DIRECTIVE ULTRA WIDEBAND ANTENNA FOR MEDICAL APPLICATIONS

HABIB ABDULLAHI MOHAMED

A project report submitted in
Partial fulfilment of the requirement for the award of the
Degree of Master of Electrical Engineering

Universiti Tun Hussein Onn Malaysia

JANUARY2020

DEDICATION

I dedicate this thesis to my family and friends who have supported me during this work process. Special my dear parents: my Mother Barni Abshir Dirie and my Father Haji: Abdullah Mohamed isse, my elder brother Hassan Abdullahi Mohamed and young brother Mohamed Abdullahi Mohamed for their unforgettable love and support, I can't thank you enough but I would like to say my Allah reward you to his paradise.

ACKNOWLEDGEMENT

First and the foremost, I would like to thank Almighty Allah for bestowing His blessings upon me and giving me the strength to carry out and complete this work.

I am extremely grateful to my supervisor Dr. Roshayati Binti Yahya
And Prof. Madya Dr. Noorsaliza Binti Abdullah for their valuable advice, guidance, beneficial discussions and encouragement throughout my research for her valuable academic advice and guidelines, she has been extremely kind, friendly, and helpful.

I am also very grateful to my thesis especially, Mr. Abdul Rashid Omar Mumin, for his helpfulness, cooperation and constructive advices. I am also thankful my friends for their encouragements and various help that they provided to me throughout my graduate studies also faculty of Electrical and Electronic Engineering and all UTHM stuff.

I would like to give my special thanks to my brothers, sister for their support, patience and love. Without their encouragement, motivation and understanding, it would have been impossible for me to complete this work.

ABSTRACT

Since the acceptance of unlicensed band of Ultra-Wideband (UWB) technology in the range between 3.1 and 10.6 GHz, the realization of low-cost UWB wireless systems is considered a fundamental research goal both for military and commercial applications. The possible use and benefits of UWB technology are significant among its potential applications, high-resolution radar and short-range ultra-high speed data transmission. However, one of the most critical challenging task of the UWB system is the designing of a compact size antenna that possess a good gain and high directivity. Thus, the aim of this project is to design and develop a directive and miniaturized antenna for UWB applications. The antenna is designed and fabricated on a Flame Retardant (FR4) laminated substrate with dielectric constant, εr of 4.3 and thickness of 1.6mm. Several numbers of antennas have been carried out throughout the completion of the project. Firstly, an antenna with slots on radiator has been designed. Subsequently, Ground Defected Structure (DGS) is implemented. For increasing bandwidth and impedance matching of the first antenna, thus an antenna with compact dimension of 25×45mm2 has been resulted. Finally, a reflector structure with the distance of 18mm is added for directivity and gain enhancement. The antenna with reflector has been fabricated using etching technique and being measured for the reflection coefficient. As the result, by applying reflector, the directivity and gain of the antenna has increased significantly, from 5.81dBi to 7.06dBi. This showed 21.52% gain improvement of the proposed antenna by implementing reflector. Therefore, the proposed antenna which has compact size and high gain is seen as a suitable candidate for the use of UWB applications.

ABSTRAK

Oleh kerana teknologi Ultra-Broadband (UWB) yang tidak berlesen diterima dalam julat antara 3.1 dan 10.6 GHz, mencapai sistem wayarles UWB kos rendah adalah matlamat penyelidikan utama untuk kedua-dua aplikasi ketenteraan dan komersil. Penggunaan teknologi UWB dan manfaat potensial penting di antara aplikasi potensial, radar ketepatan tinggi dan transmisi data berkecepatan tinggi ultra cepat. Walau bagaimanapun, salah satu tugas yang paling mencabar yang dihadapi oleh UWB adalah reka bentuk antena padat dengan keuntungan yang bagus dan stereng yang tinggi. Oleh itu, matlamat projek ini adalah untuk merekabentuk dan membangunkan antena berarah dan kecil untuk aplikasi UWB. Antena direka dan dihasilkan di atas substrat berlapis api Flame Retardant (FR4) dengan pemalar dielektrik ofr 4.3 dan ketebalan 1.6mm.Beberapa antena telah direalisasikan semasa projek selesai. Pertama, antena dengan slot pada radiator direka. Kemudian, Struktur Kekurangan pada Tingkat (DGS) digunakan. Untuk meningkatkan lebar jalur dan keserasian impedans antena pertama, antena kompak 25 × 45mm2 diperolehi. Akhirnya, struktur reflektor 18 mm ditambah untuk fleksibiliti dan keuntungan yang meningkat. Antena reflektor dihasilkan menggunakan teknik etsa dan diukur untuk pekali refleksi. Akibatnya, dengan menggunakan reflektor, keupayaan dan keuntungan antena meningkat dengan ketara dari 5.81dBi hingga 7.06dBi. Ini menunjukkan kenaikan keuntungan sebanyak 21.52% daripada antena yang disyorkan dengan menggunakan reflektor. Oleh itu, antena yang dicadangkan dengan saiz padat dan keuntungan tinggi dilihat sebagai calon yang sesuai untuk penggunaan aplikasi UWB.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

