

ULTRA WIDEBAND ANTENNA FOR MICROWAVE  
IMAGING USING MODIFIED FRACTAL  
STRUCTURE

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ULTRA WIDEBAND ANTENNA FOR MICROWAVE IMAGING USING  
MODIFIED FRACTAL STRUCTURE

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Dedicated to,

My beloved father and mother,  
MOHAMMED QASEM RASHEDA  
and  
MASAUDA HUSSAIN ABDULLAH

All my brothers, Sisters and Family

,

My supervisor  
Dr. NOORSALIZA BINTI ABDUALLH

My friends.

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## ABSTRACT

Since the Federal Communication Commission release of bandwidth of 7.5 GHz (from 3.1 GHz to 10.6 GHz) for ultra wideband application (UWB), UWB is rapidly advancing as a high data rate wireless technology. Moreover, there are more challenges in designing a UWB antenna than a narrow band antenna. A suitable UWB antenna should be capable of operating over an ultra wide bandwidth as allocated by the FCC. In addition, satisfactory radiation properties over the whole frequency range are necessary as well. This project presents the design with fractal geometry of an UWB patch antenna. To achieve UWB characteristic, a planer antenna is considered for the design purpose. The configuration of designed antenna consisted of a partial ground and the patch with addition of two stairs in its bottom edge connected with the feed line. The antenna was designed and optimized using CST Microwave Studio 2014. The proposed antenna is optimized to achieve a fractal shape by introducing slots in the patch at various positions with half grounded structure. A compact design has been observed as a result of optimization. Moreover, the results have been analysed to get the desired bandwidth, and for the comparison purpose the antenna design has been fabricated using FR-4 dielectric substrate and measured its scattering parameters using vector network analyzer (VNA). The obtained results from the measurement have the bandwidth ranges from 2.2 GHz to 12GHz. The analysis of simulated and measured results shows a little deviation due to fabrication and coaxial cable losses.

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## CHAPTER 1

### INTRODCUTION

#### 1.1 Research Background

In general, communication plays an important role in human life at present times and the monitoring systems are rapidly changing from being wired to wireless. Still, the telecommunication sector is rapidly growing due to the development of low profile, lightweight and single-feed antennas [1]. Ultra-wideband antenna is defined as an antenna that has a bandwidth greater than 500 megahertz (MHz) and ranges from 3.1 GHz to 10.6 GHz. Instead of sinusoidal waveforms compressed in frequency, ultra-wideband signals are pulse-based waveforms compressed in time. UWB technology has been regarded as one of the most promising wireless technologies for high data rate transmission, higher bandwidth and low power requirements. The difference between a narrowband signal and a UWB signal is that the bandwidth of the UWB signal is much larger than the narrowband, which means UWB signals can operate over wider frequencies [2]. Within this operating range of frequency (3.1 GHz to 10.6 GHz), the antenna should have stable response in terms of impedance matching, gain, radiation pattern polarization, and at the same time it should be of small size, conformal, low cost and should be easily integrated into the RF circuits. The difference between a narrowband signal and a UWB signal is that the bandwidth of the UWB signal is much larger than the narrowband, which means UWB signals can operate over wider frequencies [4, 5]. For that reason, the development in communication systems required the development of low cost, minimal weight and low profile antennas that are capable of maintain high frequency over wide spectrum of frequencies. However, microwave imaging of the application of medical have been received very increasing interest. Moreover, fractal antenna engineering research is a relatively very modern development because significant computing speeds in required to comprehensive the

design [6, 7]. The fractal shapes radiate electromagnetic energy well and have a number of properties that are advantageous over traditional antenna types as it has been discovered. In addition, other advantageous property is that they are compact, meaning that they can occupy a portion of space more efficiently than other antenna types. . While, the most problem of patch antennas in their narrow bandwidth due to surface wave losses and large size of patch for better performance. Fractal geometry allows us to design a small antenna and combine multiple telecommunication services into single device. One of the most applicable developments for wireless devices is reducing size. A small design become an essential for the next generation of antennas for microwave imaging applications which have to integrate multiple services such as medical sector , and radar application and so on . In this condition, we need the smallest fractal antenna to make use of the available in service and for application of the different frequency bands is made possible with wide-band antenna design.

## **1.2 Problem Statement**

Nowadays, the study of fractal antenna has made great progress. Compared with conventional antennas, fractal antennas have more advantages of smaller, multiband as compared to other antennas. However the bandwidth and gain of antenna are considered as the main performance limitation. The narrow bandwidth is mainly due to its resonant nature. With bandwidth as low as a few percent, microwave imaging application using conventional designs are limited. So, in this project the efficient methods used for the enhancement of fractal antenna bandwidth is loading or fractal antenna with two shapes in the patch of the antenna.

This research focus on the enhancement of the gain and bandwidth within the frequency range. Moreover, the study of a geometric fraction concept is as a method to reduce the antenna size is one of the purposes of this project. The effect of material properties on the gain and bandwidth performance of fractal antenna will be investigated.

### **1.3 Objective of the Project**

The following are the objectives of this project:

1. To design an ultra wide band antenna for microwave imaging application using fractal structure.
2. To verify the simulation result with measurement result.

### **1.4 Scope of the Project**

The scope of the project focuses the design of a fractal structured patch antenna to obtain an ultra wideband bandwidth. Addition of stairs at the bottom of patch and the use of reduced ground plane are introduced to obtain the bandwidth. Optimum bandwidths are achieved by varying the width of the slot and its position, stair lengths and widths as well as feed width. The project scopes focusing on four major components which represent as follows:

- 1- Study the characteristic of ultra wideband antennas by means of calculation and simulation.
- 2- Design and model the antenna for Ultra-wide-band (3.1GHz- 10.6 GHz) using CST software.
- 3- Investigate a suitable fractal structure.
- 4- Fabricate and measure the parameters such as S-parameters, radiation pattern and gain after simulation.

