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Measurements Of Dielectric Constant Of Solid Material (Leather Belt) At X-Band And Proposed Wearable Antenna

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Abstract: *This article discusses the experimental measurement technique for dielectric constant (i.e. permittivity) of leather belt at X-band. This measurement play selection of dielectric constant for antenna substrate. This leather can be used as flexible substrate of wearable microstrip antenna. This measurement system consist of solid state klystron power supply, isolator, VSWR meter, frequency meter, solid dielectric cell (XC-501). This data may be interested in flexibility wearable microstrip antenna studies and design.*

Keywords: *Solis dielectric cell; leather belt; Ansoft HFSS*

I. Introduction

Recently, as the number of system using high frequency electromagnetic wave has increased , serious electromagnetic compatibility (EMC) problem have become apparent. This has lead to search for electromagnetic wave absorbing material useful in microwave frequencies.

The permeability and permittivity of a Leather belt plays an important role to determine reflection properties. It is very essential to determine accurately the dielectric constant of Leather material. Such type of absorbing materials have varied application such as construction of wearable microstrip antenna , improvement of antenna pattern and improvement in wearable antenna performance[13].

In this paper we determine dielectric constant of Leather and used as wearable antenna substrate. Emerging trends in monitoring people (patients, soldiers, athletes, etc.) have led to numerous recent advances in body area communication networks (BAN). Wireless sensor communication opens up tremendous potential for wireless patient monitoring. Body centric wireless networks use RF sensor nodes in close proximity to the human body. Body networks include on body, body to body and off body communication. Antenna design and analysis plays an important part in the development of sensors for BAN. Antennas for on-body communication include the inverted F antenna, wearable (fabric) antennas [9]-[12] . In this paper we discuss a low cost, nearly circularly polarized truncated patch antenna design on Zelt [8] fabric and Felt substrate for performing off body communication centered at 0.8344 GHz for Leather and 0.9029 GHz for Felt for monitoring patients after operation. This low cost antenna provides good return loss comparable to the fabric antennas.

II. Measurement Using Rectangular Waveguides X- Band

A representative study was carried on leather belt . In this work the thickness of dielectric sample of leather 2.2 cm. [1]. The accuracy of sample largely depends upon smoothness of the sample in waveguide and care which has been taken to ensure that its surface are properly squared with respect to each other.[2]. The machine sample has taken very carefully for smoothness, the size and squared surfaces.

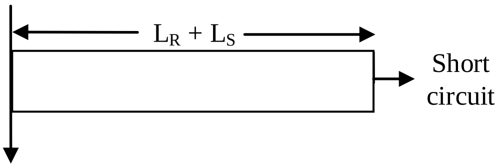
The figure 1(a) shows an empty short circuited waveguide with probe located at voltage minimum L_R Figure 1(b) the sample waveguide containing sample of length L_S with a probe located at new voltage minimum L[13].

Factor affecting Dielectric Constant of Leather

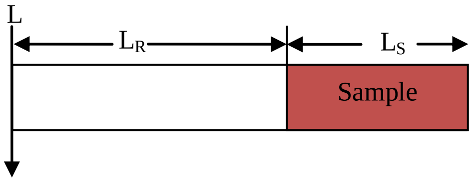
Electromagnetically a leather is, in general a three component dielectric mixture consisting of air , rawhide, bound water. Due to forces acting upon it the bound water molecule interacts with an incident electromagnetic wave in a manner dissimilar to that free water molecule, thereby exhibiting a dielectric dispersion spectrum, very different from that of free water molecule. Therefore, the dielectric constant of leather mixture is greatly influenced by a number of factors such as total water content due to humidity of environment ,frequency, temperature etc.[6].

Many of the studies on dielectric properties of leather have been carried out in laboratory conditions. In general, it has been observed that dielectric constant of leather primarily related to leather moisture content [7]. Dielectric constant of water is 80, hence variation in leather moisture content makes significant in dielectric properties of leather[13].

