

Design, Analysis and Implementation of Microstrip Ultra-Wideband Antenna (UWB) to monitor Prenatal Development in the Uterus

Submitted in partial fulfillment of the
requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering

By

LAKSHAYA J J (Reg.No – 39130254)
KAVIYADHARSHINI N (Reg.No – 39130219)



DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRONICS

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade “A” by NAAC
JEPPIAAR NAGAR, RAJIV GANDHISALAI,
CHENNAI - 600119

APRIL - 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with —All grade by NAAC

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

www.sathyabama.ac.in



DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Final Year Project Report is the bonafide work of LAKSHAYA J J (Reg.No – 39130254) and KAVIYADHARSHINI N (Reg.No – 39130219) who have done the project work as an individual who carried out the project entitled “Design, Analysis and Implementation of Microstrip Ultra-Wideband Antenna (UWB) to monitor Prenatal Development in the Uterus” under my supervision from Jan 2023 to April 2023.

Internal Guide

Dr. S. KARTHIKEYAN, M.E., Ph.D.

Head of the Department

Dr. T. RAVI, M.E., Ph.D.

Submitted for Viva voce Examination held on _____

Internal Examiner

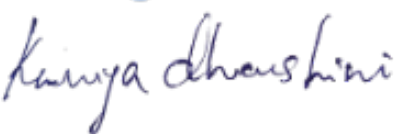
External Examiner

DECLARATION

We, **LAKSHAYA J J (Reg.No – 39130254)** and **KAVIYADHARSHINI N (Reg.No – 39130219)** hereby declare that the Project Report on “**Design, Analysis and Implementation of Microstrip Ultra-Wideband Antenna (UWB) to monitor Prenatal Development in the Uterus**” done by us under the guidance of **Dr. S. KARTHIKEYAN, M.E., Ph.D.** at Sathyabama Institute of Science and technology is submitted in partial fulfilment of the requirements of the award of Bachelor of Engineering degree in **Electronics and Communication Engineering**.

DATE:

PLACE: Chennai

1. 
2. 

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Biomedical telemetry antenna has gained a lot of attention with the development in the healthcare industry. The Series of integrated hilbert curve expandable antenna technology has made it feasible to monitor the physiological signs of patient remotely with the traditional hospital appointments and follow up routine checkups. The proposed integrated Hilbert curve expandable biomedical antenna devices (IHEBAD) play an important role to monitor the fetus detected in the patient through wireless telemetry like an ISM (2.45 GHz) and UWB (4.25 GHz) bands. The Various factors need to be considered for the expandable antenna such as miniaturization, patient safety, bio compatibility, low power consumption, lower frequency band of operation with dual band specification. The selection of antenna is a challenging task to design Hilbert curve with wearable substrate.

In this article the critical solution in proposed integrated Hilbert curve expandable biomedical antenna with wearable substrate is presented. A microstrip ultrawideband antenna (UWB) has been designed to be a part of a UWB medical radar system providing high-resolution and reliable simultaneous monitoring of the prenatal development in the uterus with multiple indicators of fetal and maternal health during virtually all stages of pregnancy. The proposed Antenna design, analysis and 3D models are performed using ANSYS-HFSS EM Simulator. The proposed antenna's necessary parameters are examined to confirm the application of the suggested antenna design they also show a good agreement with simulations when performed.

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LIST OF ABBREVIATIONS

ABBREAVIATION	MEANING
UWB	Ultrawide band antenna
PMR	Prenatal mortality rate
PAN	Personal area network
FCC	Federal communications commission
ITU-R	International telecommunication union radiocommunication sector
RF	Radio Frequency
LOS	Line of sight
NLOS	None line of sight
WSN	Wireless sensor networks
WBANS	Wireless body area networks
PG	Processing gain
TOA	Time of arrival
PIFA	Planar inverted-F Antenna
MSPA	Microstrip patch antenna
GPS	Global positioning system
SAR	Specific absorption rate
MIMO	Multi input multi output

VSWR	Voltage standing wave ratio
RL	Return loss
ISM	International safety management
TLM	Transmission line method
EM	Electro magnetic
HFSS	High frequency structure simulator

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CHAPTER – 1

1. INTRODUCTION

Given that the perinatal death rate looked to be high in many countries, particularly developing nations like Indonesia, it is crucial that pregnant women's and the foetus' health receive more serious consideration and prompt medical care [1]. As a result, all research organizations and centers must actively promote and conduct continuous studies related to this subject. The foetal monitoring system's ultimate design is straightforward, affordable, transportable, and based on UWB technology. In the last two years, a lot of research has been conducted on wearable technologies and gadgets for medical applications, frequently with the goal of continually monitoring patients in their surroundings and as they go about their everyday lives. A sustainable healthcare system is needed that can manage acute treatment, outpatient care (primarily for chronic conditions), care for healthy people going about their daily lives, and routine monitoring to spot prospective illnesses. Short-range low data rate communications have lately benefited from recent advancements in Ultra Wide Band technology. It offers a radically different approach to wireless technology than traditional narrow band systems because to the massive channels bandwidth and low power characteristics. Given the variety of potential uses, this makes medicine attractive. When compared to traditional narrow band systems, ultra-wide band wireless communications provide an entirely new approach to wireless technology, which piques research interest. The microstrip patch antenna, which was once the most popular antenna, is now a prerequisite due to the advancement of wireless communication technologies [2]. Microstrip patch antennas are frequently employed in microwave frequencies due to their simplicity. These antennas are suitable for a variety of uses due to their benefits, including their light weight, low cost, and ease of assembly [3]. The thin strip patch antenna was selected as a need due to its extremely low profile, ability to be placed on a flat surface, and likelihood that it is a form of radio antenna[4]. The fetal monitoring device was developed specifically for use by high-risk pregnant patients who have transportation issues to hospitals. The integrated UWB foetal monitoring apparatus can identify the fetus in spite of the numerous risk factors present throughout pregnancy. this can be improved. While the microstrip line patch antenna has a

better radiation gain, the coaxial cable patch antenna has a larger operational frequency band [12].

1.1 OVERVIEW OF BIOMEDICAL ANTENNA

The rate, intensity, and frequency of the movements determine how healthy the maternity is. Reduced fetal activity is a sign that pregnant women are having fewer preterm babies, spontaneous abortions, and vertebrate development. Pregnant women must be informed of the regular vertebral kicks in order to warn others about the risk of vertebral drive alternatively, diminished vertebral movements should be reported. The creation of UWB medical monitoring systems is used for prenatal and neonatal care diagnostic and therapeutic reasons. There are more persistent and serious efforts made to lessen the hazards associated with pregnancy. In order to improve healthcare for both fetal and maternal health difficulties, several medical indicators from the mother and the infant may be gathered and analysed further. Utilising UWB technology and the fundamentals of UWB-compatible microwave imaging systems, UWB microstrip antenna has been developed. Fetal monitoring is a routine check-up procedure offered to expectant mothers to assess the health of the fetus. Due to available statistics, it appears that some nations have a high perinatal mortality rate (PMR), which calls for more urgent attention to pregnant women's and the fetus's health. The fetal monitoring system's ultimate design must be straightforward, affordable, and portable utilising UWB Technology. This makes it possible for those who are impoverished and live in rural areas to get improved health treatments. The RF processing setup and UWB microstrip antenna of the earlier foetal monitoring system prototype were both improved. Performance enhancement of the patch antenna is the main objective of the optimisation process. Numerous crucial RF electronic transducer characteristics, including impedance matching, bandwidth, radiation pattern, and gain, were meticulously documented and further assessed throughout the numerical analysis.

1.2 FETAL DETECTION AND MONITORING SYSTEM

Fetal monitoring is a technique for examining the fetus while the mother is pregnant to make sure the baby is developing normally and healthily. Your healthcare professional will want to examine the fetus's health both throughout pregnancy and

labor. The baby's heart rate and other vital signs are monitored to do this. There are two methods for monitoring. External monitoring is a technique for doing it on the outside of your abdomen. Alternately, internal monitoring can be performed on the child while it is still inside your uterus.

According to the facts previously given, the perinatal death rate is still rather high, necessitating considerable attention to the monitoring of pregnant women's and the fetus's health. The signal processing device, controller, and display unit on the laptop may be used to build the detecting and monitoring system's hardware, as illustrated in fig. 1.1 below.

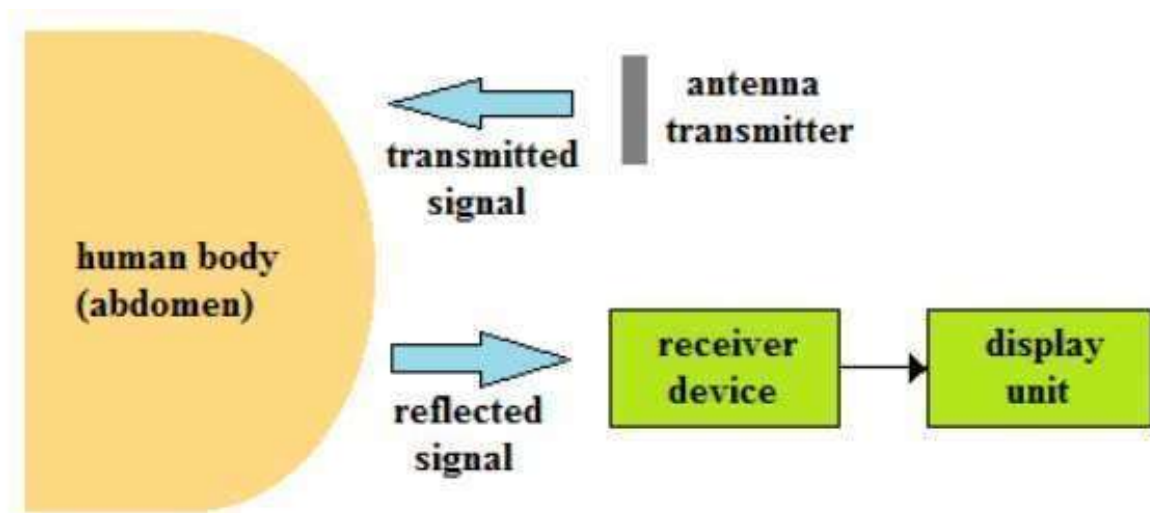


Fig: 1.1 : Fetal monitoring system device

1.3 FETAL SURVEILLANCE TESTS

Each individual instance will determine the kinds of tests a pregnant woman may undergo as part of foetal monitoring. Ultrasound, non-stress testing, contraction stress tests, and biophysical profiles are a few examples of assessments that may be performed. Only specific high-risk pregnancies often require for foetal observation. Low-risk pregnancies often don't require this kind of monitoring, and women shouldn't feel pressured to ask for it because foetal surveillance will only be given if a doctor deems it necessary. If difficulties emerge in a pregnancy that is generally healthy, foetal monitoring may be necessary at any point in the pregnancy.

For instance, a drop in a baby's movements during a certain time frame can call for testing. Similarly, if a baby is responding well, foetal surveillance may be reduced; nevertheless, if the infant does not respond to the monitoring as predicted, more suggestions will be made and steps will be taken. Figure 1.2 depicts a foetal detection and monitoring system.

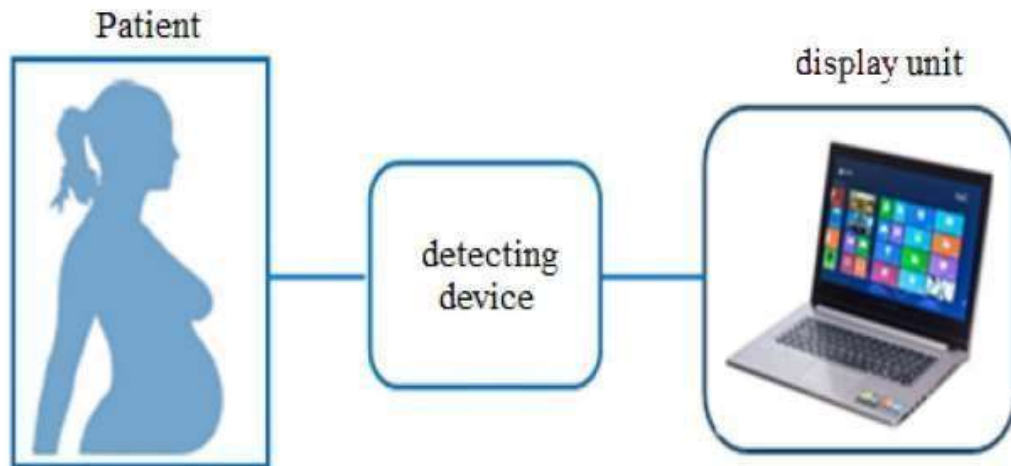


Fig: 1.2 : Fetal detecting and monitoring system.

1.4 FETAL OUTER STRUCTURE

Between the bladder and the rectum in a woman's lower stomach is the uterus, often known as the womb. It is a hollow, pear-shaped organ. During menstruation, it loses its lining once a month. The foetus develops when a fertilised egg (ovum) is inserted in the uterus.

1.4.1 Fetal problems

Included in the foetal difficulties of pregnancy are birth abnormalities, genetic issues, growth issues, and issues brought on by maternal antibodies. An accurate diagnosis enables us to start prenatal care and get ready to treat the newborn upon birth.

1.5 ULTRA WIDE BAND (UWB) TECHNOLOGY

In the same frequency range, the ability to transmit data over a broad bandwidth (more than 500 MHz) and a significant amount of signal energy without interfering

with more conventional narrowband and carrier wave transmission is known as ultra-wideband. This effective use of radio spectrum is made possible by regulatory restrictions in many nations, They also enable high-data-rate personal area network (PAN) wireless connection and longer-range low-data-rate applications, and the seamless coexistence of radar and imaging systems with existing communications systems. It combines research from several disciplines, including wireless communications, radar, and medical engineering. The UWB frequency in the United States is regulated by the Federal Communications Commission (FCC) and ranges from 3.1GHz to 10.6GHz. But in Europe, the frequency ranges are split into two bands: 3.4 GHz to 4.8 GHz and 6 GHz to 8.5 GHz. Current equipment would not be harmed by UWB because of its limited power radiation needs and spectrum that mimics background noise.

The International Telecommunication Union Radiocommunication Sector (ITU-R) and the Federal Communications Commission (FCC) now define ultra-wideband (UWB) as a transmission through an antenna whose signal bandwidth exceeds the lower limit of 500 MHz or 20% of the arithmetic centre frequency. As a result, pulsebased systems that broadcast pulses that take up the whole UWB bandwidth are permitted to use the UWB spectrum. Ultra Wide Band (UWB) wireless communication technology has lately gained a lot of popularity and has a wide range of possible uses, including one in the medical profession. UWB technology has been used in prior research for the early identification of breast cancer, brain tumours, etc.

1.6 UWB IN MEDICAL APPLICATION

A lot of research interest has been focused on an emerging field of wireless communications known as Ultra Wide Band (UWB), which takes a completely different approach to wireless technologies than traditional narrow band systems. Because of this, there are a lot of UWB applications that may be studied. Medicine is one of the applications that has a lot of potential. UWB is ideally suited for the medical industry thanks to a few special properties. Currently, medical imaging and monitoring are two of its most important uses.

Compared to conventional narrow band systems, ultra wide band (UWB) wireless communications provide a fundamentally new approach to wireless technologies, sparking considerable research interest. Because of this, there are a lot of UWB applications that may be studied. Medicine is one of the applications that has a lot of potential. UWB is ideally suited for the medical industry thanks to a few special properties. Currently, medical imaging and monitoring are two of its most important uses. As a result, the UWB technology continues to spark the curiosity of academics working on medical applications. In a nutshell, the two UWB modulation modes represent the two primary UWB functions of sensing and communicating. The UWB biomedical spectrum is seen in fig. 1.3 below.

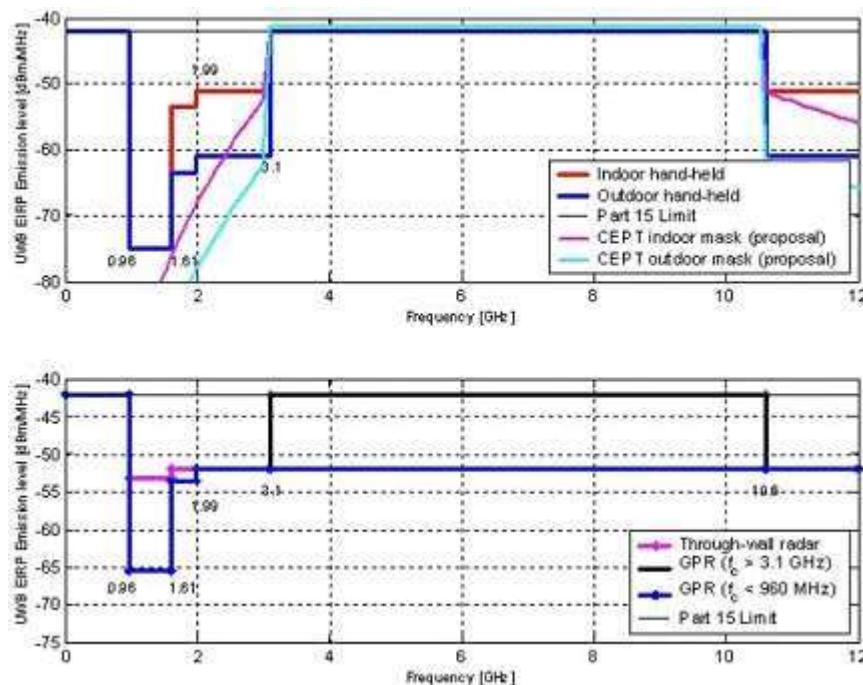


Fig: 1.3 : UWB biomedical Spectrum

1.7 MEDICAL UWB HISTORY

A new research trend is the use of Ultra-Wide Band (UWB) technology in medical applications. The first US patent application for medical UWB radar was submitted on August 9, 1994. The "Radar Stethoscope" teaching initiative was launched by MIT a year later. With the aid of photographs and sample tracings, the biological use of UWB radars was better defined in 1996, the same year that the US Patent was granted. Since then, UWB has frequently been considered in substitute of imaging and remote sensing. It has been determined that employing non-ionizing

electromagnetic waves with UWB radar probes is less dangerous for individuals than using X-ray imaging. The UWB radar also has a very low average power level and is exceptionally power-efficient. Consequently, it is appropriate to be a potentially affordable method of photographing the human body, particularly in real-time imaging.