### **1.5 Thesis Outline**

In this project, several topics are covered and there are contains in to 4 chapters and the organizations of the chapters are as follows:

The first chapter provides an introduction to antennas, especially the UWB antenna. The problem statement is also presented in this chapter along with the objectives and scope of the project.

The second chapter presents a comprehensive literature review. There will be two types of researches providing a perfect insight about the complete project and its ideas. The fundamental idea on the basic antenna characteristics such as input return loss, radiation pattern, bandwidth, VSWR, input impedance and beam width are discussed. This is followed by discussion of relevant theory and literature review on the designed antenna structures.

The third chapter presents the project methodology and the proposed project antenna design. In addition to that, the components selection and the analytical calculation of the proposed antenna design parameters are presented in detail. The simulation software for analyzing the antenna performance is outlined as well. The fourth chapter presents the design of the proposed antenna design. And it describes the process of design and simulation of a single element antenna. All this results are discussed and also do discussions about the result will be taken.

Chapter four presents the results and analysis of the antenna design. This chapter also elaborated on the results for the whole project as well as frequency response band that is obtained after completing the simulation process. In addition, it covered a detail on the analysis of the result due to fabrication and flowed by measurement testing.

Last chapter is chapter five, where it is on overall conclusion for the project. It is also includes the future works of the projects. The conclusion is related to the project. It is important in order to assure that our objective is achieved

## **1.6 Summary**

In this chapter, the introduction to antenna design and especially fractal antenna is stated. The objectives are clearly identified. The research problem is outlined and justification of the research is evident as well. Justification of the research describes to what extent this research helps to solve the stated problem and benefits the people.

## CHAPTER2

### LITERATURE REVIEW

#### 2.1 Introduction

This chapter discusses the literature reviews related to this project. The items of discussion are about what other people have done related to the design a fractal antenna for the medical application project. There is also a discussion on the outcome result from other journals, articles and books.

#### 2.2 Previous Work

An Ultra Wideband antenna for portable brain stroke diagnostic system is proposed by A.T. Mobashsher et. al., (2015). Universally, stroke is the most important cause of mature disability. Stroke occurs when the blood supply in a part of brain is disturbed as a blood vessel bursts or is blocked by a clot. Delayed or wrong medical analysis can be fatal for the stroke affected patient. In this paper, a compact antenna is proposed for the brain stroke detection system. However, the proposed antenna is a directional antenna of simple and compacted structure with ultra wideband performance. The antenna exhibits 77% fractional bandwidth with around 5 dBi stable gain and high front to back ratio. All these characteristics are highly required in UWB imaging system. The proposed antenna is utilized in a compact monostatic radar based stroke detection system to investigate a stroke affected realistic head phantom. Lastly, the image is reconstructed using a confocal delay-and-sum algorithm. The imaging results demonstrate the potentiality of using the proposed antenna in a compact stroke diagnostic system which can lead to the final clinical trials [8].

Randouane et al. (2014) proposed the miniaturized UWB microstrip antenna for microwave imaging. The proposed antenna presents an antenna design of a miniaturized microstrip antenna for microwave medical imaging applications which operated from 2.68 GHz to 12.06 GHz using CST. This antenna has designed in order to meet the ultra wideband characteristics in terms of bandwidth and reflection coefficient and for system to detect malignant tumors by microwave imaging. A certain techniques being used of miniaturization and expansion of bandwidth in order to achieve our intention. The antenna has an ordinary rectangular radiating patch, therefore displays a good omnidirectional radiation pattern. Accorded to final structure of our antenna after optimization of various parameters that allow them to expand the bandwidth, with two slots in the patch and slot in the partial ground plane with length of 1.75mm and width of 3mm. This result shows the presence of resonance frequencies at 3.45GHz, 5.97GHz, 7.86GHz and 11.36GHz with a maximum level of S11 parameter at -38.7dB. Bandwidth measured at -10dB ranges from 2.68GHz to 12.06GHz, presenting a width of 9.38GHz [9].

On the design of Tree-type ultra wideband fractal antenna for DS-CDMA system is presented. This paper describes the CPW-feed ultra wideband tree type monopole fractal antenna and its backscattering. The prototype antenna is fabricated with optimized dimension. The antenna exhibits 96.297% impedance bandwidth. To achieve UWB characteristics from 5.825 GHz - 10.6 GHz for DS-CDMA system, the effects of various design parameters have been studied thoroughly. The experimental and simulated results are in good agreement. The effects of various design parameters on impedance bandwidth have also been studied in detail using EM simulator. The nature of H and E – plane radiation patterns are omnidirectional and bidirectional respectively. The measured group delay is almost constant throughout band which is less than 0.75 ns. This indicates the phase linearity. The monostatic RCS of antenna is also simulated iteration-wise for antenna and structural scattering mode. This antenna can be useful for UWB system, Microwave Imaging and vehicular radar and military high data rate wireless communications. The experimental result of proposed antenna exhibits the excellent UWB characteristics from 4.9 GHz to 14.0 GHz at VSWR 2:1. It corresponds to 96.296 % impedance bandwidth. (Raj Kumar and Prem Narayan, 2012).