BW	Bandwidth
CATV	Cable Television
CST	Computer Simulation Technology
EM	Electromagnetic
FCC	Federal Communications Commission
GHz	Gigahertz
GPS	Global Positioning System
MHz	Megahertz
MIMO	Many Input Many Output
MRI	Magnetic Resonance Imaging
MWIS	Microwave Imaging System
PDA	Personal Digital Assistant
S11	Scatter Parameters
UWB	Ultra-Wideband
VNA	Vector Network Analyser

CHAPTER 1

INTRODUCTION

1.1 Research Background

These days the speedy growth of sectors using microwave and radio frequencies brought a lot of changes in our daily life recently. Nowadays the applications of the Ultra-wideband radio technologies has allured increasing attention of the industry also academia, especially in medical and telecommunication applications.[1] [2] [3] an UWB technology antenna is defined as a system(antenna) which its bandwidth is larger than 500 MHz and its operation frequency starts from 3.1GHz ends 10.6 GHz[4].

The UWB technology is firstly aimed at the short-range about four to ten meters [5] and wide bandwidth indoor wireless communication applications. This radio microwave systems technology which has got a low-power consumptions employs a large portion of the EM spectrum and the use of ultra-wideband radio microwave system reduces the data transfer interferences and improves the speed of the transferring data, compared to the other recently used technologies [6].The US Federal Communications Commission (FCC) and also the independent governmental regulator and competition authority for the UK communications industries (Ofcom), regulation for UWB allocates the regulation for the technology that allows for the unlicensed RF operation within the range of 3.1–10.6 GHz, and the transmit power of 41.3-dBm/MHz [6] [7][8]. Ever since the FCC the federal communication Commission FCC has assigned the free licensed spectrum which lies range of 3.lGHz up to 10.6 GHz for commercial applications in 2002[9].Many researchers have been focusing on the wide use of ultra-wide band (UWB) antennas because of applicability

for using in many different applications such as medical issues, military purpose, radar and communication systems, trucking and ground positioning. At present time, a microwave technology for medical applications and imaging system is broadly employed for using health and medical applications such as brain stroke detection, heart failure detection, health monitoring issues and so many other medical applications [10]. The last decays the Ultra-wideband communication technology has got a considerably attention in the world wireless technologies due to many advantages they possess, like high speed data rate, spectral power density, high precision ranging, low cost, non- ionizing, low health risk issues, sensitive to tumors and specific to malignancies, easy integration with monolithic microwave integrated circuits (MMIC) and ease to fabrication [11].

However, one of the major challenges in UWB antenna technology is the Finding a appropriate antenna design for the applications of UWB technology and designing of the compact directional ultra- wideband antenna with a with a reasonable gain and directivity [9].The compact planar antennas are suitable candidates for UWB radio system integration due to the number of merits they possess like, low profile, light weight, possible cost and availability of components that it contains [12].

1.2 Problem Statement

A common method used to cover a large frequency range which encompasses many different communication systems is to employ ultra-wideband microwave radio antennas [13]. The major concept behind Ultra-wide band radio systems is because unlike other conventional communication techniques and schemes these technologies transmit very short duration pulses, those send sinusoidal waves signals [4].

