Design and Fabrication of Microstrip Patch Antennas for Brain and Breast Cancer Detection

A Thesis submitted in partial fulfillment of the requirement for the Award of the Degree of

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DECLARATION

I, Sukhpreet kaur hereby declare that the work presented in this thesis entitled "Design and Fabrication of Microstrip Patch Antennas for Brain and Breast Cancer Detection" in partial fulfillment of the requirement for the award of degree of Master of Engineering (ECE) submitted at Electronics and Communication Engineering Department, Thapar Institute of Engineering & Technology (Deemed to be University),Patiala is an authentic record of work carried out under supervision of **Dr. Jaswinder Kaur** (Assistant Professor, Electronics and Communication Engineering Department), Thapar Institute of Engineering & Technology (Deemed to be University),Patiala The matter presented in this has not been submitted either in part or full to any other university or institute for the award of any other degree.

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It is certified that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

In this thesis, primary antenna used is microstrip patch antenna. Two antenna designs are fabricated in this work. First one describes a hexagonal shaped wearable antenna with circular slots and reduced ground plane for the detection of brain cancer which operates at ISM (Industrial, Scientific, and Medical) band at 2.4-2.4835 GHz. The antenna is fabricated on a FR-4 substrate having thickness 0.8 mm and relative permittivity 4.35 F/m. The actual size of the antenna is 30 mm × 20 mm. The designed antenna has an advantage that its dimensions are small which makes it practically wearable on human head. This antenna is placed on the human head phantom model which consists of skin layer only and is simulated using CST Microwave Studio. S-parameter analysis is used to identify whether or not tumor is present in the brain. The S-parameter results of a Human Head Phantom Model with cancerous tissue that contains a 5 mm tumor inside the Human Brain (-38.788 dB) are different from the S_{11} results of normal head (-31.955 dB) at the resonance frequency of 2.46 GHz. Various other performance parameters are also analyzed for the proposed antenna such as Voltage Standing Wave Ratio (VSWR), SAR and radiation pattern. SAR value of the antenna with the input power of 2mW is found to be 0.3747 W/Kg at the resonance frequency of 2.46 GHz as given by ICNIRP and FCC guidelines that SAR should not exceed 1.6W/kg. Finally, a comparison between simulated and measured results without cancerous tumor is illustrated which verifies the prototype of proposed antenna.

Second paper describes the detection of tumor in human breast tissue using a microstrip patch antenna operating at MICS (Medical Implant Communication Services) band which is in between 402-405 Mhz. This antenna is designed and fabricated on the FR-4 substrate with thickness 1.6mm. The actual size of the antenna is 15mmX15mm. To analyze the characterstics of the antenna, it is embedded in the gel type tissue material whose electrical properties is the same as that of the human skin in case of conductivity and permittivity. MICS band is preferable because of its docility towards higher bandwidth. There is a difference in the simulated and measured return loss of the antenna which indicated the presence of tumor inside the breast. Various parameters are also measured for the designed antenna such as return loss, VSWR (Voltage Standing Wave ratio), Radiation pattern, Directivity and Gain at the resonance frequency of 402-

405 Mhz. A comparison technique is used to identify whether or not tumor (benign or malignant) is present in the breast.

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LIST OF GLOSSARY

BAN	Body Area Network
IMD	Implantable Medical Device
MICS	Medical Implant Communication Services
ISM	Industrial, Scientific and Medical
MRI	Magnetic Resonance Imaging
MI	Microwave Tomography
OUT	Object Under Test
CT	Computed Tomography
PET	Positron Emission Tomography
UWB	UltraWide band
CSF	Cerebrospinal Fluid
GBC	Graphene based conductor
CP	Circularly Polarized
PEC	Perfect Electric Conductor
FR-4	Flame Retardant-Fiber Glass Epoxy
VNA	Vector Network Analyzer

CHAPTER 1

INTRODUCTION:

In recent years, Biomedical engineering is one of the fastest-growing fields of technology which grasps an important place as a means of enhancing medical diagnosis and treatment. Cardiac pacemakers, Medical imaging, artificial limbs, Laboratory instrumentation and computer analysis of the human genome are some of its familiar products. Biomedical devices have become an interesting topic in the field of medical and healthcare applications. The main advantages of these biomedical devices are that they have the capability to stimulate inner body organs, or continuously monitor the vital signs of the human body and transfer data to the outside environment. Depending upon the user application, the necessity of power for these biomedical devices ranges from a few microwatts to tens of milliwatts. The two types of antennas used for biomedical applications are Implantable Antennas and Wearable Antennas.

1.1 Implantable Antennas

There has been an increasing interest in the body area network (BAN) especially in recent years [1]-[3**].** Implantable antennas or Implantable medical devices are those which can communicate wirelessly with external equipment. As the name suggests implantable antennas are those that can be embedded inside the human's body for further diagnosis and treatment. An implantable antenna is the main component of an implantable device which is used to transfer the human's body data to the outside equipment. Nowadays these IMDs (Implantable Medical Device) [4] are exceedingly used medical devices and is used to provide healthcare at a distance. When these antennas are implanted inside the human body it must fulfill the miniaturization demand and have good radiation pattern [5-7]. For early disease detection, these implantable devices are mostly used in the medical science field to achieve physiological signals. There are many challenges while designing an implantable antenna such as low power requirements, biocompatibility and antenna size [8-11]. There are many people all over the world who devolve on implantable medical devices for encouraging and developing their lives aspect. Typical examples of implantable medical devices are neurostimulators, Glucose monitors and

Pacemakers, etc. As these devices are embedded into the individual's body implanted inside the human body so designing this type of antenna is a difficult venture as many factors need to be

considered such as Patient Safety, Good radiation efficiency, and Miniaturization. In Implantable antenna, the most used frequency bands are ISM band (2.45-2.48 GHz) and MICS band (402-405 MHz). There are many researchers who can design an implantable antenna that can operate at MICS (Medical Implant Communication Services) band and ISM (Industrial, Scientific, and Medical) band.

The main requirements while designing an implantable patch antenna are-

- Miniaturization
- Far-field Gain
- Biocompatibility
- Low Power Consumption

1.1.1 Miniaturization

Miniaturization is one of the greatest challenges while designing an implantable antenna. Currently, many researchers have been focusing on the miniaturization of wireless systems to develop small devices for biomedical telemetry applications [12-13]. For implantable antennas, the use of patch designs may permit many supplementary miniaturization techniques. The goal of this technique is to diminish the size of the antenna at a stated functioning frequency, while still keeping requisite electromagnetic performance. Implantable devices operate at a very low frequency typically at MIBS band (402-405 MHz) and Medradio band (401-406 MHz). Miniaturization can be done in many ways: High permittivity dielectric Substrate/Superstrate, Lengthening of the current-flow path on the patch surface, addition of shorting pins and Patch stacking.

- High Permittivity dielectric Substrate/Superstrate

  For implantable patch antennas, high permittivity dielectrics are mostly chosen (like RogersRO 3210,$\in_r = 10.2$) because they reduce the functional wavelength and results in lower resonance frequencies, thus accommodate antenna miniaturization. Moreover, with these high permittivity dielectrics, the superstrate layer still wraps the antenna from the higher-permittivity tissue. The antenna with thick superstrate increases the operating frequency of the antenna [14].

- Broadening of the current-flow pathway on the surface of the patch

Larger operative current flow pathways elevated on the emitting patch can minimize the functioning frequency and accomplish more small size for the implantable antennas.

- Shorting Pins addition

When inserting the shorting pins between the patch and the ground planes of the antenna it increases the operative size and also minimizes the requisite physical dimensions at a given operating frequency. This skill works relative to the same method that the ground plane of the antenna twice the height of the monopole antenna as it generates a PIFA (Planar Inverted-F antenna) with the same resonance attainment as it doubles the size of the antenna without shorting pin [15].

- Patch stacking

By vertically stacking two radiating patches of the antenna, it minimizes the size of the antenna by increasing the current-flow path length [16-17].

1.1.2 Biocompatibility

For patient's safety, these antennas should be biological acceptable for long term duration. Further, the person's tissues are heat conductive so the metal heating element is kept unreachable from it. For this sake, the metal heating element is either wrapped with a superstrate layer or with low-loss biocompatible coating [18]. Material used for biomedical encapsulation are zirconia (29 $\in_r$ = ; tan 0 δ ≈) [19], PEEK (3.2 $\in_r$ = ; tan 0.01 δ =) [20], and Silastic MDX-4210 Biomedical-Grade Base Elastomer (3.3 $\in_r$ = ; tan 0 δ ≈) [21]. From an electromagnetic point of view, Zirconia is a better applicant material from an electromagnetic viewpoint biological acceptable insulation because of its electrical properties. Likewise, Base Elastomer is much easier to compose and manipulate than PEEK and Silastic MDX-4210 Biomedical-Grade layer. The thickness of the biocompatible insulation layer is an important factor while designing an antenna. The estimation of its maximum value is examined to be highly consequential for lowering power loss without aimlessly increasing antenna size [22-23].

1.1.3 Far-Field Gain

MICS band i.e. Medical Implant Communication Systems band are composed of an external monitoring and the implantable medical devic (IMDs) that is located at few distant (typically 2 m) apart from the human body [24]. Medical telemetry links can be used to transfer the saved instruction, device-parameter adjustment, along with the real-time transportation of essential monitoring instruction. Regardless of any power limitations, the implantable antenna can accommodate a signal that is powerful sufficient to be chosen up by the external apparatus.

1.1.4 Low Power injection

If IMDs transceiver is manipulated uninterruptedly, it will absorb the significant energy and degrade the device lifetime. There are some approaches for reloading the battery, e.g. by means of an inductive-loop method [25- 26] and using medical telemetry connection only when it is required. Likewise, Base Elastomer is much easier to compose and manipulate than PEEK and Silastic MDX-4210 Biomedical-Grade layer. The thickness of the biocompatible insulation layer is an important factor while designing an antenna. The estimation of its maximum value is examined to be highly consequential for lowering power loss without aimlessly increasing antenna size [22-23].

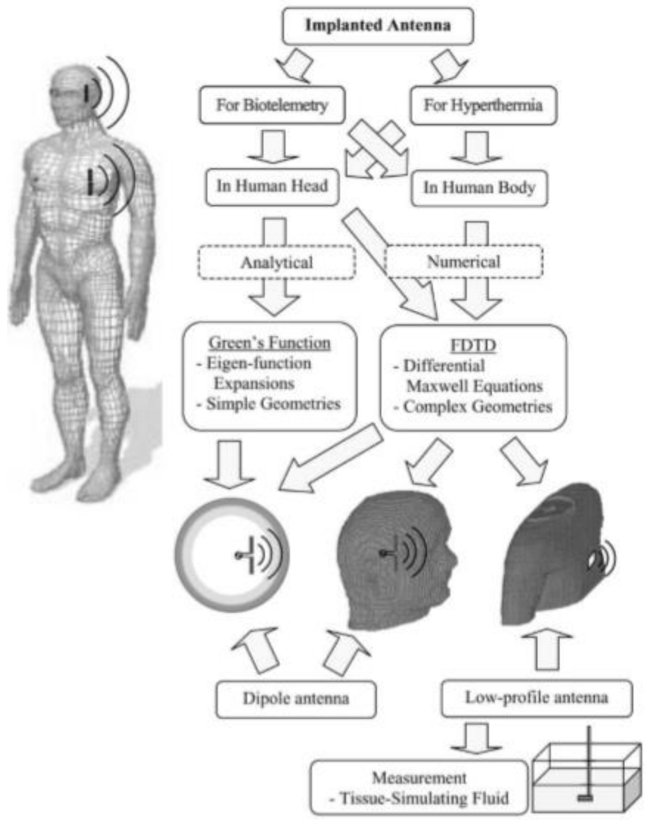

Figure 1.1 Diagram of Implantable antenna interior to Human body [24]

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1.2 Wearable Antennas

Antennas technology exists in lots of modern applications which facilitate and improve the quality of humans' daily life. Such applications include mobile phones, satellite communications, Wi-Fi, GPS, Bluetooth, Zig-bee, television, telemedicine radio, RFID cards [25], [26]. An important category which belongs in the antennas technology is the wearable antennas one. Wearable antennas are supposed to be worn (placed on or are part of the garment) and to operate on a live tissue (e.g. human body) environment. Wearable antennas technology has rapidly grown over the last couple of decades. It could be said and assumed that this technology is the future of smart garments and furthermore the future of our daily life. A wearable antenna or electronic is meant by definition to be part of the garments worn by humans or animals. Smart garments will emerge in various applications including sports, emergency workers, military, medical and space applications or even in casual clothes or fashion [27], [28]. So far, a large number of wearable antennas has been already proposed for many different applications including miniaturized or low profile rigid and flexible textile antennas [27] emerging radiation characteristics appropriate for On/Off-body communication link requirements [29].

