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Performance Evaluation of Wearable Wideband Circularly Polarized Textile Antenna using Copper as a Conducting Material of the Patch and Ground plane at 2.45 GHz

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Abstract - The growth of portable wireless communication devices has pushed the designers to design miniature size antennas. The most prized among miniature antenna choices is the micro strip patch antenna[5],[17]. These antennas have significant advantages such as low profile, light weight, relatively low fabrication cost and polarization diversity. A wearable antenna, a part of the clothing, is used for communication purposes such as mobile computing, tracking and navigation, medical application and public safety which are also called as Textile Antenna[6]. In this paper we are going to present a wearable wideband circularly polarized textile antenna. Slot antenna having coplanar waveguide is designed[8]. Our aim is to design flexible, robust and a light weight antenna so that it can be easily incorporated on a cloth that can be used for body centric applications as well as in military applications. Authors aim is to fabricate circularly polarized textile antenna that has 3dB axial ratio bandwidth greater than 396 MHz (18%) and a return loss bandwidth (RLBW)(2.7889-2.0151GHz) of 743 MHz (33%)[1],[2],[16].For better enhancement for the S11 and VSWR parameter the design of the antenna is added by the inverted L grounded slits.

Keywords-Wearable textile antennas, Slot antenna, circular polarization, coplanar waveguide feed, ISM band

I. INTRODUCTION

The growth of portable wireless communication devices has pushed the designers to design miniature size antennas. The most prized among miniature antenna choices is the micro strip patch antenna. These antennas have significant advantages such as low profile, light weight, relatively low fabrication cost and polarization diversity. A wearable antenna, a part of the clothing, is used for communication purposes such as mobile computing, tracking and navigation, health care and public safety [7]. Both linearly polarized and circularly polarized textile antennas are studied. A special type of antenna called as a textile antenna has been chosen for such application due to its easy integration because of flexibility of fabrics, light weight, small size and affordable cost due low cost textile material. However we observe that literature on simulation of body worn textile antennas for far field power harvesting and transmission is hardly found. In our previous paper, we have explained about linearly polarized antenna and circularly polarized antenna. Due to independence of orientation antenna with circular polarization is preferred over linear polarization for power transmission[13]. For a patch antenna to generate circular polarization modifications are required such as cutting a notch or providing 90º out phase feedings at orthogonal edges but this method is complicated for implementation and has limited bandwidth so unable to cover the whole 2.45GHz ISM band(2.4-2.485GHz). Moreover due to bending, proximity of human body and the narrow bandwidth of a patch antenna the resonant frequency may be shifted due to the movement of a human body or manufacturing variations .Due to this, efficiency of power transmission is degraded at the desired frequency. In recent years, several high performance wide slot circularly polarized antenna have been proposed. A coplanar waveguide (CPW) fed antenna features wide impedance and axial ratio bandwidth that are essential to body worn textile antenna application as it has higher tolerance to different conditions on a human body. The proposed antenna consist of a single layer of metal. Therefore, cost reduces to half as compared to patch antenna in which two metal layers are present that are ground plane and radiating patch. Proposed antenna design based on wide slot antenna technology. Due to missing ground plane in our proposed antenna influence of human body to the antenna near field has to be carefully simulated in Ansoft HFSS to ensure the effectiveness of operation. Also the antenna structure has to be simple and robust enough for bending on a human arm and the antenna is able to operate at various distances from a human body. For proposed antenna our aim is to measure the different antenna parameters such as -10 dB impedance bandwidth (VSWR≤ 2), Axial ratio bandwidth, Return Loss (RL), Gain (dBi) Voltage standing wave ratio (VSWR)[1],[3],[16],[17].Simulation and fabrication will be performed for copper as copper is highly conductive and readily available in the market at an affordable price.

