Effect of Dielectric Materials on UWB Antenna for Wearable Applications

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Abstract **-**This paper represents the implementation of Ultra Wideband (UWB) antenna with circular patch for wearable applications. Wearable antenna is used in various fields such as medical, mobile communication, navigation and military. Wearable antenna is an intelligent device which is part of smart clothing. These antennas should have low profile, light weight & should be very flexible for wearing. Textile patch antenna uses fabric material for substrate, patch and ground and it becomes part of wearable clothing. To improve bandwidth & reduce surface wave losses fabric dielectric constant should be as low as possible. Specific Absorption Rate (SAR) is a crucial factor in designing such antennas. As antenna has to be weared by the person, SAR should have least value. Here, effect of various substrate materials on the performance parameters like Return loss, Voltage Standing Wave Ratio (VSWR), Bandwidth, Radiation pattern, SAR are observed. All the structures are designed to work in the UWB range from 2 to 12GHz and above, and simulated using Ansys HFSS software.

Keywords - Circular patch; Slot; UWB; Textile material; Wearable; Return loss; Bandwidth; SAR.

I. INTRODUCTION

The large bandwidth of ultra wideband (UWB) has several advantages.UWB antenna has large channel capacity, more jamming resistivity, low transmission power with lower signal to noise ratio. Ultra-wideband (UWB) (3 GHz to 12 GHz) is an emerging technology that promises high-speed data transmission at low cost for short-range communications. [1]

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The use of UWB technology in the area of Wearable Antenna is one of the most promising applications.Here, Roger 5880 material (dielectric constant, $\varepsilon_r = 2.2$) is taken as substrate & various parameters are calculated. Then these values are compared with other substrate materials having dielectric constant, ε_r less than 2.2.

II. ANTENNA WITH TEXTILE AS SUBSTRATE

Ultra-Wideband (UWB) antennas seem most suitable for integration into clothing. These antennas consist of a metallic patch on top of a dielectric substrate that is mounted onto a conducting ground plane. These types of antennas when integrated into clothing will have a compact geometry, light weight, low cost, soft and comfortable to the wearer. Moreover, UWB antennas are often used for mobile communication equipment. Additionally, in low or medium data-rate applications, like wearable computing, UWB antenna offers low-power operation and extremely low radiated power, thus being very attractive for body-worn battery-operated devices. Wearable telecommunication devices operate in the vicinity of human body, SAR is important factor to be considered. Since UWB antennas provide a kind of Omni-directional radiation pattern component, special attention must be paid to the Specific Absorption Rate (SAR) in order to avoid harm to human body.[2] For wearable antenna jeans fabric, denim, silk, wash cotton, polyester ,curtain cotton,

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flannel material could be suitable as a substrate material in the UWB range.

II. ANTENNA DESIGN SPECIFICATIONS

This design consists of circular patch of radius 7.76mm which is resonant at 7.76GHz frequency

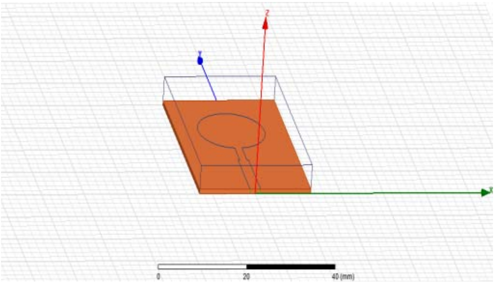

Figure 1: Design1- Circular patch Antenna

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
6	Centre square Slot	-	3 × 3
7	Upper square slot	-	6 × 6

Table II : Materials & their dielectric values

Sr. No.	Substrate	Dielectric Constant (ε_r)	Tangent Loss
1	Rogers 5880	2.2	
2	Flannel	1.7	0.025
3	Polyster	1.44	0.003

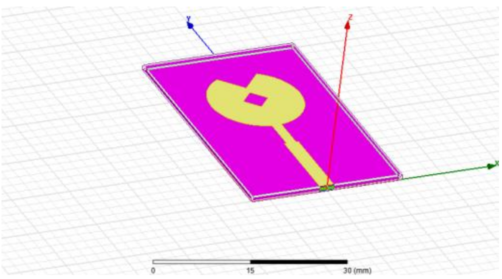

Figure 2: Design 2 - Implemented structure using Rogers 5880 as substrate[2]

