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Design of Wearable Microstrip Patch Antenna for Health Monitoring

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Abstract—The variety and impact of modern technology may be seen in all spheres of existence. It has enabled sick and elderly people to live comfortably. A technological solution created for this objective is the health monitoring system. A wearable antenna is essential to these devices. Since it will be fastened to the patient's clothing, a trustworthy wearable antenna should be small, light, and flexible. A wearable microstrip patch antenna for health monitoring and detection is suggested as a solution to these limitations. The 2.4 GHz unlicensed ISM band is where this antenna is intended to operate. The design is constructed on a shielded FR epoxy substrate. It is a conducting metal with a feeding arrangement for microstrip lines. The Computer Simulation Technology (CST STUDIO 2019) tool is used for its design and simulation. The suggested design's dimensions are 23 x 29 x 0.035 mm3. It has a return loss of -10.95 dB and a resonance frequency of 2.4 GHz. Other antenna characteristics like VSWR, Gain, Directivity, Efficiency, and SAR are also covered in this work.

Keywords—CST STUDIO 2019, Health Monitoring, SAR, wearable antenna, FR4 Epoxy.

I. INTRODUCTION

A radiating device used for both transmitting and receiving is called an antenna. While receiving antennas take in radio waves from space and transform them into corresponding electrical signals, antennas gather electrical signals from transmission lines and transform them into radio waves. Textile or cloth-based antennas are now necessary for military use, telemedicine, WLAN, and navigation. The primary drawback of antenna efficacy in medical applications is its size, which adds bulk and complexity to the entire measuring system. A tiny microstrip antenna that can be sewn over dress material is one way to solve this issue. This microstrip antenna is designed to operate in close proximity to the target health for detection and monitoring.

II. LITERATURE REVIEW

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.

In 2018, Nisha M., Sai Shweta S., et al. examined a textile antenna utilized for wireless medical applications that operates at the 2.4GHz ISM band. To achieve improved impedance matching with lower backward radiation, co-planar waveguide feed is employed. The CST microwave tool is used to design, analyze, and monitor the antenna's parameters. This antenna has a 2.22 dB directivity at 2.45 GHz[1].

A multiband Fractal Koch dipole textile antenna was created by Mohd E. Jalil, Mohamad K. A. Rahim, et al. (2013) for wearable applications. This article examined the performance of antennas in a variety of situations, including bending, moist conditions, and placement on human bodies. This antenna is capable of operating at 3.45 GHz, 5.8 GHz, and 0.9 GHz [2].

In 2019, Sivabalan A and Jothilakshmi P created an O-shaped reconfigurable microstrip antenna intended for use in medical settings. Polyurethane foam that is flexible is used as a dielectric material. Copper has a thickness of 1 mm and a surface resistance of 0.0171Ω-mm2 /m when employed as a radiating element. There are two modes of operation for the antenna: ON and OFF. It resonates between 2.38 and 2.52 GHz in ON mode, with a return loss of roughly -26.9 dB; in OFF mode, it resonates between 5 and 5.5 GHz, with a reflection coefficient of -19.96 dB[5].

II. MATERIAL DESCRIPTION

2.1 Conducting material

Shield It 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/ m^3. The properties of this radiating element are given in the Table I.

TABLE.I PROPERTIES OF CONDUCTING MATERIAL

PARAMETERS	**VALUES**
PERMITTIVITY	1.7
PERMEABILITY	1
THICKNESS	0.035 MM
ELECTRICAL CONDUCTIVITY	1.8 X 105 S/ M

2.2 Substrate material

FR4 Epoxy 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.

Table II. PROPERTIES OF SUBSTRATE MATERIAL

PARAMETERS	VALUES
Permittivity	4.3
Thickness	1.6mm
Electrical Conductivity	1.4-3.7×10-15S/ m

III. DESIGN CONSIDRATION

The suggested system employs a wearable microstrip patch antenna that resonates at 2.4GHz frequency, built using CST Studio suite 2019. The antenna patch is attached to a denim substrate that is 1.6 mm thick. Its loss tangent is 0.02 and its dielectric constant is 4.3. The antenna measures 23 x 29 x 0.035 mm3. Using a conducting patch is Figure 1 depicts the antenna structure and its dimensions. The CST Studio Suite 2019 simulation is used, and the outcomes are covered here. Fig.1. Antenna structure without Phantom placed over FR4 substrate and desired shape is attained by etching the remaining area in the radiating element.

