# *Initial Study for Detection of Multiple Lymph Nodes in the Axillary Region Using Microwave Imaging*

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***Abstract*—Breast cancer staging largely depends on the evaluation of whether there are cancer cells in the axillary lymph nodes. This work proposes a non-invasive method of detecting metastases in the lymph nodes using an Ultra-Wideband Microwave Imaging radar system. Energy profiles of the axilla are created with this system in which high energy regions may indicate the presence of cancer cells in the nodes.**

**Index Terms—Microwave Imaging, Breast Cancer Diagnosis, Axilla Imaging, Ultra-Wideband, Lymph nodes, Sentinel Node.**

## I. Introduction

Breast cancer is the most common type of cancer among women all over the world. An important issue that is not commonly addressed in breast cancer imaging literature is the importance of imaging the underarm region – where up to 80% of breast cancer cells can metastasise to [1, 2]. The first axillary lymph nodes to receive drainage from the primary tumour in the breast are called Sentinel Nodes. If cancer cells are found in the Sentinel Node it is more likely that metastases have spread to other organs in the human body [3]. Therefore, this evaluation is crucial to decide what follow-up exams and therapy to follow.

Neoadjuvant (*i.e.* pre-operative) analysis of axillary lymph nodes is of extreme importance to the complete diagnosis of breast TNM staging (T relates to the tumour size, N relates to the number of lymph nodes that have been metastasised, and M relates to whether the tumour has been metastasised to other parts of the body [4]). Non-invasive detection of cancer cells in the lymph nodes is often inconclusive [5-7], leading to the surgical removal of too many nodes which causes adverse side-effects for patients. Consequently, it is very important to keep improving the current techniques for diagnosis and therapy, as well as exploring new techniques that will ultimately improve the quality of life of patients diagnosed with breast cancer.

Microwave Imaging is one of the most promising imaging modalities for breast cancer early screening and monitoring. This technique is based on the fact that malignant tissues have different dielectric properties when compared to healthy tissues. Also, Microwave Imaging presents several advantages compared to other imaging systems, namely the fact that it uses non-ionising radiation, it is non-invasive, it is potentially low-cost and can be portable.

## II. Methods

The present study tests the feasibility of imaging the axilla region by means of an Ultra-Wideband Microwave Imaging radar system. This approach involves illuminating the axilla with an Ultra-Wideband pulse, and recording the resulting backscattered signals. Subsequently, these recorded signals are processed: firstly a skin artefact removal is applied to remove the skin reflection; secondly a beamformer is used to spatially focus the backscattered signals so that returns from high scattering regions (*e.g.* metastasised lymph nodes) add coherently and returns from clutter add incoherently; and thirdly an image of the dielectric scatterers in the axilla is created [8-10]. There is a significant amount of novelty in this work as Microwave Imaging of the underarm region has never been attempted before.

## III. Results

In this work, simulations of a Microwave Imaging system are completed in several 2D underarm phantom models that mimic the axilla (example in Figure 1). Initial imaging results are obtained (an example is shown in Figure 2, more imaging scenarios will be tested and provided during our presentation) by using several image beamforming algorithms. The quality of the resulting images is compared by visual inspection and through the following performance metrics (Table 1): Signal-to-Clutter Ratio (SCR), Signal-to-Mean Ratio (SMR), Max-to-Max Ratio (MMR), Full Width Half Maximum (FWHM) and $L_{error}$. SCR is the ratio between the maximum metastasis response and the maximum clutter response, SMR is the ratio between the maximum metastasis response and the average energy of all other tissues, MMR is the ratio between the maximum metastasised lymph node response and the maximum response from healthy lymph nodes, FWHM expresses the physical extent of the metastasised lymph node response, and $L_{error}$ is the difference between the location of the metastasis peak response and the actual location of the metastasised lymph node.

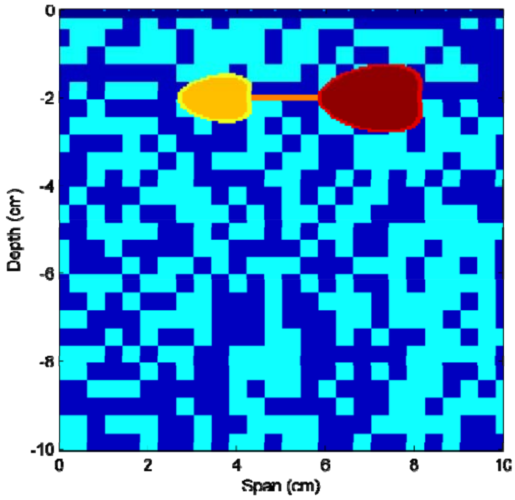


Fig. 1. Numerical phantom of the axilla, consisting of a layer of skin, a 15 mm long healthy lymph node (2 cm under the skin, represented in yellow), a 22 mm long metastasised lymph node (2.0 cm under the skin, represented in red), and heterogeneous tissue surrounding the lymph nodes.

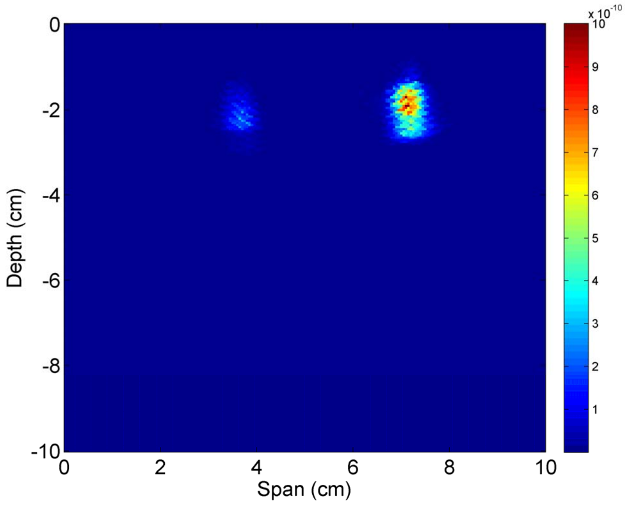


Fig. 2. Energy profile of the axilla that results from the implemented Microwave Imaging system using an Adaptive Filtering skin artifact removal and a Channel-Ranked Delay Multiply and Sum beamformer. The region of higher energy indicates the location of the metastasised lymph node.

Table 1 – Performance metrics.

| SCR (dB) | SMR (dB) | MMR (dB) | FWHM (mm) | $L_{error}$ (mm) |
|---|---|---|---|---|
| 3.02 | 26.87 | 5.01 | 5.00 | 3.5 |

## IV. Conclusion

This study aimed to provide a proof-of-concept for the application of Microwave Imaging as a method to detect and evaluate lymph nodes as a complementary imaging modality to diagnose breast cancer. The results in this study showed that Microwave Imaging is a promising non-invasive technique that has the potential to identify the presence and location of metastasised cancer cells in axillary lymph nodes. These results support the fact that Microwave Imaging might be used as a complement to the breast examination, allowing for a more complete diagnosis in terms of its TNM staging and adequate follow-up treatment. This technique can avoid health risks that result from the unnecessary extraction of healthy lymph nodes (most significantly lymphedema) which can prevent breast cancer patients from living a normal life. Additionally, the health system would also benefit from this new imaging technique. On the one hand, a more personalised healthcare will be offered, both in terms of diagnosis with better specificity and sensitivity, and also by allowing patients to be offered the most adequate therapies. On the other hand, personalised healthcare will ultimate reduce the financial burden on both patients and national health schemes as costs of follow-up medical visits and additional therapies can be significantly reduced.

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