Sarinka and Manish (2016) proposed an overview on microstrip patch antenna for UWB application from 3.1 – 10.6 GHz band. The commercial wireless devices based on ultra-wideband radio technology (UWB-RT) is widely awaited and anticipated. The Microstrip Patch antenna is the basic element of wireless

communication devices due to its compact size. Ultra wideband microstrip patch antennas are of higher interest because they cover all the WLAN standards. According to federal communications commission (FCC) rules, the 3.1 - 10.6 GHz band is allocated to the ultra wideband (UWB) applications. In this paper, a brief overview on the recent development of small UWB antennas is presented. Several compact and small UWB antennas are exemplified to illustrate their respective performance [16].

A design of microstrip patch antenna using slotted partial ground and addition of stairs and stubs for UWB application is outlined. This paper presents the design with optimum geometry of a novel UWB rectangular patch antenna. A simple narrowband patch antenna is designed before proceeding to the geometry of UWB antenna. A special configuration of patch antenna with slotted partial ground and addition of stairs and stubs was designed and optimized using CST Microwave Studio (CSTMWS). The designed antenna was fabricated, tested and compared with the simulation results. The proposed antenna's characteristics were investigated with various options and found to operate satisfactorily. A remarkable improvement has been noticed in this design. Moreover, the antennas structure offers great advantages due to its simple designs and small dimensions. The designed antenna can operate from 3.2 - 15.7 GHz frequency bands with more than 12 GHz band width with 7.5 dB maximum gain. The return loss is reached up to -40 dB and radiation patterns are acceptable throughout the entire frequency range. In addition, the antenna's structure offers great advantages due to its simple design and small dimensions [13]. (Islam Md et al. 2012).

Design and Optimization of UWB Vivaldi Antenna for Brain Tumor Detection proposed by He Yu et. al., (2016). This paper is designed to detect brain tumor, by transforming the conventional two-layer Vivaldi antenna into a three-layer structure, the cross-polarization effect of antenna is sharply reduced. Based on different conductivity of brain tissues, the microwave absorption effect of brain tumors is analyzed in the end, which indicates the broad prospect of microwave imaging system in the field of tumor detection. In the operating bandwidth, the relative bandwidth is larger than 25%, which meets the needs of ultra wide band. Besides, the return loss is considerably below -10 dB, which means the designed antenna at the feed port is perfectly matched with the transmission line and realizes the goal of low power consumption and high efficiency power transmission. However, the maximum gain of the proposed optimal Vivaldi antenna can reach 7.78 dB at 8.5GHz.

N. Seladji et al. (2012) proposed an UWB bowtie slot antenna for breast cancer detection. In this paper an UWB Bowtie slot antenna with enhanced bandwidth is

suggested. Effects of varying the geometry of the antenna on its performance and bandwidth are studied. The proposed antenna is simulated in CST Microwave Studio. Details of antenna design and simulation results such as return loss and radiation patterns are discussed in this paper. The final antenna structure exhibits good UWB characteristics and has surpassed the bandwidth requirements. The antenna is realized on FR-4 substrate with dielectric permittivity  $\epsilon_r = 3.34$  and thickness  $h = 0.794\text{mm}$ . Its length and width denoted by  $L$  and  $W$  are respectively  $44\text{mm}$  and  $24\text{mm}$ . The antenna is fed by a coplanar waveguide, the width of the coplanar lines is  $w_a = 1.5\text{mm}$ , separated by a distance of  $1\text{mm}$ . The first antenna presents a multiband behavior, but the  $10\text{ dB}$  return loss bandwidth in the UWB frequency range extends only from  $3.63$  to  $8.31\text{GHz}$ . Whereas it extends from  $3.67$  to  $16.47\text{GHz}$  for the second one, covering the required UWB band. It displays resonant frequencies at  $5.65\text{ GHz}$  with  $S_{11}$  of  $-24.7\text{dB}$ ,  $11.75\text{GHz}$  with  $S_{11}$  of  $-25\text{dB}$  and  $15.5\text{GHz}$  with  $S_{11}$  of  $-13\text{dB}$ . This result shows that for the same dimensions of the structure, we can improve the impedance bandwidth of the antenna by rounding antenna's ends [18].

S.Sayi and S.Ramprabhu (2016) proposed a design and fabrication of modified fractal antenna for UWB application. In this paper a modified fractal antenna for bandwidth enhancement. The proposed antenna has stair-slots on the ground plane and cross square fractal element as radiating element. The overall size of the proposed antenna measures  $31.35\text{ mm} \times 18.7\text{ mm} \times 1.6\text{ mm}$ . The proposed fractal UWB antenna is simulated using CST Microwave Studio. The antenna has broad impedance bandwidth of  $8.1\text{ GHz}$  from  $2.6\text{ GHz}$  to  $10.7\text{ GHz}$  at  $8\text{ dB}$  reference level of return loss. The antenna is designed on a low cost FR-4 substrate. The proposed antenna is fabricated and the results are validated using measurements. The proposed antenna may be a useful tool for UWB communication systems. Peak return loss of  $36\text{ dB}$  is observed for the proposed antenna. Effects of defected ground planes have been analyzed. The proposed antenna has the advantage of better size reduction suitable for space constraint application. The prototype of the proposed fractal antenna is fabricated and measured. The measured results agree well with the simulated results.

A DGS & DMS Based Hexagonal Fractal Antenna for UWB Applications is presented. This paper proposed a hexagonal shaped fractal monopole antenna is thoroughly investigated for UWB applications. The antenna is mounted on FR4 dielectric substrate and is fed by a  $50\text{ ohm}$  microstrip feed line. Basically DGS and DMS structures are introduced to obtain multiband characteristics in UWB frequency range. The simulated results show stable radiation patterns and good return loss of less

than -10 dB in the frequency range of 2.7-9.2 GHz. Each and every modification in the basic structure is supplemented with sufficient simulations and explanation to consolidate the results. (Divyanshu et al. 2012).

