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# Design of High Gain Wearable Rectangular Microstrip Textile Antenna for Wireless Application

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***Abstract: Wireless body area networks have paying more attention in the recent decade. The microstrip textile antenna used for wireless applications (ISM Band) such as emergency rescue, health monitoring and medical care. In this paper, the square patch microstrip textile antenna is introduced which is mounted on the flexible jeans substrate. The physical size of the suggested/simulated textile antenna is 52.99 X 45.23 mm$^2$ & the jean's material is used as substrate with its relative permittivity of εr = 1.67. The proposed antenna is radiating at the center frequency of 2.45 GHz with a return loss of -15.76 dB & VSWR 1.389, the far field directivity of an antenna is 8.05 dBi at 2.45GHz. The designed antenna is wearable on the clothes because the use of textile material for antenna fabrication by keeping SAR at 1.6 W/Kg.***

***Keywords* : *Microstrip textile antenna, Jeans material, SAR, Wi-Fi etc.***

## I. INTRODUCTION

In the recent era of communication, the wireless body area network (WBAN) plays a vital role in WiFi application. The proposed antenna is designed in the ISM band and used for wireless application at an operating frequency of 2.45GHz. Normally WiFi operates in the frequency range of 2.4GHz to 2.485GHz in India. Because of the use of the textile substrate as jeans, the antenna is mounted on the clothes & used for WiFi communication. The square slot CPW fed antenna is used for ultra-wideband application which is resonating at the frequency range of 3.2 GHz to 16.3 GHz & provides a bandwidth of 135 MHz used for wearable applications [1]. The fully textile-integrated microstrip-fed slot antenna is designed with a directivity of 4.9 dBi & S11 parameter -34 dB at 5.9 GHz frequency for dedicated short-range communications [2]. The on body wearable micro strip antenna designed in Dual-Mode & A Robust Snap-On Button Solution for Reconfigurable Wearable Textile Antennas is designed for ISM band with a return loss of -18dB & -25dB at 2.45 GHz frequency [3][4]. The wearable textile antenna is simulated at 2.45 GHz frequency with various substrate Cotton, Polyester, Cordura & Lycra have return loss of -32 dB, -35 dB, -29 dB & -31dB [5]. The multiband microstrip antenna is designed with a moon-strip line structure for wireless applications.

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This multiband antenna is resonating at the frequency band of 5.3 GHz to 10.15 GHz with the bandwidth of 62.78% & S11 parameter -25dB at 5.44GHz & -24dB at 8.05GHz [6]. Circular polarized textile-based antenna and dual-band wearable textile antenna by using U slot conical via hole are designed at ISM band with a frequency range of 2.4 GHz – 2.45 GHz and the antenna had a return loss of -35dB & -20dB and provided directivity of 6.7dBi & 7dBi [7][8]. The microstrip textile antenna is fabricated for multiband wireless communication with frequencies of 3.4286 GHz, 9.7311 GHz & 11.176 GHz used for wearable body area networks with directivities of 3.353 dBi at 3.4286 GHz, 4.237 dBi at 9.7311 GHz & 5.193 dBi at 11.176 GHz & efficiencies 87.2% at 3.42286 GHz, 89.6%.at 11.176 GHz [9].
This paper consists of single rectangular patch designed in the frequency range of 2.4GHz to 2.485 GHz which covers WiFi application. The proposed antenna is more compact & provides good directivity which is requirement of wireless communication.

## II. ANTENNA DESIGN

The microstrip antenna is mostly used in wireless application due its properties compact size, lightweight & simple to fabricate. The basic structures of printed microstrip antenna consist of top patch & ground plane which is made up of thin copper layer of 30-35 micron. These two copper layers are separated by dielectric substrates as shown in figure 1. The microstrip textile antenna plays an important role in the recent era of wireless body area network (WBAN), in this type of antenna the various textile materials are used as the dielectric constant. The top patch & ground plane is made with copper foil which is separated by the textile material. The proposed rectangular microstrip textile antenna is designed in ISM band & it is resonating at the center frequency of 2.45GHz. The physical dimensions width & length of the proposed antenna is 52.99 X 45.23 mm$^2$.

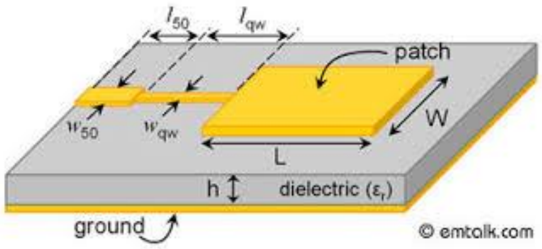


**Figure1: The microstrip antenna**

The jeans is textile material used as substrate material with $\varepsilon_r$= 1.67 & substrate height is 2.84mm. Figure1a shows the top patch of rectangular microstrip textile antenna, resonating at 2.458 GHz at return loss of -15.76dB.

