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Impact of Antenna Configuration and Artefact Removal Algorithms for Axillary Microwave Imaging

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Abstract

Microwave Imaging (MWI) has been studied to aid breast cancer staging through the detection of Axillary Lymph Nodes (ALNs) metastasised by breast cancer. The anatomy of the axillary region imposes a limited angular view on MWI prototypes which may hinder artefact removal performance and, consequently, a correct detection of ALNs. In this initial study, we compare different antenna configurations for axillary MWI, while evaluating the performance of different artefact removal algorithms. The imaging results highlight the importance of choosing an optimal combination of antenna configuration and artefact removal algorithm for accurate target detection.

1 Introduction

In 2020 alone, 2.26 million new cases of breast cancer were diagnosed, making breast cancer the most incident cancer in the world [1]. Breast cancer commonly metastasises to the Axillary Lymph Nodes (ALNs), and so imaging the axillary region is crucial for better breast cancer diagnosis. Current diagnosis include the use of imaging techniques and biopsy analysis. Literature indicates that sensitivity and specificity of the imaging modalities are insufficient, and inconsistently reported [2]. Biopsy remains the gold standard diagnosis technique, reaching values of specificity and sensitivity of 100% and 90%, respectively [3], despite the fact that it is both invasive and time-consuming.

Microwave Imaging (MWI) has been the object of significant research in the area of breast cancer screening. It offers several advantages compared to other modalities, namely it is non-invasive, uses low power and non-ionising radiation, and it is potentially low cost. Our group has addressed the potential of using microwave imaging to screen the axillary region. Godinho et al. [4] and Savazzi et al. [5] performed studies on experimental prototypes of the axillary region with anatomically realistic phantoms using a cylindrical antenna configuration. Pato et al. [6] also evaluated different algorithms for a 2D model of the axillary region with a planar set of antennas. There are still some challenges in the development of an experimental axillary imaging MWI device, namely the study of the more suitable antenna configuration, which is of outmost importance.

In this paper, we aimed to evaluate the impact of antenna configurations on imaging results of the axillary region, while comparing the potential of different artefact removal algorithms. The considered antenna configurations were defined with different spatial distributions around an anatomically realistic model of the axillary region and imaging results with simulated signals were evaluated.

2 Methodology

2.1 Numerical models and simulation

One of the Magnetic Resonance Imaging-based axillary region models presented in [7] was used to simulate the axillary region using an FDTD electromagnetic simulator developed in MATLAB. This simulator is called CASE, is accelerated by NVIDIA GPU-cards, and was shared by the Translational Medical Device Lab from the University of Galway. An approximate ALN shape was considered and placed in different positions considering the ALN depth modeled in [4]. We tested and compared four antenna configurations as shown in Fig. 1: two semicircles (one larger and one smaller), a planar set of antennas and a subset with antennas following the shape of the axillary region, i.e. parallel to the skin. The antennas were simulated as ideal source points emitting an Ultra-WideBand (UWB) pulse with a central frequency of 4 GHz.

2.2 Imaging algorithms

Two artefact removal algorithms developed for time-domain monostatic signals were used: the Wiener filter [8] and the Entropy-based time window algorithm [9]. The Wiener Filter algorithm applies a compensation to each antenna artefact waveform, due to possible antenna-to-antenna variations caused by variations in skin thickness, breast heterogeneity and differences in the distances between the antennas and the skin. The artefact of each recorded signal is calculated as a filtered combination – hence the name of the algorithm – of the signals from all other antennas. While the Wiener filter algorithm requires prior knowledge about the time interval in which the skin

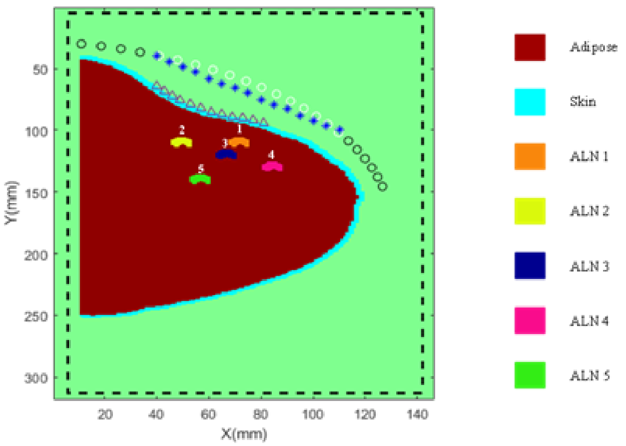

Figure 1. Homogeneous axillary model, with skin, adipose tissue and five ALNs (different colour and number). The antenna configurations are distinguishable by the marker (circle, asterisk and triangles). For the circle set, two subsets were created, using all the antennas or using only the antennas in white.

artefact is present, the Entropy Based Time Window delivers an alternative that does not require prior information and no distortion happens to the artefact removed signals. In this algorithm, the window is calculated from the entropy value between the different recorded signals. After the skin response was removed from the signals, the Delay and Sum [10] algorithm was used as the image reconstruction algorithm.

3 Results and Discussion

Figs. 2 and 3 show the imaging results using the two artefact removal algorithms and three of the four different antenna configurations with two ALN positions. The results of the remaining ALNs will be shown during the conference.

