

Design of Miniaturized Flexible Planar Antenna for Biomedical Application

Padmalatha N, Deepa T, Susila M

Abstract— The proposed design of a Microstrip patch antenna for biomedical applications is represented in this paper which is operating at 2.4GHz frequency range in ISM Band. The significant feature of the proposed antenna is to make it perfect for on-body biomedical applications. The Polyimide substrate which has dielectric constant (ϵ_r) of 3.5, thickness of 0.0508 mm and loss tangent 0.0027 is used. The proposed antenna dimension is 21 mm x 17 mm x 0.0508 mm length, width and height respectively. The radiating patch has the length and width is 20 mm and 16.5 mm respectively. The antenna is designed using 3D EM simulation tool and S11 response is of less than -10dB. The designed and developed antenna has been fabricated in the laboratory and measured using RF equipment for parameters like reflection coefficient, VSWR and input impedance. The experimental results agree well with simulation results which proves that it is a good candidate for Biomedical applications.

Keywords— Miniaturized antenna, ISM Band, Meandering, Reflection coefficient, Radiation pattern.

I. INTRODUCTION

Over a past decade wearable device has become a well know for many applications in the area of medical devices, and for several applications like system for emergency rescuing and various type of modern communications, entertainment and media etc. For the application scope of wearable, electronics devices, which can be bent flexed, reconfigured and is largely considerable[1]. Generally Microstrip patch antenna has important parameters to design the antenna. Here ISM band 2.4GHz is the one type of wireless fidelity. In recent year the maximum attention given to the microstrip patch antenna among the antenna community. Using a conventional microstrip fabrication technique we can construct a very simple microstrip patch antenna. Microstrip patch antennas consist of metallization of the patch on a grounded electric substrate. Fabrication of patch antenna is done by a substrate acts in-between ground plane which is in bottom of the substrate and patch which radiates on top of the substrate. In the antenna design, Microstrip patch antenna substrate act as main parts for all parameters and results. The proposed antenna composition is used polyimide material and it has dielectric constant of 3.5 is represented in these paper. The

Revised Manuscript Received on June 22, 2020.

* Correspondence Author

Padmalatha N* Department of Electronics and Communication Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamilnadu-padmalathanathan@gmail.com

Deepa T, Department of Electronics and Communication Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamilnadu-, deepaprabavathi@gmail.com

Susila M, Department of Telecommunication Engineering at SRM Institute of Science and Technology, Kattankulathur, TamilNadu, susilam@srmist.edu.in

ISM band represents Industrial, Scientific and Medical band. ISM band frequency 2.4 GHz widely used for several wireless communication systems. The miniaturization of antennas[1,2] can be done by an important techniques[3], some of the techniques for patch antenna are folding, patch modification, shorting and folding[4,5], Meandering(meander lines on patch)[6,7], DGS(defected ground structure)[8], substrates which has high dielectric constant values[9], fractal geometry method[10], using of metamaterial[11], modifications on the ground plane. Positives and negatives are evaluated for each techniques, That is, miniaturization will be done at the cost of other factors. Therefore it is chosen according to the application and requirements[13]. The physical dimension of the proposed radiating patch antenna operating at frequency at 2.4GHz is designed by the fundamental TM010 mode has an electrical length of $\sim \lambda_0/2$ which might be used for applications operating for ISM band[1,15]. The meander antenna was introduced in the year 1991, Now adays for miniaturization of antennas the meander antenna are used. The main objective of the miniaturization of radiating patch antenna is longer bending and shorter length and width using a straight line for overall patch antenna. The structure meander lines can be explain in simple version is zigzag lines (example-river)[3]. Generally, Microstrip patch antennas can achieve the compactness by using the meandering technique which shows the constructive technique for achieving compactness of the radiating patch. The meander line on the patch is achieved by inserting slits at the non radiating edges of the antenna's radiating patch[6,7].The radiating patch is designed by the meander slits which gives the results as, the radiating patch surface current density is lengthened, where as the antennas resonant frequency is lowered. That is the typical size of the antenna at a fixed operating frequency can be achieved meandering technique for radiating patch[3,12].