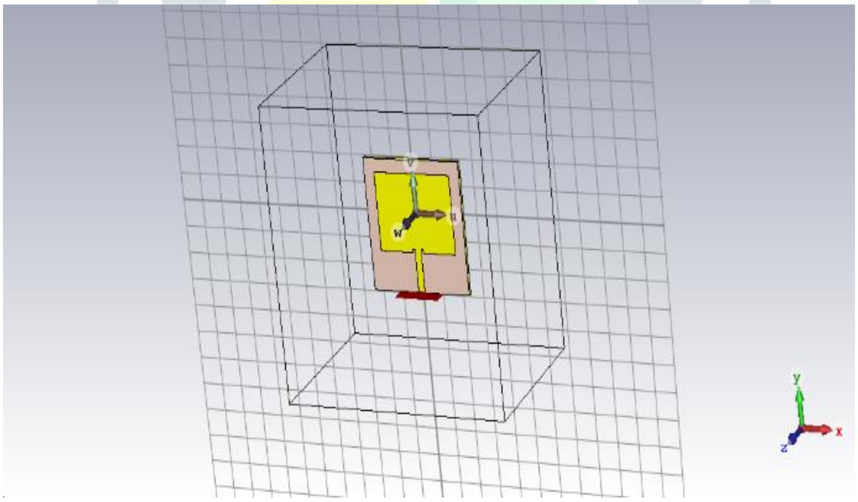


Table III. PROPERTIES OF ANTENNA STRUCTURE

Antenna Parameters	**Values**	
	Width(mm)	**Length(mm)**
Ground	23.61	29
Substrate	23.61	29
Patch	18.61	14.41
Patch Cut	2.54	14.41
Feedline	2.54	-13.21

3.1 Feeding Technique

The proposed system uses length of 13 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. In this design we used Inset feeding technique.

3.2 Tool Description

A popular 3D electromagnetic (EM) simulation program for particle, multiphysics, and electromagnetic spectrum applications is CST Studio Suite. It is adaptable enough to examine an entire system composed of several different parts. Leading technology and numerous engineering firms use it globally[4]. Engineers, designers, and researchers in prestigious firms and sectors, such as aerospace, electronics, automotive, health care, and telecommunications, employ this licensed instrument.

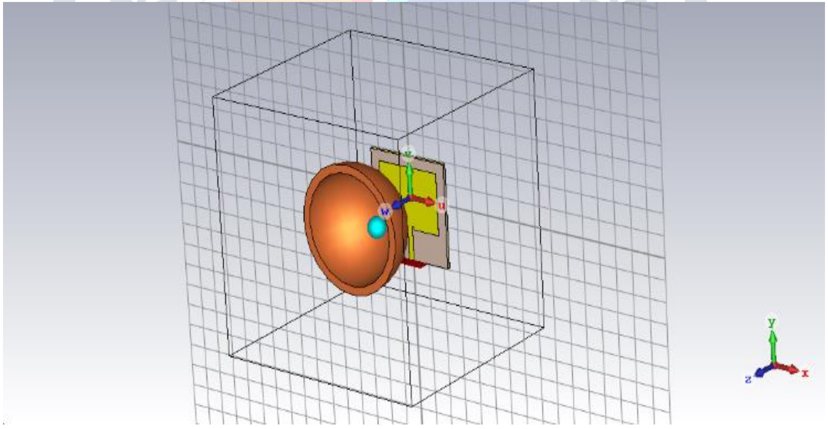
Table. IV PROPERTIES OF HUMAN TISSUES

Tissue	**Properties of Human Tissues**		
	Density	***Conductivity (S/m)***	***Permittivity***
Skin	1109	2.34	36.7
Fat	911	0.262	4.84
Tumor	1058	4	54.9

IV. HUMAN BODY EFFECTS

The antenna's changing radiating frequency is due to the human tissues' high permittivity. Therefore, the antenna performance is first assessed in free space and then tested for the on-body flat part. The CST design is used for the three-layer phantom model that the antenna will be positioned across. The skin, fat, and tumor make up the three layers of the model[3]. For optimal results, the antenna should be placed on the triceps and thighs, which have average skin and fat. Resonant frequency increases reduce permittivity, which lessens the radiation's impact on the human body. In Figure 2, the designed phantom model is displayed.

