Performance Comparison and Analysis of Rectangular and Hexagonal Textile Antenna using Denim as Substrate at 2.45 GHz

Mith Jain*, Jeet Chhaniara*, Pradyanesh Parabkar*, Sayali Patade*, Prof. Kiran Rathod

Department of Electronics and Telecommunication Engineering
K. J. Somaiya Institute of Engineering and Information Technology, University of Mumbai, Maharashtra, India
E-mail: mith.jain@somaiya.edu*, jeet.c@somaiya.edu*, pradyanesh.p@somaiya.edu*, sayali.patade@somaiya.edu*, kiran.rathod@somaiya.edu

***Abstract*—This paper highlights the performance of Rectangular Textile Antenna (RTA) and Hexagonal Textile Antenna (HTA) for bio-medical application using Denim as substrate. The main objective of this paper is to compare both RTA and HTA with respect to antenna parameters for similar design specifications. The parameters considered in the analysis using denim textile material as a substrate has relative permittivity(ϵ_r=1.7) , loss tangent (tanδ=0.025) and thickness (5mm). The width and length of RTA and HTA has been optimised in HFSS. The result shows that Return Loss Bandwidth (RLBW) of HTA i.e. 150MHz. (6.12%) is greater than RLBW of RTA i.e. 120MHz (4.9%).**

Keywords—Simulation, Rectangular Textile Antenna(RTA), Hexagonal Textile Antenna(HTA), Denim, Bandwidth, Voltage Standing Wave Ratio(VSWR).

I. Introduction

Textile antennas are essential components in smart fabrics and interactive textile systems that implement sensing, localization, and wireless communication functionality while being unobtrusively and comfortably integrated inside garments. The implementation of such antennas in textile materials first requires dedicated material characterization techniques together with suitable fabrication procedures. Moreover, to ensure stable characteristics in proximity of the human body, a designer must also carefully select the right antenna topology [1].

Patch antennas are planar antennas used in wireless links and other microwave applications. A patch is typically wider than a strip and its shape and dimension are important features of the antenna. Hexagonal Textile antenna (HTA) is one of the popular patch geometries like rectangular, circular and triangular [3]. To make optimal use of the area consumed by the antenna, active electronic circuitry may be integrated directly onto the antenna feed plane. Moreover, the large area available in garments can be exploited to deploy multiple antennas, realizing diversity gain to combat fading and body shadowing. Generally, Microstrip antennas are designed using FR4 Epoxy as substrate which obstructs the human body, thus textile substrate such as denim is used in the proposed antenna .The Proposed design is simulated using FEM based software HFSS and results are compared using denim material as substrate with dielectric constant taken as 1.7. Dielectric constant of denim has been assumed initially from literature and then verified using cavity resonance method. Recent literature shows that many research papers on single band[4],dual band[9] as well as multiband textile antennas are available but nowhere it compares RTA with HTA. Hence the paramount aim of this paper is to compare HTA and RTA with respect to antenna parameters.

The rest of the paper is scheduled as follows: Section II clarifies the approach used for calculation of length and width of proposed RTA and HTA. Section III explains the structure model of RTA and HTA. Section IV compares the antenna performance with simulated results. Finally, Section V presents the conclusion for proposed research.

II. Antenna Design and Geometry

A. RTA Design Methodology:-

A rectangular textile antenna contains a patch on top of a dielectric substrate which has a ground plane on the other side. The textile antenna was designed to operate at 2.45 GHz ISM band.[2]

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \tag{1}$$

$$L = \frac{1}{2\sqrt{\epsilon_{eff}}} - 2\Delta L \tag{2}$$

where, c is velocity of light and kmn = 1.84118 , ϵ_{eff} is Effective Dielectric Constant, $fr$is Resonating Frequency, $\Delta L$is Actual Length of Patch

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{3}$$

$$\Delta L = 0.412.h.\frac{(\epsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \tag{4}$$

B. HTA Design Methodology:-

Area of HTA is equated with that of a Rectangular microstrip antenna (RTA) , an HTA with side S, with feed along X axis is considered, the length for equivalent RTA is given $L = \sqrt{3}S$ and $W = 3S/2$. Similarly for the feed along the Y axis, L = 2S and W= 3$\sqrt{3}$S/4 [3] .

