An analysis of Miniaturized and Engergy Enhanced Microstrip Patch Antenna For Biomedical application

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Abstract—
Antennas play a pivotal role in modern wireless communication, facilitating connections between devices through wireless mediums by transmitting and receiving radio waves. In healthcare and biomedicine, Body-Centric Wireless Communication (BCWC) has gained prominence due to advancements in miniaturized sensors, wearable electronics, and biomedical technologies. This has revolutionized the field by enabling continuous disease monitoring and treatment. Our focus is on modeling and characterizing microstrip patch antennas to identify dilated tissues within the human body. What sets our approach apart is our use of antenna modeling instead of traditional biomedical sensors for detecting these tissues. In this project we have attained the values for directivity, gain, VSWR, S-parameters and SAR values as 6.3339 dB, 2.757 dB, 1.012, -43.89 dB and 1.4572 W/Kg respectively. These results are attained in the frequency range of 2 to 2.4 GHz at the resonant frequency of 2.11 GHz. The different S-parameters for the different tissue mesh like skin, fat and tumor can help in the detection of dilated tissue.

Keywords—biomedical, BCWC, VSWR, SAR, directivity, gain

I. Introduction

The microstrip patch antennas have recently found their dominance in the antenna industry. In this particular attempt our main objective is to try out the abilities of the microstrip patch antenna in the biomedical field. Specifically, to detect the dilated tissue in human body testing on different microstrip patch configurations on the software-based body elements like muscle and skin elements.

The intended client for this expedition is mainly the biomedical industry and researchers who wish to work in this particular domain. As these days the sensor based dilated tissue testing is practiced, but the major issues relating this concept is the cost and complexity involved in the design of small scaled sensor design for biomedical purposes. To deal with this issue we propose the antenna-based detection system of the dilated tissue in human body that can be less complex in manufacturing compared to sensor-based counterpart. Also, detection of the tissue type by the proposed method we can estimate the amount of cancer developed and tumor stages in future.

II. EXSISTING WORK

The existing paper focuses on the design and testing of a microstrip antenna tailored for medical applications, specifically in the detection of various tissues and breast tumors. It comprehensively reviews the fundamental principles and characteristics of microstrip antennas, elucidating the design intricacies for four distinct types: rectangular, circular, U-slot, and rectangular with gap. The study investigates the electrical properties of different tissues, emphasizing conductivity and permittivity, and their impact on microwave interactions. Through simulations and experiments using HFSS software and the LPKF machine, the research highlights the effectiveness of the rectangular patch antenna with a gap in differentiating tissues, validated by Vector Network Analyzer (VNA) tests with biological tissues like beef and pork. The results indicate that the antenna discerns tissues based on their microwave absorption, particularly influenced by water content and quantity. The paper concludes by asserting the microstrip antenna's potential for detecting diverse tissues, specifically advocating its applicability in breast cancer diagnosis. The proposal for future work includes animal experiments to further validate the antenna's feasibility and accuracy in vivo.

The novel clover-shaped slot antenna designed for biomedical applications, particularly wireless communication with biomedical devices. Fabricated on an alumina ceramic substrate, the antenna features a coplanar waveguide (CPW) feed. The paper thoroughly covers design parameters, dimensions, and an equivalent circuit model based on transmission line theory. Expressions for input impedance, reflection coefficient, VSWR, return loss, and bandwidth are derived. Simulated and measured results demonstrate favorable characteristics, including a 72% size reduction, 180 MHz broader bandwidth, near-omnidirectional pattern, and -6 dBi gain. Comparative analysis with other implantable antennas highlights the proposed design's superior performance. Circular polarization is verified through measurements of co-polar and cross-polar components. The paper concludes that the antenna is well-suited for biomedical applications, offering advancements in biotelemetry and biomedical therapy. Overall, the paper is well-organized, providing a clear and concise description of the antenna design and its contributions to the field of implantable antennas.