Fig.2.Antenna Desigen with Phantom



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

$$SAR=\frac{\sigma|E|^2}{\rho} \qquad (1)$$

Where,
σ – Conductivity of tissue (S/m)
E –Electric field (v/m)
ρ –Density of tissue (Kg/ m3)

V. SIMULATION RESULT

5.1 Reflection co-efficient

The reflection coefficient(S-parameter) of simulated design is shown in the Fig.3. 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 -10.95 dB the antenna will perform better.

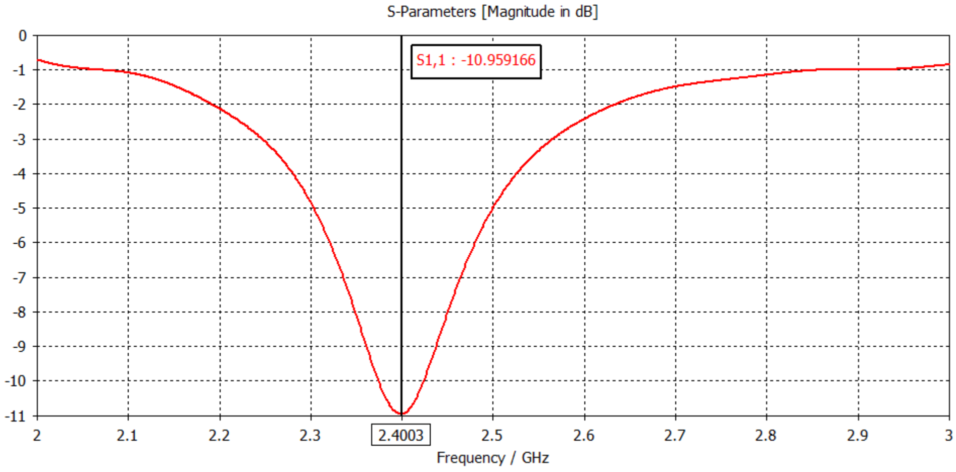


Fig.3. S parameter

5.2 *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 5.231 dBi which is shown in the Fig.4.

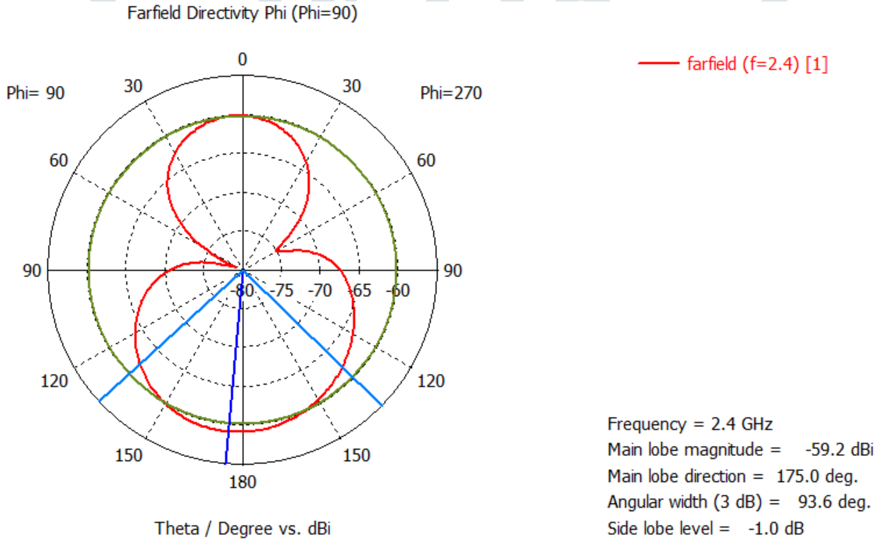


Fig.4.Directivity

5.3 Gain

Gain is the ability of the antenna to radiate in any direction. The gain of designed antenna is 1.369 dBi shown in the Fig.5.