An advantages of using this system for imaging applications is included low power and highly precise image resolutions. The one of the most critical challenging work in the UWB system especially in the medical applications is the designing and developing of a small size antenna with good gain and directivity, because of the antenna size affects antenna's performance such as gain and the directivity. Therefore achieving a design of a small size antenna that can provide high gain and ultra-wide frequency bandwidth at the same time is a big challenging task. Thus coplanar ultra-wide band antenna is a good candidate of this UWB microwave application.

1.3 Objectives

The objective of the project is:

I. To design and simulate a reasonably size UWB antenna for medical imaging.
II. To fabricate antenna and measure it's reflected coefficient (S11)
III. To compare and validate the simulation results with the measurement results.

1.4 Scope of Study

The scope of this project is:

Designing an Ultra-wideband antenna and simulate by using the Computer Simulation Technology (CST) which is radio frequency and microwave simulator software.

- To design and fabricate an UWB antenna by using FR-4 substrate.
- Design will only be measured for S11 by using Vector Network Analyser (VNA).

1.5 Thesis Structure

The study consists of five (5) chapters, which are: introduction, literature review, research methodology result and discussion and finally conclusion and recommendation, sections and details of each chapter are below. This chapter one focuses on introduction of the research topic. It encompasses the research background, the problem statement, project Objectives, scope of work, and Structure and arrangement of Thesis.

The following chapter two discusses the literature review that related to this study from previous researches in addition techniques and principles of UWB antenna that can be used improve antenna performance and application of UWB in different fields has been studied.

Furthermore, chapter three will focus on the research strategies, and research methodology that will be used during this work. Subsequently the obtained results

presented and analysed in chapter four, the findings of the simulations and measurements and results were discussed in this chapter. Finally it also includes the discussion about the result obtained during optimization process. Finally, chapter five presents conclusion and recommendations which were driven by the data analysis and discussion of the findings obtained. The chapter summarizes the entire research work to be conducted where conclusion would be made.

1.6 Chapter Summary

In the above chapter, introduction of antenna specifically the UWB antenna has been outlined, objectives of this work are also stated clearly. The problem statement of this work is identified and the justification of this project is been clarified, followed by the scope of this project and main its main points and finally thesis structure has been mentioned.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is presented some past researches related to this study which is done by other researchers. Although it is mostly considered a new breakthrough in broadband technology and wireless systems, the principle and concept of Ultra-wideband dates back so many years. Firstly UWB technology has allocated for the military and government agencies of U.S., for use of some applications such as covert (low probability of detection and intercept) of communication and radar systems. The recently enhancement of chip development have made the Ultra-wideband technology most valuable for such applications like civilian and commercial usage. The first company that produced Ultra-wide band technology chips in the world was the free scale semiconductor.

2.2 Application of UWB Technology

The federal communication commission, (FCC) has given the name of an ultra-wideband (UWB) any device which possess a fractional bandwidth, greater than twenty percent 20% or in terms of frequency spectrum occupying at least 500MHzz of the spectrum or more than that [4]. As the fractional bandwidth is measured at -10 dB points on either side of the peak emission. Or $(f_u - f_l)/ (f_u - f_l)$, where F u and Fl are the upper and lower frequencies of ultra-wideband antenna respectively. Another words F_u is the 10db upper cut-off frequency and f_l is the 10db lower cut-off

frequency. In 2002 the FCC allocated the frequency band between 3.1Gigaherz and 10.6 Gigahertz for free or unlicensed ultra-wideband transmission.

As mentioned above, the federal communication commission assigned that the range of frequencies for the ultra-wideband techniques, from 3.1GHz to 10.6GHz in United States of America. However, in Europe, the frequencies include two parts: from 3.4 GHz to 4.8 GHz and 6GHz to 8.5 GHz. the power radiation requirement of ultra-wideband is strict and it would not disturb the existing equipment because ultra-wide band's spectrum looks like a background noise [14]. The accepted federal communication commission power spectral density emission limit for UWB emitters operating in the UWBs band is 41.3dBm/MHz [6].

