Design of Flexible Slot Antenna using different substrate materials for UWB applications

M.Pandimadevi, R.Tamilselvi, A. Saba Afroze, M. Parisa Beham

Abstract: Utilization of Flexible antennas for the development of wearable devices have been extensively increased due to less weight, high performance, compact design and easy fabrication. The proposed antenna is designed with circular patch with slot using different flexible substrate materials. The various antenna parameters of all the designed structure were checked, correlated and analyzed. Ultra Wide Band (UWB) frequency range of 3.1-10.6 GHz was selected as operating frequency. The results show that proposed antenna with jute material as substrate has shown better results in return loss, VSWR, Gain and Directivity both in flat and on-body bending conditions. Results demonstrate the suitability of these flexible antennas for on-body wireless communications.

Index Terms: Flexible, wearable, ultra wide band, Bandwidth, bending

I. INTRODUCTION

In recent times, it was evidenced a huge concern from academic as well as industrial area in the field of flexible electronic system. Currently the analysis shows that the earnings of flexible technology was predicted over 300 billion US dollars in the year 2028 [1]. Their lesser weight, cheaper production, easier fabrication, and the availability of less cost stretchable materials i.e.: cotton, paper, foams, plastics etc., make flexible technology a desirable for the future electronics world. In addition to that, current achievements in the development of miniaturized, flexible wireless elements paved the way for the immortalization of such flexible systems [2,3] . The efficiency of such electronics mainly depends on the behavior of the antenna which have flexible substrate with bending compatibility. The flexible antennas require the combination of adjustable, less weight and compact antennas [4]. By the meantime, these antenna elements should be effective with a wider bandwidth and desirable radiation properties. There are several antenna types in our modern world. For example, Yagi Uda, Loop, parabolic and Micro strip Patch antenna. Each of them has their own advantages and disadvantages. Among them, patch antenna is the commercially popular radiating element, that is used in the stretchable antenna design. The need for small size and easy design for the antenna has brought the patch antenna to the leading edge among all antennas. The following are the few principal advantages of patch antennas compared to conventional antennas [5]:

- Less weight and flat profile configurations, which can be made conformal to shaped surfaces;
- Low cost;
- Easily fit with MICs (microwave integrated circuits);
- Easy to fabricate.

The remaining portion of the paper has been organized as follows: Section 2 explains survey of various existing methodologies available in the flexible antenna. Section 3 deals with the structure of the proposed antenna. Section 4 deals with the comparison of the various antenna parameters for the different substrate materials. Section 5 deals with the bending results and discussions. Section 6 deals with the conclusion and future work.

II. LITERATURE SURVEY

Prior to the antenna design, it is necessary to know the existing techniques and its drawbacks. Sonia C. Survase [6] et al designed micro strip yagi patch antenna for telemedicine application. Two types of yagi uda antenna: circular and rectangular were designed having gain 2dB and 7.8dB respectively in HFSS software. The operating frequency is 2.54GHz. In this paper, reasonable return loss(-24dB) and VSWR (1.1) was achieved, but there is no evidence of on-body applications of the antenna. Mai Osman et al [7] designed a Ultra Wide Band antenna with substrate as flannel fabric and patch as ground plane from both copper conducting sheet and Shieldit conducting fabric. Substrate material used is Flannel fabric is a smooth and fluffy surface made the material eligible for stretchable and wearable applications..The fabricated antenna was tested under various bending conditions The return loss was also obtained less than -10 dB. Gain also improved with the frequency ranging from 2 to 15 GHz. Saadat Hanif Dar et al [8] proposed patch antenna on a rubber substrate and its performance near human body is investigated. Simulations were done using CST studio suite. It was realized that antenna parameters such as return loss and bandwidth were enhanced by combining with rubber substrate material. At the meantime, the gain and its efficiency was reduced, however it was taken into account due to the characteristics of natural rubber.