A UWB Antenna for Microwave Brain Imaging is proposed by Adhitya Satria et. al., (2016). This paper mentions that Brain tumor is one of degenerative diseases that have been concerned by doctors and researcher to be investigated. MRI, PET, or CT is widely used modalities for brain tumor scanning, which it can provide accurate and high resolution image. However, it costs still relatively high particularly in developing countries with high population like Indonesia. Hence, it is desirable to develop a new brain tumor imaging system that is affordable, easy to operate (portable), non-ionization (safe radiation) and use a non-invasive technique. Microwave imaging is considered as a suitably matched modality to those requirements. In this paper, an UWB antenna is proposed as a transceiver of microwave imaging on brain tumors, which it operates in UWB range (i.e. 3.1–10.6 GHz). The proposed antenna is a printed dipole-like fed by a coplanar waveguide because it provides high frequency response. The antenna is numerically simulated using CST Microwave Studio 2014 and experimentally measured near to a semi-solid head-equivalent phantom, particularly  $S_{11}$  and radiation pattern on  $xy$ - and  $yz$ -plane at 5.8 GHz.

Navid (2016) presented Huygens principle based UWB microwave imaging method for skin cancer detection. Recently, Ultra Wideband (UWB) technology has emerged as a promising alternative for use in a wide range of applications. One of the potential applications of UWB is in healthcare and imaging, motivated by its non-ionizing signals, low cost, low complexity, and its ability to penetrate through mediums. Moreover, the large bandwidth covered by UWB signals permits the very high resolution required in imaging experiments. In this paper, a recently introduced UWB microwave imaging technique based on the Huygens principle (HP), has been applied to multilayered skin model with an inclusion representing a tumor. The methodology of HP permits the capture of contrast such that different material properties within the region of interest can be discriminated in the final image, and its simplicity removes the need to solve inverse problems when forward propagating the waves. Therefore the procedure can identify and localize significant scatterers inside a multilayered volume. Validation of the technique through simulations on multilayered cylindrical model of the skin with inclusion representing the tumor has been performed.

On the Design of CPW-Fed Square Octal Shaped Fractal UWB Antenna is presented. The antenna has been designed on FR4 substrate  $\epsilon_r = 4.3$  and thickness 1.53

mm. The antenna has been fabricated and tested using VNA. The experimental results of this antenna offer ultra wide bandwidth from 2.86 GHz to 14.38 GHz. This corresponds to the impedance bandwidth 11.42 GHz and 132.48 %. The experimental results also exhibits the first band from 0.62 GHz to 1.657 GHz corresponds to 1.037 GHz bandwidth. The radiation pattern of this antenna is nearly omni directional. This type of antenna can be used for ultra wide band system, positioning system, microwave imaging and Radar application [15] ( Raj Kumar et al. 2012).

Deepshikha et al. (2015) proposed a design of microwave imaging based microstrip Ultra-Wideband Antenna. The designed micro-strip ultra-wideband (UWB) antenna is based on a travelling wave propagating along the tapered surface with a phase velocity less than the speed of light. It results in end-fire radiation with a good penetration and resolution characteristics. The designed antenna for microwave imaging (MI) works on a technique which requires the measurement of reflected electromagnetic waves by the object under test. The UWB antenna with overall size of 70x40x1 mm using Rogers RO3003 substrate with a relative permittivity of 3 is designed using ANSYS-HFSS software. The results for the frequency band 3 to 20 GHz are optimized on the parameters return loss, VSWR and gain. The effect of different medium on the parameters of antenna is also tested. The designed UWB antenna has obtain return loss better than - 10dB and VSWR less than the 1.8 within the band (3GHz to 20GHz). The designed UWB microstrip antenna has wide practical application in concealed weapon detection, medical imaging, remote sensing, through the wall imaging etc.

A microstrip-fed low profile and wideband wide-slot antenna for breast imaging proposed by S. S. Tiang et. al., (2012). This paper presented a novel low profile and wideband wide-slot antenna fed with a microstrip-line. A p-shaped wide slot is printed on a substrate with a compact size of 16 mm x 16 mm and fed by a simple 50  $\Omega$  microstrip transmission line. The antenna is designed for microwave breast imaging that cover the ultra-wideband (UWB) frequency band. The design exhibits more than 70% reflection coefficient at 10 dB with stable radiation pattern at the desired bandwidth. The size reduction offers better array ability and well-suited for breast imaging [19].

## **2.3 Ultra-wideband**

Ultra-wideband (UWB) is a new and modern technology with some attractive and very unique features which includes areas of other fields such as wireless communications, radar, and medical engineering. Before 2001, ultra-wideband applications were mainly limited in military areas. But since 2002, The Federal Communication Commission (FCC) has since slowly allowed the use of these commercial bandwidths, and this usage makes it possible that every researchers could benefit the ultra-wideband features. As we have mentioned previously, the Federal Communications Commission (FCC) regulates that the frequency for the ultra-wideband techniques is 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 6 GHz to 8.5 GHz. The power radiation requirement of ultra-wideband is strict and it would not disturb the existing equipments because ultra-wide band's spectrum looks like a background noise [4, 20].

### **2.3.1 Ultra-Wideband Modulation Modes**

The ultra-wideband has two modulation modes with respect to available bandwidth or frequency resource: the Multiband OFDM and the Impulse Radio (IR) [21]. These modulation techniques or modes have different advantages and could be applied in different fields in medical area. Multiband OFDM mode of ultra-wideband could be used for small range high speed data communications. For Impulse Radio (IR) mode, by using low-power ultra-short pulses (sub-nanosecond interval), ultra-wideband has many applications such as high resolution penetrating radar in the medical engineering, short-range high-speed broadband access to the Internet, accurate localization at centimetre level. In these applications the accuracy detection and location is much adapt to the medical monitor, and the high resolution imaging is suitable for pathologic imaging, which is modulated by the Impulse Radio (IR). So the ultra-wideband technology has many attracts for conducting many researchers in medical applications area.