Last decades , great fast enhancements have been experimented on the technology by Employing the UWB signals, Ultra-wideband (UWB) communication systems draw great attention in the wireless world because of their advantages, like high speed data rate, extremely low spectral power density, precision, high precision ranging, low complexity and low cost[11]. UWB technology offer major developments in three wireless application areas: communications, ranging or positioning and radar [4]. This technology (UWB) is also able to deliver through cables and wire lines such as cable television applications. Every one of above mentioned applications shows the specific use of UWB devices.

2.2.1 Communication Systems

The modern wireless communication systems require multiple antennas to operate at various standard applications such as Wi-Fi, GPR, Bluetooth, 3G, and 4G.

However, this results in large volume devices due to using many antennas [15].

The MIMO technology which plays an important role in the today's modern communication systems is the one of the most interested UWB technologies, in the MIMO antenna, multiple antennas are used for data transmission and reception simultaneously which enhances data throughput rate.

This MIMO system can enhance data transmission speed and channel capacity without requiring additional frequency spectrum and power, for the small size and limited space in the modern wireless devices, compact MIMO antenna with high

isolation is required [16]. The use of UWB technology and the available large radio frequency bandwidth, the UWB communication links become possible to achieve. The available of extremely large BW has used as the fundamental of the short distance range wireless local area network (WLAN) which has throughput or date rate that approaching gigabits per second [10].

Since the available on BW is at very low range of frequencies so that an attenuation caused by building materials is remarkably lower for UWB transmissions compared to millimeter wave high bandwidths solution. To achieve better performance, the required emitted power is reduced and path losses are also minimized by operating at low frequencies [17].

The existing of more interference or high level of interferences, UWB radios operate by trading data rate for processing gain. The cause of wide signal bandwidth and low emitted power results a very low spectral power density of the Ultra-wide band signal. That indicates the operating spectrum space of the UWB radios is the same as the space spectrum the narrowband radios on a non-interfering basis. Peripherals of the Computer offers another important applications of the Ultra-wideband technology, specifically whenever the mobility is necessary thus, so may wireless systems are utilized in a shared one space. A mouse keyboard, printer, monitor, microphone, joystick, audio speakers, and also PDA are in wireless, and all sending commands to the same system(computer) from anywhere in that network topology [18].

The UWB technology therefore used as the communication linkage in a sensor network and remote sensors, the UWB sensor network gives the patient freedom to move and frees from the tangle of wired sensors, it's better than wired one in terms of mobility and portability. In addition UWB is used as a communication link in the sensor network. The sensors are being employed in medical conditions to determine a patient temperature, function as a sensor of respiration, heartbeat, and in many cases for medical imaging and other importance life evidences, UWB is used to transport the sensor information by means of wireless therefore the UWB wireless sensor networks is easier than wired ones.

2.2.2 Positioning Systems

The Positioning and location For Global Positioning System (GPS), requires the signals resolution to allow position determination of target object within ten meter, unique techniques are used to enhance more accuracy [19]. Since between bandwidth and precision, there is a direct proportionality, so that increasing bandwidth will therefore increase accuracy of positional measurement and precision. In a satellite communication where the wide bandwidth feeds save weight and space by supporting huge number of transmission channels in one single system (antenna). The structures of the Ultra-wideband for determination of positioned , the UWB systems is similar to the conventional systems, the advanced army location and reporting system allow multiple changes such as GPS or radio combination [20].

The of the positioning systems in UWB are similar to the conventional systems; the advanced army location and reporting system allow multiple changes such as GPS or radio combination.

Possessing very low operation frequency, this kind of system has an ability to work within buildings in countering the lowest attenuation of the signal. With the UWB techniques, it becomes feasible to fuse these unique applicability into only one single system. Therefore, there is a possibility to create communication systems in which position is determined within less than a centimetre, in addition, it is possible to build radars systems that communicate two way simultaneously.

Since the UWB technology exhibits all of these properties while allowing spectrum BW re-use and maintain that little or no interference to be generated between other communication systems.

Though, the UWB emission will boost greatly the performance of an intrusion detection radar precision geo-location system, proximity fuses and secures ground communication transmission links for troops which far outweigh the effect of the Ultra-wide band may have on other systems which are nearby.

2.2.3 UWB Medical Applications

Nowadays, microwave imaging system is largely applied for medical imaging applications like , health monitoring, early-stage breast cancer detection, detect the damaged brain tissue,, heart failure detection, brain-stroke and lung tumor detection and imaging and so on [10][21] [22].