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Liu Jianying, Dai Fang et al [9] proposed a flexible antenna with substrate material as polyimide substrate for wireless body area network (WBAN). The antenna type designed is Yagi-uda. The designed antenna operates over 2.45GHz band. The effects of bending along horizontal as well as vertical direction for the antenna are analyzed. Results show that with slightly increasing the bending angle, the input matching become worse. It is also evident that the maximum radiation occurs at H-plane of end fire Yagi-Uda antenna deviates with bending along y-axis. Hamid Reza Sanjari et al [10] presented an analysis be asedon the effects of bending on a rectangular patch antenna using textile material as substrate. The antenna was simulated in two modes. One is patch structure with elongated and another is patch structure with fixed mode of dimensions. The results show that the mechanical properties of the antenna can change the antenna behavior under bent conditions.

III. ANTENNA DESIGN

The proposed microstrip antenna was designed with ground plane of copper sheet of thickness 0.03mm thickness having dimensions 50x40mm as shown in figure 1. Above the ground plane was the substrate layer of same dimension as that was of ground plane having thickness 1 mm.

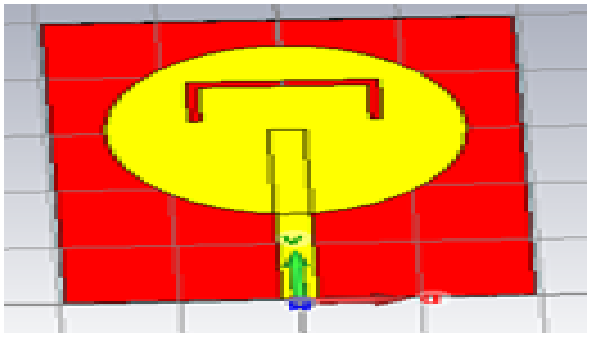

Fig.1 Proposed antenna design

The substrate materials such as jute, Teflon, paper, rubber and foam material were used for the design. The circular patch of 30mm diameter is chosen with inverted U-slot of 20mm length and 2 mm wide. The strip line of 30mm length with 4 mm wide was excited from port 1 via a 50Ω coaxial probe transmission line.

IV. ANTENNA SIMULATION

The design was simulated in Computer Simulation Technology (CST) Studio suite software with varying the substrate material. Figure 2 shows the proposed design using Jute substrate in CST software..The dual band operating frequency is achieved with return loss of -24.5 and -33.54 dB at 3.3 and 6.6 GHz respectively as in figure 3.The VSWR ,gain and directivity measurements are shown in figures 4, 5 and 6 respectively.

