Wearable -Textile Patch Antenna using Jeans as Substrate at 2.45 GHz

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Abstract*—Utilization of wearable textile materials as antenna substrate has been speedy due to the recent miniaturization of wireless devices. A wearable antenna is to be a part of the clothing used for wireless communication purposes, which include tracking and navigation, mobile and wearable computing and public safety. For user convenience there is an increasing need for integrating antennas on or in the clothing. The conventional antennas are not flexible and difficult for user to movements. There is a need of antennas made of flexible textile materials that can be part of user clothing defined as wearable antennas. In particular, the micro strip patch antennas are good candidates for body-worn applications, as they mainly radiate perpendicularly to the planar structure and also their ground plane efficiently shields the body tissues.[1] This paper shows research on wearable patch antennas designed and developed for various applications at 2.45 GHz frequency . Here at 2.45 GHz frequency patch antenna is designed and simulated using HFSS.

***Keywords* — jeans, self adhesive copper tape Wearable Patch antenna**

I. INTRODUCTION

One of the interesting researches in antennas for body-centric communications is wearable, textile -based antennas. Commonly, wearable antenna requires light weight, low cost, almost maintenance-free and easy installation. There are number of specialized occupation segments that can use body centric communication systems, such as medical, fire fighters, and military. Besides, wearable antennas also can be applied for patient monitoring, astronauts, and athletes for the purpose of monitoring

For integration into clothing, antennas are usually required to be small, lightweight, and flexible. They should have stability and exhibit safe to person health when placed close to the body. There are several candidate antenna types suitable for wearable antennas, which are PIFAs, micro strip antennas, and planar monopoles. Micro strip antennas are usually preferred among these options. Micro strip antennas are useful for on-body wearable communication, because of their ease of construction, their cost effectiveness. One of the main advantage of patch antenna as wearable application is that its associated metallic ground plane that when used between the body and the radiating elements can significantly reduce the energy absorbed by the body. However, micro strip antennas tend to have narrow bandwidth and may need to be relatively large if they are to be robust against perturbation by the body. However monopole and dipole has no ground plane so there its radiation pattern is effect to the body. So patch antenna is preferable.

In general, textiles material has a very low dielectric constant that reduces the surface wave losses and increases the impedance bandwidth of the antenna. Textile material used here is jeans; its dielectric constant is 1.6. Here we can make a prototype of partial wearable antenna using self-adhesive copper tape which was tested using scalar network analyzer.

II. DESIGN OF MICROSTRIP PATCH ANTENNA

A. Basic of Patch Antenna

In its most fundamental and basic form, a Micro strip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Fig 1[2]. The patch is generally made of conducting material such as copper silver, or gold and can take any possible shape like square, rectangular, circular. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

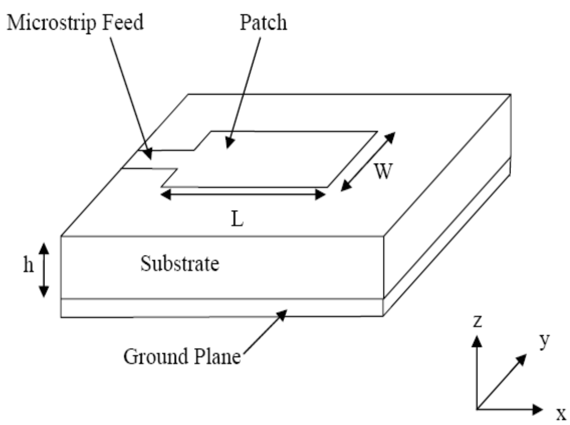

Figure 1 Rectangular Patch antenna

B. Design of Rectangular Patch Antenna

The main factor involved to design a rectangular patch.

- Decide the desire frequency
- Selection of substrate material and height

- Design of patch dimension
- Feeding method and its position

To design a rectangular patch antenna frequency is 2.45GHz because it is license free and ISM band so it can use for various application. For wearable patch antenna substrate is textile material, here textile material is jeans which has dielectric constant is 1.6. The height of substrate is 3.5mm because less than 3.5mm it not gives return loss at desire level.