1.8 UWB FEATURES FOR MEDICAL APPLICATION

A new technology called ultra-wideband (UWB) radio has certain distinct and alluring characteristics that have been integrated with studies in other disciplines including wireless communications, radar, and medical engineering. Below is a summary of both the benefits and drawbacks of using UWB antennas in medical applications.

1.8.1 Advantages

It is understood that the UWB pulse is produced in less than a nanosecond. As a result, the spectrum is below the permitted noise level. Using this capability, 10GHz Gbps speed spectrum is available. UWB can thus be used for high-speed communications over short distances. Such a "noise-like" characteristic relies on incredibly short waveforms and may operate at baseband frequencies without IF processing. Long recognised as a crucial benefit for medical engineering, this UWB characteristic.

- Penetrating through obstacles

We could contrast UWB with ultrasonography when describing this capacity. UWB differs from ultrasound, which has a wide range of applications in the modern world, despite the fact that they are actually very similar and that UWB systems may leverage many of the signal processing methods used in ultrasonic systems. The main distinction is that ultrasound has a relatively narrow range and relies heavily on line-of-sight technology. Medical imaging uses ultrasound, however it normally only works across a few inches. UWB, on the other hand, differs because it does not use high frequency sound waves, which may be able to pass through barriers. UWB is able to achieve gains that are significantly higher than those of other widely used

conventional spread spectrum systems because it uses RF pulses and has high gain. That explains how UWB can pass through walls as well. Because of this, UWB can be used in situations where impediments are likely to be present, even if ultrasonography may also not be practical. The capability makes it simple to photograph human bodily organs for medicinal purposes.

- High precision ranging at the centimeter level

Another aspect of UWB is its high precision centimeter-level range, which is based on the ultra-short pulse characteristic we covered in the preceding section of the study. Strong multi-path resolving capabilities also translates to high range precision. Continuous waves were employed in the traditional wireless technology, and the standing time was substantially longer than the multi-path transmission time. The UWB pulse has substantially stronger temporal and spatial resolution capabilities due to its shorter duration (for a 1 nanosecond pulse, the multi-path resolving power is equal to 30 cm), making it ideal for localization and detection in medical applications. Multipath is an inherent occurrence in wireless communication networks. Multiple reflections of the sent signal from different surfaces, such as buildings, trees, people and water, are what produce it. Line of sight (LOS) is the straight line that connects a transmitter and a receiver; non-line of sight (NLOS) is the signal that is reflected off of surfaces. depicts the narrowband and UWB signal multipath phenomena. As demonstrated in, the impact of multipath on narrowband signals may be rather severe and result in signal deterioration of up to -40 dB as a result of the out-of-phase addition of LOS and NLOS continuous waveforms. On the other hand, UWB pulses are less susceptible to the multipath effect because to their extremely short length. Because a UWB pulse's transmission time is often less than a millisecond, there is very little time for the reflected pulse to collide with the LOS pulse and weaken the signal.

- Low electromagnetic radiation

The low electromagnetic radiation caused by the low radio power pulse of less than -41.3dB in an interior setting is the third aspect of UWB. Four out of

the twelve uses for the low radiation are in hospitals since it has little impact on the surrounding area. Furthermore, the UWB may be used with clairvoyant equipment because the low radiation is safe for human body even at close range.

- Low processing energy consumed

Due to UWB's use of extremely brief radio transmission pulses and careful signal and architectural design, the transmitter may be built simply and with extremely low energy consumption, allowing for the use of long-lasting battery-operated devices. These characteristics are fairly comparable to the Wireless Sensor Networks (WSN) nodes' need for extremely rigorous power management mechanisms and great power effectiveness when operating in challenging conditions. Since UWB signals are difficult to detect and have excellent jamming resistance, medical sensor deployment is extremely likely thanks to their intrinsic noise-like behaviour. Due to this capability, Wireless Body Area Networks (WBANs) for body monitoring may be implemented. The average power radiated by the transmitter is extremely low since pulses are only delivered during a very short portion of the transmission duration. A UWB device can lengthen the battery life using transmission powers in the microwatt range.

- Resistance to Jamming

The UWB spectrum enables high processing gain for UWB signals and encompasses a wide range of frequencies from close to DC to several gigahertz, in contrast to the well-defined narrowband frequency spectrum. Processing gain (PG), which is the ratio of a signal's RF bandwidth to its information bandwidth, is a gauge of a radio system's susceptibility to jamming and is given below in Equation (1.1).

$$PG = \frac{RF \text{ Bandwidth}}{Information \text{ Bandwidth}} \quad (1.1)$$

Because no jammer can simultaneously jam every frequency in the UWB band, the frequency diversity brought on by high processing gain renders UWB signals reasonably resistant to both deliberate and inadvertent

jamming. As a result, even if part of the frequencies are jammed, a substantial portion of frequencies continue to be unaffected. However, only in comparison to narrowband and wideband systems does this resistance to jamming exist. Because of this, a UWB communications system's performance may still be negatively impacted by heavy narrowband interference from conventional radio transmitters operating in the same frequency range as the UWB receiver, depending on the modulation method used.

- Superior Penetration Properties

UWB technologies, in contrast to narrowband technology, may successfully pass through a variety of materials. UWB signals may pass through a number of materials, including walls, thanks to the long wavelengths of the low frequencies that make up the wide range of the UWB frequency spectrum. This characteristic makes ground penetrating radars and through-the-wall communications possible with UWB technology. However, UWB signals' capacity to penetrate material is only effective when they are permitted to inhabit the low-frequency region of the radio spectrum.

- High Ranging Accuracy

As was said above, the UWB signals' precise temporal resolution enables us to create a system that can resolve multipath components without the need of complicated algorithms. As a result, time-of-arrival (TOA)-based range estimate applications are well suited for UWB. It is important to note that while these time-base ranging techniques take use of UWB signals' great temporal resolution, they are not without their own setbacks. For instance, clock jitter becomes a limiting concern due to the UWB pulses' short length.

- Low cost

Because UWB uses minimal power and is thus less expensive to produce, it may be possible to tune a pulse onto an antenna in a manner similar to that of a straightforward transmitter. Multipath immunity: Due to the small form of

the UWB pulses and their ability to separate pulses, UWB pulses can deliver a high resolution of reflected pulses at the receiver. This is crucial since the main challenge to error-free wireless systems is the interference between pulses in the channels. The ability to do both exact object localization and high-speed data connection using the UWB technology opens up a world of exciting possibilities for innovative applications.

1.9 MICROSTRIP PATCH ANTENNA FOR UWB APPLICATIONS

Micro-strip patch antennas are becoming more and more necessary. Researchers are more drawn to this topic because of the rising demand, which caught their interest. There has been a tone of research on this topic in recent years. For new age experts, this topic is intriguing. The essential need of a new mobile communication system is larger bandwidth, high gain, and small size antennas that can deliver effective performance over a wider variety of spectrum.

1.9.1 Patch Antenna

A low-profile antenna that may be installed on a surface is called a patch antenna. It comprises of a planar metal sheet or "patch" installed on top of a larger metal sheet known as a ground plane. The sheet can be rectangular, circular, triangular, or any other geometric shape. The two metal sheets combined create a resonant section of microstrip transmission line with a length of around one-half the radio waves; they are the original kind of microstrip antenna that Howell first described in 1972. The radiation mechanism is created by the fringe fields that surround the radiating edges. Because the radiation at the edges causes it to operate electrically slightly bigger than its physical dimensions, the antenna requires a length of microstrip transmission line just slightly shorter than one half the wavelength at the frequency in order to be resonant. The patch antenna performs best at microwave frequencies because the wavelengths are brief enough for the patches to be properly small. It is often used in portable wireless devices due to how simple it is to fabricate on printed circuit boards. Several patch antennas on the same substrate or microstrip antennas can be used to build high gain array antennas and phased arrays with electrically steerable beams. The shorted patch antenna, also known as a planar inverted-F antenna (PIFA), is a kind of patch antenna that is frequently used

in mobile phones. In this antenna, a ground pin is used to ground one patch corner (or occasionally one edge). Compared to the conventional patch, this variation has better matching. A particularly adaptable antenna for dual-band operations is the printed monopole antenna, a variation of patch antenna with a partly etched ground plane. It is also referred to as a microstrip antenna or a printed antenna since it is constructed on a printed circuit board using the microstrip technology. In general, patch antennas are utilised for microwave frequency applications with frequencies larger than 100 MHz and are regarded as low-profile antennas.

1.9.2 Construction of patch antenna

Patch antennas have 2D geometry. These antennas come in a variety of shapes depending on the metallic patch's shape and how it is attached to the dielectric material. The patches can have any shape, including rectangular, square, triangular, annular, circular, or elliptical.

Consider a rectangular patch antenna glued to a rectangular metallic patch to a ground plane is constructed and covering it with a dielectric layer. It may be stated simply that a ground plane supports a dielectric substance with a conducting patch.

Here, we've demonstrated the most basic type of patch antenna, using a patch that is etched onto the substrate that is half a wavelength long and has a very thin profile.

The figure 1.4 shows the top view of the microstrip antenna:

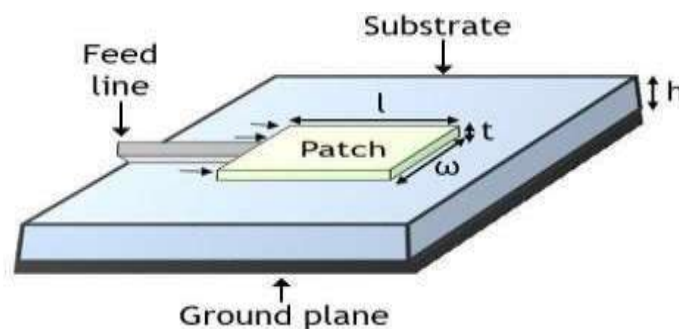


Fig: 1.4 : Structure of microstrip antenna

Although there are many other ways to make patches, as we've already discussed, the most common shapes used are rectangular, circular, or square ones since they are the easiest to produce.

Up to this point, we have only talked about a single patch of etched substrate. On a dielectric substrate, however, a collection of various patches can also be used to create patch antennas. To excite the antenna, either a single feed line or a number of feed lines are utilised. Microstrip element arrays enhance directivity, boost gain, and extend transmission range while reducing interference.

1.9.3 Working of Patch Antenna

When energy from a feed line reaches the strip of a microstrip or patch antenna, it begins to emit electromagnetic waves.

The waves of the patch emanate from the width side. The edge of the strip, however, serves as a reflector for the waves created within the substrate because of the strip's very tiny thickness. Radiation cannot be emitted because of the strip's constant structure over its length. Furthermore, radiations are once more emitted from the patch's second breadth side when its structure abruptly discontinues. Due to the discontinuous structure's preference for reflections, Only a very small fraction of the received energy is sent out by the patch antenna. As a result, the antenna is useless since it acts more like a cavity than a reliable radiator.

Due to their limited radiating capacity, microstrip antennas can only transmit over short wave transmission distances, such as those that exist between close-by businesses, offices, or other interior sites. Poor transmission cannot thus be permitted across such a large area at a single location. In order to provide hemispheric coverage at an angle of 300 to 1800 at width from the mount, a patch antenna is frequently utilised. The radiation pattern of the microstrip patch antenna is shown in Figure 1.5 below.

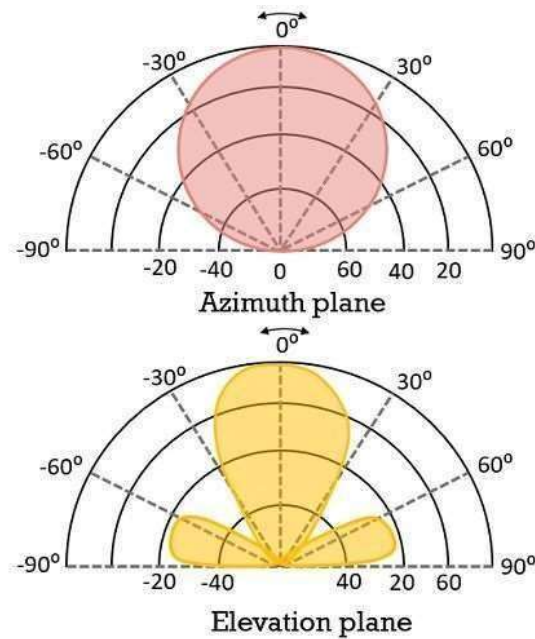


Fig: 1.5 : Radiation pattern of the microstrip antenna.

1.9.4 MSPA Characteristics

- The antenna patch has to be a very small, conductive region with wavelength t_0 (free space wavelength).
- The ground plane's dimensions must be significantly larger than the patch.
- The feed lines and radiating element are constructed on the substrate via photoetching.
- Microstrip component arrays in the antenna layout provide higher directivity.
- High beamwidth is provided by microstrip antennas.
- A patch antenna offers a very high quality factor. The substrate's thickness can be increased to make up for this, though. Beyond a certain point, however, an increase in thickness will result in power loss.

1.9.5 Feeding Methods of Patch Antenna

The microstrip antenna is supplied via a variety of techniques. However, contacting feeding is one of the main and vital feeding methods.

1.9.5.1 Contacting feed

Here, power is sent directly to the radiating element. For this, a coaxial cable or microstrip is employed. The two types of touching feed are:

- Feeding via microstrip

It is a conducting strip with a much narrower width than the radiating element. The feed line makes it simple to etch the substrate since the strip's dimensions are lower. There are three possible locations for the feed line for the structure: the centre, inset, or offset.

- Coaxial feed

The inner conductor is linked to the patch when coaxial feeding is utilised on the antenna. As the position of the coaxial feed changes, so does the impedance. Impedance matching is facilitated by the fact that the feed line can be connected anywhere on the patch. Connecting the feed line with the ground plane is rather difficult since this calls for drilling a hole in the substrate.

1.9.6 MSPA Advantages

- The fabrication process is simple; the antenna is tiny and less bulky
- It is simple to install because of these features.
- It allows for straightforward device integration.
- It has the ability to operate on two and three frequencies.
- The antenna provides a great degree of ruggedness over solid surfaces and its arrays are simple to build.

1.9.7 MSPA Disadvantages

- These antennas exhibit extremely sensitive behaviour to environmental influences and have low antenna efficiency.
- These are more susceptible to false positive radiation because they have a narrow bandwidth, a weak gain, and a low power handling capability.
- Microstrip antennas have larger conductor and dielectric losses.

1.9.8 Applications of Patch Antenna

- These antennas are employed as communication antennas on missiles because of their thin construction.

- One of the main benefits of microstrip antennas is GPS. because it makes monitoring trucks and marines simple.
- Because of its low profile design, microstrip antennas are commonly utilised in wireless communications. This explains why some antennas list their compatibility with pagers, mobile phones, and other portable devices.
- Because of their small size, microstrip antennas are utilised in microwave and satellite communications.

CHAPTER – 2

2. LITERATURE SURVEY

Mathur, et al., (2021). Design of Wearable UWB Microstrip Patch Antenna for Breast Cancer Tumor Detection. *Annals of the Romanian Society for Cell Biology*. (Apr. 2021), 7751–7759. This study describes the development of a small UWB antenna that utilised a partial ground plane to function throughout the whole UWB frequency range. The two UWB antennas were supposed to be placed one on each side of the breast, therefore they were built within a cover that could be worn. In order to show how the transmitting and receiving antennas will work together, the breast model was built and simulated with antennae on its two sides. Among the electrical properties that were simulated were E field, H field current density, and SAR values. This method might be used to detect tumours once the outcomes were compared with and without tumours. It was also examined how the size and location of the tumour affected the outcomes [16].

Mohammad Ojaroudi, et al., (2020). A Novel Approach of Brain Tumor Detection using Miniaturized High-Fidelity UWB Slot Antenna Array. *Conference on Antennas and Propagation in Europe*. To improve the accuracy of cancer diagnosis inside the human brain phantom for 2D reconstructed image data, the researchers created a unique high resolution arraybased ultra-wideband (UWB) microwave imaging method. For a circular arraybased microwave imaging system, 18 elements of the intended UWB slot antennas were simulated in CST medium encircling the phantom inside a designated matching medium. They have shown a slot antenna that has a flawed ground plane made of two C-shaped slots on one side and a rectangular slot with a large usable fractional bandwidth of more than 100% (3.19-10.73 GHz) on the other. There were consequently stronger signals available to boost accuracy for accurate spatial localisation. To demonstrate the viability of the suggested approach for accurately determining the time-dependent position of targets, simulated results were given [17].

A S. Pradeep , et al; (2020). Design and Analysis of Wearable Microstrip Patch Antenna Applied for Breast Cancer Detection. In order to detect breast cancer, a wearable microstrip patch antenna with a novel design and analysis was reported

in this study. The recommended antenna operating frequency was 2.4GHz. In order to create a wearable antenna, a microstrip antenna with a 1.6 dielectric constant was employed as the dielectric substrate. In order to power the hexagonal microstrip patch antenna, transmission feedline was provided. Using the ANSOFT HFSS EM simulator, The creation of 3D breast models and the study of antenna designs were done [18].

