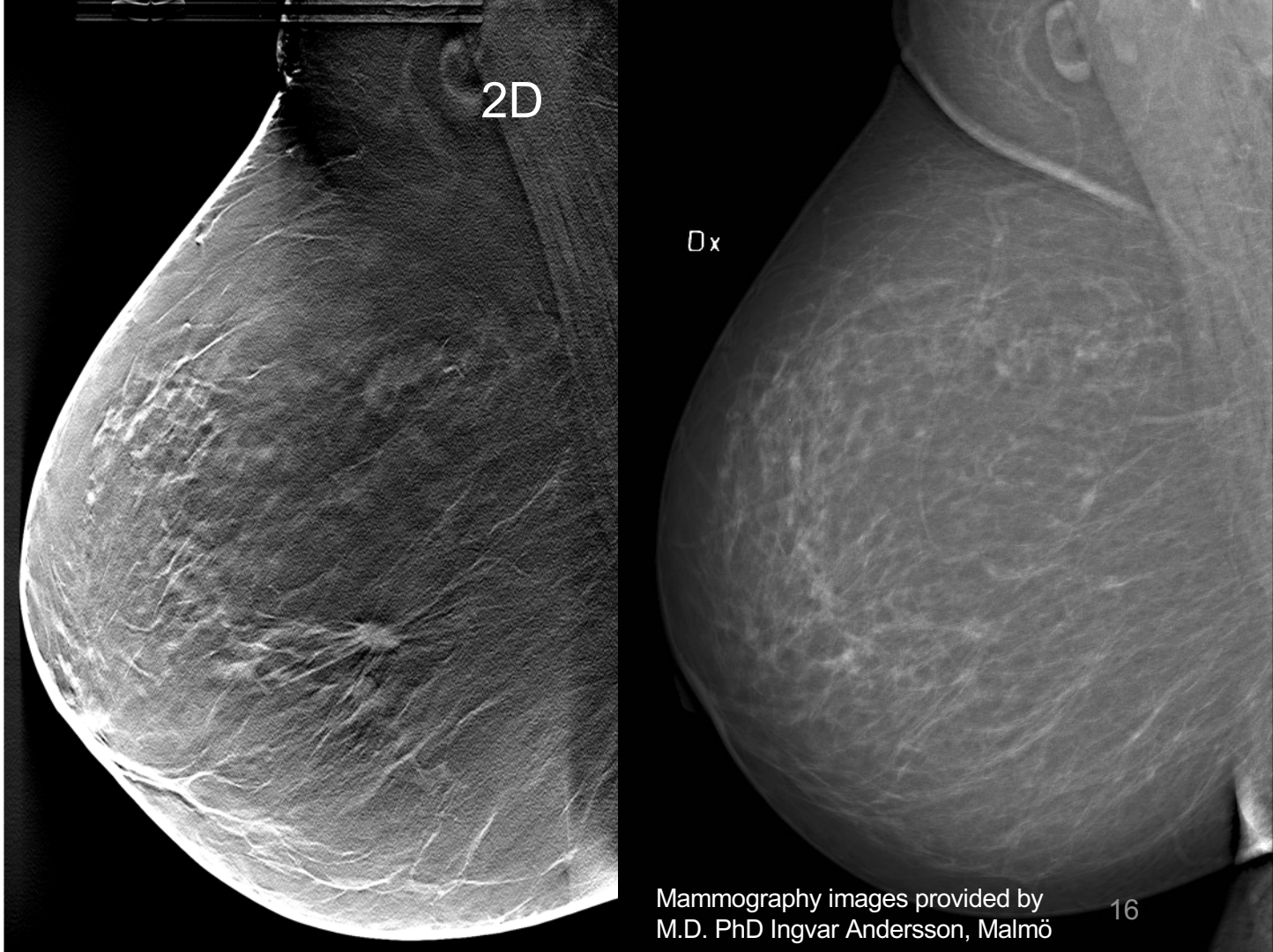
68-y-old asymptomatic woman (2D mammography)





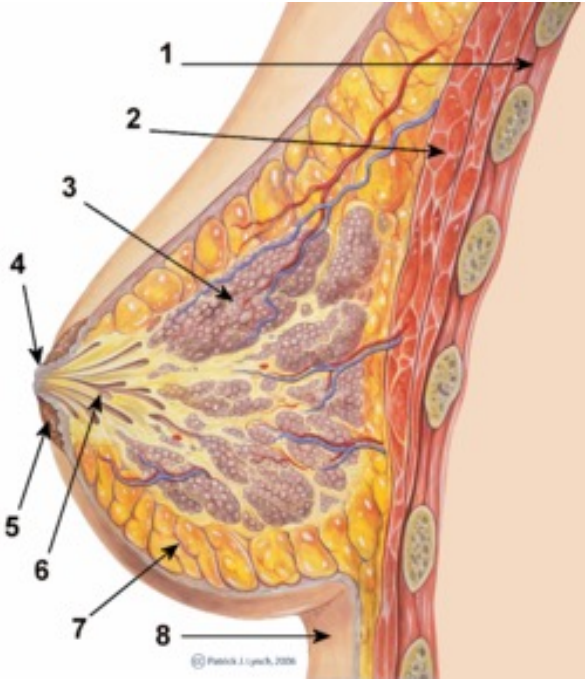
Mammography images provided by M.D. PhD Ingvar Andersson, Malmö

A cross-section image obtained with tomosynthesis (”3D” mammography) reveals a tumor not visible in the 2D projection image



Mammography images provided by M.D. PhD Ingvar Andersson, Malmö

Breast anatomy



Cross-section of the human mammary gland.