### **2.3.2 Ultra Wideband Medical**

Ultra-wideband (UWB) technology is an emerging application trend in medical applications in the new technology. The first time ultra-wideband radar was attempted to use in medical applications in the human body monitoring was in 1993. In 1994, the first US Patent application was filed for medical ultra-wideband radar. A year later, Massachusetts Institute of Technology (MIT) has begun an educational project for the “Radar Stethoscope” [22]. The biomedical use of ultra-wideband radars was better described with photo and sample tracings in 1996, and in the same year the US Patent [23] was awarded, ultra-wideband is often renowned since then to remote sensing and imaging as a possible alternative. So the ultra-wideband in comparison with the X ray imaging and in respect to the human body safety the ultra-wideband radar probes use non-ionizing electromagnetic waves which showed to be harmless to human body. The ultra-wideband radar has very low average power level and is very power efficient which makes it very suitable to medical application. Moreover it is suitable to be a potentially cost effective way of human body screening, especially in real time imaging. By the end of 20<sup>th</sup> century and in 1999 in particular, many works have begun for ultra-wideband medical applications in cardiology, obstetrics, breath pathways and arteries.

### **2.4 Ultra-wideband for Medical Application**

The ultra-wideband pulses are generated in a very short time period (sub-nanosecond). Because of that its spectrum is below the allowed noise level. This is what makes possible for the ultra-wideband to get Gbps speed by using 10GHz spectrum. For that reason ultra-wideband is suitable to be used for high-speed over short distances. The ultra-short waveforms are generated from the noise-like feature and at the same time does not require IF processing because they can be operated at baseband. This feature is a key advantage for medical engineering [25].

### **2.4.1 Comparison between Ultra Wideband and Ultrasound**

We can compare ultra-wideband to ultrasound. Although ultra-wideband and ultrasound are in fact very similar and many of the signal processing techniques used in ultra-wideband systems can be applied to ultrasonic, only the difference is that the ultrasound has broad applications in many of the latest technologies this time. Ultra-wideband is different because it does not use high frequency sound waves which cannot penetrate obstacles.

In contrast ultrasound is basically a line of sight technology and it is very short range and it is used for medical screening but it typically works only over a few inches. Ultra-wideband impulse of every bit is so many that it can get much higher gain than other popular conventional spread spectrum systems because ultra-wideband uses RF pulses and has high gain. That also explains why ultra-wideband can penetrate through walls. This is what makes ultra-wideband viable for wide area applications where obstacles are certain to be encountered, even though ultrasound may also operate in these kinds of circumstances. The feature makes it easy to image organs of human body for medical application.

### **2.4.2 High Precision Ranging at the Centimetre Level**

One more important feature of ultra-wideband is that it has high precision range at centimetre level based on the ultra-short pulses characteristics. High precision range means strong multi-path (the propagation which results signals reaching the receiving an antenna by two or more paths) resolving capability. The usual and considerate wireless techniques which use continuous wave and the standing time are much longer than multi-path transmission time. The ultra-wideband pulses are much shorter (for 1 nanosecond pulse, the multi-path resolving power equals to 30cm) so it has very strong space resolving and temporal capability, which is suitable for the localization and detection in the medical applications.

### **2.4.3 Ultra-wideband Electromagnetic Radiation**

Yet another important feature of ultra-wideband and perhaps due to the low radio power pulse is the low electromagnetic radiation and these power pulses are less than -41.3dB in indoor environment. This feature which the low radiation of ultra-wideband has little influences on the environment and makes it suitable for hospital applications. So advantage here is that the low radiation is safe for human body even in the short distance which makes it possible to apply ultra-wideband to the clear vision equipments for the ability to gain information about an object, person, location or physical event through human sight senses [26] in the form of extra-sensory perception.

## **2.5 Medical Screening and Monitoring through UWB**

Ultra-wideband is very suitable for the application of medical screening and monitoring. These monitoring applications could be medicine storage monitoring, patient motion monitoring, and the wireless vital signs monitoring of human body.

### **2.5.1 Ultra-wideband and Patient Motion Monitoring**

Ultra-wideband radar can be used in medical field for remote monitoring and measuring the patient's motion and in short distance because of the highly intense pulses used in ultra-wideband technology, this monitoring function could be applied in emergency rooms, home health care, intensive care units, paediatric clinics to alert for the Sudden Infant Death Syndrome SIDIS, rescue operations (to look for some heart beating under ruins, or soil, or snow).

Since ultra-wideband has a short detection range of less than 10 meters, if a large area wanted to be monitored more ultra-wideband sensors will be needed. These sensors using ultra-wideband sub-nanosecond pulses can be motivated for gathering and exchanging a large quantity of sensory data. The energy requirement for these devices is small and is suitable for long time sensing. Bluetooth devices are less suitable for

medical applications because their energy requirement is higher and data transmitting speed is low.

### **2.5.2 UWB Enabled Sensors and Vital Signs Monitoring of Human Body**

The ultra-wideband-enabled sensors can detect the micro movement inside human body and not only limited to the detection of the human body macro movements [28]. In medical engineering, the capability of non-invasive sensing of vital parameters such as respiration system of human body is important and very useful. The ultra-wideband monitoring of respiratory movement in emergency rooms or intensive care units will be attractive and will save much cost especially for large-scale hospitals. Some other typical vital sign monitoring application of ultra-wideband include the cardiology system, pneumology system and neurology system. There are increasing requirements for the vital sign monitoring applications of ultra-wideband, for example health monitoring for the old people.