Liting Wang, et al., (2021). Design of ultra-wide band MIMI antenna for breast tumor detection. *International Journal of Antennas and Propagation*. This work describes the construction of a novel ultra-wideband multi-in multi-out antenna that operates between 2.3 GHz and 12.2 GHz. It was possible to achieve this ultrawideband feature by loading a rectangular patch onto a circular slot antenna. For MIMO applications, such antennas had two components. Due to the orthogonal polarisation, the suggested structure acquired minimal mutual coupling and envelope correlation [19].

Rabia toprak, et al., (2019). Microstrip antenna with circular patch for skin cancer detection. 17-16. This project's objective was to locate a tumorous skin tissue using a microstrip antenna design. The system was built on a microstrip patch antenna. Evaluations were done concerning the presence of tumour based on the variations in electromagnetic radiation from antenna with the dielectric characteristics of the normal skin tissue and the one with tumour. The simulated three-dimensional system design as well as the normal and cancer architecture of the skin tissue were measured using two identical-type microstrip patch antennas. Pathologists used slides to make both. Based on modelling and experiment results, the differences between measures of cancer and normal tissues were evaluated and reported. Patients can now receive their results more quickly because to pathologists' streamlining of the analysis and reporting stages of the process for tissue samples taken from patients. This is because the measuring and recording of the differences observed could be done quickly. To offer a solution to the aforementioned problems, two antenna configurations were constructed with the identical size for the transceiver and receiver. FR-4 substrate material with a dielectric constant of 4.4 was utilised for antennas that operate at a frequency of 2.45 GHz. The built-in antennas were used to create a model to find the existence of skin cancer. With the

help of pathologists' preparations of the normal and malignant architecture of skin tissue, similar antennas and an experimental setup were made. As a result, the scattering parameters' differences were calculated. It has been demonstrated that malignant tissue may be identified using various values that are as a consequence. Designs and simulations were performed using the Ansys HFSS programme [20].

Jianli Pan, et al., Medical applications of ultra-wideband (2019). In this paper, The writers go into great detail on the functions and main applications in the medical fields, such as medical imaging and monitoring. Discussions also included the various uses, prospective applications in the future, and future research initiatives. On this topic, current research organisations were provided. The authors have finally provided a summary of the whole survey article [21].

Shaik Rizwan, et al., (2022). An ultra-wideband monopole antenna for skin cancer detection. Journal of physics: Conference series. The paper presents a low-profile modified elliptical structure ultrawide-band monopole antenna for skin cancer detection. The antenna was built on a FR-4 lossy substrate, has a permittivity of 4.3, and a height of 1.6 mm. The antenna has a frequency range of 2.82 to 12.56 GHz with measurements of 20 x 28 x 1.6 mm³. The proposed antenna consisted of elliptical and circular radiators with a partial ground plane to provide the optimum low profile design with an ultra-wide band. The proposed ultrawideband antenna (UWB) was used to locate the malignant skin cancer using time-domain and SAR analysis. The full wave simulator was used to create a rectangle human skin model including layers of skin, fat, muscle, and bone. At 3.4 GHz, the proposed UWB antenna showed SAR [1g] of 0.296 W/Kg, indicating that skin exposure was safe. The recommended UWB antenna provided a viable substitute to confirm the existence of diseased tissue in the human body using time-domain and SAR analyses [22].

Mbanya Tchafa, et al., (2018). Microstrip patch antenna for temperature sensing. Smart Materials and Structures. The size of the radiation patch and the dielectric constant of the substrate determine the fundamental resonance frequencies of a patch antenna, which consists of a patch, substrate, and a ground. This work studied simultaneous strain and temperature sensing utilising a single antenna that

has two basic resonant frequencies because these qualities are affected by the applied strain and temperature. The primary criterion for selecting the dielectric substrate on which an antenna sensor with a rectangular radiation patch was designed and created was the theoretical relationship between changes in the antenna resonant frequency, temperature, and applied strain. For thermomechanical research, a test specimen for tensile strength with an antenna sensor was employed. Theoretical hypothesis that the normalised antenna resonant frequency shifts were inversely proportionate to the applied strain and temperature variations were validated by the experimental data [23].

Mary Sushmitha Asha, et al., (2019). Design of Microstrip Patch Antenna for Lung Tumor. International Research Journal of Engineering and Technology (IRJET). The identical antennas and experimental setup were created using pathologists' preparations of the normal and malignant structures of skin tissue. As a result, the scattering parameters' differences were calculated. It has been demonstrated that malignant tissue may be identified using various values that are as a consequence. Designs and simulations were performed using the Ansys HFSS programme. Microstrip patch antennas are currently mostly chosen in the biomedical fields because of their many benefits. Since both the transmitter and the receiver have the same size and are designed to address the problems associated with pathology, this study concentrated on two antenna structures. FR-4 substrate material with a dielectric constant of 4.4 was utilised for antennas that operate at a frequency of 2.45 GHz. The built-in antennas were used to create a model to find the existence of skin cancer. The model served as a way to compare the differences between two antennas made from healthy and malignant tissue specimens mounted on glass slides in terms of their E-field and scattering characteristics [24].

Elsherif, Mostafa, et al., (2021). Early Detection of Breast Cancer using Microstrip Patch Antenna. 1-6. 10.1109/ICEEM52022.2021.9480646. This study describes the early diagnosis of breast cancer by the use of a 2.45 GHz rectangular patch microstrip antenna (RMSA) to identify tumours inside the breast tissue. Insect feed is used to improve impedance matching. A ground plane slot is included to keep the specific absorption rate (SAR) within allowable bounds. FR4epoxy was used to create the antenna. For the early identification of breast cancers, the voltage

standing wave ratio (VSWR), return loss (RL), and bandwidth have been discovered. SAR has been considered while operating the antenna on breast phantoms with and without tumours using High Frequency Simulation Software (HFSS). The antenna's VSWR-2 bandwidth is 40 MHz, or around 1.63% of its resonant frequency of 2.45 GHz. The SAR limit has been established at 1.6 W/Kg by the US Federal Communications Commission (FCC), and India is allowed to use the same unit of measurement. The antenna used in this investigation exhibits acceptable SAR values of 1.2 W/Kg without tumour and 1.4 W/Kg with cancer. The suggested RMSA is utilised to identify breast tumours in their earliest stages since it has a wide enough bandwidth and a tolerable range of SAR values [25].

2.1 PROBLEM STATEMENT

- In the previously present wearable biomedical antenna, ISM and UWB bands are not present jointly with single antenna access.
- Since they are both present separately so input power of antenna will have to be increased and so there will be possibility that human body might suffer from unwantedly emitted radiation.
- They never worked together because of high frequency having mismatched impedance. So, We have matched the losses and impedance.
- Hilbert curve was used with match terminal to get a matched impedance for the antenna to work at the same time.
- Hilbert curve was never used to design in wearable substrate and this is the first design to make use of Hilbert curve to reduce the unwanted radiation emission.
- To avoid that possibility, we have also utilized med cotton which controls unwanted emission.

CHAPTER – 3

3. PROPOSED WORK FOR THE DESIGN AND CREATION OF UWB MICROSTRIP PATCH ANTENNA

The final fetal monitoring system's design is straightforward, affordable, and transportable and uses UWB technology. These antennas are suitable for use in wireless body area networks and wireless body-centric communication and have been fabricated and tested for S11 and VSWR using a network analyzer [10]. By using metamaterials, gain enhancement and size reduction can be achieved for wireless C-band applications [11]. The basic design was made and several optimization steps were done according to the result. At last, a box which is considered to be as uterus with its permittivity and permeability values is given and the antenna design which is done will be placed inside it. Optimizations were done with the grounding methods and then the proposed antenna design was finalized after observing the simulated results. The performance of the patch antenna is being improved as the major objective of the optimization process. Certain physical antenna characteristics and those that are connected to them were continuously adjusted to match the necessary antenna output in order to accomplish this purpose. By suitably creating a woman's abdominal phantom with phantom structural details and inserting the specified antenna inside of it, the optimization was carried out. Many significant RF electronic transducer parameters, including impedance matching, bandwidth, radiation pattern, and gain, were painstakingly recorded during the numerical analysis and later assessed. Moreover, the fetus' size was established. The fetal monitoring system's ultimate design is straightforward, affordable, and transportable and uses UWB technology. The antenna was created and put to the test, showing stable performance [14]. ISM and UWB bands were not present simultaneously with single antenna access in the wearable biomedical antenna that was previously available. As a result of the antenna's input strength having to be increased because they were both present individually, there is a chance that the human body could be exposed to radiation that is not wanted. Due of the mismatched impedance at high frequencies, they were unable to cooperate. We have thereby balanced the losses and impedance. We have also made use of Hilbert curve to design our antenna which is the first time it is being used in a wearable material, It helps with high gain Transformation and it helps reducing

unwanted emission of radiation. For the antenna to operate simultaneously, a matched impedance was obtained using the Hilbert curve and a match terminal. For the antenna to operate simultaneously, a matched impedance was obtained using a Hilbert curve and a match terminal. By implementing the Hilbert curve in the patch after several optimization in the length and width of the ground plane [9], finalizing it as our proposed antenna design and also by using Med Cotton or dry cotton as our substrate material to reduce the unwanted radiation, an optimized microstrip patch antenna was created with a working frequency of 4.2 GHz. A brand-new wideband harmonic suppression microstrip patch antenna achieved by a dual-point feeding technique can regulate higher-order harmonics and excite the fundamental mode. Simulated and measured results validate the feeding approach [13].

3.1 METHODOLOGY TO CREATE UWB MICROSTRIP PATCH ANTENNA WITH HILBERT CURVE DESIGN

Several Optimizations were done with the Hilbert curve antenna design on a rectangular patch, the proposed antenna is finalized after several optimization methods on the ground plane to get a perfectly working antenna in desired frequency range and a low SAR value. By comparing the results, we concluded the antenna with quarter wave transmission line model as our proposed antenna. The UWB antenna is designed and simulated in Ansys HFSS software. Place the antenna on the uterus phantom with and without a fetus for analysis purposes. By using HFSS software to create a fake phantom, we have performed an artificial analysis. An Artificial Uterus was created and given qualities such as permittivity ($8.00E+1$) and dielectric conductivity (s/m) ($9.42E-1$) to the uterus box model. The return loss is analyzed by placing the antenna close to the uterus. A cylindrical model that is considered to be a fetus of 1.1mm size was created and placed inside the uterus model. In Fig. 2 it shows the antenna which has been placed on the abdomen part of human phantom model.

3.2 CONFIGURATION OF THE UWB MICROSTRIP PATCH ANTENNA USED

ISM band used for bio medical application is 2.4 -2.5 GHz. The Frequency used for UWB bio medical application is 4.25 GHz. The SAR value for biomedical application is 0.1-0.99 W/Kg.

3.3 TRANSMISSION LINE MODEL

In electrical engineering, the distributed-element model or transmission-line model of electrical circuits assumes that the attributes of the circuit (resistance, capacitance, and inductance) are distributed continuously throughout the material of the circuit. At high frequencies, transmission lines exhibit quite peculiar behaviour. Wires link devices in conventional (low-frequency) circuit theory, but they have no resistance. Furthermore, a short-circuited line always produces zero resistance and there is no phase delay across wires. High-frequency transmission lines exhibit quite distinct behaviour. For instance, open circuits can act like shortcircuited wires, while short-circuits can really have an infinite impedance. At the transmission line's terminals, a load's impedance can be changed to one that is significantly different from Z_L . The transmission line method (TLM) is nearly ideal for representing sources, such as antennas, and computing wave propagation in the presence of diverse mediums [5].

It makes minimal assumptions about the size or frequency of the source waveform because it is a time domain approach. The material characteristics, such as lossy media and ideal conductors, as well as a range of contact circumstances are all supported. There are generally three basic methods of design microstrip antenna whose names are transmission line, cavity & full-wave model. Here, we'll be using transmission model [7].

3.4 CAVITY MODEL

In the cavity model, the space between the patch and the ground plane is modelled as a cavity bounded by electric walls on the top and bottom and magnetic waves surrounding the Periphery. The field inside the cavity is consistent along the thickness of the substrate since thin substrates are employed. Regular shapes like rectangles, circles, triangles, and sectors can have their fields below the patch described as a sum of several resonant modes of the two-dimensional resonator. An alternate way of incorporating the radiation effect in the cavity model is by introducing an impedance boundary condition at the walls of the cavity. the fringing field and the radiated power are not included inside the cavity but are localized at

the edges of the cavity. however, the solution for the far field, with admittance wall is difficult to evaluate.

3.5 HILBERT CURVE

The Hilbert curve is one of a number of "space-filling curves", where a single curve (normally regarded as a one-dimensional object) "fills" a higher dimensional space. In this case the space filled is the two-dimensional area inside a square.

3.5.1 Hilbert curve structure

The Hilbert curve is constructed as a limit of piecewise linear curves. The final Hilbert curve is the limit of all these infinitely many iterations. The stages are shown in the fig.3.1.

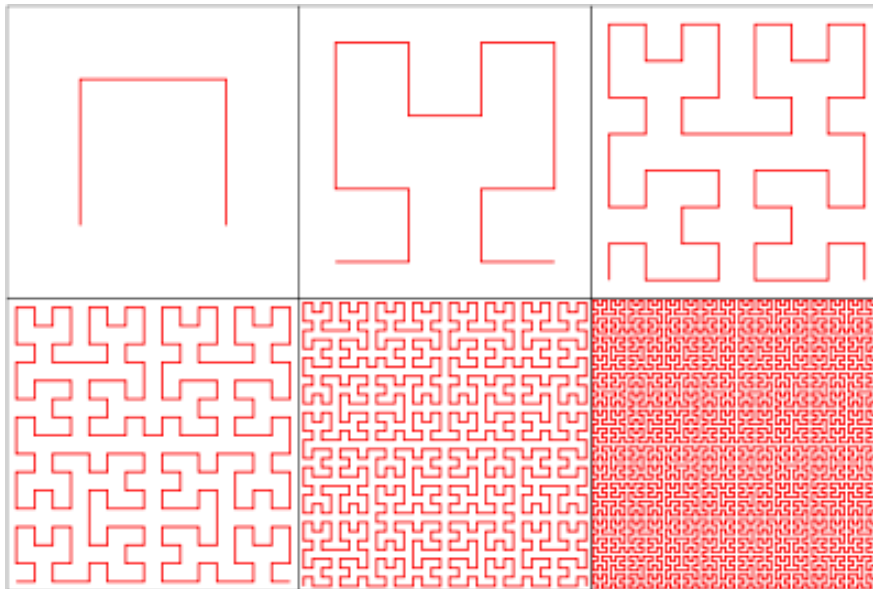


Fig: 3.1 : Hilbert curve

Curves that fill space can also be defined for other uses. For instance, it would be feasible to create a curve that completely fills a cube's interior. One degree of freedom, or utilising a single integer, can be used to represent points on the curve. This demonstrates that the notion of "degrees of freedom" is insufficient to describe the conventional notion of dimension. In other words, each concept of dimension is a unique abstraction of the well-known one. The Hilbert curve has a fractional dimension of two since it completely fills a two-dimensional space with a single curve.

3.5.2 Impact of Hilbert curve

The bandwidth and resonant frequency of a Hilbert curve antenna decrease as the number of iterations rises. The antenna gets smaller and its bandwidth gets smaller by using fractal geometry and various feeding methods [6].

Utilising the Hilbert curve, the antenna achieves a very small electrical dimension. The antenna provides great gain, efficiency, and a wide bandwidth. The fractal iteration order can be increased to drastically lower the antenna's resonance frequency. As a result, our strategy aims to get around one of the major problems with antenna engineering when it comes to tiny antennas.

Hilbert curve geometry in antenna design has been configured to reduce the size of antenna as well as to get multiple resonances. Total length of the Hilbert curve increases when increasing the iteration stage, while keeping the overall space of the entire geometry fixed.

3.6 IMPEDANCE MATCHING

Impedance matching for antennas are intended to ensure maximum power transfers into the antenna so that the element can radiate strongly. The process of antenna impedance matching entails matching the feedline's characteristic impedance to the input impedance at the end of the antenna. Often, filter circuits are utilised because they can be set up to deliver a specified impedance at the required transmission frequency [8].

3.6.1 Definition of Impedance Matching condition

The best power transfer and hence the best efficiency are attained by making sure that a precise impedance match is obtained. This is significant since antenna performance is so vital when using radio communications systems or broadcast transmitters. Although certain antenna designs have a high SWR in a twin or open wire feeder, the optimum power transmission ultimately depends on a good match with the transmitter.

A transmitter won't operate effectively and, in some cases, there may be a danger of injury if it identifies a poor match. Any radio communications or broadcast

transmitter operating at a meaningful power level needs a solid impedance match. Even though high performance antennas are occasionally not as necessary, having a solid match will ensure the best signal is received when receiving.

3.6.2 Need for impedance matching in antenna

A good match between the antenna and the feeder is necessary to provide a low amount of standing waves, or SWR. A transmitting antenna typically needs a low level of SWR, also known as VSWR or voltage standing wave ratio, to operate efficiently. For transmission, a particularly well-matched feeder and antenna combination might be crucial even though reception does not require it as much. Through a feeder, the antenna will receive electricity from the transmitter. If there is a terrible match, power will be reflected back along the feeder. The reflected power will cause standing waves to develop along the feeder. Voltage and current maxima will occur along the feeder at various points.

3.7 FLOWCHART FOR DESIGNING OF UWB MICROSTRIP PATCH ANTENNA

The below fig. 3.2 shows the design methodology or the block diagram for the design of UWB microstrip patch antenna with Hilbert curve design.