1.Chest wall
2.Pectoralis muscles
3.Lobules
4.Nipple
5.Areola
6.Milk duct
7.Fatty tissue
8.Skin

Source: https://en.wikipedia.org/wiki/Mammary_gland

X-ray mammography suffer from the following limitations

- Limited sensitivity (45-90%)
  - Different sensitivities in different studies depend on surrounding tissue, tumor size, growth pattern
- High false positive detection rate
- Exposure to ionizing radiation
- Painful breast compression

Ultrasound as alternative to x-ray mammography

- No ionizing radiation
- Sensitive in dense breasts
- Inexpensive
- Moderate specificity
- Operator dependent

Ultrasound image provided by
M.D. PhD Ingvar Andersson, Malmö

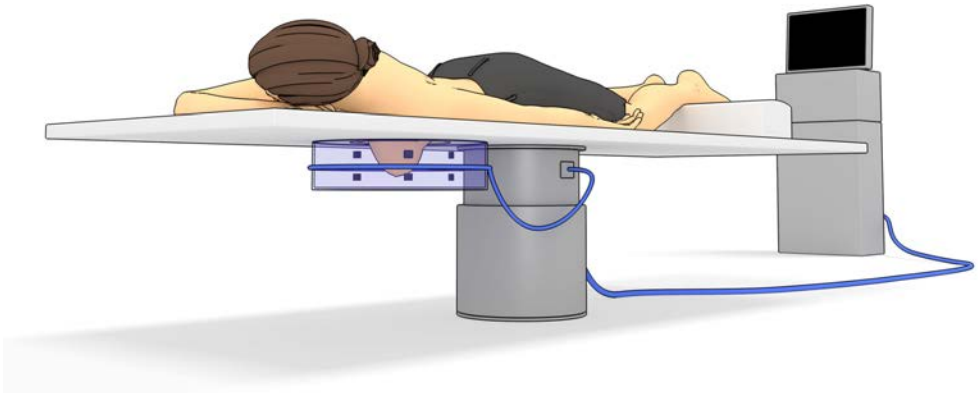
Magnetic resonance imaging as alternative to x-ray mammography

- No ionizing radiation
- Expensive
- Moderate specificity
- Contrast agent can improve specificity

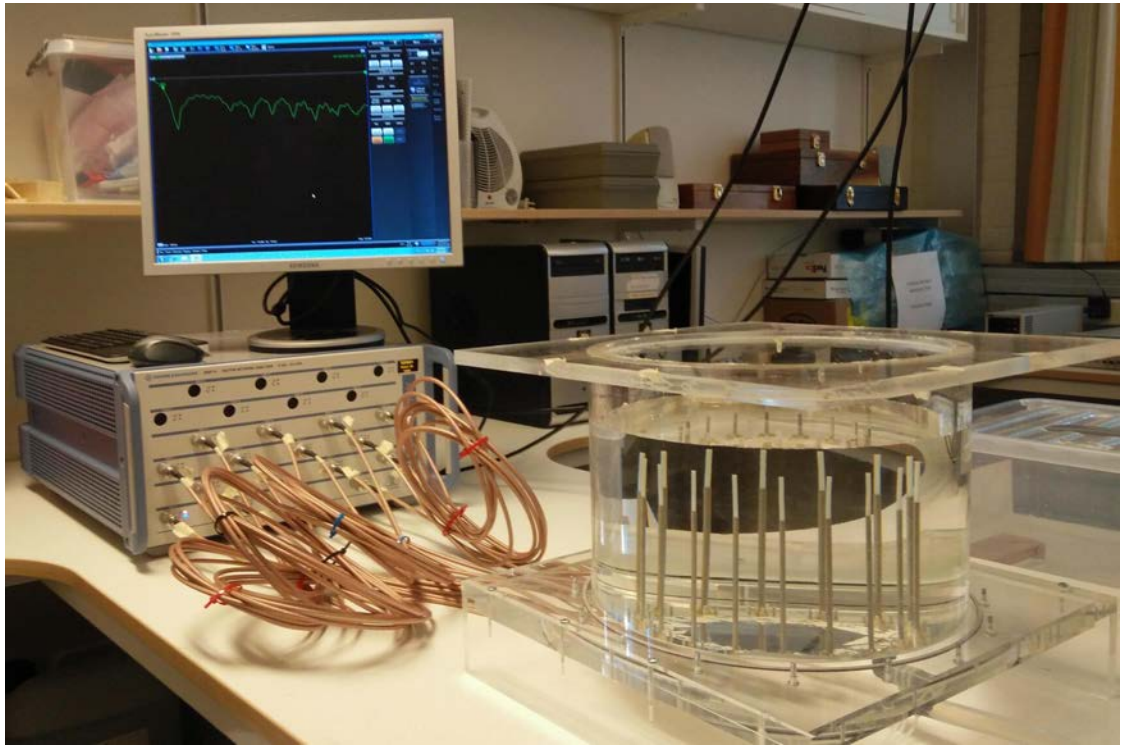
MRI image provided by
M.D. PhD Ingvar Andersson, Malmö

