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Bow-Tie Slot Antenna for Microwave Imaging in Breast Cancer Detection

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Abstract

A bow-tie slot antenna configuration with coplanar feeding mechanism is proposed in this work to be adopted in the framework of microwave tomography system for breast cancer detection. The specific antenna layout leads to satisfy all requirements for a successful operation of the microwave imaging system, imposing unidirectional pattern, and allowing also broadband features. Numerical simulations, as well as preliminary experimental validations on the realized antenna prototypes are discussed.

1. Introduction

The adoption of microwave imaging for breast cancer detection is investigated since many years [1], due to the appealing features in terms of safety (non-ionizing radiations) and thus frequent repeatibility, patient comfortability, and improved screening, leading to overcome limitations of standard X-rays diagnostic methods in terms of sensitivity and specificity, and hopefully enhancing early-stage detection. The conjuncted adoption of machine-learning techniques is recently proven also to further increase the reliability of microwave imaging tools in cancer detection, assuring accurate results even in the presence of highly dense breast phantoms [2-4]. The adoption of magnetic nanoparticles enhanced microwave imaging is also proven in recent works to be an effective approach for an early stage detection of breast cancer [5].

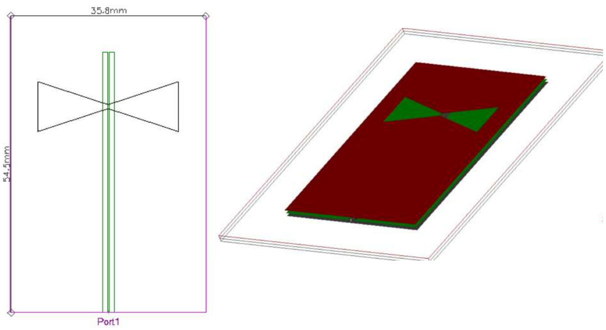
A crucial role in the overall design of the microwave tomograph system is given by the antenna, whose physical size should be small enough to fit the compact constraint of the microwave imaging system, not so easy to satisfy due to the low operating frequency range (typically around 2 GHz). Many additional challenges are required to imaging antennas, which are demanded to radiate into a dispersive (biological) medium for possible in-depth inspection, thus prescribing an optimization design to properly work close to the human body.

A specific antenna configuration is proposed in this work to fit all the above issues, while guaranteeing also additional features in terms of polarization, unidirectional pattern and potential broadband operation.

2. Antenna Configuration

The proposed antenna layout is illustrated in Fig. 1. It consists of a multi-layer structure, with a bow-tie radiating slot excited by a coplanar stripline. This specific configuration leads to simultaneously satisfy a number of requirements imposed by the microwave tomography applications, namely:
- vertical linear magnetic polarization;
- unidirectional pattern, with one-side radiation and ability to reject external noise fields.

As a further important feature, the adoption of bow-tie geometry leads to achieve broadband operation [6], thus compensating for possible frequency shifts, caused by realization and/or operation errors, while opening also to multifrequency and/or ultra-wideband microwave imaging applications.



(a) (b)

Figure 1. Proposed antenna configuration: (a) front-view, (b) 3-D view.

The dielectric substrate for both the feeding and the radiating layer is fixed to Rogers Duroid 880 (ε_r =2.2, $\tan\delta$ = 0.0009) with 0.762mm thickness. The antenna is designed to radiate into a biological medium with parameters ε_r =23 and $\tan\delta$ = 0.05. This leads to a significantly compact size (see dimensions in Fig. 1(a)) at the design frequency around 2 GHz.

To avoid spurious radiations as well as magnetic effects due to the proximity of the magnetic field in the microwave tomography system, the antenna layout is specifically modified to host a feeding line external to the microwave tomograph, as illustrated in Fig. 2, with an elongation of about 30 cm.

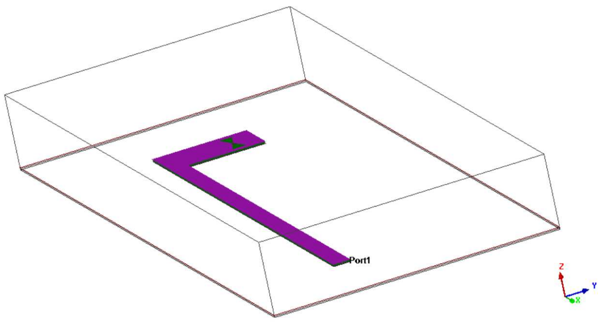


Figure 2. Final antenna configuration for microwave tomography applications.

3. Numerical and Experimental Results

The proposed antenna configuration is designed, realized and experimentally tested into ERMIAS Laboratory at University of Calabria. A photograph of the antenna prototype corresponding to the original layout of Fig. 1 is illustrated in Fig. 3, where the measured return loss (in air) is also reported. As the antenna is designed to have an optimized behavior when radiating into the biological medium, a non-optimum matching condition can be observed at the resonance frequency.

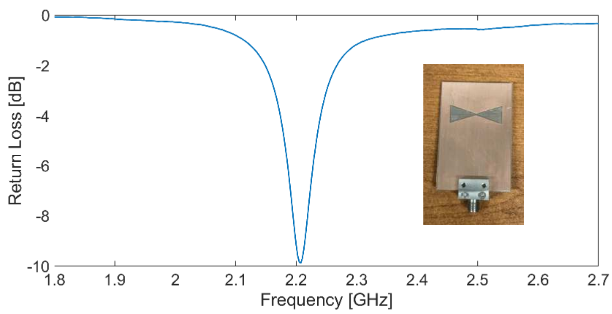


Figure 3. Measured return loss of realized prototype of antenna layout in Fig. 1.

A set of 8 antennas in the final configurations of Fig. 2, to be adopted in the microwave tomography system designed in cooperation with IREA-CNR (Naples, Italy), is also realized and preliminary tested (in air) into ERMIAS Laboratory at University of Calabria (Fig. 4). The simulated return loss of the final antenna layout in Fig. 2 when radiating in the presence of the biological medium confirms the optimum matching condition around 1.9 GHz (Fig. 5).

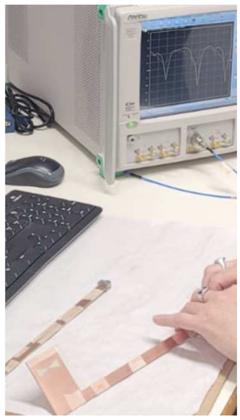


Figure 4. Setup of return loss measurements (in air) into ERMIAS Laboratory at University of Calabria for the realized prototypes of antenna layout in Fig. 2.

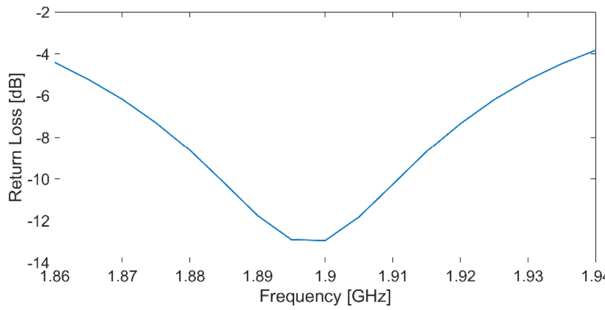


Figure 5. Simulated return loss (Ansys software) for antenna layout in Fig. 2, radiating into a biological medium with parameters ε_r =23 and $\tan\delta$ = 0.05.

Future work will be addressed to the experimental validation of the antenna prototypes immersed in the biological phantom, when assembled into the microwave tomography system.

4. Acknowledgements

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