III. Structure Models of RTA and HTA

A. RTA

The structure model of RTA is shown in fig 1. The length of the patch is 42.35mm and width is 47.25mm. The thickness of the dielectric substrate is 5mm. The width and length of the substrate as well as ground plane is taken as 120x120mm^2. A physical notch is introduced by the inset feed, which in turn introduces a junction capacitance by increasing the path length. The physical notch and its corresponding junction capacitance influence the resonance frequency. As the inset feed-point moves from the edge toward the centre of the patch the resonant input impedance decreases monotonically and reaches zero at the centre. The length of inset feed for RTA is taken as 15mm and width as 3.5mm. The length and width of the transmission line is 45mm and 5mm respectively.

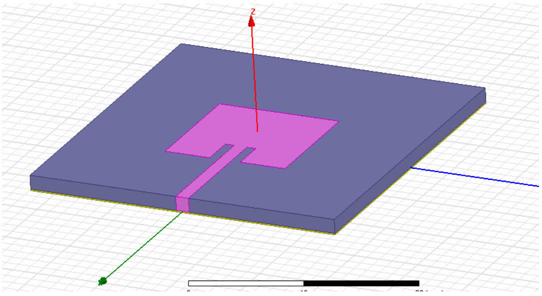

Fig. 1. Structure model of RTA in HFSS

B. HTA

The structure model of HTA is shown in Fig. 2. The length of the hexagon side of the patch is 28.35mm The thickness of the dielectric substrate is 5mm. The width and length of the substrate and ground plane is taken as 120x120mm. The length of inset feed for HTA is taken as 15mm and width as 3.5mm. The length and width of the transmission line is 51.5 mm and 5mm respectively.

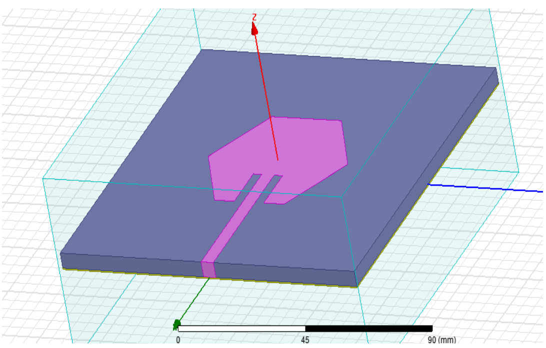

Fig. 2. Structure model of HTA in HFSS

Table I: Comparison of RTA and HTA with respect to various parameters various parameters

Parameters	Structure	
	RTA	HTA
Substrate Area (A)	$0.9835\ \lambda_o^2$	$0.9835\ \lambda_o^2$
Patch Area (A)	$0.137\lambda_o^2$	$0.142\lambda_o^2$
Bandwidth (BW)	120MHz	150MHz
Return Loss Bandwidth(RLBW)	4.9%	6.12%
VSWR	1.24	1.06
Return Loss(RL)	-19.38 dB	-30.72 dB
Impedance (Z_0)	0.877+0.1614i	0.99+0.058i

IV. Performance Simulation and Analysis

The proposed antennas RTA and HTA are simulated using the HFSS between 2GHz to 3GHz with step size of 0.01GHz having a resonating frequency of 2.45 GHz. RTA has a bandwidth of 120 MHz(RLBW =4.9%) and HTA of 150 MHz(RLBW =6.12%) which is shown in Fig. 3. The VSWR curve of both RTA and HTA is compared in Fig. 4. The values of VSWR are 1.24 and 1.06 at 2.45 GHz for RTA and HTA respectively. This shows that HTA has more Bandwidth than RTA as shown in Fig. 3