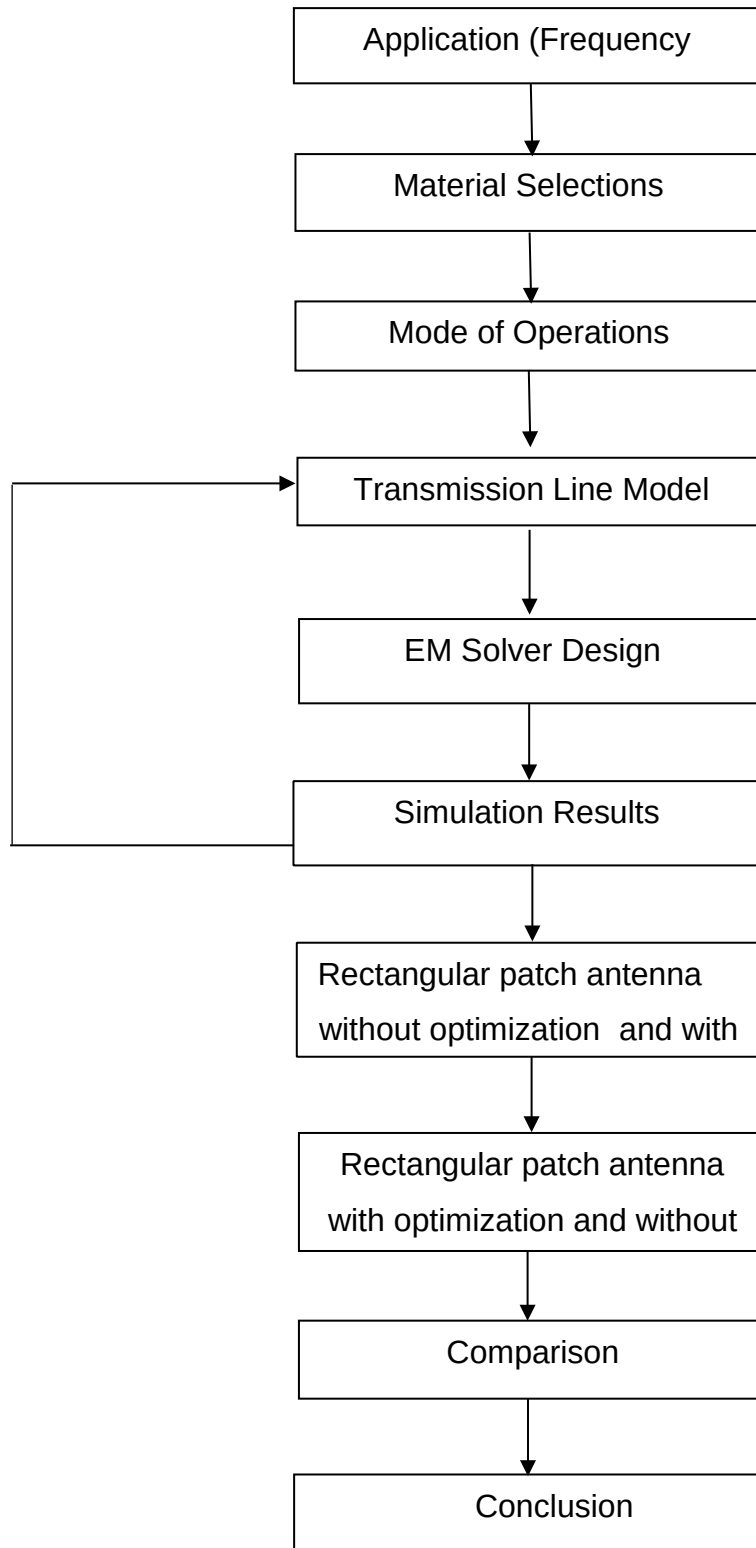


Fig: 3.2 : Hilbert curve antenna design flowchart

3.8 DESIGN EQUATIONS TO CALCULATE THE DIMENSION OF UWB PATCH ANTENNA

The equations shown below are used to calculate the dimensions of the antenna for example Equations (3.2) and (3.4) are used to find the length and width which would be used for the antenna and the values are again substituted in Equations (3.5) and (3.6) to find the ground and substrate values.

- Wavelength

$$\lambda = \frac{c}{f} \text{ mm/sec} \quad (3.1)$$

- Length

$$L = L_{\text{eff}} - 2\Delta L \text{ mm} \quad (3.2)$$

- Thickness

$$H = \frac{0.0606\lambda}{\sqrt{\epsilon_r}} \text{ mm} \quad (3.3)$$

- Width

$$W = \frac{\lambda}{2} \sqrt{\frac{2}{\epsilon_r}} \text{ mm} \quad (3.4)$$

- Ground and Substrate Dimensions

$$L_g = L + 6h \text{ mm} \quad (3.5)$$

$$W_g = W + 6h \text{ mm} \quad (3.6)$$

3.9 UWB MICROSTRIP PATCH ANTENNA OPTIMIZATION

The goal of antenna optimisation is to develop electromagnetic devices that compete in terms of performance, serviceability, and cost effectiveness. The choice of appropriate design variables, constraints, and parameters is a step in this process. The majority of antenna optimisation challenges require simultaneous satisfaction of multiple objectives in order to reach an ideal outcome. In this case, various ground-level optimisation techniques were applied to obtain the necessary ISM frequency for biomedical application.

3.9.1 Rectangular patch antenna without optimization

Here the Rectangular patch antenna is placed on a ground without any optimization that is, the ground is given the same dimension as of the substrate of the antenna.

It has been shown in the fig.3.3 where UWB antenna's Hilbert curve design and the full ground without optimization is shown.

3.9.1.1 Design Specification

Ground:

- Length = 46 mm
- Width = 13.4 mm

Substrate:

- Length = 46 mm
- Width = 53 mm
- Thickness = 1.6 mm

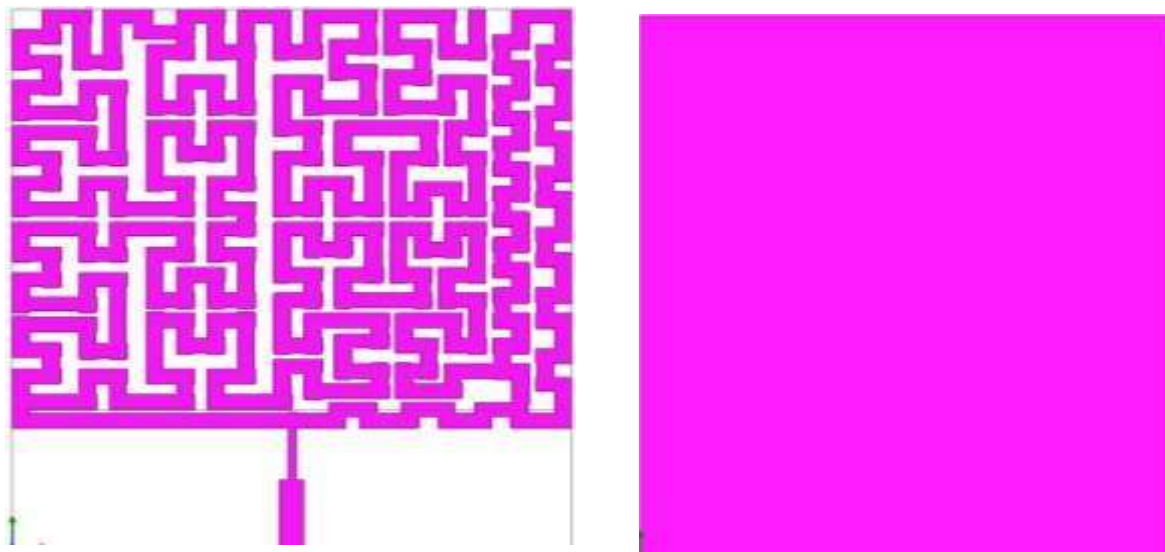


Fig: 3.3 : Structure of rectangular patch antenna without optimization

3.9.2 Rectangular patch antenna with parallel quarter wave transmission grounding method

Here the Rectangular patch antenna is placed on a ground with parallel quarter wave optimization where two separate rectangular boxes were created and considered to be as ground by giving values, placing it in the antenna. Both grounds are united

and considered to be a single ground that has been shown in the fig.3.4 and then simulated results were taken for comparison.

3.9.2.1 Design Specification

Ground:

- Length = 46 mm
- Width = 13.4 mm

Substrate:

- Length = 46 mm
- Width = 53 mm
- Thickness = 1.6 mm

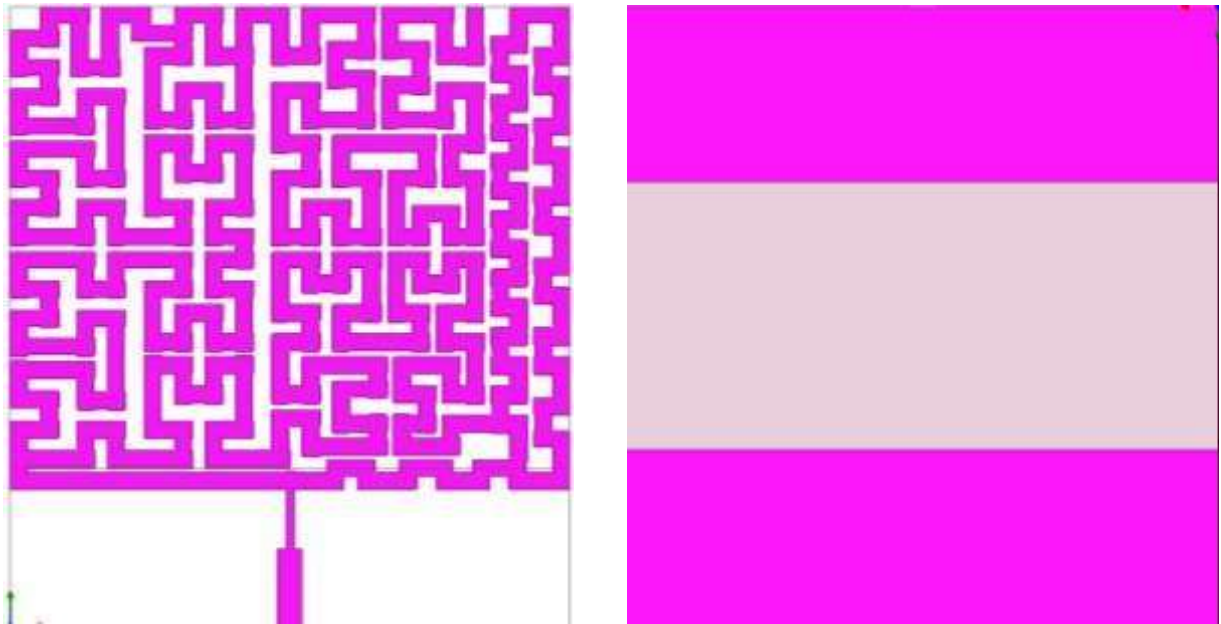


Fig: 3.4 : structure of rectangular patch antenna with parallel quarter wave transmission grounding method

3.9.3. Rectangular patch antenna with quarter wave transmission grounding method

Here the Rectangular patch antenna is placed on a ground with quarter wave optimization where a rectangular box is created and given values to be considered as ground that is shown in the fig.3.5 and then simulated results were taken for the comparison to finalize the proposed UWB patch antenna design.

3.9.3.1 Design Specification

Ground:

- Length = 46 mm
- Width = 13.4 mm

Substrate:

- Length = 46 mm
- Width = 53 mm
- Thickness = 1.6 mm

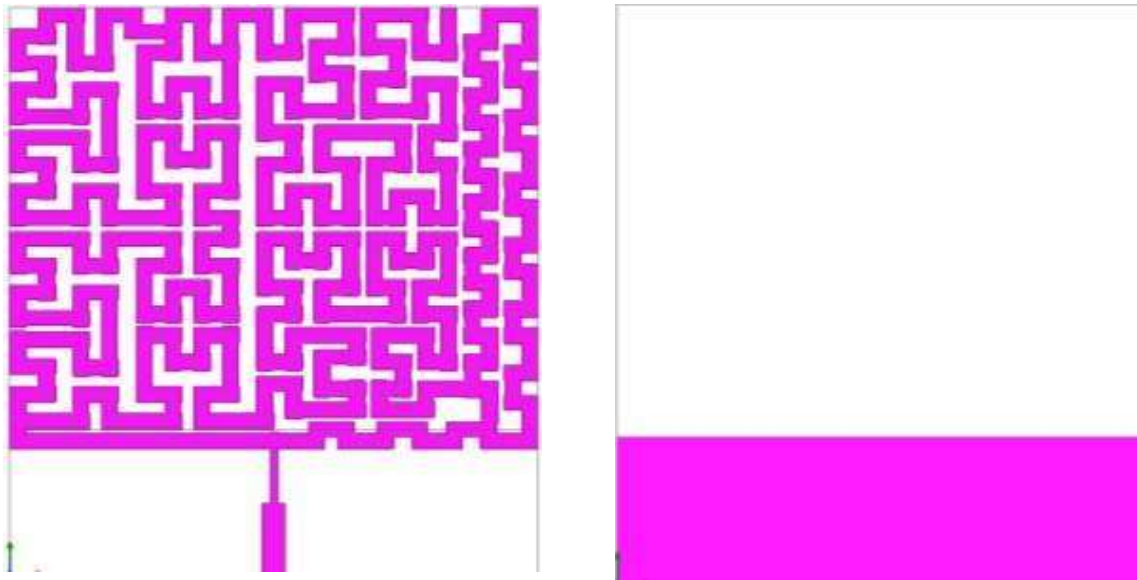


Fig. 3.5 Structure of Rectangular patch antenna with quarter wave transmission grounding method

3.9.4. Design method of UWB Microstrip patch antenna using Hilbert curve

The Substrate is first created as a box and is considered to as wearable dry cotton or med cotton by giving its dielectric values along with the dimensions for the substrate. The other parts like ground, feedline, port are also assigned and giving specific values. The Hilbert curve is then designed by creating multiple interconnecting boxes and then united together to be a single design. Everything is then joined to be able to work as a single antenna. The antenna is then placed on the artificially created uterus phantom by giving the permittivity and permeability values of uterus tissue and then considered to be as uterus. An artificial hole is then created on the phantom which is considered to be as the defected fetus. Now the simulated results are taken to see how effectively the antenna works and to determine the size of the fetus. Parts of the Antenna with substrate and grounding method is shown in the Fig 3.6.

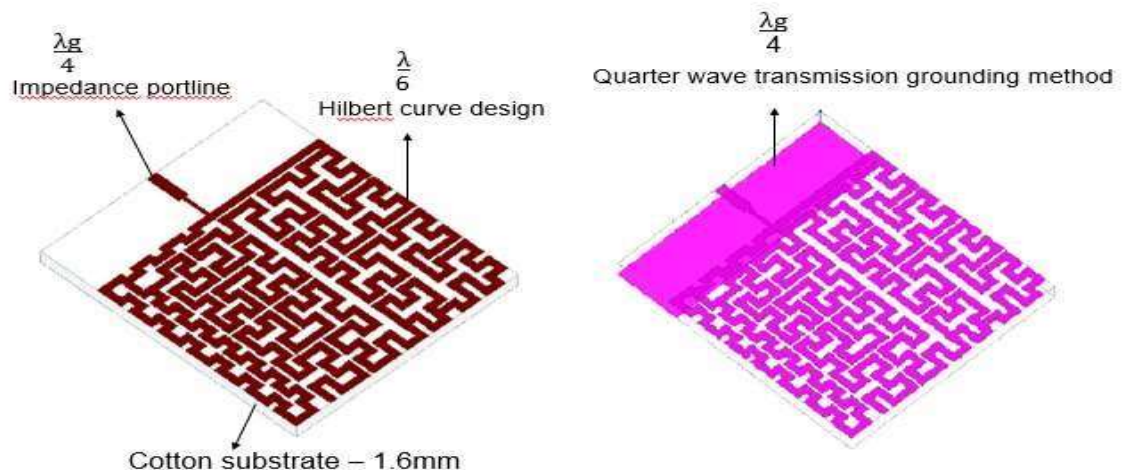


Fig: 3.6 : Parts of Antenna with substrate and grounding method

3.9.5 Comparison of antenna's return loss, gain, directivity through optimization

The below table 3.1 shows the comparison of return loss, gain, directivity throughout the optimization which was do bring out the most effective design. The quarter wave transmission line method was found to be more effective considering the return loss

for the antenna to avoid losses and reflection and since the gain and directivity values were very close to each other and to get the antenna work properly at 4.2 GHz frequency.

Table 3.1 : Comparison of return loss, gain, directivity

Parameters	No optimization	Parallel Quarter wave	Quarter wave
Working Frequency (GHz)	4.3	4.2	4.2
Return Loss (dB)	-21.9100	-17.4753	-26.5772
Gain (dB)	Max: -2.5 Min: -25.0	Max: 4.1 Min: -12.5	Max: 3.5 Min: -26
Directivity (dB)	Max: 7.1 Min: -20.2	Max: 4.3 Min: -12.4	Max: 3.8 Min: -25.7

3.10 DESIGN TABLE OF RECTANGULAR PATCH ANTENNA WITH QUARTER WAVE TRANSMISSION GROUNDING METHOD

The below table 3.2 shows the design dimensions of rectangular patch antenna with quarter wave transmission grounding method that was used as final design of the UWB patch antenna of Hilbert curve design.

Radiating layer for Hilbert curve = 1 x 6 mm in series

Substrate material = dry cotton

Dielectric constant=2.17

Table 3.2 : Dimensions of proposed antenna

	Length(mm)	Width(mm)	Thickness(mm)
Substrate	46	53	1.6
Ground	46	13.4	-
Feedline1	2	6.6	-
Feedline2	0.7	6.6	-
Port	2	-	-1.6

The below table 3.3 shows the phantom structure details which was given to the artificially created box which was considered to be the human phantom.

