Detection of Brain Stroke Using Microstrip Slot Antenna

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Abstract: Stroke is one of the world's most serious health issue. A decrease of blood flow to a portion of the brain that results in brain tissue damage is termed as stroke in medical science. Blood clots and ruptured blood arteries in the brain are the main causes of strokes. A brain stroke can be categorized under ischemic stroke and hemorrhagic stroke. Existing approaches are noninvasive, but they are constrained by cost and reliability concerns. These diagnostic approaches are insufficient to detect stroke in human head. Hence, a microstrip slot antenna has been designed with stroke model and human head phantom model, and stroke is detected with the help of antenna. In 2.45GHz ISM band frequency range proposed antenna with circular edge slots and circular slot in the front plane and ground slotted plane has been designed.

A 3-D seven layer simulated head phantom model is designed and interfaced with the proposed antenna with and without stroke model. The stroke is detected by observing changes in antenna performance parameters viz. return loss, peak gain, radiation efficiency. Sphere shaped stroke is detected by observing variation in the antenna performance parameter.

The stroke detection is applied on the cylindrical phantom on the HFSS software. The result shows that the change in performance is experienced as the distance between the antenna and the head phantom changed. The value of peak gain and radiation efficiency decreases thus depicting the presence of stroke.

Keywords: Microstrip Slot Antenna, Brain Stroke, Head Phantom, HFSS,FR4 Substrate.

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1. Introduction

One of the biggest and most intricate organs in the human body is the brain. It consists of more than 100 billion nerves, which connect in trillions in a process known as synapses. A decrease of blood flow to a portion of the brain that results in brain tissue damage is termed as stroke in medical science. Blood clots and ruptured blood arteries in the brain are the main causes of strokes. Depending on which portion of the brain is injured and how long the brain is deprived of blood flow, a stroke may result in either temporary or permanent disability. Possible complications may include some of the complications like lack of muscle mobility or paralysis, may it be one side of the face or arm. Other difficulties like talking or swallowing difficulties, language skills including reading, writing, and speaking or interpreting speech.

According to the data, stroke is the second most common cause of mortality and the third most common cause of disability. Many researchers have worked in the field of science especially for diagnosing Breast cancer or detecting Brain stroke which led to advancement in the field of medicine. Patients who receive treatment for strokes sooner have a better chance of recovering. Significant efforts have been suffused over the years by the researchers in the diagnostic systems for stroke keeping in mind the necessity of accurately identifying and categorizing this kind of stroke within a few hours after the development of stroke symptoms. Both imaging and non-imaging modalities are used in the current brain stroke diagnosis methods. Many techniques like Computed Tomography (CT), Positron Emission Tomography (PET), and other traditional techniques which are used to detect brain strokes are present . Magnetic Resonance Imaging (MRI), Emission Tomography (EEG) and Magneto-Encephalography are all examples of electroencephalography. Different literary techniques Microwave imaging technology called Electromagnetic Impedance Tomography (EMIT) is used to diagnose brain strokes. . EMIT imaging is an alternative screening technique that can be applied inside or by the patient's bedside. An ambulance is needed for point of care detection and early screening. The antenna is a crucial part of the EMIT-based brain stroke detection technique.

A technique for stroke detection based on the comparison of reflection phases that required obtaining scattered signals from the antennas and analyzing them to minimize the system's load comes into action namely Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) classification algorithms which assess the performance of the antenna and discover precise classification for stroke detection.

The simulation software used in the proposed work is High Frequency Structure Software(HFSS). It is a finite element based method (FEM). HFSS is capable of designing and simulating printed circuit boards, IC packages, antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, and connectors. Developing high-frequency, high-speed electronics for communication networks, satellites, and internet-of-things (IoT) gadgets involves the usage of Ansys HFSS software. It can calculate various parameters like return loss, reflection coefficient, VSWR, SAR, Peak Gain, Radiation Pattern, etc.

