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Multiband Wearable Textile Antenna Design For Wireless Communication Applications

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Abstract:

In this paper, a wearable textile antenna with a rectangular microstrip patch is designed to resonate in the ISM band as well as other commercial wireless applications. The proposed antenna consists of a jeans material as a substrate with electric permittivity of 1.6 and thickness of 1.12 mm. The proposed antenna was designed using Ansys HFSS simulation software tool. The performance of proposed antenna can be analyzed and measured in terms of return loss, bandwidth, VSWR (Voltage Standing Wave Ratio), radiation pattern, gain, antenna efficiency using HFSS Simulation software tool. The main objective of this project is to improve return loss, gain . The proposed wearable textile antenna can be used for various applications in the C-band (7.52GHz-7.56GHz), X-band (9.68GHz-9.73GHz), Wi-Fi (2.5GHz) and ISM (2.5-2.54GHz) band frequencies.

Keywords—*Wireless Communication, Microstrip patch antenna, ISM band, Textile antenna, Multiband, Return loss, Simulation, VSWR, Gain, Directivity, HFSS.*

I. INTRODUCTION

INTRODUCTION

The Communication system is a system which describes the information exchange between two points. The process of transmission and reception of information is called Communication. The major elements of Communication are the Transmitter of information, the Channel or medium of Communication and the Receiver of information. Wire Communication system uses wire, optical fibre which works on the phenomenon of total internal reflection to communicate from one point to another point. Wireless communication systems use radio waves, electromagnetic waves and infrared waves to communicate from one point to another point.

Wireless Communication are divided into the following types. They are:

- Ground wave communication
- Skywave communication
- Space wave communication

- Satellite communication

An antenna that is shaped by simply etching out a piece of conductive material above a dielectric surface is called a microstrip antenna or a patch antenna. On the ground plane of this microstrip antenna, the dielectric material is mounted, where this plane supports the entire structure. In addition, the excitation to this antenna can be provided with feed lines that are connected to the patch. Generally, these antennas are considered low-profile antennas that are used in microwave frequency applications that have above 100 MHz frequency.

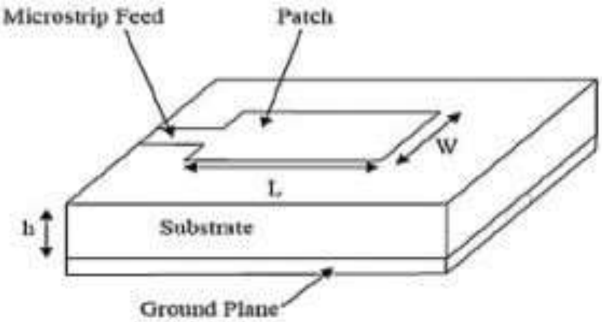

Fig. 1: Microstrip patch antenna

Textile antennas are a subset of wearable technology, specifically designed to blend seamlessly with clothing and other textile-based materials like jeans, cotton etc..,. They function just like conventional antennas but with the added benefit of being flexible, lightweight, customization, comfortable to wear, durability, discreteness, aesthetics. Textile antennas can transmit and receive electromagnetic signals, making them ideal for wireless communication in wearable applications.

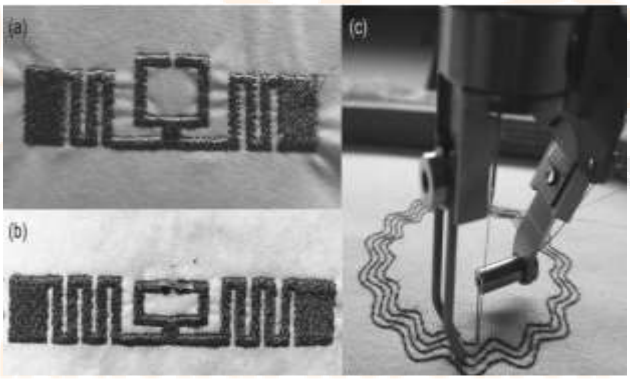

Fig. 2: Textile antenna

LITERATURE REVIEW

From the3 article [1], a Novel Wearable Textile Antenna Design for Medical and Wireless Applications was designed. The proposed antenna is a textile horn-shaped multiband wearable antenna which was designed by using CST Microwave Studio simulation software tool. This article consists of totally three antenna designs with various dimensions, but they proposed the antenna which gives best antenna performance results. The antenna was designed with horn shaped slots in the patch and the partial ground plane. The horn shaped antenna is designed with the rectangular slot cut from the rectangular ring patch antenna design. The design comprises of jeans material with dimensions 50×80 mm2, thickness of 0.56 mm & electric permittivity of 1.6 used as substrate and copper tape as a radiating patch with dimensions 24.008×53.675 mm2 & thickness 0.035 mm and the ground plane with dimensions 50×80 mm2. The feeding mechanism employed in antenna design is the Microstrip Line Feed technique. A rectangular wearable textile antenna is analyzed using the Transmission Line Model and Moment of Method techniques. The multiband wearable textile antenna is applicable for medical applications as it works in the ISM (Industrial, Scientific, and Medical) band and resonates at other frequencies suitable for various wireless applications.

From this article [2], a Dual-band Circularly Polarized Wearable Textile Antenna was designed. The proposed antenna was analyzed with the help of a commercial electro-magnetic solver, CST Microwave Studio simulation software tool in the design and optimization process. It consists of a full ground plane and a square microstrip patch with an SR-shaped slot on a single-layered felt substrate with a relative permittivity of $\varepsilon_r = 1.44$, a loss tangent, $\tan \delta = 0.044$, and a thickness, H of 3 mm. It is made up of 3-mm felt substrate with a 46 × 46 mm^2 square patch over 70 × 70 mm^2 ground plane. The square patch radiator is modified using slotted split-ring to cater for dual-band resonance. An SR-shaped slot is introduced in the center of square patch to facilitate bandwidth broadening of the upper band. The circular polarization (CP) characteristic is achieved through a diagonally fed probe and chamfered edge at each corner of the square patch. The antenna can provide dual-band coverage for the entire 1.8 and 2.6 GHz for the Fourth Generation (4G) Long Term Evolution (LTE), and for the 2.45-GHz Wireless Local Area Network (WLAN) applications.

