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Wearable Textile Antenna Designs for Multiband Frequencies

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Abstract:
This paper explains the implementation of two different microstrip feeding techniques i.e. with and without inset feed.This paper also deals with the comparative study of the behaviour of the antenna designs for different substrate materials and the effect of the slot on the antenna performance. The antenna design with inset feed has return loss of -42.947dB and the antenna design without inset feed design has -10.53 dB return loss at 2.5GHz. The return loss of Jeans substrate with inset fee design is -43.44dB whereas the return loss of curtain cotton and polyester substrate is-14.44dB&-13.19 dB respectively. After analysing various antenna parameters like gain, return loss and the bandwidth, it has been observed that the microstrip without inset feed with jeans material is better than curtain cotton and polyester to meet the desired features of the wearable antenna designs. The proposed antenna designs resonate at multiband frequencies suitable for WiFi, Bluetooth ,WiMax ,Medical and RF applications

Keywords: *Servicesss*

I. INTRODUCTION

Nowadays, there is rapid growth in the development of wearable technologies. The wearable devices demand and requirements in the daily routine life has arose more and more advancement in this field. The area of applications of the wearable devices cover each and every aspect which includes rescue and search operations[1], remote computing, public safety[2],military , medical etc.

To design the wearable antennas, different textile materials are used like cotton, foam, polycot, jeans, nylon etc.[3-4]. The textile materials are flexible, durable and sustainable in different areas of applications. Therefore, demand for wearable textile materials is increasing vigorously. Different type of antennas has been designed using different patches with various textile substrate materials for multiband frequencies. The wearable antennas are designed for various applications which includeWifi,WiMax, Bluetooth and medical applications [5].

In the proposed antenna designs, microstrip patch antennas are designed which work in various frequency bands at the same time. In this paper, the different antennas are designed with different textile materials and different feeding structures. The different antenna designs resonates at different frequency band (1.4GHz, 2.4 GHz, 3 GHz and 5 GHz) which can be used for various wireless communication applications like WiFi, WiMax, GPS etc.

II. ANTENNA DESIGN

The antenna design of microstrip patch antenna(Antenna1)using the microstrip feeding technique with the inset feed line is designed as shown in Fig.1.The microstrip feeding technique is used with inset feed length of different lengths to understand the effect of inset feed length on the antenna performance. The length of the inset feed (Fi) is increased from 10.5 mm to 12.45 mm and the return loss graph is analysed for both the Fi dimensions.

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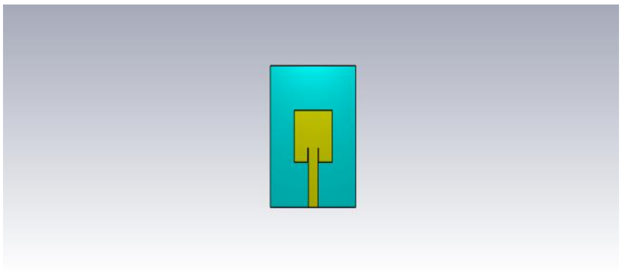

Fig.1. Microstrip Textile Patch Antenna Design using Jeans as a Substrate with inset feed.

The substrate used for the design is jeans textile material with relative permittivity of 1.6 and loss tanget is 0.07. The thickness of jeans substrate is 3.5mm. The copper annealed is used for the ground plane and the patch. The parametric values of the antenna design is shown in Table 1.

Table 1. Parametric values of proposed antenna designs

Parameters	**Description**	**Values**
Wt	Width of patch	53.675mm
Lt	Length of patch	44.262mm
Hs	Height of substrate	3.5mm
Ls	Length of substrate	120mm
Ws	Width of substrate	120mm
Lg	Length of ground	120mm
Wg	Width of ground	120mm
Ht	Height of patch	0.03mm
Wf	Width of feedline	13.198mm

The another antenna (Antenna 2) is designed with the microstrip feeding technique without the inset feed as shown in Fig.2. The another dimensions and parameters are kept same as that of Antenna 1.

