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Dielectric Permittivity Analysis on Wearable Antenna Substrate Materials

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ABSTRACT

This paper presents a novel dielectric measurement of textile materials using waveguide method. The textile material dielectric property is used to design wearable antennas. The experimental analysis is done to measure the dielectric constant of fabric substrate materials in the X-Band using Microwave test bench with center frequency 9.8 GHz. The maximum power used for radiation testing is 18.1mW. The formula for dielectric permittivity measurement is developed and proved for known dielectric Teflon. With reference methodology, the various fabrics material dielectric values are determined. The dielectric constant measurement is done based on the waveguide method.

Keywords: Microwave, waveguide method, Dielectric, Permittivity, Textile fabrics, Wearable antennas.

1. INTRODUCTION

The design of wearable antenna becomes more complex due to the presence of human body. The majority type of wearable antennas are based on textile and fabric materials that are used for either substrate or radiating elements. Various substrate materials have been proposed for designing and development of flexible antenna. The usage of this electro textiles is used for optimization of wearable antenna structure [1]. The accurate value of the dielectric constant of the fabric material can easily be extracted from the measured resonant frequency of the patch radiator. The microwave methods of measuring the dielectric properties of the material can be divided into the following two main categories [2].

1) non resonant methods
2) resonance methods.

Non-resonant methods mainly include reflection methods and transmission or reflection methods. Reflection methods utilize in- formation on the reflection of electromagnetic (EM) wave from free space to the sample under test to extract the value of the dielectric constant of the sample. In transmission/reflection methods, the dielectric properties are calculated on the basis of reflection from the sample and transmission through the sample [3]. Resonance methods are used to get accurate knowledge of dielectric properties at a single frequency or several discrete frequencies. These methods generally include the resonator method and the resonance perturbation method. The resonator method is based on the fact that the resonant frequency and quality factor of a dielectric resonator with given dimensions are determined by its permittivity and permeability [4]. The complex permittivity of the material can be calculated at a single frequency by simply measuring the shift in frequency and the value of Q-factor. These techniques require more complex sample preparation. In practice, it is very difficult to place the sample at exactly the same position for each measurement, which can lead to non-repeatability in the measurement data and large errors in the measurement values. The values of substrate dielectric constants are in the range of $2.2 \leq \varepsilon_r \leq 12$. It can be used mostly in military applications by integrating the wearable antenna on clothing to enhance the performance of soldier and create awareness, survivability in the time of wars [5].

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2. DIELECTRIC MEASUREMENT PRINCIPLE

Dielectric constant is the ratio of the permittivity of a substance to the permittivity of free space [6]. It is an expression of the extent to which a material concentrates electric flux and is the electrical equivalent of relative magnetic permeability.

As the dielectric constant increases, the electric flux density increases if all the factors remain unchanged. This enables objects of given size, such as set of metal plates, to hold their electric charge for long periods of time and/or to hold large quantities of charge. Materials with high dielectric constants are useful in the manufacture of high value capacitors [7].

Substances with high dielectric constants breakdown easily when subjected to intense electric fields then do materials with low dielectric constants [8]. For example dry air has a low dielectric constant, but it makes an excellent dielectric material for capacitors used in high power radio frequency transmitters [9]. Even if air does undergo dielectric breakdown (a condition in which the dielectric suddenly begins to conduct current), the breakdown is not permanent. When the excessive electric field is removed, air returns to its normal dielectric state. Solid dielectric substances such as poly-ethylyne or glass however can sustain permanent damage [10]. The design of wearable antenna developed from the patch antenna requires dielectric with various permittivities to achieve good radiation characteristics. The wearable antenna developed on textile and fabric materials require simple methods to determine this dielectric permittivity.

3. DIELECTRIC MEASUREMENT

The measurement of dielectric permittivity is done by using a novel formulation developed with a combination of waveguide method and impedance calculation procedure [4]. This dielectric measurement is done using the microwave test bench setup arranged in the waveguide method as shown in the Figure 1.

The microwave test bench using klystron as source is used to generate a maximum power of 18.1mW, which is measured using a power meter. The test bench is connected with the klystron source connected