1.2.1 Rigid wearable antennas

A shorted spiral-like patch antenna operating at 430 MHz suitable for military RF Communications was presented in [30] (Fig. 1-1 a). This antenna was etched on a rigid FR4 dielectric. The use of an electromagnetic bandgap (EBG) structure makes this antenna suitable for wearable applications by reducing the power radiated towards the wearer. The overall size of this antenna is 11.4 cm × 7.6 cm, which is small compared to the wavelength at the resonant frequency. In [31] a dipole and a spiral antenna (Fig. 1-1 b) for military wearable applications (100–500 MHz) were proposed. These antennas are unobtrusive and low profile.

In [32] three antennas: (a) $\lambda g/4$ antenna with a ground shield; (b) a dipole V antenna and (c) a square dipole antenna was made out of copper with a glass—epoxy substrate ($\varepsilon r = 4.8$) and proposed for operation at 868 MHz, for medical telemonitoring applications. These antennas would be more suitable for a patient to wear if they were textile which will make them more flexible and comfortable.

Figure 1.2 Rigid Antenna

1.2.2 Textile Wearable Antennas

Textile antennas are a special class of antennas that are partially or entirely made out of textile materials, in contrast to conventional antennas, which consist of rigid materials. The textiles composing a textile antenna are divided into electrically conductive fabrics, denoted electro textiles and applied for the radiating and grounding parts, and dielectric materials for the insulating parts of the antenna.

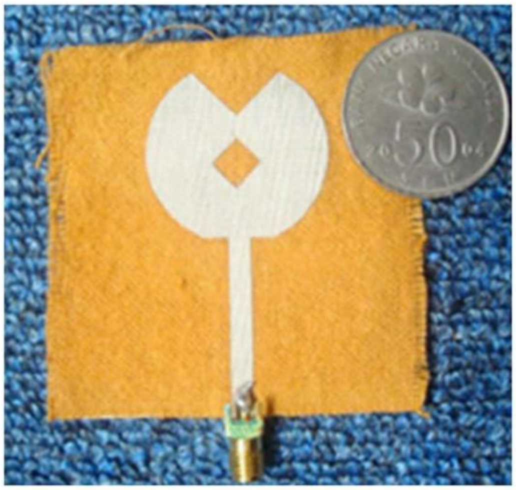

Figure 1.3 Textile Antenna [33]

As can be intuitively understood, the reason behind the use of textile materials in antennas lies in the application for which they are intended, being smart textile systems and body-centric communication.

Smart textile systems represent a new concept of garments that, in addition to traditional functions such as protecting the body against the environment, also offer additional functionality such *as* sensing, actuating, and communication, realized by wearable devices that are integrated into the “smart” garment. The communication is realized in a wireless way by means of an integrated wearable textile antenna in combination with a wearable transceiver. Such a kind of wireless communication takes place between the human body and the surrounding environment and is also referred to *as* body-centric communication. In parallel with textile antennas, this has become a very popular field of research over the last decade, with crucial importance for plenty of applications, ranging from monitoring of vital signs of patients to coordination and monitoring of rescue workers, but also in the entertainment sector and in sports.

Suitable topologies for the realization of wearable textile antennas exhibit a low profile and compact dimensions. Those features are particularly convenient for on-body placement and seamless integration into garments. For this reason, the majority of existing textile antennas are microstrip *or* patch antennas.

1.2.3 Wearable Antenna Challenges

There are 2 challenges to wearable devices that make antenna design particularly difficult:

- Proximity to the Human Body

  The human body is a lossy material for electromagnetic waves. This means the body converts Electric Fields into heat; put another way, the body absorbs energy from electromagnetic waves. Consequently, when an antenna is placed near the body, the result is a large reduction of the antenna efficiency of your wearable antenna. For example, if you design an antenna and measure the efficiency of -3 dB (50%), when placed on the body the efficiency may easily drop to -13 dB (5%). This is a huge hit to the performance of the wireless system.

- Very limited Volumes

  Wearable devices must be as small as possible. No one wants a watch with a big dipole antenna hanging out the side. Space is at an extreme premium on wearable devices, particularly for anything near the face (such as google glass). As such, industrial designers and product designers often give very little space for the antenna, which further makes the antenna design problem more difficult.

1.3 Breast Cancer Detection

Nowadays, Breast cancer is one of the most harmful diseases which affects women's health. It occurs when some breast cells originate to grow abnormally. Breast cancer can be detected using several techniques like X-ray mammography, MRI (Magnetic Resonance Imaging) and ultrasound echography. But all these techniques have some drawbacks. X-ray mammography is a definite type of breast imaging that uses low quantity X-rays to detect cancer before and after the women encounters the symptoms. The drawback of this technique is the ionization radiation and the intolerable compression. Beyond the age of 40, the radiation risk among the women is very small but today the original hazard of a 50-year-old woman would be influenced by the breast cancer spans around 88%. Ecography is a technique which uses the reflections of the high-frequency sound waves to build an image of a body organ. It is frequently used to perceive fetal growth and study body organs whereas MRI i.e. Magnetic Resonance Imaging requires an exceedingly large and costly machine. Therefore, many researchers have been proposed a Microwave Imaging technique as a possible solution [34-36]. Microwave imaging technique has some advantages such as unionization radiation and uses low-cost apparatus and this technique requires no compression and are operator-independent.

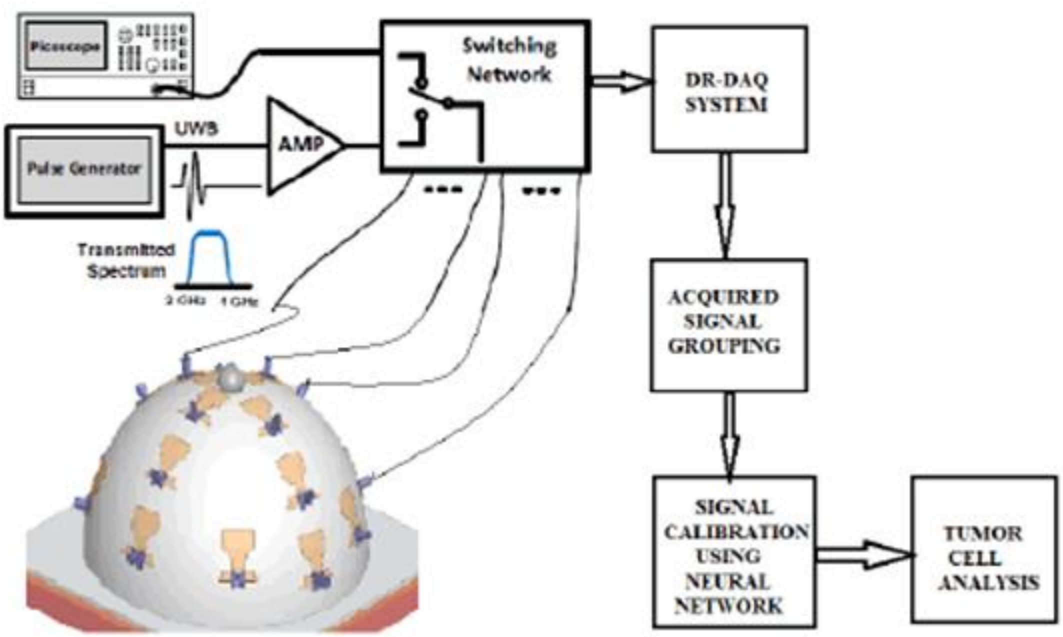

Figure 1.4 Block Diagram of Breast Cancer Cell Detection [37]

In Microwave Imaging, there are basically two approaches used for detecting Breast Cancer, one is Microwave Tomography and other is Radar Based approach. Microwave Tomography (MI) is a technique which is used for detecting Breast Cancer that further uses dielectric property contrasts for detection of unhealthy tissues at microwave frequencies i.e. around 1 GHz and this process is a safe process. Microwave tomography is a process that is used to approximate the composite permittivity distribution inside the object under test (OUT) by resolving the inverse scattering problem only when the object is irradiated under many conditions. Many researchers have been proposed a Microwave Tomographic Breast Cancer Imaging based on single and multi-frequency approaches [38-40]. Although this technology needs large computation work that causes large generation time. There are many other tomographic techniques which are used to monitor different unhealthy tissues in the body such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and Positron Emission Tomography (PET), etc. Whereas in Radar-based technique, it detects the existence of notable backscattered energy appears from high dielectric tissue properties (fibroglandular tissue and tumors [41]). This technique uses an antenna to irradiate the breast with small power, ultrawideband pulses of microwave energy and the scattered fields are accepted at the same antenna or by an antenna array. Each received signal accommodates both early and late-time scattered field contributions. In early-time scattered fields, the antenna resonance and reflections from the skin–breast interface (the skin response) are contained while the late-time fields carry backscatter from possible lesions (the tumor response) and clutter. Basically, clutter refers to a signal which appears from scattering mechanisms other than the tumor. Effective suppression of the clutter is necessary for the radar-based methods to successfully diagnose and limit small tumors.

1.3.1 Advantages of Microwave Tomography

- Microwave Tomography(MT) does not necessitate mechanical approach with the object.
- This technique can perform at high temperatures as compared to semiconductor sensors.
- The microwaves do not damage in any way the material under test. Hence, they permit high-speed, effective and uninterrupted monitoring.
- In contrasts to infrared sensors, these microwave tomography techniques are unresponsive to environmental circumstances.

- These microwave techniques are very quick to be practicable and are safe.

1.3.2 Disadvantages of Microwave Tomography

- The structural cost of the Microwave Tomography is very high-priced. The cost of the material will decrease unceasingly with time as the material has its own lifetime and market value.
- The requirement of the Microwave Tomography is to calibrate it individually especially for the different materials.
- If there is more than one variable, Microwave Tomography result is not faithful, the sensor becomes sensible.

1.3.3 Applications of Microwave Tomography

Microwave Tomography is used in many fields like Medical, Agricultural, oil, and gas, etc. The table represents different applications for Microwave Tomography.

Table 1.1 Represents different applications for Microwave Tomography.

Reference	Type of Antenna	Field	Application
[42]	32 transmitting and receiving antenna	Medical	Construct image of bone, fat, muscle and water
[43]	Monopole	Oil and gas	Apply image reconstruction algorithm in a simulation model with same antennas as the experimental system, at 4.5GHz, images of gas and oil distributions with different oil and gas phase fractions (0%, 25%, 50%, 75% and 100% of oil) will be constructed
[44]	Monopole antennas	Medical	Investigation of the reconstruction of breast cancer's image by using

			microwave tomography in two-dimension. 1 transmit and 15 receive antennas had been used.
[45]	Log periodic antenna	Agriculture	Identifying the interior of wood trunks
[46]	resonance sensor	Medical	Design a microwave tomography to investigate and study biological tissue in order to perform on skin
[47]	ground penetrating radar	Oil and gas	Oil detection and monitoring by using GPR and construct 3D microwave tomography

1.4 Brain Tumor Detection

A brain tumor is a fibrous tracery of undesirable tissue growth inside our brain. Obviously, this tissue is unfortunate but the real problem arises when the tissue continues to grow incidentally. This unwanted growth begins to disturb our typical brain operations. There are many causes of Brain tumor-like exposure to radiation, local trauma, and injury, etc. In General, two types of tumor are Benign and Malignant. Benign tissue refers to the tissue without any cancerous cells while malignant tissues are those which include the cancerous cells. Researchers were shown that there has been a large difference between the normal tissue and the tumor affected tissue [48]. Early detection of Brain cancer and treatment can improve the lifetime of the patient. One of the best-used technique for brain cancer detection is the Microwave Imaging. There are many techniques by which brain cancer can be detected such as MRI (Magnetic Resonance Imaging), positron emission tomography (PET) and X-ray screening, computed tomography (CT) scans [49]. But these techniques also have some disadvantages. One of the best-used technique for detecting brain cancer is Microwave Imaging.