Microwave imaging in breast cancer detection

- No ionizing radiation
- No compression needed
- Inexpensie technology
- High tissue contrast



Imaging System



Phantom experiments

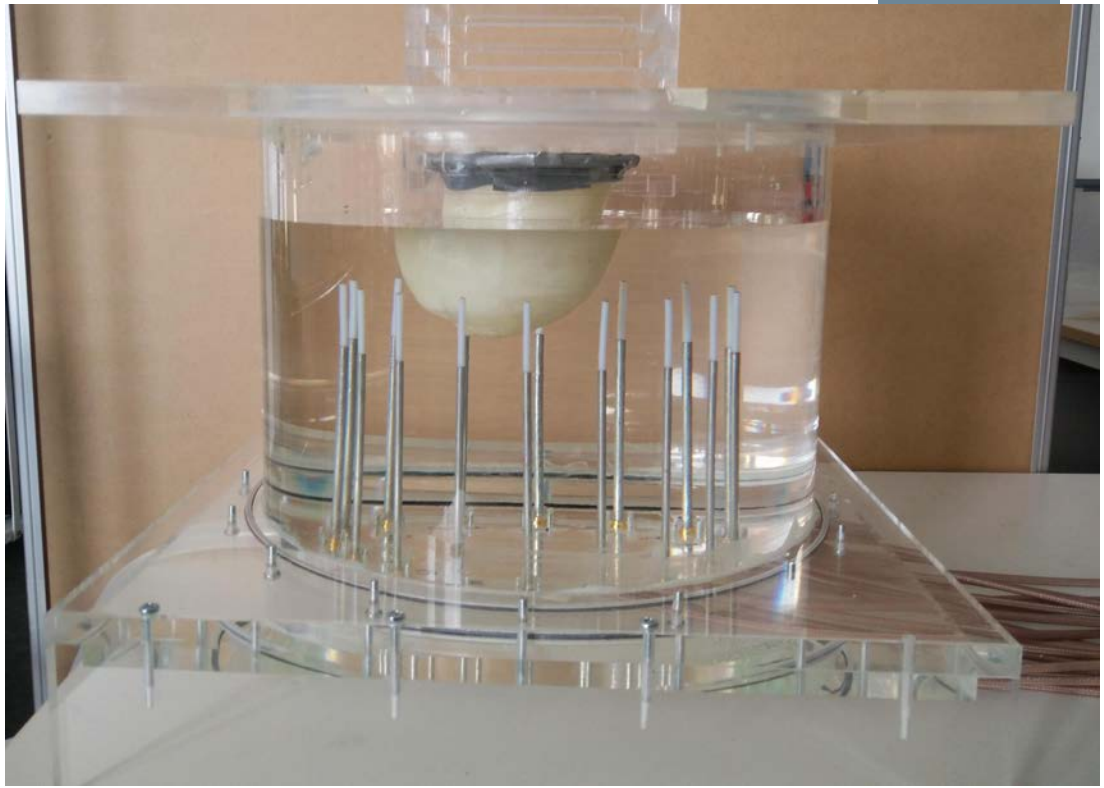
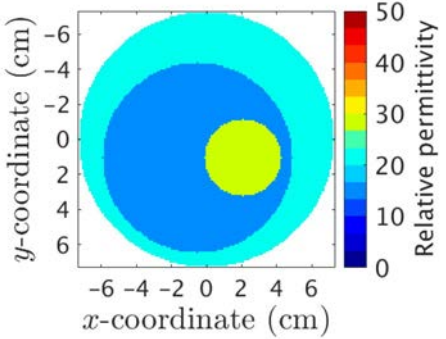
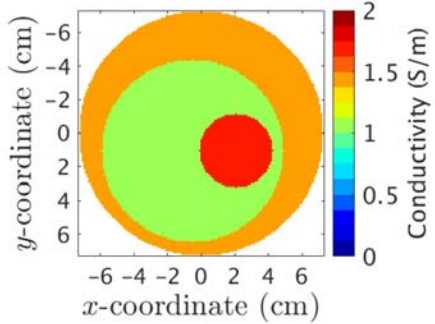
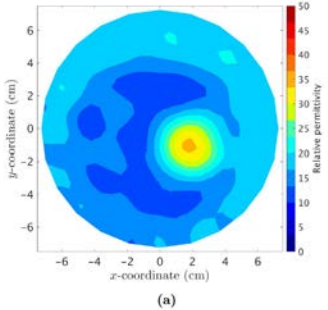