DESIGN EQUATIONS & FLOWCHART

The microstrip patch antenna design equations are used to compute the dimensions of the antenna patch according to the resonating frequency. The wearable antenna is designed byusing the jeans material substrate having dielectric constant (εr) of 1.6 and loss tangent ($\tan\delta$)value 0.02. The thickness of the jeans material is taken as 1.12 mm.
The microstrip patch antenna design dimensions are computed by following steps:
Step 1: Calculation of the Width of patch (*W*).

$$W = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

The width of patch

Where, *c* is free space velocity of light (3. 108 m/s).
ε_r is dielectric constant of the substrate.
f_r is resonant frequency for the current design.
Step 2: Calculation of effective dielectric constant (r_{eff}).

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-\frac{1}{2}} \quad (2)$$

h is height or thickness of the substrate.
Step 3: Calculation of the length extension ΔL, which is given by

$$\Delta L = \frac{0.412h(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.268)\left(\frac{W}{h}-0.8\right)} \quad (3)$$

Step 4: Calculation of the length of patch

$$L = L_{reff} - 2\Delta L \quad (4)$$

L_{eff} is calculated as

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (5)$$

According to the equations used, the dimensions of the patch are 24.008 and 53.675 mm^2.
The dimensions of the parameters for the antenna structure in table

Parameters	Proposed Work Using HFSS		Existing Work Using CST MWS
	Design 1 (50x80x1.12 mm^2)	Design 2 (80x80x1.12 mm^2)	
Length of Ground	50 mm	80 mm	50 mm
Width of Ground	80 mm	80 mm	80 mm
Length of Substrate	50 mm	80 mm	50 mm
Width of Substrate	80 mm	80 mm	80 mm
Height of Substrate	1.12 mm	1.12 mm	0.56 mm
Loss tangent	0.02		0.0631
Length of Patch	24.008 mm	24.008 mm	24.008 mm

Width of Patch	53.85 mm	53.85 mm	53.675 mm
Height of the Patch	--	--	0.035 mm
Length of Feedline	13 mm	43 mm	13 mm
Width of Feedline	4.23 mm	4.23 mm	2.113 mm