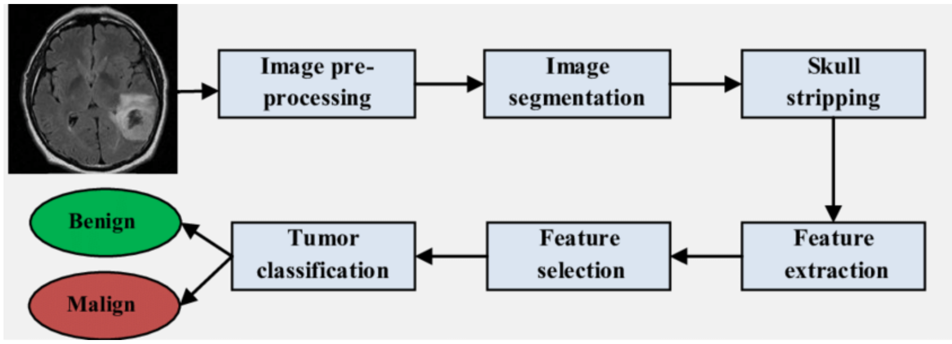

Figure 1.5 Block diagram shows the Brain tumors detection [50]

1.4.1 Advantages of X-ray Screening

- It is cheaper
- It helps in recognizing cancer
- It helps in testing Bone fractures and tumor
- The main advantage of X-rays is that they are easy to use as compared to MRIs and CT scans.

1.4.2 Disadvantages of X-ray

- Disadvantages of X-rays are that they do not give a detailed image of the body.
- Do not use the same kind of energy in all scanning types
- Huge exposure to the rays may create skin cancer
- Many times the DNA of the body has to be changed.

1.4.3 Advantages of MRI (Magnetic Resonance Imaging)

- Do not involve exposure to radiation thus can be used in pregnant women and babies
- Show swelling and inflammation
- Shows both 3-D and cross-section images of the body

- Useful for showing soft tissue structures such as ligaments and cartilage

1.4.4 Disadvantages of MRI (Magnetic Resonance Imaging)

- Expensive
- Involve loud noises while processing because they involve a high amount of electric current supply
- Done in an enclosed space

1.4.5 Advantages of PET (Positron Emission Tomography)

- Diagnose cancer
- Discover whether cancer has grown in the body.
- Discover blood circulate to the heart muscle.

1.4.6 Disadvantages of PET (Positron Emission Tomography)

- Expensive
- Might be dangerous
- Discover the difference in the brain that may produce epilepsy

These disadvantages can be overcome by using Microwave Imaging systems. Microwave Imaging is a prominent technique used to have low-priced and convenient medical disease detection tools. The motive of the microwave imaging technique is to detect the difference between the electrical properties of healthy and unhealthy tissues. One of the most popular forms of microwave imaging is Brain Tumor detection. The antenna is the main element of the microwave Head imaging system. While designing the microwave-based imaging system, the main purpose of this system is to make them portable. This demand represents a sincere challenge especially when talking about head imaging as the operation band for this application is the low microwave band of frequency i.e. 1-4 GHz.

Table 1.2 Different types of antennas used for Brain Cancer detection

Reference	Antenna Specifications	Summary of work
[51]	Antenna array composed of three ultra-wideband Vivaldi antennas	Analysis of the reflected signals shows that using a smart antenna array based imaging system can be used for brain cancer detection.
[52]	3-D slot-rotated antenna	The compact size, wide operating bandwidth, unidirectional radiation, and detection viability are merits of the presented antenna and the subsequent system
[53]	Ultra wide-band (UWB) Vivaldi antenna array	Results are presented, showing the effect of the optimization process on the distribution of the specific absorption rate SAR inside the head phantom.
[54]	Graphene-based tapered slot antennas	reconstructed tumor image indicates that the suggested antenna has the potential to be

		reliably utilized in such UWB application
[55]	Wearable pentagon-shaped microstrip patch antenna	The proposed antenna was found useful to detecting cancerous tumor consisting of head the model that carries a 5 mm tumor inside human brain.

1.5 Problem Statements

The fabrication and measurement complexities are another important issue in the development of biomedical antenna structures. Working in suitable biomedical band requires an efficient compact antenna that fits either inside or around implanted device. Miniaturization of wireless devices is required but it is easy to be achieved without affecting the performance of antenna. The rapid advancement of wearable body sensors in biomedical applications necessitates the need for their implementation on flexible and conformal materials. However, the placement of such radiating structures at a close proximity to the human body causes changes to its performance. Breast cancer and brain tumor detection using conventional methods is not very accurate and tedious task.

1.6 Objective of Thesis

- Design and simulation of hexagonal shaped inset fed microstrip patch antenna for Brain Cancer detection at ISM band
- Design and simulation of rectangular inset fed implantable microstrip patch antenna for Breast Cancer detection at MICS band
- Fabrication and testing of primary microstrip patch antenna and proposed metamaterial loaded antenna.
- Comparison of simulated and measured results.

1.7 Scope of Work

This thesis comprises of two concepts and accordingly designing and manufacturing two different antennas. First antenna includes microstrip patch antenna for detecting Brain cancer resonating at 2.46 GHz i.e. ISM band. The key feature of this antenna is its small size which supports in its wearability by human body. Second paper is used breart cancer detection. Technique comprises of designing and manufacturing of rectangular inset fed microstrip patch antenna resonating at 402 MHz frequency. The significant feature of this antenna is its implantability in human body.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, an overview of the work, regarding microstrip patch antennas that are used to detect Brain and Breast cancer is discussed and also it gives detailed study by various researchers on this concept. Some of the research works related to patch antennas for Cancer detection are presented in this section.

2.2 Breast Cancer Detection

Radouane Karli et.al [56] presented a UWB planar antenna for detecting Breast Cancer functioning at a frequency approved by FCC The hemispherical breast model is used in this work which further consists of three layers such as skin, fat and tumor tissue. Results were carried out by placing the tumor at various locations inward to dissimilar breast model. When vulnerable to microwave emission, the tumor's electrical belongings, conduction, and specific absorption rate modify substantially from those of healthful organic tissue.

Jingjing Zhang et.al [57] proposed a novel Cross-Vivaldi antenna for detecting Breast Cancer. The performance of the antenna is investigated over the frequency range of 2.2– 5.4 GHz. In this antenna, the examination of cross-polarized observations has been presented for radar-based breast tumor detection.

M. Tarikul Islam et. al [58] proposed a compact slotted patch antenna for detecting Breast Cancer. To attain the omnidirectional radiation pattern with high gain and for enhancing the electrical length, the slots are pierced in the patch and the ground plane of the antenna. By cutting the slots in the antenna, it increases the gain, efficiency and operating frequency without disturbing the antenna dimensions. The actual size of the antenna is 23mmX21 mm. Many antenna parameters are calculated on the breast phantom model with the tumor for recognizing the antennas performance inside the breast.

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Takamaro Kikkawa et.al [59] presented 4X4 planar Ultrawideband (UWB) antenna array for detecting Breast Cancer. The actual antenna size is 11mmX13.1mm.The bandwidth and the center frequency of the antenna is 12.5 GHz and 6 MHz respectively. Using Breast phantoms

Takamaro Kikkawa and Takumi Sugitani, Planar UWB Antenna Array for Breast Cancer Detection, 7th European Conference on Antennas and Propagation, 2013, 339-343.

Mahrukh Khan et.al [60] designed a UWB V-slot patch antenna for early Breast cancer Detection. The size of the antenna is 13.69mmX18.97mm and is excited by an L-probe feed. The simulated bandwidth and gain of the proposed antenna are 57% and 6.8 dB. Additionally, this design has the advantage of high and balanced gain over a wide range of frequency. The antenna properties like low cost and small form factor make it an appropriate building block for the microwave sensor array. To identify the antenna element the full-wave EM simulator FEKO was used.

Engy Alaa El-Din Hanafy et.al [61] designed a Spiral PIFA antenna for Breast cancer detection operating at ISM band. In this work, we can observe that there exists a difference between the electrical characterstics of benign and harmful breast tissues. The breast model is fabricated in such a way so that it can mimic the realistic case. This antenna is created to be used as a stethoscope and the size of the antenna is 2X2 mm^2 with thickness 1.524mm.

2.3 Brain Tumor Detection

Rafat Raihan [62] et.al presented a wearable pentagon-shaped antenna for Brain Cancer detection. The proposed antenna operates at ISM band. The advantage of this antenna is its small thickness and dimension. The size of the antenna is 33X23X1 mm^3 and is fabricated on FR-4 substrate. This antenna located on the person’s head phantom model which contains six layers such as fat, Dura, Cerebrospinal fluid (CSF), skin, skull, and brain. This antenna notices several parameters like VSWR, return loss and radiation pattern in the head phantom model and these outcomes are contrasts with a cancerous tumor that contains 5mm tumor inside the human brain.

Md. Ahasan Ibna Aziz [63] proposed a UWB microstrip patch antenna using GBC (Graphene-based conductor) to identify the tumor inward the brain. This antenna contains a radiative component and is operating between 3.15-9.15 GHz frequency band. To attain the antenna performance, ground patch lengths have been examined as the main element in this work. Six layer head phantom model is used in this design and is situated at 20mm away from the human head to detect tumor inside the brain.

Jasmine Angel. J et.al [64] presented a UWB Vivaldi antenna for brain cancer detection. A brain phantom model has used whose dielectric properties are the same as that of the human brain. Several parameters like SAR, radiation pattern, etc. have been analyzed in this paper. It was observed that the value of SAR is higher in the case of the human brain phantom model with a tumor cell as compared to the healthy brain model.

N. Mahalakshm [65] proposed an Aperture Coupled Microstrip patch antenna for detecting Breast Cancer operating at ISM band. In this work single layer, the microstrip patch antenna is used and it is then it collates to a twice layer stacked patch antenna. The outcomes were shown that the fabricated single-layer antenna has a good implementation and radiation pattern across the required frequency range than double layer stacked patch antenna. The proposed antenna gives a wide slot efficiency of 62.6% and narrow slot efficiency of 62.2% (narrow slot).

Srinivasan Ashok Kumar1 [66] presented novel flexible implantable CPW fed Z-monopole antenna for ISM band. This antenna operates at 2450MHz frequency band which is a wideband communication for high-data-rate implantable biomedical application. The actual size of the antenna is 7mmX8mmX0.65mm with biocompatible Al2O3 ceramic substrate. Due to substrates higher permittivity and quality factor, this antenna indicates lower return loss, good VSWR, better impedance matching at 50 ohm with CPW structure. The simulations were done in many slot widths which depicts that the antenna covers the complete ISM band.

S. Ahdi Rezaeieh et.al [67] designed a three-dimensional slot-rotated antenna for microwave brain imaging system. The necessity of the described imaging system is to have a wideband and unidirectional performance at the low microwave frequency and this antenna is designed in such a way that it can fulfill the demands of the specified imaging system. Miniaturization is done in this technique. Many traditional techniques are applied to enhance the bandwidth as well as directivity of the antenna. To degrade the operating frequency of the antenna, four series of staircase shaped slots are applied whereas a folding process is used to improve the directivity and reduce the overall size.

Yong-Xin Guo et.al [68] designed a single-fed miniaturized circularly polarized (CP) microstrip patch antenna for biomedical applications. The actual size of the antenna is 10×10×1.27 mm3. This antenna is designed employing the capacitive loading on the radiator. If comparing the proposed antenna with a square patch antenna, this antenna has attained outstanding size-reduction of ~72%. Many parameters like radiation pattern, simulated impedance and axial ratio (AR) are calculated and are then compared in a different phantom model.

