

Design of Wearable Microstrip Patch Antenna for Patient Monitoring

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ABSTRACT: Today's technology has become diverse and it has touched all walks of life. It has made elderly and sick people to live their life effortlessly. One such technology developed for this purpose is patient monitoring system. In these systems, wearable antenna plays a vital role. A reliable wearable antenna should be compact in size, slighter in weight and flexible as it is attached to the attire of the patient. For resolving these constrains, a wearable microstrip patch antenna for patient monitoring is proposed. This antenna is designed to operate at an unlicensed ISM band of 2.4 GHz. The design is built on denim (jean cloth) substrate with shieldIt as a conducting metal having a microstrip line feeding structure. It is designed and simulated using Computer Simulation Technology (CST) tool. The dimension of the proposed design is 25 x 35 x 0.7 mm³. Its resonant frequency is 2.4 GHz with return loss of -27.01 dB. This paper also discusses the other antenna parameters like VSWR, Gain, Directivity, Efficiency and SAR.

KEYWORDS: CST, denim, ISM band, Patient Monitoring, SAR, ShieldIt, wearable antenna.

I. INTRODUCTION

Antenna is a radiating device that is used at both transmitting and receiving end. Antenna collects the electrical signals from the transmission lines and converts them into radio waves whereas receiving antenna accepts the radio waves from the space and converts them into equivalent electrical signals. Textile or cloth-based antennas has become a requisite part in WLAN, Telemedicine, military, Navigation. The main downside of antenna efficacy in medical applications is its size which makes the whole measuring setup as bulkier and complicated [1]. Solution to this problem can be arrived by using a compact microstrip antenna that can be sewed over dress material. This microstrip antenna works in close proximity with the patient to be monitored [2].

II. LITERATURE SURVEY

The antenna used for medical applications are of two types namely, wearable antenna and implantable antenna. These antennas are studied in various journals and the survey mentioned below is mainly focused on wearable antenna, otherwise known as textile antenna.

Mohd E. Jalil, Mohamad K. A. Rahim, *et al.*, (2013) designed a multiband Fractal Koch dipole textile antenna for wearable applications. In this paper, antenna performance was tested for various conditions like bending an antenna, antenna on wet conditions and placing antenna on the human body are observed. This antenna operates over 0.9 GHz, 2.45 GHz and 5.8 GHz.

Qingshuang Liu, Yilong Lu, (2014) designed a wearable L-shaped textile antenna operating at ISM band of 2.4 GHz feed by coplanar waveguide. The waveguide structure provides wider bandwidth along with high tolerance value. Denim is chosen as a substrate. Denim cloth is of 1mm thickness, 1.6 as dielectric constant and loss tangent of 0.02.

Laura Corchia, Giuseppina Monti, *et al.*, (2017) reviewed there are two different methods in designing a wearable antenna. Some of antennas are designed like a logo using jean substrate, embroidered patch antenna made by conductive sewing thread. There are two different antenna fabrication methods, one method uses adhesive-backed non-woven conductive fabrics and other one is based on embroidery of conductive threads. Antenna performance after washing, drying and ironing are observed.

Nisha.M, SaiShweta.S, *et al.*, (2018) reviewed a textile antenna that operates at ISM band of 2.4GHz used for wireless medical applications. Co-planar waveguide feed is used for better impedance matching with reduced backward radiations. This antenna is designed and analyzed on CST microwave tool and antenna parameters are observed. The directivity of this antenna is 2.22 dB at 2.45 GHz.



G.Indumathi, J.Bhavithra (2018) developed a wearable textile antenna that operates over ISM band of 2.4 GHz, designed for indoor applications like patient monitoring. It is designed using EMpro software and various parameters are analyzed and observed. Antenna is designed using copper tape as conducting material which is a good conductor, malleable and attachable to the substrate material.