Early detection of the cancer make the treatment process more effective and easier [23] [24]. Besides the ultra-wideband imaging system, there are many methods that can be used for the medical detection issues like the X-ray mammogram, ultrasound and magnetic resonance imaging MRI.

All these techniques uses ionizing radiation and very painful compression is required for the target area of the body (e.g. breast in case of breast cancer detection) [25]. However, X-ray mammography produces a relatively high number of both false negative diagnoses (between 10% and 30%) and false positive diagnoses (more than 5%). Not only that but also to have a good image, X-ray mammography uses radiation that requires uncomfortable compression of the breast during the examination and is of limited value for younger women [26].

In addition, there is an evidence that the ionization caused by X-ray mammography, represents a severe health threat and there is even a chance of ionization causing the cancer to the healthy tissue [27]. Ultrasound method is an alternative detection method and it has some limitations such as, having 17% false negative rate. In addition it is its not easy to detect deep-lying and solid damaged or cancerous tissues. Moreover it is expensive, and Magnetic Resonance Imaging (MRI) method which can produce high-resolution images but is costly and also time consuming during the last decade, microwave-based medical imaging systems and especially ultra (UWB) imaging have been widely exploited and investigated both as a complementary method to the available imaging techniques and as an alternative solution [12].

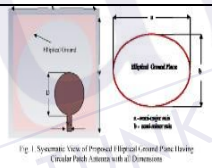
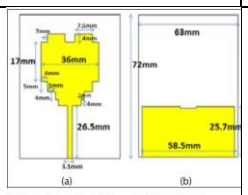
Among the UWB applications. Microwave imaging system (MWIS) is the potential candidate to replace standard screening technology for cancer such as X-ray and magnetic resonance imaging (MRI) technologies due its reduced complexity, high data rate and gain [28] UWB antennas for microwave medical applications (e.g. breast tumor detection, brain tumor detection, health monitoring, cancer detection and so on) have considerable interest in recent years owing to their numerous advantages such as

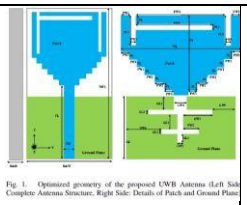
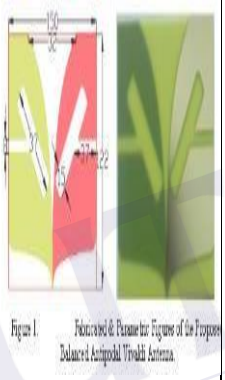
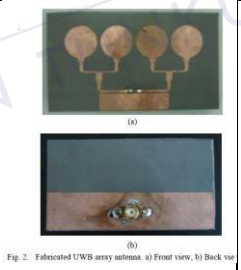
low cost, non-ionizing, low health risk, sensitive to tumors and specific to malignancies, easy integration with monolithic microwave integrated circuits (MMIC) and ease of fabrication.[4]. .

2.3 Some Previous Work Related To This Study

There are some previous works done by other researchers. Here some researches are studded since researchers are the important resources of this study. These give to understand the concept behind this project and give several ways in modify and solve the problems. Table 2.1 shows some previous researches that give the theoretical information that relate to the study.

Table 2.1: The summary of some previous work

	Antenna dimensions	**Method**	**The structure of antenna**	**Results**
[7]	Elliptical Shape Ground Plane Directional Ultra-Wideband Antenna for Microwave Imaging Application ns	In this paper the backside of the substrate an elliptical shaped ground plane is used to improve the directivity.		Here result is high bandwidth, high radiation efficiency, constant group delay and high data rate transmission capability with low power spectral densities and increase of directivity. .
[2]	The antenna size is 63mm x 72mm x 1.6mm. The.	This paper a Defected Ground Structure (DGS) is incorporated in the top and side of the ground plane to enhance the bandwidth.	 Fig. 1 configuration (a) Top view (b) Bottom view	Result here is very large bandwidth range by using the signals in short pulse duration. Clearly, the reduction of the pulse duration increases the down-range resolution.