O. Fiser et.al [69] proposed three types of antennas for Brain stroke detection operating at the frequency between 1.5–3GHz. Three types of antennas are 1) Bowtie antenna, 2) Double ridge horn antenna, 3) Microstrip antenna. This system provides a comparatively inexpensive diagnostic tool which is used to categorize two types of brain strokes: ischemic stroke and hemorrhagic one (detection of changes in permittivity and conductivity). In this work comparison study of three types of UWB antenna through numerical simulation is conducted.

Kim Mey Chew et.al [70] described an evolution of a microwave signal acquisition, simulated brain model, 2D and 3D representation and signal processing. The phantom model is the key element in this research. The human brain like the phantom model is designed in this work whose permittivity is same as that of the real human brain. The goal of this study is to describe the size of the tumor and find the tumor location in the human brain. In the microwave signal data acquisition process, the data were acquired based on the simulated brain model. Window functions, Envelope detection, subtraction, and proposed superposition technique function are utilized to extract the information from the microwave signal.

Adhitya Satria Pratama et.al [71] proposed an Ultrawide Band CPW fed dipole like an antenna for Brain tumor detection. The actual size of the antenna is 74mmX42mm. In this paper UWB antenna is designed as a transceiver of microwave imaging on brain tumors, operating between the frequency range of 3.1-10.6 GHz. This antenna is simulated using CST Microwave Studio and experimentally measured with the person brain phantom model for the analysis of the antenna.

Haitham Abu Dami et.al [72] presented two square loop wearable antennas for biomedical applications operating at 2.4 GHz frequency band. These two antennas are firstly simulated using CST Microwave Studio and then printed on flexible DuPont Kapton sheets for further calculations. To enhance the performance of the antenna, this square loop antenna was altered by adding four circular patches to its sides. The new antenna called Quadruple Loop (QL) antenna is then designed. The QL antenna gives better performance over a wide impedance bandwidth compared to that of the standard square loop antenna.

Hana Trefn et.al [73] designed an array of antennas which contains triangular microstrip antenna elements having V-shaped and short-circuiting walls for the brain stroke detection. The total size of the antenna is 37mmX25mm with thickness 14.4mm. The main advantage of this antenna is small size, lightweight and low cost. In this work, the researchers explore the probability to upgrade monitoring of sufferers with transient cerebral ischemic affairs using microwaves. The return loss of this antenna conveys that it is sensitive enough to diagnose even little changes in the brain.

Farhad Gozasht et.al [74] designed a triple-band implantable miniaturized slot PIFA antenna for biomedical applications operating at MICS band at 433 MHz as well as Medical (ISM) band at 2.4GHz. Homogeneous and inhomogeneous Phantom models are fabricated so that it can easily be etched in the human armor under the chest. The results were obtained by putting the proposed antenna into the phantom model. The size of the antenna is 19mmX30mmX1.6mm. This antenna is designed in such a way so that it can also radiate at other frequencies without even changing the antenna dimensions.

2.4 Conclusion

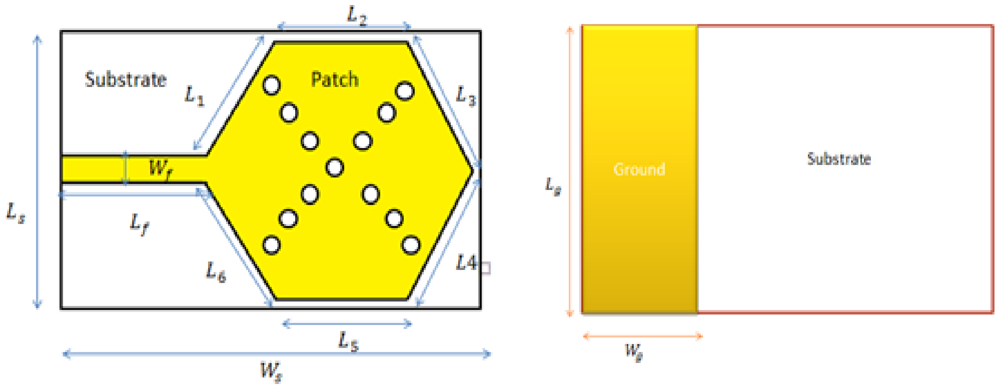
In this chapter, various methods for cancer detection are studied in detail. The survey provides ease of understanding what can be required for this work.

CHAPTER 3

Detection of Brain Tumor using microstrip-line fed Hexagonal shaped antenna at ISM band for wearable applications

3.1 Antenna Design

The proposed hexagonal-shaped wearable microstrip patch antenna is designed using non-conductive material FR-4, the largest well known inexpensive substance to fabricate circuit boards, having relative permittivity (ε_r) 4.35, loss tangent (tan δ) 0.025 and thickness 0.8 mm. The actual length of the antenna is 30mmX20mm. The material used for patch line feed and ground plane of the antenna is copper that is regarded as perfect electric conductor (PEC) in CST MWS. The frequency on which antenna is resonating of the antenna is 2.46 GHz. The figure depicts the geometrical arrangement of the proposed antenna. The design of the hexagonal-shaped antenna is initiated using some standard equations derived from the transmission line model. There are thirteen circular slots in the patch so as to increase the bandwidth of the proposed antenna.



(a) (b)

Figure 3.1 Arrangement of the designed antenna

(a) Radiating structural design having Pentagonal shaped patch
(b) The ground plane of the antenna

This paper describes a compact microstrip-line fed the hexagonal-shaped wearable antenna with circular slots and reduced ground plane for brain tumor detection. Patch antennas are usually preferred because they have an enormous variety of use in medical applications. A microstrip patch antenna is preferred because of its low profile, lightweight, ruggedness, and compatibility with microwave and monolithic ICs. In particular, the proposed antenna is used to detect and characterize a hidden tumor inside the brain. The detection is based on comparing the S_{11} properties of benign and malignant brain tissues when radiated with microwave energy. Benign tissues are those which do not include any cancerous cells whereas the malignant tissues do. The simulation results presented here reveal the effectiveness and sensitivity of the simple antenna structure in the detection of a tumor.

TABLE 3.1 Measurements of proposed antenna

ELEMENT	PARAMETERS	DIMENSIONS(mm)
Ground	Length,L_g	5
	Width,W_g	20
	Thickness,T_g	0.1
Substrate	Length,L_s	30
	Width,W_s	20
	Thickness,T_s	0.8
Patch	Thickness,T_p	0.1
	Length,L_1	8.28
	Length,L_2	10
	Length,L_3	8.06
	Length,L_4	9.48
	Length,L_5	11
	Length,L_6	8.28
Feed	Length,L_f	11
	Width,W_f	1.5
Circular Slot	Radius	0.5

To prevent the unfavorable outcome of the non-magnetic region, the ground plane of the antenna is attached to the person brain Phantom Model surface [16]. The coordinates where an antenna is placed are selected as x=0, y=0, z=25. The realistic human head phantom is designed using CST Microwave Studio as shown in Figure 3.2.

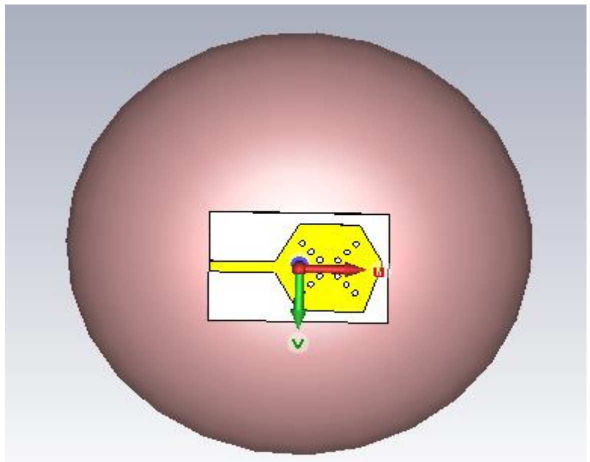


Figure 3.2 Front CST view of the designed antenna in Human Head Phantom Model.

The antenna is investigated on the human head model with a spherical tumor of radius 5 mm. The spherical tumor is located on the individual brain phantom model as shown in Figure 3. The proposed antenna consists of only skin layer which is attached to the ground plane of the antenna with relative permittivity 42.85, conductivity 1.59 S/m, density 1090 kg/m^3 and thickness 1 mm.

3.2 Results

3.2.1 Return loss

The simulated return loss plot of proposed microstrip-line fed the hexagonal-shaped antenna with and without cancerous tumor is depicted in Figure 7. We can observe that the S_{11} characterstics head with the tumor is -38.788 dB whereas the return loss without tumor is -31.995 dB at resonating frequency 2.46 GHz. The shift in the S_{11} values clearly depict the presence of malignant tissues in the brain.

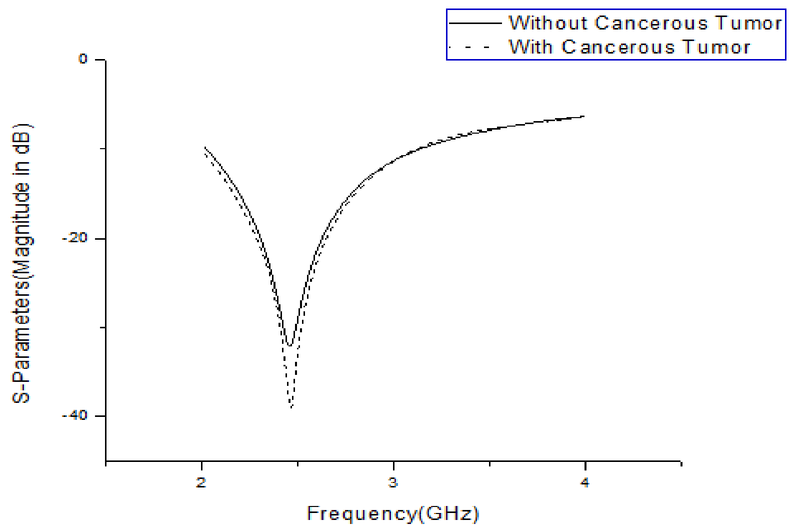


Figure 3.3 Return loss of the proposed antenna with and without cancerous tumor.

3.2.2 3D and Polar view of Radiation Pattern

Figure 3.4 illustrates the 3D view of the far-field radiation pattern of proposed antenna in human head phantom model with malignant tumor at position (x=0, y=0, z=25). We can observe that the designed antenna has a total radiation efficiency of -11.87 dB and directivity of 2.98 dBi at the resonant frequency 2.46 GHz as shown in figure 3.5.