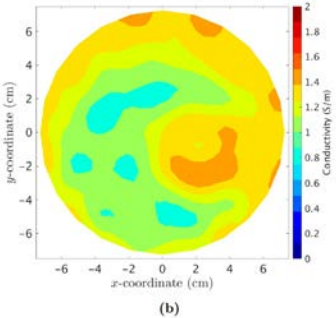
Image reconstruction algorithms



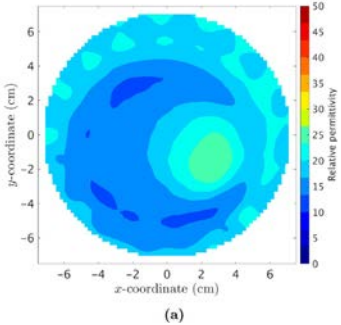


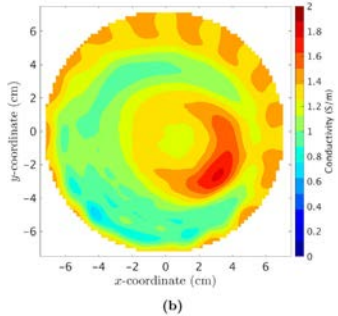
Original





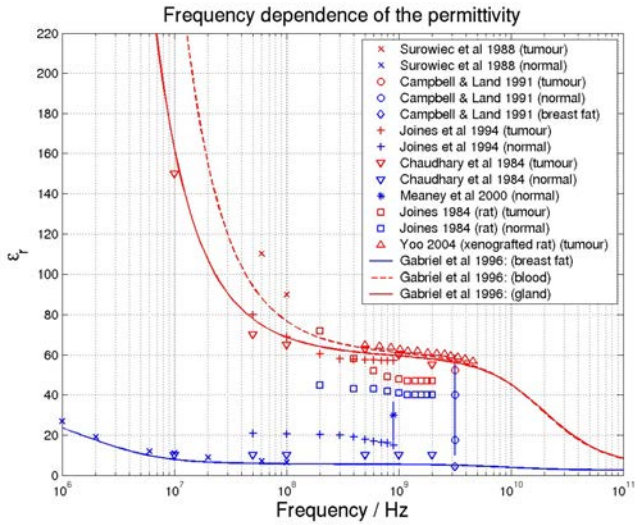
FEM algorithm

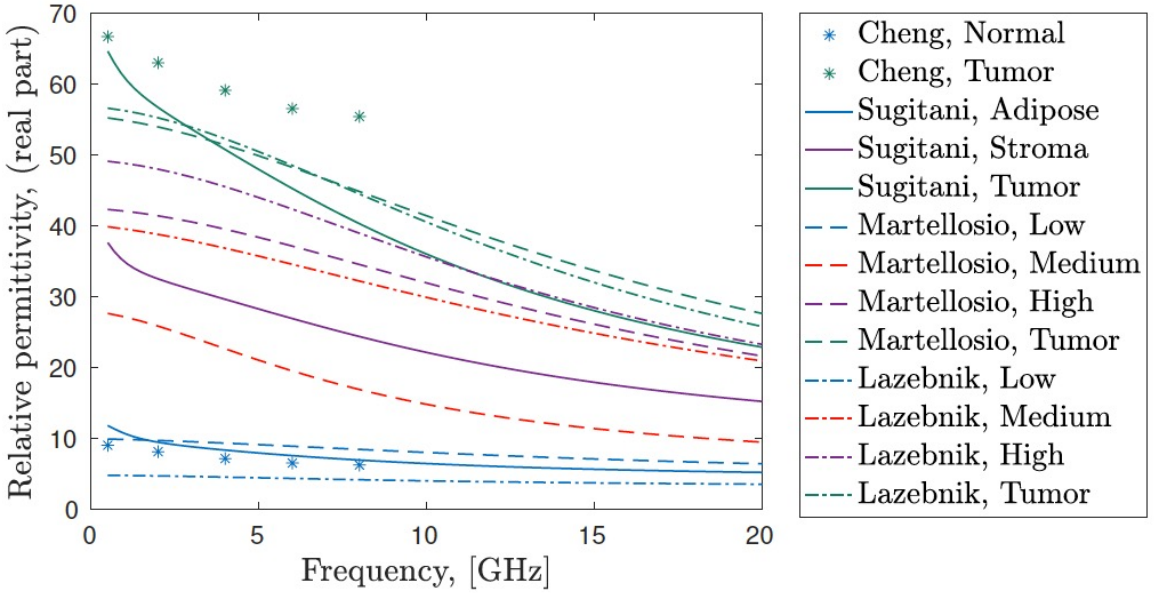




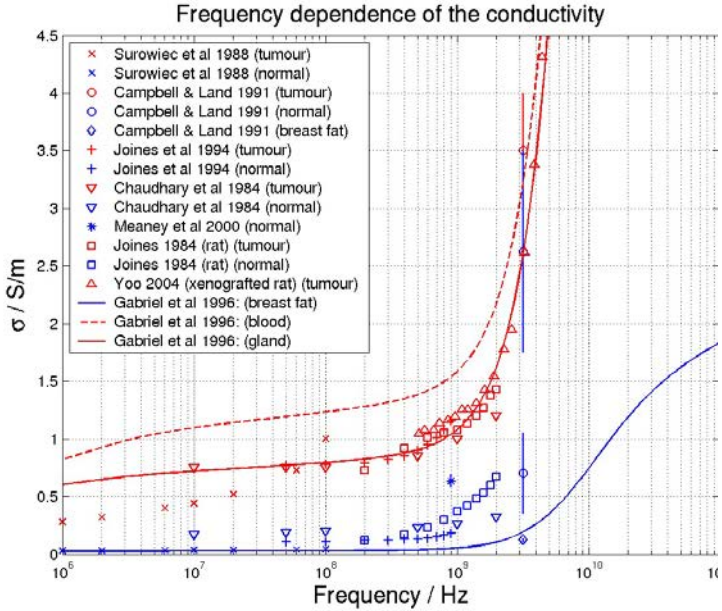
FDTD algorithm

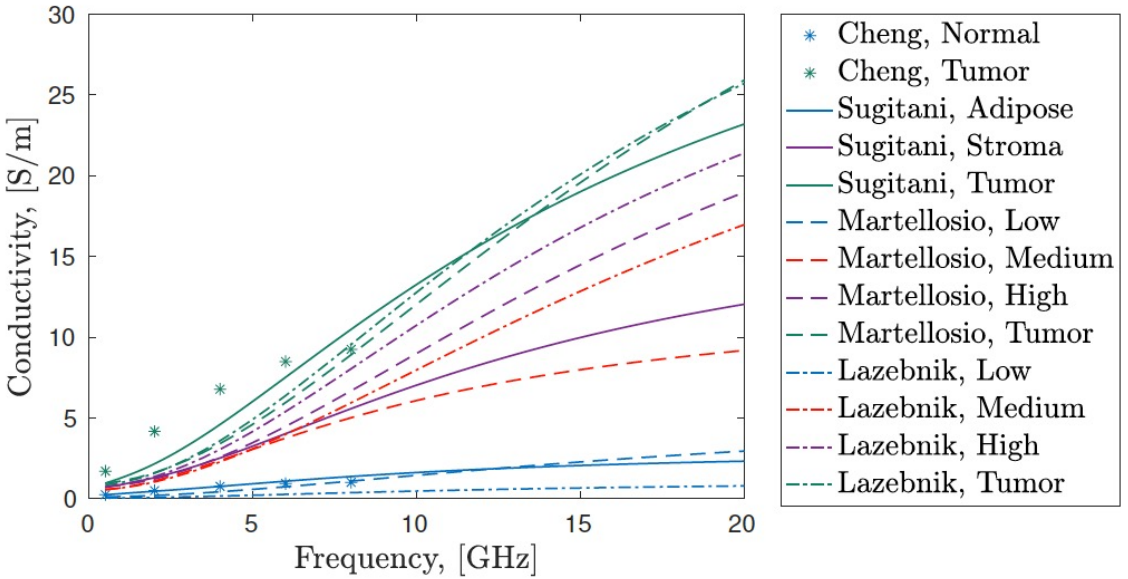
Breast imaging is possible thanks to a high contrast in dielectric properties between healthy and malignant tissue



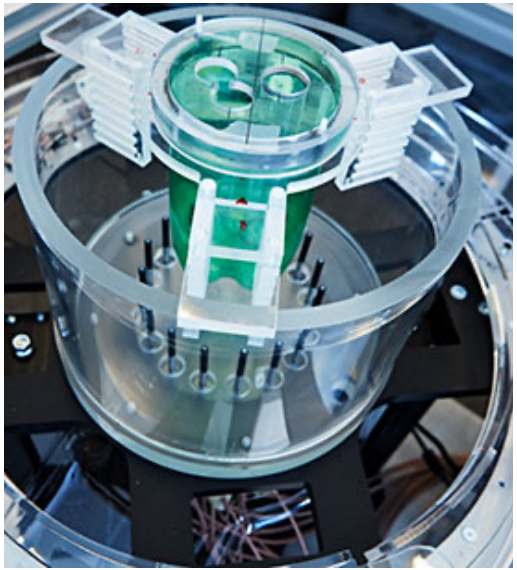


Breast imaging is possible thanks to a high contrast in dielectric properties between healthy and malignant tissue