The proposed antenna is implemented in the WiFi switches which will provide wireless portability. The rectangular microstrip textile antenna is simulated with full ground plane and has dimensions of 105.98 x 90.46 $mm^2$ is shown in figure 1a &1b.

**Steps:** The rectangular textile antenna is designed in ISM band at a frequency of f= 2.45 GHz with $\varepsilon_r$= 1.67 & h=2.84 mm.

**a) Effective Width of patch**

$$W = \frac{c}{2f\sqrt{(\varepsilon r+1)}} = \frac{3\times10^8 m/s}{2\times2.45\times10^9\sqrt{(1+1.67)}} = 52.99 \text{ mm}$$

**b) Effective Length of patch**

Effective dielectric constant

$$\epsilon\, reff = \frac{\epsilon r+1}{2} + \frac{\epsilon r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$$

$\epsilon$ reff = 1.60

$$Le = \frac{c}{2f\sqrt{\varepsilon reff}} = \frac{3\times10^8 m/s}{2\times2.45\times10^9\sqrt{(1.60)}} = 48.46 \text{ mm}$$

Due to fringing effect, change in the length of patch can be calculated

$$\frac{\nabla L}{h} = 0.412\left[\frac{(\epsilon\, reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon\, reff-0.258)\left(\frac{W}{h}+0.8\right)}\right]$$

$\Delta L$ = 1.61mm

**c) Length of patch L =** Le – 2ΔL = 48.46 – 3.23

L = 45.23 mm

**d) Length & Width of ground plane**

Wg = 2 x W = 2 x 52.99 = 105.98 mm

Lg = 2 x L = 2 x 45.23 = 90.46 mm

**e) Length & Width of Inset feed line**

Wf = 8mm as per 50 ohm line impedance

Lf =Fi = 6h/2 = 6x2.84/2 = 8.52 mm

Gpf = 5 mm

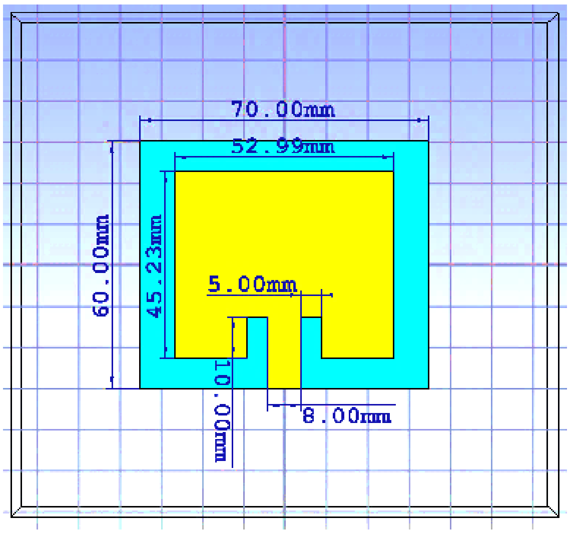


**Figure1a: Top of proposed rectangular microstrip Textile antenna**

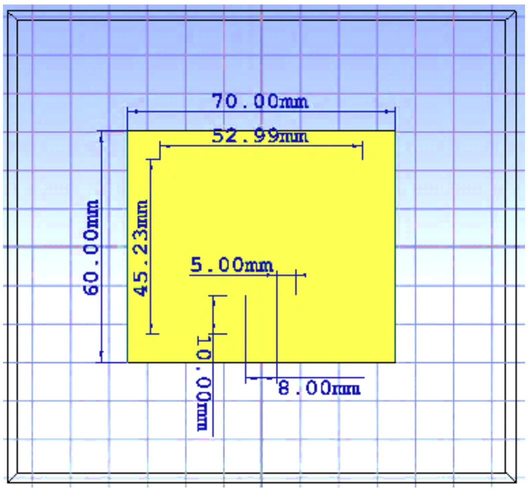


**Figure1b: Ground plane of proposed rectangular microstrip Textile antenna**

**Table no 1 : List of parameters**

| Parameter | Value (mm) |
|---|---|
| Gpf | 5 |
| Hs | 2.84 |
| Ht | 0.035 |
| L | 52.99 |
| Lg | 70 |
| R | 10 |
| W | 45.23 |
| Wf | 8 |
| Wg | 60 |
| εr | 1.67 |

## III. RESULT AND DISCUSSION

I) S11 parameter: The value of return loss decides the radiation of the antenna & it should always maintain minimum -10dB to resonate at designing frequency. Figure 2 stated that the value of return loss (S11) is -15.76 dB at a resonating frequency of 2.458 GHz. From a figure 2, the observation is made that the value of S11 is less than -10dB and provides the bandwidth of 54.2MHz.