Table. 1: Proposed and Existing antennas

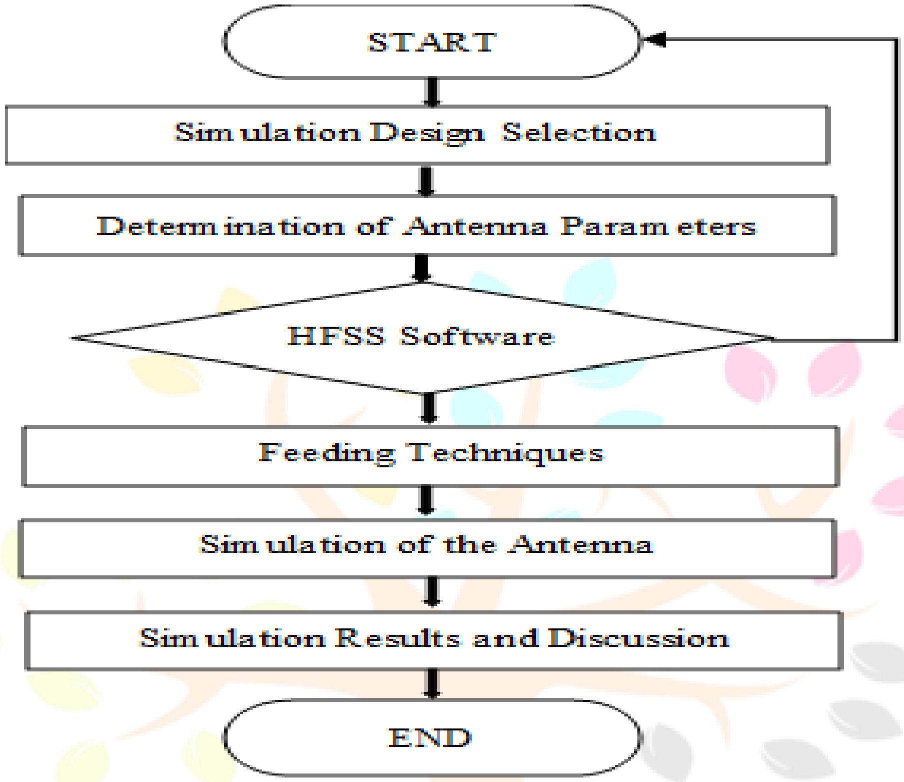

Fig. 3: Flow chart for Designing the Proposed antennas

STRUCTURES OF PROPOSED ANTENNAS

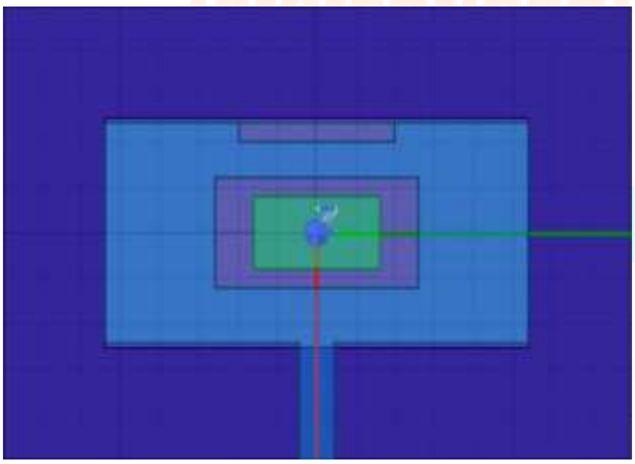

Fig. 4:2D view for Design1

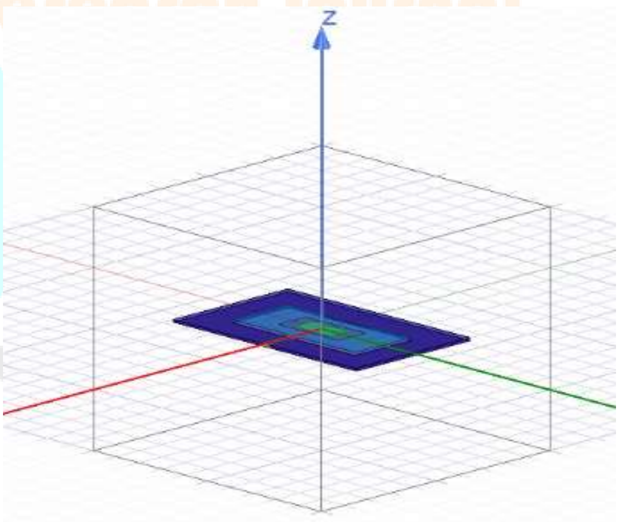

Fig. 5:3D view for Design1

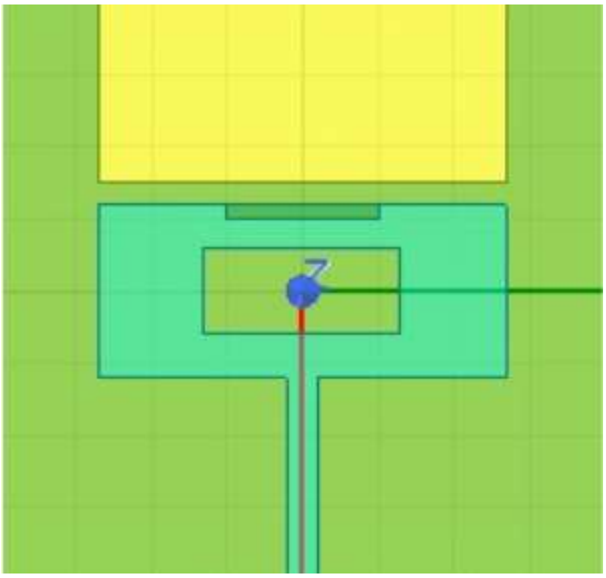

Fig. 6:2D view for Design2

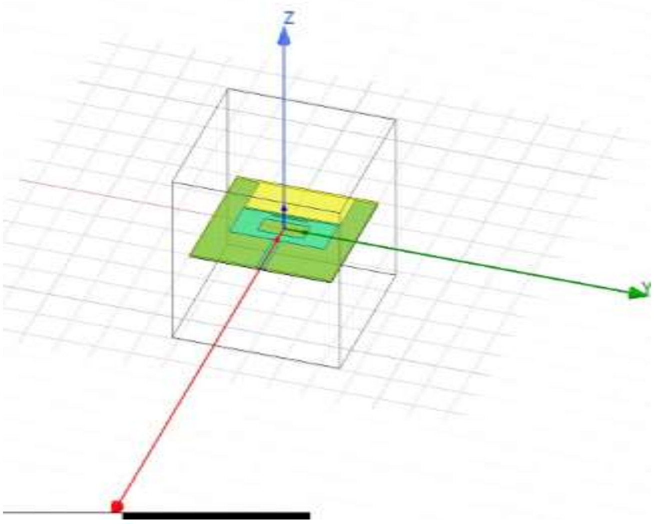

Fig. 7:3D view for Design2

RESULTS AND DISCUSSION

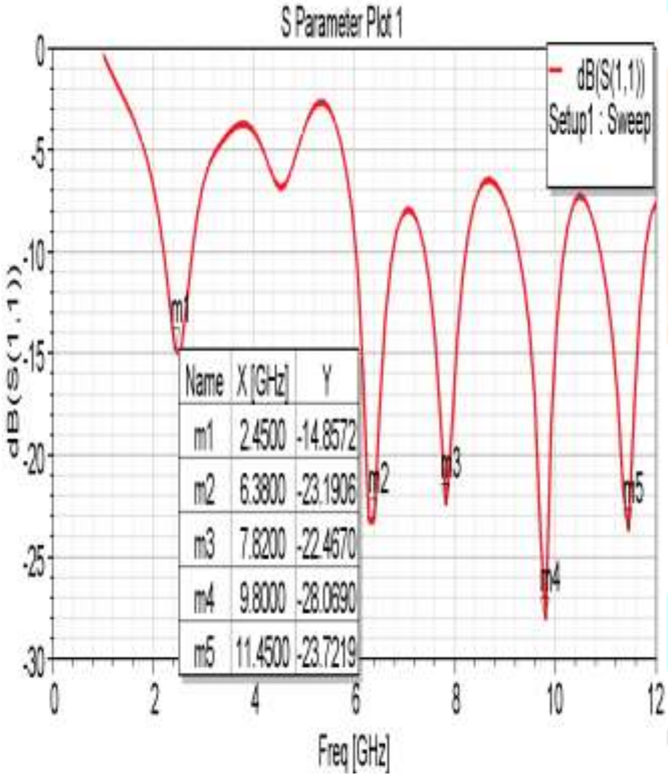

Fig. 8: S-Parameter for Design1

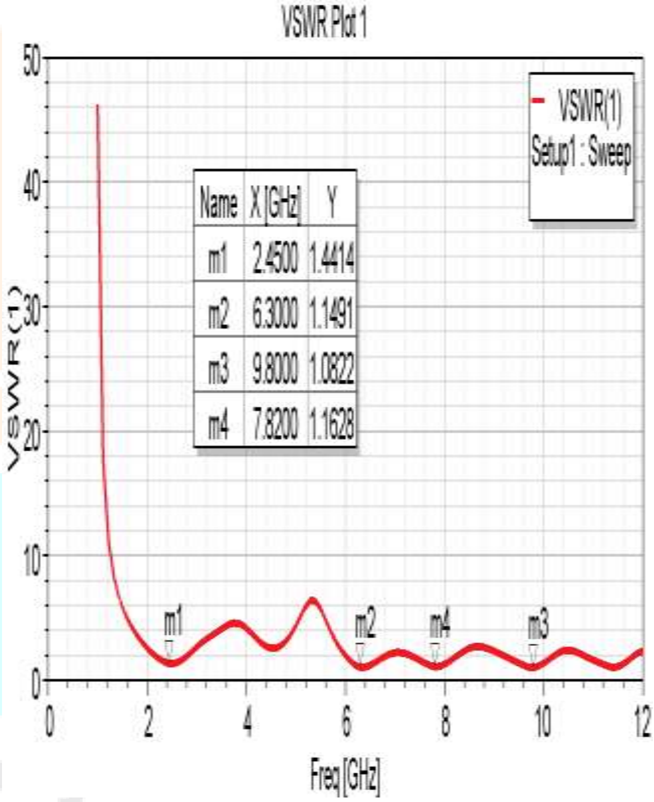

Fig. 9: vswr for Design1

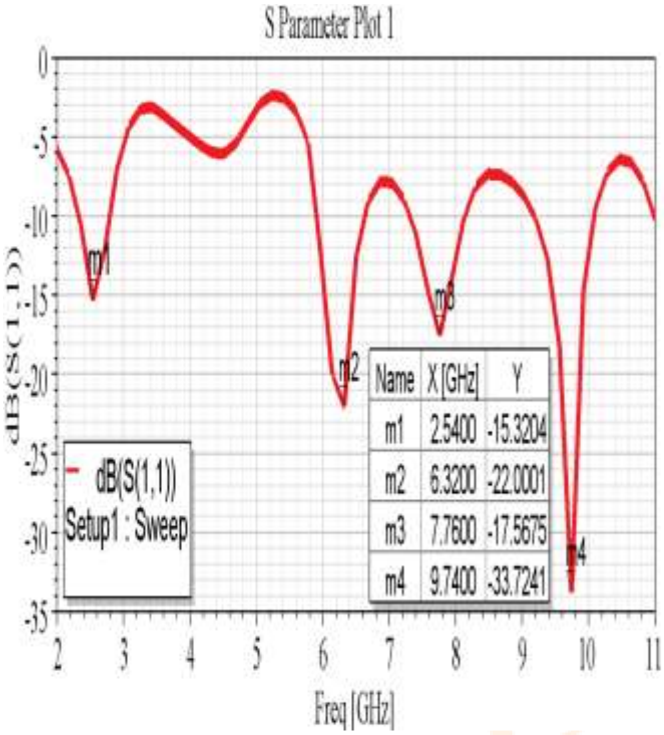

Fig. 10: S-Parameter for Design2

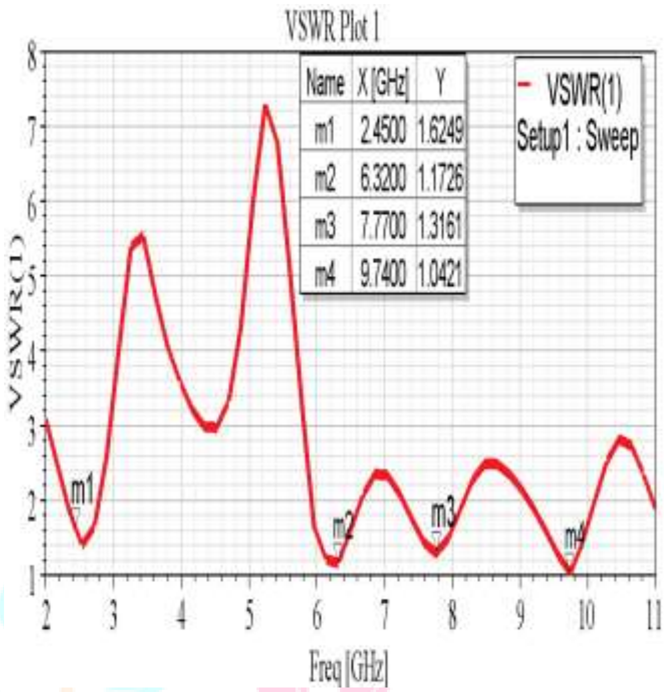

Fig. 11: vswr plot for Design2

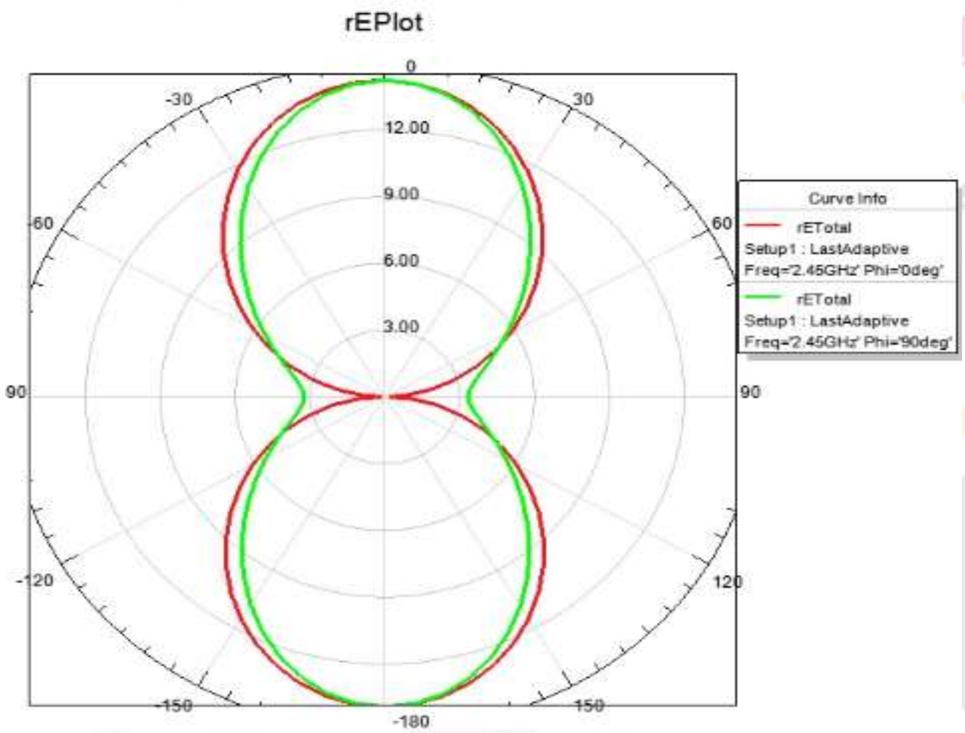

