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Design of Miniaturized Flexible Planar Antenna for Biomedical Application

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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 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 ~ $\lambda_0/2$ 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.

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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 εr = 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].

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(Pw)is calculated according to the equation given below, where, Pw= radiating patch width, C= speed of light, *εr* = constant value of dielectric substrate,

$$W = \frac{C}{2f_o}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

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],

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

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,

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

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

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

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

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=41mm, L_g=33mm, and the substrate W_s=42mm, L_s=34mm. 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 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)***	***Dimensions***
Subtrate	Length(L_s) Width(Ws) Height(h)	21mm 17mm 0.0508mm
Patch	Length(L_g) Width(W_g) Height(h)	20.5mm 16.5mm 0.035mm
Feed line	Width(W_f) length(L_f)	2.8mm 6mm

D. Evolution of Proposed Antenna

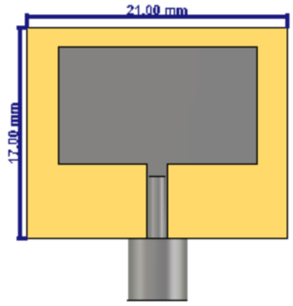

Fig1(a).Antenna1

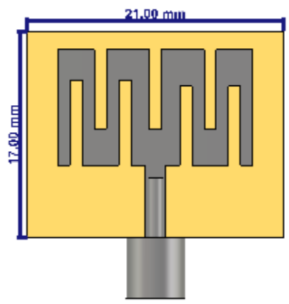

Fig1(b).Antenna 2

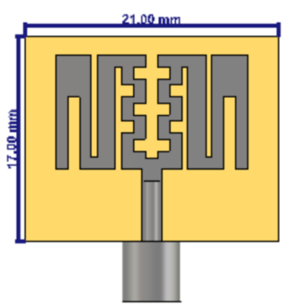

Fig1(c).Antenna 3

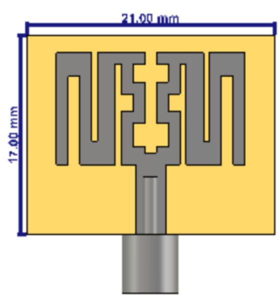

Fig1(d).Antenna 4

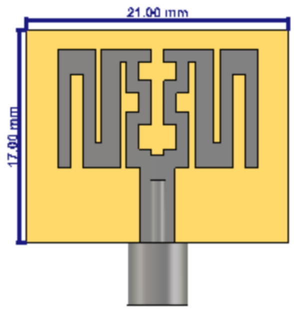

Fig1(e).Antenna5 The Proposed antenna

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.

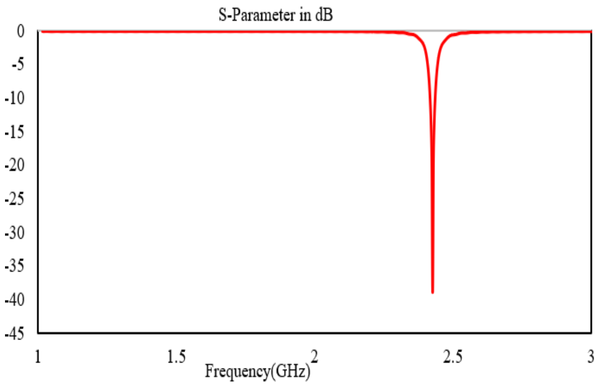

Fig2. S11 response for proposed antenna

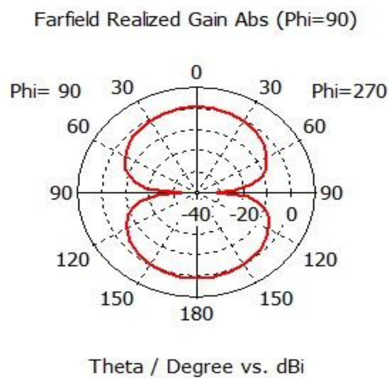

Fig3. Radiation Pattern for proposed antenna

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.

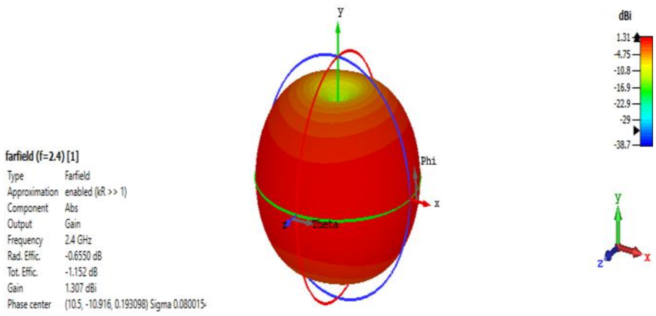

Fig4. 3D Far-field plot for proposed antenna

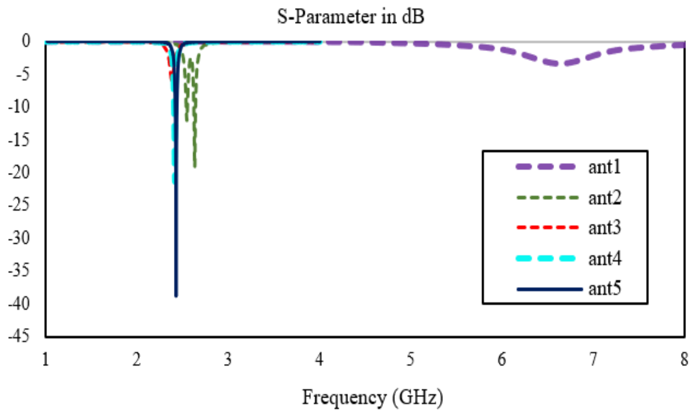

Fig5. Evolution process S11 of the proposed antenna

IV. CONCULSION

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].

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