Dielectric Characterization of Small Breast Biopsy Via Miniaturized Open-Ended Coaxial Probe

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***Abstract*— The classification between normal and malignant tissues based on the use of an open-ended coaxial probe reveals an advantageous rapid support to traditional biopsy. The present work proposes an assessment of small biopsy breast dielectric characterization with our custom-designed open-ended coaxial probe. To this end, this study was accomplished by means of numerical simulations; results were confirmed by experimental measurements, performed at the University Hospital in Toledo.**

***Keywords—open-ended coaxial probe; dielectric properties; breast biopsy; non-invasive measurements;***

1. INTRODUCTION

Breast cancer is the leading cause of death in women worldwide [1]. To characterize any suspicious radiological findings discovered through traditional imaging, each medical breast unit employs a variety of biopsy techniques and laboratory analysis methods. However, they have several limitations: biopsied tissues can be acquired incorrectly due to the difficulties of the technique and waiting times for pathology results may be long. To overcome these limitations, systems based on the use of an open-ended coaxial probe for early diagnosis are becoming available; representing an advantageous rapid support to traditional biopsy but with the added benefit of real-time results.

Several works [2] have stated differences in the dielectric properties between normal and malignant tissues: the malignant contains a quantity of water more than normal ones; thus its dielectric values are generally higher. Furthermore, extensive literature is based on the open-ended coaxial probe used for the dielectric characterization of healthy and malignant breast tissue[3], [4], due to its simple use and no sample preparation.

As far as we know, a research employing real biopsy samples has never been conducted, as the operating principle of the open- ended coaxial probe is based on semi-infinite sample size. However, in the case of biopsy, the dimension cannot clearly satisfy the latter hypothesis, due to its very small size (in the order of millimeters). In our previous work [5], we have inferred that to obtain accurate dielectric properties results, the minimum sample size be equal to 14 mm. On the other hand, breast biopsy tissues may be smaller.

To fill this gap in the open literature, we propose a systematic work to assess whether it is possible to characterize smaller breast biopsy tissues with our custom-designed open-ended coaxial probe [6]. This research was accomplished by means of numerical simulations, and results were confirmed by experimental measurements, performed at the University Hospital (formerly named Virgen De La Salud Hospital) in Toledo, Spain.

1. MATHERIALS AND METHODS

We previously designed an optimized open-ended coaxial probe, with a small diameter to guarantees high accuracy in the detection of both healthy and malignant tumor tissue [5], [6]. To obtain the minimum optimal size of the biological specimen, a numerical analysis has been performed with CST Studio Suite (Dassault Systems) (Figure 1). Since the biological tissues are not stiff, the effect of probe insertion depth has been evaluated.

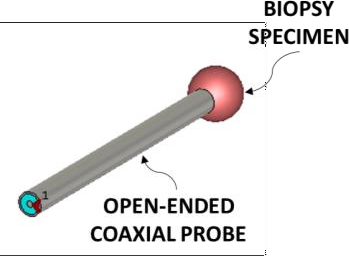


Figure 1. 3D Numerical CST Model of the open-ended coaxial probe put in contact with the breast spherical numerical phantom.

A spherical numerical phantom has been designed by taking into account the dispersive properties of malignant breast tissue [7]. Its diameter has been fixed to 4 mm (the minimum realistic biopsy size), while the insertion depth ranged from 0.1 to 1 mm. The numerical tests have been performed in the frequency range between 10 MHz and 3 GHz.

1. NUMERICAL AND EXPERIMENTAL RESULTS

By applying our in-house reconstruction algorithm based on the equivalent analytical probe model, namely Virtual Transmission Line Model (VTLM) [6], to the numerical reflection coefficients, we reconstructed the dielectric properties. In Figure 2, it is possible to observe that the spherical

specimen curvature radius affects coupling with respect to the probe. Thus, generates errors in the reconstruction of the dielectric parameters. Nevertheless, by ensuring minimal insertion of 0.3 mm, it is possible to achieve an accurate and faithful dielectric characterization of spherical specimens with a minimum diameter of 4 mm.



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| --- | --- | --- | --- |
| **Dielectric Properties:**  **SAMPLE I** | **Literature Model** [7] | **Numerical:**  **0.3 mm insertion (Figure 2)** | **Experimental Measurements** |
| **ε'** | 60.85 | 59.95 | 61.74 |
| **σ** | 1.29 | 1.28 | 1.36 |
| **Dielectric Properties:**  **SAMPLE II** | **Literature Model** [7] | **Numerical:**  **0.3 mm insertion (Figure 2)** | **Experimental Measurements** |
| **ε'** | 60.85 | 59.95 | 58.92 |
| **σ** | 1.29 | 1.28 | 1.36 |

TABLE I. DIELECTRIC PROPERTIES AT 1 GHZ:





(a)



(b)

1. CONCLUSIONS

In this work, we have proposed an assessment of the minimum biopsy breast size that can be characterized via our custom-designed open-ended coaxial probe. To this aim, we first performed some numerical simulations to find the optimal probe positioning. Finally, we have validated the numerical results by means of experimental measurements; such results are in good agreement. Further experimental results will be presented at the



Figure 2. Dielectric properties extracted from numerical reflection coefficients:

(a) real part of dielectric permittivity of malignant breast tissue; (b) conductivity of malignant breast tissue.

The last part of our work was devoted to the validation of the numerical results through experimental measurements; they have been performed in collaboration with medical staff in the context of the Mammowave clinical trials at Radiology Breast Unit Department of University Hospital (Toledo, Spain).

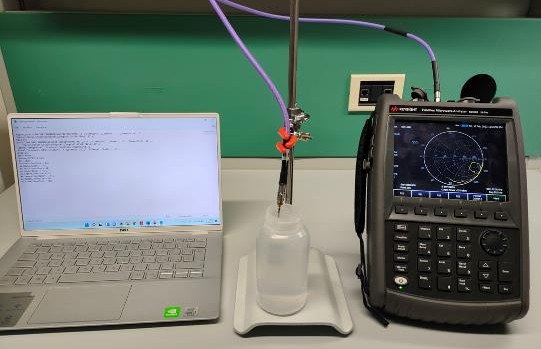


Figure 3. Experimental measurements setup.

To assess the functioning of our custom-designed open- ended coaxial probe for the characterization of small breast biopsy samples, an experimental protocol was designed in accordance with medical staff. The reflection coefficients measurements were carried out using our custom-designed open-ended coaxial probe connected to a calibrated VNA (N9918A-FieldFox).

During the measurements (Figure 3), the coaxial probe was slightly pressed against the samples under investigation, to ensure optimal probe tip-to-tissue contact. The dielectric properties measurements were performed in the range of 0.5GHz–9GHz and were taken within 2-3 minutes following the biopsy excision. Example of measurements performed on two different malignant breast tissue biopsies are shown in Table I.

In Table I, it is possible to observe a good agreement between experimental measurements, full-wave numerical simulations and literature model [7]. Additional experimental results will be provided at the conference.

conference.

Future developments will be devoted to evaluating the feasibility use of an open-ended coaxial probe as a support technique for biopsy procedure.

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