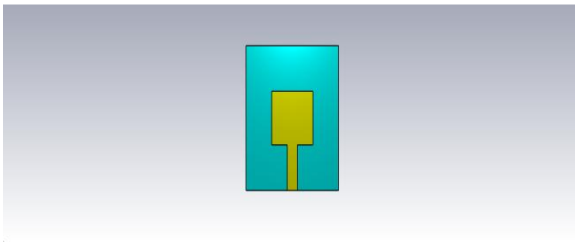

Fig.2. Antenna2: Microstrip Textile Patch Antenna Design using Jeans as a Substrate without inset feed technique

The Antenna 3 is designed by introducing slot to further improve the antenna performance parametersas shown in Fig.3.The Antenna design is also tested with the FR4 substrateto compare the performance of the textile and the conventional substrate material antenna.

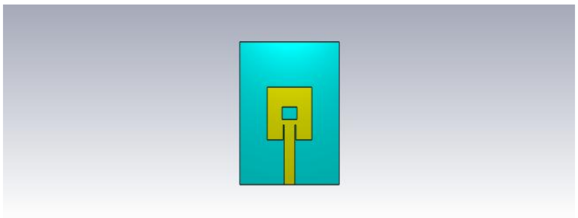

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Fig.3: Antenna3: Microstrip Textile patch antenna with slot at centre

Further the Antenna 1 & Antenna2are tested with different textile substrates to compare different textile materials that can be used in the wearable antenna designs. Table 2 describes the dielectric constant of different substrates that are used in the microstrip patch antenna design.

Table 2: **Different Substrate materials used in designs with dielectric constant**

Textile Material	Dielectric Constant	Loss Tangent
Curtain Cotton	1.54	0.01395
Polyester	1.44	0.01
Polycot	1.26	0.01386
Jeans	1.67	0.07
FR4	4.3	0.02

III. RESULTS AND DISCUSSIONS

The return loss characteristics of the simulated Antenna1 design using CST STUDIO suite 2018 are

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shown in Fig.4. The return loss plot shows that the antenna resonates at frequency band 2.5 GHz and 4.2 GHz. It shows that with the increase in length of the inset feed, the return loss changes from -43 dB to -17 dB at 2.5 GHz. But at 4.2 GHz frequency there is slight variation in the return loss.The increase in inset feed length causes very less variation in return loss at higher frequencies.

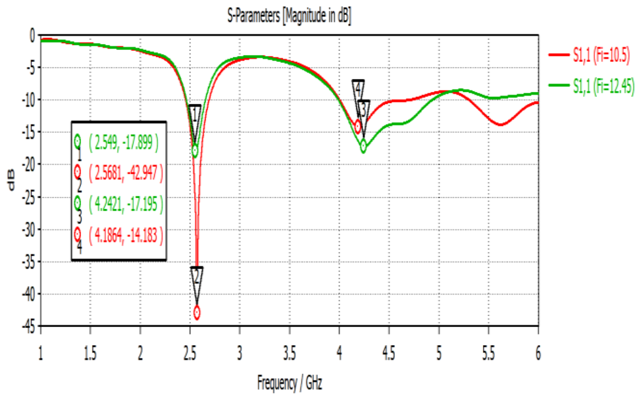

Fig 4: Return loss with the change in the dimensions of inset feed(Fi)

The Antenna 2 is designed with the modification in the feedline structure i.e. microstripfeedline without inset feed. This modification is done to compare the two different techniques so that better technique can be opted in further improved antenna designs.

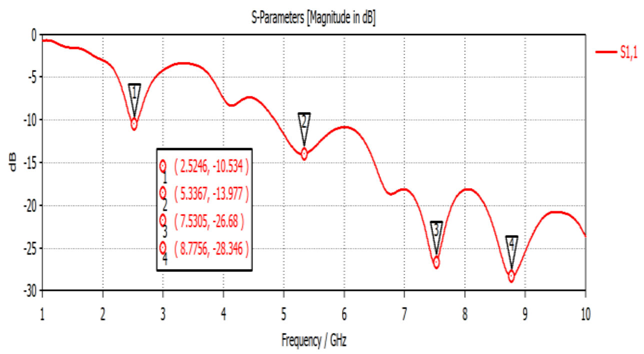

Fig 5: Return loss characteristics of Antenna 2 (without inset feed)

The Fig.5 shows the return loss characteristics of Antenna 2 i.e. the antenna without inset feed technique.The return loss characteristics comparison from Fig. 4 & Fig.5 reveals that at frequency 2.5 GHz, the return loss for Antenna 1 is -43.23 dB whereas for Antenna 2 the return loss is -10dB at 2.5GHz.At higher frequencies, the Antenna 2 is proved to be better than the Antenna 1 design. So, for the frequencies which work on higher frequencies, the antenna without inset feed technique is the better option to be opted as an antenna design.