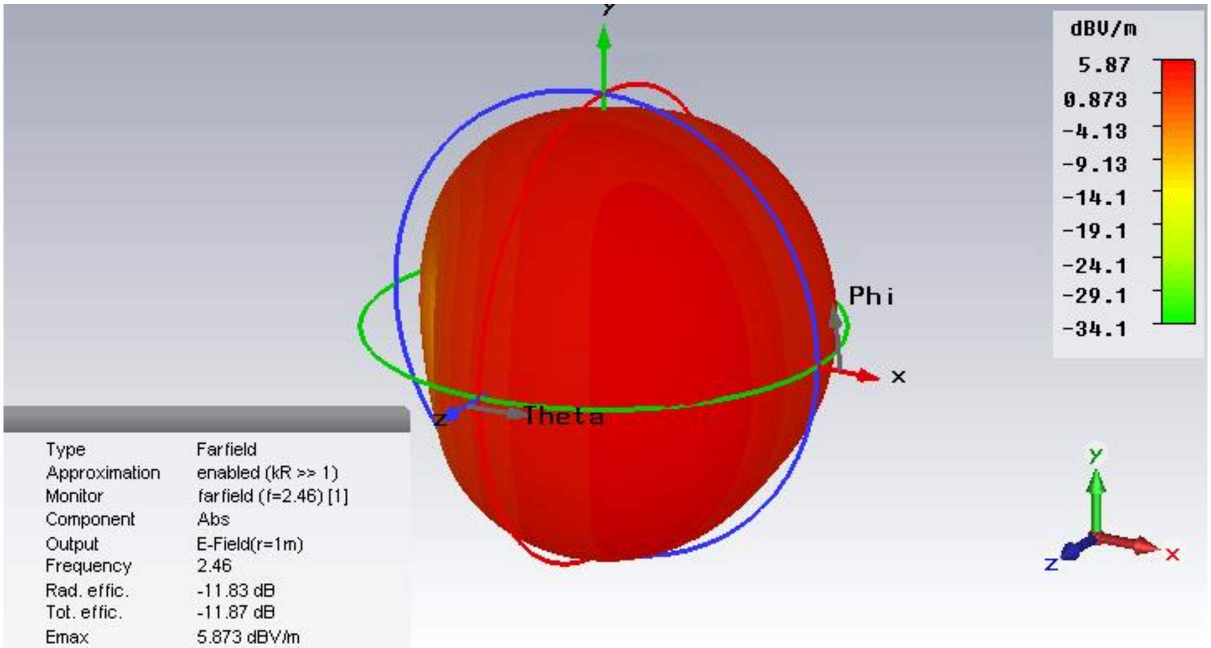


Figure 3.4 3D Far Field Radiation Pattern of the proposed antenna in human head phantom model with tumor

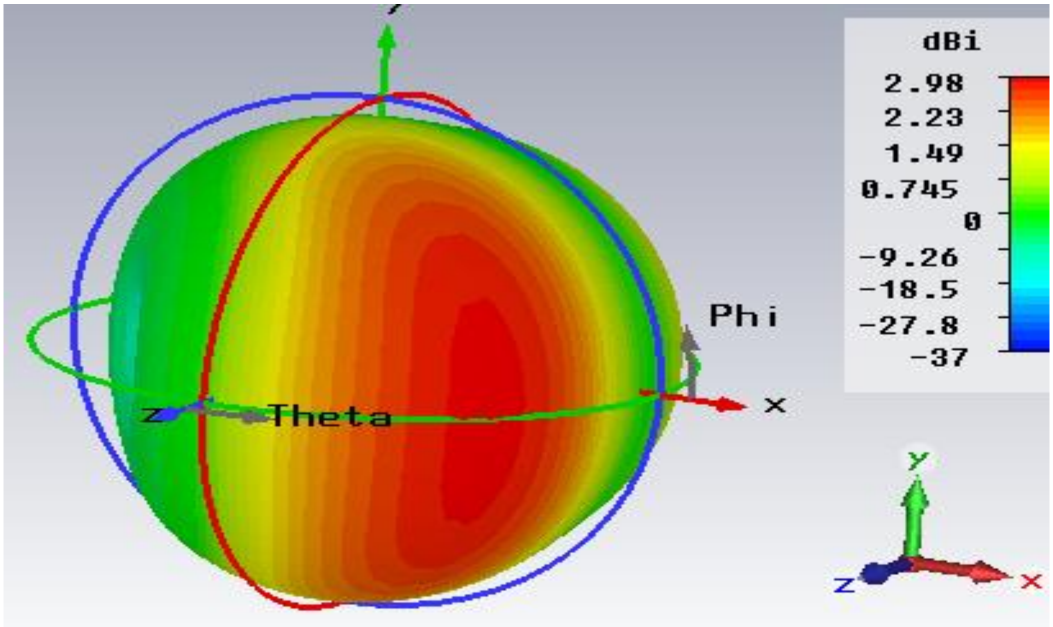


Figure 3.5 Directivity of the proposed antenna

Figure 6 shows the polar view of the far-field radiation pattern of the proposed antenna where the main lobe magnitude is found to be 5.98 dB/m, main lobe direction 45 degrees and angular 3dB width is 147.3 degrees at the resonance frequency 2.46 GHz.

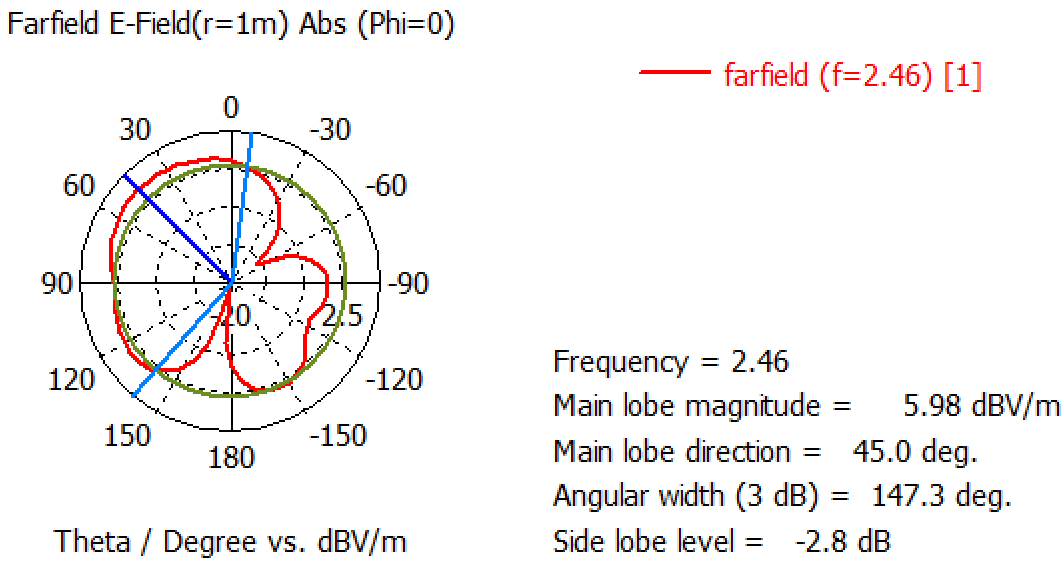


Figure 3.6 Polar plot of the radiation pattern of the proposed antenna.

3.2.3 Specific Absorption Rate (SAR)

Specific Absorption Rate i.e. SAR can be measured from the calculated electric field E (V/m). It is defined as the measure of heat distribution in the body tissue and is considered for safety purposes. SAR calculation standard is regulated by IEEE C95.3-2002, where the 1-gram averaged SAR should not exceed 1.6W/kg as given by ICNIRP and FCC guidelines. Figure 8 shows the SAR value of the proposed antenna with the input power of 2mW which is found to be 0.3747 W/Kg at the resonant frequency 2.46 GHz.

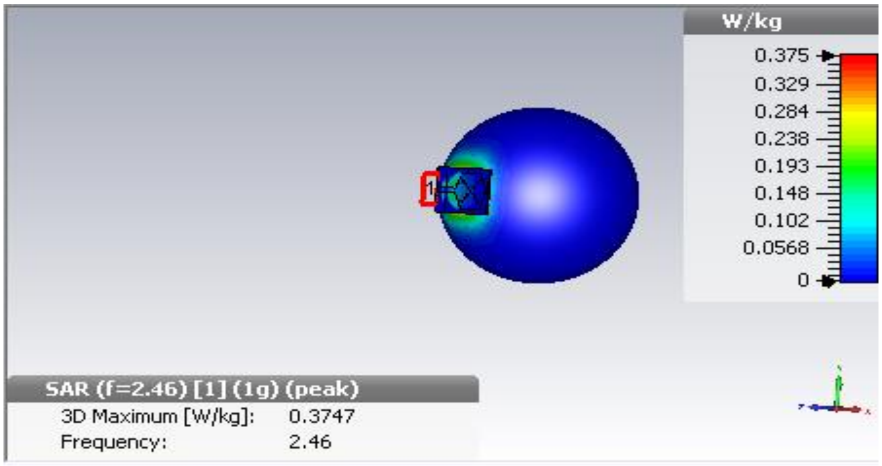


Figure 3.7 SAR of the proposed antenna at the input power of 2mW.

3.2.4 Voltage Standing Wave Ratio (VSWR)

VSWR is a function of reflection coefficient which describes the power reflected from the antenna and indicates that the antenna is better matched to the transmission line and sufficient power is given to the microstrip patch antenna. The VSWR plot of the proposed antenna is depicted in Figure 9 that clearly indicates that VSWR is 1.022 at the resonant frequency of 2.46 GHz.

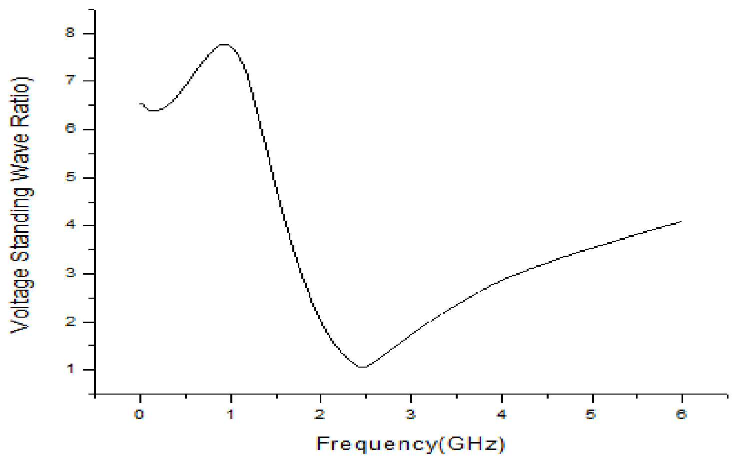


Figure 3.8 VSWR plot of the proposed antenna.

Table 3.2 Comparison of different types of antennas for Brain Cancer detection

Reference	Antenna Size	Substrate Used	Return Loss (dB)	SAR(W/kg)	Gain (dBi)
[75]	39X39X2.1 mm^3	FR-4	-16.69	1.57	-
[76]	90X90X0.17mm^3	Felt	-48.42	-	6.052
[77]	96X47X0.13mm^2	Felt	-33.30	1.57	-5.5
[78]	108.7X46.6X0.2 mm^3	Fleece	-22.64	-	7.59
[79]	35X33X1.6 mm^3	-	-28.9	-	-0.342
[80]	70X70X0.2 mm^3	Cotton	-32	-	4
Proposed Antenna	30X20X0.8mm^3	FR-4	-31.955	0.3747	-8.742

3.3 Conclusion

In this paper, a hexagonal shaped microstrip patch antenna is designed, fabricated and tested for brain tumor detection operating at ISM band. After designing, it is placed in an individual brain Phantom model for further calculations. It was observed that there is a difference in the return loss of the normal and the affected head phantom. The return loss value for the affected head was -38.788 dB, whereas, in case of the normal head it is -31.955 dB at the resonant frequency of 2.46 GHz. It was observed that there is a shift in the return loss value of affected tissues which indicates the presence of tumor inside the human brain. The maximum radiation gain and directivity are 8.74 dBi and 2.985 dBi respectively. The value of SAR of the proposed antenna is 0.3747 W/kg with the input power of 2mW at the resonant frequency 2.46 GHz which makes it a successful candidate in brain tumor detection for wearable applications.

CHAPTER 4

Inset-fed Microstrip Patch Antenna for Detecting Breast Cancer for MICS band Applications

4.1 Antenna Design

In this work, the microstrip patch antenna is used. A microstrip patch antenna is mostly preferred because of its merits such as low cost, lightweight, easy fabrication, low profile, etc. Also, it includes many disadvantages like the narrowband, low gain, and low power-handling capability. Microwave Imaging employs microstrip patch antenna because of its advantages such as comfort, low cost, unionization and safe. Moreover, these antennas are mostly utilized in wireless technologies not because of only they are compact and easy to implement but also they can be made appropriately under various conditions consisting those involving low loss conditions, customized radiation pattern and tight frequency selectivity.

In this work, the inset-fed microstrip patch antenna is used. Figure 2 represents the proposed antenna configuration. The actual antenna size is 15mmX15mm with thickness 1.6mm. The proposed antenna is developed and fabricated ona FR-4 substrate (Flame Retardant-Fiber Glass Epoxy). Microstrip line feed is used to feed the inset-fed microstrip patch antenna and the resonating frequency of the antenna is in between 402-405 MHz.The two main factors which are to be examined while designing implantable antennas is Person's safety and Miniaturization. For patient's safety, these antennas should be biological acceptable for long term duration. Further, the person's tissues are heat conductive so the metal heating element is kept isolated from it. For this sake the metal heating element is either wrapped with superstrate layer or with low-loss biocompatible coating on the other hand, miniaturization is the key element in the implantable devices. To shorten the effective wavelength and size of the antenna high dielectric permittivity materials are used. Another approach for miniaturization of the antenna is to use a shorting pin within patch and ground planes because by embedding shorting pin into the patch the operating frequency gets reduced. The diameter, position and the number affect the resonance frequency of the shorting pin.