C. Calculation of Patch Width

The patch width (W) has a minor effect on the resonant frequency (f_r), and it is calculated using the following formula (1)

$$w = \frac{c}{2fr}\sqrt{\frac{2}{(\varepsilon r + 1)}} \quad (1)[3]$$

Where c is the speed of light in free space and ε_r is the relative permittivity of the fabric material under test. [3]

D. Calculation of Effective dielectric constant (εreff)

The micro strip patch lies between air and the dielectric material, and thus, the EM wave sees an effective permittivity (ε_{reff}) given by . (2).

$$\varepsilon reff = \left[\frac{\varepsilon r + 1}{2}\right] + \left[\frac{\varepsilon r - 1}{2}\right]\left[1 + \frac{12h}{W}\right]^{-1/2} \quad (2)[3]$$

Where h is the thickness of the substrate.

E. Calculation of actual Length of Patch

The patch length (L) determines the resonant frequency and it is a critical parameter in design because of the inherent narrow bandwidth of the patch. The design value for L is given by . (3)

$$L = \left[\frac{c}{\left(2fr\sqrt{\varepsilon reff}\right)}\right] - 2\Delta L \quad (3)[3]$$

Where ε_{reff} is the effective permittivity of the material under test. [3]

F. Calculation of extension length ΔL

At both ends of the patch length, due to the effect of fringing fields,the extention of length is given by

$$\Delta L = 0.412h\left[\frac{(\varepsilon reff + 0.3)}{(\varepsilon reff - 0.258)}\right]\left[\frac{\left(\frac{W}{h} + 0.264\right)}{\left(\frac{W}{h} + 0.8\right)}\right] \quad (4)[3]$$

G. The effective patch length Le

The effective patch length can be calculated

$$Le = L + 2\Delta L \quad (5)[3]$$

The feeding technique for wearable antenna is inset feeding because it is easy and comfortable for person to wear the antenna and fabrication of this feeding is easy.

According to above equation and some optimization the calculated dimension of antenna is given in table 1.

TABLE 1 DIMENSION OF PATCH ANTENNA

Desire Parameter	Calculated Value
Frequency of patch antenna	2.45 GHz
Dielectric constant	1.6
Height of Patch antenna	3.5 mm
Width of Patch antenna	53.6974 mm
Length of patch antenna	46.6 mm
Width of micro stip line	13.1197 mm
Dimension of substrate	120mm X 120 mm
Length of inset feed	12.45 mm

According to above calculation following simulated result is obtained.

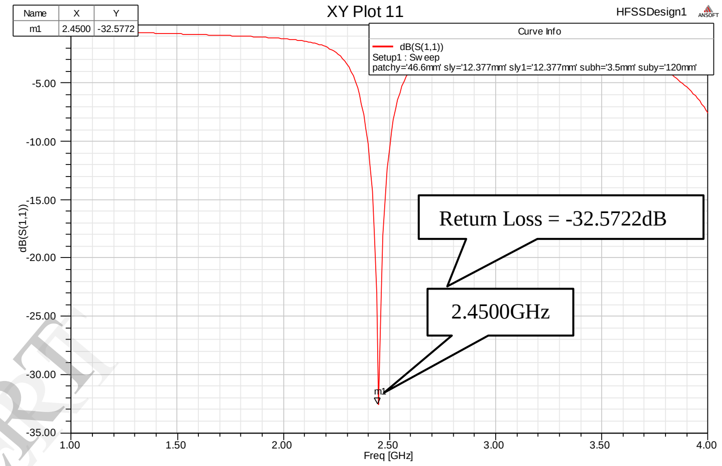

Figure 2 Return loss of antenna

According to simulated result resonat frequency is 2.4 GHz with S11is- 30 db as shown in fig 2.

