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Shri-Shape UWB Wearable Antenna & its Performance with Human Tissue

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***Abstract:** Wearable technology is growing technology in today's wireless world. So, there is great demand for wearable devices comprising wearable antenna. Wearable antenna has to be worn on the human body in the form of jackets, wrist watches, glasses, smart clothing, head-mounted displays, GPS shoes etc. Wearable antenna is major part in all the devices. These devices can be used for health monitoring, physical training, navigation, RFID, military, medical, human safety and security applications. Radiations from such antenna greatly effects on the human body parts. This paper represents a novel structure for UWB wearable applications. The major focus is given on effect of antenna on human body. Along with the VSWR, return loss, bandwidth, specific absorption rate (SAR) has been measured using equivalent head model. The structure is designed using Rogers 5880 as substrate material and compared with FR4, polyester, flannel, jean fabric using Ansys HFSS simulation software. All structures are designed to work in the UWB range (1 to 10GHz and above) useful for wearable applications.*

***Keywords:** Equivalent Human head model, Performance parameters, UWB, Wearable antenna.*

I. INTRODUCTION

In the today's world of technological evolution there is great demand for wearable devices comprising wearable antenna.

Conventional Microstrip antennas has many limitations, mostly large in size, & due to large size it is difficult to embed in the cloths.[8] Similarly, such antennas radiate more electromagnetic radiations & affect the human health. The specific absorption rate (SAR) is a parameter which indicates effect of such EM fields on the human behavior & health. [9] The antenna has to be analyzed on human head to observe the effect radiations of antenna on the human head as shown in figure 2. But it is difficult to anayze the antenna on the actual head model. For the analysis, memory requirement of the processor is too much high, so, simulation was difficult. Hence, equivalent model of human tissue as shown in figure 1, is designed & antenna is implemented on the model. Simulation is done on the designed structure. While doing simulation on the equivalent human head model it is observed that the memory required is low & we get results within the finite duration of time.

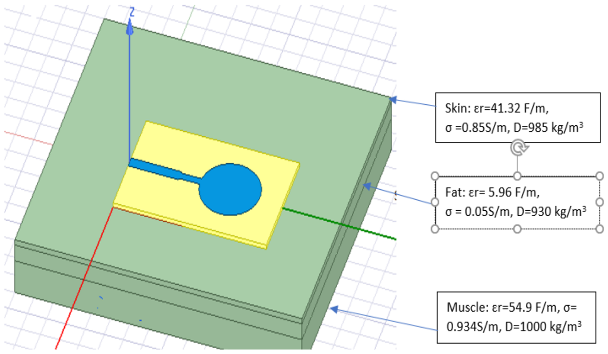

Fig. 1: Circular patch antenna mounted on human tissue equivalent - Top View [6]

Following dimensions have been considered for the implementation of an antenna to work in the UWB range.

Table I: ANTENNA DESIGN SPECIFICATIONS

Sr. No.	Parameter		Dimensions (mm)
1	Substrate Roger 5880	Length	40
		Width	26
		Thickness	0.787
2	Ground	Length	18
		Width	26
3	Patch	Radius	7.76
4	Feed line	Length	13.2
		Width	2.48
5	Step	Length	5.3
		Width	1.7

II. DESIGN

A. Resonant frequency of Circular patch antenna:[5]

$$f_r = \frac{1.8412 * v_o}{2 * \pi * a_e * \sqrt{\varepsilon_r}} \quad \text{---1)}$$

Here,
v_o = velocity of light = $3*10^8$ m/s
a_e = effective radius of the patch = 7.76mm
ε_r = relative permittivity = 2.2

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Hence,

f_r= 7.6 GHz.

Antenna is designed for resonant frequency of 7.6GHz.

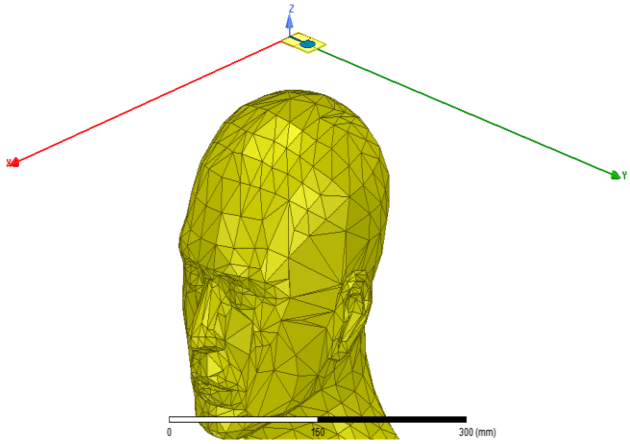

Fig.2: Implementation of Antenna placed near to human head.