The antenna is further modified to as an antenna design (Antenna 3) in which slot is introduced to analyse the effect of slot on the antenna performance parameters. The Fig.6 reveals that with the introduction of slot in the design, the resonance frequency slightly changes from 2.5 GHz to 2.4 GHz and 4.18 GHz to 4.9GHz.The return loss of antenna design without slot is -42.513dB at resonance frequency 2.5 GHz whereas for the design with slot the return loss is -17.43 dB at 2.42 GHz. At higher resonating frequencies Antenna 2 provides –14.17dB at 4.19 GHz & -13.815 dB at 5.6GHz .At higher resonating frequencies Antenna 32 provides –28.93 dB at 4.9 GHz & -31.9 dB at 5.4GHz.The antenna designs with slot shows that the return loss improves at higher frequencies.

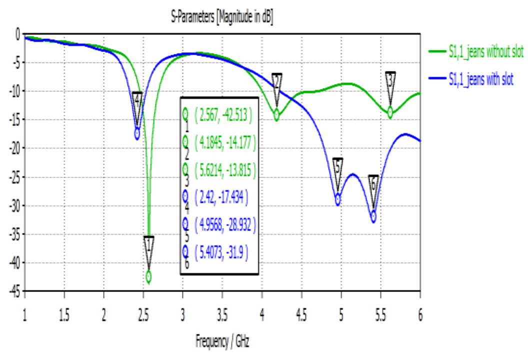

Fig 6: Effect of slot on the return loss in jeans textile antenna design

The Fig.7 shows the return loss parameters for the FR4 & Jeans substrate material for Antenna 3. The return loss for FR4 substrate is -17.063 dB, -19.62dB & -16.02 dB at 2.9 GHz, 3.8 GHz & 4.9 GHz respectively. The return loss for Jeans substrate is -17.32 dB, -28.95 dB & -32.058 dB at 2.4 GHz, 4.9 GHz & 5.4 GHz respectively.The Fig. 8 reveals that the gain value for FR4 substrate is 1.98dB and the gain value for Jeans substrate is 4.19 dB. The directivity for FR4 substrate is 6.2 dBi whereas for

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the Jeans substrate the directivity is 9.05dBi. From the Fig.7, it is observed that the bandwidth for the FR4 antenna design is 4.63 % at resonant frequency 2.96 GHz whereas the bandwidth for Jeans slot antenna design is 8.38% at resonant frequency 2.54 GHz. The Fig 7 also reveals that the bandwidth is 4.63 % and 3.83 % at 2.96 GHz and 3.83 GHz respectively. Thus, with the increase in resonance frequency, the bandwidth also increases for FR4 slot antenna design. Hence the Jeans textile material is proved to be much better than the conventional FR4 substrate based antenna design as the textile jeans substrate provides better return loss at the resonance frequencies 2.4 GHz, 4.9GHz and 5.4 GHz and has higher gain, bandwidth and directivity values.The comparison of the antenna performance parameters is shown in the Table I.