2. Microstrip Antenna

It is widely known that high frequency electromagnetic fields can harm biological tissues, including human tissue, by altering molecular structure and raising body temperature. It is discovered that frequencies between 1 GHz and 3 GHz are more practical for analysis. Wideband antenna with compact size is essential for making the detecting system portable and compact**.** Rahman et al.[13] proposed an inkjet printed slotted disc monopole antenna for early brain stroke detection. It was designed, produced, and studied at 2.45 GHz ISM band on a PET substrate. This PET substrate had a loss tangent of 0.022 and a relative permittivity of 3.2. CPW feed, or coplanar waveguide method is employed. With the CPW feeding, a SMA (Sub-miniature version A) connector was attached using conductive paste to line. The dimensions here were taken into consideration by further evaluating and minimizing the dimensions henceforth trying to achieve higher gain and enhancement in bandwidth for further analysis.

In this research work, a compact slotted microstrip antenna is to be designed and printed on a FR4 substrate for early detection of brain stroke with the help of HFSS Simulation Software. Four major components make up a microstrip antenna: a patch, a dielectric substrate, a ground plane, and a feeding port. On one side of a thin, non-conducting layer of a dielectric substrate, there is a patch, and the ground plane is situated on the other side. Typically, the same metal is used to make the patch and ground plane. The design of microstrip antennas can be done on a wide range of substrates. The size of the microstrip antenna is reduced when a dielectric substrate with a greater dielectric constant is chosen whereas a thin substrate with dielectric constant larger provide tightly bound fields hence making the antenna less efficient.

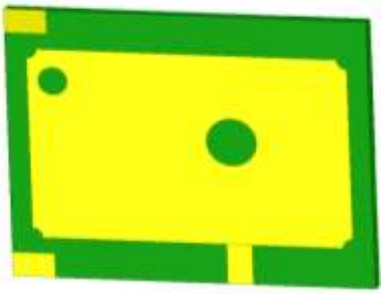
One or more of MSA's major benefits comprises of lighter weight, smaller size, low profile, lower cost, etc. which makes it affordable and has engaged researchers working in present wireless communication. Microstrip antennas have some significant operational drawbacks, such as low efficiency, low power, high Q, poor scan performance, spurious feed radiation, poor polarization purity and a very small frequency bandwidth, which is typically a fraction of percent which can be fixed with different methods. Microstrip antennas are often referred to as patch antenna. As for this research, the rectangular patch antenna should have some length and width and FR4 substrate will have some fixed thickness, which will decide the characteristics of the antenna. Then, the results will be calculated and simulation will take place. Based on results, changes will be made.

Mathematical calculations of the dimensions of the antenna for simulation in 2.45GHz operating frequency is done using Transmission Line Model(TLM). In order to attain maximized efficiency and space slotting in the ground and the patch can be done.

A 3D model of the antenna is created by HFSS. HFSS provides a wide range of geometry for designing various patterns. Models can be driven models, driven terminals, or eigen models, among other types. A driven model is used to calculate the S parameter for passive and high frequency structures. The driven terminal is used to determine the terminal-based S parameter for ports on single-conductor transmission lines and multi-conductor transmission lines.

3. Proposed Antenna

In order to reduce the size and make an affordable antenna which is capable of providing with the desired outcomes an antenna with FR4 substrate is presented in this research work. The proposed antenna for the applications is designed and simulated as shown in the Figure mentioned below. The proposed antenna exhibits the desired ISM band frequency range required for detection of Brain stroke in a human head. Two rectangular patches are added to the substrate on the left side of the antenna in order to fulfill the desired output as shown in the Figure 3.1(a) which shows the final antenna model. Figure 3.1(b) represents the backend of the proposed antenna that is the slotting performed on the antenna ground to fetch results.



(a)

(b)

Figure 3.1: Proposed antenna (a) front end of the proposed antenna(b) back end of the proposed antenna

Table 3.1 carries the parameters of the proposed antenna which is modified and the final design has been taken for further simulations and output calculations. The slotting performed in the antenna design has sizes as well which have been discussed in the section above.

Table 3.1: Parameters of the proposed antenna

Parameters	Length(mm)	Width(mm)
Substrate	34	43
Patch	24	38
Feed	3	5
Ground	34	43

The return loss of the modified antenna can be seen in the Figure 3.2 where at 2.46GHz that comes under ISM band frequency range -23.6 dB is simulated. The simulated S11 plot further shows a dip at 4GHz of -23.8 dB along with -24db dip at 5.73 GHz which is again an ISM band frequency range for wireless communication and provides a bandwidth of 430MHz.