II. ANTENNA DESIGN

2.1 Textile Materials and Manufacturing

A planar textile antenna consists of 2 layers as shown in Fig. 1. The top layer is the conductive fabric and the bottom layer is the felt substrate. Both materials have to be highly flexible but also rigid enough to conform on any surface of a human body. A Copper self-adhesive EMI shielding sheet has been chosen for this purpose due to its flexibility and high conductivity. A common 20mm-thick 100% acrylic self-adhesive felt is chosen as the substrate for the antenna due to its flexibility and easy stacking for different thicknesses. The dielectric constant and loss tangent are determined as 1.5 and 0.02, respectively by matching the resonant frequencies of a simple patch antenna from the experimental and simulation results[10]. The antenna is hand-made by cutting along the antenna pattern on the back of the shielding sheet and sticking on a 76×76 mm^2felt. An end-launch SMA connector is press-fit to the antenna by clamping the feet together and then the conductive silver epoxy is applied to further secure the connection as shown in Fig. 1. The gap between the feed line and the ground is 3.6 mm for easier hand-cutting and so the input impedance is 50ohms at free space due to the relatively large gap in the feed. Corner Slits of 10*10mm copper with thickness 0.35mm is chosen for simpler design and application.[13]

2.2 Antenna Topology and Simulation

The antenna design objective is to have a wearable antenna to deliver robust low-power transmission to a human body covering the 2.45 GHz ISM band. For easy integration into clothing, the textile antenna has to be flexible and should have wide impedance bandwidth such that any shift in the resonant frequency due to bending is still within the 2.45 GHz ISM band. Therefore, a CPW is chosen for instead of coupling line because the design gets simplified by using only one layer of conductive material without any additional layer. The feed line in Fig.1 produces the necessary x and y components of magnetic current for circular polarization. The orientation of the bending controls the direction of the circular polarization and RHCP is chosen in this context. The approximate resonant frequency can be estimated by the slightly modified equations.

$$f_r = 300/ [(L+W) \sqrt{\varepsilon_{reff}}] \quad (1)$$

$$\varepsilon_{reff} = 2\, \varepsilon_r / (1+ \varepsilon_r) \quad (2)$$

where,

L= length of the slot

W= width of the slot

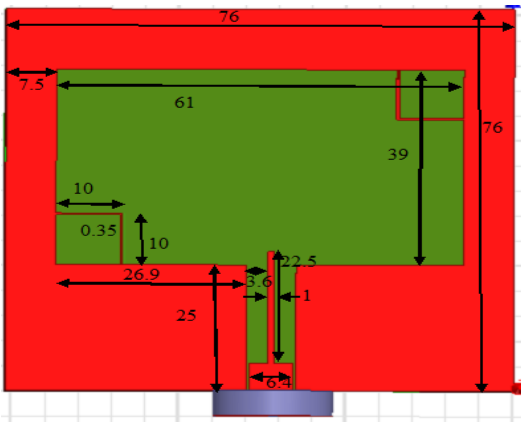

Table No.1 Characteristics of Human Tissues at 2.45 GHz

Tissue	Thickness (mm)	Conductivity (S/m)	Relative Permittivity	Loss Tangent
Skin	3	1.46	38	0.28
Fat	10	0.11	5.28	0.15
Bone	30	0.81	18.5	0.32
Muscle	50	1.73	52.7	0.017

Fig. 1 Textile antenna with planar structure and dimensions in mm.