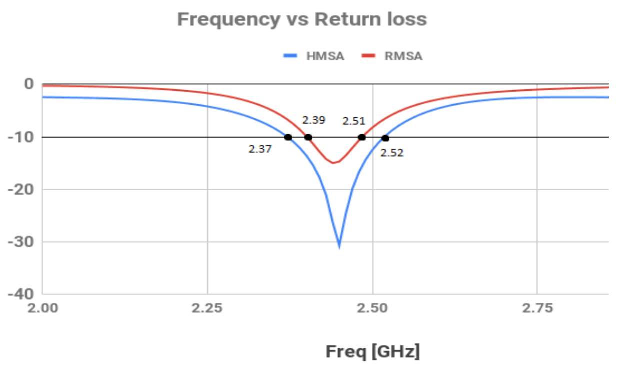

Fig. 3. Frequency vs. Return Loss of RTA and HTA

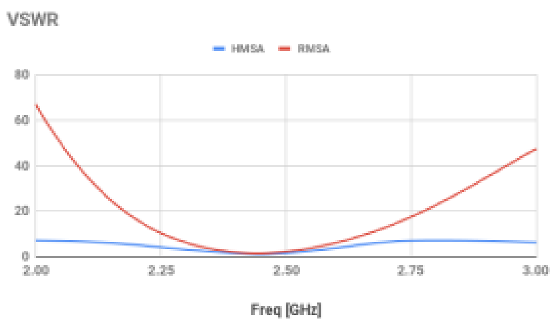

Fig. 4. VSWR curve of RTA and HTA

The radiation patterns of RTA and HTA where E-Plane, H-Plane and its cross polarisation is shown in Fig. 5 and Fig. 6, respectively.The Smith Charts of RTA and HTA is shown in Fig. 7 and Fig. 8. 3-D Polar Plot of RTA and HTA is shown in Fig. 9 and Fig. 10 respectively. This shows that the antenna is radiating more in the broad side direction.

The Impedance (Z_0) of RTA and HTA is 0.877+0164i and 0.99+0.058i shown in Fig. 7 and Fig. 8 respectively.