[30]	Compact Low-profile Ultra-Wideband Antenna for Biomedical Application ns.	This paper the back side of the substrate an elliptical shaped ground plane is used to improve the directivity.is incorporated in the top and side of the ground plane to enhance the bandwidth.		Here results is the bandwidth enhancement, impedance matching and omnidirectional radiation pattern and high gain.
[29]	UWB Antenna Design and Implement action for Microwave Medical Imaging Applications.	This paper minimization of coupling between the Antenna Elements was used.		Result here is a broad bandwidth, high gain, low cross-polarization, and antenna good directivity.
[23]	HighPerformance Novel UWB Array Antenna for Brain Tumor Detection via Scattering Parameters in Microwave Imaging Simulation System	In this paper Array structure, coaxial feed, and a partial ground structure are used to contribute in realizing high gain performance throughout the Frequency ranges.		Result here is a wide bandwidth, linear polarization and high directivity.

The above table 2.1: shows the some methods and techniques that can be used to improve antenna performance such again and impedance matching of antenna used in previous work by other researcher so that for this work defected ground structured method has been chosen as the directivity and impedance match improvement of proposed antenna.

2.4 Chapter summary

Proceeding chapter some pervious paper and thesis done by other researchers related to this work has been deeply studied, techniques and methods that are suitable to apply UWB were also encountered in this chapter, and finally the table summary which presented some special papers and method they had used is also mentioned here

REFERENCES

[1] Wang Y, Abbosh A and Henin B 2012 Microwave Breast Imaging Sensor Using Compact and Directive Antenna with Fixed Mainbeam Direction *2012 Cairo Int. Biomed. Eng. Conf.* 187–90

[2] Selvaraj V, Srinivasan P, J J K K and Krishnan R Highly Directional Microstrip Ultra-Wide Band Antenna for Microwave Imaging System 35–40

[3] Shairi N A, Sanusi N M, Zakaria Z, Ibrahim I M, Kejuruteraan F, Komputer K, Teknologi F and Elektrik K 2019 Ultra-wideband SPDT and SP8T Switches using Silicon-Glass PIN Diodes for Microwave Medical Imaging *2019 IEEE Int. Conf. Autom. Control Intell. Syst.* 6–9

[4] Mohammed H and Rasheda Q 2017 Ultra-Wideband Antenna for Microwave Imaging Using Modified Fractal Structure

[5] Lakshmanan R and Sukumaran S K 2016 Flexible Ultra-Wide Band Antenna for WBAN Applications *Procedia Technol.* 24 880–7

[6] Sarjoghian S, Alfadhl Y and Chen X 2017 Compact ultra-wideband double-ridged horn antennas for medical imaging *2016 Loughbrgh. Antennas Propag. Conf. LAPC 2016* 1–4

[7] Meena M L, Kumar M and Parmar G 2016 Elliptical shape ground plane Directional ultra-wideband antenna for microwave imaging applications *Int. Conf. Commun. Control Intell. Syst. CCIS 2015* 63–5

[8] Sharma A, Kumar G and Kumar R 2018 Design of dual polarized Ultra-Wideband antenna for Microwave imaging *2018 Int. Conf. Intell. Circuits Syst.* 121–5

[9] Ahmed F, Hasan N and Chowdhury M H M 2017 A compact low-profile ultra-wideband antenna for biomedical applications *ECCE 2017 - Int. Conf. Electr. Comput. Commun. Eng.* 87–90

[10] Islam M M, Islam M T, Samsuzzaman M, Faruque M R I and Misran N 2015 Omni-directional microstrip monopole antenna for UWB microwave imaging system *I4CT 2015 - 2015 2nd Int. Conf. Comput. Commun. Control Technol. Art Proceeding* 580–3

[11] Azim R, Islam M T and Misran N 2010 Compact Planar Antenna for UWB Applications 4 1070–3

[12] Jalilvand M, Li X, Zwirello L and Zwick T 2015 Ultra-wideband compact nearfield imaging system for breast cancer detection *IET Microwaves, Antennas Propag.* 9 1009–14

[13] Saraereh O and Jayasinghe J W 2017 Bandwidth optimization of an ultra-wide band microstrip antenna Bandwidth optimization of an Ultra-Wide Band Microstrip Antenna

