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UNIDIRECTIONAL WIDEBAND ANTENNA WITH IMPROVED CIRCULAR PARASITIC ELEMENT FOR MICROWAVE BREAST IMAGING APPLICATIONS

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DOCTOR OF PHILOSOPHY

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Faculty of Electronics and Computer Technology and Engineering

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A thesis submitted
in fulfillment of the requirements for the degree of
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DEDICATION

Dedicated to ALLAH Almighty, my loving husband, parents and all my family's members for your infinite and unfading love, sacrifice, best wishes, patience, and encouragement.

ABSTRACT

Early cancer detection, especially in the breast, is crucial due to its asymptomatic nature. Intricate measurement techniques are essential for accurate cancer identification, with the antenna being a key element. Ideally, it should be flexible, unidirectional, wideband, lightweight, and compact compared to previous research, improving antenna performance for precise measurements in breast cancer detection using a radar-based approach. The research aims to create a unidirectional, interference-avoiding, wideband antenna using flexible material. It presents a co-planar waveguide (CPW) wideband antenna with felt material for the 3 GHz to 7 GHz frequency range, incorporating a double-layer reflector for enhanced unidirectionality and flexibility. To confirm the antenna's performance, a model of a breast (breast phantom) was created and assessed, achieving a safe SAR level below 1.65 W/kg at a 10 mm distance. In microwave breast cancer detection, strict limitations on antenna size exist to accommodate the limited breast area, requiring a maximum typical diameter for unidirectional radiation and signal distortion suppression. The proposed antenna, enhanced by a double-reflector element, exhibited improved performance, broad 3.06 GHz to 7.0 GHz bandwidth, with measurement result of directivity (6.98 dBi), FBR (9.81 dB), and gain (5.44 dBi).The antenna and breast phantom, connected to a vector network analyzer, utilized a MATLAB algorithm (modified Delay and Sum imaging) for signal processing and image reconstruction. They successfully detected five diferent sizes of breast cancer with outstanding measurement responses, including cancers as small as 1milimeter, consistent with simulation results.

ANTENA JALUR LEBAR EKAARAH DENGAN ELEMEN PARASITIK BULAT YANG DIPERTINGKAT UNTUK APLIKASI PENGIMEJAN PAYUDARA MENGGUNAKAN GELOMBANG MIKRO

ABSTRAK

Penemuan kanser awal, terutamanya dalam payudara, adalah penting disebabkan sifatnya yang tidak menunjukkan gejala. Teknik pengukuran yang rumit adalah penting untuk pengenalpastian kanser yang tepat, dengan penggunaan antena sebagai kunci utama. Idealnya, antena seharusnya mudah lentur, satu arah, berjalur lebar, ringan, dan kecil berbanding dengan penyelidikan terdahulu, dapat meningkatkan prestasi antena untuk pengukuran yang tepat dalam pengesanan kanser payudara menggunakan pendekatan berdasarkan radar. Kajian ini bertujuan untuk mencipta antena satu arah, mengelakkan gangguan inteferens, berjalur lebar dengan menggunakan bahan mudah lentur. Ia mempersembahkan antena jalur lebar pandu gelombang co-planar (CPW) untuk julat frekuensi 3 GHz hingga 7 GHz, digabungkan dengan lapisan dua elemen pemantul untuk meningkatkan antenna satu arah dan kelenturan. Untuk mengesahkan prestasi antena, model payudara (phantom payudara) dicipta dan dinilaikan, mencapai tahap SAR selamat di bawah 1.65 W/kg pada jarak 10 mm. Dalam pengesanan kanser payudara menggunakan gelombang mikro, terdapat batasan ketat pada saiz antena untuk menyesuaikan kawasan payudara yang terhad, memerlukan diameter tipikal maksimum untuk radiasi satu arah dan mengelakkan gangguan inteferens. Antena yang dicadangkan, ditingkatkan oleh elemen pemantul berganda, menunjukkan prestasi yang lebih baik, mempunyai julat frekuensi 3.06 GHz hingga 7.0 GHz yang luas, dengan keputusan pengukuran di mana pengarahan (6.98 dBi), FBR (9.81 dB), dan gandaan (5.44 dBi). Antena dan phantom payudara, yang disambungkan ke analisis rangkaian vektor, menggunakan algoritma MATLAB (pemprosesan isyarat Tangguh dan Jumlah yang diubahsuai) untuk pemprosesan isyarat dan pembinaan imej. Ia berjaya mengesan lima saiz kanser payudara yang berbeza dengan respon pengukuran yang cemerlang, termasuk kanser sekecil 1milimeter, sejajar dengan hasil simulasi.

ACKNOWLEDGEMENT

In the Name of Allah, Most Merciful, Most Gracious,

Above all, I express my gratitude to ALLAH for granting me the strength and courage to complete this thesis, bestowing the opportunity, courage, and patience for this endeavor. I feel honored to glorify His name through this small achievement.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CMI	-	Confocal Microwave Imaging
CPW	-	Coplanar waveguide
CST	-	Computer Simulation Technology
DAS	-	Delay-and-Sum imaging
DMAS	-	Delay Multiply and Sum
EDAS	-	Enhanced Delay and Sum
EM	-	Electromagnetic
FBW	-	Voltage Standing Wave Ratio
GPR	-	Ground Penetrating Radar
IDAS	-	Improved Delay and Sum
IoT	-	Internet of Things
LHM	-	Left-Handed Metamaterial
mDAS	-	modified Delay and Sum Imaging Algorithm
MRI	-	Magnetic Resonance Imaging
MUT	-	Material Under Test
RBA	-	Radar- Based Approach
RF	-	Radio Frequency
SAR	-	Specific Absorption Rate
SCR	-	Signal to Clutter Ratio
SNR	-	Signal-to-Noise Ratio
SSVA	-	Side Slotted Vivaldi Antenna