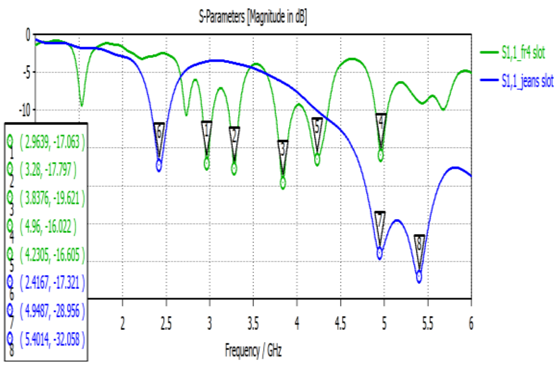
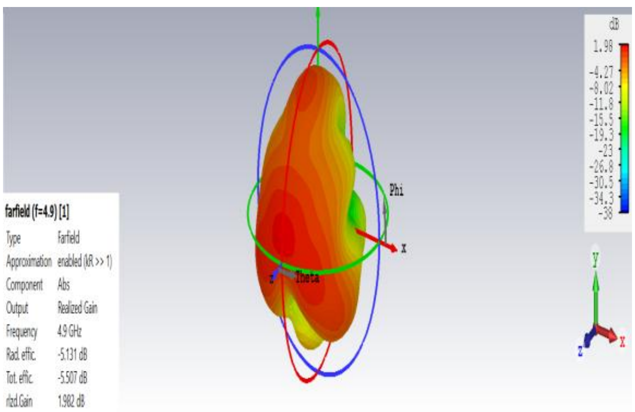
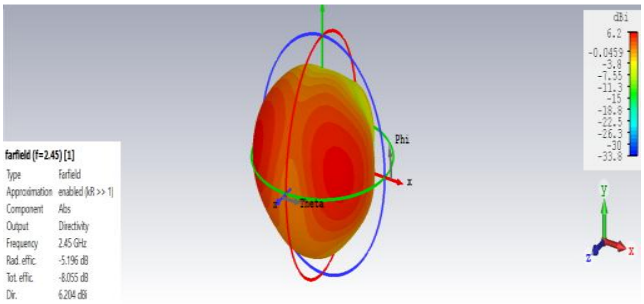


Fig 7: Comparison of S-Parameters of Jeans and FR4 with slot in the patch antenna design





i) ii)

Fig 8.a)FR4 substrate with slot in the patch antenna design: i) Gain measurement ii) Directivity measurement

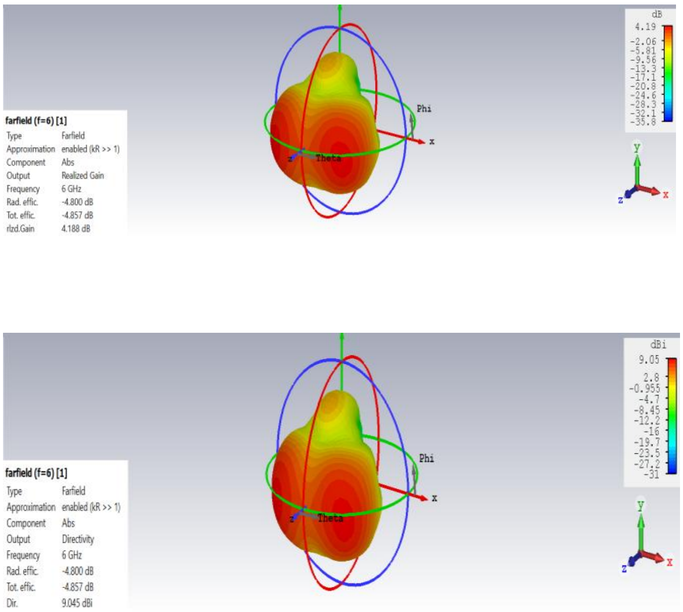


Fig 8.b) Jeans substrate with slot in the patch antenna design: i) Gainmeasurementii)Directivity measurement

Table I: Comparison of various performance parameters of microstrip patch antenna design with the slot in the patch

Substrate	Return Loss	Gain	Directivity	Resonant Frequency
FR4	-16.022 dB	1.98dB	6.2 dBi	4.9GHz
Jeans	-28.956 dB	4.19dB	9.05dBi	4.9GHz

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Comparison of antenna performance using different substrate materials

The two different antennas i.e. Antenna 1(with inset feed)& Antenna2(without inset feed) are designed using different substrate materials so that the choice can be made for the better substrate material based on the antenna performance parameters.