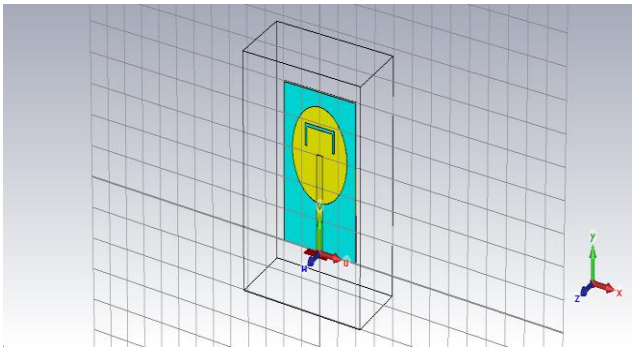

Fig.2 Design of antenna using Jute substrate

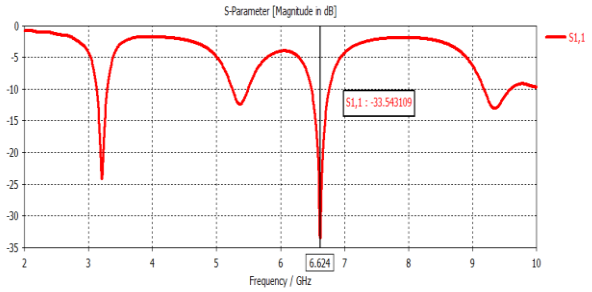

Fig.3 Return loss measurement

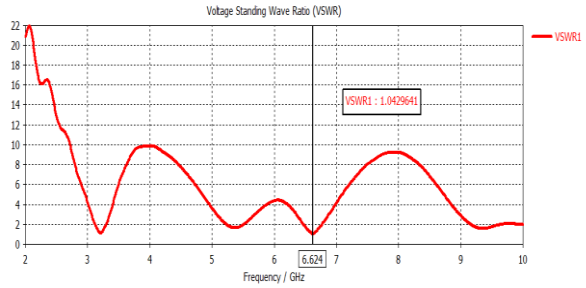

Fig.4 VSWR measurement

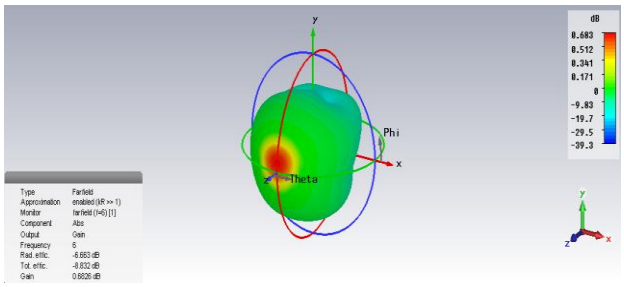

Fig.5 Gain measurement

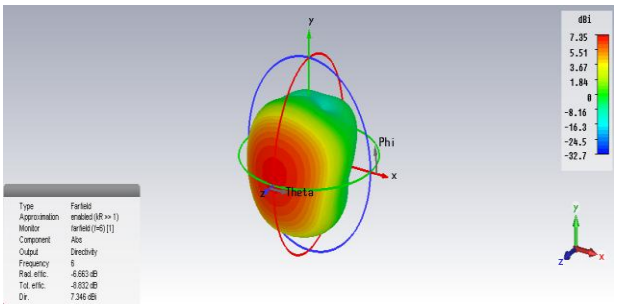

Fig.6 Directivity measurement

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The antenna is simulated using other substrate materials like Teflon, foam, rubber and paper. The simulated results are compared and tabulated in Table1.From the table 1 it is observed that, antenna with Jute substrate have better results. Since it is a natural fiber, low cost and easily available, Jute fabric have better advantageous over other substrate materials.

V. ANTENNA SIMULATION UNDER BENDING CONDITION

The proposed antenna using jute substrate was tested under bending condition on Poly Vinyl Chloride cylinder as shown in figure 7 and on body conditions as shown in figure 13 in CST software.

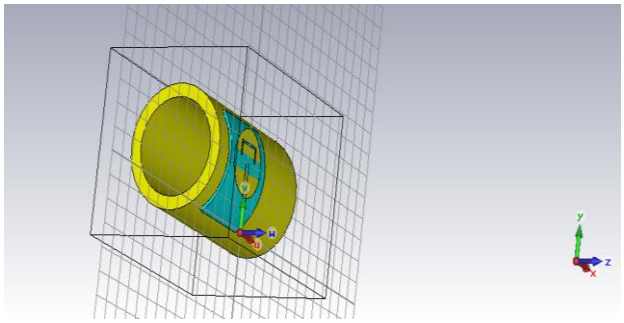

Fig.7 Antenna Bending under PVC cylinder

The antenna was first bent under polyvinyl chloride cylinder having relative permittivity of 2.8 which is a synthetic plastic polymer material having diameter 30 mm. The PVC was used for bending support because the proposed antenna cannot be bent independently on air with any specific radius. The antenna under bending was simulated and the parameters were measured as shown in figures 8,9,10 and 11. Then the proposed antenna was bent and tested under on-body conditions. Figure 12 shows the different layers in the hand of human body that was designed in CST software. Five layer structure of the human hand was modeled in the CST software by concentric circle of cylinders with a diameter of 50 mm. The inner most layers are bone surrounded by fat, muscle, blood and finally skin. Then the proposed antenna was bent on the designed hand of human body in CST software. The antenna was simulated under the position as shown in figure 13.