III. RESULTS & DISCUSSION

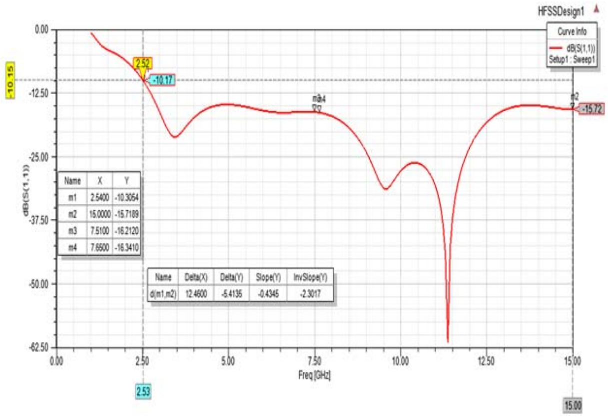

Figure 3: S11(dB) Vs. Frequency(GHz)- indicating bandwidth improvement & S11 values below -10dB for all over the range for Rogers 5880

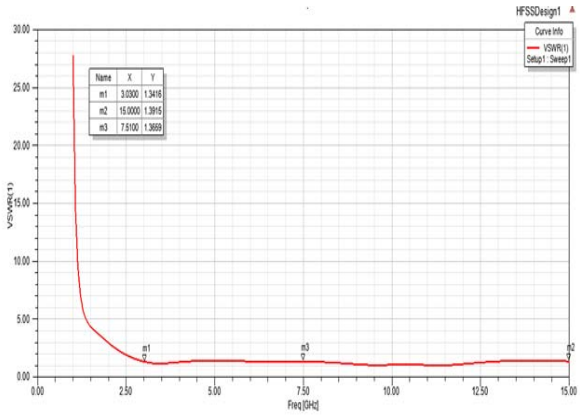

Figure 4: VSWR Plot Vs. Frequency(GHz), with Rogers 5880 as substrate. VSWR value is below 2 for all over the UWB range.

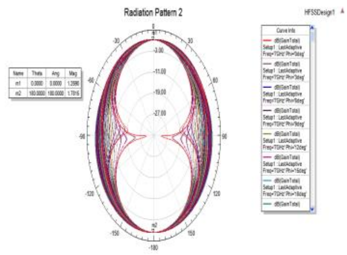

Figure 5: Radiation pattern with Rogers 5880

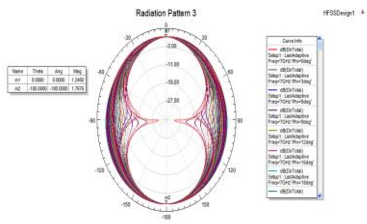

Figure 6: Radiation pattern with Rogers 5880

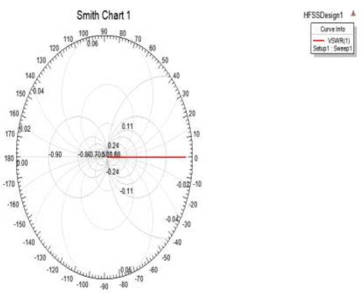

Figure 7: Smithchart for Rogers 5880

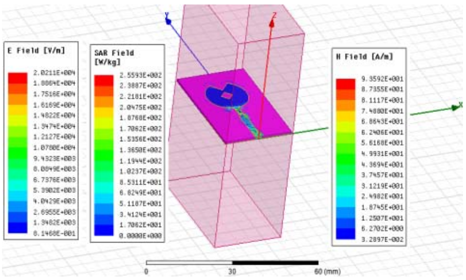

Figure 8: Local SAR for substrate, air & all objects for Rogers 5880

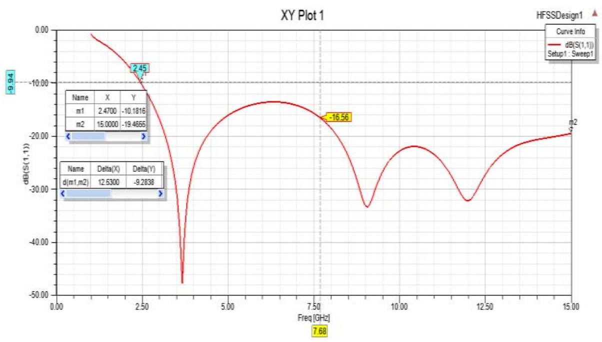

Figure 9: S11(dB) Vs. Frequency(GHz)- indicating bandwidth improvement & S11.