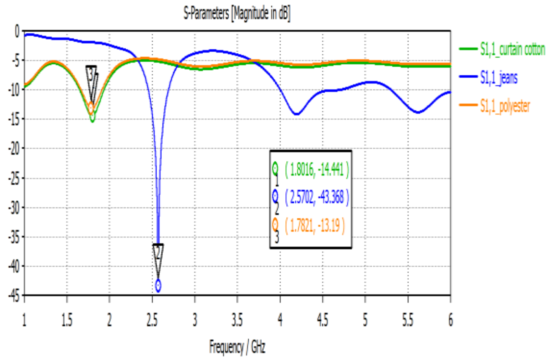
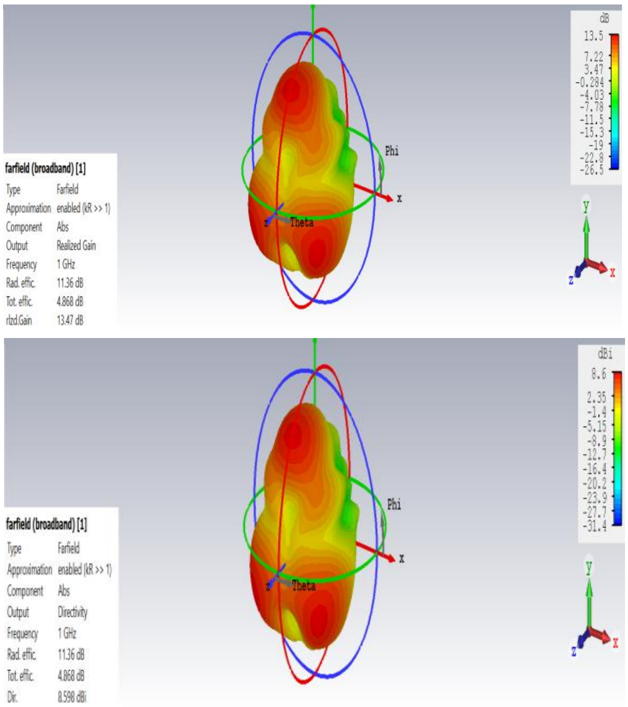
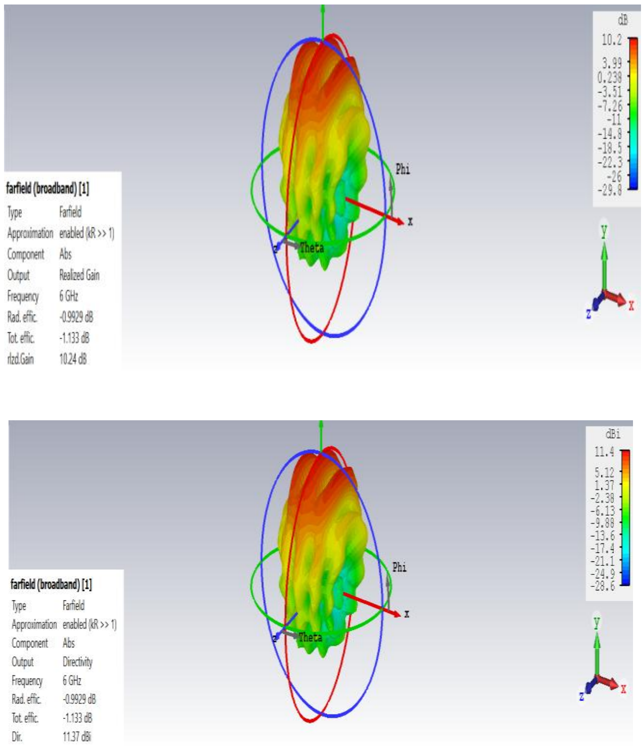