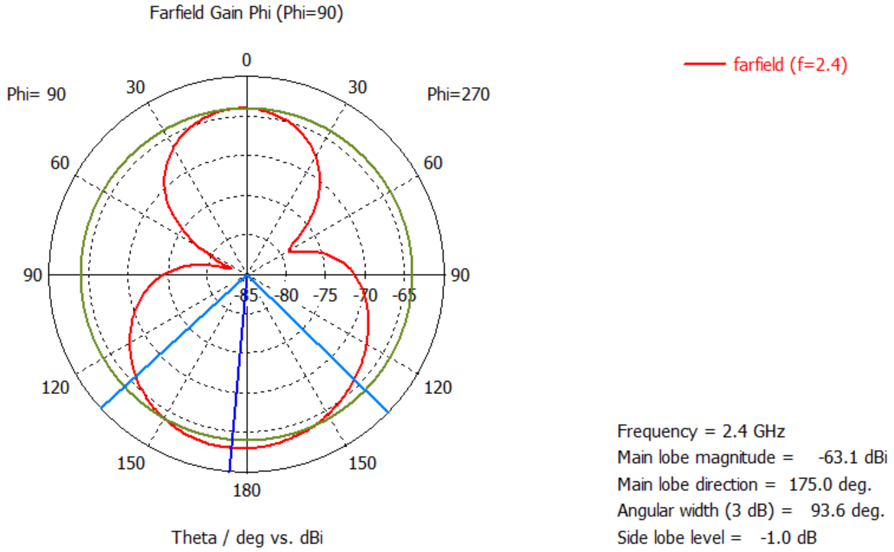


Fig.5. Gain

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5.4 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 75%. Power distribution of an antenna is shown in the Fig.6.

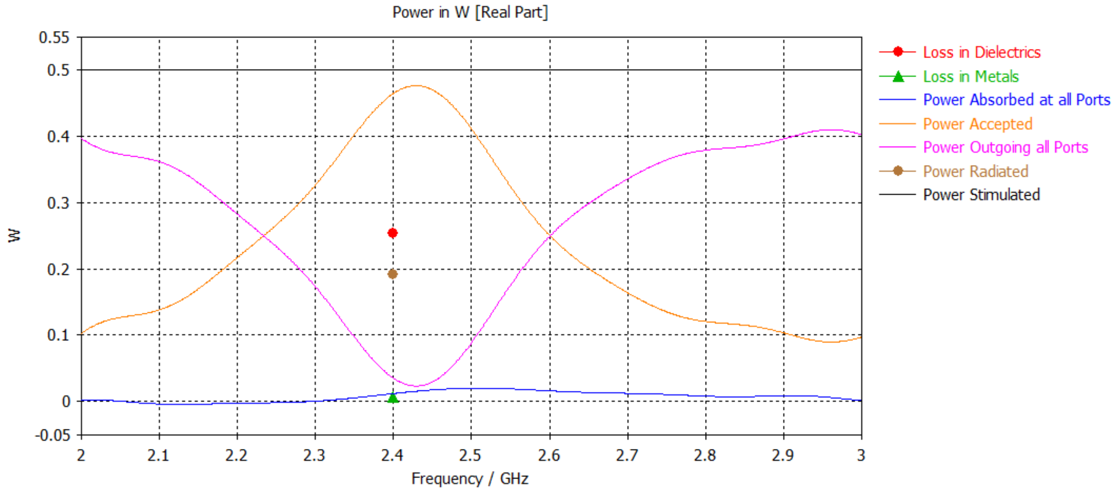


Fig.6.Efficiency

5.5 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 VWSR of 1.708 at 2.4 GHz as shown in Fig.7.