### **2.5.3 Medicine Monitoring Storage**

The radar of ultra-wideband can be used for guarding the medicine storage room [29]. The ultra-wideband electromagnetic waves form a defence sphere detecting any moving objects around the guarded perimeter line. Any unauthorized people want to get access to the monitored object will be alarmed when they are close enough. The fluctuations of radar signals corresponding to the things want to cross the secured line will initialize the alarm.

In conclusion, the ultra-wideband feature makes it very powerful and promising in the area of medical screening and monitoring. It can not only monitor the vital signs inside human body by wireless RF waves and the motion of the patient, it can be used in monitoring the medicine storage. And may be in the near future, there will be more ultra-wideband apparatus and equipments in these fields.

## 2.6 Fractal Antenna

A fractal antenna is created using fractal geometry, a self-similar pattern built from the repetition of a simple shape. The inherent qualities of fractals enable the production of high performance antennas that are typically 50 to 75 percent smaller than traditional antennas.

Fractal antennas are also reliable and cost-effective. Antenna performance is attained through the geometry of the conductor, rather than with the accumulation of separate components or elements that increase complexity and potential failure points. Fractal antennas also allow for multiband capabilities, decreased size, and optimum smart antenna technology.

Fractal antennas can be produced in all existing antenna types, including dipole, monopole, patch, conformal, bicone, discone, spiral, and helical. Many hybrid designs greatly extend frequency ranges.

The inherent wideband qualities of fractal antennas are ideal for defense and intelligence applications. Compact size, versatile form factor, rugged construction, and superior wideband performance provide system integrators with the flexibility needed to meet rigorous requirements. With field-proven technology and an innovative, experienced engineering staff, Fractal Antenna Systems is uniquely qualified to serve this sector, with antennas that can cover up to a 200:1 frequency range. Fractals can also be classified according to their self-similarity.

There are three types of self-similarity found in fractals:

1. **Exact self-similarity** – This is the strongest type of self-similarity; the fractal appears identical at different scales. Fractals defined by iterated function systems often display exact self-similarity.
2. **Quasi-self-similarity** – This is a loose form of self-similarity; the fractal appears approximately (but not exactly) identical at different scales. Quasi-self-similar fractals contain small copies of the entire fractal in distorted and degenerate forms. Fractals defined by recurrence relations are usually quasi-self-similar but not exactly self-similar.
3. **Statistical self-similarity** – This is the weakest type of self-similarity; the fractal has numerical or statistical measures which are preserved across scales. Most reasonable definitions of "fractal" trivially imply some form of statistical self-similarity. (Fractal dimension itself is a numerical measure which is preserved

across scales.) Random fractals are examples of fractals which are statistically self-similar, but neither exactly nor quasi-self-similar.

### 2.6.1 Fractal Geometry

Fractal geometry has been around since before man-time, yet its name and thus placement of objects into the title of fractal geometry is only relatively recent. With this new and exciting discovery of fractal geometry we begin to divide into this new world. The following is just a small glimpse into that world.

Fractal was first defined by Benoit Mandelbrot in 1975 as a way of classifying structures whose dimensions were not whole number. Fractal can be defined as fragmented or rough geometric shape that can be subdivided in part, each of which is a reduced sized copy of the whole. It was very unique because of the self similarity and it has the infinite complexity and details [32]. The word fractal was chosen because it is based on the Latin adjective 'fractus' which corresponds to the Latin verb 'frangere' which means to break [33]. Besides that it also can model the nature very well such as coastline, the branching of tree and clouds.

Fractal also a class of shapes which have no characteristic size [34]. Each fractal is composed of multiple iterations of a single elementary shape. The iteration can continue infinitely, thus forming a shape within a finite boundary but of infinite length or area. This compactness property is highly desirable in mobile wireless communication applications because smaller receivers could be produced. Many theory and innovative applications was developed using fractal concept.

Several of antenna elements can be developed by applying the general concept of fractals. The major advantage of this application of the antenna elements allows for smaller resonant antennas that are multiband and may be optimized for gain. Most fractals have infinite complexity and details that can be used to reduce antenna size and developed low profile antennas. Despite, the antenna can achieve multiple frequency bands when antenna elements or arrays are designed with the concept of self-similarity because different parts of antenna are similar to each other at different scale.

This fractal concept was approved by Cohen, who the first to develop an antenna element using the concept of fractals could be used to significantly reduce the antenna size without or degrades and checks the performance. Fractal antenna are very

important nowadays in designing wireless devices, it can be utilized in a variety of applications, especially where shape is limited [35]. (Simendra, 2004).

Fractal geometries are generated in an iterative fashion leading to self-similar structures. This iterative generating technique can best be conveyed pictorially. The starting geometry of the fractal is called the initiator is a Euclidean square. Each of the square straight segments of the starting structure is replaced with the generator. This iterative generating procedure continuous for an infinite number of times. The final result is a curve with an infinitely intricate underlying structure that is not differentiable at any point (Ramesh Garg , el .at, 2001).

The iterative generation process creates a geometry that has intricate details on an ever shrinking scale. In a fractal, no matter how closely the structure is studied, there never comes a point where the fundamental building blocks can be observed. The reason for this intricacy is that the fundamental building blocks of fractals are scaled versions of the fractal shape. This can be compared to it not being possible to see the ending reflection when standing between two mirrors. Closer inspection only reveals another mirror with an infinite number of mirrors reflected inside (P.Fleber, 2000).

Fractals can be either random or deterministic. Most fractal objects found in nature are random, that have been produced randomly from a set of non-determined steps. Fractal that has been produced as a result of an iterative algorithm, generated by successive dilations and translations of an initial set are deterministic.