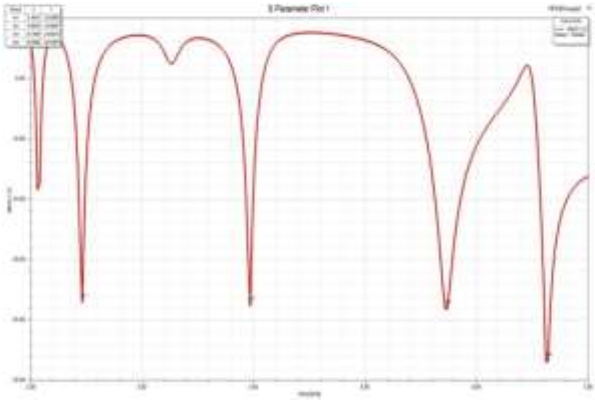


Figure3.2: Return loss S11 of the proposed antenna

The radiation pattern received for the proposed antenna is directed in the upward direction more as compared to other sides and provides a 2.2 dB gain which falls under the application of the desired antenna thus making it feasible for usage for the purpose of healthcare as can be seen in Figure 3.3.

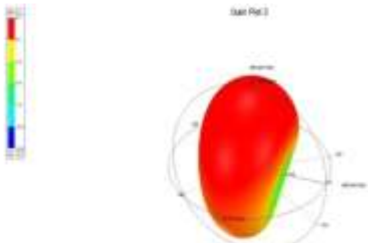


Figure 3.3: Radiation pattern of the proposed antenna

Peak gain of the proposed antenna can also be seen in Figure 3.4 which gives a range from 2 GHz till 4GHz where the antenna gives 10 fold increase in the signal level as a result.

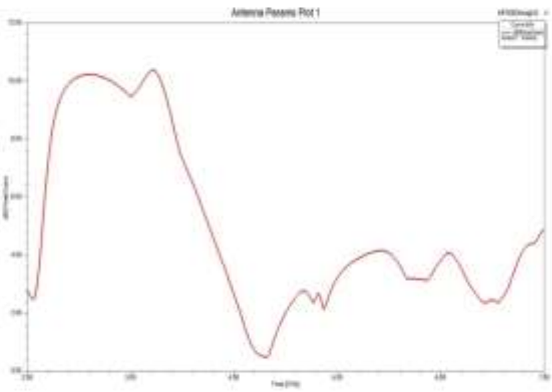


Figure 3.4: Peak gain of the proposed antenna

3.1 Antenna mounted on body

Antenna performance is evaluated by placing it on a human body when it is brought close to a human being. Through simulations, different antenna characteristics, including S11, gain, and radiation efficiency, are estimated and compared for both on- and off-body conditions.

In HFSS, a seven -layer model of the human body is constructed. The seven layers, which have roughly the same thickness as a human body, are dry skin, fat, and muscle, skull, dura, cerebero spinal fluid, brain. Each layer's conductivity and permittivity, as well as its individual thickness, are given below in Table 3.2. The reference is taken from the reference model taken for the proposed antenna from [**13**].

Table 3.2: Seven- layer human head phantom

Frequency (MHz)	Head Layers	Thickness (mm)	Permittivity (ε)	Conductivity (S/m^2)
2450	Dry Skin	2	38.006660	1.464073
2450	Fat	2	5.280096	0.104517
2450	Muscle	4	53.573540	1.810395
2450	Skull	10	14.965101	0.599694
2450	Dura	1	42.035004	1.668706
2450	Cerebro Spinal Fluid	2	66.243279	3.457850
2450	Brain	10	42.538925	1.511336
2450	Stroke Model	Radius = 15	58.263756	2.544997

A representation of the human head phantom according to the contents of the table 3.2 mentioned above are designed in HFSS Software and can be seen in Figure 3.5 where all the layers of human head are provided with the permittivity and conductivity as mentioned. The outer layer with skin color is the dry skin followed by a blue colored layer called fat. The sequence is followed as mentioned in the table. The cylindrical representation of the human head is provided below.

