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Measurement of Dielectric Constant(ε_r) and Loss Tangent (tanδ) of Textile Substrates.

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Abstract

In this paper, the design and fabrication of four types of textile substrates made by four types of textiles materials (wool, corduroy, bed sheet cotton & terry wool) are presented. The RF characteristics of these four types of textile substrates have been investigated by using micro strip ring resonator method.

Index Terms- Microstrip wearable textile antenna, textile based substrate, dielectric constant measurement, loss tangent (tanδ).

1. INTRODUCTION

Wearable textile antenna has a high demand for the smart protective garments [1] . In future , garments will not only protect the human body against the worse condition of environment, it also gives data about the wearer's condition of health and environment[2]. Where flexibility and comfort is an issue for the protective garments, antennas should be integrated into garments[3]. For that purpose antenna should be made by using textile material .Micro strip antenna is a suitable candidate for design and fabrication of wearable smart protective electro textile antenna. The performance of microstrip antenna is dependent on the fundamental properties (dielectric constant & loss tangent) of the textile substrate. Therefore, the development of more accurate textile material substrate characterization methods in the microwave range is of great importance. In this paper measurement of dielectric constant & loss tangent using micro strip ring resonator method have been carried out. Measurement of dielectric constant & loss tangent (tanδ) of four different textile materials(wool, corduroy, bed sheet cotton & terry wool Substrate) by using ring resonator method[4,5,6,7] have been done. There are many existing procedures [8,9] for measuring dielectric constant and loss tangent. In this paper, the micro strip ring resonator method was used. The main advantages of the ring resonator technique are:-

1)Compared to other planar transmission line techniques the radiation losses of the ring resonator are typically negligible because of the absence of the end-effects[10] and higher values of quality factor [11]
2)The current flows predominantly only on the surface of the conductor and the roughness correction is better studied [12].
3)Easy to design and fabricate.
4)Compared to micro strip line resonator method [5,6] , a micro strip ring resonator does not suffer from open-ended effect and can be applied to give more accurate measurements.
5)During recent measurements of PWB materials using the ring resonator structures [13, 14] no effects due to the non-uniformities of the line width has been observed.
Apart from measurement applications, the microstrip ring resonator has also been utilized in filters, oscillators, mixers, and antennas [15] because of its advantages of compact size, easy fabrication, narrow pass-band bandwidth, and low radiation loss. Recently, interesting compact filters using microstrip ring resonators for cellular and other mobile communication systems have been observed [16],[17].

II **MEASUREMENT OF DIELECTRIC CONSTANT AND LOSSES OF TEXTILE SUBSTRATE:**

In order to design a micro strip antenna on textile surface the dielectric constant of the substrate should be known. For this purpose the dielectric constant of the chosen substrate is to be measured. For measuring dielectric constant , the micro strip ring resonator method[4,5,6]was used. The structure was fabricated by pasting the copper foil on the surface of the different textile materials. The adhesive used was synthetic resin adhesive. Adhesive resin has limited effect on the high frequency performance of the anisotropic conductive adhesive (ACA) flip-chip joint[18]. So resin adhesive was used .After pasting the copper foil, heavy pressure was applied on the top of the microstrip ring resonator structure for removing the air gap in between the textile material and copper foil. The desired micro strip ring structure was obtained by cutting the copper foil of the top surface. The thickness of the substrate material was measured by using screw gauge. The thickness of the different substrate materials for ring resonator is given in Table:-1.

TABLE -1
Substrate material thickness for ring resonator structure.

Substrate Material	Thickness of the Substrate (mm)
Bed sheet cotton	1.26
Corduroy	1.04
Wool	1.19
Terry wool	1.14

The copper foil was 0.20 mm. thick. The desired micro strip ring resonator structure on different textile substrate materials are shown in Fig 1 . For measurement , at first two SMA connecters were connected at the two ports of the ring resonator structure as shown in Fig 1 .The measurement was carried out using Agilent E5071B Vector network analyser.

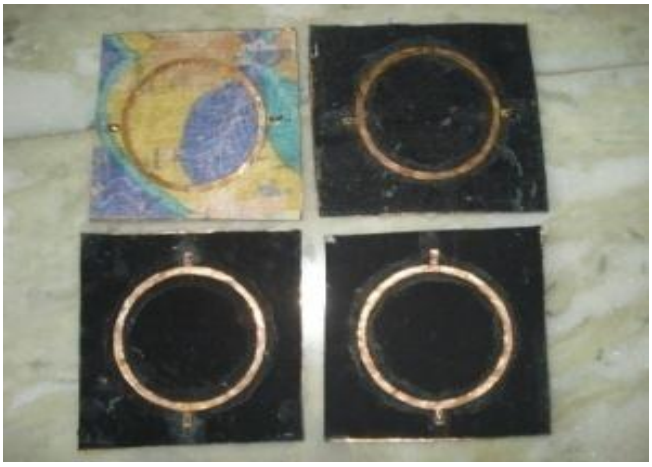

Fig:-1 Photo of fabricated micro strip ring resonator on four different substrates.(bed sheet cotton, wool, terry wool & corduroy).

