Microwave tomograph for medical application

Topic: Life Sciences and Healthcare

Title, Name: Samuel Poretti, Manuela Maffongelli, Andrea Salvadè, Ricardo Monleone
Department: DTI , Institute ISEA
University of Applied Sciences: SUPSI
Email: samuel.poretti@supsi.ch, manuela.maffongelli@supsi.ch, andrea.salvade@supsi.ch, ricardo.monleone@supsi.ch
Title, Name: Matteo Pastorino, Andrea Randazzo, Alessandro Fedeli
Department: DITEN
University of Applied Sciences: UNIGE
Email: matteo.pastorino@unige.it, andrea.randazzo@unige.it, alessandro.fedeli@unige.it

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1. Introduction

Microwave imaging is increasingly gaining interest and relevance in the non destructive analysis of materials. Many institution such universities and research centres aims at the development of microwave based investigation systems [1]. Applications of such systems are wide and in different areas, from production industry as example analysis of raw materials or in-homogeneities inspection in finished products [2] to medical applications. In fact Microwave-based approaches were not only adopted for non-destructive evaluations of industrial and civil area, but they are also applied in medical diagnostic and therapeutic fields [3]-[5]. In this field particular researches have been conducted in the breast imaging field where tissues and anatomic parts are more accessible. Also a commercial opportunity is envisaged since currently gold standards imaging technique in breast cancer screening programs carries several well known shortcomings such as limited sensitivity and specificity, in particular for dense breast tissue and high genetic risk population. Moreover, the use of X-ray methodology involves patients to high safety risks when repetitive exposures are required to monitor the evolution of for detection. The high interest of microwaves techniques is due to the fact that microwaves can be safely and reproducibly exploited for early detection of breast cancer and for therapy monitoring [6]. The focus of the presented article is aimed at the development of a compact, fast, and easy to use microwave tomograph to be applied for breast cancer detection and monitoring. The research involves many specific areas such as computed simulations, antenna design, radio frequency circuits design and imaging algorithms development. The paper is organized as follows. In section 2, the realized antenna and entire systems simulation and realization are described. Measurement setup and imaging algorithm are described in 3, reconstruction results in 4 and finally conclusions are drawn in section IV.

2. Measurement system design and realization

For the specific purpose the author have developed an innovative imaging system prototype based on a fully automated system especially designed for breast analysis. Fig. 1 shows the block diagram of the system. A personal computer (PC) dedicated at the selection of active antenna pair, gathers vector network analyser (VNA) measurements, and performs the reconstruction algorithms. The switching control board and the RF switch boards have been specifically designed in order to allow to independently drive 16 antennas located around the inspected area every 22.5°. The antennas have been developed by authors in order to overcome strong signal reflections due to the high dielectric constant of the inspected area avoiding the use of matching medium such as dielectric liquids. All the system is able to operate in broadband condition from 1GHz to 8GHz.

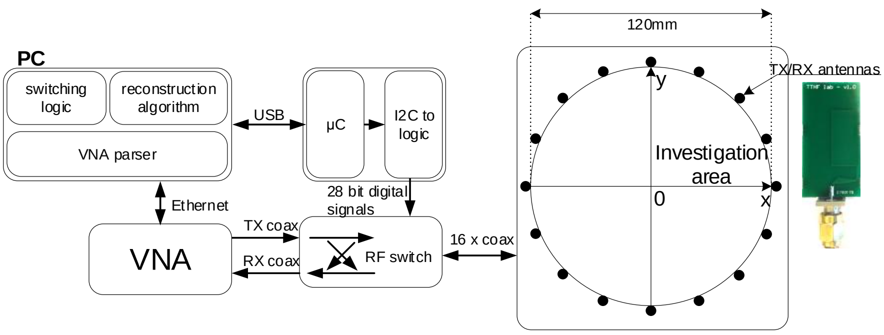

Fig. 1 developed tomograph block diagram

3. Measurement setup and reconstruction algorithm

The SUT has been prepared using a plexiglass cylinder with an external radius of 60mm filled with an oil-water-salt mixture resulting in a dielectric constant of εr of approximately 7.4 and a conductivity σ of approximately 0.7 S/m @ 2 GHz. The inclusions was implemented by two plastic drinking straws of 8mm diameter filled with another mixture of the same ingredients and resulting in an $\varepsilon r \approx 42$ and a $\sigma \approx 4.6$ S/m and placed at position $x_1 = -20$ mm, $y_1 = 4$ mm, respectively $x_2 = 45$ mm, $y_2 = 10$ mm from the center as depicted in Fig. 2.
The measurements consisted of obtaining the complex S21 parameters over a frequency range 1.5 GHz to 6 GHz subdivided into 2048 frequency steps and for each possible combination of antenna pairs.

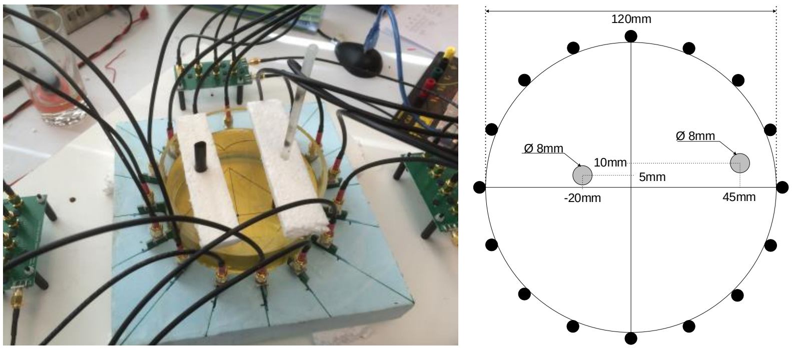

Fig. 2 measurement setup

In order to obtain a robust image reconstruction a radar approach has been adopted. The used reconstruction procedure is a DAS (Delay And Sum) derivative explained in [7] and called RAR (Robust Artifact Resistant). The algorithm operates with differential measures; a reference measurement is therefore necessary. In the present paper the measurement procedure consists in firstly subtracting the reference measures obtained from an plain SUT without inclusions from the measures of the real SUT having inclusions and successively applying the RAR reconstruction algorithm.

4. Reconstruction results

The Fig. 3 shows the reconstruction results. The system is able to discriminate the two inclusions despite working with highly different dielectric constant materials.

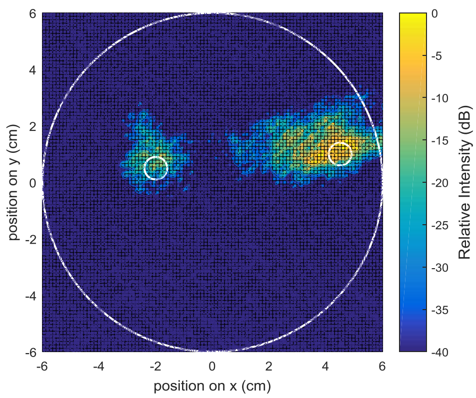

Fig. 3 reconstructed image

5. Conclusions

A fully automated microwave tomograph prototype aimed for breast cancer detection has been presented. The image resolution and real application reliability needs further in-depth studies on antennas, measurement electronic and reconstruction algorithms in order to obtain a reliable system to be used in support of current survey techniques.

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