Fig. 12: 2D Radiation plot for Design1

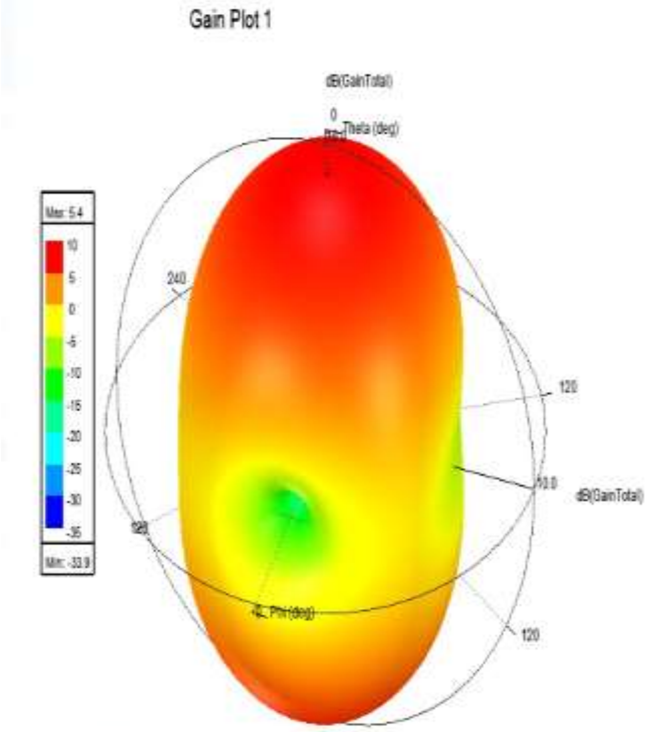

Fig. 13: Gain polar plot at 2.45GHZ for Design1

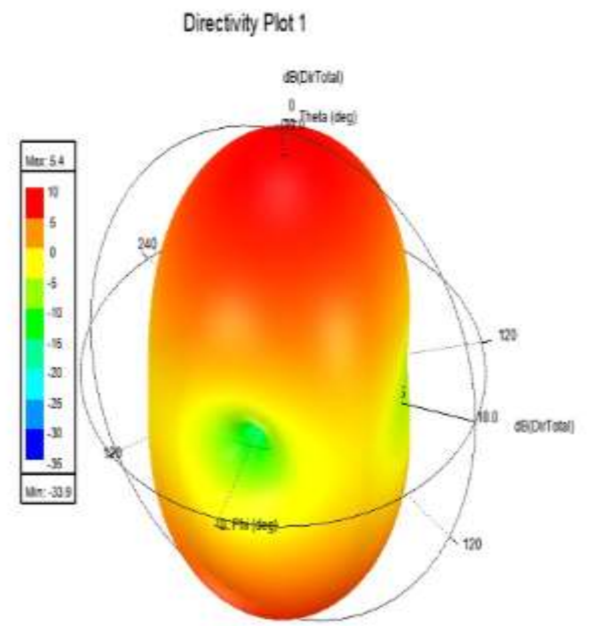

Fig. 14: Directivity polar plot at 2.45GHZfor Design1

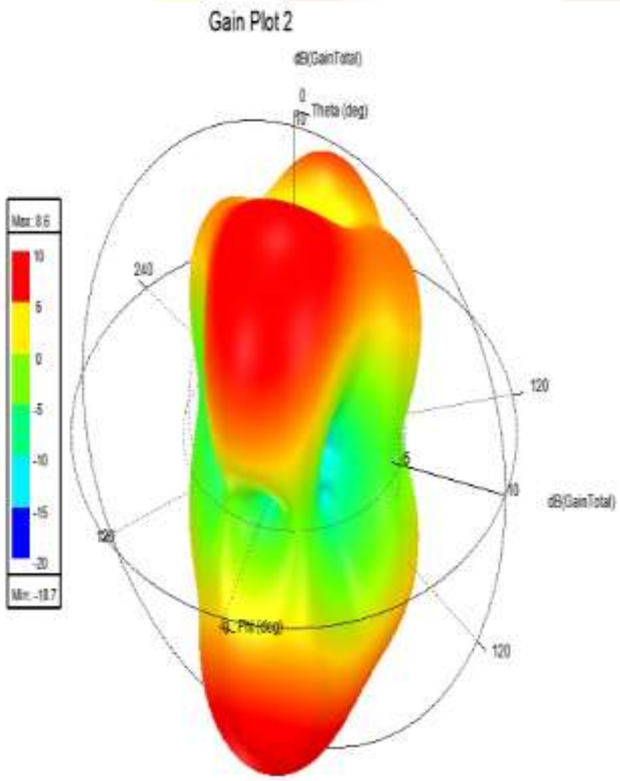

Fig. 15: Gain polar plot at 6.38GHZ for Design1

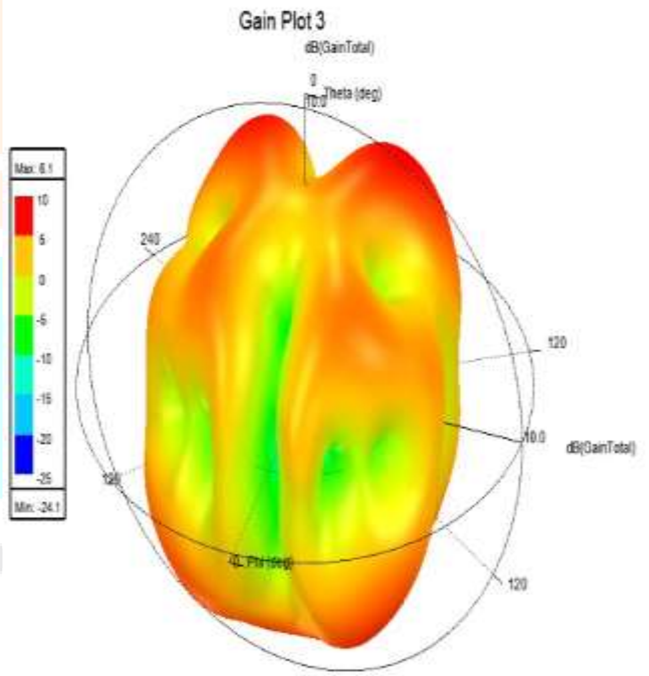

Fig. 16: Gain polar plot at 7.82GHZ for Design1

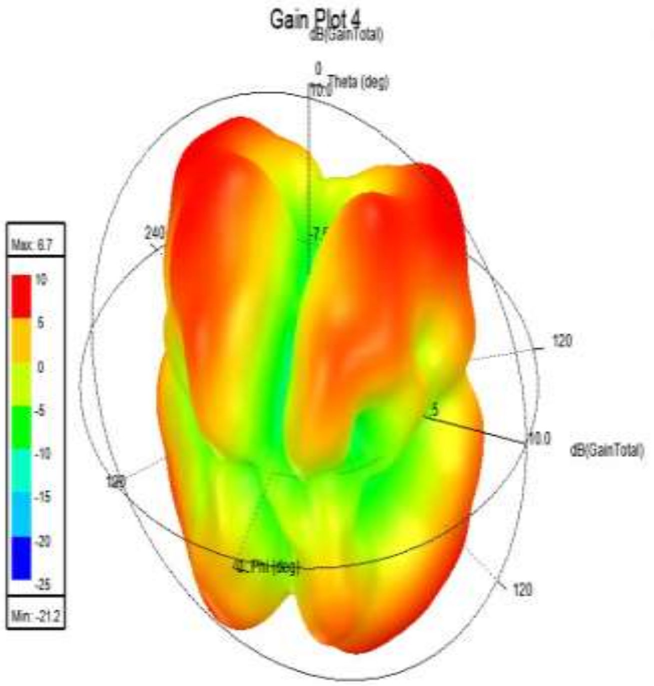

Fig. 17: Gain polar plot at 9.8GHZ for Design1

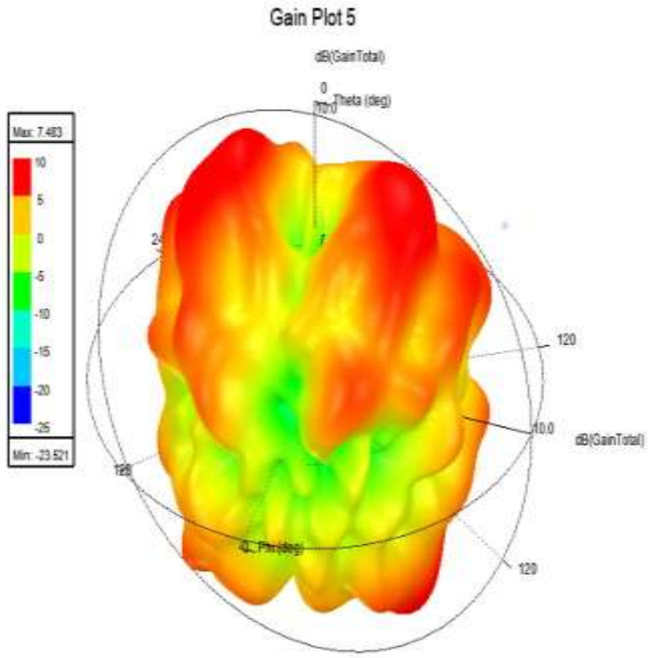

Fig. 18: Gain polar plot at 11.45GHZ for Design1

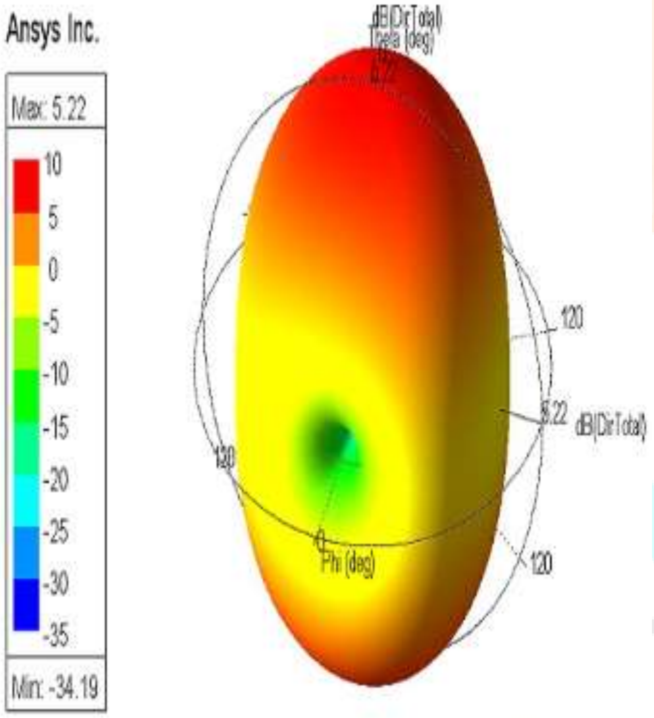

Fig. 19: Gain polar plot at 2.54GHZ for Design2

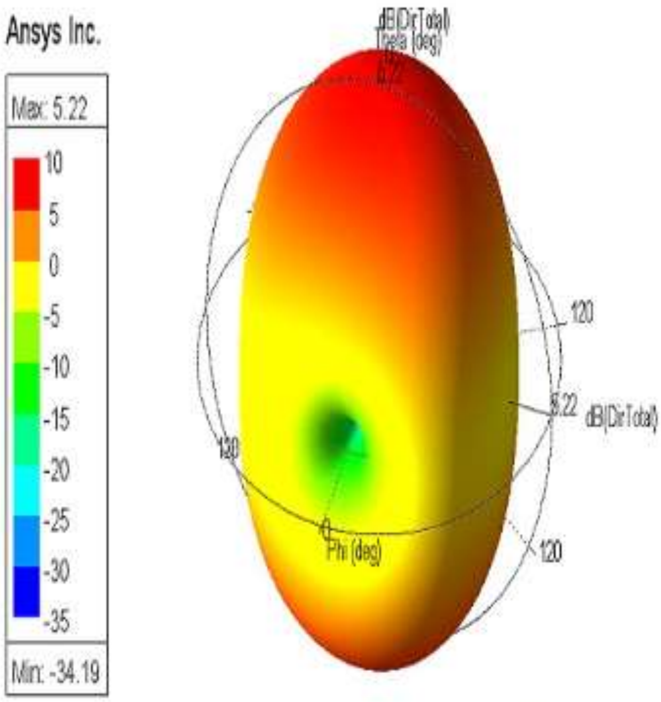

Fig. 20: Directivity polar plot at 2.54GHZ for Design2