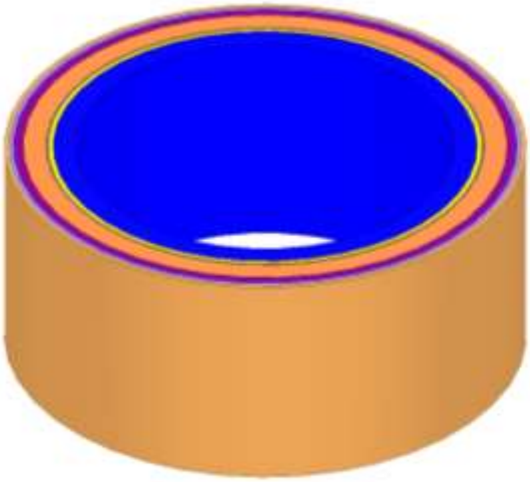


Figure 3.5 Seven Layered Head Phantom

Due to the lossy nature of the human body, any antenna placed close to it will undergo frequency shift, loss, and decreased radiation efficiency. This is because the majority of radiation that is present close to the human body gets absorbed by the body.

Near the human body, absorption above a particular amount is prohibited and is thought to be harmful, causing illnesses like cancer.

Antenna is put close to the human body at a certain distance, and simulations are run for the antenna's properties like gain and radiation efficiency.

An antenna's distance from its body is measured as ‘d’. In the first scenario, the distance between the antenna and the seven -layer head phantom without stroke present is assumed to be I0 mm.

Antenna placement is 10mm away from the seven-layer body, the model depicted in figure 3.6.

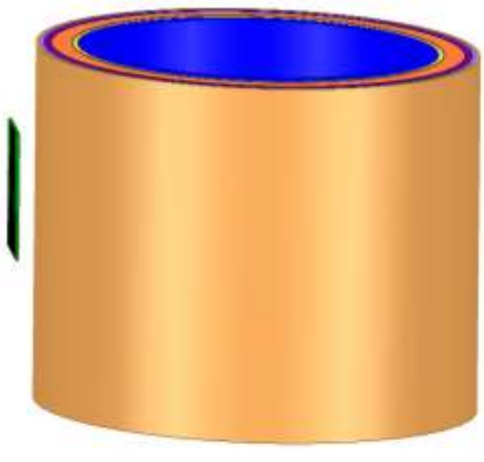


Figure 3.6: Antenna placed near Human head Phantom

After simulation of the antenna with the head phantom results are obtained which depicts return loss at 2.427GHz as -26.4 dB which shows a shift in the frequency if compared to the antenna in free space where return loss was obtained at 2.46 GHz. Similarly return loss below -10dB is also observed at 3.88GHz and 6.66GHz which is -12dB and -31 dB respectively. Though the bandwidth achieved in these frequency ranges is similar to that of the antenna in free space. This can be seen in Figure3.7.

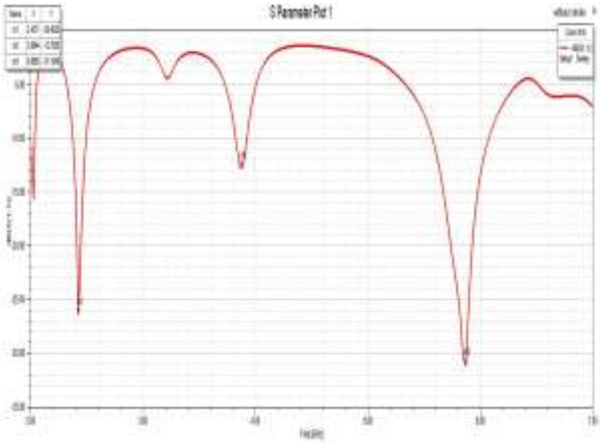


Figure 3.7: Return loss S11(dB) of antenna placed with head phantom

Radiation pattern of the antenna when placed with the head model without stroke achieved is 2.882 dB and is omni-directional in nature. This portrays an increase in the gain when compared to the antenna in free space.

Figure 3.8 represents a stroke model where stroke is placed inside the phantom model.

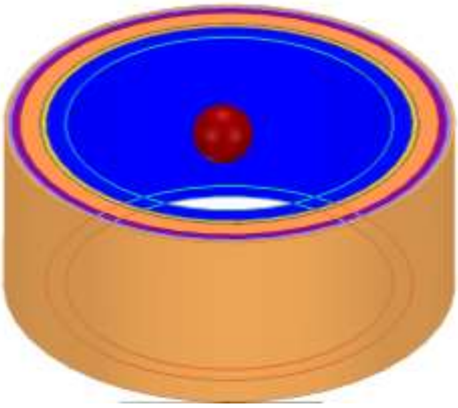


Figure 3.8: Stroke Model

Figure 3.9 represents the proposed antenna placed near stroke model inside the phantom model. The simulation takes place and parameters like return loss , radiation pattern, peak gain, radiation efficiency and bandwidth is taken.