II. ANTENNA DESIGN

A. Design procedures for patch antenna

In design procedure Patch antenna design is done by the parameters width, length, height. The Microstrip patch antenna has substrate, patch, ground and feed line. The parameters given has substrate length(L_s), substrate width (W_s), substrate height (h), and the substrate permittivity. The patch length(L_g), patch width(W_g), patch height (h). The polyimide substrate which has dielectric constant value of $\epsilon_r = 3.5$ is used[16,17], thickness taken as 0.0508 mm and 0.027 of loss tangent and operated at 2.4GHz frequency range in ISM Band. Initially we have know about general antenna theory[22].

Design of Miniaturized Flexible Planar Antenna for Biomedical Application

Analytical formulation: To design a antenna the operating frequency and substrate material is selected initially, according to the given formulas below the parameters are calculated[13,14].

Patch width(W_g): The patch width(P_w)is calculated according to the equation given below, where, P_w = radiating patch width, C = speed of light, ϵ_r = constant value of dielectric substrate,

$$W = \frac{C}{2f_0} \sqrt{\frac{2}{\epsilon_r + 1}}$$

Effective refractive index: In the designing the patch antenna procedure, the important parameter is effective refractive index[5]. Fringing effect is generally a the radiations traveling towards the ground from the patch pass through air and some through the substrate. Both the air and the substrates have different dielectric values, therefore in order to account this we find the value of effective dielectric constant. The effective dielectric constant (ϵ_{reff}) is calculated using the following equation[13],

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

Patch length(L_g): Due to fringing, electrically the size of the antenna is increased by an amount of (ΔL). Therefore, the actual increase in length (ΔL) of the patch is to be calculated using the following equation,

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{reff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

Where 'h'= height or thickness of the substrate.

The length (L_g) of the radiating patch is calculated using the below mentioned equation,

$$L = \frac{C_0}{2f_r \sqrt{\epsilon_{reff}}} - 2\Delta L$$

Length (L_g) and width (W_g), the dimensions of a patch are known. The length and width of a substrate (L_s),(W_s) are calculated using the following equations,[13,14].

$$L_s = 6h + L_g$$

$$W_s = 6h + W_g$$

Ground plane is taken has half of the radiating patch mentioned in table1. Generally there are different methods for feeding techniques available for the microstrip patch antenna, for example, coaxial probe feed and feed line method. The proposed radiating patch antenna is designed by the coaxial probe method as shown in fig1.e

B. Antenna Design and Development

After the analytical calculation from the above equations of antenna we get the patch dimensions has $W_g=41$ mm, $L_g=33$ mm, and the substrate $W_s=42$ mm, $L_s=34$ mm. Though the physical size of the antenna is large for the Bio-medical application, aiming to reduce the size of the antenna into half, from the actual dimensions by $\lambda_0/2$ [1,15] and the proposed antenna shown in fig1.e has a dimensions of 21mm x 17mm x 0.0508mm length, width and height respectively. The shape of the patch can be represented by meander lines on the patch

and the length and width of the patch is 20.5mm and 16.5 mm respectively.

C. Table I Dimensions of proposed antenna

Dimension of proposed antenna		
Antenna elements	Parameter(mm)	Dimension s
Substrate	Length(L_s)	21mm
	Width(W_s)	17mm
	Height(h)	0.0508mm
Patch	Length(L_g)	20.5mm
	Width(W_g)	16.5mm
	Height(h)	0.035mm
Feed line	Width(W_f)	2.8mm
	length(L_f)	6mm