Fig 9: Comparison of S-Parameters with different substrates with inset feed



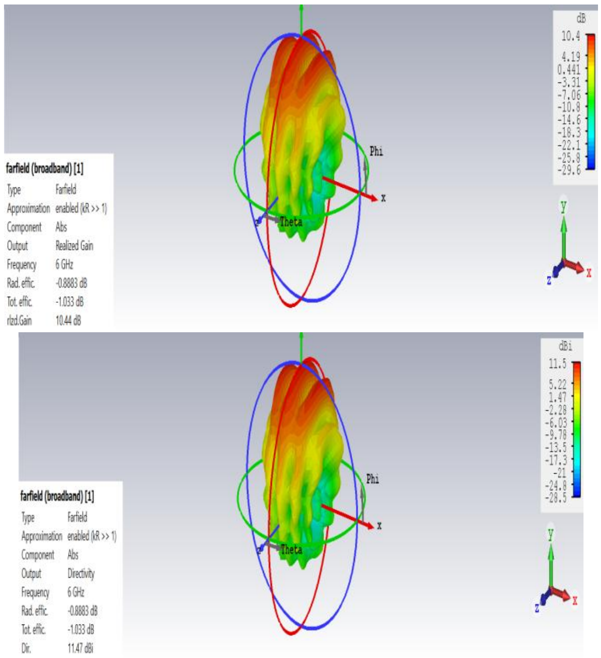
i) ii)

Fig 9.a) Jeans substrate Microstrip patch antenna design with inset feed: i)Gainmeasurementii) Directivity Measurement



i) ii)

Fig 9 b) Curtain Cotton substrate Microstrip patch antenna design with inset feed: i) Gain measurement ii) DirectivityMeasuremet



i) ii)

Fig 9 c) Polyester substrate Microstrip patch antenna design with inset feed: i) Gain Measurement ii)Directivity Measurement

Table II: Comparison of various performance parameters of microstrip patch antenna design with inset feed using different substrate material.

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Substrate material	Return loss	Resonant Frequency	Gain	Directivity
Curtain cotton	-14.441 dB	1.78 GHz	10.2 dB	11.4 dBi
Jeans	-43.368 dB	2.5GHz	13.5 dB	8.6 dBi
Polyester	-13.19 dB	1.78 GHz	10.4 dB	11.5 dBi

The microstrip patch antenna with inset feed antenna performance parameters are shown in Fig.9 . It shows that the jeans material provides the return loss of-43.368dB at 2.5 GHz, the curtain cotton and polyester substrate resonates at 1.8 GHz frequency with return loss of -14dB approx. The gain value for jeans, curtain cottonand polyester material is 13.5 dB,10.2dB&10.4 dB respectively. The directivity for jeans, curtain cotton and polyester material is 8.6 dBi,11.4dBi& 11.5 dBirespectively.The Table II compares the performance parameters for the three different substrates. The comparison proves that the jeans textile substrate has lower directivity but higher gain value as compared to the curtain cotton and the polyester substrate materials. The curtain cotton and the polyester material provides almost same performance parameters.So, the jeans material is proved to be the better substrate material to design an antenna which can be used for WiFi, WiMax, Bluetooth and medical applications.