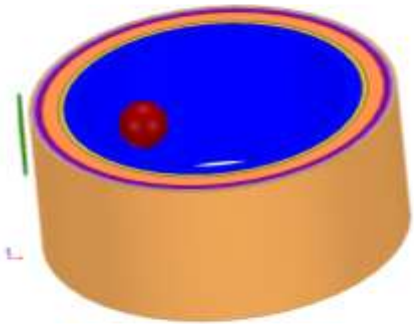


Figure 3.9: Antenna placed around Stroke Model

It is visible that antenna when kept at a distance of 10mm from the stroke model is in good accordance with the return loss of the antenna in free space from Figure 3.34 where return loss parameter is produced after simulation for antenna with stroke model. A slight shift in the frequency can be seen where at 2.47GHz -20dB is achieved. Similarly, at 3.9Ghz -31dB can be seen and at 5.7db -21dB is achieved. The bandwidth received for these ranges is same as that f the antenna in free space. Thus making it an asset for the application of the proposed antenna.

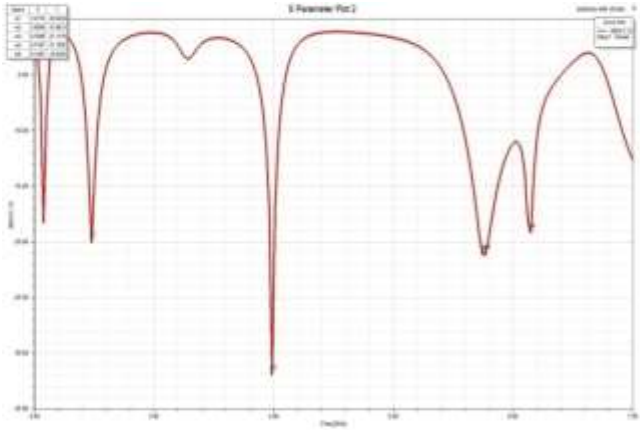


Figure 3.10: Return loss S11(dB) for antenna with stroke model

A radiation pattern of 3dB is achieved when antenna is run with the stroke model. This can be seen in Figure 3.11

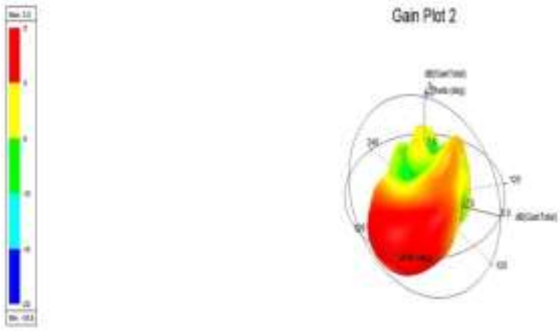
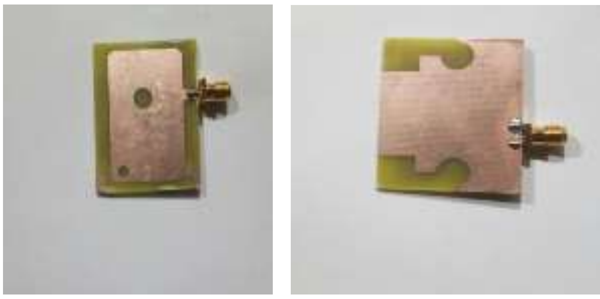


Figure 3.11: Radiation pattern for antenna with stroke model

3.2 Fabrication of Antenna

The antenna's fabrication comes after its design. The fabrication goal is achieved using a PCB designing machine. The creation of a dxf file is the initial stage. The next action is to make a gerber file. There are four steps that must be carried out in the proper order after the gerber file has been created correctly. Establishing the drill position is the first step in figuring out the antenna's perimeter. In this process, the sheet from which the antenna will be produced is drilled with four holes that correspond to the antenna's four corners. The next step is surface inspect, where any imperfections on the substrate's top copper surface are looked for. Once this phase is over, the following process is engraving, which removes any remaining copper while etching the actual patch design and ground on the substrate. Soldering the SMA connection to the antenna is the subsequent step in the process. Figure 3.12 represents the Fabricated antenna where patch is etched at FR4 substrate. Ground and patch have copper as materials with a practical height of nearly 0.001mm. the figure shows the soldered portion near the feedline where SMA connector is connected.