D. Evolution of Proposed Antenna

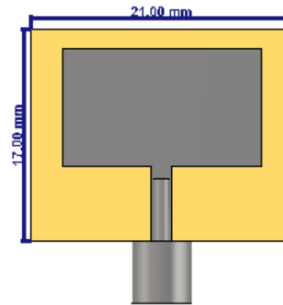


Fig1(a).Antenna1

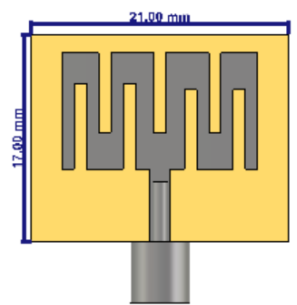


Fig1(b).Antenna 2

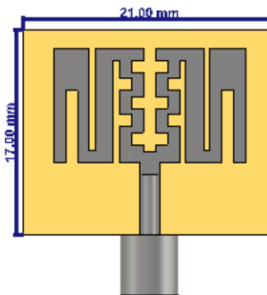


Fig1(c).Antenna 3

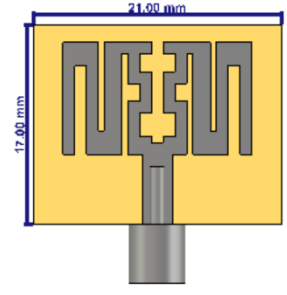


Fig1(d).Antenna 4

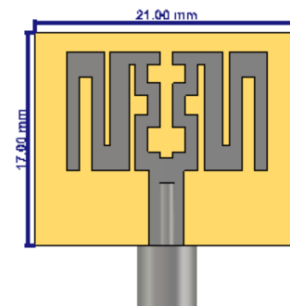


Fig1(e).Antenna5 The Proposed antenna

Table1 represents the proposed antenna dimensions. To achieve a proper design like meandering lines on the patch the proposed radiating patch antenna undergone some evolutions as shown in Fig1e. In order to achieve compactness, the patch dimensions is reduced as represented by antenna 1 in fig1(a). In fig1(b) the antenna 2 is structured with meander lines. In antenna 3 the notch are added on the middle of the radiating patch shown in fig1(c), therefore it improves the length of the current path and therefore resonant frequency is decreases. In antenna 4 the notches which is introduced on the middle of the radiating patch is reduced to 3 notches for resonant frequency and the feed width is increased as shown in the fig1(d) for preferable antenna s11 response and antenna gain. And finally in antenna 5 shown in fig1(e) the radiating patch feed width is increased into 0.2mm from fig1(d) that is antenna 4 for better return loss of 38dB.

III. RESULTS AND DISCUSSION

The proposed antenna shows better radiating output which is enhanced by the return loss achieved by the antenna. CST Microwave Studio[23] has been used for the simulation which provides a platform for antenna parameters measurements. The antenna parameters like return loss and bandwidth are realised successfully from the simulation results at operating frequency 2.4 GHz for biomedical applications. Generally antenna designers looks for innovative ways for improving the performance. This antenna resembles meander lines patch antenna with compactness. The miniaturized antenna has a low profile and an omnidirectional pattern. The return loss of the proposed antenna can cover the required bandwidth of the $S_{11} < -38$ dB at 2.4GHz shown in fig 2. The radiation pattern is shown in fig 3.

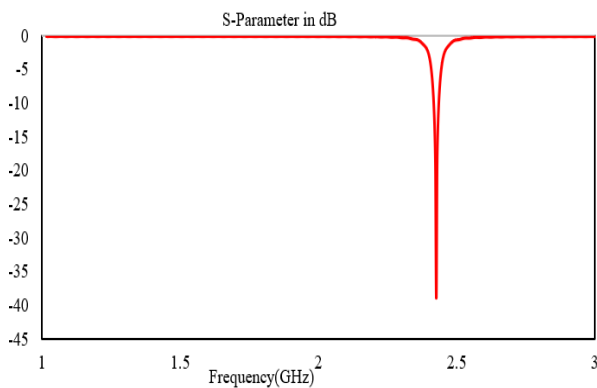


Fig2. S11 response for proposed antenna

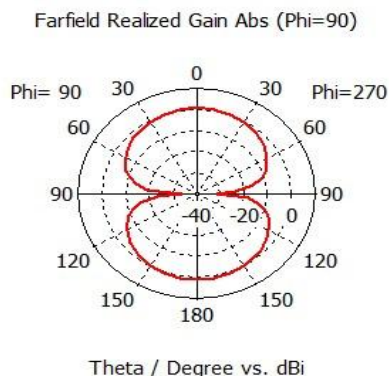


Fig3. Radiation Pattern for proposed antenna

The proposed antenna provides the better return loss of 38 dB and 17.8 MHz for lower frequency application[12], with the bandwidth efficiency of 74%, and the gain of the proposed patch antenna is 1.307dBi shown in fig 4. The S_{11} (return loss) for the evolution s11 of the proposed patch antenna is shown in fig 5.