Table 3.3 : Phantom structure details

	Source	Permittivity	Elec. Cond.(s/m)
uterus	utrerus	8.00E+1	9.42E-1

3.11 UTERUS TISSUE CREATION

Modelling and simulation of the presented approached were performed in high frequency simulation software (hfss). Simulation models consisting of a part of uterus , an antenna, and a fetus were developed in hfss. A part of uterus tissue was been designed and given the properties liked permittivity and elec. Cond. (s/m)

3.11.1 Creating human phantom model analysis

A part of uterus tissue was been designed and given the properties liked permittivity and elec. Cond. (s/m). Where an artificial box was created giving the values and

considered to be the uterus. The uterus permittivity was 8.00×10^1 and elec. Cond. (s/m) was 9.42×10^{-1} . The antenna was then placed on the uterus, placing antenna near the uterus and analyzing we would get returned loss that has been shown in the fig.3.7 and the size of the defected fetus which was also created inside the artificial uterus by creating a hole on it was also found.

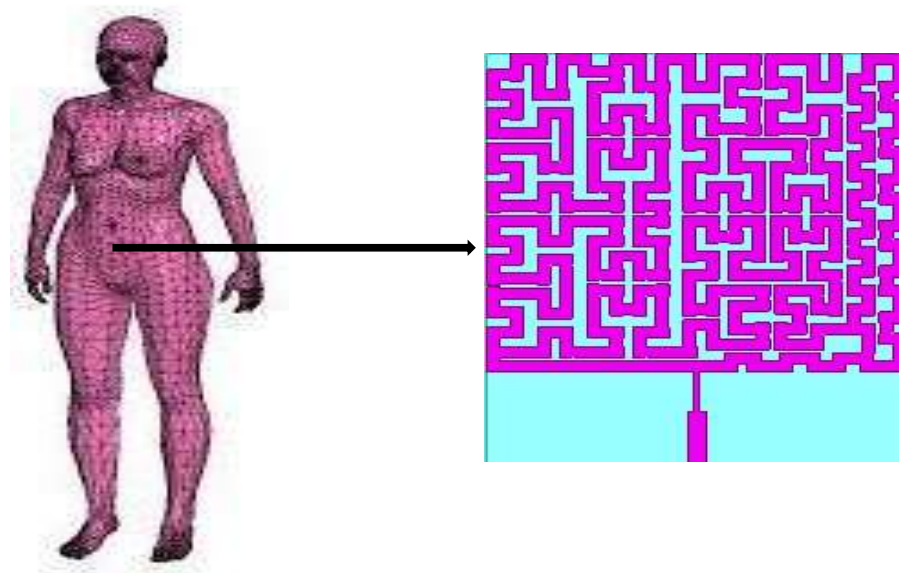


Fig: 3.7 : Antenna being placed in abdomen part of human phantom model

3.12 SUMMARY

The comparison of gain, directivity and return loss is shown above through all the stages of optimization. The antenna is also being placed on the human abdomen phantom where the phantom structure details is given manually to a box which is considered to be the uterus. The fetus is then created a cylindrical part inside the phantom and the result of return loss difference shows the difference between antenna without phantom, with phantom, with phantom and fetus.

CHAPTER - 4

4. RESULT ANALYSIS OF UWB MICRO STRIP PATCH ANTENNA

Gain, input impedance, directivity, radiation pattern, effective area, and polarisation qualities are just a few of the characteristics that define an antenna in general. The next sections go over the experimental process for determining the antenna's parameters. The antenna measuring setup in conjunction with the network analyzer can be used to compute the radiation patterns and determine the S parameters. Higher frequency ranges are where the losses of the cables and connectors are found. Before utilising the measurement device, it should be calibrated. The network analyzer has a wide range of calibration processes. The three most common calibration techniques are single port, full two port, and TRL. The single port calibration method can be used to assess input impedance, VSWR, and return loss.

4.1 RETURN LOSS

It is the measure of loss of power in the signal reflected by a transmission line to a load. The two major cause of return loss are discontinuity and impedance mismatching and it is expressed in decibel. Return loss equation (4.1) to find numeric values that has been shown below where S11 parameter is taken from the simulated graph result of m3 and m1 value where S11 with m1 value given the ISM band return loss value and S11 with m3 value given UWB band return loss value in Equation (4.2) and (4.3). The graph below shows the return loss without phantom in fig 4.1. This return loss value is then substituted in VSWR equation (4.4).

$$RL(dB) = 20 \log \frac{1}{S_{11}} \quad (4.1)$$

$$RL(ISM) = -35.1039 \quad (4.2)$$

$$RL(UWB) = -26.5772 \quad (4.3)$$

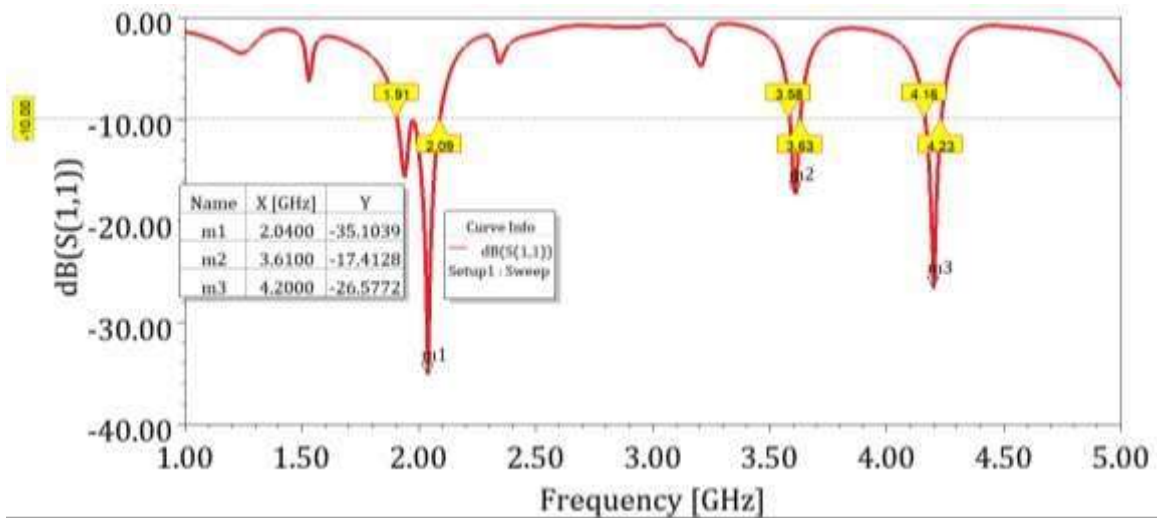


Fig: 4.1 : Return Loss

4.2 VSWR

VSWR can be expanded as voltage standing wave ratio. It is a measure of how efficiently the RF power is transmitted from power source. If the given signal is completely radiated by the antenna without any reflection then the antenna has a unit value of VSWR. The numerical value of VSWR ranges from 0 to 1 and so the antenna has no impedance mismatch. VSWR equation (4.4) to find numeric values that has been shown below and the graph below shows the VSWR without phantom in fig 4.2. The VSWR values for UWB and ISM band are in unit values as shown in the equation (4.5) and (4.6). Here the calculated value of VSWR and graph value of VSWR matches perfectly. Therefore the antenna is considered to be safe with causing no harm to human tissue.

$$\text{VSWR} = \left| \frac{1+r}{1-r} \right| \quad (4.4)$$

$$\text{VSWR(ISM)} = \left| \frac{1+0.0468}{1-0.0468} \right| = 1.0984 \quad (4.5)$$

$$\text{VSWR(UWB)} = \left| \frac{1+0.0468}{1-0.0468} \right| = 1.0984 \quad (4.6)$$

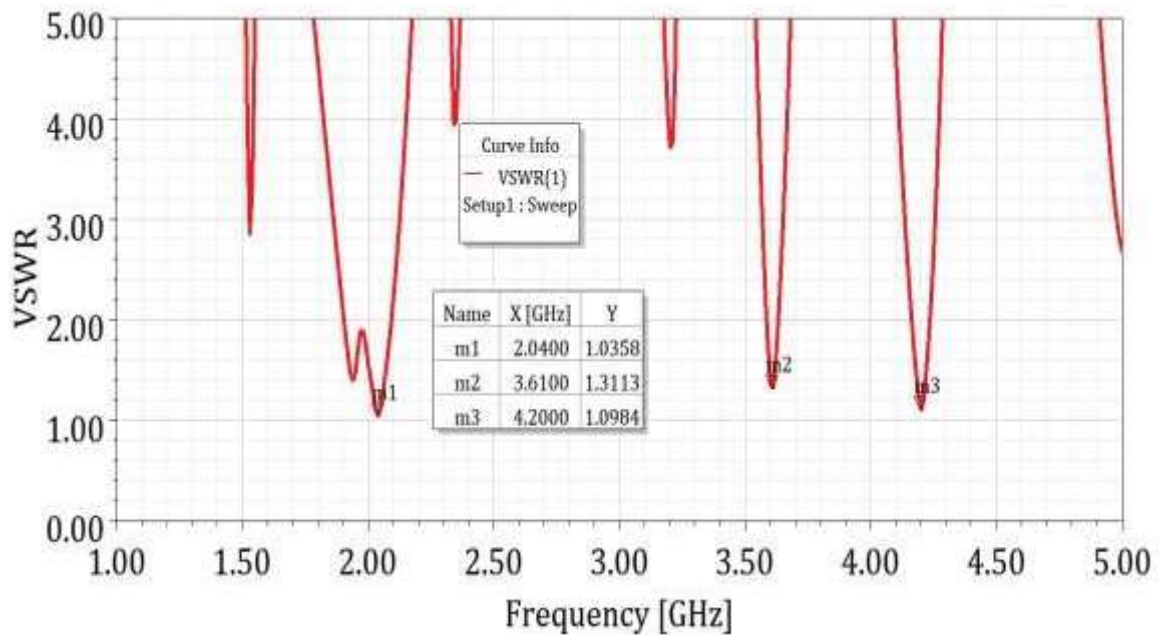


Fig: 4.2 : VSWR

4.3 SMITH CHART

Smith charts can be used to solve transmission line issues, and Phillip H. Smith created them in 1940. When measured on a vector network analyzer (VNA), it is used to illustrate the impedance of an antenna. It has two sets of circles for charting different transmission line parameters that aren't lined up. Z, Y, and the reflection coefficient are among the parameters. The Smith Chart gives a graphical representation that makes it possible to calculate values like VSWR or terminating impedance of a device that is being tested. It projects the complex impedance plane onto the complex plane via a bilinear Moebius transformation. A smith chart is a circular layout with numerous interlaced circles on it when used properly, matching impedances with apparent complicated structures can be made without any computations. Smith chart equation (4.7) to find numeric values. The below output simulation shows the impedance in fig 4.3.

$$Z = R \pm j \omega X \quad (4.7)$$

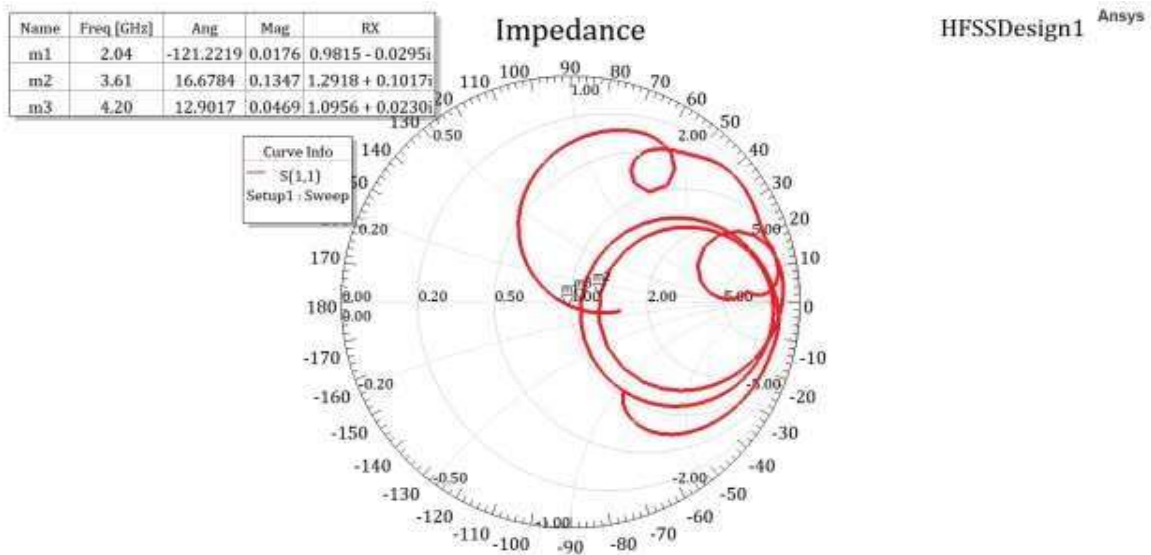


Fig: 4.3 : Smith Chart

4.4 UTERUS PHANTOM WITHOUT FETUS

A part of uterus tissue has been designed and given properties like permittivity and elec. Cond. (s/m). The brain permittivity was 8.00E+1 and elec. Cond. (s/m) was 9.42E-1. Placing the antenna near the uterus and analysing we would get returned loss. Uterus phantom without fetus that has been shown in th fig.4.4.

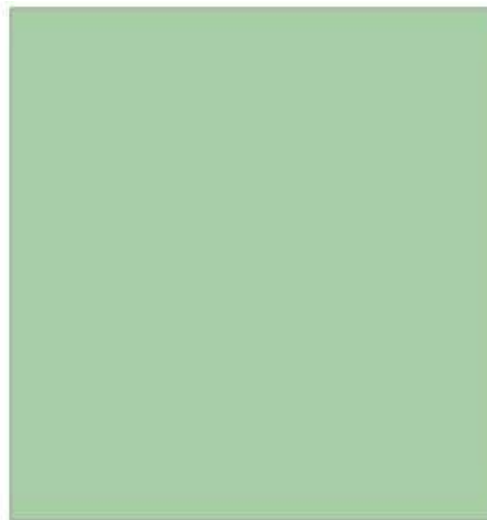


Fig: 4.4 : Uterus Phantom without Fetus

4.5 UTERUS PHANTOM WITH FETUS

A part of Uterus tissue is designed and given the properties like Permittivity and Elec.Cond.(S/m), another brain tissue was also designed and inserted a 1mm size

tumor inside of it. The brain permittivity is $8.00\text{E}+1$ and Elec.Cond.(S/m) is $9.42\text{E}-1$. Uterus phantom with fetus that has been shown in the fig.4.5.

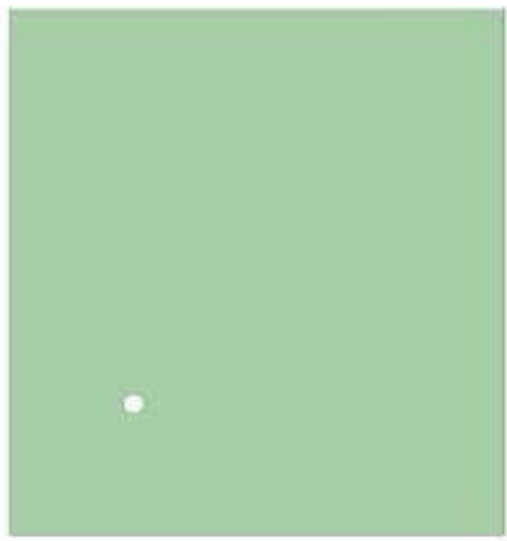


Fig: 4.5 : Uterus Phantom with Fetus

4.6 ANALYSING UTERUS PHANTOM WITHOUT FETUS

Placing the antenna near the uterus and analysing we will get return loss of different values in each case. For the simulation without defect, we will get a return loss of 33.1445 dB. The graph below shows the output of uterus phantom without fetus in fig 4.6.

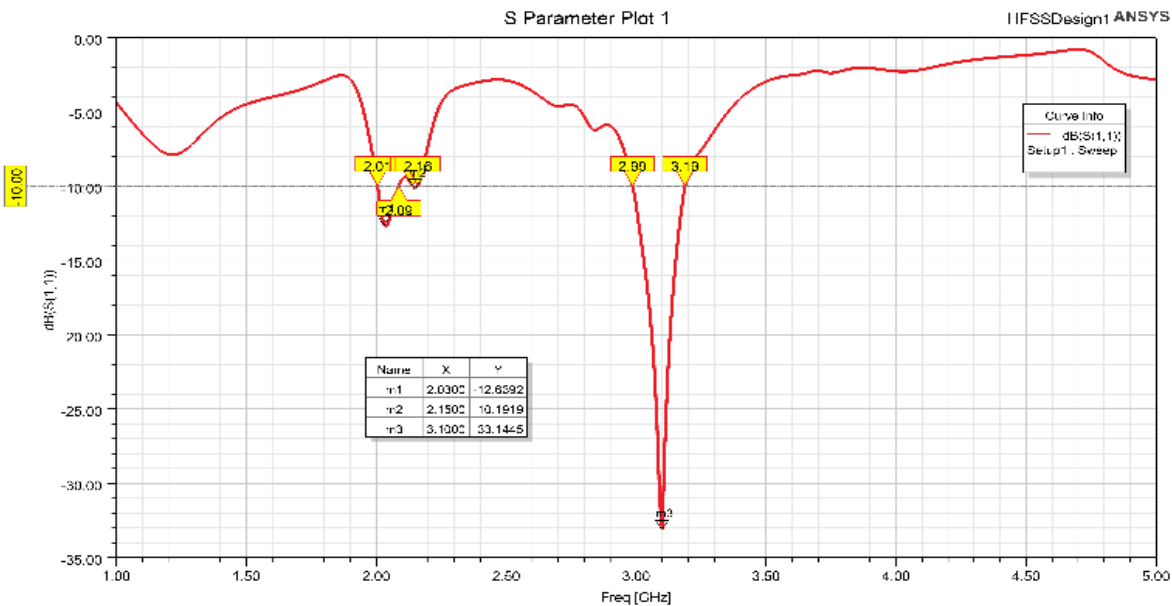


Fig: 4.6 : S11 parameter without fetus

4.7 ANALYSING UTERUS PHANTOM WITH FETUS

Placing the antenna near the fetus and analysing we will get return loss of different values in each case. For the simulation with the tumor, we will get a return loss of 19.0008dB. The graph below shows the output of uterus phantom with fetus in fig 4.7.