(b)

(b)

Figure 3.12: Fabrication of the proposed antenna (a) Front end of the proposed antenna (b) Back end of the proposed antenna

3.3 VNA testing of Antenna

Testing of the antenna's different properties, such as the reflection coefficient, bandwidth, and VSWR, is done using a vector network analyzer. They are applied in high frequency systems. Scalar network analyzers and vector network analyzers are the two different types of network analyzers. While a vector network analyzer monitors both magnitude and phase, a scalar network analyzer just measures magnitude.

The antenna is linked to the VNA, and the antenna's bandwidth is evaluated for both on and off the body conditions. First, the measurement calibration of the vector network analyzer is required. The open short load method is utilized for VNA calibration. And to eliminate any offset present in the VNA, the antenna is attached to the open port, short port, and load port one by one. After a successful calibration, the antenna is linked to the VNA, and as shown in Figure 3.38, measurements are made for bandwidth and other parameters in both on- and off-body conditions.

Figure 3.38: VNA testing of the antenna in free space

4. Result and Discussion

This section of the paper gives a brief description about the architectural design and Materials and techniques for the development of a small, microstrip antenna for brain stroke detection. By using HFSS, the proposed antenna has been simulated. A detailed comparison of the simulated and measured outcomes has been covered in this chapter. Here are charts of the S11 return loss (dB), VSWR, peak gain, radiation efficiency, and radiation patterns in 2 to 7 GHz frequency range.

The reference work and the proposed work are also discussed. Multipurpose of on and off body antenna and compactness are crucial components of the proposed work. The results of the simulation and measurement are in good agreement with one another.

4.1 Measured results of the proposed Antenna placed off body

VNA is used to measure the reflection

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coefficient, S11 (dB), and VSWR. Prior to calibrating the port, the frequency range has been established in the VNA to account for environmental and other losses. The findings have been measured after the antenna has been linked to the VNA via optical cable. The measured return loss S11 (dB) value for the suggested antenna is in the frequency range of 2.475GHz, 3.973GHz and 5.838GHz with a bandwidth of 120 MHz, 120 MHz and 420Mhz respectively is shown in Figure 4.1.

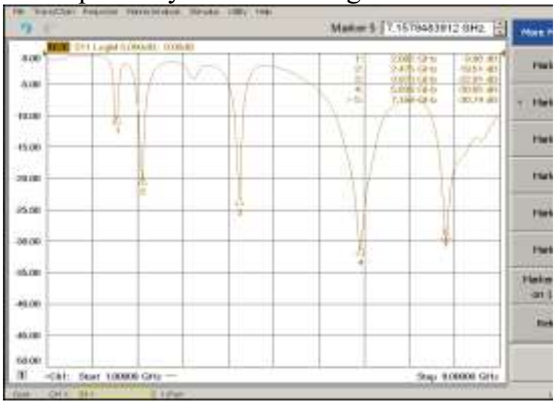

Fig.4.1: Measured return loss S11(dB) of proposed antenna using VNA

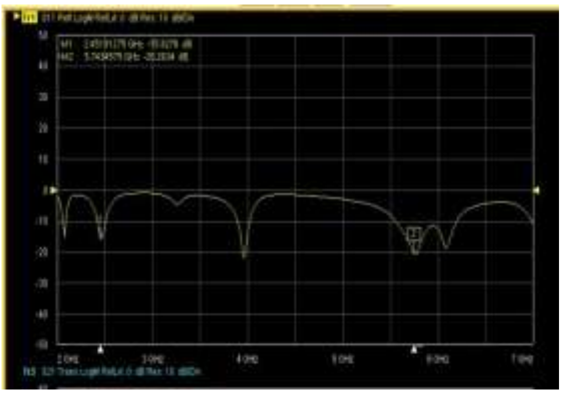

Fig.4.2: Measured return loss S11(dB) of proposed antenna in free space

4.2 Comparison of Simulated antenna vs Measured antenna placed off body

The comparison of the return loss S11(dB) <-10dB findings from simulation and measurement is depicted in Fig. 4.3. As can be seen in Figure 4.3, the simulated results are in good agreement with the measured results at 2.45 GHz frequency band and at 4 GHz.