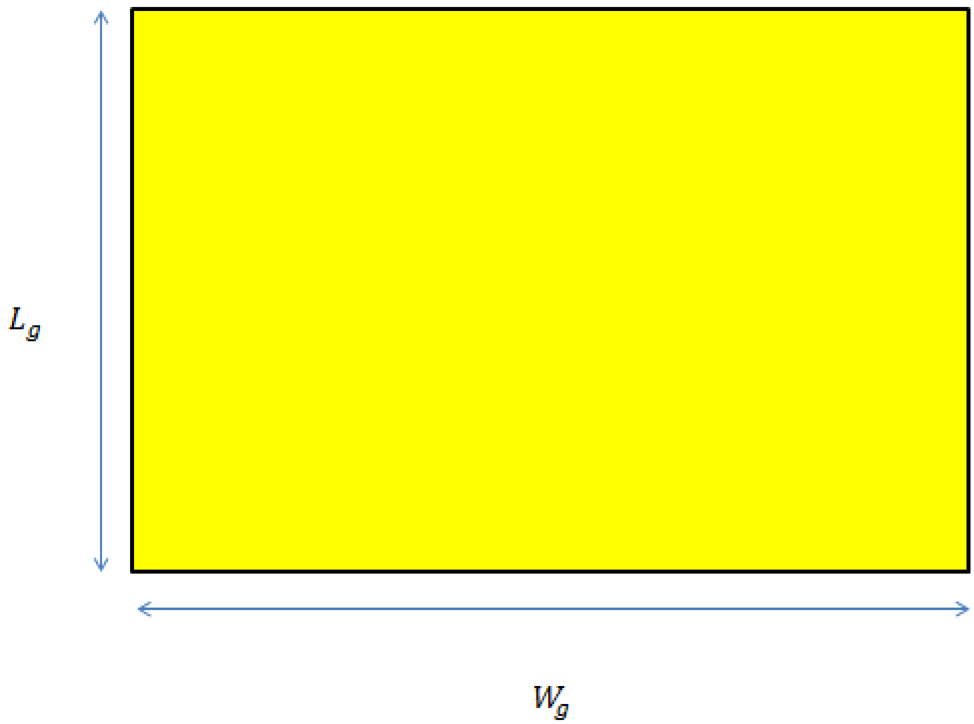


Figure 4.1 Ground plane of the Proposed Antenna

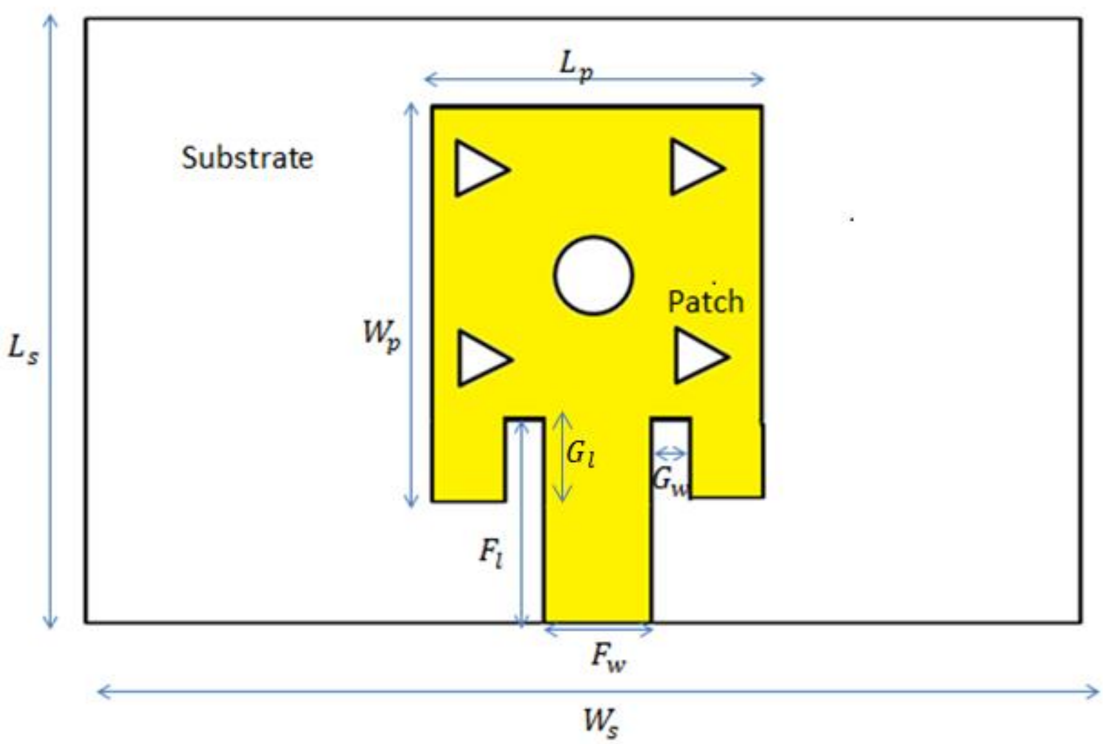


Figure 4.2 Proposed Antenna Configuration

Table 4.1 Measurements of Proposed Antenna

Antenna Parameters	Dimensions(mm)
L_g	15
W_g	15
H1	0.035
L_s	15
W_s	15
T_s	1.6
L_p	6
W_p	6
F_l	3
F_w	2.25
G_l	1
G_w	0.6
H_2	0.64

The geometrical configuration of the designed antenna is shown in the fig1. Our goal is to design a basic inset-fed microstrip patch antenna resonating at 402 MHz and is fabricated on FR-4 ($\in_r$= 4.4) substrate with length 15mm, width 15mm and thickness 1.6mm. The proposed antenna was stuffed with ROGERS 3010 superstrate and has a thickness of 0.64mm. The purpose of the superstrate is to block the direct communication between the human tissues and the patch and also to enhance the radiation Also, there are many slots on the patch which can increase the bandwidth of the antenna. However, in this paper, we adopted a square shape for the skin layer inside which the antenna is placed.

(a) (b)

Figure 4.3(a)&(b)**:** Antenna Structure with Superstate & Skin Layer

4.2 Results

The proposed antenna was simulated using CST microwave studio. As shown in the figure, the antenna resonates at 402 MHz. In this paper, we have used only the skin layer with dimensions 10mmX10mm for simulation whose Relative permittivity and conductivity are 36 and 4 S/m. The antenna is embedded in the gel type tissue material whose electrical properties are analogous to human skin in terms of permittivity and conductivity.

4.2.1 Return loss

Figure 4.4 and 4.5 show the return of the loss of the designed antenna without and with the tumor. It was observed that the return loss is -49.95 dB without tumor and -55.24 with tumor at the resonance frequency of 402 MHz. The shift in the peak depicts the presence of a tumor inside the breast.

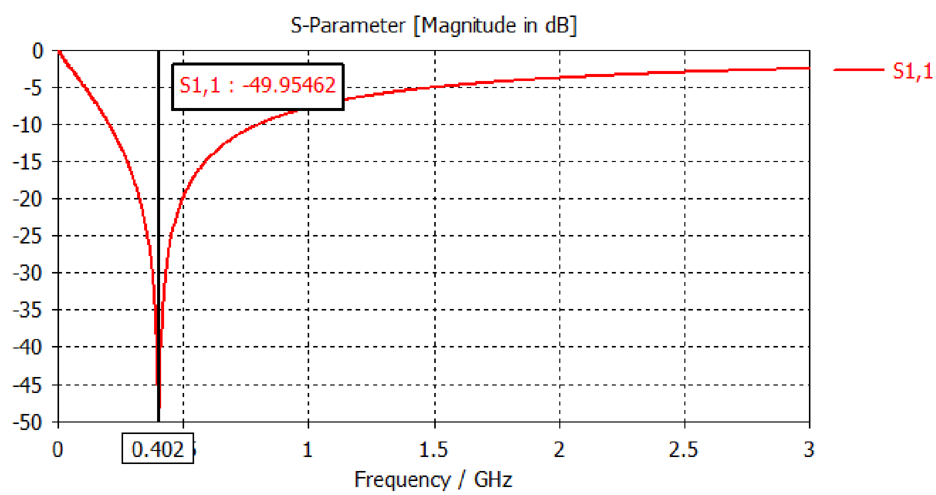


Figure 4.4 Return loss of proposed antenna without tumor

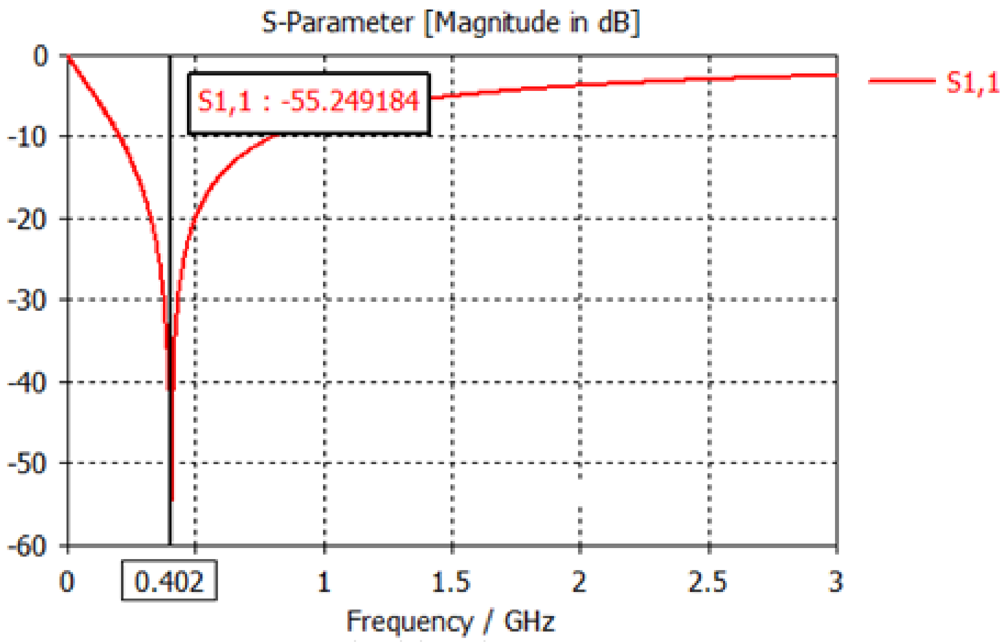


Figure 4.5 Return loss of proposed antenna with tumor

4.2.2 Radiation Pattern

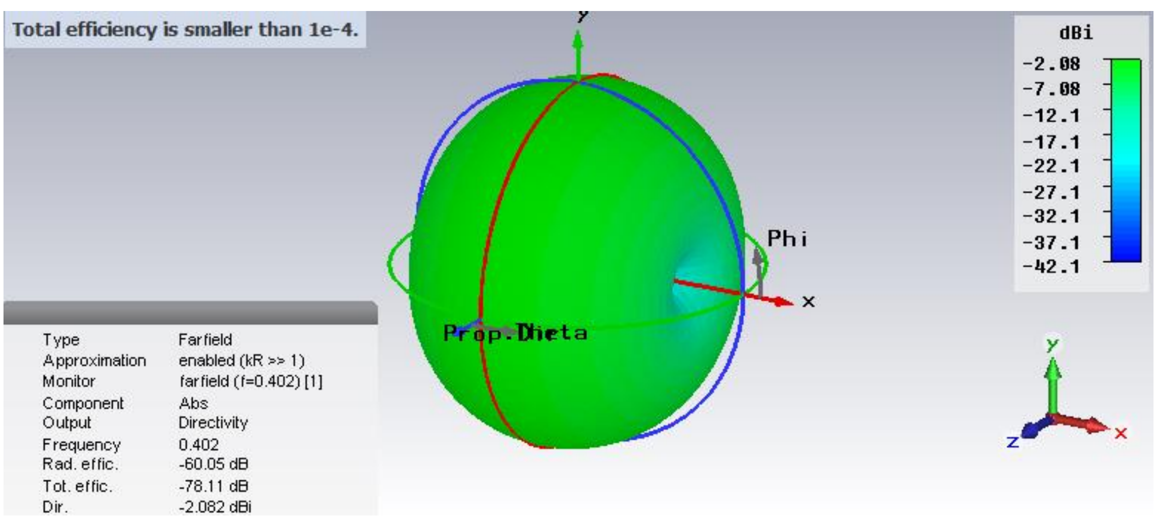


Figure 4.6 3D view of the far-field radiation pattern of the proposed antenna

The figure illustrates the 3D view of the far-field radiation pattern of the proposed antenna with skin layer model.We can observe that the designed antenna has a total radiation efficiency of -60.05 dB and directivity of -2.082 dBi at the resonant frequency of 402 MHz as shown in figure