III. SIMULATED RESULTS

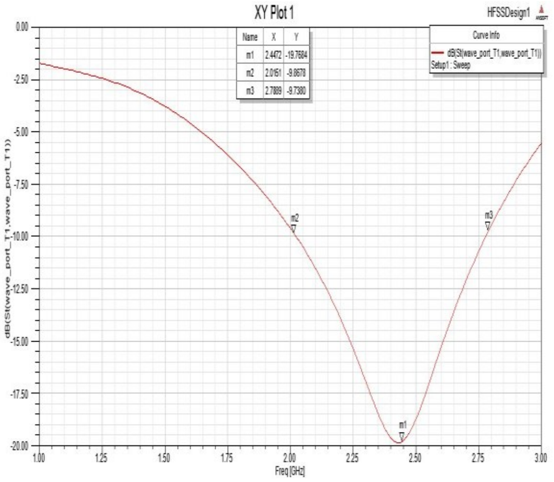

Fig. 2 Simulated S11 of the textile antenna

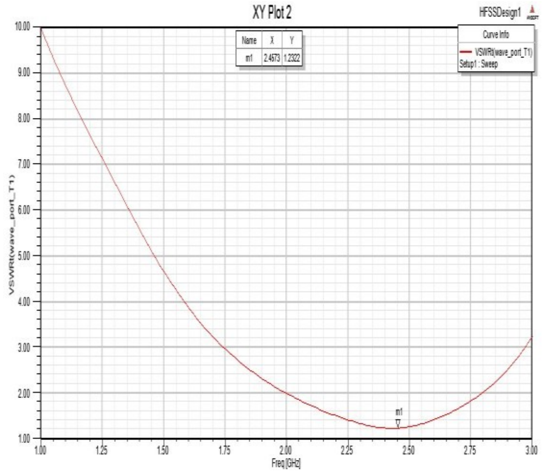

Fig. 3.Simulated VSWR of the textile antenna

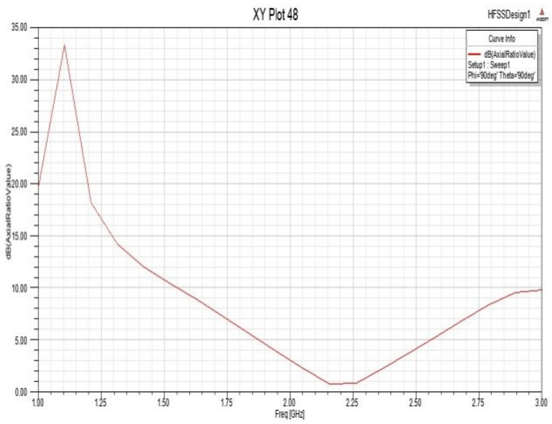

Fig. 4 Simulated Axial Ratio Bandwidth

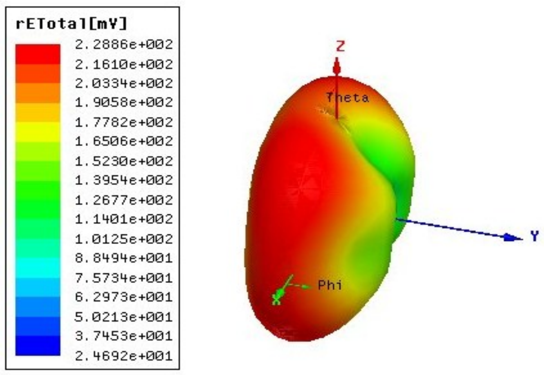

Fig. 5 Radiation polar 3D plot

3.1 SIMULATED RESULTS

Material	Return Loss (dB)	Return Loss Bandwidth (MHz)	3dB Axial Ratio Bandwidth (MHz)	VSWR	Gain (dB)	Fr (GHz)
Copper	-19.7684	733(31%) (2.79-2.015)	396(18%) (2.025-2.45)	1.2322	7.1	2.45

IV. CONCLUSION

Design of wideband circularly polarized textile antenna is proposed. Our aim is to get 3dB axial ratio bandwidth of 396 MHz (18%) and return loss bandwidth of 733 MHz (31%) with the maximum gain of 7.1 dB wherein these antenna can be used in body centric applications. Also the textile antenna if attached to the human arm with the wirelessly-powered sensor system proved to be operational over a meter range with low power transmission from base station. Its structure is simple with only a single conductive layer and a single fed to produce circular polarization .This demonstrates that a robust and ultra low -power battery -less sensor system can be implemented and integrated into clothes for other sensing applications in future.

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