III. DESIGN PROBLEM FORMULATION

The major area where this paper finds to make a difference is the approach to sense the dilated tissue in human body. As, of the current technology piezoelectric sensors based or chemical sensor-based models are used as sensing devices to detect the presence of dilated or inflammatory tissue. The major issue in this technique is that the sensor fabrication is complex and costly. To make this process easier and simpler the idea proposes the use of microstrip patch antenna instead of MEMS based sensor. Although some work is done in this domain, this paper attempted to improve the previous results on the design of the U-slot microstrip patch antenna tested on the Phantom.

IV. METHODOLOGY AND DESIGN PRESCRIPTION

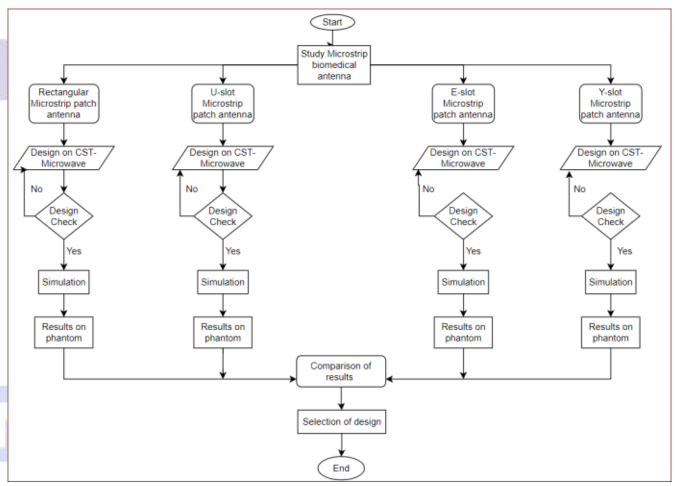


Fig. 1. Methodology

The methodology/approach to the problem starts by the study of microstrip patch antennas and literature related to the problem statement. After that the design of antennas was made on the CST microwave design suite. After the designing of the rectangular microstrip antenna, U-slot microstrip antenna, E-slot microstrip antenna and Y-slot microstrip antenna. Performed the design checking and errors in the design process. Rectified and corrected the design and re-simulated the corrected design. Introduced phantom layers for Skin, Fat and Tumor and its radiation effect on these layers. Compared the 3 design results based on different properties and parameters and selected the best fit. Further, the S-parameters, VSWR, Farfield gain and directivity and SAR values were calculated for the best fit design.

This antenna was made in the form of English letter 'U' and using the central curved line as the extended line for feeding the input signal. The substrate used was cotton based material with specifications as shown in Table 1.

TABLE I. COTTON SUBSTRATE INFORMATION

Cotton Substrate Information		
S.No.	Parameter	Value
1	Type	Normal
2	Epsilon	1.6
3	Electric Conductance	0.036 S/m
4	Mu	1
5	Density	1540 Kg/m^3
6	Thermal Conductivity	0.3 K/W/m

V. RESULT AND DISCUSSIONS

This paper discuss about the designed microstrip patch antenna for biomedical application using the CST Microwave Design Suite. As per the prescribed methodology in the previous portion the designing of all the 4 microstrip patches was completed and the results of all the antennas were recorded.