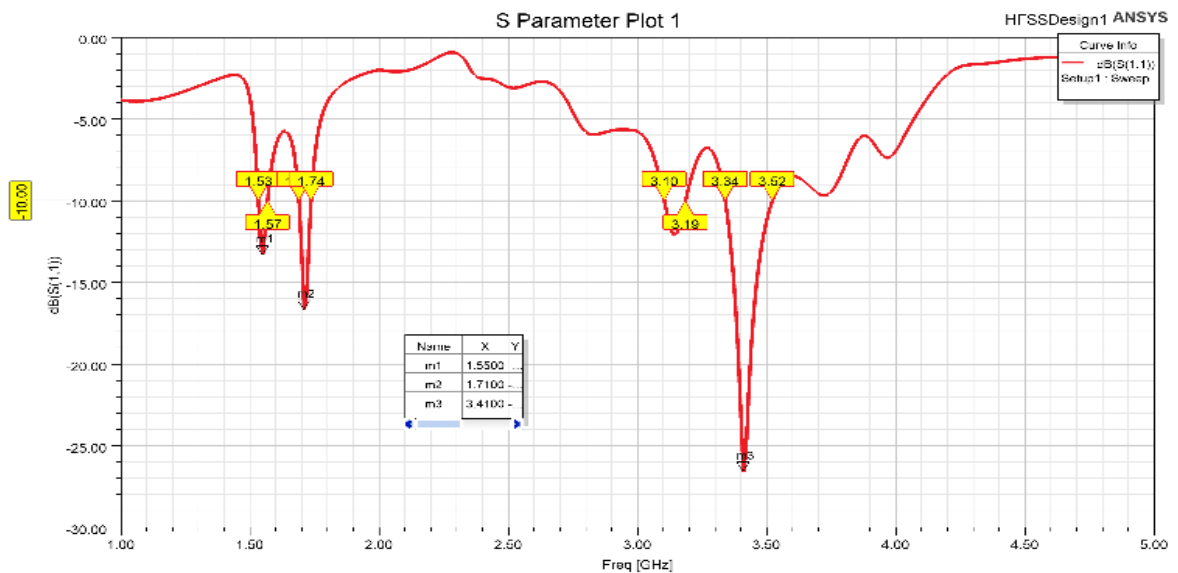


Fig: 4.7 : S11 parameter with fetus

4.8 HUMAN MODEL ANALYSIS

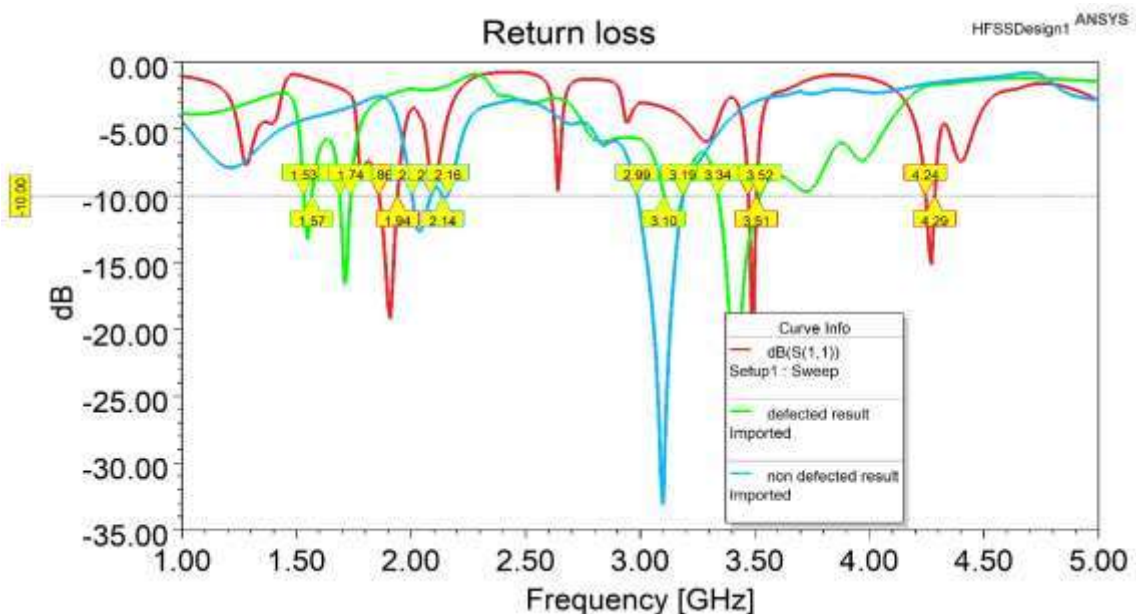


Fig: 4.8 : Return loss of antenna with phantom, without phantom, with defect

$$\text{Calculation} = 2.99 - 3.10 = 0.11$$

$$\frac{0.11 \times 100}{10} = 1.1\text{cm}$$

Defected Place Size = 1.1 cm

Through above combined return loss graph, the values for the calculation is taken with the return loss difference between defected and not defected antenna. Through this it is determined that the defected place or the fetus size is 1.1 cm. The graph shows the output of human model analysis in fig 4.8.

4.9 GAIN

The amount of power transmitted from an isotropic source to the direction of peak radiation is known as antenna gain. Because it takes into consideration the actual losses that happened, antenna gain is given in the antenna specification sheet. For instance, a 3dB gain antenna will result in a 3dB increase in the power received at a distance compared to a lossless isotropic antenna.. The real antenna gain is as high as 40-50dB in large dish antenna. Here the proposed patch antenna shows a gain of 3.5dB. The graph below shows the output of gain plot in fig 4.9.

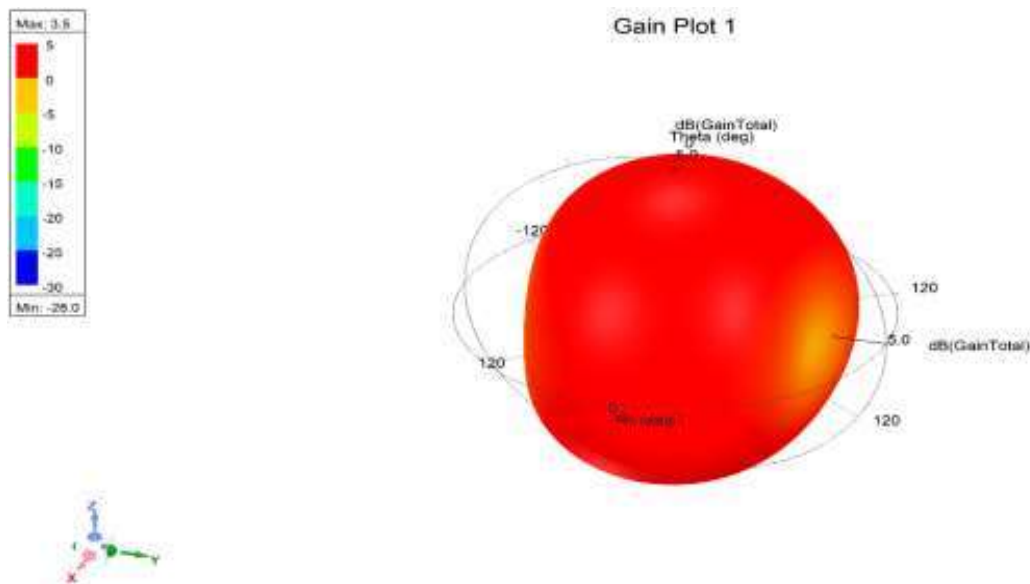


Fig: 4.9 : Gain plot

4.10 DIRECTIVITY

A fundamental antenna parameter is directivity. It gauges how 'directional' an antenna's radiation pattern is. Effectively zero directionality and 0dB directivity would be the properties of an antenna that radiates equally in all directions. A more focused or directed antenna is implied by an increase in directivity. Short dipole antennas have a directivity of 1.76 dB, but larger antennae like horn and dish antennas have a range of 10 to 40 dB. The patch antenna has a directivity range of 2 to 10 dB. So applications involving Bluetooth, Wi-Fi, and ZigBee predominantly use patch antennas. The square patch in this instance displays a directivity value of 3.8dB. The graph below shows the output of directivity in fig 4.10.

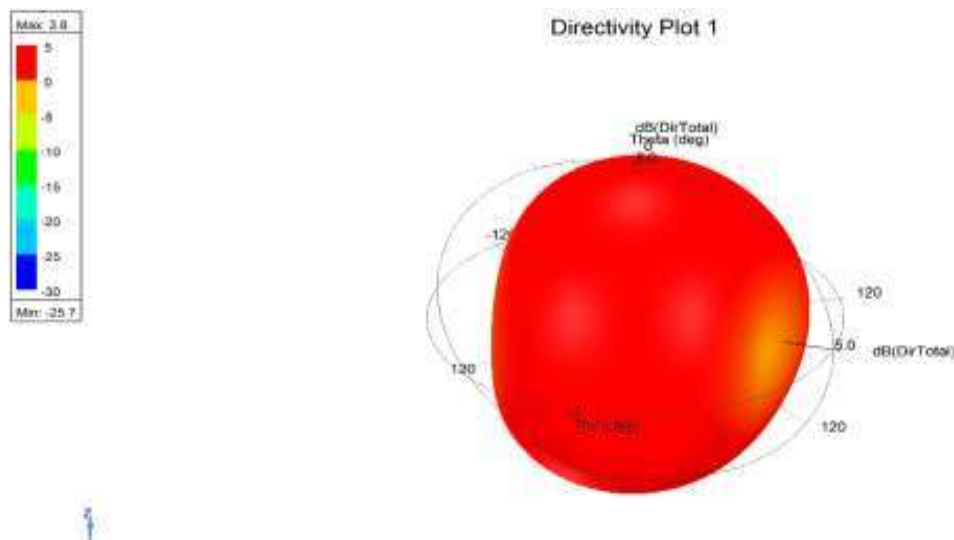


Fig: 4.10 : Directivity Plot

4.11 RADIATION EFFICIENCY

The ratio of the power given to the antenna to the power it radiates is known as the antenna's efficiency. The majority of the power applied at an antenna's input is radiated out by a high-efficiency antenna. The majority of the power used by a lowefficiency antenna is lost as internal losses or is reflected away owing to impedance mismatch. The gain and directivity values are acquired, and from these values, the efficiency of the antenna is computed and given as a percentage (%). The effectiveness of our suggested antenna is 96%, which implies that it operates flawlessly without endangering the patient.. The graph below shows the output of radiation efficiency in fig 4.11.

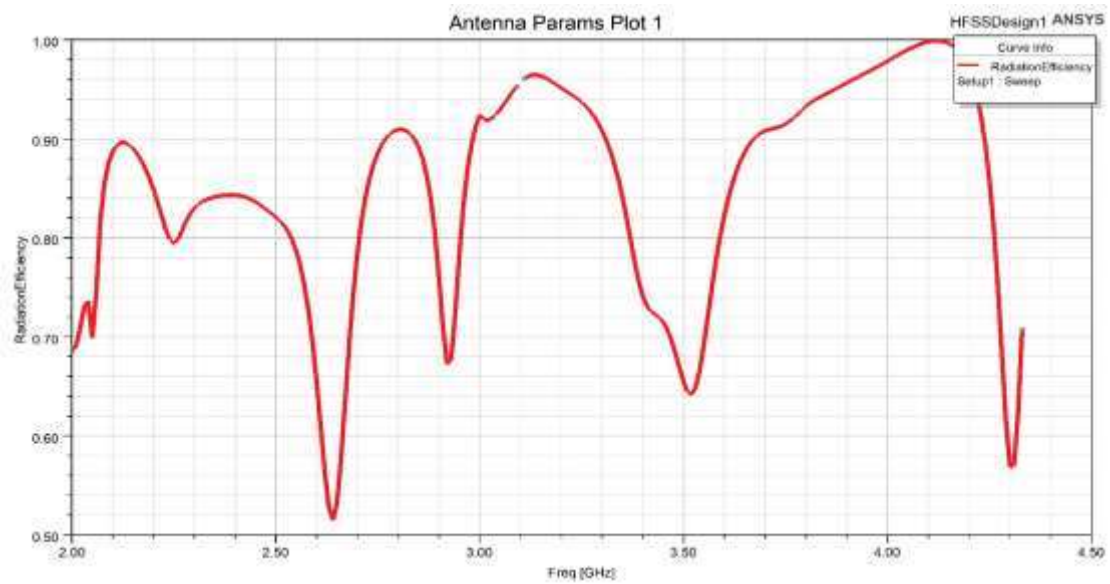


Fig: 4.11 : Radiation Efficiency

4.12 ACCEPTED POWER

An ideal transmitting antenna accepts power from a source (perhaps a power amplifier) and radiates the power into space. The graph below shows the output of accepted power in fig 4.12.

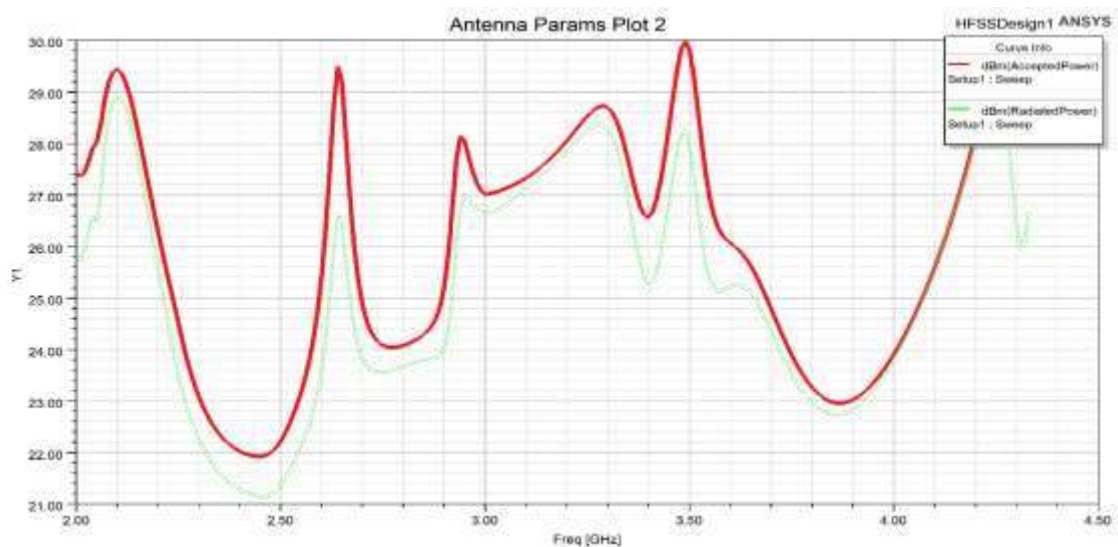


Fig: 4.12 : Accepted Power

4.13 RADIATED POWER

Total Radiated Power (TRP) is a radio frequency (RF) engineering term used to describe the sum of all power radiated by an antenna connected to a transmitter. Total Radiated Power is closely related to the efficiency of the antenna, and is in fact tied to the definition of efficiency. The graph below shows the output of radiated power in fig 4.13.