### **2.6.2 Fractal Dimension**

The second concept for a fractal is a fractional dimension. This requirement distinguishes fractals from the Euclidean geometry, which have integer dimensions. The common intuitive idea of dimension is referred to as topological dimension. A point, a line segment, a square and a cube have topological dimensions zero, one two and three respectively. This intuitive dimension is always expressed as an integer. In the Hausdroff-Besicovich dimension is referred as the fractional dimension and it defined as a real number that precisely measures the object's complexity.

Mandelbrot defines a fractal as a set for which the fractional dimension or Hausdroff-Besicovich dimension strictly exceeds the topological dimensions. He refers to fractional dimensions as the fractal dimension of a set. Fractal dimension have been

defined in many ways, depending on application. Fractional dimension is related to self-similarity. From the properties of self-similarity the fractal dimension  $D$  of a set  $A$  is defined as

$$D = \frac{\text{Log}N}{\text{Log}\frac{1}{r}} \quad (2.1)$$

Where  $N$  is the total number of distinct copies similar to  $A$  and  $A$  is scaled down by a ratio of  $r$ . The same approach can be followed for determining the dimension of several fractal geometries.

### 2.6.3 Fractal Antenna Elements

As with several other fields, the nature of fractal geometries has caught the attention of antenna designers, primarily as a past-time. However with the deepening of understanding of antennas using them several geometrical and antenna features have been inter-linked. This has led to the evolution of a new class of antennas, called fractal shaped antennas.

Cohen, who later established the company Fractal Antennas, is among the first to get into the bandwagon. He has tried the usefulness several fractal geometries experimentally. Koch curves, Minkowski curves, Sierpinski carpets are among them. These geometries have a large number of tips and corners, a fact that would help improve antenna efficiency. Fractal trees were explored for the same reason, and were found to have multiband characteristics. Self-similarity of the geometry is qualitatively associated with the multiband characteristics of these antennas.

To summarize the survey on fractal antenna engineering, key aspects of using fractals in antennas are presented here. For fractal arrays, several novel synthesizing algorithms have been developed to tailor radiation patterns. It has been established that random fractals can be used for better control of side lobe levels. Multi-band operation and a certain extent of frequency independence are possible with such array designs.

The advantages of using fractal shaped antenna elements are manifold. These geometries can be used to design smaller sized resonant antennas. The antenna radiation efficiency is thought to have improved by large number of bends and corners in many

of such fractals. These geometries can lead to antennas with multi-band characteristics, often with similar radiation characteristics in these bands.

## **2.7 Summary**

This chapter, literature review to the UWB at 3 GHz to 10.6 GHz for microwave imaging is stated. Reading and researching of the other contributors' research have been reported, but the most related one was written in here. The reviews on the parameters and the software which has been done by other contributors regarding this antenna on medical sector project. This initial work was done in order to have a better, clear view about this project. Moreover, the important parameters for the fundamental for antenna theory are defined in this chapter. This attracts researchers to investigate the performance of this antenna in various ways. Fractal antenna can be designed in various shapes such as Koch Curve, Sierpinski Gasket, Sierpinski Carpet, Hilbert Curve and Minkowski. These geometries have been particularly useful in reducing the size of the antenna and have multiband characteristics.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 Introduction**

In this chapter, the project improvement plan is presented. The whole plan and the design steps are outlined in the flow chart as it is shown in Figure 3.1. Therefore, this project consists of design specification and parameter, software, hardware and material selection. Moreover, calculation for specific material and component selection will be done. The end of this chapter will be concluded with the discussion of proposed methodology, and the time management to show the work plan of the project.

#### **3.2 Proposed Methodology**

The proposed methodology is the first step and it is considered as the overall plan and steps of designing an ultra wide band antenna for microwave imaging using fractal geometry. The project is explained and summarized in the flow chart below.