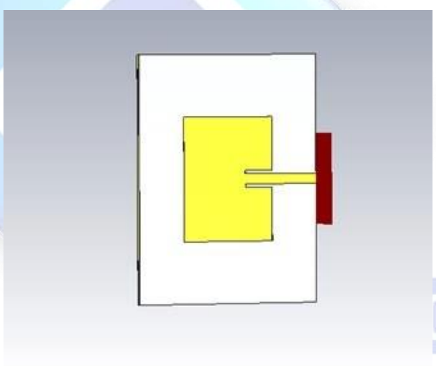


Fig. 2. Rectangular patch microstrip antenna

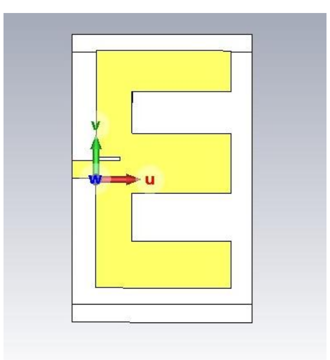


Fig. 3. E-slot patch microstrip antenna

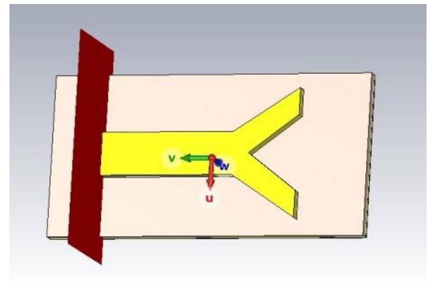


Fig. 4. Y-slot patch microstrip antenna

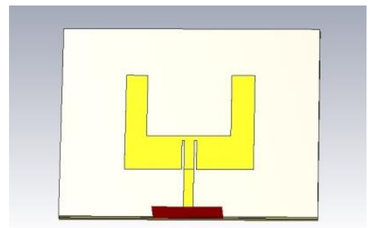


Fig. 5. U-slot patch microstrip antenna

Then finally the major work was done on the U-slot microstrip patch antenna for further analysis because of their best result of directivity and gain among all other designed antennas at the resonant frequency of 2.11 GHz. The results so encountered are enlisted in the following tables and figures. In this section, the results of the best design of U-slot antenna is only discussed with their results.

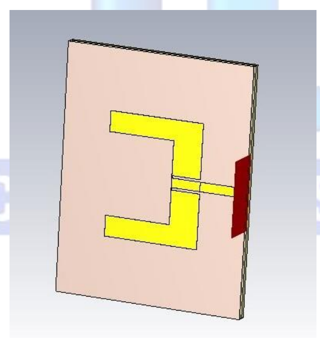


Fig. 6. U-slot antenna with modified cotton based substrate

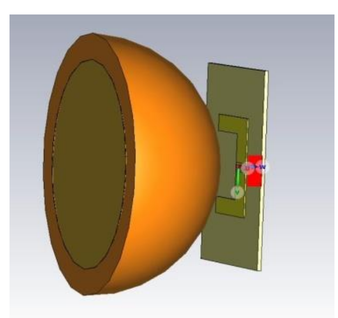


Fig. 7. Antenna design with the Phamton (breast) with Skin, fat and Tumor

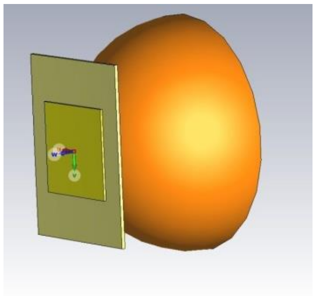
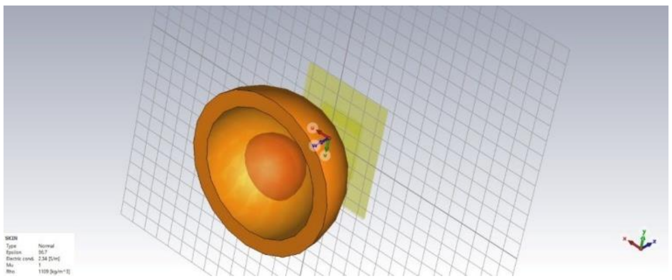
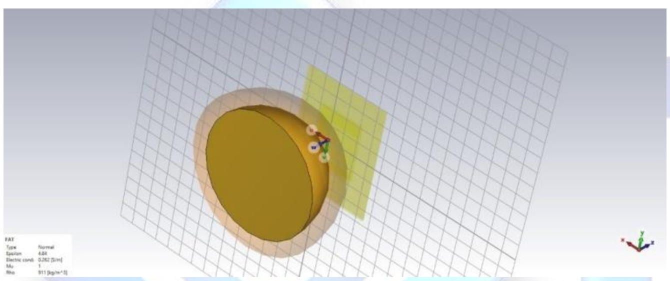


