Coaxial Feed Ultra-Wideband Microstrip Antenna for Medical Applications

Muhammad Asfar Saeed
Faculty of engineering
University of Greenwich
London, United Kingdom
M.A.Saeed@greenwich.ac.uk

Muneeb Ahmad
IT Convergence Engineering
Kumoh National Institute of Technology
Gumi, South Korea
muneeb.ahmad@kumoh.ac.kr

Augustine Nwajana
Faculty of engineering
University of Greenwich
London, United Kingdom
a.o.nwajana@greenwich.ac.uk

Masood Ur Rehman
James Watt School of Engineering
University of Glasgow
Glasgow, G128QQ
United Kingdom

Muhammad Ammar Sohaib
Faculty of Engineering
Qurtuba University of Science and technology
Dera Ismail Khan, Pakistan
mast2126@gmail.com

Ateeqa Naseer
University of Management and Technology, Lahore
ateeqa.naseer@umt.edu.pk

***Abstract*— In this article, an ultra-wideband antenna has been presented for medical applications which have a resonant frequency of 10.35GHz and offers a bandwidth of 1400MHz with a return loss of -19db. The presented antenna is low-cost lightweight and can easily be integrated inside the circuit. As this antenna is designed for medical applications its size is compact and is fed utilizing a coaxial feeding technique which is especially plentiful for operative radiotherapy applications. The designed antenna is rectangular and covers an overall size of 24x12mm with a thickness of 1mm. The proposed antenna is designed using CST studio as a simulation tool, the extracted results of important parameters like return loss, surface current, reference impedance, and far-field have achieved remarkable results which are illustrated in the article. which makes it suitable for radiotherapy. A high epsilon valued ε r = 4.8, tan δ = 0.02 substrate GT-008 has been employed as a dielectric material whereas copper is being used for the ground and radiating patches. The performance of the antenna in the X-band is satisfactory which makes it suitable for radiotherapy.**

Keywords—UWB, microstrip patch antenna, Coaxial feed, GT-008, X-band, mm-Waves, CST,

I. INTRODUCTION

Wearable wireless applications are emerging with the recent growth in 5G, advent of IoT and smart technologies has also made wearable sensors a highly desirable candidate in medical communication society [1]. Antenna plays a vital role in bodywear communication however the general requirements of the antenna suitable for wearable communication are high gain, directivity, and radiation pattern, wearable antennas dimensions are necessary to be compact and easy in design to enable freedom of mobility, ease of integration and minimum antenna-body coupling [2]. As the tumour patients are gradually expanding with the expansion of the modern world, the researcher provided a variety of solutions to detect tumors tissues inside the body [3] The most preferred solutions contain microstrip patch antennas as they can be designed in different shapes and sizes. Its inherent feature of reducing the complexity [4-5].

According to the UK research center, millions of cases were diagnosed around the world and most of the cases are reported in females. Early detection of the tumors cell can increase the patient situation to be improved [6]. In literature several methods and techniques have been invented like X-rays, mammography, ultrasound, and magnetic resonance imaging (MRI), all of these have some drawbacks which led the researcher to think of a microwave imaging technique, as it has the potential to overcome the issues reported in the literature. It also offers remote monitoring of the patient [7].

Microwave imaging using a microstrip patch antenna is feasible for a patient of all ages because of its easy scanning and less harmful effects, the human body is exposed to the EM radiations with the assistance of a microstrip patch antenna, reflection caused by the inhomogeneous nature of normal and cancerous cells which is received and mapped to get the electrical and magnetic property distribution and geometrical constraints of shape, size, and location of scanned body parts [8]. Previous studies show different antennas have been designed and presented [9-13]. These antennas offer complex geometry which is difficult to design in bulks and the size of the device preferred is to be compact as these antennas are for medical applications. These loopholes necessitate further improvements and research of a novel efficient microstrip patch antenna. In this article a compact microstrip patch antenna is proposed which is lightweight, low cost, and can easily be integrated. The antenna is designed using a GT-008 as a substrate material to maintain a lightweight and compact structure for medical applications.

Following the introduction, the article comprises four sections. In the next section II, the antenna modelling, and development is explained whereas in the III section antenna performance is analysed describing the simulated results of

CST microwave studio. The last section IV draws the conclusion.