OUT	-	Object Under Test
VNA	-	Vector Network Analyser
WB	-	Wideband
WBAN	-	Wireless Body Area Network
WLAN	-	Wireless Local Area Network

LIST OF SYMBOLS

$tan\delta$	-	Tangent loss
ε_r	-	Dielectric constant
λ	-	wavelength

LIST OF APPENDICES

LIST OF PUBLICATIONS

The research papers produced and published during this research are as follows:

1. N. A. Koma'rudin, Z. Zakaria, P.J. Soh, H. Lago, H. Alsariera, N. Hassan, Nornikman, 2020. A Review of Recent Microwave Breast Imaging, *International Journal on Communications Antenna and Propagation (IRECAP).* vol.10 (4). August 2020 0.257. 10.15866/irecap.v10i4.18560.
2. N. A. Koma'rudin and Z. Zakaria and A. A. Althuwayb and Herwansyah Lago and H. Alsariera and H. Nornikman and A. J. A. Al-Gburi and P. J. Soh, 2022. Directional Wideband Wearable Antenna with Circular Parasitic Element for Microwave Imaging Applications. *Computers, Materials & Continua*, vol.72 (1). pp. 983-998.
3. Nur 'Atika Koma'rudin, Zahriladha Zakaria, Ping Jack Soh, Nornikman Hassan dan Mohd Manoj Jumidali, 2023. 'Compact Dual-Layered Wideband Wearable Monopole Antenna with Circular Parasitic Element for Breast Cancer Detection'. *2023 IEEE Symposium on Industrial Electronics & Applications*. pp. 1-6.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent decades, the increasing demand, particularly in military and medical applications requiring tracking, monitoring, and screening, has led to significant advancements in microwaves and radio frequencies (Guan et al., 2018). Microwave imaging represents an innovative scientific technique that has evolved from detection and location methods (such as radar or tomography) to assess objects or structures embedded or hidden in any medium using electromagnetic waves (EM) within the frequency range of ~300 MHz to 300 GHz (Fallahpour, 2013). Two main approaches have been proposed in microwave imaging: microwave tomography, based on the scattered EM field, and the radar-based approach, utilizing short pulses transmitted towards a target with measured scattered fields, as illustrated in Figure 1.1 (Craddock et al., 2008). Most researchers have reported using the radar-based approach, employing a set of antennas to transmit low-power microwave signals into tissues. Backscattered signals are then utilized to generate microwave images, providing information on the cancer's distance from the antenna (Chandra et al., 2015; Khan et al., 2016; Bourqui et al., 2010; Zarnaghi Naghsh et al., 2018; Porte et al., 2016; Zeng et al., 2011; Gibbins et al., 2017).

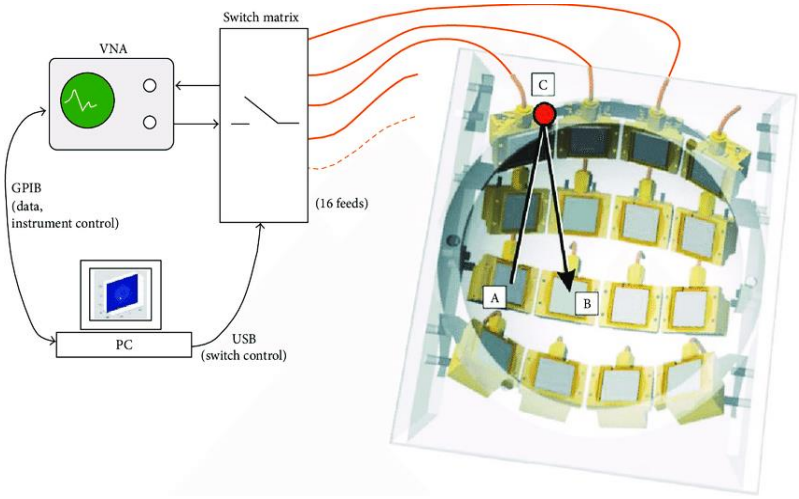

Figure 1.1: Radar – based approach in Microwave Breast Imaging System by Craddock (Craddock et al., 2008)

Due to global advancements and lifestyle changes, diseases are on the rise. In Malaysia, cancer is a significant health concern, causing 19,000 deaths per 100,000 people in 2016. It ranks third after respiratory (18.54%) and circulatory system diseases (22.77%) (my Metro, 2016; mStar, 2016). The most prevalent cancers include breast (14.5%), colorectal (12.1%), lung (11.8%), cervix (5.7%), and throat cancer (5.4%). Breast cancer tops the list for women, while lung and prostate cancer lead among men (Guan et al., 2018). Notably, 30% of breast cancers go undetected by mammography, with a high false-positive rate of around 70% in screening mammograms (Pace et al., 2014; Lazebnik et al., 2007; Chandra et al., 2015; Kwon et al., 2017).

In Malaysia, cancer detection methods often involve painful procedures. X-rays, while effective, emit ionizing radiation with potential harm. Biopsy and bronchoscopy, though accurate, can cause mental trauma. Magnetic resonance imaging (MRI) has limitations, including high costs and equipment size. Microwave imaging (MWI) emerges as a low-cost alternative, offering easy operation, high data rates, and non-invasive, non-