Md.Amanath Ullah, Mohammad Tariqual Islam, *et al.*, (2018) reviewed a paper based flexible antenna that operates at 2.4 GHz for telemedicine application. Flexible photo paper of 0.54 mm thick is used for fabricating and copper strip of 0.03 mm is used as a radiating element. The size of antenna is 40 x 35 x 0.6 mm³. In normal condition it operates at 2.33-2.53 GHz. Its radiation efficiency is 70% and gain is 2 dB. Design started with basic microstrip fed antenna as primary structure and modified the design to radiate properly. The performance of antenna is studied in different substrate such as paper, resin-coated paper, jeans and FR-4.

M.Annakamatchi, V.Keralshalini (2018) proposed a wearable spiral shaped antenna which use fleece as substrate material. The design is successfully simulated in CST Microwave Studio and it operates at 2.4 GHz for biomedical applications. The antenna is compact in size with dimension of 36 mm x 28 mm rectangular shaped fleece substrate. The antenna is designed with many numbers of turns in radiating elements to enhance the gain and to achieve better bidirectional radiation characteristics.

Shenbaga. K, TakshalaDevapriya. A (2019) designed a flexible antenna used for medical applications. The antenna is designed on different conducting material and its characteristics has been studied. Conducting material like Cu sheet, conductive sewing thread, electro textile and silver are used. Circular patch with slots on strips produces better performance compared to other designs. The antenna is designed for medical application. Mica is chosen as substrate and stimulated using the HFSS software. It resonates at the frequency of 2.8 GHz with low return loss of -19.007dB and VSWR value of 1.2525.

Sivabalan. A, Jothilakshmi. P, (2019) designed an O-shaped reconfigurable microstrip antenna for medical applications. Flexible polyurethane foam is taken as dielectric material. Copper is used as a radiating element with the thickness of 1 mm and surface resistivity of 0.0171Ω-mm²/m. The antenna works on two modes namely ON-mode and OFF-mode. In ON-mode it resonates over the frequency of 2.38-2.52 GHz and its return loss is about -26.9 dB, whereas in OFF-mode it resonates over 5GHz-5.5 GHz with reflection coefficient of -19.96 dB.

III.MATERIAL DESCRIPTION

3.1 Conducting material

ShieldIt is chosen as a radiating element as it is flexible and durable. In this compound, Copper has high thermal conductivity but when it is alloyed with nickel, the overall thermal conductivity decreases. This material weights about 230 g/ m³. The properties of this radiating element are given in the Table I. [3-5]

Table I. Properties of ShieldIt

PARAMETERS	VALUES
Permittivity	1.7
Permeability	1
Thickness	0.17 mm
Electrical Conductivity	1.8 x 10 ³ S/ m

3.2 Substrate material

Denim cloth is chosen as substrate because it has lower dielectric constant. A Substrate with low dielectric constant not only reduces surface wave loss but also improves the antenna bandwidth and impedance matching. Its various properties are provided in the Table II. [6] [7]

Table II. Properties of Denim

PARAMETERS	VALUES
Permittivity	1.6
Permeability	1
Thickness	0.7 mm

IV.ANTENNA STRUCTURE

In proposed system wearable microstrip patch antenna is designed using CST MW Studio suite resonating at 2.4GHz (ISM Band). The patch of the antenna is mounted on 0.7 mm thick denim substrate. Its dielectric constant is 1.6 and loss tangent is 0.02. The dimension of the antenna is 25x35x0.7mm³. Conducting patch is placed over denim substrate and desired shape is attained by etching the remaining area in the radiating element. The antenna structure with its dimension is shown in the Fig.1. It is simulated in CST Studio Suite and results are discussed below.