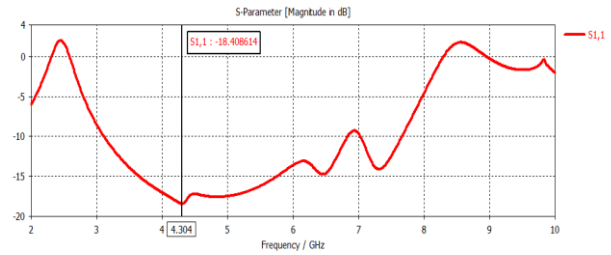

Fig.8 Return loss measurement

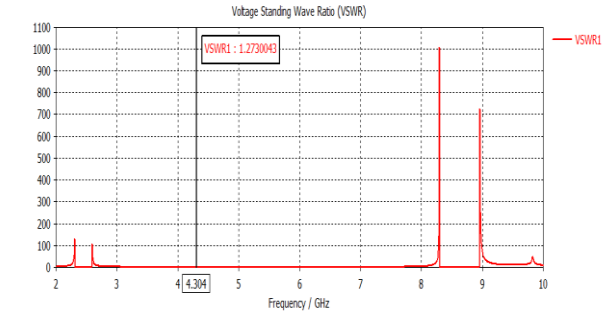

Fig.9 VSWR measurement

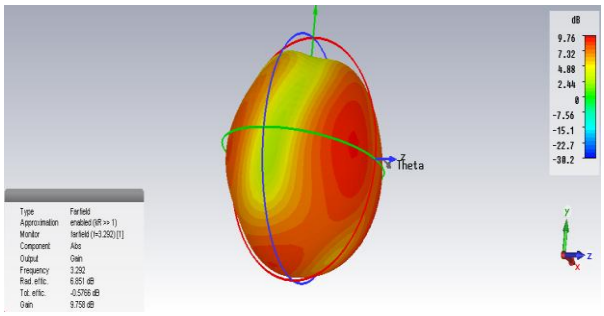

Fig.10 Gain measurement

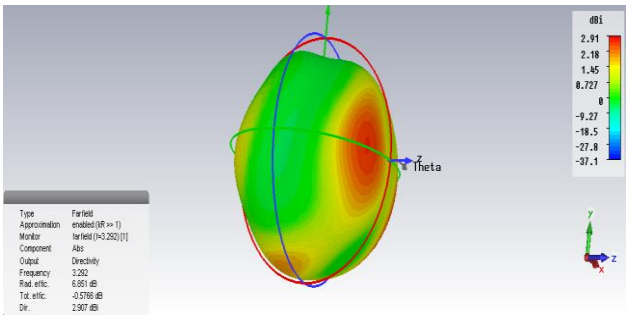

Fig.11 Directivity measurement

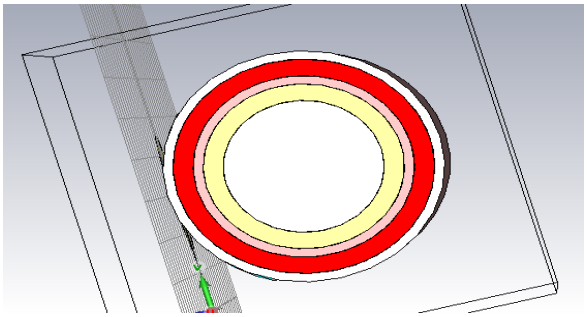

Fig.12. Human hand model in CST software

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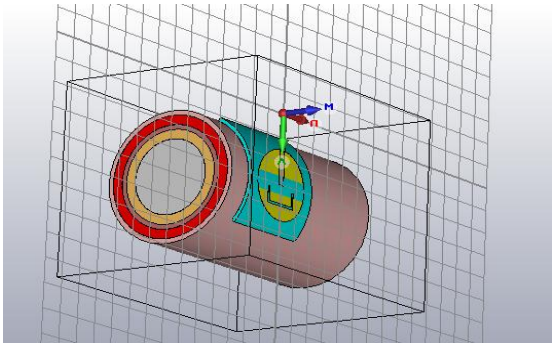