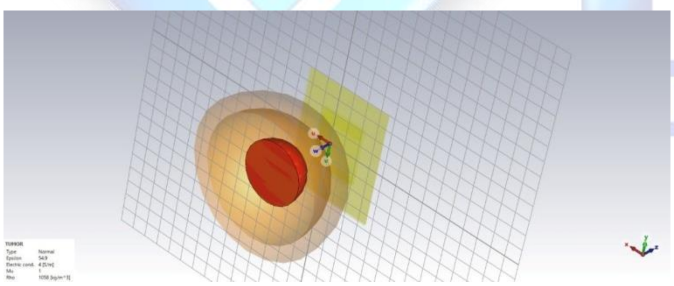
Fig. 8. Modified ground for better results in antenna design



(a)



(b)



(c)

Fig. 9. Phamton (a) Skin (b) Fat (c) Tumor

The results are calculated for the S- parameters which contained the values for all the meshes for substrate, skin, fat and tumor in the design. The values so attained are -43.89 dB, -28.53 dB, -24.54 dB, -23.28 dB respectively.

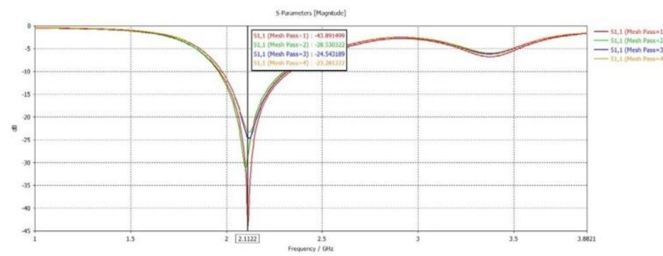


Fig. 10. S-parameters at 2.11 GHz

The VSWR attained after the simulation valued 1.012 at the resonant frequency of 2.11 GHz.

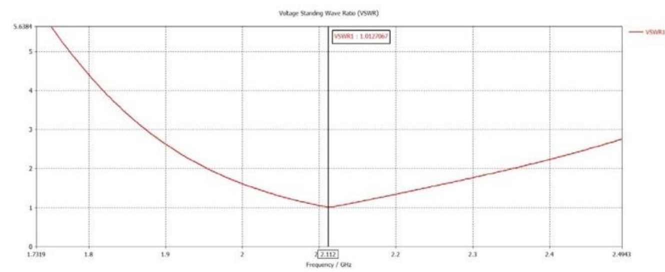
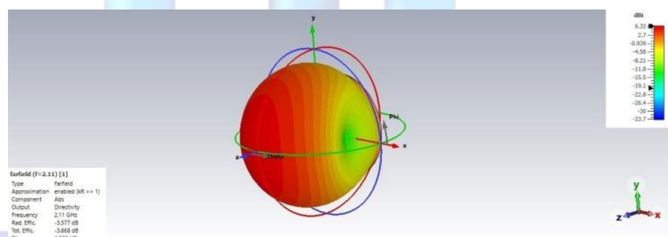
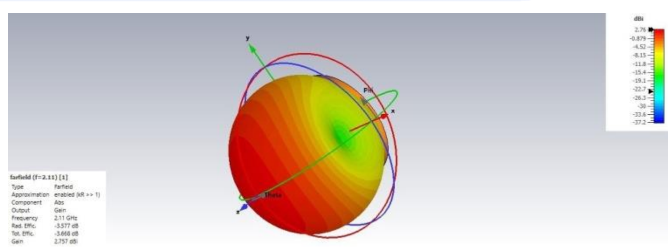


Fig. 11. VSWR at 2.11 GHz

The farfield results that include the Directivity and Gain were calculated to the values of 6.333 dBi and 2.757 dBi respectively.