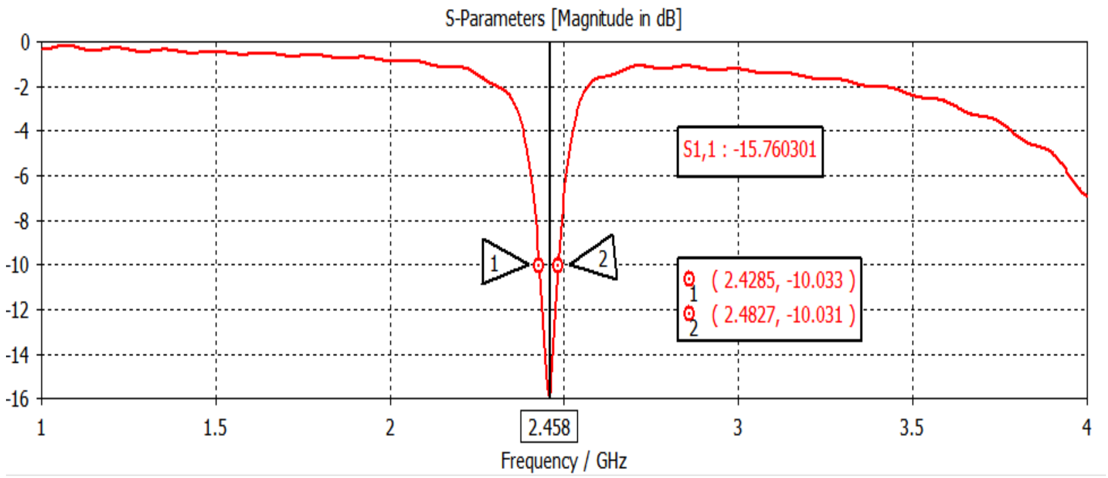


**Figure 2: S11 Parameter at 2.45GHz**

II) The Directvity of the proposed antenna: From the observation of figure 3, the antenna is highly directive with directivity 8.05 dBi at a frequency of 2.45 GHz & the polar plot of antenna figure 4 shows that an angular bandwidth of 75.8˚ which covers large broadside area & side lobe level is of -16.9dB.

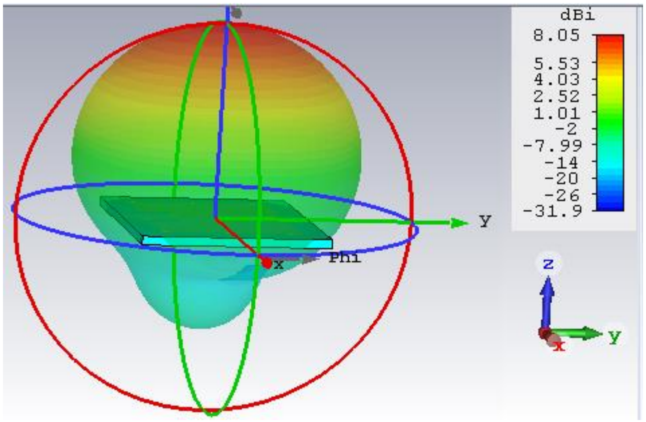


**Figure 3: Directivity of the proposed antenna**

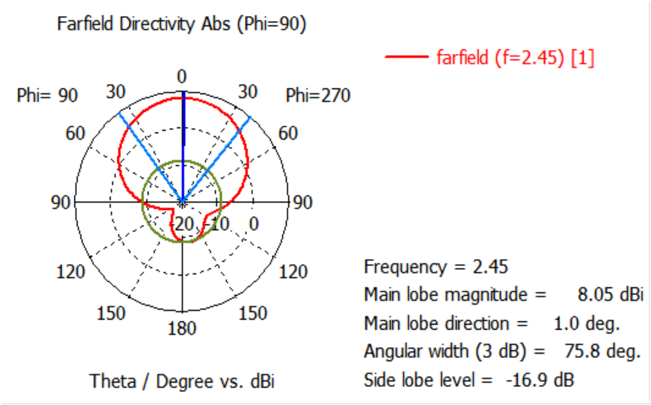


**Figure 4: polar plot of the proposed antenna**

III) VSWR of the proposed antenna: From figure 5, it has been concluded that the value of VSWR at a frequency of 2.45GHz is 1.389 which is best for WiFi communication as per IEEE802.11 standard. The VSWR value must be between 1 to 2 for effiecient working of antenna. It is discussed in the resul table number 2