Fig.13. Proposed antenna bend on human body

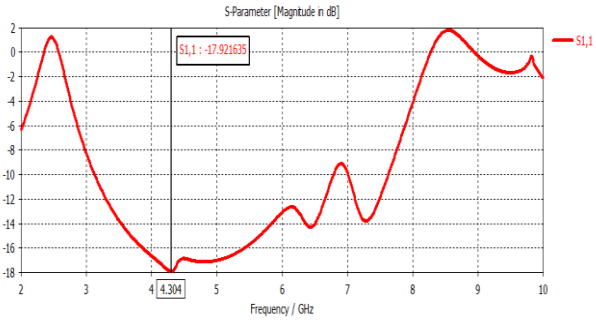

Fig.14. Return loss measurement

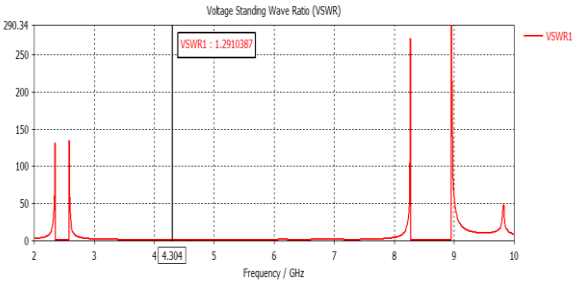

Fig.15 VSWR measurement

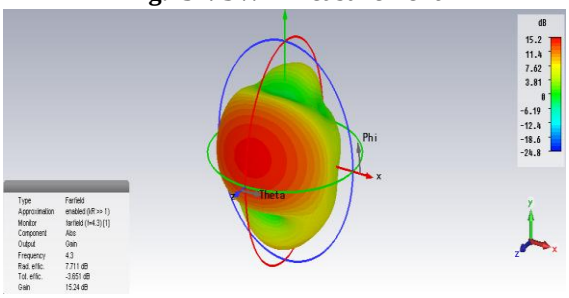

Fig.16 Gain measurement

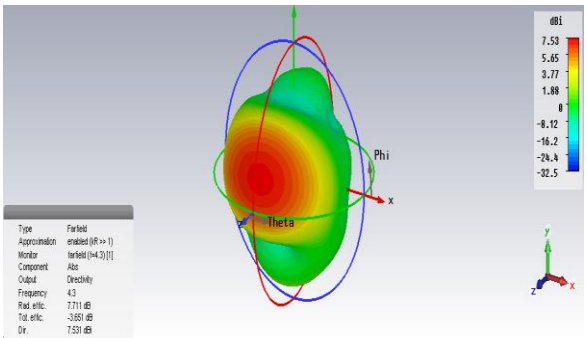

Fig.17 Directivity measurement

The different parameters such as S_{11} (return loss), VSWR, directivity and gain measurements were shown in figure 14,15,16 and 17 respectively.

VI. RESULTS AND DISCUSSIONS

Thus the proposed antenna using various substrate material was designed and simulated. Of them, Antenna using Jute substrate has shown better results. Then the antenna was also tested on bending under PVC and on-body conditions. The measured values were compared and tabulated in table 2.The results show that the jute substrate is well adaptive with better return loss, VSWR, gain and directivity under all conditions. Since the jute fiber is a biodegradable, cheap, flexible, nontoxic, environment-friendly, strongest fiber [11-12], compatible, higher thermal stability and easily dryable after wash and recyclability, it is the correct choice as a substrate for the fabrication of microwave antennas. The bandwidth of 3.5GHz, 4.5 GHz and 4.2 GHz was achieved under flat, bending under PVC cylinder and bending under on-body respectively. Thus improved bandwidth also possible with Ultra wide band frequencies. Thus, the results made the antenna suitable for wearable and UWB applications.

Table II. Comparison of proposed antenna under flat and bending conditions

Substrate Material	Operating frequency (GHz)	Return loss (dB)	VSWR	Gain (dB)	Directivity (dB)	Bandwidth (GHz)
Jute - flat	**6.624**	**-33.54**	**1.04**	**0.6826**	**7.34**	**3.5**
Bending on PVC	4.34	-18.40	1.27	2.907	9.758	4.5
Bending on-body	4.34	-17.92	1.29	15.24	7.531	4.2

VII. CONCLUSION AND FUTURE WORK

The proposed antenna presented hereis very easily adaptable and also is very much easy to make it operate at various frequency bands. In addition, antenna using jute substrate will improve the bandwidth thus suitable for wearable antennas too. The results were also satisfactory with flat and bending conditions. In future, the proposed antenna will be fabricated and measured under all conditions and will make them suitable for commercial applications.

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