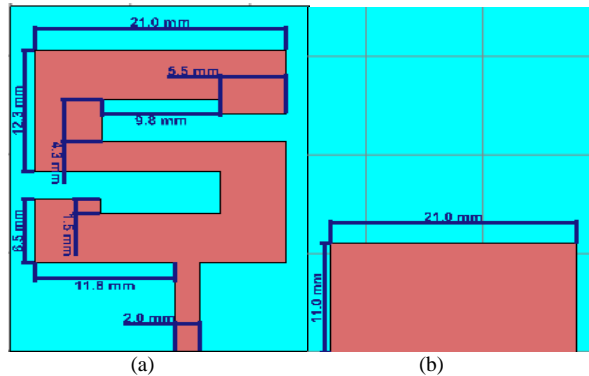


Fig.1. Antenna structure (a) Radiating patch (b) Ground plane

4.1 Feeding technique

The proposed system uses length of 9 mm microstrip feed where a radiating strip is connected directly to the edge of microstrip patch. The main advantage of this technique is simple to design and fabricate.

V.TOOL DESCRIPTION

CST Studio suit is a 3D electromagnetic (EM) simulation software widely used for electromagnetic spectrum as well as Multiphysics and particle applications. It is flexible to analyze whole system which is made up of multiple components. It is used by leading technology and many engineering companies all over the world. It is a licensed tool used by engineers, designers, and researchers in leading companies and industries including aerospace, electronics, automotive, health-care and in telecommunications.

VI.SIMULATION RESULT

6.1 Reflection co-efficient

The reflection coefficient(S-parameter) of simulated design is shown in the Fig.2. From this we can infer that the antenna resonates at 2.4 GHz. The performance of the antenna will be better if the return loss is less than -10dB. Since the obtained return loss of is -27.01 dB the antenna will perform better. [8-11]

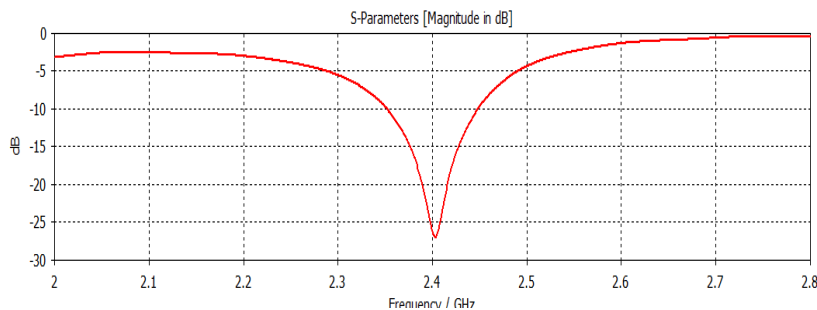


Fig.2. S-Parameter

6.2 Directivity

Directivity gives the ratio of power density between direction of strongest emission of the antenna and ideal isotropic radiator. The directivity of an antenna is 2.24 dBi which is shown in the Fig.3.[12]

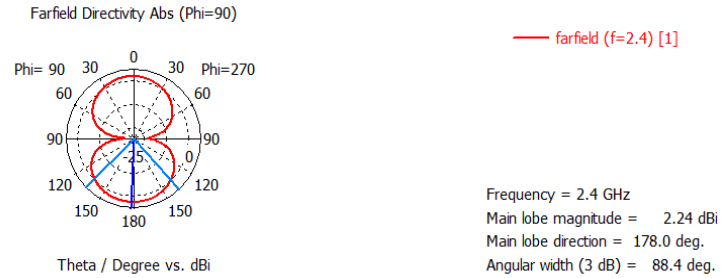


Fig.3. Directivity

6.3 Gain

Gain is the ability of the antenna to radiate in any direction. The gain of designed antenna is 1.66 dBi shown in the Fig.4.

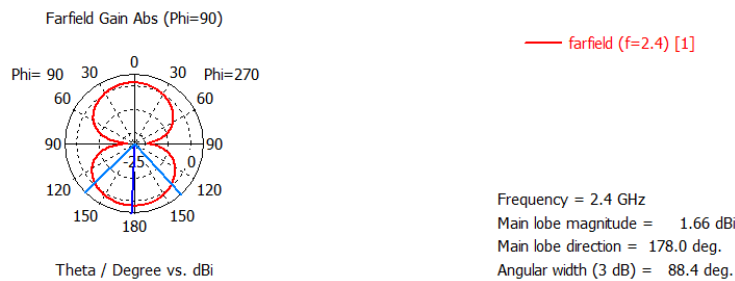


Fig.4. Gain

6.4 Efficiency

Efficiency is the ratio of power radiated by an antenna to the power supplied to an antenna. It can also be represented as the ratio of gain of an antenna to its directivity. The efficiency of the designed antenna is 74%. Power distribution of an antenna is shown in the Fig.5.