(a) ***Dielectric constant:*** As shown in Fig 2 S_{21} as a function of frequency give resonances at different frequencies. In this method, ε_r can be extracted from the location of the resonances of a given radius of ring resonator .The effective dielectric constant of the substrate is given by [4,5,6,7].The results of ring resonator for dielectric extraction are shown in Table 2.The data(Table 2) in column 2, 3,4 & 5 are obtained from Agilent E5071B Vector network analyser reading.

(b)Measurement of losses of chosen textile substrate:The total attenuation constant (α_{total}) is the sum of the conductor attenuation factor (α_c), the dielectric attenuation factor (α_d) and radiation attenuation factor (α_r)[7] .Subtracting the conductor attenuation constant and the radiation attenuation constant from the total attenuation constant, the dielectric loss tangent (tanδ) of textile materials can be determined [5,6,7]. The calculated value of dielectric attenuation constant is shown in Table :-2

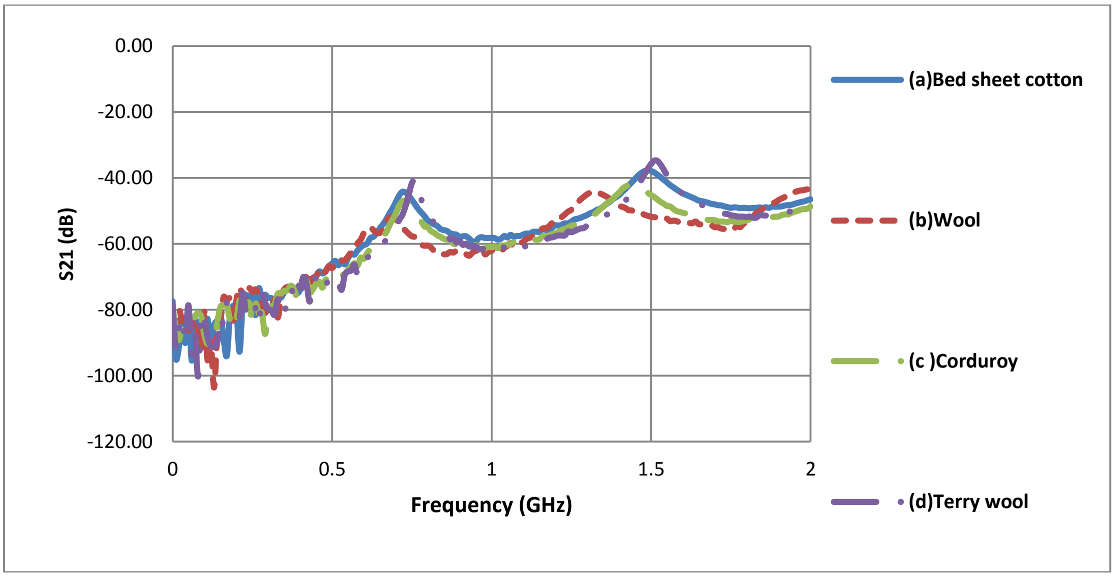

Fig 2:- Measured S_{21} as a function of frequency for the ring resonator for four substrates.(a)Bed sheet cotton (b)wool (c)corduroy (d)Terry wool.

TABLE-2
RESULTS OF RING RESONATOR FOR CHARACTERIZATION OF TEXTILE SUBSTRATE

Name of the Substrate Material	**Mode**	**Resonant Freq (*fo*)**	**BW - 3dB (MHz)**	**Insertion Loss** ($\|S_{21}dB\|$)**dB**	**Dielectric Constant (€r)**	**Loss Tangent (tanδ)**
Bed sheet cotton	n=1	727.81 MHz	59.99	43.70	3.27	0.00786
	n=2	1.4874Ghz	89.98	38.25	3.13	0.00572
Wool	n=1	683.597MHz	49.99	51.68	3.74	0.00635
	n=2	1.3226GHz	109.98	44.36	3.98	0.00804
Corduroy	n=1	723.7914Mhz	49.99	46.78	3.25	0.00622
	n=2	1.435 GHz	89.98	41.83	3.32	0.00592
Terry wool	n=1	755.94MHz	29.99	40.26	2.98	0.00265
	n=2	1.5156GHz	49.99	34.63	2.96	0.00224

IV. CONCLUSIONS

The employment of micro strip ring resonator method ,for measurement of RF characteristics of jeans material was already reported .In this paper measurement of RF properties like dielectric constant and loss tangent of four substrates are reported for the first time using ring resonator method . The results show that these textile material substrates have attractive properties for design , fabrication of low cost ,eco-friendly wearable embedded microstrip antennas on textile substrates as they have low loss tangent and moderate dielectric constant .

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