A slight shift in the frequency range can be seen in the figure for 5.8GHz ISM but overall the antenna is resonating in close approximation with respect to both the results. . The simulated impedance bandwidth exhibits a shift in operating frequency as a result of minor fabrication defects.

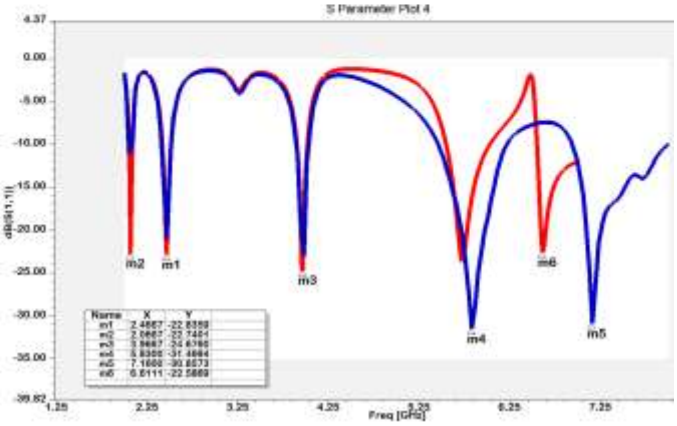

Figure 4.3: Comparison between Simulated and Measured Return loss S11(dB) of antenna in free space

In Figure 4.3, red line depicts the simulated return loss of the antenna in free space and blue line depicts measured return loss of antenna in free space.

The simulated bandwidth of 120 MHz, 120 MHz and 430 MHz is observed in the frequency range 2 - 7 GHz for return loss S11, (dB) <-10 dB which is demonstrated in Figure 4.3

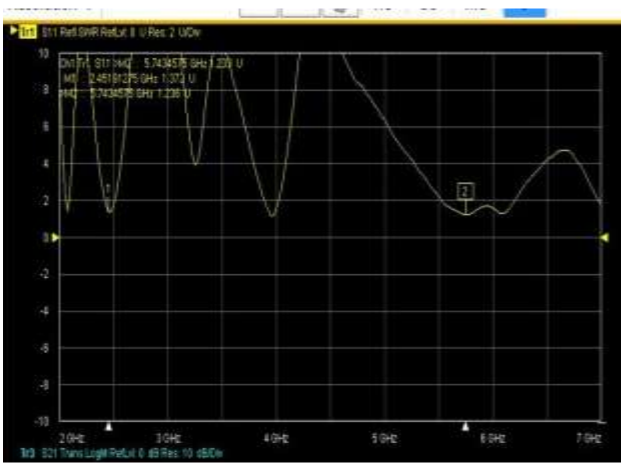

Figure 4.4: Measured VSWR of the proposed antenna using VNA

4.3 Radiation Efficiency of proposed antenna in free space

Radiation efficiency is defined as the total power radiated by the antenna to the total power that the antenna can accept when connected to the transmitter. The following portion displays the simulated peak radiation efficiency of the antenna which can be seen in Figure 4.5. as can be seen, the antenna shows great amount of efficiency from 2 GHz to 4 GHz which proves to be a benefit for the applications it is designed for.

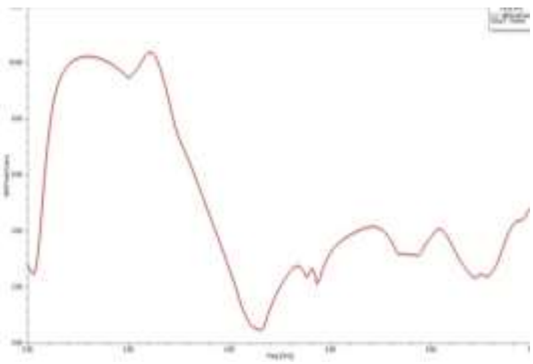

Figure 4.5: Radiation efficiency of proposed antenna

4.4 Measured results of Antenna on body testing

The proposed antenna when kept in free space and connected to the VNA displayed return loss S11 equivalent to -15dB at 2.451GHz and return loss S11 equivalent to -20dB at at 5.736 GHz. These results are in good accordance with the results fetched for on- body placement of the antenna as shown in the figures below. Figure 4.6 is in very good accordance with the results when antenna is in free space showing practically a very little deflection of 0.07 GHz for the frequency range of 2 to 7 GHz.