IV)

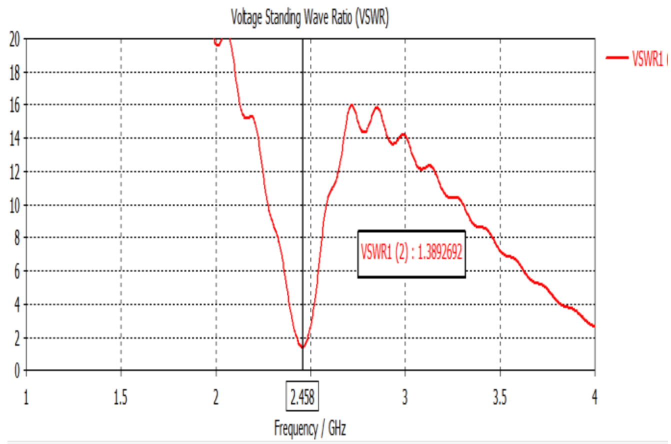


**Figure 5: VSWR of the proposed antenna**

V) Efficincy: The radiation efficiency & total efficiency may differ because of loss takes place due to the impedance mismatch loss. So that total efficiency is always equal to radition efficiency multiplied with impedance mismatch loss. Et = Zl * Er , where Et = Total Efficiency , Er = Radiation Efficiency & Zl = Impedance mismatch loss.

From Figure 6, it has been shown that radiation effiecieny is 88.61% total efficiency is 85.80% at a frequency of 2.458GHz. But radiation efficiency is giveb by the ratio of amount of radiated power to the input power applied to the antenna. The Pi input power applied to port is 0.4867 watt & radiated power Pr is 0.4290

$$\eta = \frac{Pr}{Pi} x\ 100 = \frac{0.4290}{0.4867} x\ 100 = 88.14\%$$

where Pr is radiated power & Pi Input power.

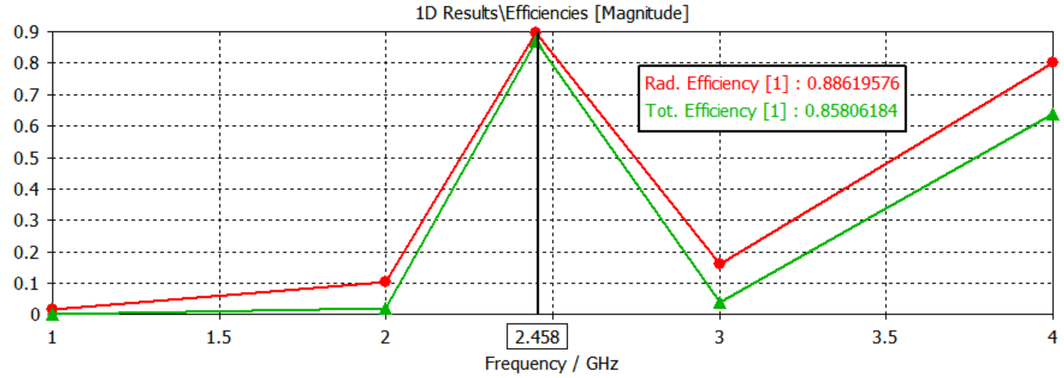


**Figure 6: Efficiencies of the proposed antenna**

**Table 2: Results:**

| Sr No | Resonating Frequency | Return Loss S11 in dB | Voltage Standing Wave Ratio | % fractional Bandwidth | Directivity in dBi | Radiation Efficiency Er | Radiation Efficiency Et |
|---|---|---|---|---|---|---|---|
| **1** | Fr1= 2.458GHz | -15.76 | 1.38 | 22.05 | 8.05 | 88.61% | 85.80% |

## IV. CONCLUSION & FUTURE WORKS

The Microstrip Textile antenna is the best alternative to the conventional antenna to avoid the change in antenna performance characteristics due to bending & crumpling conditions.

In this paper the rectangular microstrip textile antenna is designed in the ISM band with an operating at the center frequency of 2.45 GHz & the designed antenna provides return loss of -15.76 dB & has a directivity of 8.05 dBi used for wireless application. The radiated efficiency of antenna is 88.61% which is efficient for WiFi application.

In future multiband microstrip, textile can be designed with lightweight by reducing substrate height. The antenna will be made compact by increasing εr value to the desired level.

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