Microwave imaging for breast cancer detection

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Summary

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Epidemiology of breast cancer

Breast tumour is nowadays the most common malignancy in women of the western world and it is the second leading cause of cancer mortality, following lung cancer.

1,000,000 cases
400,000 deaths

30,000 cases
11,000 deaths

Why is early diagnosis so important?

The probability of surviving decreases very rapidly as the tumour develops. Early-stage diagnosis is the principal instrument to face this pathology.

Source: American Cancer Society (www.cancer.org)
Outlook over early diagnosis

The most common and efficient diagnostic method is mammography, which has remarkably reduced the mortality rate of breast cancer, BUT:

- it suffers from a high false negative (10-30%) and false positive (10%) rate;
- it is often unable to distinguish between malignant and benign lesions;
- its efficiency decreases when it is applied to radiographically dense tissues;
- it is uncomfortable and painful for patients;
- it is based on the use of ionizing radiations.

State of the art

Microwave imaging for breast cancer detection was proposed for the first time in 1998 by an international group of researchers [1].

It is a pretty new topic which keeps evolving.

What has been done up to now can be resumed as [2]:
- numerical analysis in 2D and 3D models
- experimental analysis on simple phantoms


Normal and tumoral breast tissues have a very high contrast (1:2-1:10) in electromagnetic properties ($\varepsilon$ and $\sigma$) in the microwave frequency range (300MHz-30GHz).

Note that biological tissues are dispersive mediums, i.e. their dielectric properties vary with the frequency.

Waves propagating through a medium are partially or totally reflected every time they encounter a discontinuity in dielectric properties.

By properly analyzing the reflections that a wave undergoes while propagating in the structure under exam, it is possible to locate any scattering element.
Basic principles of μwave imaging (3)

An antenna, located in proximity of the breast, transmits a wave and collects the reflected signal; the antenna is moved to different positions and in each location a new acquisition is performed.

\[ ds_i = \frac{dt_i \cdot v_{prop}}{2} \]

The examination apparatus can be represented as follows:

The patient lies in prone position with her breast extending through a hole in the examination table.

The antenna is moved to different positions around the breast.
Advantages of microwave imaging

- **simplicity** (mobile antenna + network analyzer + PC);
- **velocity** (data are collected and their elaboration is performed in post-processing);
- **comfort** for the patient (no breast compression);
- it is based on the use of **non-ionizing radiations** (no radiological risk and low cost).

The signals must be elaborated in order to reduce the disturbing elements (skin reflection, noise, clutter due to the dishomogeneity of tissues…) and highlight the response of the tumour.

At each point of the domain (breast) is assigned a value of “intensity”, obtained by summing the informations collected in the different positions of the antenna.

\[ I(P) = \left[ \sum_{n=1}^{N_{\text{antenna}}} S_n(\tau_{P,An}) \right]^4 \]
Numerical simulations on a 2D model

**tumour** 
\((\varepsilon_i=50, \varepsilon_r=4, \sigma=0.7 \text{ S/m, } \tau=6.4 \text{ ps})\)

**source point**

**mammary tissue** 
\((\varepsilon_s=10, \varepsilon_r=7, \sigma=0.15 \text{ S/m, } \tau=6.4 \text{ ps})\)

Dishomogeneity of \(\varepsilon \pm 10\%\).

**coupling medium** 
\((\varepsilon_r=10)\)

**skin layer (2 mm)** 
\((\varepsilon_r=34, \sigma=0.4 \text{ S/m})\)

**domain's boundary**

(absorbing condition on the domain's boundary)

2D results

![2D simulation results](image-url)
Beside the breast structure, the 3D model includes the transmitting/receiving antenna. The project of the antenna was one of the main features of our work. The antenna requirements are the following:

- ultrawideband (1-8 GHz)
- good directivity
- small dimension

We chose the Vivaldi antenna.
The model is far more realistic than the 2D one: it includes breast tissue, glands, skin and the nipple.
3D results (2)

- Planar map, 1cm tumour
- Sagittal map, 1cm tumour

Future work

- Improvements of the post-processing algorithm;
- Construction of the antenna;
- Construction of breast simulant phantoms and measurements;
- Measurements on real patients.
Thank you for your attention

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