(a)



(b)

Fig. 12. Farfield results (a) Directivity (b) Gain

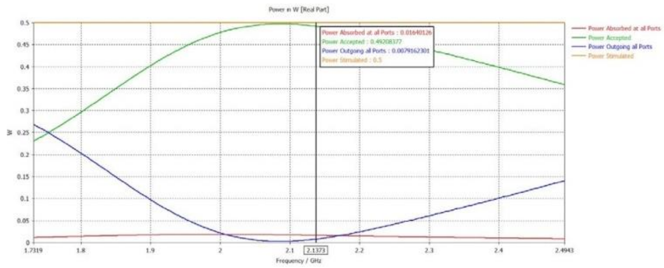


Fig. 13. Power plot

The post-simulation was completed to get the SAR results, that were calculated for 1g at 2.11 GHz which were calculated to the value of 1.4572 W/Kg.

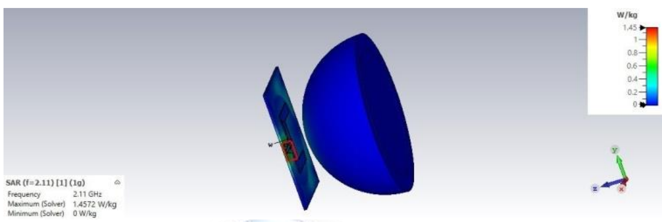


Fig. 14. SAR results at 2.11 GHz

The results of the full simulation and post-simulation are tabulated below:

TABLE II. COMPARISION OF RESULTS AND VALUES

Parameters	**Values (Base Paper)**	**Parameters**	**Values (As per our results)**
S-parameter (in dB at 2.45 GHz)	Less than -10 dB	S- Parameter (in dB at 2.11 GHz) i. Substrate ii. Skin iii. Fat iv. Tumor	i. -43.89 ii. -28.53 iii. -24.54 iv. -23.28
VSWR	Good VSWR (value not mentioned)	VSWR	1.012
Farfield Directivity (in dBi)	Not mentioned	Farfield Directivity (in dBi)	6.333
Farfield Gain (in dBi)	-6	Farfield Gain (in dBi)	2.755
SAR (in W/Kg at 2.11GHz)	Not mentioned	SAR (in W/Kg at 2.11GHz)	1.4572

VI. CONCLUSION

In conclusion, antenna design emerges as a burgeoning technology, exhibiting immense potential in facilitating wireless connectivity for body sensor nodes. Its attributes of being safe, non-invasive, and highly sensitive position it as a valuable tool for medical diagnosis. Additionally, the simplicity, cost-effectiveness, and minimally invasive nature of antenna-based techniques make them promising for applications such as thermal ablations. This project underscores the transformative role of antenna design in advancing medical technologies, offering solutions that are both innovative and accessible for enhancing healthcare practices. A comprehensive study is done that not only identifies key issues on the critical design challenges but also presents effective and meticulously crafted solutions that leverage the capabilities of advanced antenna technologies and a well-defined solution is incorporated with antenna technology is described. This theoretical research is presented has explored the intricacies of microstrip patch antennas with a focus on mitigating inherent disadvantages. By strategically introducing slots into the patch antenna geometries, significant improvements have been achieved in terms of gain, bandwidth, and VSWR, rendering the antenna more suitable for application-specific purposes. The designed U-Slot Microstrip patch antenna, implemented and analyzed using CST Microwave Studio and High-Frequency Structure Simulator, has exhibited notable enhancements over conventional microstrip antennas. The simulated results demonstrate a substantial increase in bandwidth, accompanied by reduced VSWR, resulting in an overall improvement in antenna efficiency.

With a bandwidth of 2 – 2.2 GHz and impressive return loss, directivity, and gain, the antenna's versatility is underscored by its applicability across a 1 to 5 GHz frequency range. The attained gain of 2.757 dBi underscores its efficacy in practical applications. Particularly, the antenna finds promising applications in the fields of bio-medical technology and wearable devices, with potential adaptations for use in defense, healthcare, and other diverse sectors. The project's findings not only contribute to the advancement of antenna technology but also open doors to innovative solutions in various domains.

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