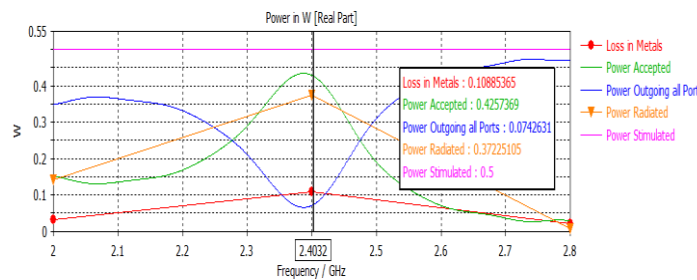


Fig.5. Power distribution

6.5 VSWR

Voltage standing wave ratio describes the reflected power from the antenna. The performance of an antenna will be better when VSWR value is less. Ideal value of VSWR is unity and maximum value can be 2, which is an acceptable value of any antenna. The designed wearable antenna has better VSWR of 1.09 at 2.4 GHz as shown in the Fig.6.

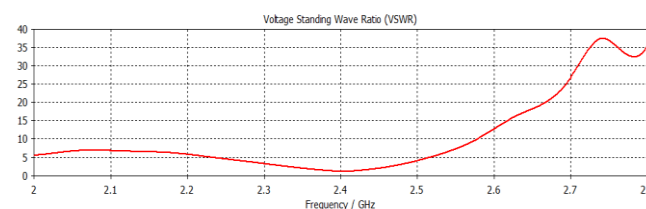


Fig.6. VSWR

VII. HUMAN BODY EFFECTS

The radiating frequency of the antenna changes on grounds of high permittivity of body tissues. So, the antenna performance is evaluated in free space primarily and subsequently tested for on-body flat section. The three layer phantom model over which the antenna to be placed is designed in CST. The three layer model is comprised of skin, fat and muscle. The antenna placement is preferable on triceps and thighs which have average skin and fat for better performance. The increase in resonant frequency decreases the permittivity and hence it has less radiation effects over human body. The designed phantom model is shown in the Fig.7.

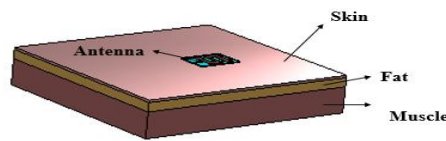


Fig.7. Phantom model

SAR is an important parameter to be considered incase of wearable antennas. The unit of SAR is W/ Kg. Its is calculated as

$$SAR = \frac{\sigma |E|^2}{\rho}$$

where

σ – Conductivity of tissue (S/m)

E –Electric field (v/m)

ρ –Density of tissue (Kg/ m³)

To calculate SAR value the 3D model is designed with dimension 140x140mm. The properties of the model are given in the Table III.

Table III. Properties of human tissues

Tissue	Thickness (mm)	Conductivity (S/m)	Permittivity
Skin	2	0.507	69.45
Fat	8	0.036	6.07
Muscle	23	0.708	65.97

SAR is generally averaged by considering the whole body or taking a small sample volume. According to FCC local SAR and average SAR should be below 1.6W/Kg and 0.08W/Kg for 1g of tissue, whereas according to ICNIRP average SAR should be below 2.0W/Kg [13-16]. Separation of 2mm is given between the patch antenna and the model. Considering ICNIRP regulations the obtained SAR value is 1.64 W/Kg, which is acceptable. The simulated results are shown in the Fig.8.