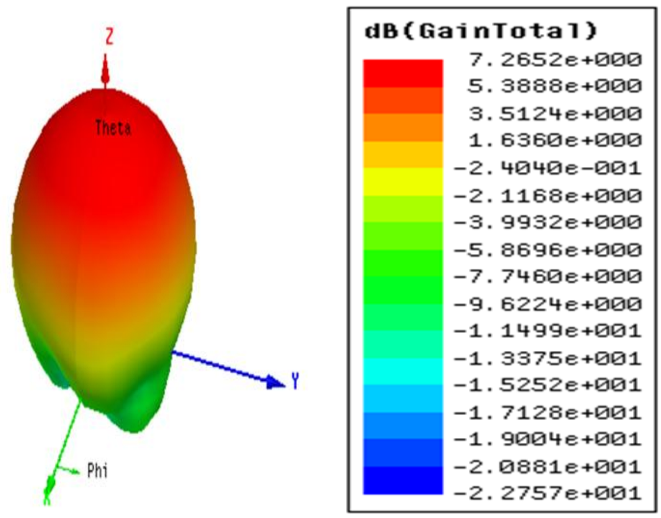

Figure 3 3-D Radiation pattern of antenna

The gain of simulated antenna is 7.26 dB as shown in fig 3. E plane and H plane radiation pattern is shown in fig 4 which is 2-D radiation pattern.

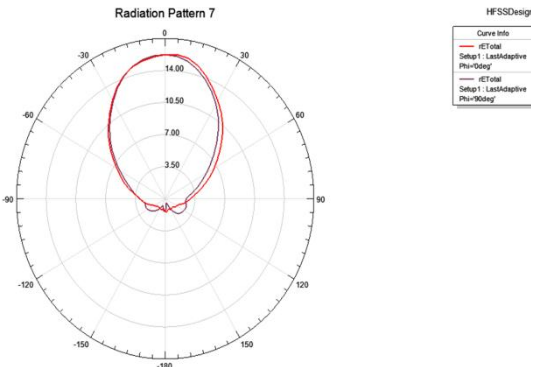

Figure 4 E and H plane radiation pattern

III. FABRICATION OF TEXTILE PATCH ANTENNA.

For fabrication of prototype textile antenna we have done following steps

A. Measure the Height of Single layer.

For the desire thickness we have to measure single layer thickness of substrate material. Measurement of single layer jeans is done using thickness gauge. It gives the 0.7mm for single layer.

B. Stack the Jeans for desire height

For the 3.5 mm thickness we have to stack the jeans according to substrate dimension 120 X 120mm stitch it at the edges. Then remaining jeans was cut using scissor. According to calculated dimension self-adhesive copper tape which has non conducting glue is cut using blade. Then using same material ground plane was cut and stick on jeans substrate.

C. SMA Connector

Then SMA connector is soldered using normal soldering techniques. There are chances of burning the jeans material so special care is taken during soldering.

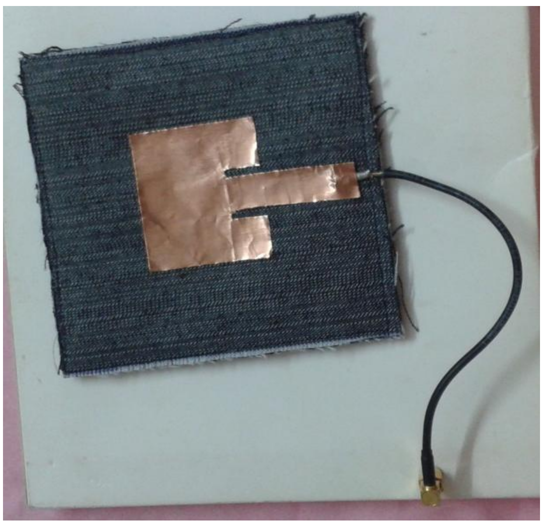

Figure 5 Fabricated wearable patch antenna

IV. FABRICATED RESULTS AND CRITICAL DESIGN ISSUES

Now after fabrication testing is done using scalar network analyzer according to test setup as shown in fig 6. According to tested result return loss is -30dB at 2.492GHz. The fabricated output result is however similar with the simulated results. There is minor difference between simulated and fabricated result because of various reasons which are as follow.