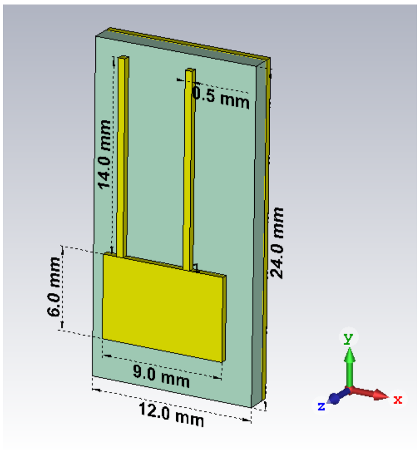

Fig. 1. Geometry of the antenna

II. MODELLING AND DEVELOPMENT OF THE ANTENNA

The design of the suggested antenna is displayed in the figure 1 below which explicts the radiating elements placed above the substrate whereas the lower portion is covered with the ground layer. The dielectric material GT-008 is employed as a substrate material which is having an epsilon ε value of 4.8 and a tangent loss of 0.02, the dielectric material is sandwiched between the ground layer and radiating elements whereas the feeding port is inserted between the ground and substrate. The antenna covers an overall size of 24x12mm which proves the antenna is compact as compared to antennas presented in the literature. The designed antenna is excited by a coaxial feeding port which is inserted into the horizontal rectangular radiating patch and the major contribution of the ultra-wideband is accumulated by the horizontal radiating element. The two vertical rectangular patches are attached to the horizontal rectangular patch, proposed UWB antenna has achieved the required resonant frequency of 10.3GHz with a bandwidth of 1400MHz which is very abundant for operative radiotherapy applications. the dimensions of the designed antenna are listed in the table below, the front view of the designed antenna is shown in figure 1 which contains the labeled dimension. Table 1 expresses the comparison of the designed antenna with the previously presented work in literature. The intended structure of the antenna is developed using CST Microwave Studio® [14].

III. SIMULATED RESULTS ANALYSIS

The accomplishment of antenna is evaluated utilizing simulated graphs of S-parameters, reference impedance, distribution of current, Gain of the antenna, and radiation pattern both in E-plan & H-plan.

A. *Reflection coefficient*

The designed antenna has achieved -19dB return loss at the resonant frequency of 10.53GHz, antenna has notched bandwidth over the range 10.500GHz to 10.64Ghz in the X-band. The antenna offers a bandwidth of 1400MHz at the resonant frequency moreover it has been verified to support the operations within the frequency range for medical applications. The simulated return loss graph is shown in the figure 2 which verifies the antenna is resonating at the required resonant frequency in X-band.

B. *Current Distribution*

The current distribution of the designed antenna is shown in the figure 3 below which illustrates the antenna current is distributed over the radiating patches and most of the current is coming from the feeding port. The feeding port is connected to the horizontal radiating patch, its contribution is maximal as compared to the vertical radiating patches.

C. *Impedance matching*

The designed antenna is fed using a coaxial feeding port, as this can easily be integrated. Moreover, the antenna is designed for medical applications which require a compact device and freedom of mobility, coaxial feed makes it effortless to wear. The transmission line is perfectly matched, and all the current is directly approaching the radiating patches with minimal losses, it is evident from the simulated results shown in figure 4 below that the feeding port is perfectly matched at 50 Ω

D. *Radiation Pattern*

The simulated three-dimensional radiation graph of the intended antenna is displayed in fig 5, while the two-dimensional radiation design is observable in fig 6. It is obvious from the polar plot that it is offering excellent coverage. In the E-plane antenna operation is Omnidirectional whereas in H-plane it is having some nulls. The main lobe magnitude is directed towards the 11° with a 3-dB angular width of 66.3°. The intended resonator has minimal side lobes of -6.2dB. The overall antenna offers good coverage at all the angles.