PROCEDURE



(a) Empty short circuited waveguide



(b) Wave guide containing sample

Where

L_R = empty cavity length

L_S = sample (i.e. dielectric material) length

Fig1. Figure shows waveguide with dielectric and without dielectric sample

The basic arrangement of equipment were connected as shown in Fig. 2.

1. Connect the equipment as shown in Fig. 2
2. With no sample dielectric in the short circuited line, measure L_R position of the minimum in the slotted line with respect to arbitrary chosen reference plane (L = 0), was find out.
3. The guide wavelength (λg) was obtained by measuring distance between alternate in the slotted line.
4. The dielectric , i.e. the leather sample in this case was inserted in the short circuit in such a manner that it touches the end of the sample.
5. Measure D, the position of minima in the slotted with respect to the reference plane.

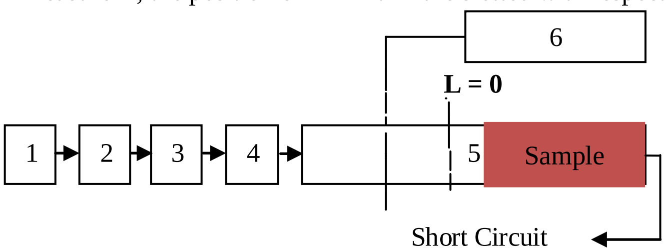


Fig. 2 Experimental Set Up for Dielectric Constant measurement

1. Microwave Source (Klystron power supply)
2. Isolator
3. Frequency meter
4. Variable attenuator
5. Wave containing sample
6. Detector

III. Waveguide inside a Dielectric

The wavelength in a dielectric medium is always smaller than free space wavelength. The wavelength in any unbounded dielectric medium λ_d is

$$\lambda_d = \frac{\lambda_0}{\sqrt{k'\mu'}}$$

Where

k' = dielectric constant of the medium (i.e. leather belt)

μ' = permeability of the medium

λ_c = cut-off wavelength of the waveguide

λ_0 = wavelength in vacuum

For most of the dielectric materials μ' = 1 and therefore

$$\lambda_d = \frac{\lambda_0}{\sqrt{k'}}$$

The wavelength λg in the air field rectangular waveguide is given by

$$\lambda_g = \frac{\lambda_0}{\sqrt{\left[1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2\right]}}$$

Where

λ_c = cut-off wavelength of the waveguide.

If the waveguide is filled with a medium of dielectric constant k' the new wavelength λ'_g in the waveguide is given by

$$\lambda'_g = \frac{\lambda_0}{\sqrt{\left[k' - \left(\frac{\lambda_0}{\lambda'_c}\right)^2\right]}}$$

Where,

$$\lambda'_g = \frac{\lambda_g}{\sqrt{k'}}$$

$$\lambda'_c = \sqrt{k'\lambda_c}$$

after solving these equation we obtain dielectric constant of leather belt (i.e. k') of leather sample is 1.6587[13].

IV. Antenna Design and Geometry

Fig. 3 illustrates the geometry of the proposed printed antenna with rectangular radiator and a finite -size system ground plane. One of the main criteria for choosing material for fabric antenna design is the ease with which it can be incorporated. the second criteria is that the fabric material for antenna and the ground plane must have good conductivity. The third criteria is that the fabric material substrate must have constant thickness and stable permittivity. Based on the basic properties required for textile antenna, Felt and Leather were chosen for the antenna substrate, where as Zelt is used as antenna material. The material properties of the fabrics and Leather are given in Table 1.

Table 1: Properties of Zelt , Felt and Leather materials

Properties	Leather	Zelt [8]	Felt
Conductivity (S/m)		1×10^6	
Resistivity (ohm/sq)		0.01	
Loss Tangent			0.023
Permittivity	1.6587		1.38
Substrate Thickness (mm)	2.2		2.2

This is based on a simple microstrip patch design (Zelt is also used as a ground plane) and backing behind the blue Felt in Figure 3. The corners were truncated to provide circular polarization. Commercially available electromagnetic solver Ansoft HFSS was used during design . As the design criterion, we look at return loss characteristics. Truncation and feed optimization were performed for obtaining a well matched, left hand circular polarization (LHCP) truncated patch design.