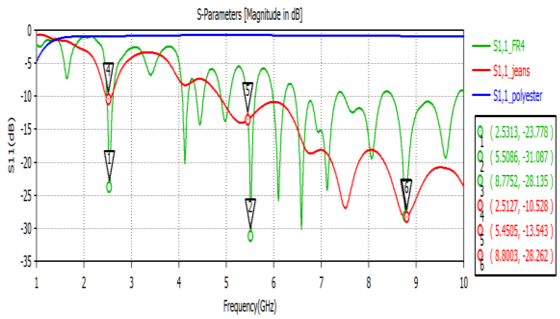
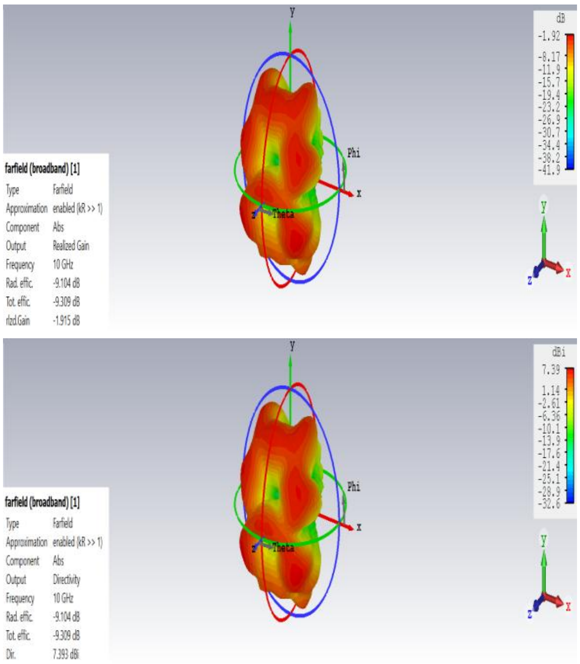
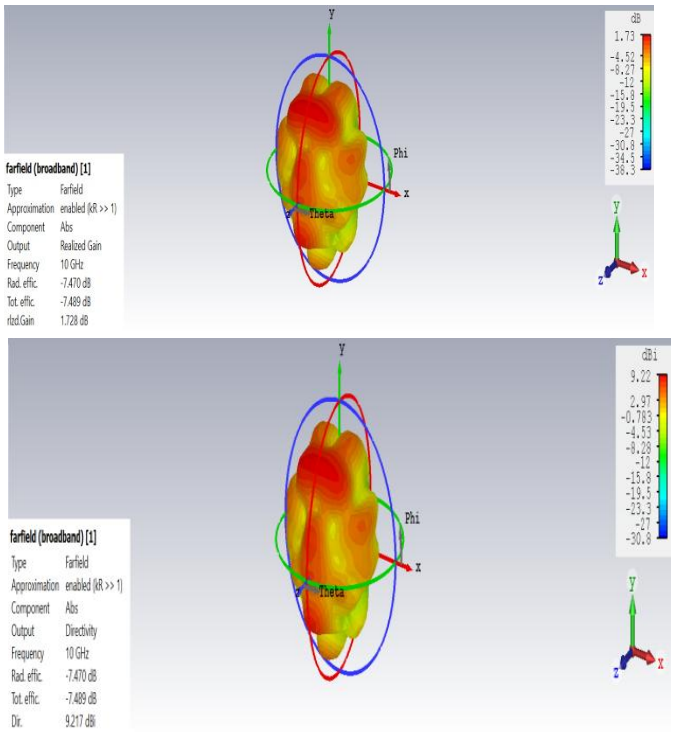


Fig 10 a): Comparison of S-Parameters with different substrates without inset feed



i) ii)

Fig 9.b) FR4 substrate Microstrip patch antenna design without inset feed: i) Gain Measurement ii)Directivity measurement



i) ii)

Fig 9.c) Jeans substrate Microstrip patch antenna design without inset feed:i) Gain ii) Directivity measurement

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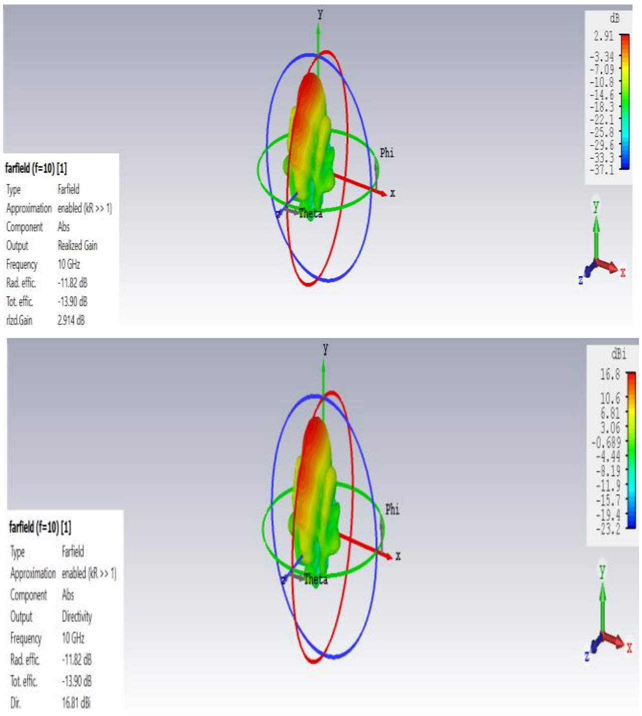
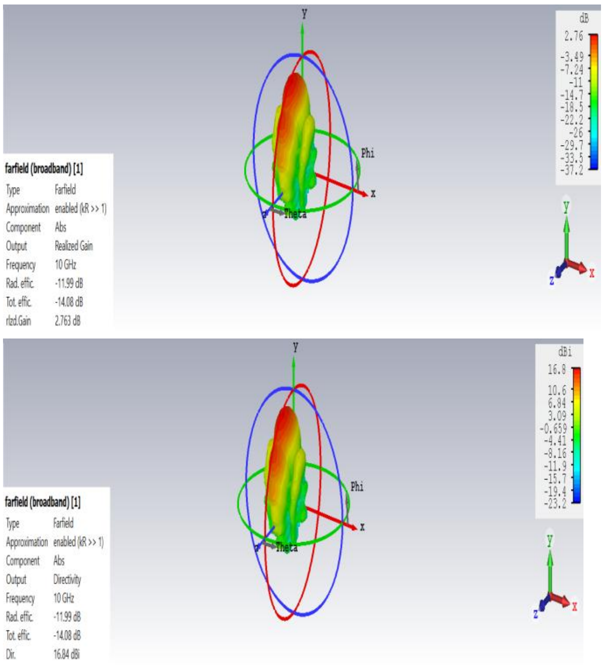