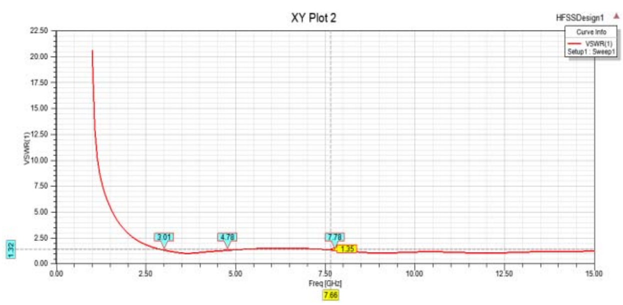

Figure 10: VSWR Plot Vs. Frequency(GHz), with Flannel as substrate

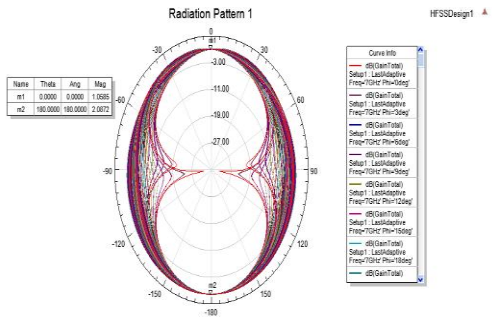

Figure 11:Radiation pattern with flannel substrate

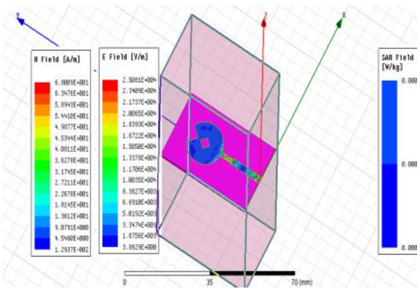

Figure 12: E- field, H-field, SAR values.

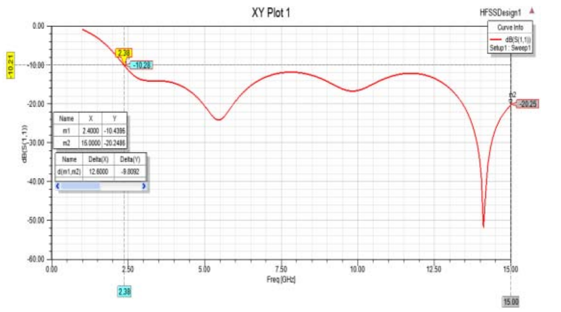

Figure 13: S11(dB) Vs. Frequency(GHz)- indicating bandwidth improvement & S11with Polyster as substrate.

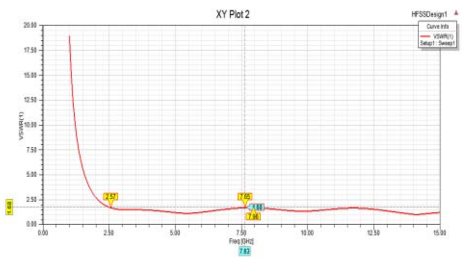

Figure 14: VSWR Plot Vs. Frequency(GHz), with Polyster as substrate

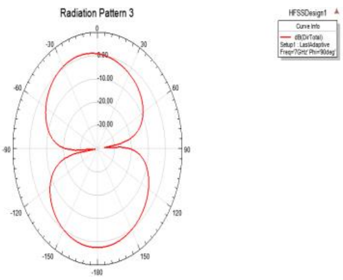

Figure 15:Radiation pattern with Polyester substrate

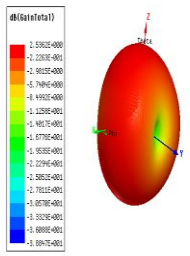

Figure 16:Radiation pattern with Polyester substrate

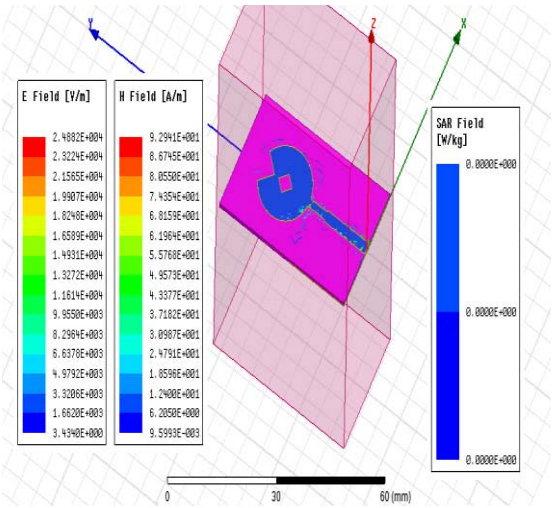

Figure 17: E- field, H-field, SAR values.with Polyester substrate

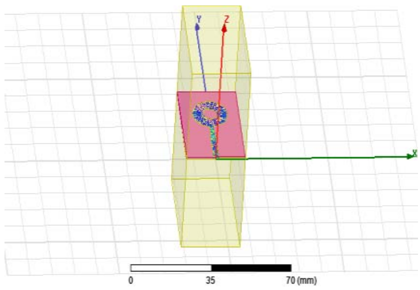

Figure 18: Design 3 - Implemented structure with circular patch &circular slot using Rogers 5880 as substrate[2]