[14] Mobashsher A T and Abbosh A 2014 Low profile ultra-wideband directional antenna operating in low microwave band for brain stroke diagnostic system *2014 Int. Work. Antenna Technol. Small Antennas, Nov. EM Struct. Mater. Appl. iWAT 2014* 180–3

[15] Skaik T and Abujalambo M 2018 Design of Microstrip Circular UWB Antenna with Reconfigurable Frequency and Radiation Pattern 52–7

[16] Zhang L, Liu W and Jiang T 2016 A Compact UWB MIMO Antenna with High Isolation *2016 IEEE Int. Symp. Antennas Propag.* 913–4

[17] Hasan N, Singh P and Nadeem D 2019 Omnidirectional UWB Antenna Loaded

With Rectangular Loop For Band Notch Characteristics *2019 6th Int. Conf. Signal Process. Integr. Networks* 425–9

[18] Dan R and Antena P 2008 Reconfigurable Ultra-Wideband Antenna Design and

Development for Wireless Communication Lebar Ultra Boleh Ubah Untuk Komunikasi Wayarles) *Communication*

[19] Conference I, Processing S, Trichy T and Trichy T 2017 Design and Analysis of TEM Horn antenna for GPR applications 15–22

[20] Ali J DEVELOPMENT OF ULTRA-WIDEBAND ANTENNA ARRAY FOR HUMAN DETECTION UNDER-DEBRIS STATUS CONFIRMATION FOR MASTER ' S THESIS DEVELOPMENT OF ULTRA-WIDEBAND ANTENNA ARRAY FOR

[21] Wang F and Arslan T 2017 Body-coupled monopole UWB antenna for wearable medical microwave imaging applications *2017 IEEE-APS Top. Conf. Antennas Propag. Wirel. Commun. APWC 2017* 2017-Janua 146–9

[22] Selvaraj V, Srinivasan P, J J K K and Krishnan R 2017 Highly Directional Microstrip Ultra-Wide Band Antenna for Microwave Imaging System *Acta Graph.* 28 35–40

[23] Jamlos M A, Jamlos M F and Ismail A H 2015 High performance novel UWB array antenna for brain tumor detection via scattering parameters in microwave imaging simulation system *2015 9th Eur. Conf. Antennas Propagation, EuCAP 2015* 3–7

[24] Guo W, Ahsan S, He M, Koutsoupidou M and Kosmas P 2018 Printed Monopole Antenna Designs for A Microwave Head Scanner 384–6

[25] Song H, Kubota S, Xiao X and Kikkawa T 2016 Design of UWB antennas for breast cancer detection *Proc. 2016 18th Int. Conf. Electromagn. Adv. Appl. ICEAA -2016* 321–2

[26] Mahmud M Z, Islam M T, Misran N, Almutairi A F and Cho M 2018 Ultrawideband (UWB) antenna sensor based microwave breast imaging: A review *Sensors (Switzerland)* 18 1–15

[27] Afifi A I, Abdel-Rahman A B, Allam A and Abd El-Hameed A S 2017 A compact ultra-wideband monopole antenna for breast cancer detection *Midwest Symp. Circuits Syst.* 16–9

[28] Ghavami N, Tiberi G, Ghavami M, Dudley S and Lane M 2016 Huygens principle based UWB microwave imaging method for skin cancer detection *2016 10th Int. Symp. Commun. Syst. Networks Digit. Signal Process. CSNDSP 2016* 8–11

[29] Bah M H, Hong J and Jamro D A UWB Antenna Design and Implementation for Microwave Medical Imaging Applications *2015 IEEE Int. Conf. Commun. Softw. Networks* 151–5

[30] Ahmed F, Hasan N and Chowdhury M H M 2017 A compact low-profile ultra-wideband antenna for biomedical applications *ECCE 2017 - Int. Conf. Electr. Comput. Commun. Eng.* 87–90

[31] Balanis C 2005 *Antenna theory: analysis and design* (John Wiley and Sons)

[32] Mishra R, Mishra R G and Kuchhal P 2016 Analytical Study on the Effect of Dimension and Position of Slot for the Designing of Ultra-Wide Band (UWB) Microstrip Antenna 488–93