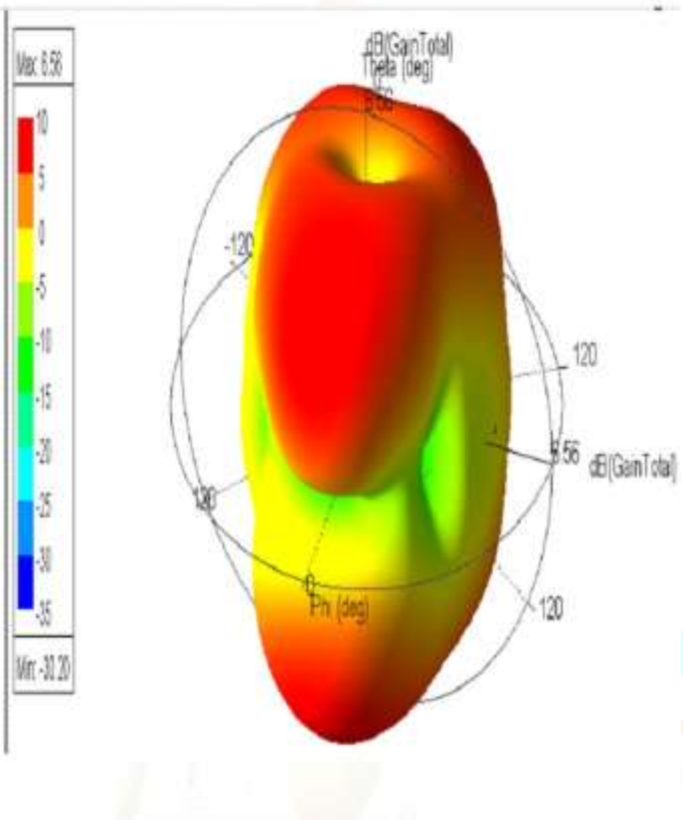

Fig. 21: Gain polar plot at 6.32GHZ for Design2

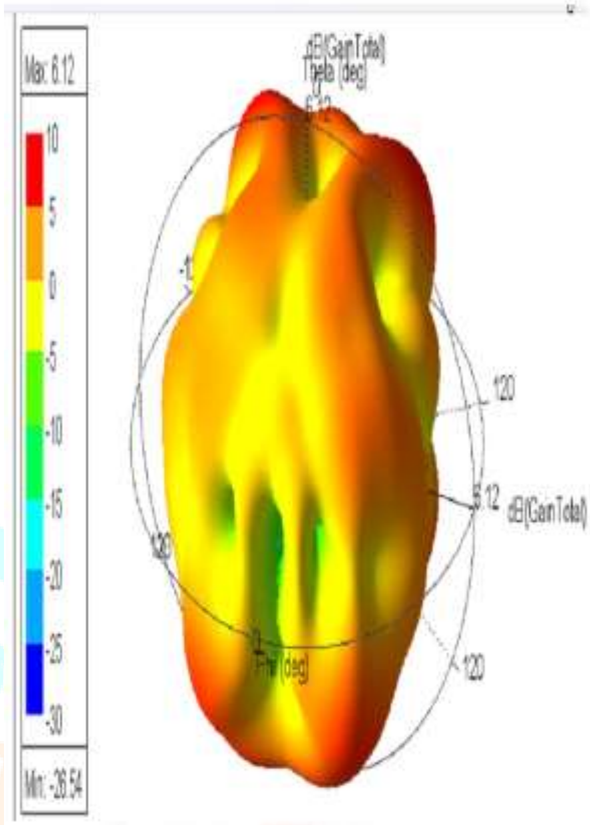

Fig. 22: Gain polar plot at 7.76GHZ for Design2

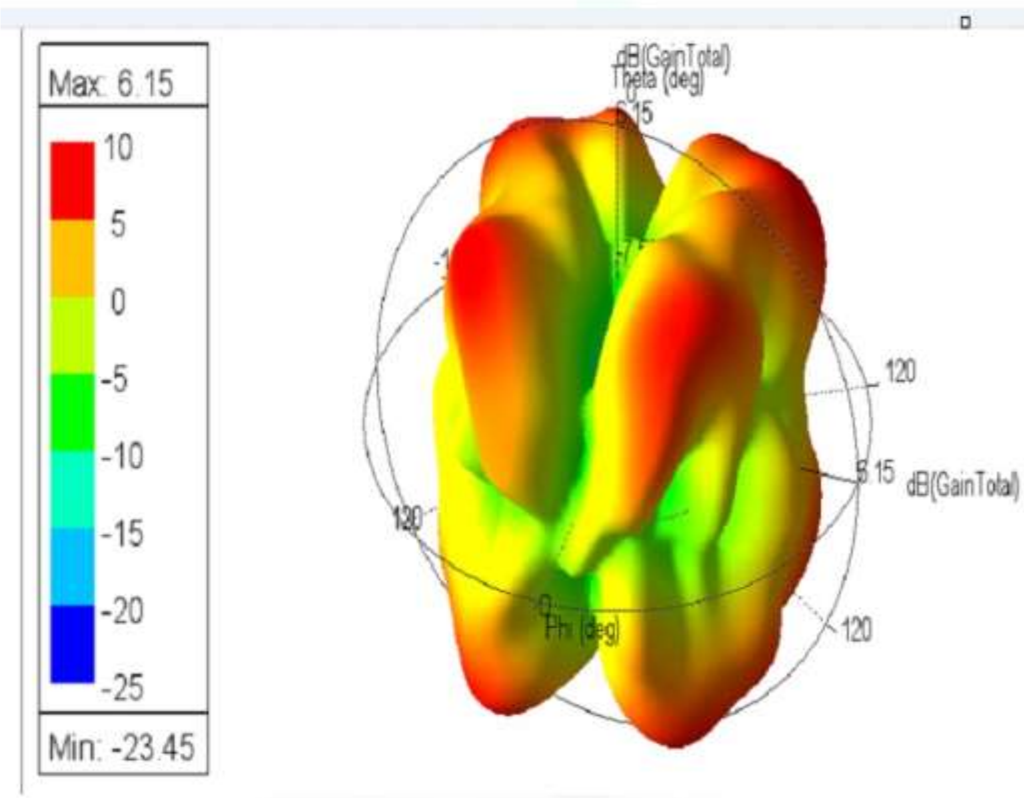

Fig. 23: Gain polar plot at 9.74GHZ for Design2

Resonating Frequency (GHz)	S-parameter (dB)	VSWR	Gain (dB)
2.45 GHz	-14.8572 dB	1.44	5.4 dB
6.38 GHz	-23.1906 dB	1.14	8.6 dB
7.82 GHz	-22.467 dB	1.08	6.1 dB
9.8 GHz	-28.069 dB	1.16	6.7 dB
11.45 GHz	-23.7319 dB	---	7.483 dB

Table. 2: Result analysis for Design1

Resonating Frequency (GHz)	S-parameter (dB)	VSWR	Gain (dB)
2.54 GHz	-15.3204 dB	1.62	5.22 dB
6.32 GHz	-22.0001 dB	1.17	6.56 dB
7.76 GHz	-17.5675 dB	1.31	6.12 dB
9.74 GHz	-33.7241 dB	1.04	6.15 dB

Table. 3: Result analysis for Design2

Antenna Parameters	Proposed Work Using HFSS		Existing Work Using CST MWS