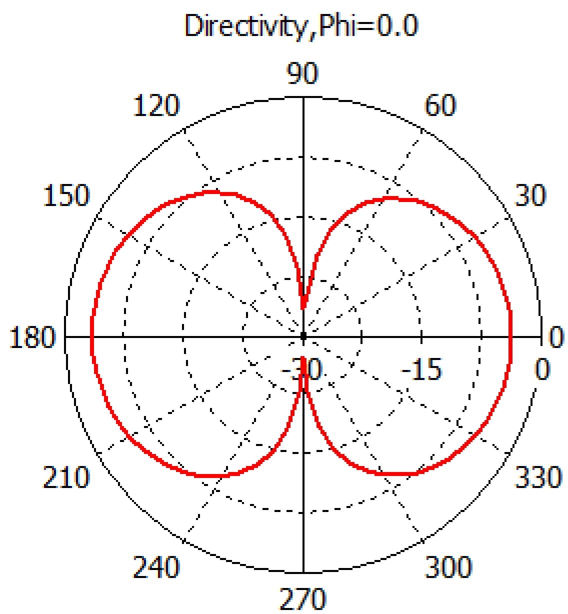


Figure 4.7 Directivity of the proposed antenna

Table 4.2 Different types of antennas used for Breast Cancer detection at different layers

Reference	Antenna Size	Substrate / superstrate	Tissue type
[81]	18x16x1 mm	ba MgTa Nb O	Skin
[82]	15.9x12.9x1.6 Mm	FR4 substrate Polycarbonate superstrate	Muscle

[83]	14x14x1.27 Mm	ROGERS 3210 substrate	
[84]	19.6x2x.254 Mm	Substrate Rogers RT/duroid 6010	Head 200 mm and trunk 230x280x625x mm elliptical cylindrical models
[85]	20x10x1.653 mm	ROGERS 3210	Skin 50x100 Mm
[86]	12.5x12.5x1.27 mm	ROGERS 3010 substrate	Muscle 92.5x92.5x39.27 mm

4.3 Conclusion

This paper presents the Breast Cancer Detection using Microstrip patch antenna resonates at MICS band. The designed antenna possesses the bio-friendly profile. Simulated impedance bandwidth of the designed implantable antenna is -49.95dB without tumor and -51.21 with the tumor. For practical applications, the designed antenna is covered with the thin layer of low-loss biocompatible coating to meet the biocompatibility requirements. This antenna is optimized and designed inside the single-layer skin phantom cube. Different parameters like radiation pattern, directivity, return loss and gain is observed in this work. The shift in the graph depicts the presence of a tumor inside the breast.

CHAPTER 5

FABRICATION AND TESTING OF ANTENNA

5.1 Fabrication and Testing of Proposed Microstrip Patch Antenna for Brain Cancer Detection operating at ISM Band

5.1.1 Introduction

This chapter presents the fabrication and test results of Brain cancer detection antenna and validation of results in practical usage of the antenna. Comparison between simulated and tested results is also presented**.**

5.1.2 Equipment Used

After examination and optimization of the geometrical specifications, the simulated antenna was fabricated on a dielectric substrate named Epoxy Glass-FR4 ($\in_r = 4.4$, thickness h=0.8) and was examined analytically. Photolithography technique along with wet etching facility was embraced for the fabrication of the proposed antenna and is photograph is presented in the figure. The return loss of the fabricated antenna was tested with the help of Agilent E5071C Vector Network Analyzer at Antenna Research Laboratory, Thapar University, Patiala.

Figure 5.1 (a) Front View (b) Back view of the Fabricated Antenna

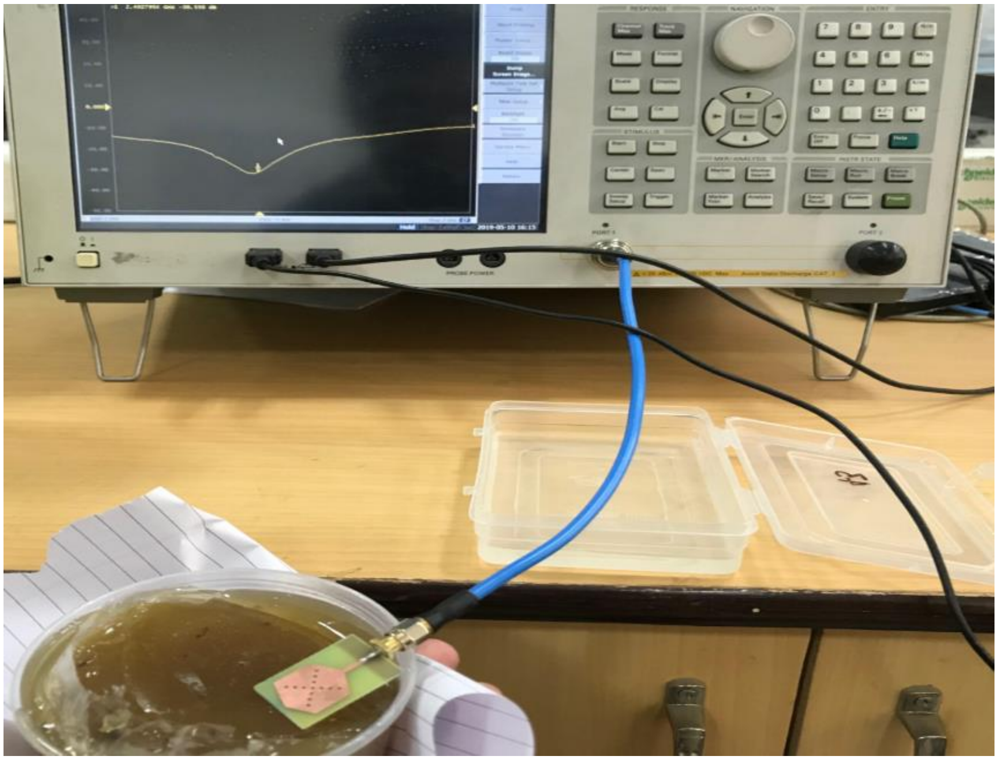


Figure 5.2 Measured Return loss of the designed antenna

The proposed microstrip-line fed hexagonal-shaped antenna at ISM band for wearable applications having thirteen circular slots in the patch and the reduced ground plane is tested followed by fabrication as shown in Figure. The return loss characteristics of the proposed fabricated antenna have been tested and analyzed using Agilent E5071C vector network analyzer available in Antenna Research Laboratory, Department of Electronics and Communication Engineering, Thapar Institute of Engineering and Technology, Patiala. Skin phantoms have been generally used as analysis models for an array of surrounding tissue imaging techniques. It is manufactured using a gelatin-oil mixture technology. The proposed antenna is embedded in this gel-type tissue material whose electrical properties is the same as that of the human skin in case of conductivity and permittivity. The magnitude of the S_{11} parameter of both the simulated and measured results of the proposed antenna without the cancerous tumor is demonstrated in Figure. Nearly close agreement is found which indicates the effectiveness of proposed antenna for wearable applications in brain tumor detection. The simulated and measured return loss of the proposed antenna having $|S_{11}| < -10$ dB level is found as -31.995 and -30.550 dB respectively**.**

5.1.3 Measured return loss of the proposed antenna

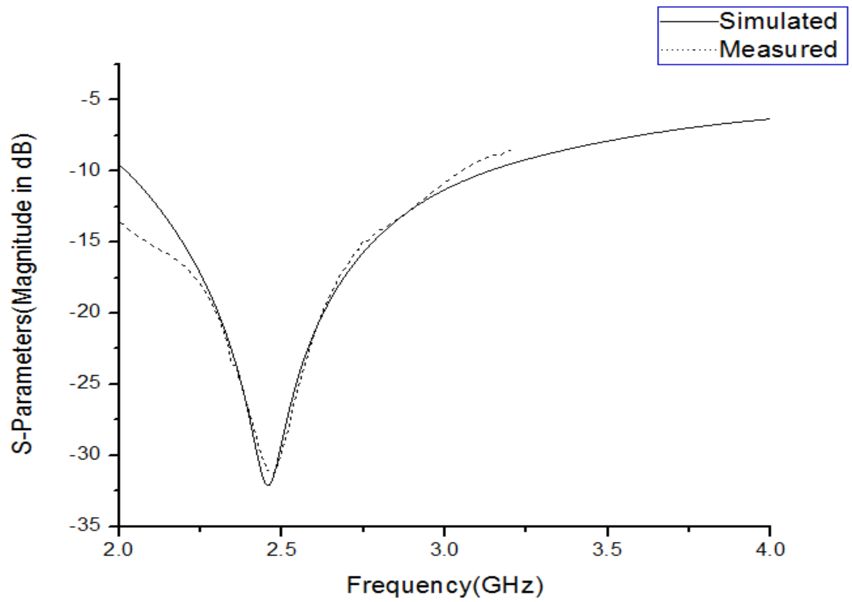


Figure 5.3 Simulated and measured return loss of the proposed antenna without the cancerous tumor.

5.2 Conclusion

There is a minor shift in the return loss of the proposed antenna without the cancerous tumor. It was observed that the simulated value is -31.995 dB and the measured value is -30.550 dB.

CHAPTER 6

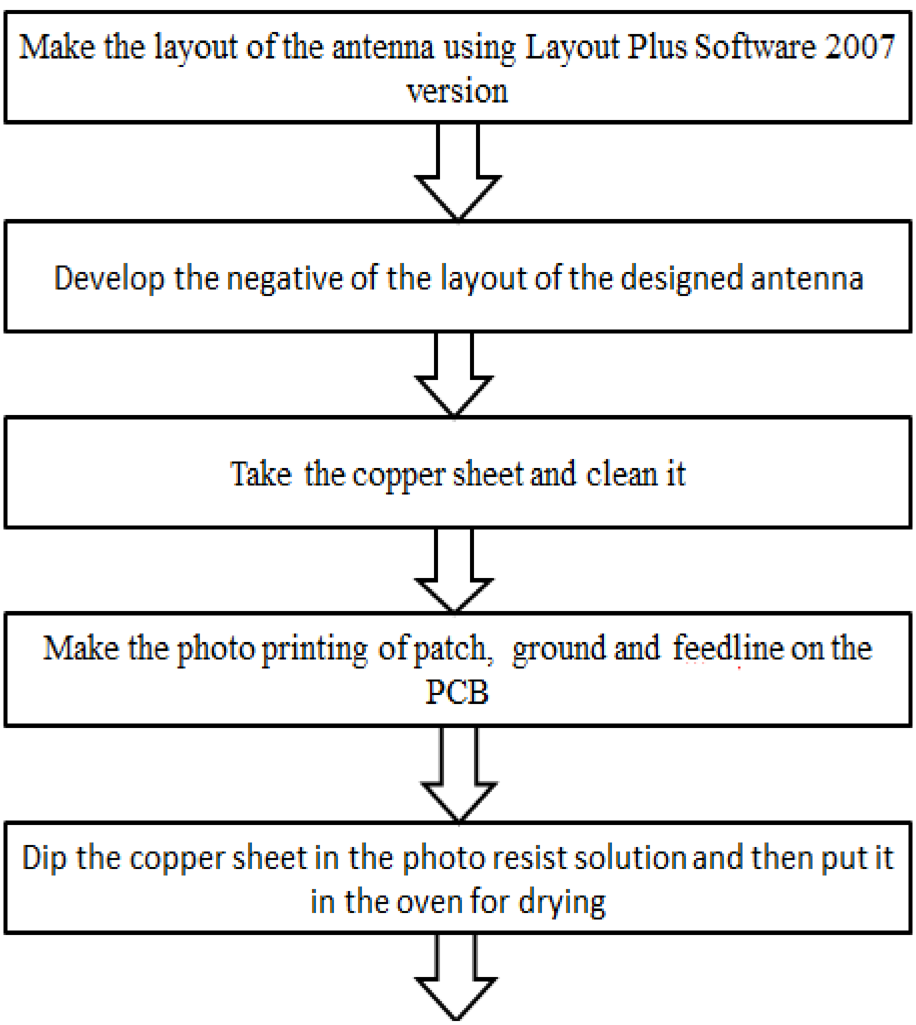
Fabrication and Testing of Breast Cancer Detection Antenna