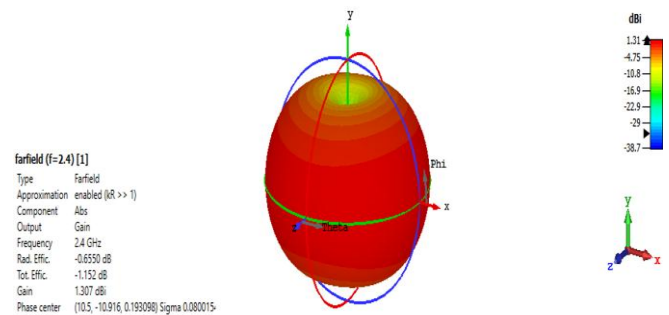


Fig4. 3D Far-field plot for proposed antenna

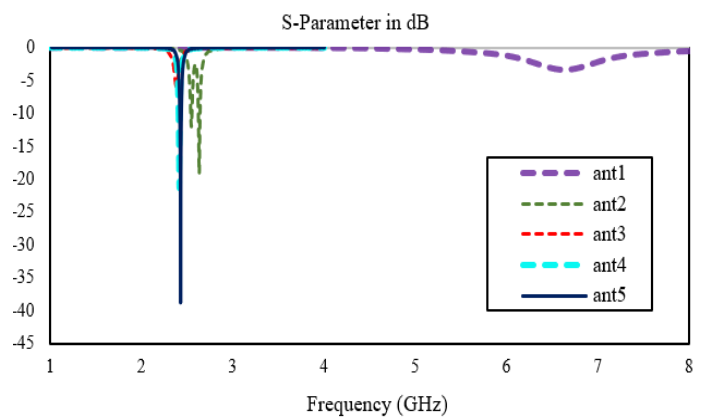


Fig5. Evolution process S11 of the proposed antenna

IV. CONCLUSION

In this work the proposed Microstrip patch antenna is miniaturised by $\lambda_0/2$ [1,15] for smaller dimensions and for the compact design, the meandering line technique is used on the patch is designed and the simulated results are provided by CST microwave studio[23] operating frequency 2.4 GHz for Biomedical applications. The proposed microstrip patch antenna design provides the parameters like return loss of 38dB and the bandwidth efficiency is 74% is realised successfully. This works concludes that the Microstrip patch antenna design enhance the performance by optimising the patch length and width. For on-body applications[19] the proposed antenna can be mainly used for medical data collections from patients and rescue operations[20].

REFERENCES

1. Ashyap, Adel YI, Zuhairiah Zainal Abidin, Samsul Haimi Dahlan, Huda A. Majid, A. M. A. Waddah, Muhammad Ramlee Kamarudin, George Adeyinka Oguntala, Raed A. Abd-Alhameed, and James M. Noras. "Inverted E-shaped wearable textile antenna for medical applications." *IEEE Access* 6 (2018): 35214-35222.
2. Ketavath, Kumar Naik, Dattatreya Gopi, and Sriram Sandhya Rani. "In-Vitro Test of Miniaturized CPW-Fed Implantable Conformal Patch Antenna at ISM Band for Biomedical Applications." *IEEE Access* 7 (2019): 43547-43554.