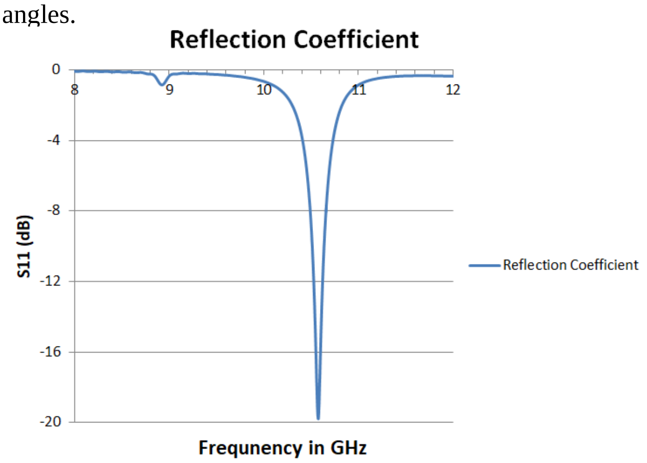

Fig. 2. Simulated reflection coefficient response

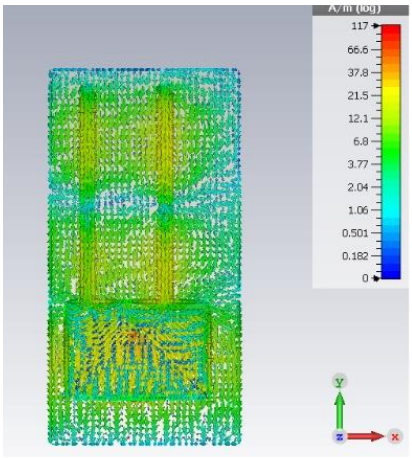

Fig. 3. current distribution over the antenna

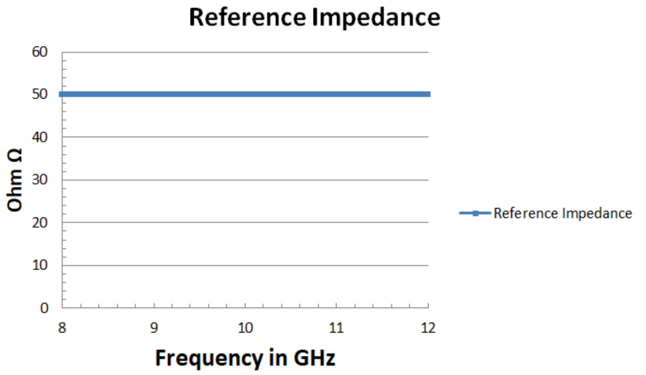

Fig. 4. Reference impedance of the designed antenna

E. Efficiency and Gain:

The gain and efficiency of the simulated resonator falls in the X-band are brilliant, it carries an acceptable Gain throughout this frequency range with a value of 6.37 dBi at the frequency of 10.53 GHz. The efficiency standards of the compact antenna are suitable with a value of 66% at the propagating frequency.

IV. CONCLUTION

An Ultra-wideband antenna has been modelled abundant for operative radiotherapy applications. The designed antenna is resonating at a frequency of 10.53GHz and is offering a –10dB impedance bandwidth of 1400MHz, it covers an overall size of 24x12mm, having a thickness of 1mm. GT-008 material is employed as a dielectric substrate which is positioned between the ground layer and radiating patch, copper is utilized as a conducting material to design the ground layer and radiating patches. The performance of the antenna is evident from the important simulated results shown above reflection coefficient, impedance matching, surface current, and far-field radiation pattern. These results validate that the antenna is suitable for medical applications as it offers a high gain of 6.37GHz along with a compact size that be easily integrated inside the circuit and offers freedom of mobility. The antenna structure and performance make it a suitable scanner for medical applications.

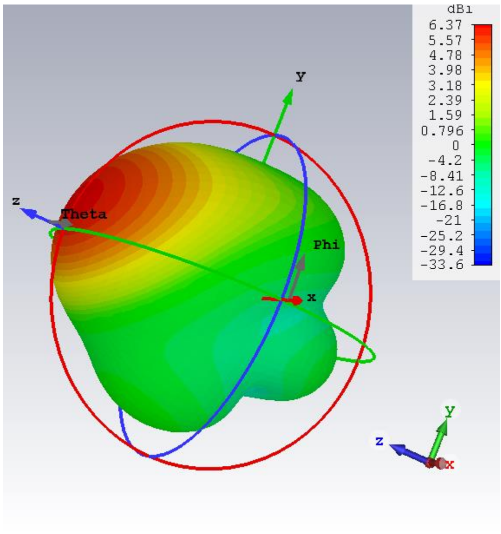

Fig. 5. 3D-radiation Pattern

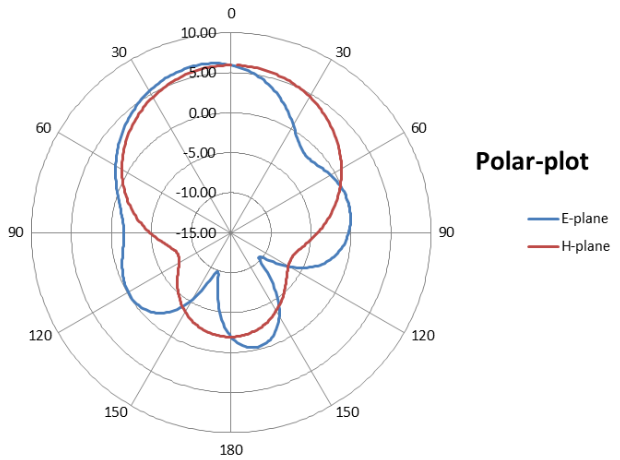

Fig. 6. E Ø=0 and H Ø=90 plane

TABLE I. COMPARISON OF THE DESIGNED ANTENNA WITH PREVIOUSLY COMPLETED WORK

Table Column Head				
Ref	***Size***	***Resonant frequency***	***Bandwidth***	***gain***
[1]	48x38mm	11	1.8GHz	3.65
[2]	30x20mm	10.53	1.8GHz	4.5
[3]	30x35mm	13.5	2.1GHz	3.2
[10]	40x40mm	8	2.4GHz	3.67
[5]	60x50mm	28	2.4GHz	
Proposed work	24x12mm	10.53	1.4 GHz	6.37

ACKNOWLEDGMENT

The article is accomplished within the guidance of Dr. Augustine and Dr. Masood-ur-Rehman. The author would like to acknowledge the Dr Ateeqa Naseer, University of Management technology Lahore for their support and encouragement. The research reported in this article is fully funded by the Department of computer science, school of systems and technology, University of Management and Technology Lahore, Pakistan.