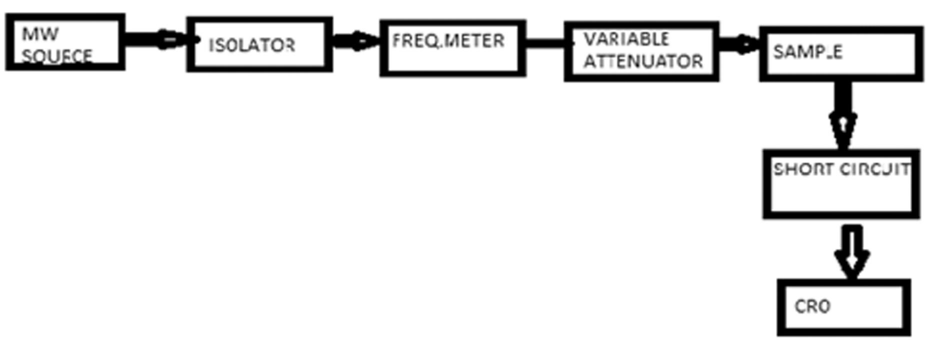

Figure 1: Block Diagram of Dielectric measurement

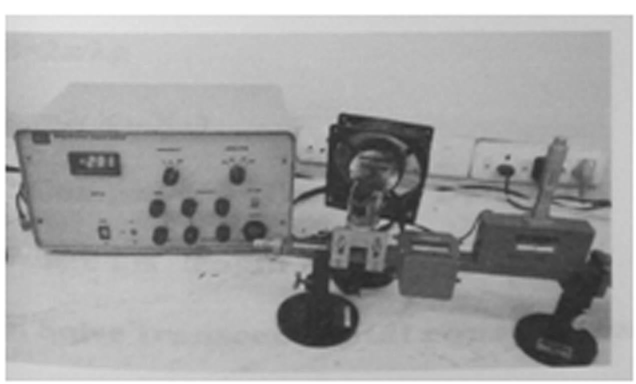

Figure 2: Microwave test bench with Klystron Mount

with isolator that allows the wave to travel only in forward direction, variable attenuator to provide needful attenuation, frequency meter and slotted line section with termination as shown in Figure 2. The solid dielectric cell is used to measure the dielectric property of the samples to be tested.

3.1. Methodology

The microwave test bench is arranged for effective dielectric measurement. The sample is kept inside the solid dielectric cell shown in Figure 3 and Figure 4.

The solid dielectric cell is connected to the slotted line section as shown in Figure 5.

Figure 3: Solid Dielectric cell

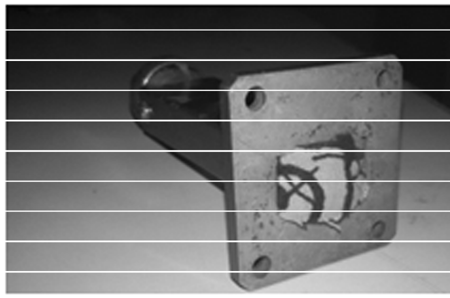

Figure 4: Sample inside the Solid Dielectric Cell

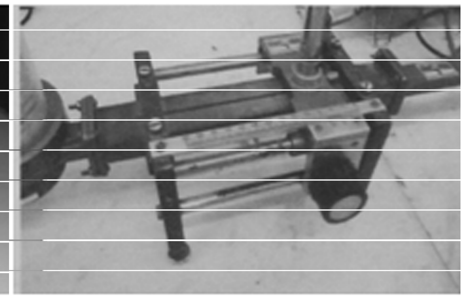

Figure 5: Slotted line section with solid dielectric cell.

The tunable probe connected with the slotted line is used to find the transmission characteristics after inserting the sample in the dielectric cell. The maximum standing wave voltage and minimum voltage are determined from the slotted line section as Vmax and Vmin as shown in the Figure 6. This value is used to determine the voltage standing wave ratio a key parameter for determining the samples dielectric permittivity.

The samples need to be kept with proper size to be fixed in the dielectric cell. The width of the sample need to be 2.286cm and the height need to be 1cm. The length of the sample needs to be measured before inserting into the dielectric cell. The slotted line section is used to measure the wavelength travelling in the slotted line before and after insertion of the sample inside the dielectric cell. The distance between the successive minimum is taken to find the wavelength using the standard formula.

4. EXPERIMENTAL ANALYSIS

The process to determine the dielectric permittivity of the sample is performed by following the procedures. Initially with no sample in short circuited line field position at voltage minima D_R with respect to an arbitrary reference is selected in the slotted line using the probe. The guide wavelength λ_g is measured by finding the distance between the two adjacent minima in slotted line. Remove the solid dielectric cell and insert a sample dielectric and replace it in such a manner that it touches the end of the sample. Measure D,

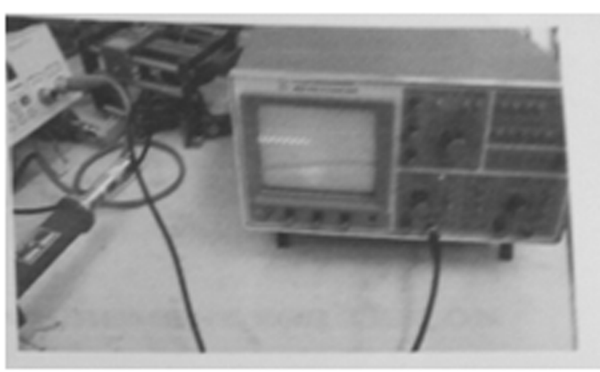

Figure 6: V_{max} and V_{min} taken from CRO

the position if minima in the slotted line with respect to the reference plane D = 0. The VSWR is measured from the slotted line for the various samples.

The formulas are used to estimate the dielectric permittivity of the sample as follows

1. The propagation constant is calculated using

$$\beta = 2\pi/\lambda_g \quad (1)$$

where $\lambda_g = 2(X_2 - X_1)$

X_2, X_1 are the voltage positions in centimetre.