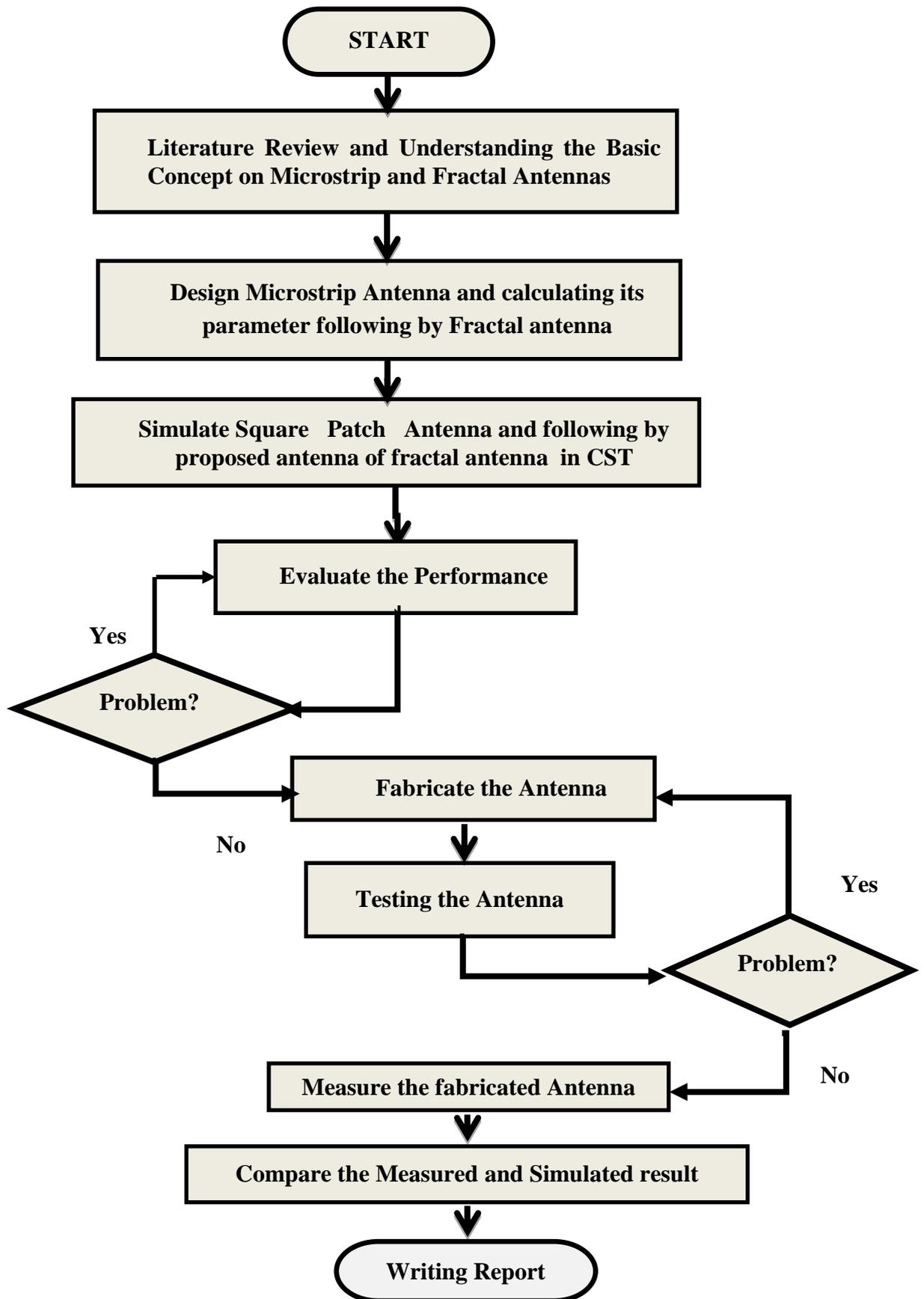


Figure 3.1: Project Flow Chart

There are several steps needed to be done in order to complete the proposed project as it shown in Figure3.1. First of all, starting with understanding the basic theoretical of microstrip patch antenna and the fractal antenna with the matching techniques and the design. In general, the matching techniques is must be chosen carefully in order to get a maximum power delivered, so in this report quarter-wave transformer matching technique will be used in this project due to its power divider.

In order to come out with the fractal antenna the single element for the patch antenna must be calculating and simulating firstly using Microwave Studio Simulator (CST) because the dimensions of the patches will find its resonant frequency then from this design the fractal antenna will be designed properly . It is important in order to analyse the parameters such as Return Loss, Gain, Directivity and Bandwidth.

Thus, when the entire designed antenna had been simulated by using CST and the result from the simulation are discussed. But if the results from the simulation are not fulfilling the design specifications, the parameters used would be rechecked and the literature study would be done for the design enhancement. Once the antenna is being success in designed and indicates better result when operating at desire frequency band. Then proceed to the documentation of the results obtained and the fabrication of proposed antenna which is square microstrip patch antenna is done. Thus, when the fabrication antenna being tested in the Anechoic Chamber by using spectrum analyzer and Vector Network analyser.

### **3.3 Design Specification and Calculation**

The proposed antenna design specifications using different materials is shown in table 3.1 and the design steps are presented in detail.

The resonant frequency of 6 GHz is selected because the frequency is suitable and commonly used in medical application and it is used for the proposed antenna. As for the substrate selection, the major concern is the dielectric constant and loss tangent. The high dielectric constant will result in a smaller patch size but this will generally reduce bandwidth and a high loss tangent will reduce the antenna efficiency. An important constituent in the design of a patch antenna is the substrate. Therefore, there

are two common Substrate materials available in the market, FR.4 and Roger Duroid 5880, so; first of all, I have stated that the FR4 as a substrate will be selected for designing the proposed antenna, with a standard thickness of 1.6 mm. With this in mind, let us discuss the effect of a dielectric on wavelength.

At 6 GHz, free space wavelength is equal to 30mm, and in our substrate this would reduce inversely by the square root of its dielectric constant. 5880 has a dielectric constant of 2.2, resulting in a wavelength of around 20.2mm. However, as you may well know, not all of the field propagating along a microstrip line, or indeed a patch, will exist in the substrate due to fringing fields in the air above. These results in an effective dielectric constant lower than 2.2 and this can be calculated for microstrip geometry using a well-known method seen in many text books. The effective dielectric constant is unfortunately not constant for all microstrip lines, and so must be assessed for different track widths; this is a particular issue when designing feed networks with various track impedances and therefore differing widths.

Secondly, The FR.4 is a cheap substrate material, and it is also easily available in the market. The problem with this material when compared with the Rogers is that it has a very high loss tangent. Its loss tangent also changes with the frequency; higher frequency generally leads to more losses in FR.4. This property of the FR.4 explains some of the differences between the measured and the simulated results. Therefore, FR.4 is not preferred when accuracy is essential. Roger Duroid, on the other hand, has all the benefits which FR.4 lacks, but it is a very expensive material. In this thesis FR.4 is used due to its availability and price.

Table3.1: Antenna Specification of Design

No.	Design Specification	Value	
1.	Operating Frequency	6 GHz	6 GHz
2.	Substrate	FR-4 (Fire Retardant-4)	Roger Duroid 5880
2.	Dielectric Constant, $\epsilon_r$	4.3	2.2
4.	Loss Tangent, $\tan \delta$	0.019	0.0009
5.	Substrate Thickness, h	1.6 mm	0.787 mm

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