Alternatives for analysis of microwave scattering data



Measured scattering data

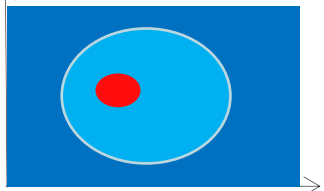
Classification and AI methods

Healthy

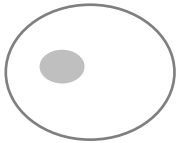
Tumor

Size/Postion of tumor

Imaging



Quantitative Imaging

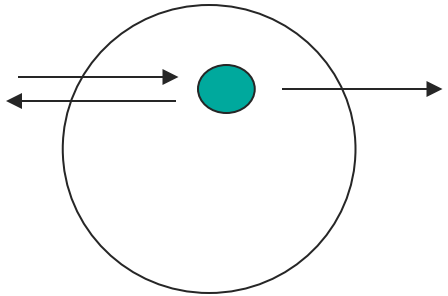


Radar Imaging

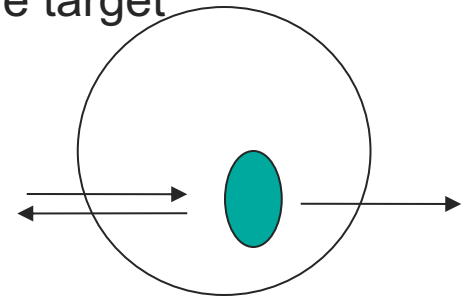
Our focus is on imaging methods

Multiple scattering makes the problem non-linear, i.e. hard to solve

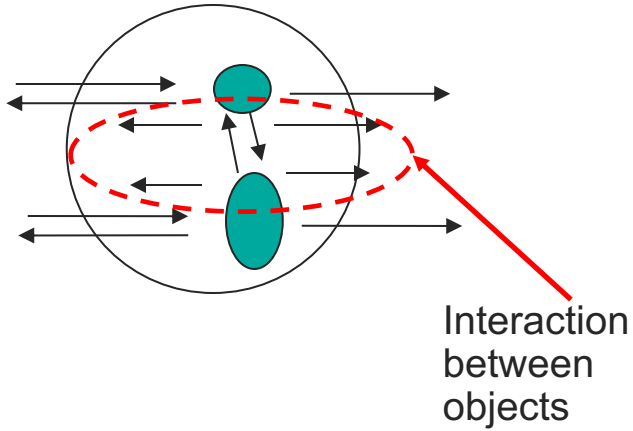
Single target



Single target



Two targets interact with each other; therefore, the scattering problem is non-linear