Figure 6 Measurement set- up of return loss

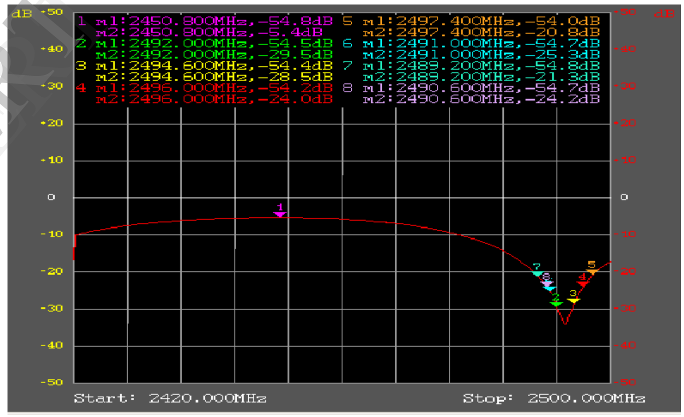

Figure 7 Practical measured result

A. The height of dielectric substrate.

The dielectric substrate height for patch antenna is taken to be 3.5 mm for jeans material. With this value, we get the simulation result. However when fabricated, the jeans material (dielectric substrate) did not give the constant thickness. Being a fabric material, it has some ups and downs in its surface and hence is not smooth. When some pressure is applied then its height is changed. For desire height the jeans is staked. Here 5 layers are used for desire thickness. All the cutting and sewing are done manually at home so there is some air gap between the layers and dimension is not as much perfect.

B. Dielectric constant of substrate material jeans

The dielectric constant of textile material should be measured with different techniques like resonance method and non resonance method with VNA and split post ring resonator, we considered material has dielectric constant is 1.6 [5].When fabricating a micro strip patch antenna with solid substrate, the copper is plated on the substrate and the unwanted material is etched out. When fabricating a textile antenna it is required to attach the radiating patch and ground plane to the dielectric substrate. This is done by self adhesive copper tape which has nonconductive glue in between the dielectric substrate and radiating patch. When the glue is added in the upper and lower layer of the substrate, the dielectric constant of the substrate is changed and due to this resonance frequency of antenna changes because the square root of dielectric constant of the substrate is inversely proportional to the frequency. Thus resonance at lower frequency occurred during measurement which can be seen in S11 plot. When the glue is applied to the surface of dielectric, the contact between the dielectric substrate and the radiating patch becomes non homogeneous. This affects the antenna performance. Between the different layers of jeans substrate there is some air gap and because of this dielectric constant of air should be changed which influence the resonant frequency of antenna.

C. Rough Edges of substrate material.

During fabrication, when the textile material is cut to give the shape according to the dimensions obtained, a knife and scissor was used. Use of this equipment's introduced two types of errors. When cutting, due to parallax error, the sides and edges of the radiating element were not straightly cut. Because of this, antenna matching is poor. Also when cutting the edges of the conductive textile material, some fiber thread comes out. These threads are on the edges from which the antenna radiates. This affects the radiation of antenna and hence the range of antenna decreased when compared with calculated results. The above mentioned problems can be solved by taking careful attention and the right tools for the fabrication.

The fabrication of textile antenna is more complicated than that of printed antenna. Considering these facts, we were supposed to fabricate the antenna in an industry with appropriate tools and materials, but due to lack of commercialization of textile antenna, we had to do it our self. However this gave us an opportunity to learn more about fabrication process and to deal with the problems that arise during fabrication process.

V. DESIRABLE FEATURES

Wearable antennas have drawn more and more attention in recent years due to the fact that they can be seamlessly integrated into clothing which is a desired feature for hands free applications and military applications requiring low visibility. More importantly wearable antennas can use all the space on clothing that can be utilized to improve quality of signal in wireless communications. Secondly multi path fading is one of the most severe problems in wireless communication since the signal strength drops as the mobile terminal moves over a distance comparable to wavelength.[7] Antenna diversity is a very effective way to combat multipath fading. However antenna diversity requires at least half a wavelength separation between each antenna in the diversity system. This is not possible on small form factor hand held units which limits the use of antenna diversity. On the other hand antenna diversity can be utilized on a large scale of a body worn wireless system [7] .Wearable textile antennas has also attracted consumer electronics industry because it fulfills the increasing demands from the rapidly evolving wireless world. Wearable antenna desirable features common to all applications require light weight, functional, robust, unobtrusive, and inexpensive, zero maintenance and no setup requirements. The important factors that can influence the wearable antenna performance are:

A. Human body interaction with the antenna.

The human body is an irregularly shaped medium with frequency dependent permittivity and conductivity [7].The distribution of the electromagnetic field inside the body and the scattered field depends largely on the body physiological parameters, geometry, frequency and polarization of the incident field. Due to high permittivity of body tissues [6] the antenna resonant frequency will change and detune to a lower one. [7] Another important parameter is the antenna Gain that directly affects the power transmitted in a maximum radiation direction. Due to human body some part of radiating power of an antenna will be absorbed by it and it will result in lower gain, variations in dimensions.[7] Due to stretching and compression which are typical for fabric, the antenna structure can easily deform and affect its performance characteristics. As a result it will be difficult to mass produce an antenna with the same radiation characteristics even using same materials.

B. Water Absorption.

Fabric antennas can easily absorb water and moisture and can consequently change the resonant frequency and impedance bandwidth of an antenna. Even sweating of wearable person can affect the resonant frequency of antenna.

C. SAR Calculation

Wearable antenna is used near the body or for on body communication for this SAR calculation is needed. The two most commonly used SAR limit are those of IEEE1.6W/kg for any 1g of tissue, and ICNIRP (International Commission on Non-Ionizing Radiation Protection [6]) 2W/kg for any 10g of tissue. The specific absorption rate (SAR) is an important parameter to be measured for any wearable antenna design. This parameter shows the rate of energy absorption by the human body tissue when exposed to fields radiated by the antenna. The SAR is potentially important to any wearable antenna as they are placed in very close proximity to the body. There is no specific legislation which considers wearable devices; however minimization of SAR is a sensible design goal.

CONCLUSION

The micro strip antenna is a suitable candidate for wearable applications, as it can be built using fabric substrate materials. Textile material has low dielectric constant normally it is 1 to 2. So it can reduce the surface wave losses and improve the antenna bandwidth. Here textile antenna structures have been tested in order to get preliminary results on the performance of antennas. The antennas presented revert versatile, and it is easy to fabricate. According to simulated results return loss is -32.57 dB at 2.45 GHz and gain is 7.2. Now according to fabrication s11 is -30dB at 2.4945GHz

FUTURE WORK

The micro strip antenna is a better candidate for wearable applications, as it can be built using textile substrate materials. Textile material has low dielectric constant (1 to 2) so it can reduce the surface wave losses and improve bandwidth of antenna. When moving or doing some physical work, the antenna may bend. If it is bent, the physical parameter of antenna may change and if the physical parameter changes, the antenna radiation parameter may also change. The antenna designed and manufactured in this paper is big in size. The smaller the textile antenna the less it bends. There is various miniaturization technique for antenna made from copper. The future work can be to work on the miniaturization of textile antenna. The miniaturized textile antenna leads to less bending and hence more stable output from the antenna can be achieved. Also increasing the radiation efficiency is one of the main challenges for the antenna made from textile material. So this topic can be explored in future studies. Also if performance deterioration under wet conditions is to be avoided then search needs to be carried out on water proof materials for future wearable communication designs. The specific absorption rate (SAR) is an important parameter to be measured for any antenna design. The SAR is potentially important to any wearable antenna as they are placed in very close proximity to the body. There is no specific legislation which considers wearable devices; however minimization of SAR is a sensible design goal. Because of this reason calculation of SAR characteristics of wearable antennas designed in research could be carried as future work. In this research for radiating and conducting part i.e. for ground and patch self adhesive copper tape is used so it is called partial wearable antenna. Now on days electro-textile material is used for conductive part. So using electro textile material we can make a fully wearable or textile material. There are different types of textile material are available in market using these material different types of antenna can be fabricated. . Wearable antenna can be washable if textile material is used as substrate and E- textile material is used as ground and radiating element then it can be called as fully textile antenna it can be done as future work.

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