i)

ii)

Fig 10 a) Curtain cotton substrate Microstrip patch antenna design without inset feed: i) Gain ii)Directivity measurement



i)

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Fig10. b) Polyester substrate Microstrip patch antenna design without inset feed: i) Gain ii) Directivity measurement

Table III: Comparison of various performance parameters of microstrip patch antenna design without inset feed using different substrate material.

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The antenna performance parameters of Antenna 2design using different substrates material are shown in Fig.10.The comparison table TableIIIrevealsthe comparison between the jeans substrate and the conventional FR4 substrate material. At higher frequency of 8.7 GHz, the FR4 and the Jeans material provides good return loss of -28.2 dB. The gain value for Jeans substrate is better than the FR4 substrate at 8.7 GHz.The directivity for FR4 substate is 7.39 dBi and for Jeans substrate is 9.22 dBi. Fig 10(a) and Fig 10(b) shows that the curtain cotton and the polyester provides same antenna performance. Thus the antenna design with the Jeans substrate is better than FR4, polyester and curtain cotton material at different resonance frequencies .The results proved that jeans material is better substrate choice for wearable antenna design at 2.5 GHz, 5.5 GHz & 8.7 GHz which cover ISM band , RF applications and wireless applications like GSM, GPS, Wifi, WiMAX& Bluetooth.

IV. CONCLUSION

This paper illustrates the microstrip patch antenna for multiband applications with the comparison ofdifferent antenna designs. The paper reveals that the antenna design without inset feed has better return loss at higher frequencies than the inset feed design whereas for the applications of lower frequencies, the antenna design with inset feed design is better choice.The paper also includes the slot effect on the antenna performance parameters like bandwidth, gain and the return loss. The two different jeans substrate antenna designs with and without slot in the patch provides maximum return loss of -31.9 dB and -42.51dB respectively. At resonating frequency of 2.4 GHz, jeans without slot is better option than the slot antenna but if requirement is of higher frequency, slot antenna is better option.So, for the higher frequencies,it is better to include slot in the antenna design for various high frequency applications. The antennas are designed using different substrate materials like jeans, curtain cotton, polyester and FR4 substrate.The gain value for jeans material with slot is 4.19 dB and the FR4 substrate with slot provides 1.98dB gain. It is observed that the bandwidth for the FR4 antenna design is 4.63 % at resonant frequency 2.96 GHz whereas the bandwidth for Jeans slot antenna design is 8.38% at resonant frequency 2.54 GHz. The paper also reveals that the bandwidth is 4.63 % and 3.83 % at 2.96 GHz and 3.83 GHz respectively for FR4 slot antenna design. Thus, with the increase in resonance frequency, the bandwidth also increases. Therefore, the slot antenna design with textile Jeans substrate is better than the conventional FR4 substrate.The textile antenna design with jeans substrate has more gain(13.5 dB) than the curtain cotton(10.2dB) and polyestersubstrate(10.4dB). The results proved that jeans material is better substrate choice for wearable antenna design at 2.5 GHz, 5.5 GHz &8.7 GHz which cover ISM band, RF applications and wireless applications like GSM, GPS, Wifi, WiMAX& Bluetooth. Hence, this research can be helpful in the further advancements in antenna designs for various multiband frequency applications.

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