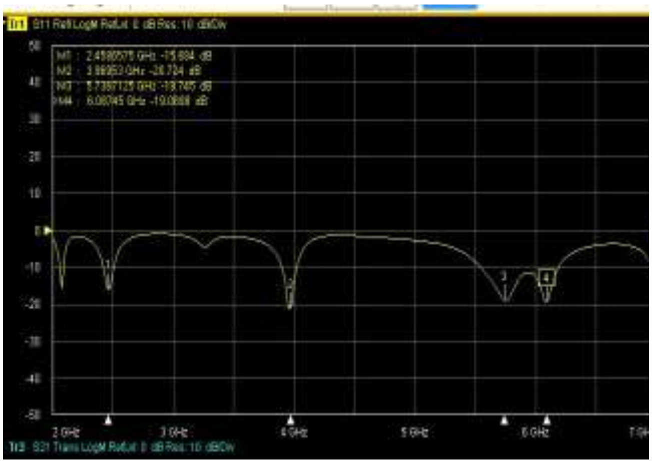

Figure 4.6: Measured return loss S11 (dB) of proposed antenna when human head is at a distance of 10mm from the antenna

4.6 Radiation efficiency and Peak gain of antenna with stroke and without stroke

A comparison of Radiation efficiency of the two models that is antenna without stroke model and antenna with stroke model is also shown after simulation where it can be seen in Figure 4.13, the radiation efficiency of the antenna without stroke model is low i.e. below 50% whereas the stroke model has a radiation efficiency above 50% as shown in Figure. This works as the ground to prove that the proposed antenna is capable of detecting the stroke in a human brain as it lies in the ISM band frequency range i.e. 2.45GHz.

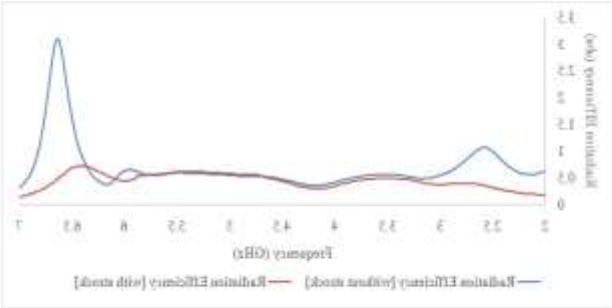

Figure 4.13: Comparison of radiation efficiency of antenna with stroke and without stroke

5. Conclusion

In the area of wireless applications, the Microstrip slot antennas has been researched .The suggested antenna uses edge slots in the patch along with circular slots inside the patch, offset in feed to achieve the ISM band required for stroke detection. To increase gain and enhance bandwidth of the proposed antenna, a combination of two rectangular slots combined with a circular slot in the ground is used on both the sides.

The proposed antenna is carefully constructed on the PCB prototype machine. In the proposed antenna, microstrip line feed technique is used whose on body measured results and simulated results are in good accordance with each other hence justifying one another. Following are the conclusions derived from the experimentation of the proposed antenna.

- The antenna is resonating in two ISM bands i.e. 2.45GHz and 5.8 GHz, henceforth providing applications both in healthcare domain as well in wireless domain.
- Bandwidth above 120 MHz and 420MHz for both the ISM bands respectively has been achieved.
- The proposed antenna also resonates in the frequency range of 4GHz achieving a bandwidth above 100MHz which is again helpful in military applications thus making it a beneficial model.
- The human head phantom model is simulated with and without stroke using microstrip slot antenna. The distance between the antenna and the phantom is 10mm.

- The designed antenna is applied for early brain stroke detection after being subjected to various parameters. The antenna is used for detecting stroke in the brain, considering the size and the bandwidth of the antenna but it is also applicable for wireless applications and applications like radio frequency in military operations.

6. Future Scope

Future potential of this work for the researcher can be used as

- The proposed antenna has a gain that can be further increased by incorporating different substrates.
- The change in feeding technique may further enhance the bandwidth and improve functioning of the antenna.
- The size can further be made compact and results in accordance can be fetched.
- To verify stroke detection methods on real life patients with an actual setup.

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