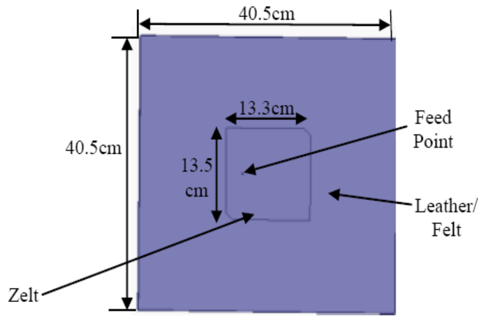


Fig3: Truncated patch antenna using Zelt fabrioc for antenna a Felt and leather substrate.

V. Simulation Result

In this section we compare simulated antenna characteristics for two different dielectric materials Felt (h= 2.2 mm and ε_r = 1.38) and Leather (h = 2.2 mm and ε_r = 1.6587) which is used as antenna substrate. The Simulated return loss (S_{11}) is compared in figure 4 and shows excellent agreement. The simulated antenna has return loss of about -32.7696 dB at 0.8244GHz for Leather and -38.9001dB at 0.9029 GHz for Felt substrate. The simulated antenna has a 10 dB-bandwidth of 0.0353GHz for Leather substrate and 0.0413 GHz for Felt substrate.

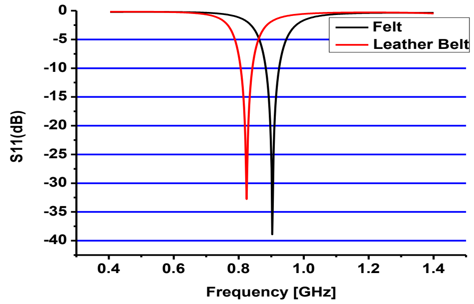
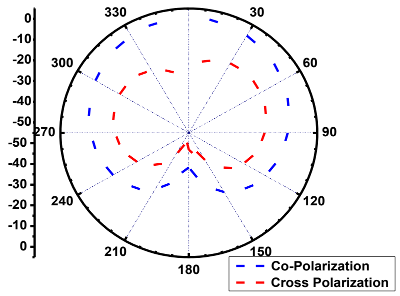


Fig 4: Simulated return loss (S_{11}) dB comparison between two material

The measured normalized co-polarized and cross polarized E-plane and H-plane radiations of the patch antenna at 0.8244GHz are shown in Fig. 5

1. For Leather Belt Gain Theta and Phi at Phi=0^0



2. For Leather Belt Gain Theta and Phi at Phi=90^0

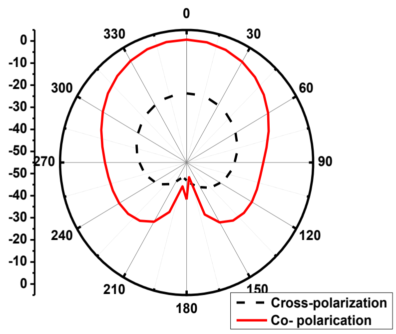


Fig. 5 Simulated E-plane (Co-pol(solid line)) and Cross pol(dotted line)) radiation pattern is at 0.8244 GHz for Leather.

IV. Conclusion

In this paper measurement of dielectric constant of leather belt determined. From the computed result it is conclude that dielectric constant depends on thickness of the sample and at lower frequency dielectric constant are high. This paper also simulates an inexpensive fabric antenna for performing communications from sensors on the human body to a near by receiver. The antenna well matched at 0.8244 GHz for leather and at 0.9029GHz for Felt substrate. It is nearly LHCP in the frequency band of nearest. The effect of antenna flexing as well as the presence of human body along with designs with improved antenna efficiency.

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