UNIVERSITI TEKNOLOGI MARA

DESIGN AND DEVELOPMENT OF A MICROWAVE IMAGING SYSTEM FOR EARLY DETECTION OF BREAST CANCER

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ABSTRACT

Breast cancer is a major global health issue and a leading cause of mortality among women. Early detection is crucial for improving survival rates, but conventional imaging methods such as mammography and MRI are limited by high costs, accessibility issues, patient discomfort, and radiation exposure. This study focuses on developing a microwave imaging system as a safer, cost-effective, and accessible alternative for early breast cancer detection. In this research, two antennas: a basic wideband antenna and a modified compact wideband antenna (CWA) were developed. The modified compact wideband antenna (CWA) was designed by incorporating notching staircase shape, stublines, and counter-backed co-planar waveguide (CBCPW), that operates between 1.85 GHz and 8.37 GHz. With a 43 × 43 mm^2 dimension and a maximum gain of 5.27 dB, the antenna offers omnidirectional radiation patterns. Simulations demonstrated its strong performance in the time domain at face-to-face, side-by-side x and y -axis angles, confirming its ability to produce clear images. A homogenous breast phantom (HBP) was created from materials based on glycerin oil to replicate human breast tissue properties for imaging validation. The semi-hemispherical breast phantom with a 140 mm diameter and 70 mm height, embedded with cylindrical tumours with a 6 mm diameter and 20 mm height, was used to evaluate the tumour detection capabilities of the system. Experimental works were carried out with the phantom containing single or two tumours to evaluate system performance. The imaging system integrates an RF switching circuit to connect, control and manage eleven antenna configurations, ensuring efficient signal acquisition and minimal signal loss. The switching circuit was developed using single pole eight throw (SP8T) RF switching module with Arduino Nano as the microcontroller, producing a compact size circuit of 60 × 70 mm^2. Image reconstruction was performed using microwave radar-based imaging toolbox (MERIT), a MATLAB-based software, successfully detected single or two tumours with high accuracy, validating the effectiveness of the system. This study shows the potential of microwave imaging as a safe and accessible method for early breast cancer detection. The work contributes through the design of a compact wideband antenna (CWA), the development of a compact RF switching circuit, and the application of time-domain analysis with MERIT for image reconstruction. These elements improved imaging quality and tumour detection in phantom experiments. The findings provide a basis for further refinement of the system and future clinical validation to supports practical use.

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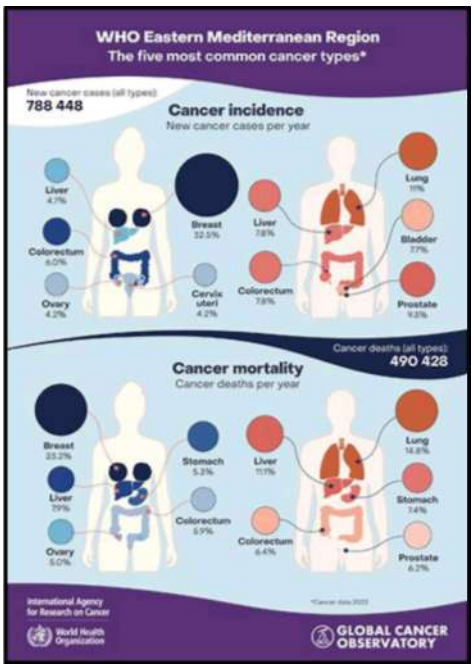
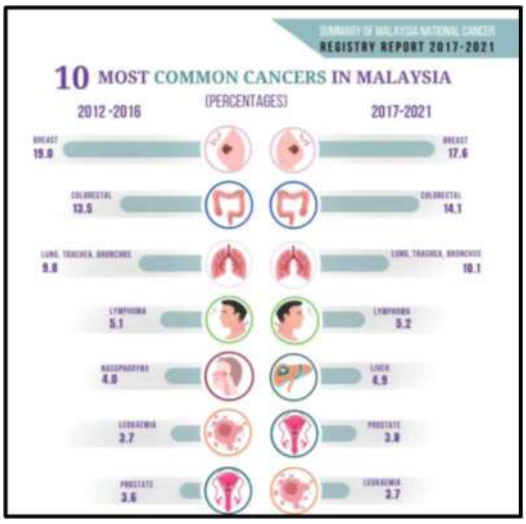
INTRODUCTION

1.1 Research Background

Cancer remains one of the most significant health challenges worldwide, contributing substantially to mortality rates across populations [1]. Fundamentally, cancer is a disease resulting from uncontrolled cell growth. In living organisms, cellular processes, including deoxyribonucleic acid (DNA) mutation, are crucial for survival as they enable cell growth, differentiation, and programmed death. However, when a group of abnormal cells grows uncontrollably, disregarding the normal rules of cell division, cancer develops. This uncontrolled growth disrupts normal cellular processes, leading to the production of proteins that disturb cellular balance within the body and form tumours. If these tumours metastasize, or spread throughout the body, they can become fatal.



(a)



(b)

Figure 1.1 Cancer Statistic By (a) World Health Organization (WHO) [2], and (b) National Cancer Institute of Malaysia [3]