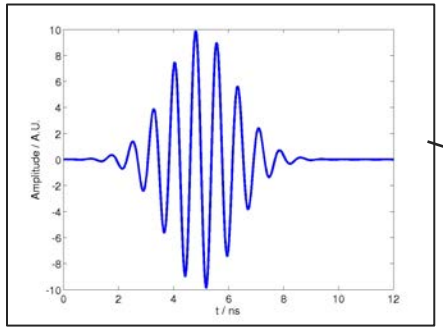


An Iterative Reconstruction Method

$$J[\varepsilon,\sigma]=\sum_{m=1}^{M}\sum_{n=1}^{N}\int_{0}^{T}\left(\left|\mathbf{E}_m^{(simulated)}(\varepsilon,\sigma,\mathbf{R}_n,t)-\mathbf{E}_m^{(measured)}(\mathbf{R}_n,t)\right|^2\right)dt$$

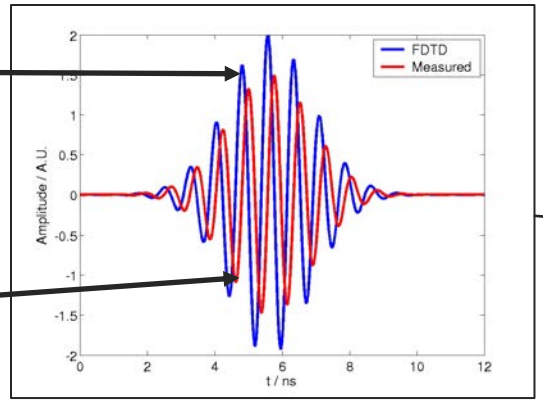
Image reconstruction is based on comparing measured data to simulated data. In an optimization process the simulated model is updated so that the corresponding data approaches the measured data.

Simulations vs. Measurements

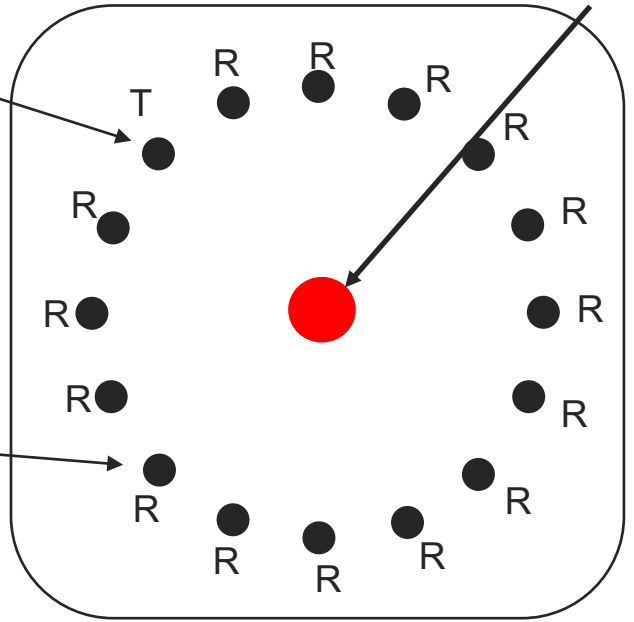


Simulated signal (blue)

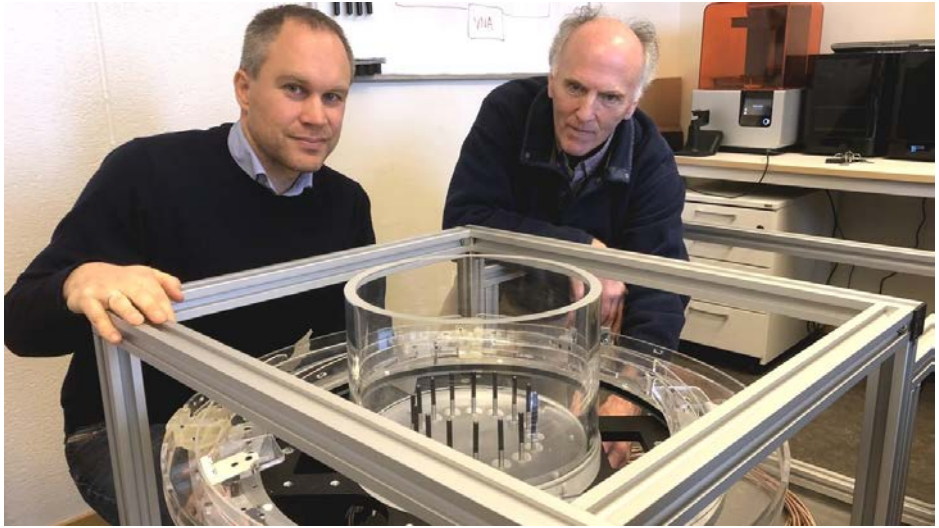
Measured signal (red)