6.1 Introduction

This chapter presents the fabrication and test results of Breast cancer detection antenna and validation of results in practical usage of the antenna. Comparison between simulated and tested results is also presented**.**

6.2 Fabrication Process Setup

The different steps incorporated in the fabrication process are shown in figure 6.1



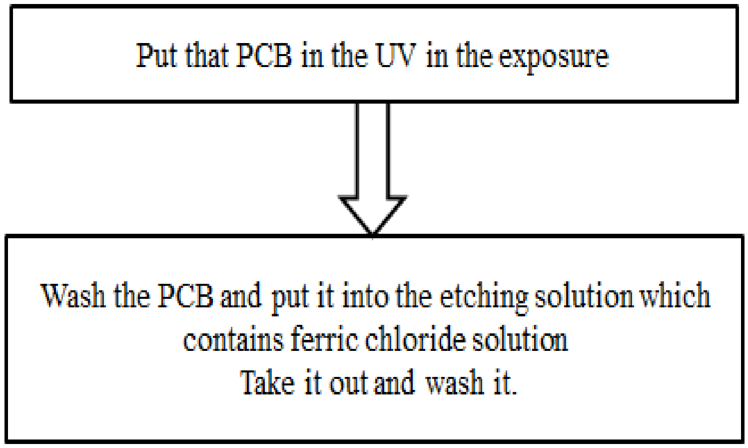


Figure 6.1 Flow chart of the antenna fabrication process

6.3 Fabricated Antenna Design

Fabricated patch antenna for breast cancer detection is shown in figure 6.2.

(a) (b)

Figure 6.2 (a)&(b) Front and back view of fabricated Antenna

6.4 Measured Results

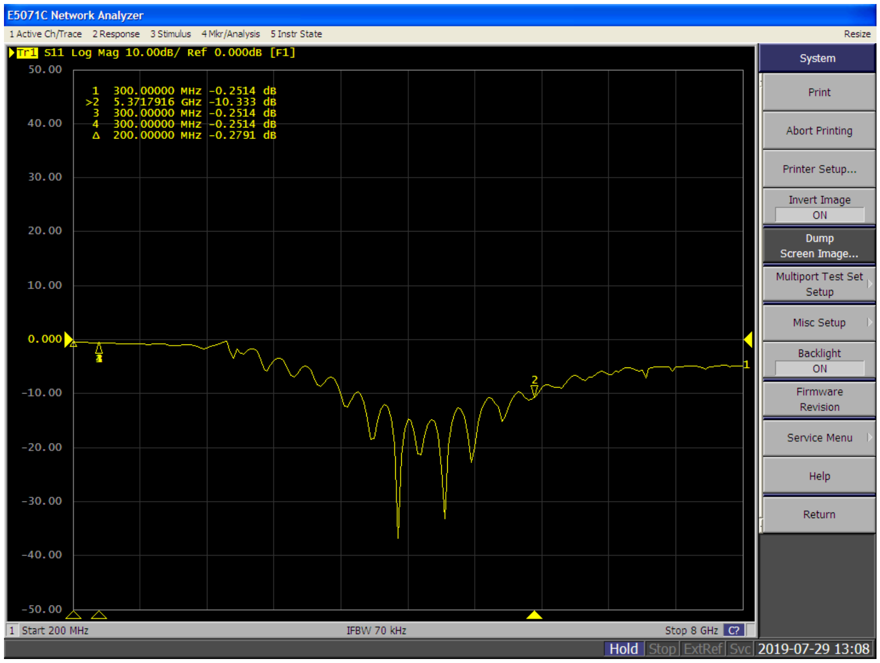


Figure 6.3 Measured results of the proposed antenna

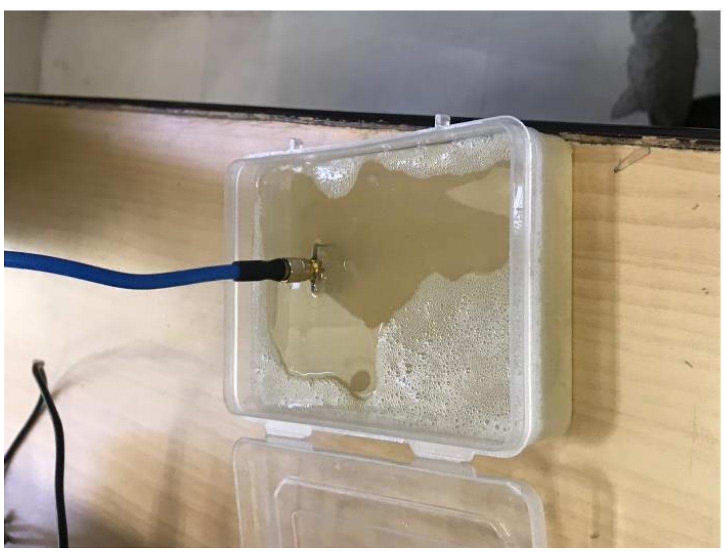


Figure 6.4 Fabricated Antenna embedded in Skin mimicking material

6.5 Conclusion

Results of the testing antenna are varied because of some amount of changes in the liquid material which we used as a skin layer. There are many cases in which the results with skin layer cannot be measured.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

The main motive of the thesis was to design and fabricate an antenna for medical and biological applications**.** This work has been divided into two parts. First part describes the hexagonal-shaped wearable antenna with circular slots and reduced ground plane for the detection of brain cancer which operates at ISM (Industrial, Scientific, and Medical) band at 2.4-2.4835 GHz. The antenna is fabricated on an FR-4 substrate having thickness of 0.8 mm and relative permittivity 4.35 F/m. The actual size of the antenna is 30 mm × 20 mm. The designed antenna has an advantage that its dimensions are small which makes it practically wearable on the human head. This antenna is placed on the human head phantom model which consists of skin layer only and is simulated using CST Microwave Studio Second part depicts the detection of tumor in human breast tissue using a microstrip patch antenna operating at MICS (Medical Implant Communication Services) band which is in between 402-405 Mhz. This antenna is designed and fabricated on the FR-4 substrate with thickness 1.6mm. The actual size of the antenna is 15mmX15mm. To analyze the characterstics of the antenna, it is embedded in the gel type tissue material whose electrical properties is the same as that of the human skin in case of conductivity and permittivity. MICS band is preferable because of its docility towards higher bandwidth. There is a difference in the simulated and measured return loss of the antenna which indicated the presence of tumor inside the breast. Various parameters are also measured for the designed antenna such as return loss, VSWR (Voltage Standing Wave Ratio), Radiation pattern, Directivity and Gain at the resonance frequency of 402-405 Mhz. A comparison technique is used to identify whether or not a tumor (benign or malignant) is present in the breast.

7.2 Future Scope

- There is a need for installing an implantable antenna capable of allowing multi and broadband data transmission due to attenuation caused by presence of body heterogeneous tissues.

- Antennas need to be designed and optimized for physical and dielectric properties of breast tissue
- Microwave techniques in imaging system can be studied for further improvement in detection of tumors
- Microwave sensors can be designed for detection of various types of cancers.

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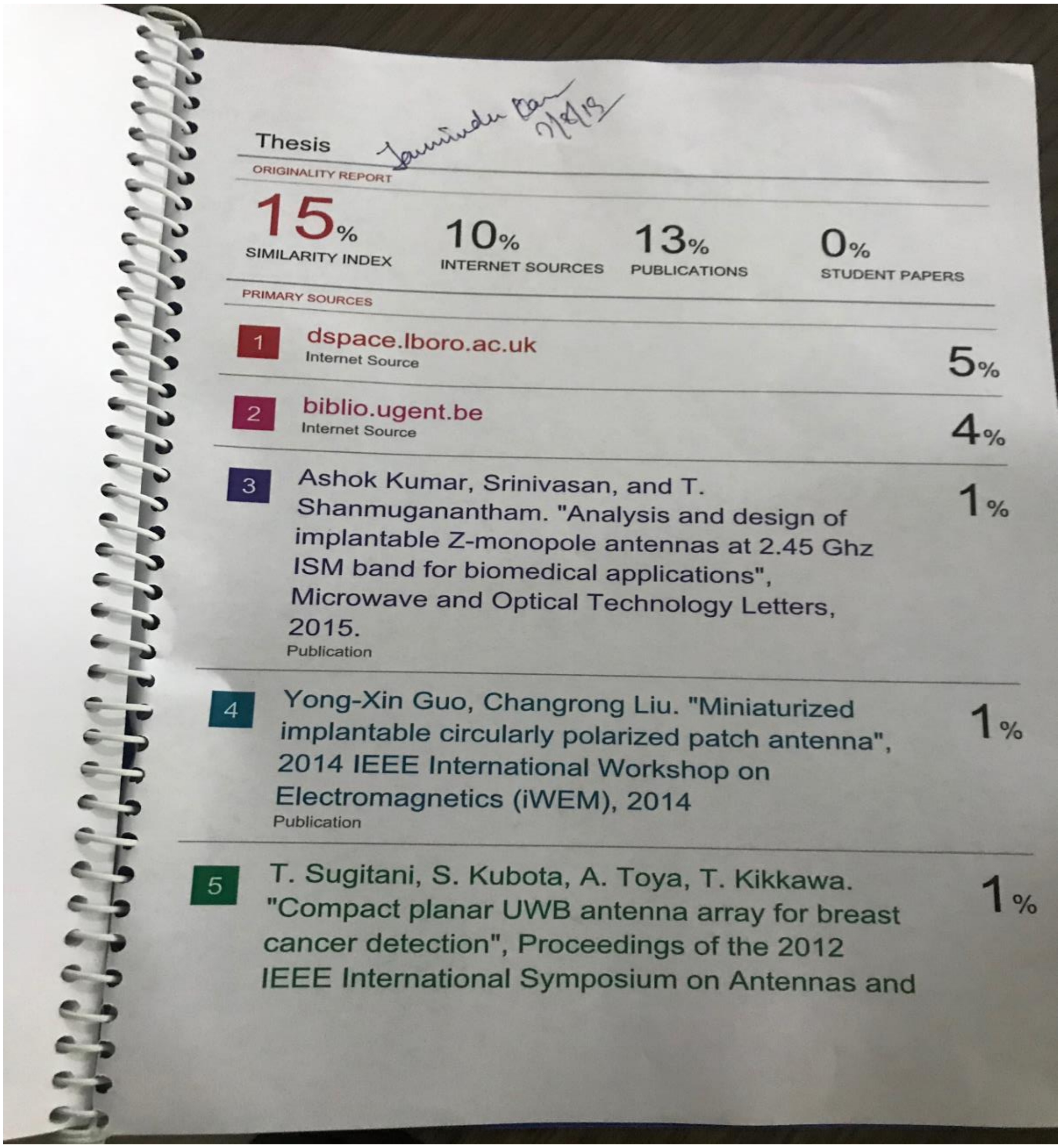
LIST OF PUBLICATIONS

Paper titled ―" Detection of Brain Tumor using Microstrip line-fed Hexagonal shaped Antenna at ISM band for wearable applications is communicated" in Microwave and Optical Technology Letters.



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