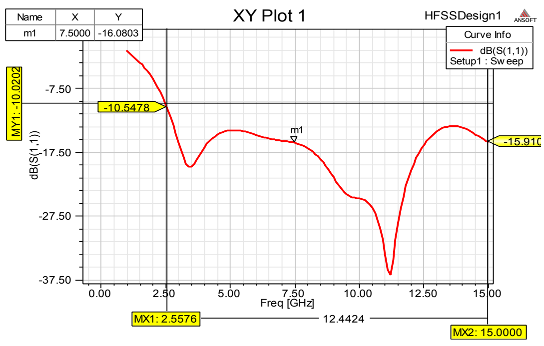

Figure 19:Design 3 -S11(dB) Vs. Frequency(GHz)

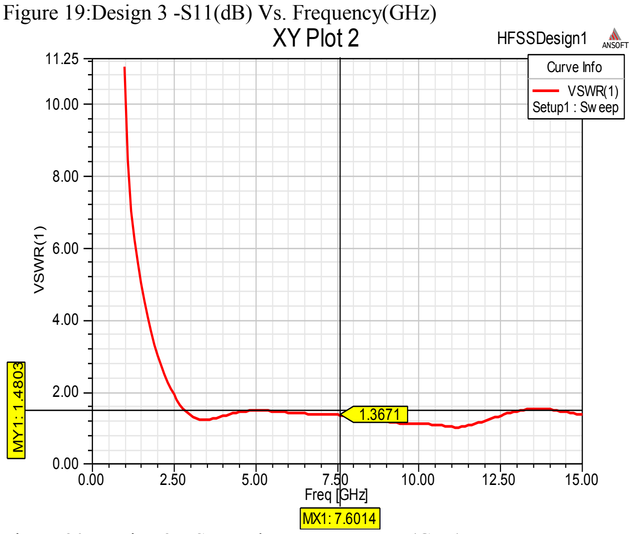

Figure 20: Design 3 VSWR Plot Vs. Frequency(GHz).

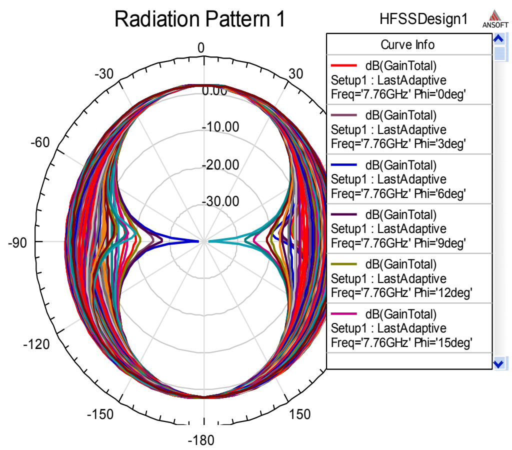

Figure 21:Radiation Pattern, with Rogers 5880 as substrate

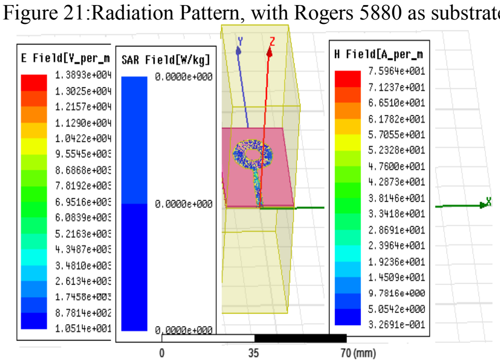

Figure 22:E- field, H-field, SAR values.

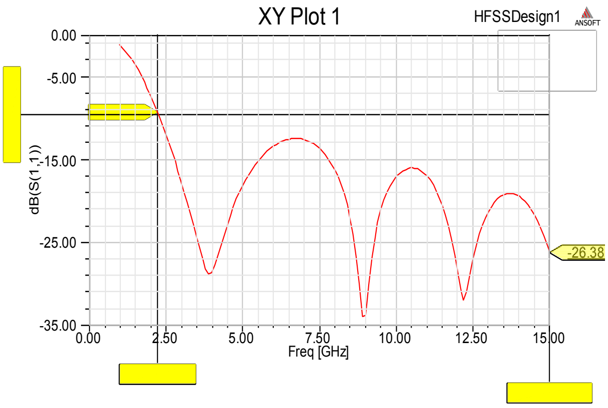

Figure 23: S11(dB) Vs. Frequency(GHz)- indicating bandwidth improvement & S11with polyster substrate.