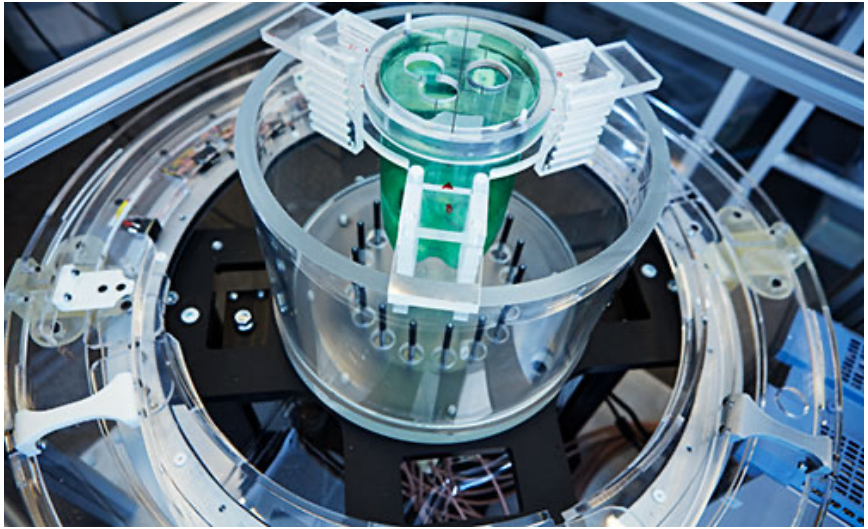


Object present in measurement



Clinical prototype under construction



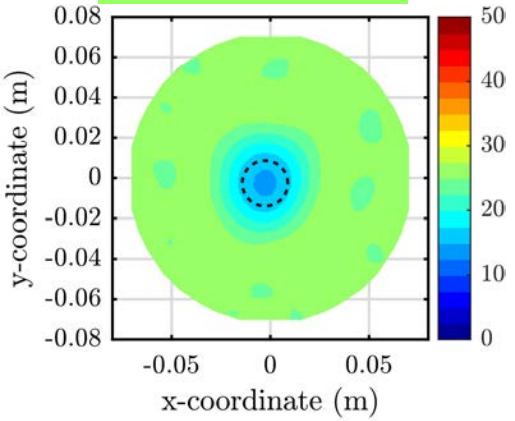


Andreas Fhager, Chalmers and
Paul Meaney, Dartmouth College, USA

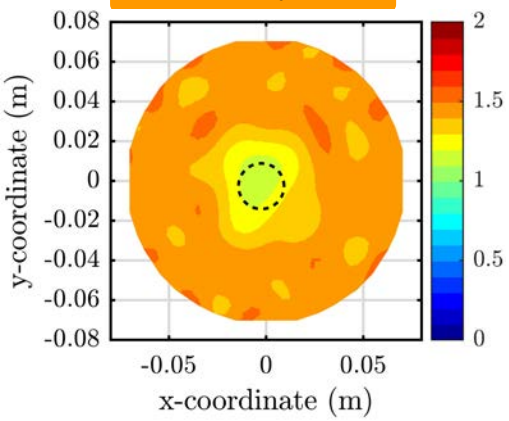
Improved reconstruction speed with the DDA Approximation method

2D images of reconstructed relative permittivity and conductivity (S/m) from experimental data

Relative permittivity



Conductivity (S/m)



Reconstruction time 6 seconds

Compared to at least 2-3 minutes with previous algorithms

Frequency $1.3\ GHz$, $\epsilon_{rb} = 25.4$, $\sigma_b = 1.44\ (\mathrm{S/m})$, $\epsilon_{rt} = 16.5$, $\sigma_t = 0.90\ (\mathrm{S/m})$, $d = 4\ cm$

Results from PhD student Samar Hosseinzadegan

Next steps

Finalise imaging prototype system

Clinical tests at Sahlgrenska University hospital

Further development of measurement electronics to reduce cost

Further developments of algorithms to improve reconstruction speed and accuracy.