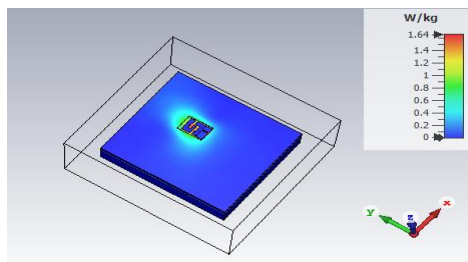


Fig.8. Simulated SAR value

VIII.ANTENNA ANALYSIS

The proposed antenna is designed iteratively by varying the structural parameters like length, width, feeding position etc., Hence various antenna design has been obtained for different resonating frequency. Graph is plotted by considering operating parameters like return loss, gain and VSWR for obtained respective operating frequency. The parameters of proposed antenna are plotted finally (dotted) for better comparison with previous design. It is shown in the fig.9.

For an antenna to be ideal the return loss should be less than -10 dB, gain must be high and VSWR should be unity. The proposed antenna meets out all the requirement.

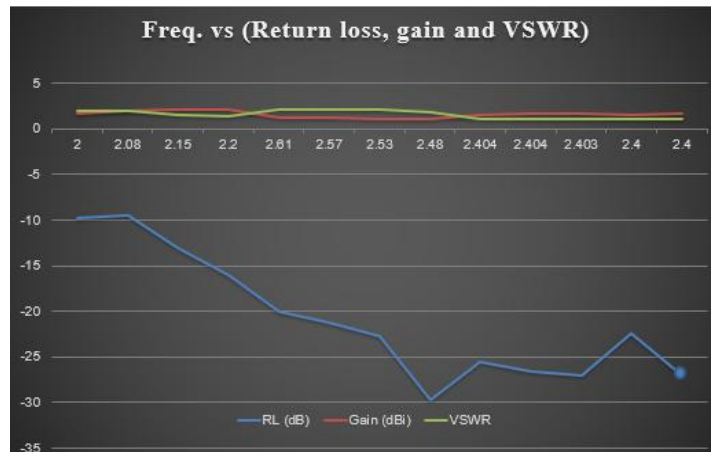


Fig.9. Parameter analysis lot

IX. RESULTS DISCUSSION

The operating frequencies for medical application are different , in proposed design ISM band is used. The other operating frequencies are 434-915 MHz, 2.9 GHz, 3.9 GHz , 5.2 GHz tc., Here we consider some of the antenna designs that resonates over the range of 2.4 GHz to 2.52 GHz and their parameters are mentioned in Table IV and the proposed design (S.no.6) is finally included for better understanding.

Table IV. Result comparison with existing design

Design structure	Fequency (GHz)	Return loss (dB)	Size (mm ²)	EBG Structure	Gain (dBi)
O-shaped patch	2.38 to 2.52	-19.96	50 x 23.5	No	7.51
C-shaped patch	2.45	-36	36 x 38	No	1.24
L-shaped patch	2.4	-35	75 x 75	No	2
Rectangle shape	2.4	-21.74	70 x 66	No	0.3
				Yes	1.66
Proposed design	2.4	-27.01	25 x 35	No	1.66

EBG structure is used as a part of an antenna to improve the performance such as gain and radiation pattern. In common antenna design , the antenna designer uses this structure to suppress the surface wave current which lead to increase the gain and efficiency of an antenna. However, by using EBG structure, the antenna size will be increased as it is used as a supersubstrate which also leads to complexity in antenna design and so we designed an antenna without this structure. When we compare proposed design with other existing design (rectangle shaped antenna) without using

EBG structure we achieved good gain and also better return loss. By comparing proposed design with another existing design (C-shaped patch) it is noted that we have better gain. Efficiency of proposed design is better since it depends on gain and directivity. It is also noted that we have designed compact sized antenna by comparing with all above mentioned existing antenna designs.

X. CONCLUSION

A low-profile and light weighted miniaturized wearable microstrip patch antenna designed for medical applications at ISM band of 2.4 GHz has been designed. It operates at 2.4 GHz and its return loss is -27.01 dB. The efficiency of the antenna is 74%. It is designed for patient monitoring but it can also be used for applications like communication, military, telemedicine and navigation.

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