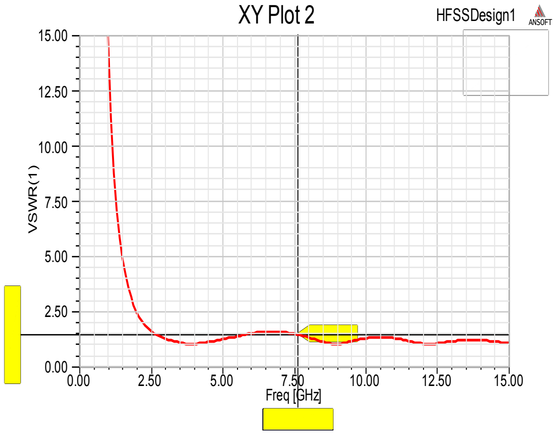

Figure 24: VSWR *Vs. Frequency(GHz)-*

A. Effect of Substrate: In this work, more focus is given on using flannel, polyster fabrics as substrate material. Flannel fabric is made from 100% cotton materials with a smooth and firm surface and suitable for wearable applications. The thickness of the mentioned fabric is approximately 1 mm.[2]

B. Thickness of the Dielectric Fabrics: The bandwidth and efficiency of a patch antenna is mainly decided by the substrate dielectric constant and its thickness. The thickness h of substrate is usually in the range of $0.003\lambda \leq h \leq 0.005\lambda$ where λ is a wavelength. For a fixed relative permittivity, the substrate thickness may be chosen to maximize the bandwidth of the patch antenna. However, this value may not optimize the antenna efficiency. Therefore, the choice of the thickness of the dielectric material is a compromise between efficiency and bandwidth of the antenna. [4] Bandwidth is inversely proportional to dielectric constant, ε_r.

IV. CONCLUSION

Here three designs are implemented & simulated using Ansys HFSS simulation software. Effects of three different substrate materials have been studied. For all designs VSWR is less than 2 & S_{11} (dB) is less than -10dB.

Design 2 with Circular Patch and rectangular slots with flannel as a substrate material shows considerable improvement in bandwidth and is of about 12.53 GHz. Return loss for this design is about -16.56dB and VSWR is 1.33.VSWR with this design is least. Directivity is also improved than with other two substrate materials. Hence Flannel is also good substrate materials.

Design 3 with Circular Patch and circular slots with polyester as a substrate material shows considerable improvement in bandwidth & is about 13.78 GHz. Hence we can conclude that to improve the bandwidth & to have results in the UWB range, Polyester is one of the best material to be used as a substrate for wearable applications. Lesser the dielectric constant better is the bandwidth. All design shows SAR value 0W/Kg than with simple circular patch antenna.

In future the effect of more substrate materials and also the presence of human body on various parameters will be studied.

Table III: RESULTS OBTAINED

Design	**Title**	**Return Loss, S_{11}(dB)**	**VSWR**	**Bandwidth (GHz)**	**Peak Gain Total (dB)**	**Directivity (dB)**	**E-Field (V/m)**	**H-Field (A/m)**	**SAR (W/Kg)**
Design 1	MSA with Circular Patch	-7@7GHz	2.5@7 GHz	3.8120GHz	-1	--	--	--	--
Design 2	MSA with Circular Patch and 2 slots (Substrate: **Rogers 5880)**	below -10dB(from 2.5 to 15GHz) **-16.21**	1.3559	12.46	1.29	1.2450	Max: 9.432 (along feed) 8.1468 (along patch) Min: 1.3482	Max:9.35 Min:1.250	**Max:2.559*10^{2} Min:1.7062**
	Substrate: **Polyester**	below -10dB (from 2.5 to 15GHz) **-12dB**	1.68	**12.6**	2.5362		Max:2.488 Min:1.60	Max:9.294 Min:1.24	**0**
	Substrate: **Flannel**	**-16.56**	**1.33**	**12.53 GHz**	**2.13**	**2.00**	Max:3.862 Min:1.17	Max:6.809 Min:4.546	**0**
Design 3	MSA with Circular Patch and circular slots (Substrate: **Rogers 5880)**	-16.06	1.36	12.44	--	--	7.819 1.042	7.59 1.4	0
	MSA with Circular Patch and circular slots (Substrate: **polyester)**	-15	1.48	**13.78**	--	--	--	--	0

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