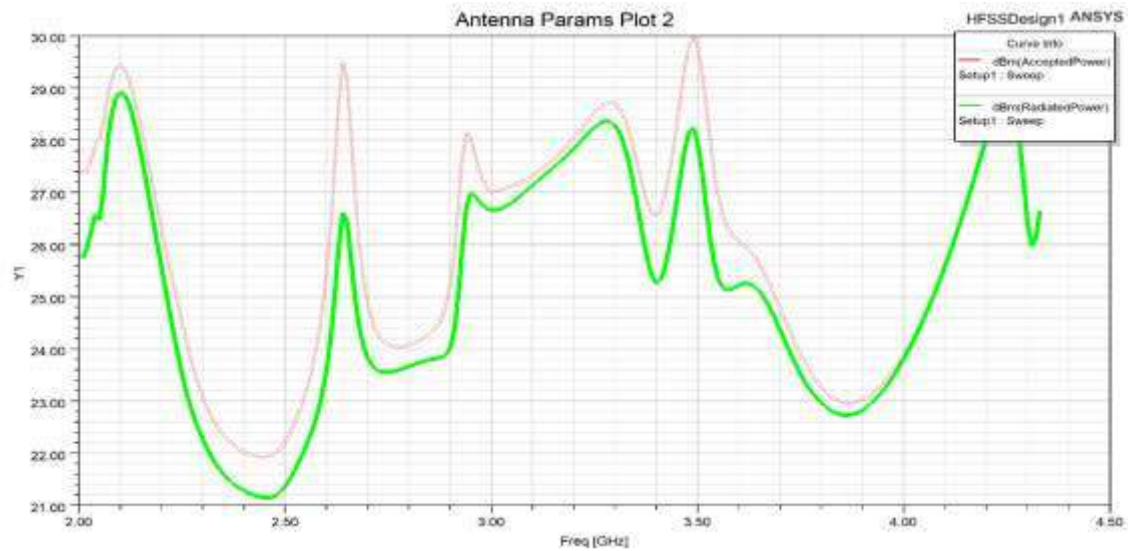


Fig: 4.13 : Radiated Power

4.14 SAR

Specific absorption rate (SAR) is the parameter that describes how much energy is absorbed per unit mass by the human body when exposed to a radio frequency electromagnetic field. In India, the max SAR a device can have is 1.6 W/kg. In fig 7 we can see the SAR of our proposed antenna design. It is 0.47 W/kg, which is very less. Hence our proposed antenna will work properly without any side effects to the patient. Here is the fig.4.14 represent the defected phantom SAR and Surface

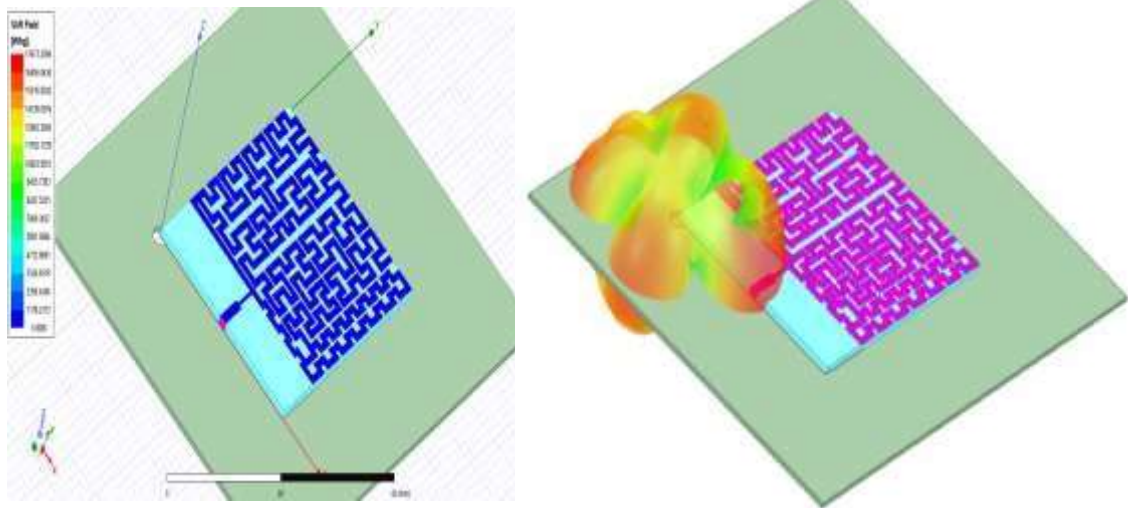


Fig: 4.14 : Defected phantom SAR and Surface

CHAPTER – 5

5. CONCLUSION

When the antenna is brought near the human abdomen there is a considerable change that occurs in the antenna's performance. The resonant frequency and return loss values get changed the antenna is kept near the high permittivity structured human abdomen phantom model. With this output, we can conclude that the proposed antenna is working perfectly at 4.2 GHz frequency without any side effects to the patient and is suitable for biomedical applications. The ISM and UWB are in unit value since the graphical and numerical value of VSWR matches perfectly while having almost no impedance mismatch. Hilbert curve was never used to design in wearable substrate and this is the first design to make use of Hilbert curve to reduce the unwanted radiation emission. To avoid that possibility, we have also utilized med cotton which controls unwanted emission. We created a phantom structure and place antenna inside it as well as a phantom with defect or fetus. Through human model analysis and calculation, the size of the antenna was determined with the use of return loss.

The proposed antenna is optimized to obtain the desired output and the antenna is analysed with the parameters such as S11 parameter and SAR, which resulted in the output of -26.5772 dB and 0.47W/kg respectively. Also, it has been found that the antenna efficiency is 96%. The losses have been minimized and fluctuated. The directional pattern, Radiation efficiency, accepted power, radiated power were also simulated and results were taken.

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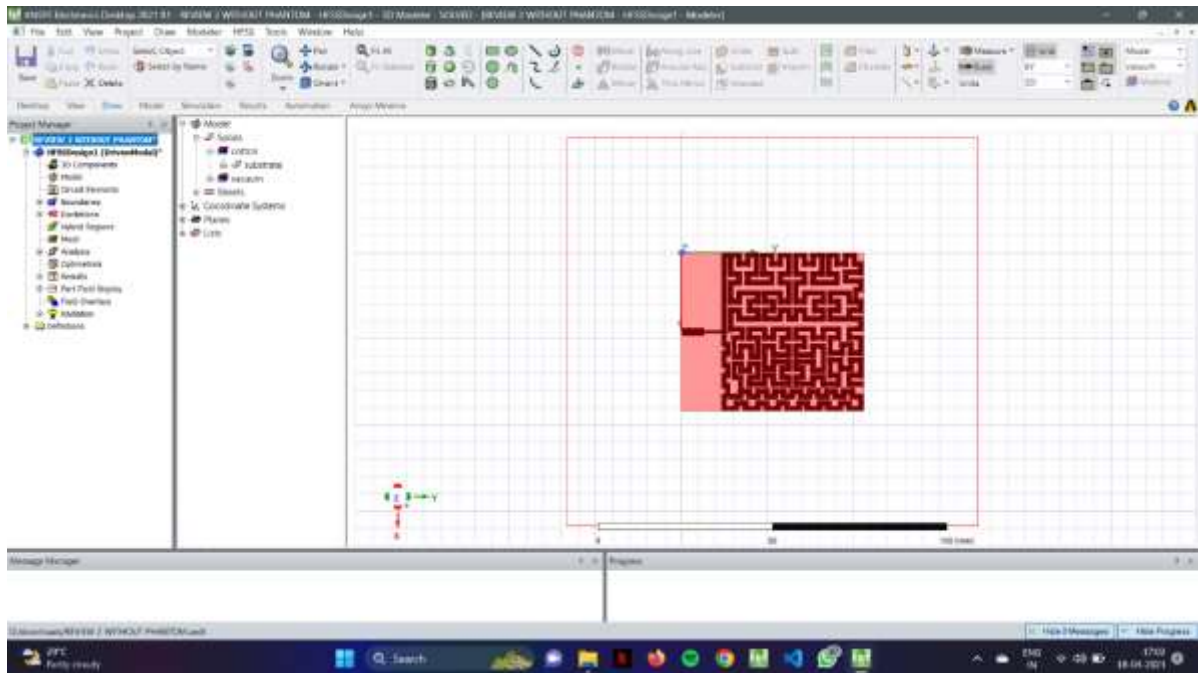
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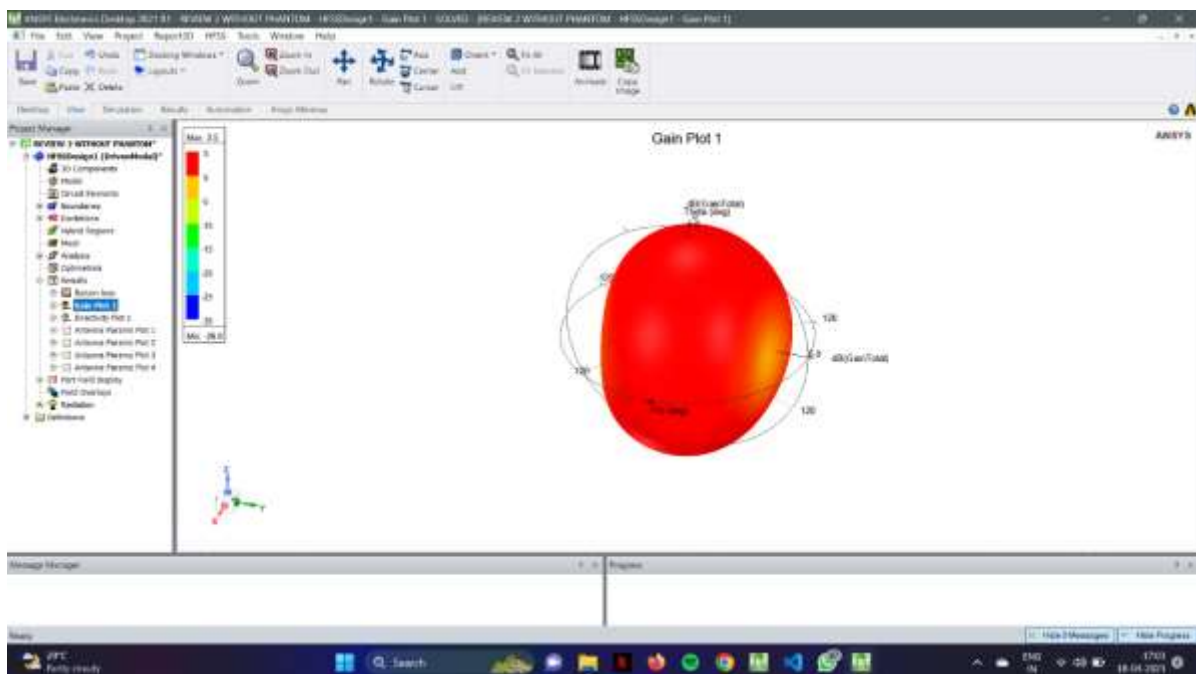
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APPENDIX

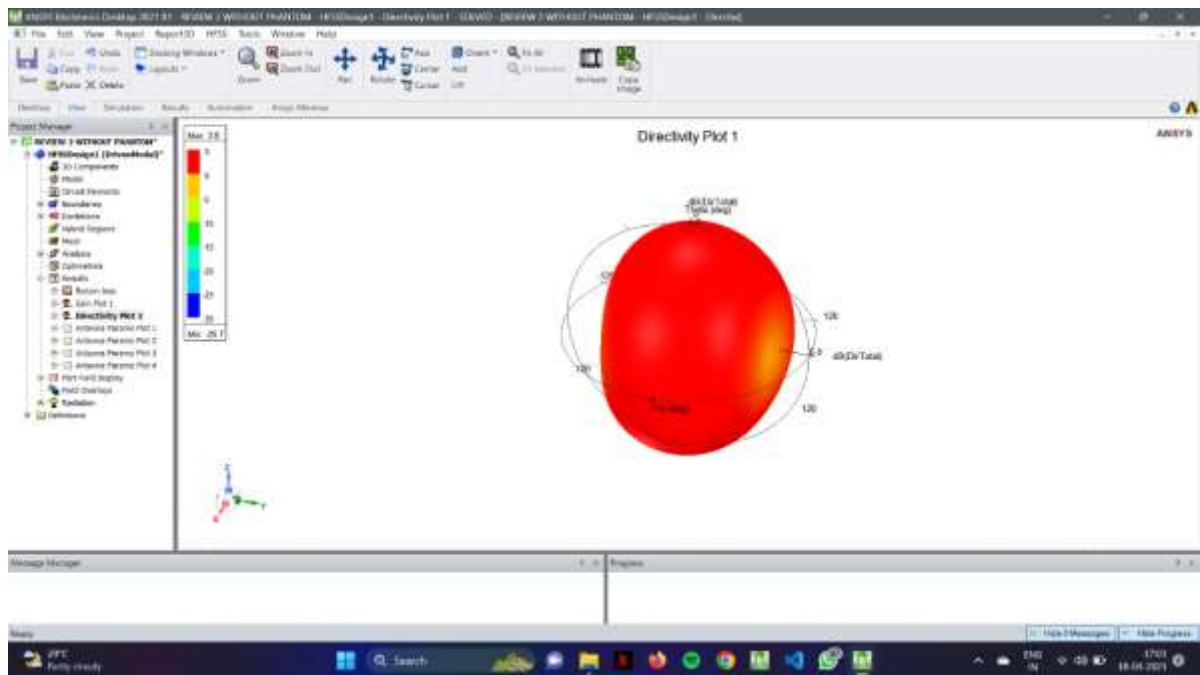
A. SCREENSHOTS



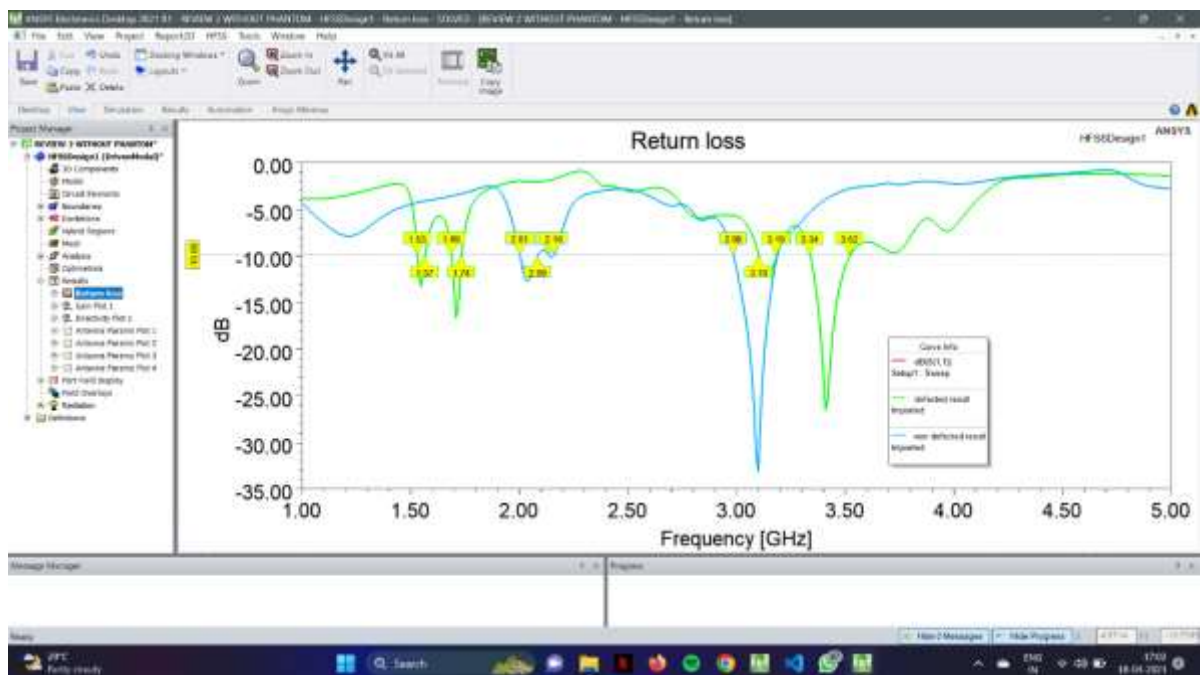
UWB microstrip patch antenna design without phantom



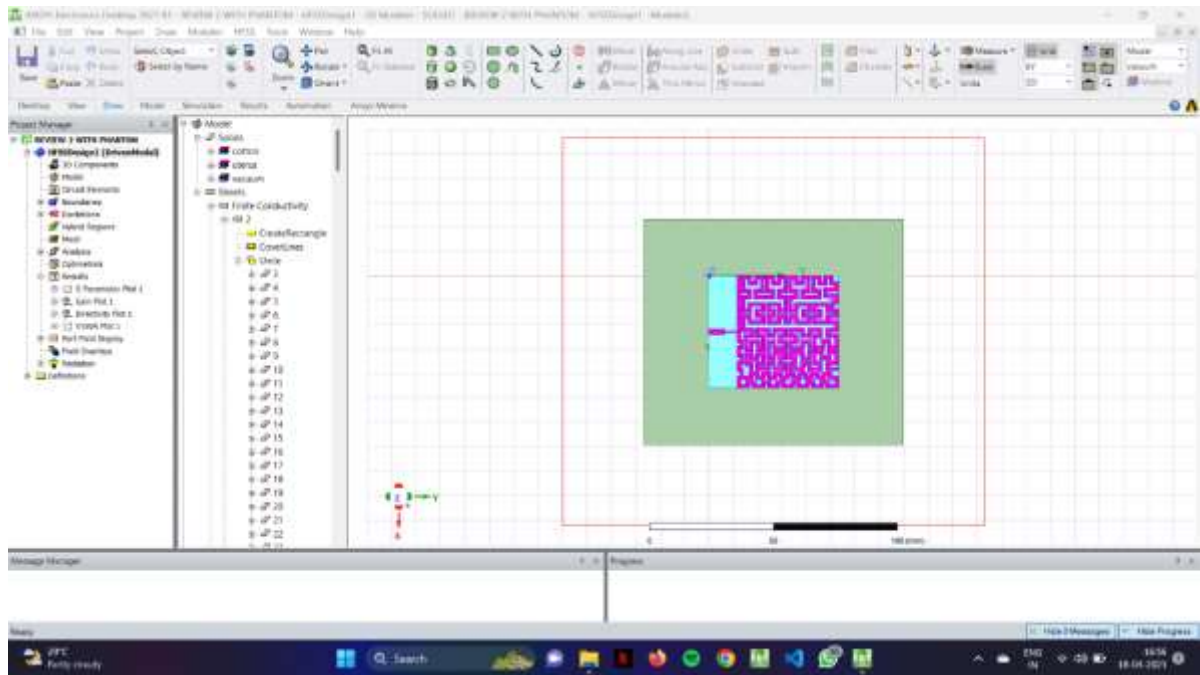
Gain plot of UWB microstrip patch antenna design without phantom



Directivity plot of UWB microstrip patch antenna design without phantom



Return loss comparison graph of UWB microstrip patch antenna design without phantom, with phantom, with phantom and defect



UWB microstrip patch antenna design with phantom and fetus



Return loss graph of UWB microstrip patch antenna design with phantom and defect

Design, Analysis and Implementation of Microstrip UWB Antenna to monitor the Fetus in Uterus.