2. Compute K

$$K = \text{Tan}\,(\beta(l_r + D_r - D)/\beta\, l_r \quad (2)$$

l_r – length of the sample

3. Solving transcendental equation for X we get K

$$K = \text{Tan}(X)/X \quad (3)$$

4. Then plot the values of Tan(X)/X vs X and determine the appropriate value of Tan(X)/X equal to K.

5. The dielectric constant ε is calculated as follows

$$= ([a/\pi]^2.[X/l_e]^2+1) / ([2a/\lambda_g]^2+1) \quad (4)$$

where a = 2.286cm

λ_g – guide wavelength in empty waveguide

Measurement For Teflon Without Sample

D = 0.0002V

$X_1 = 8.9$, $X_2 = 11$, $l_e = 12$mm

Measurement For Teflon With Sample

D = 0.0002V

$V_{max} = 0.002$V, $V_{min} = 0.0004$V

VSWR = $V_{max} / V_{min} = 5$V

$\lambda_g = 2(11-8.9) = 4.2$

Table 1
Dielectric constant of Sample fabric materials

S. No.	Name of the fabric material tested	Assumed Values	Calculated Values	Fabric length
1.	Teflon	2.5	2.1	2.286
2.	Wash Cotton	1.6	1.43	3.2
3.	Jeans Cotton	1.6	1.49	2.85
4.	Curtain cotton	1.5	1.29	2.83
5.	Bed Spread	1.8	1.52	3.0
6.	Polyester	1.4	1.3	2.65
7.	Polycot	1.3	1.5	2.85

The dielectric measurement for seven fabric material was experimentally analysed and calculated using the formula. The values of various materials was analysed and are listed in table 1.

5. CONCLUSION

This simple novel technique is used with waveguide method in which even a small change in the value of the dielectric constant of the fabric substrate material produces a substantial shift. This is used to determine the sample dielectric permittivity. The known sample Teflon formulation using this method is shown to obtain the dielectric permittivity and the remaining samples were computed. This method makes the dielectric calculation simple and helps to design the wearable antenna with known substrate values for any textile or fabrics used for the design. This method provides good accuracy, simple sample preparation needed and precise measurement without error. Moreover, this is a non-destructive method. By performing this experiment, it is understood that the textile materials have generally low dielectric constant and are useful substrates for flexible antenna.

REFERENCES

[1] S. Sankaralingam, Senior Member, IEEE, and Bhaskar Gupta, Senior Member, IEEE Determination of Dielectric Constant of Fabric Materials and Their Use as Substrates for Design and Development of Antennas for Wearable Applications IEEE Transactions On Instrumentation And Measurement, Vol. 59, No. 12, December 2010.

[2] L. F. Chen, C. K. Ong, C. P. Neo, V. V. Varadan, and V. K. Varadan, Microwave Electronics: Measurement and Materials Characterization, 1st ed. Chichester, U.K.: Wiley, 2004.

[3] F. Declercq, H. Rogier, and C. Hertleer, "Permittivity and loss tangent characterization for garment antennas based on a new matrix-pencil two- line method," IEEE Trans. Antennas Propag., vol. 56, no. 8, pp. 2548– 2554, Aug. 2008.

[4] Annapurna Das, SisirK.Das ,Microwave Engineering, 3rd edition, McGraw Hill Education Private Limited, New Delhi pp 607-611.

[5] S. Daya Murali1, B. NaradaMaha Muni1, Y. Dilip Varma1, S.V.S.K Development of Wearable Antennas with Different Cotton Textiles S. Daya Murali1, B. NaradaMaha Muni1, Y. Dilip Varma1, S.V.S.K. Chaitanya1 1 DST-FIST Sponsored ECE Department, KL University, Vaddeswaram, Guntur DT, AP, India.

[6] S. Daya Murali et al Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 7(Version 5), July 2014, pp.08-14.

[7] Maria Lucia Scarpello, IldaKazani, Carla Hertleer, Hendrik Rogier Stability and Efffciency of Screen-Printed Wearable and Washable Antennas IEEE Antennas And Wireless Propagation Letters,Vol.11,2012.

[8] ZhiHao Jiang, Member, IEEE, Donovan E. Brocker A Compact, Low-Profile Metasurface-Enabled Antenna for Wearable Medical Body-Area Network Devices IEEE Transactions On Antennas And Propagation, Vol. 62, No. 8, August 2014 .

[9] C.A.Balanis, AntennaTheory: AnalysisandDesign,2nded. Singapore: Wiley, 1997, pp. 722–736.

[10] P. Salomen and H. Hurme, "A novel fabric WLAN antenna for wearable applications," in Proc. IEEE APS Int. Symp., Jun. 2003, vol. 2, pp. 700–703.

[11] P. Salomen and H. Hurme, "Modeling of a fabric GPS antenna for wear- able applications," inProc .IASTED Int.Conf.Model.Simul., 2003, vol.1, pp. 18–23.