Table II: Specifications human tissue model

Human Tissue	Thickness (mm)	Relative permittivity, εr (F/m)	Bulk conductivity , σ (Siemens/m)	Mass density , D (kg/m^3)
Skin	1	41.32	0.85	985
Fat	3	5.46	0.05	930
Muscle	6	54.9	0.934	1000

B. Specific Absorption Rate (SAR):

SAR is a measure of how transmitted RF energy is absorbed by human tissue. The SAR is calculated by averaging (or integrating) over a specific volume (typically a 1 gram or 10-gram area): [7]

$$SAR = \frac{\int \sigma(r)\, |E(R)|^2 \, dr}{\rho(r)} \qquad \text{------2)}$$

The standard value of SAR limit is 1.6 W/kg, averaged over 1 gram of tissue.

III. EXPERIMENTAL OBSERVATIONS

Table III: Measured performance parameters (For Rogers 5880 substrate)

Sr. No.	Solution Frequency (GHz)	VSWR	Return Loss S11(dB)
1	7	2.03	-9.36
2	7.5	2.65	-6.88
3	4	1.04	-32.32

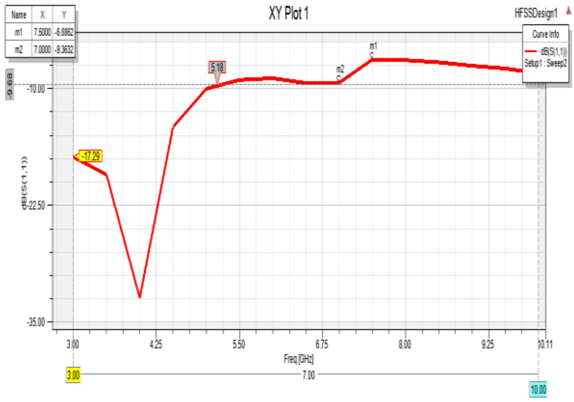

Fig.3: Return loss(S11-dB) Vs. Frequency

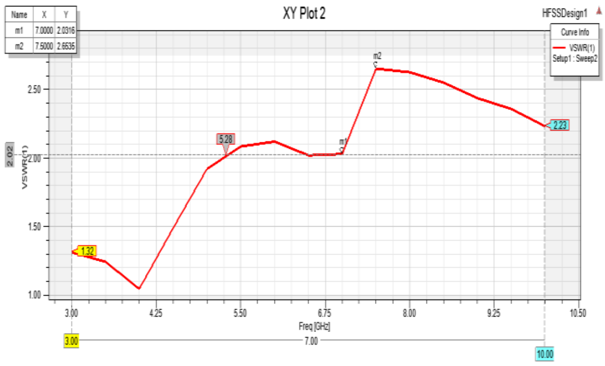

Fig.4: VSWR Vs. Frequency

In wearable antenna applications, as antenna is very close to human body, some heat is generated around the antenna, it gets absorbed by the human tissues which affects human body parts. Hence effect of antenna on human body is necessary to be observed. Following figure shows radiations i.e SAR field generated by antenna.

Table IV: Substrate Materials & their parameters [3,4]

Sr. No.	Substrate	Dielectric Constant (ε_r)	Tangent Loss	Type of Antenna
1	Rogers 5880	2.2	0.009	Conventional Antenna
2	Flannel	1.7	0.025	Textile or Wearable Antenna
3	Polyester	1.44	0.003	
4	Jean	1.59	0.05	

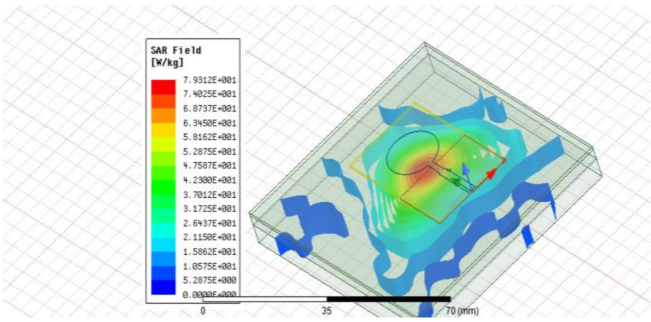

Fig.5: SAR field for circular patch antenna

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Design2 & 3 are same, but design 3 structure is kept on reduced size of human tissue. It improves processing speed.