J.J. Lakshaya
Department of ECE
Sathyabama Institute of
Science and Technology
Chennai, India
lakshayajai2002@gmail.com

Kaviyadharshini. N
Department of ECE
Sathyabama Institute of
Science and Technology
Chennai, India
kdharshini697@gmail.com

Dr. Karthikeyan. S
Department of ECE
Sathyabama Institute of
Science and Technology
Chennai, India
karthijoy1@gmail.com

Dr. I. rexlin Sheeba
Department of ECE
Sathyabama Institute of Science and
Technology
Chennai, India
rexlinseebea.ece@sathyabama.ac.in

Abstract— With the growth of the healthcare and biomedical industries, biomedical telemetry antenna has attracted a lot of interest. With the help of conventional hospital visits and follow-up routine check-ups, it is now possible to remotely monitor a patient's physiological indications. This is made possible by the Use of integrated Hilbert curve expandable antenna technology. The integrated Hilbert curve expandable biomedical antenna devices (IHEBAD) that have been proposed play a significant part in the monitoring of the fetus found in the patient using wireless telemetry such as an ISM (2.45 GHz) and UWB (4.25 GHz) band. For the extendable antenna, a number of elements need to be taken into account, including miniaturization, patient safety, biocompatibility, low power consumption, reduced frequency band of operation, and dual band specifications. Choosing an antenna is a difficult task for Hilbert to design. This paper presents the key finding in the integrated Hilbert curve expandable biomedical antenna proposal with wearable substrate. To confirm the use of the suggested antenna design, the proposed antenna's essential characteristics are analyzed. They also demonstrate a good level of simulation agreement.

Keywords—Hilbert curve, bio medical, IHEBAD, telemetry, fetus.

I. INTRODUCTION

Due to the fact that the perinatal mortality rate (PMR) looked to be high in several countries, including emerging nations like Indonesia, it is imperative that pregnant women's and the fetus' health receive more serious consideration and prompt medical care [1]. As a result, all research centers and institutions need to significantly support and carry out ongoing research efforts linked to this topic. The fetal monitoring system's ultimate design is straightforward, affordable, and transportable and uses UWB technology. Research has been particularly active in the past 2 years in creating wearable systems and gadgets for medical-related applications, frequently targeted at continually monitoring patients in their environment and while engaging in regular activities. A sustainable health system is required that can handle acute care, care of outpatients (mostly chronic),

including healthy persons during their normal lives, and periodic monitoring to prevent potential ailments. Recent years have seen the development of Ultra Wide Band (UWB) technology within the context of short-range low data rate communications. In comparison to traditional narrow band systems, it offers a radically different approach to wireless technology because to the vast channels bandwidth and low power features. With so many potential uses, this makes the field of medicine exciting.

Compared to traditional narrow band systems, Ultra-Wide Band (UWB) wireless communications offers a fundamentally different approach to wireless technology, which generates significant research interest. The most common antenna was the microstrip patch antenna, which has become a necessary requirement due to the development of wireless communication technology [2]. Microstrip patch antennas are frequently employed in microwave frequencies due to their simplicity. Because of their benefits, including their small weight, low cost, ease of construction, etc., these antennas make themselves appropriate for a variety of applications [3]. The tiny strip patch antenna was selected as a mandatory requirement mostly due to its extremely low profile, ability to be mounted on a flat surface, and likelihood that it is a form of radio antenna [4]. The fetal monitoring system was created with the express purpose of being used by high-risk pregnant patients who have trouble getting to hospitals. The built-in UWB fetal monitoring device is capable of sensing the fetus despite the numerous risk factors present during pregnancy, this can be improvised further. The coaxial cable patch antenna has a wider operating frequency band, while the microstrip line patch antenna has a higher radiation gain [12].

The transmission line method (TLM) is nearly ideal for representing sources, such as antennas, and computing wave propagation in the presence of diverse mediums. As a time domain approach, it makes few assumptions about circumstances are all supported. A brief overview of the method and its formulation for perfect conductors and dielectrics is

followed by a discussion of its extension to include lossy dielectrics. This discussion puts the method in comparison to other time-domain techniques that are suitable for wave propagation and antenna modelling [5]. It is almost perfectly suited for representing sources, such as antennas, and computing wave propagation in the presence of different mediums. It makes few assumptions about the size or frequency of the source waveform because it is a time domain approach. The material properties, such as lossy media and ideal conductors, as well as a range of interface circumstances are all supported. In order for the antenna to radiate effectively, impedance matching techniques are used to ensure that the antenna receives the most power possible. The process of antenna impedance matching entails matching the feedline's characteristic impedance to the input impedance at the end of the antenna. Often, filter circuits are utilised because they can be set up to deliver a specified impedance at the required transmission frequency [8]. For the rectangular microstrip antenna, a precise and effective numerical model is proposed. It focuses on a transmission-line model that has the following three key advantages over earlier versions of the model full consideration of the mutual radiative coupling between equivalent slots; implicit consideration of the effect of side slots on radiation conductance; and the introduction of straightforward analytic expressions for all significant model parameters. The new idea is applied, for instance, to antennas with a single microstrip feed line. The input impedance of a rectangular antenna is demonstrated to be in excellent accord with the results of relevant experimental and theoretical studies. A square antenna is used to illustrate the improvements over earlier transmission-line models [7]. Microstrip antennas are often designed using one of three fundamental techniques: transmission line, cavity, or full-wave model. For this reason, the transmission line model was selected as the antenna's operation mode.

The bandwidth and resonant frequency of a Hilbert curve antenna decrease as the iteration count rises. The antenna gets smaller and its bandwidth gets smaller by using fractal geometry and various feeding methods. These curves are straightforward and self-similar, and they also have the extra characteristic of roughly filling a plane. The method can be used to any antenna element and array design, but we'll restrict ourselves to simple linear arrays of dipoles so we can compare analytical results [6]. This method produced a resonant antenna with a size less than $\lambda/10$ and performance similar to a dipole with a resonant length close to $\lambda/2$. Using the Hilbert curve, the antenna achieves a very small electrical size. The antenna provides great gain, efficiency, and a wide bandwidth. The fractal iteration order can be increased to drastically lower the antenna's resonance frequency. As a result, our plan seeks to get around one of the major problems with antenna engineering when it comes to tiny antennas. In antenna design, Hilbert curve geometry has been set up to generate many resonances while also reducing the size of the antenna. When the iteration stage is increased, the Hilbert curve's overall length grows while the overall geometry's space remains constant. The culmination of all of these infinite iterations is the final Hilbert curve. Therefore, Hilbert curve was used to improve the antenna's efficiency by 90% due to its sharp edges.

In order for the antenna to radiate effectively, impedance matching techniques are used to ensure that the antenna receives the most power possible. The best power transfer and hence the best efficiency are attained by making sure that a precise impedance match is obtained. This is significant since antenna performance is so vital when using radio communications systems or broadcast transmitters. Although certain antenna systems use a high amount of SWR in a twin or open wire feeder, a strong match with the transmitter is ultimately required to enable the best power transfer. Therefore, impedance matching was ensured to be done. To determine the differences between the characteristics of each tissue layer, the antenna will be evaluated under two conditions that is with and without fetus models [15].

II. RELATED WORK

The final fetal monitoring system's design is straightforward, affordable, and transportable and uses UWB technology. These antennas are suitable for use in wireless body area networks and wireless body-centric communication and have been fabricated and tested for S11 and VSWR using a network analyzer [10]. By using metamaterials, gain enhancement and size reduction can be achieved for wireless C-band applications [11]. The basic design was made and several optimization steps were done according to the result. At last, a box which is considered to be as uterus with its permittivity and permeability values is given and the antenna design which is done will be placed inside it. Optimizations were done with the grounding methods and then the proposed antenna design was finalized after observing the simulated results. The performance of the patch antenna is being improved as the major objective of the optimization process. Certain physical antenna characteristics and those that are connected to them were continuously adjusted to match the necessary antenna output in order to accomplish this purpose. By suitably creating a woman's abdominal phantom with phantom structural details and inserting the specified antenna inside of it, the optimization was carried out. Many significant RF electronic transducer parameters, including impedance matching, bandwidth, radiation pattern, and gain, were painstakingly recorded during the numerical analysis and later assessed. Moreover, the fetus' size was established. The fetal monitoring system's ultimate design is straightforward, affordable, and transportable and uses UWB technology. The antenna was created and put to the test, showing stable performance [14].

ISM and UWB bands were not present simultaneously with single antenna access in the wearable biomedical antenna that was previously available. As a result of the antenna's input strength having to be increased because they were both present individually, there is a chance that the human body could be exposed to radiation that is not wanted. Due of the mismatched impedance at high frequencies, they were unable to cooperate. We have thereby balanced the losses and impedance. We have also made use of Hilbert curve to design our antenna which is the first time it is being used in a wearable material, It helps with high gain Transformation and it helps reducing unwanted

emission of radiation. For the antenna to operate simultaneously, a matched impedance was obtained using the Hilbert curve and a match terminal. For the antenna to operate simultaneously, a matched impedance was obtained using a Hilbert curve and a match terminal. By implementing the Hilbert curve in the patch after several optimization in the length and width of the ground plane [9], finalizing it as our proposed antenna design and also by using Med Cotton or dry cotton as our substrate material to reduce the unwanted radiation, an optimized microstrip patch antenna was created with a working frequency of 4.2 GHz. A brand-new wideband harmonic suppression microstrip patch antenna achieved by a dual-point feeding technique can to regulate higher-order harmonics and excite the fundamental mode. Simulated and measured results validate the feeding approach [13].

III. PROPOSED METHODOLOGY

Several Optimizations were done with the Hilbert curve antenna design on a rectangular patch, the proposed antenna is finalized after several optimization methods on the ground plane to get a perfectly working antenna in desired frequency range and a low SAR value. In Table. 1 the comparison of those methods are shown.

TABLE I. COMPARISON OF GROUNDING METHODS

Parameters	No Optimization	Parallel Quarter wave	Quarter wave
Working Frequency (GHz)	4.3	4.2	4.2
Return Loss (dB)	-21.9100	-17.4753	-26.5772
Gain (dB)	Max: -2.5 Min: -25.0	Max: 4.1 Min: -12.5	Max: 3.5 Min: -26
Directivity (dB)	Max: 7.1 Min: -20.2	Max: 4.3 Min: -12.4	Max: 3.8 Min: 25.7

By comparing the results from the table, we concluded the antenna with quarter wave transmission line model as our proposed antenna. The UWB antenna is designed and simulated in Ansys HFSS software. The top view of the proposed antenna is shown in Fig. 1. The dimensions of the substrate is (46 x 53' x 1.6) mm and (46 x 13.4) mm for the ground.

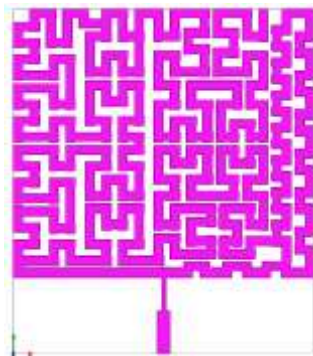


Fig. 1. Top view of the antenna.

Place the antenna on the uterus phantom with and without a fetus for analysis purposes. By using HFSS software to create a fake phantom, we have performed an artificial analysis.

An Artificial Uterus was created and given qualities such as permittivity (8.00E+1) and dielectric conductivity (s/m) (9.42E-1) to the uterus box model. The return loss is analyzed by placing the antenna close to the uterus. A cylindrical model that is considered to be a fetus of 1.1mm size was created and placed inside the uterus model. In Fig. 2 it shows the antenna which has been placed on the abdomen part of human phantom model.

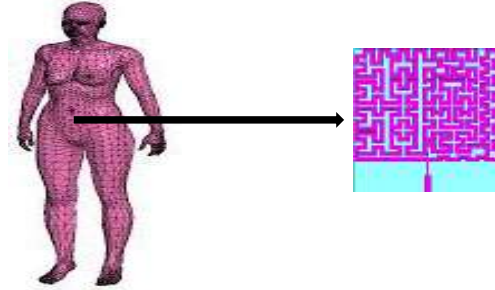


Fig. 2. Antenna being placed in human phantom model abdomen

IV. RESULTS AND DISCUSSIONS

A. Calculating Fetus Size

The return loss indicates how much power is being lost and does not return as reflection. Hence, it indicates how well the matching is between the transmitter and antenna. For an ideal antenna, the expected return loss should be below -10 dB. The antenna was analyzed by placing it near the uterus phantom in each case with just the antenna, phantom without fetus and phantom with fetus. The return loss noticeably had different values in each case and the graph of all three cases are combinedly shown in Fig. 3.

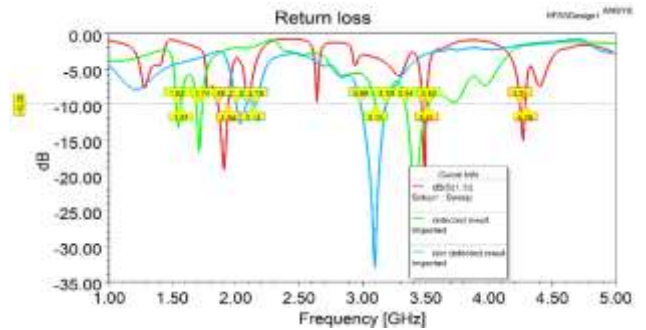


Fig. 3. Return loss of antenna with phantom, without phantom, with defect.

$$2.99 - 3.10 = 0.11 \text{ GHz} \quad (1)$$

$$(0.11 \times 100) \div 10 = 1.1 \text{ cm} \quad (2)$$

In Equation (1) the values for the calculation were taken with the return loss difference between defected and not defected antenna (with and without fetus). In Equation (2) it was determined that the defected place or the fetus size is 1.1 cm.

TABLE II. WITH AND WITHOUT PHANTOM OBSERVATION

Observations	S11 Parameter (dB)	VSWR	Gain (dB)	SAR (W/Kg)
With Phantom	-33.1447	1.6015	Max: -3.6 Min:-24.7	0.52
Without Phantom (free space Propagation)	-26.5772	1.0987	Max: 3.5 Min:-26.0	0.47

From the above Table. 2, the changes in the values of Return loss, VSWR, Gain, SAR have been observed for the antenna with phantom and without phantom.

B. SAR

Specific absorption rate (SAR) describes how much energy is absorbed by the human body when exposed to a radio frequency electromagnetic field per unit mass. In India, a device's maximum SAR is 1.6 W/kg. The proposed antenna design's SAR is found to be a very minimal of 0.47 W/kg. As a result, the patient won't experience any negative effects from our suggested antenna.

C. VSWR

The measure of how effectually RF power is transmitted from the source of power is the voltage standing wave ratio, or VSWR. The antenna has a VSWR unit value if the given signal is entirely transmitted by it without any reflection. The antenna will have no impedance mismatch if the VSWR value ranges between 0 and 1. Equation (3) gives the VSWR formula to find its numerical value. Here, the numerical value of VSWR in (4) and (5) matches perfectly with its graph value, which is 1.0984. Therefore, there's almost no impedance mismatch present. The graphical VSWR value of the proposed antenna is displayed in Fig. 4 below.

$$VSWR = \left| \frac{1+r}{1-r} \right| \quad (3)$$

$$VSWR(ISM) = \left| \frac{1+0.0468}{1-0.0468} \right| = 1.0984 \quad (4)$$

$$VSWR(UWB) = \left| \frac{1+0.0468}{1-0.0468} \right| = 1.0984 \quad (5)$$

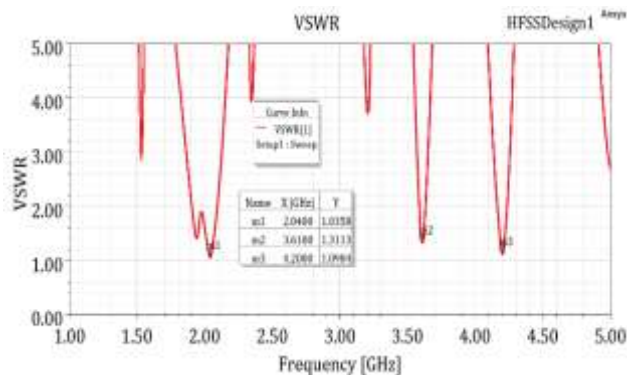


Fig. 4. VSWR graph of proposed antenna

D. Gain and Directivity

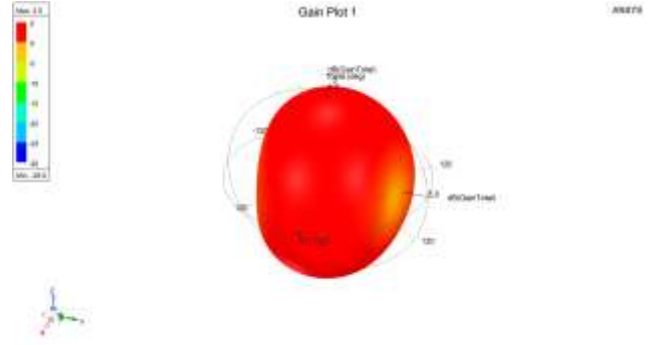


Fig. 5. Gain.

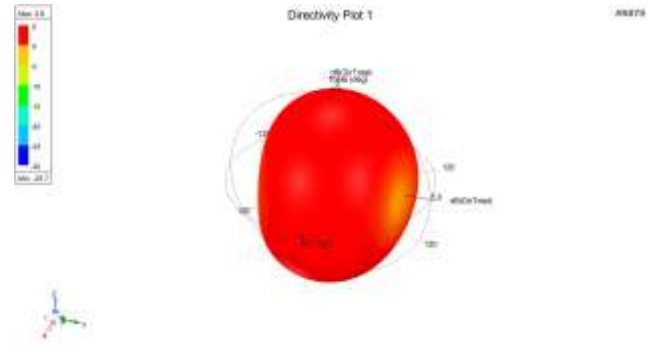


Fig. 6. Directivity.

From Fig. 5 and Fig. 6, The gain value was found to be min -26.0, max 3.5 and the directivity value was found to be min -25.7, max 3.8 for the antenna without fetus.

V. CONCLUSION

When the antenna is brought near the human abdomen there is a considerable change that occurs in the antenna's performance. The resonant frequency and return loss values get changed the antenna is kept near the high permittivity structured human abdomen phantom model. With this output, we can conclude that the proposed antenna is working perfectly at 4.2 GHz frequency without any side effects to the patient. The ISM and UWB are in unit value since the graphical and numerical value of VSWR matches perfectly while having almost no impedance mismatch. The SAR value was found to be 0.47W/kg.

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