3. Fallahpour, Mojtaba, and Reza Zoughi. "Antenna miniaturization techniques: A review of topology-and material-based methods." *IEEE Antennas and Propagation Magazine* 60, no. 1 (2017): 38-50.
4. Kapoor, Janak. "Miniaturization of microstrip patch antenna obtained by patch meandering and shorting pin loading technique." *J. Nat. Phys. Sci* 24 (2011): 5-9.
5. Haque, Sk Moinul, and Khan Masood Parvez. "Slot antenna miniaturization using slit, strip, and loop loading techniques." *IEEE Transactions on Antennas and Propagation* 65, no. 5 (2017): 2215-2221.
6. Wang, Chien-Jen, and Christina F. Jou. "Compact microstrip meander antenna." *Microwave and Optical Technology Letters* 22, no. 6 (1999): 413-414.
7. Kuo, Jieh-Sen, and Kin-Lu Wong. "A compact microstrip antenna with meandering slots in the ground plane." *Microwave and Optical Technology Letters* 29, no. 2 (2001): 95-97.
8. Sarkar, S., A. Das Majumdar, S. Mondal, S. Biswas, D. Sarkar, and P. P. Sarkar.
9. "Miniaturization of rectangular microstrip patch antenna using optimized single-slotted ground plane." *Microwave and Optical Technology Letters* 53, no. 1 (2011): 111-115.
10. Ullah, Mohammad H., Mohammad T. Islam, Mandeep S. Jit, and Norbahiah Misran. "A three-stacked patch antenna using high-dielectric ceramic material substrate." *Journal of Intelligent Material Systems and Structures* 23, no. 16 (2012): 1827-1832.
11. Kumar, Raj, P. Malathi, and J. P. Shinde. "Design of miniaturized fractal antenna." In *2007 European Microwave Conference*, pp. 474-477. IEEE, 2007.
12. Ripin, N., W. M. A. W. Saidy, A. A. Sulaiman, N. E. A. Rashid, and M. F. Hussin. "Miniaturization of microstrip patch antenna through metamaterial approach." In *2013 IEEE Student Conference on Research and Development*, pp. 365-369. IEEE, 2013.
13. Kiourti, Asimina, and Konstantina S. Nikita. "A review of in-body biotelemetry devices: implantables, ingestibles, and injectables." *IEEE Transactions on Biomedical Engineering* 64, no. 7 (2017): 1422-1430.
14. Afridi, Muhammad Aamir. "Microstrip patch antenna- designing at 2.4 GHz frequency." *Biological and chemical research* 2015 (2015): 128-132.
15. Memon, Mosin I., and Anurag Paliwal. "Microstrip Patch Antenna Design Calculator." In *International Journal of Engineering Research & Technology*, vol. 2, no. 9, pp. 3080-3084. 2013.
16. Holub, Alois, and Milan Polivka. "A novel microstrip patch antenna miniaturization technique: A meanderly folded shorted-patch antenna." In *2008 14th Conference on Microwave Techniques*, pp. 1-4. IEEE, 2008.
17. Starodubov, Andrei V., Viktor V. Galushka, Alexey A. Serdobintsev, Anton M. Pavlov, Galina A. Korshunova, Peter V. Ryabukho, and Sergey Yu Gorodkov. "A novel approach for fabrication of flexible antennas for biomedical applications." In *2018 18th Mediterranean Microwave Symposium (MMS)*, pp. 303-306. IEEE, 2018.
18. Raad, Haider Khaleel, Hussain M. Al-Rizzo, Ayman Issac Abbosh, and Ali I. Hammoodi. "A compact dual band polyimide based antenna for wearable and flexible telemedicine devices." *Progress In Electromagnetics Research* 63 (2016): 153-161.
19. Delaveaud, C., and S. Sufyar. "A miniaturization technique of a compact omnidirectional antenna." In *2009 3rd European Conference on Antennas and Propagation*, pp. 384-388. IEEE, 2009.
20. Biswas, Akash, Akib Jayed Islam, Khandoker Tanjim Ahammad, and Bithi Barua. "A miniaturized on-body matched antenna design and its performance evaluation at ISM band." In *2017 3rd International Conference on Electrical Information and Communication Technology (EICT)*, pp. 1-6. IEEE, 2017.
21. Christina, G., A. Rajeswari, M. Lavanya, J. Keerthana, K. Ilamathi, and V. Manoranjitha. "Design and development of wearable antennas for tele-medicine applications." In *2016 International Conference on Communication and Signal Processing (ICCSP)*, pp. 2033-2037. IEEE, 2016.
22. Liu, Chen, Ying-Qi Jiang, Shuo Ji, Shao-Long Chang, Hong-Fei Li, Yu-Xing Ding, Kwok L. Chung, and Wei-Hua Zong. "A Novel Flexible Implantable Antenna at ISM Band." In *2018 IEEE International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM)*, pp. 1-2. IEEE, 2018.
23. C. A. Balanis, *Antenna Theory: Analysis and Design*. 2005.
24. CST Microwave Studio [Online] Available: <http://www.cst.com>.

AUTHORS PROFILE



Padmalatha N is pursuing M.Tech Electronics and Communication Engineering specialization in Telecommunication Networks at SRM Institute of Science and Technology, Kattakulathu, Tamilnadu, India. She finished her B.E in Electronics and Communication Engineering. Her research interest in antenna design and development, Networking.



Microwave devices and MIMO antennas.

Deepa T currently pursuing her Doctor of Philosophy at SRM Institute of Science and Technology and received her BE degree Electronics and Communication Engineering at Panimalar Institute of Technology, Poonamalle, Chennai and ME at Anna University, Guindy. Her research interest are Microwave sensors, Reconfigurable filtenna,



Susila M is currently holding the position of Assistant Professor (Selection Grade) in Department of Telecommunication Engineering at SRM Institute of Science and Technology, Kattakulathur, TamilNadu, India. She is in teaching profession since 1998. She received her M.Tech. degree in Communication Systems (2007) and Doctor of Philosophy (2019). Her research interest includes antenna design and development, radio wave propagation, device to device communications and microwave photonics. She is member of various professional bodies like IEEE, OSI, OSA and life member of ISTE, IETE and IEI.