Regarding the antenna set that has antennas in direct contact with the skin, the differences in skin response between antennas were significantly larger compared to the other three antenna configurations which suggests the algorithms fail to accurately remove the skin response. The imaging results for the configuration with the antennas touching the skin were either zero or had the maximum response located in the vicinities of the skin. For that reason, the results are not shown.

The remaining imaging results show that both the antenna configuration and algorithm used have an impact on the detection of the target. A good detection of the target with some clutter is observed in most tested scenarios. A more comprehensive analysis of other artefact removal algorithms, antenna configurations and imaging scenarios will be shown during the conference.

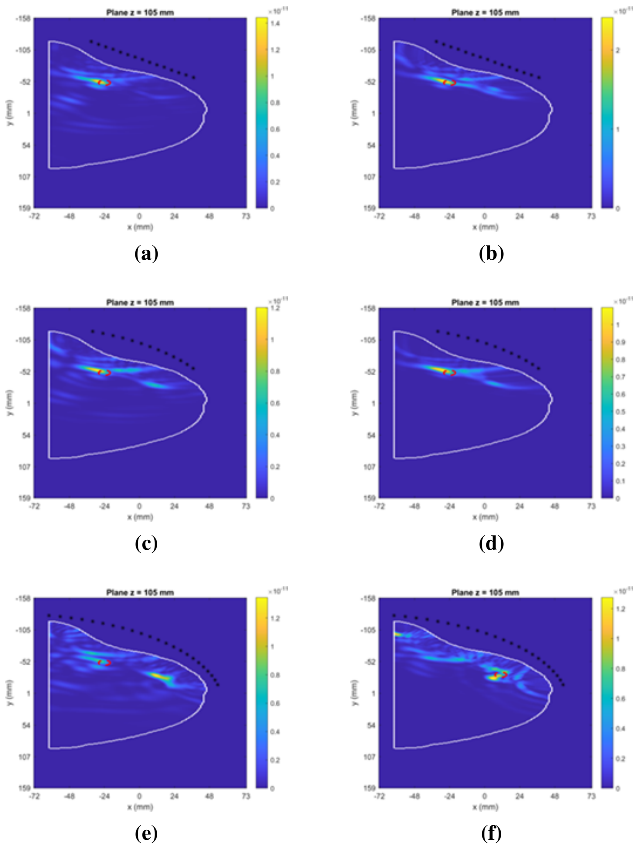

Figure 2. Reconstructed images of the axillary region model with ALN 2 using the (a,c,e) Wiener filter and (b,d,f) entropy-based time window artefact removal algorithms. Each line corresponds to a different antenna configuration. The dashed red circles indicate the true location of the ALN. The white line corresponds to the skin contour. The black asterisks denote the position of the antennas.

4 Conclusions and future work

In the present study, we assessed the impact of using different antenna configurations and artefact removal algorithms in the target detection for axillary MWI. We observed the artefact removal algorithm, the chosen antenna configuration and target depth influence the quality of the detection. Thus, more systematic analysis is needed to find the optimal combination for axillary MWI.

Future work comprises testing of different numbers of antennas, other possible antenna configurations, and additional artefact removal algorithms, as presented in [4].

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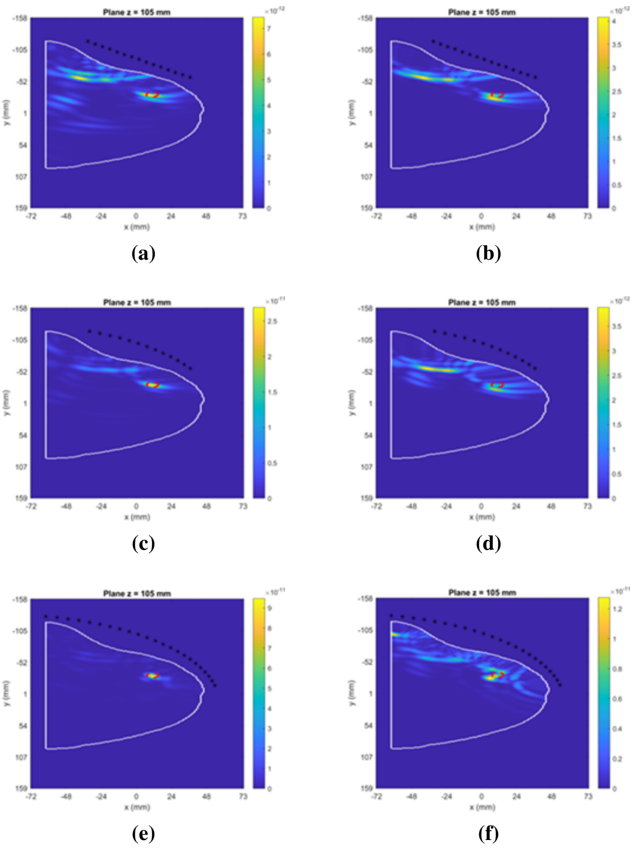

Figure 3. Reconstructed images of the axillary region model with ALN 4 using the (a,c,e) Wiener filter and (b,d,f) entropy-based time window artefact removal algorithms. Each line corresponds to a different antenna configuration. The dashed red circles indicate the true location of the ALN. The white line corresponds to the skin contour. The black asterisks denote the position of the antennas.

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