Stroke

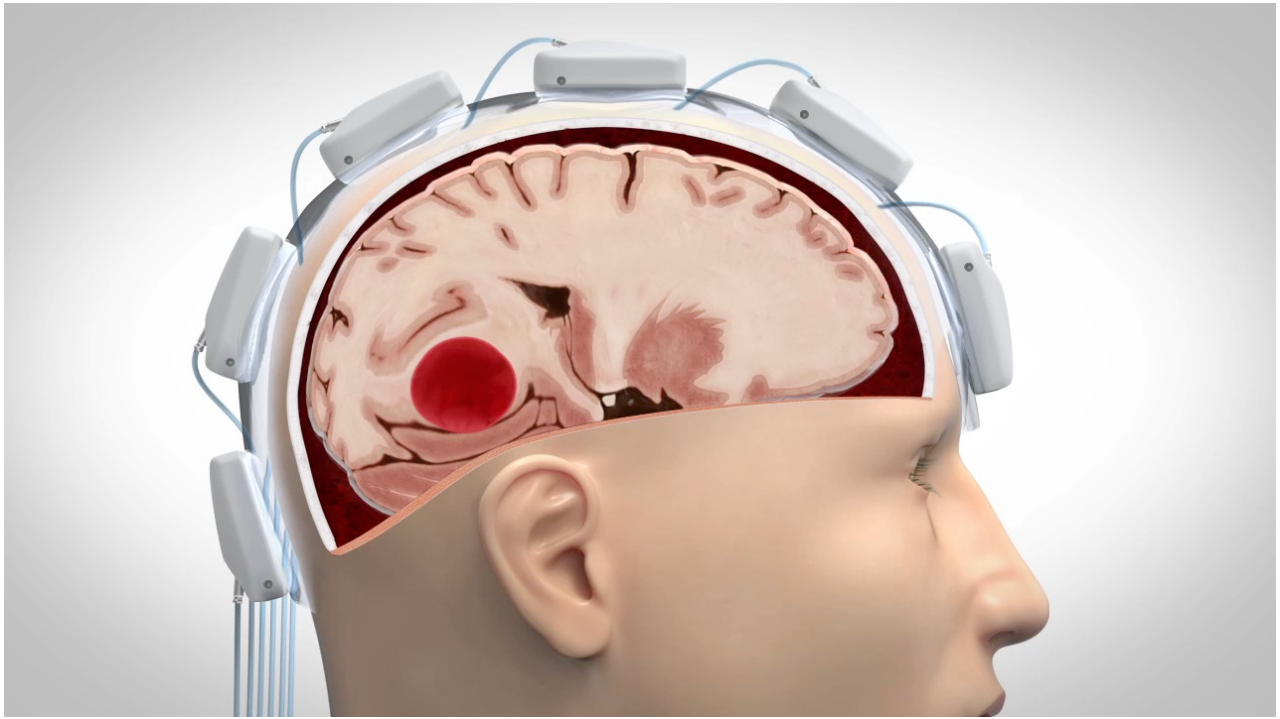
MD100 for Stroke and Trauma Diagnostics

Treatment options

- Clot resolving medicine
- Trombectomy at hospital with neuro surgery capability
- Intracranial bleeding patients benefit from blood pressure management.

Microwave Based Diagnostics

Transission measurements



2022-02-02

Our focus is on AI based classification methods

Stroke and trauma diagnostics

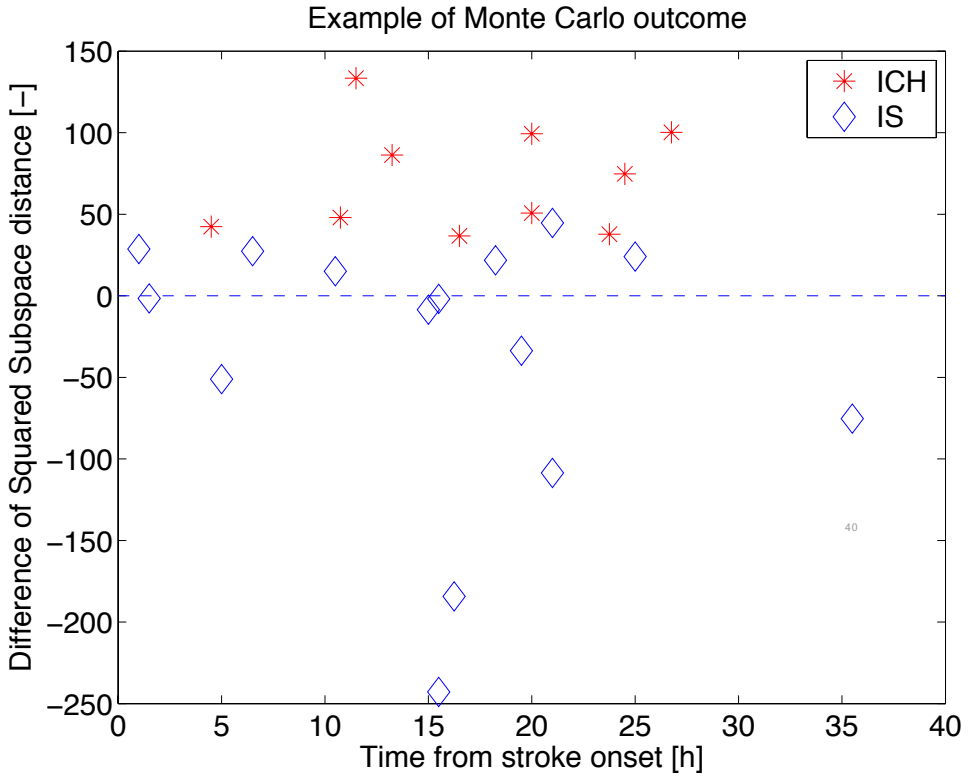
Ongoing studies in collaboration with hospitals in 4 countries

- Sahlgrenska University Hospital
- Helsingborg Hospital
- King's College Hospital and St George's Hospital, London
- Haukeland University Hospital, Bergen and Stavanger University Hospital, Norway
- Hunter Medical Research Institute, Newcastle, Australia
- Healthy Volunteers, Medfield Diagnostics

Collaborators SU/SA

Mikael Elam, Jan-Erik Karlsson, Alexandros Rentzos, Annika Nordanstig, Johan Ljungqvist, Lars Rosengren

Classification results
Bleedings (ICH) vs. Clots (IS) – MF02



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