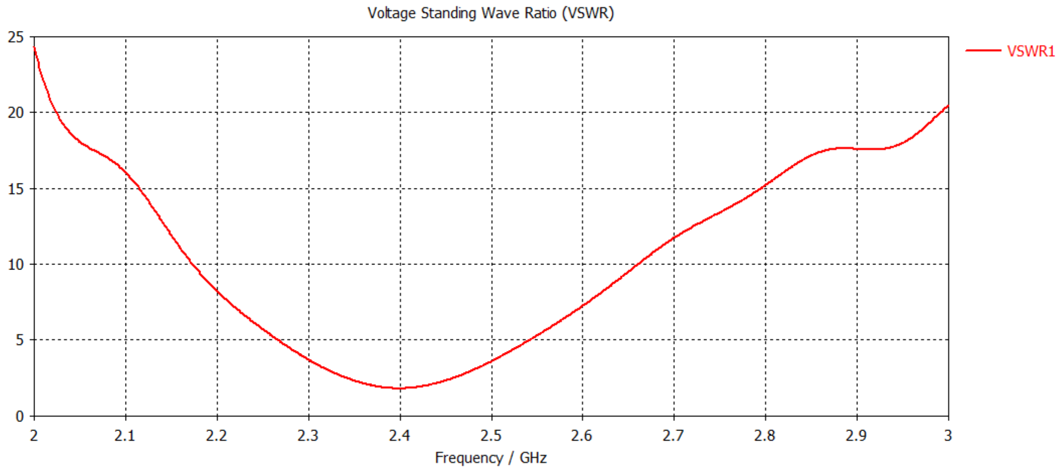


Fig.7. VSWR

VI. RESULT AND ANALYSIS

By adjusting the structural parameters of the proposed antenna, such as length, width, feeding location, etc., iteratively, several antenna designs have been obtained for different resonating frequencies. Plotting of the graph takes into account operational factors such as gain, return loss, and VSWR for the obtained operating frequency. Plotting the final parameters of the proposed antenna (dotted) allows for a more accurate comparison with the prior design. It can be seen in Figure 9.

For an antenna to be ideal the return loss should be less than -10.95 dB, gain must be high and VSWR should be unity. The proposed antenna meets out all the requirement.

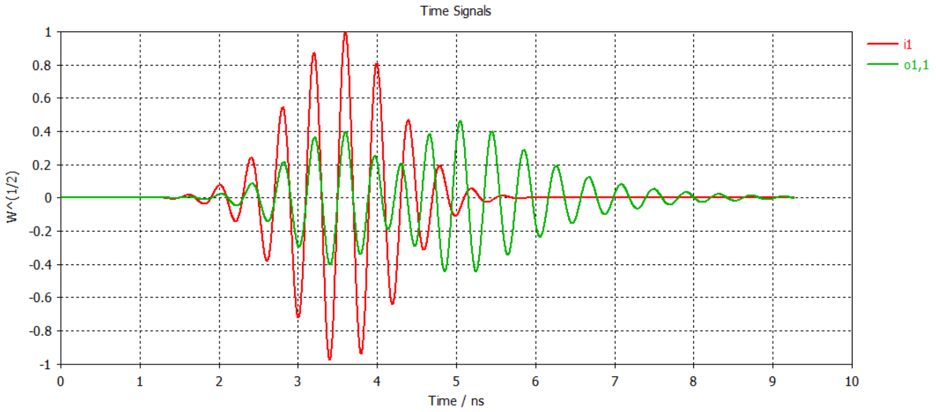
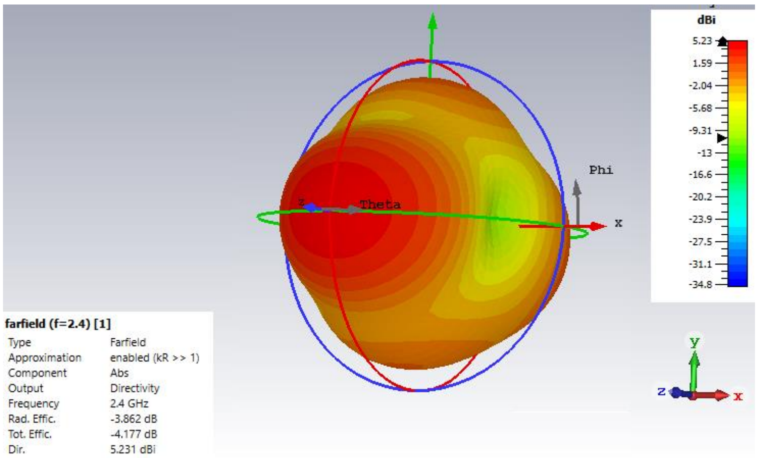


Fig.8.Port Signal



farfield (f=2.4) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	2.4 GHz
Rad. Effic.	-3.862 dB
Tot. Effic.	-4.177 dB
Dir.	5.231 dBi

Fig.9 Farfield at 2.4 frequency

VII. CONCLUSION

A wearable microstrip patch antenna with a low profile and light weight has been developed for medical applications operating in the 2.4 GHz ISM band. Its return loss is -10.95 dB and it runs at 2.4 GHz. The antenna has a 75% efficiency. Although its primary purpose is to monitor and identify health problems, it can also be utilized for military, medical, communication, and navigational purposes.

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