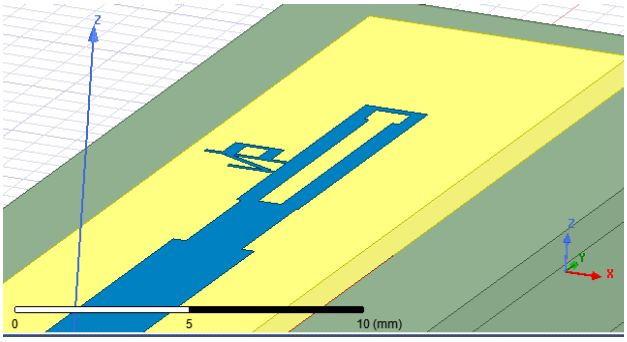

Fig.6: Design2: Simulated structure for Microstrip Antenna

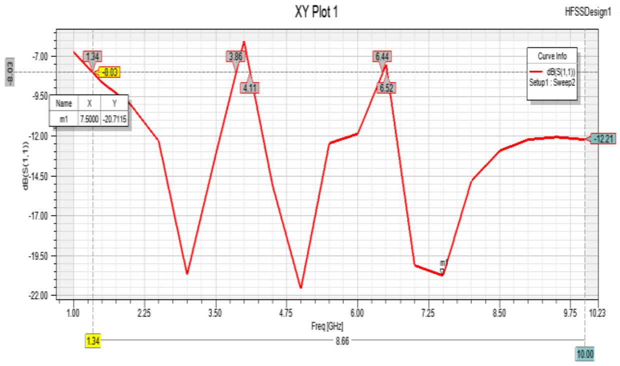

Fig.7: Return loss(S11-dB) Vs. Frequency for antenna using FR4substrate

Fig.8: VSWR Vs. Frequency for new structure of antenna using FR4 substrate.

IV. RESULT AND DISCUSSION

Table V: Measured performance parameters for Design 2 & 3

Sr. No.	**Parameters**	**Design 2**	**Design 3**	**Design 3**
		Rogers 5880	**Rogers 5880**	**FR4**
1	Length, width of human tissue specifications	More (75mm *50mm)	Less (50mm* 15mm)	Less (50mm* 15mm)
2	Frequency of operation (GHz)	3 - 10 GHz	1-10 GHz	Less (50mm* 15mm)
3	Bandwidth (GHz)	4.64	8.23	8.66
4	VSWR	Below 1.8	1.42	1.2
5	Return Loss (dB) @ 7.5 GHz	-12.5	-15.17	-20.71
6	Directivity (dB)	10	5	5

For the designed UWB patch antenna, parameters such as VSWR, Return LossS11(dB), Gain (dB), Bandwidth have been observed. Antenna is placed on equivalent human tissue model for the simulation. It has been observed that for design 4 bandwidth is more than design 3, VSWR & return loss also have been improved in design 4 (Analyzed & mentioned for 7.5GHz solution frequency).

Specific absorption rate is also measured for various substrate materials. For the polyester as a substrate SAR is less but bandwidth is 6.25GHz, which is to be improved.

Table VI: Obtained Vales of SAR(W/Kg) for various substrates

Parameters	**Rogers 5880**	**FR4**	**Flannel**	**Jeans**	**Polyester**
SAR	4.24 e+01	2.24e+02	2.95e+02	2.460e+2	1.1266
Bandwidth	8.23	8.66	5.70	7.82	6.25

V. CONCLUSION

Hence, it is concluded that results obtained for design 4 with low values of length, width, height specifications of equivalent human tissue model are better than design 3. So, for analysis more focus is to be given on design 4 for UWB wearable applications.

Also, for wearable applications, effect of various substrate materials is observed & study of SAR is done very carefully. Polyester has lesser SAR value & bandwidth is also smaller than all remaining substrates. The effort has to be taken to improve the bandwidth & also to keep SAR within specified limit.

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