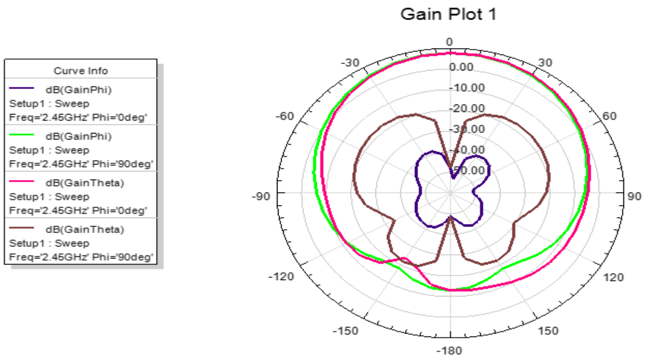

Fig. 5. Radiation Pattern of RTA

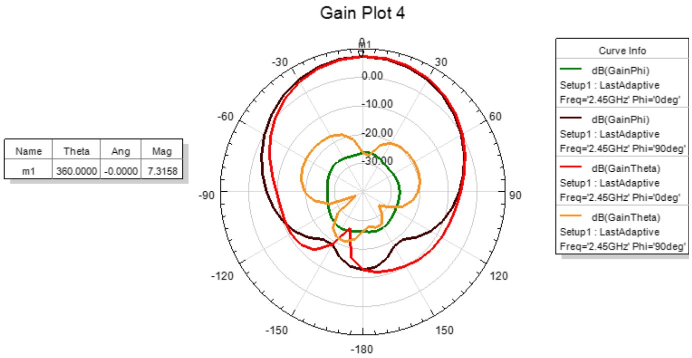

Fig. 6. Radiation Pattern of HTA

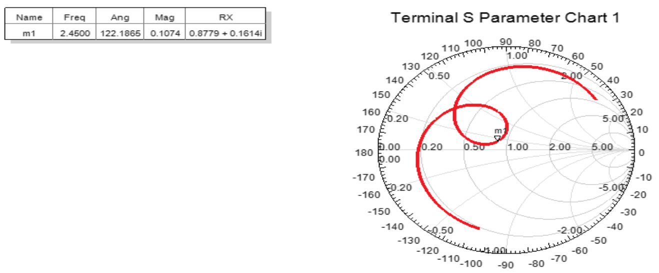

Fig. 7. Smith Chart of RTA

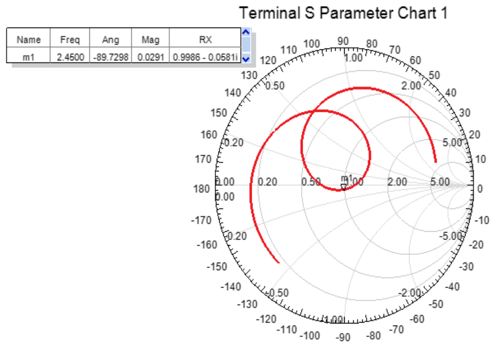

Fig. 8. Smith Chart of HTA

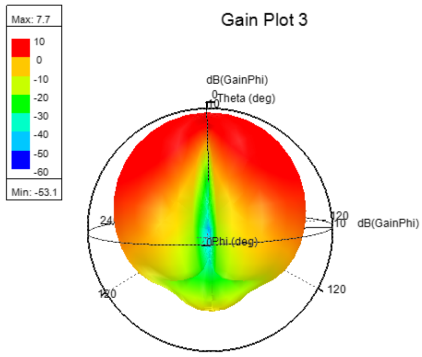

Fig. 9. 3D Polar Plot of RTA

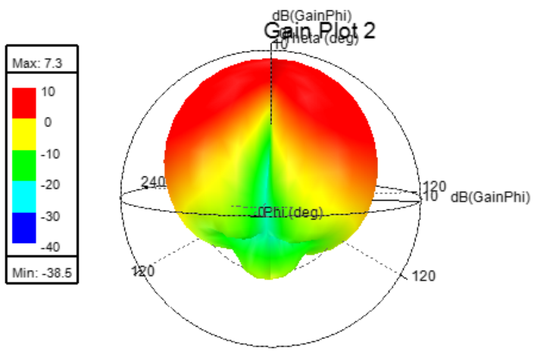

Fig. 10. 3D Polar Plot of HTA

V. Conclusion

The configurations of HTA and RTA using denim as substrate have been proposed and investigated successfully . Considering the above results, it is observed that HTA has better performance than RTA in parameters w.r.t. VSWR, ,return loss bandwidth and also HTA has better impedance matching as compared to RTA both operating at the same resonant frequency i.e. 2.45GHz which is in the ISM Band. The Textile Antenna is a suitable candidate for wearable applications, as its bandwidth is greater than 83.5GHz(ISM band i.e. 2.4GHz-2.4835GHz) which is suitable for bio-medical applications such as cancer detection as well as wireless communication applications . The future work on textile antennas includes testing of RTA and HTA under bending conditions.

Acknowledgment

Authors would like to thank Somaiya Vidyavihar Management, Dr. Suresh Ukarande, Principal KJSIEIT and Dr. Jayashree Khanapuri, HOD(EXTC) KJSIEIT for providing infrastructure facility. Authors would also like to thank Entuple Technologies for their support and guidance.

References

[1] Rogier H. ,Textile Antenna Systems: Design, Fabrication, and Characterization. In: Tao X. (eds) Handbook of Smart Textiles. Springer, Singapore,2015.

[2] C. A. Balanis, Antenna Theory Analysis and Design, 3rd ed., John Willey & Son, Inc., 2010.

[3] Shivraj Rathod , Arpan Shah, Devichand Rathod, Mangesh Dhakane and Priyanka Deosarkar,"Dual band slotted hexagonal microstrip antenna"International Conference on Computing Communication Control and Automation,2015.

[4] K. R. Rathod and B. K. Mishra, "Parametric study of wearable annular ring textile antenna using woven and non-woven polyester fabrics," Proc. International Conf. on Microwave, Antenna, Propagation and Remote sensing, Jodhpur, India, pp. 146-149, Feb. 2017.

[5] Sajina Pradhan[1], Dong-you-Choi[2*] ,"Inset Feed Microstrip Patch Antenna for Wireless Communication at 2.45Ghz" Journal of the Korea Institute of Information and Communication Engineering, Vol. 18, No. 8 : 1785~1790, Aug. 2014.

[6] Sweety Purohit , Falguni Raval, "Wearable-Textile Patch Antenna using Jeans as Substrate at 2.45Ghz" International Journal of Engineering Research and Technology(IJERT), Vol. 3 Issue 5,May-2014.

[7] G. Kumar and K. P. Ray, Broadband Microstrip Antennas, 1st ed., Artech House, USA, 2003.

[8] R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon, Microstrip Antenna Design Handbook, 3rd ed., Artech House, USA, 2001.

[9] Kiran R. Rathod*, B. K. Mishra ,"Low Cost Dual Band Circularly Polarized Textile Antenna Using Electro-textile and Polyester Fabrics"International Journal of Microwave and Optical Technology ,January 2019.

[10] HFSS simulator software by Ansoft version 19.