	Design 1	Design 2	
Operating Frequency (GHz)	2.45 GHz 6.38 GHz 7.82 GHz 9.8 GHz 11.45 GHz	2.54 GHz 6.32 GHz 7.76 GHz 9.74 GHz	2.39 GHz 4.5 GHz 6.8 GHz 8.4 GHz
Return loss (dB)	-14.85 dB at 2.45 GHz	-15.32 dB at 2.54 GHz	-20.5 dB at 2.39 GHz
VSWR	1.44 at 2.45 GHz	1.62 at 2.45 GHz	1.21 at 2.45GHz
Gain (dB)	5.4 dB at 2.45 GHz	5.22 dB at 2.45 GHz	4.74 dB at 2.45 GHz
Directivity (dB)	5.4 dB at 2.45 GHz	5.22 dB at 2.45 GHz	---
Efficiency (%)	100% at 2.45 GHz	100% at 2.45 GHz	---

Table. 4: Comparison between Proposed and Existing antenna

The Proposed Rectangular Shaped Wearable Textile Antenna (Design 1) is simulated using Ansys HFSS Software. The Fig shows the Proposed Multiband Wearable Textile Antenna (Design 1) provides resonance at Wi-Fi (2.45GHz), ISM band (2.4-2.48 GHz), C-band (6.38 GHz & 7.82 GHz), X-band (9.8 GHz) applications. The Antenna resonates at 2.45 GHz, 6.38 GHz, 7.82 GHz, 9.8 GHz and 11.45 GHz with Reflection Co-efficients of -14.8572 dB, - 23.1906 dB, -22.467 dB, -28.069 dB and -23.7219 dB respectively. Compared to the reference paper, their Proposed Antenna doesn't resonate at 2.45 GHz frequency but resonates at 2.39 GHz however our Proposed Antenna resonates exactly at 2.45 GHz Resonant Frequency. The Fig shows the Bandwidth Characteristics of Proposed Antenna at multiple frequencies.The VSWR value is 1.4414 at 2.45GHz resonant frequency, 1.1491 at 6.38 GHz, 1.0822 at 9.8 GHz and 1.1628 at 7.82 GHz which shows a very good value has a very suitable for Wireless Communications.

Conclusion

The Proposed Textile Rectangular Shaped Multiband Wearable Antenna is applicable in ISM band (2.4–2.48 GHz), Wi-Fi (2.45 GHz), C-band (6.38 GHz & 7.82 GHz) and X-band (9.8 GHz) applications. The Proposed Antenna is successful to work as a Multiband Antenna with small dimensional geometry using thin textile substrate of 1.12 mm. The measured S11 parametric results validate the antenna with Jeans Substrate as a Comfortable Wearable Antenna. The Design 1 Textile Antenna (Proposed Antenna) provides 5.4 dB for both Gain and Directivity at 2.45 GHz and provides 100 % efficiency at 2.45 GHz resonant frequency. And also, the Design 2 Textile Antenna provides 5.22 dB for both Gain and Directivity at 2.54 GHz resonant frequency and provides 100 % efficiency at 2.54 GHz resonant frequency.

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