REFERENCES

[1] M. A. Saeed, S. u. Rehman, M. u. Rehman, S. M. S. Zia, M. A. Sohaib and Z. A. Aqeel, "Multiband Stepped Impedance Resonator (SIR) Based Antenna for Future Wireless Applications," 2020 International Conference on UK-China Emerging Technologies (UCET), 2020, pp. 1-4, doi: 10.1109/UCET51115.2020.9205463.

[2] F. Zheng, W. Lou and Y. Han, "Simulation Design of Array Electromagnetic Vibrator Combined Ultra Wide Band Antenna," 2018 12th International Symposium on Antennas, Propagation and EM Theory (ISAPE), 2018, pp. 1-4, doi: 10.1109/ISAPE.2018.8634209.

[3] M. A. Saeed and M. Ur-Rehman, "Design of an LCP-based Antenna Array for 5G/B5G Wearable Applications," 2019 UK/ China Emerging Technologies (UCET), 2019, pp. 1-5, doi: 10.1109/UCET.2019.8881850

[4] O.P. Falade, M. Ur Rehman, Y. Gao, X. Chen and C.G. Parini, "Single Feed Stacked Patch Circular Polarized Antenna for Triple Band GPS Receivers", *IEEE Transaction on Antennas and Propagation*, Vol. 60, No. 10, pp. 4479-4484, 2012.

[5] K. Shafique, B.A. Khawaja, M.A. Tarar, B.M. Khan, M. Mustaqim, andA. Raza, "A Wearable Ultra-wideband Antenna for Wireless Body Area Networks", *Microwave and Optical Technology Letters*, Vol. 58, pp. 1710-1715, 2016.

[6] A.S. Alqadami, K.S. Bialkowski, A.T. Mobashsher, and A.M. Abbosh, "Wearable Electromagnetic Head Imaging System Using Flexible Wideband Antenna Array Based on Polymer Technology for Brain Stroke Diagnosis", *IEEE Transactions on Biomedical Circuits and Systems*, Vol. 13, pp. 124-134, 2018.

[7] P.B. Samal, P.J. Soh, and Z. Zakaria, "Compact Microstrip-Based Textile Antenna for 802.15.6 WBAN-UWB with Full Ground Plane," *International Journal of Antennas and Propagation*, Vol. 2019, Article ID 8283236, 2019.

[8] Y. Kuwahara, "Microwave Imaging for Early Breast Cancer Detection", in New Perspectives in Breast Imaging, A.M. Malik, IntechOpen, October 2017

[9] N. -W. Liu, L. Zhu, G. Fu and Y. Liu, "A Low Profile Shorted-Patch Antenna With Enhanced Bandwidth and Reduced H-Plane Cross-Polarization," in IEEE Transactions on Antennas and Propagation, vol. 66, no. 10, pp. 5602-5607, Oct. 2018, doi: 10.1109/TAP.2018.2855730.

[10] K. Li, M. Liu and H. Zhang, "An L-Band Ultra Wide-Band Vivaldi Antenna with Wide Beam Angle," 2020 13th UK-Europe-China Workshop on Millimetre-Waves and Terahertz Technologies (UCMMT), 2020, pp. 1-3, doi: 10.1109/UCMMT49983.2020.9296122.

[11] P. Meena and A. Garg, "A design of compact ultra-wide band antenna with dual band notched characteristics," 2017 International Conference on Information, Communication, Instrumentation and Control (ICICIC), 2017, pp. 1-5, doi: 10.1109/ICOMICON.2017.8279091.

[12] M. -J. Sun, N. -W. Liu, L. Zhu and G. Fu, "Wideband Microstrip Patch Antenna with Low RCS Using Multi-Mode Resonance," 2021 15th European Conference on Antennas and Propagation (EuCAP), 2021, pp. 1-3, doi: 10.23919/EuCAP51087.2021.9411319.

[13] M. A. Saeed, U. Ahmad, M. F. Ullah, Siddique, U. Ali and M. S. Qammar, "Rectangular Loop microstripAntenna for Wearable Applications," 2021 International Conference on Electrical, Communication, and Computer Engineering (ICECCE), 2021, pp. 1-4, doi: 10.1109/ICECCE52056.2021.9514220.

[14] CST-Microwave Studio, User's Manual, 2019.