NON-INVASIVE NEAR-FIELD MICROWAVE DETECTION OF BREAST CANCER

Submitted by

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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ABSTRACT

The spread of breast cancer worldwide and the need for new technologies to improve breast cancer detection present a challenge to the standard medical screening methods. Tumour detection, in the early stages, is crucial if patients are to be treated effectively and with minimally invasive procedures. Thus, any technique that can improve on, or add to, existing breast tumour detection methods is welcome. In this thesis just such a technique based on near-field microwave imaging is investigated, both theoretically and experimentally. The electromagnetic waves interaction with dielectric structure is fundamental for any microwave application. Thus it is essential to understand the interaction of the microwaves radiated from the sensor (open-ended rectangular waveguide) with the breast structure under investigation.

A detailed mathematical model describing the interaction of microwaves emitted from an open rectangular wave-guide with an N-layer dielectric structure is developed, using the Fourier Transform Matching method. The model is capable of calculating the electric field properties anywhere within the N-layer structure, as well as the complex reflection coefficient existing at the waveguide aperture.

Computer simulations, based on the mathematical formulations derived using the Fourier Transform Matching method, of the near-field radiation patterns in a 3-layer approximation to the general N-layer model are presented. Such simulations are most useful in assessing the suitability of near-field microwave non-invasive testing and evaluation (NIT&E) technique for breast tumour detection. In addition, simulated 1-D and 2-D reflection phase and magnitude images are calculated and presented for the 3-layer structure with an inclusion to represent the presence of a tumour. Parameters controlling the detection sensitivity, specifically the frequency of operation, waveguide filling, and standoff distance dielectric filling, are investigated to obtain the optimal

parameters for the inspection system. The theoretical simulations show that a high sensitivity in both reflection coefficient magnitude and phase should be obtainable.

Experimental measurements of the reflection coefficient magnitude and phase when imaging a breast phantom that imitates real breast dielectric properties contrast are also presented. The phantom comprises a plexiglass container filled with soybean oil to represent normal breast tissue, with a small balloon filled with diacetin solution to represent the tumour. Both uncalibrated and calibrated measurements of reflection coefficient magnitude and phase were performed. The microwave source comprised an open-ended rectangular waveguide operating in the frequency range of approximately 8.2 to 12.4 GHz. Calibrated measurements were performed using a slotted waveguide system. An in-depth analysis between calibrated measurements and simulation results for a simple dielectric structure is illustrated to verify the simulation results. Then, calibrated measurements for breast phantom are obtained. Finally, a theoretical-versus-experimental qualitative assessment for the breast phantom verifies the mathematical model developed in the thesis. Thus, a near-field microwave non-invasive detection prototype is designed to experimentally detect tumour presence via measuring the sensor's aperture reflection coefficient.

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