Dielectric Measurements of solids in wave guides

Mangesh Ambadas Kadam[1], Prashant Gawali[2]

[1]Research Scholar, B.S. Collage, Basmath Dist: Hingoli (MH) India
[2]Professor, Dept. of Physics, B.S. Collage Basmath Dist: Hingoli (MH) India

ABSTRACT

There are number of ways in which measurement of dielectrics in wave guides may be made. The advantage of employing wave guides is that the radiation is enclosed and there is no loss of energyoutside the system. If solids are to be measured then solids may be machined or die-pressed to fit wave guide and some adjustment of length is necessary. The solids are not fit the sample holder snugly. In our work we have employed X-band microwave bench to measure dielectric constant and loss factor. In this method the length of sample column in the cell changed in steps and corresponding output from the crystal detector is recorded. The data obtained is used to determine the value of propagation constants in the sample. The values of ∈' and ∈'' can be obtained from these propagation constants. As there are many methods like Histon and Polly's method, Serber's Technique, slot line technique and Reflectometer Technique. Reflect meter Technique is used rapid measurements of VSWR and hence calculated the ∈' and ∈''. It is found this technique is more suitable for the measurement of dielectric parameters of solids.

Keywords: **Reflect meter technique, Dielectric constant, X-microwave band.**

INTRODUCTION

The physics of dielectric is too broadand in its study various types of problems involved the latest investigation revealed new applications based on more intricate effect of microwave action on agriculture, medical, biological and organic materials. Permittivity of a material is one of the factors that determines how the materials interact with an electromagnetic field. Quantity consisting of a real part (dielectric constant) and imaginary part (loss factor).Accurate measurement dielectric properties can provide scientists and engineers with valuable information that allows them the properly incorporate the material into its intended applications or to monitor a process for improved quality control. The permittivity is a fundamental property of the material and is independent of measurement technique.

Measurement techniques typically involved placing the material in an appropriate sample holder and determining the permittivity from measurements made on the sample holder. The experimental method for the measurement of dielectric of materials as a function of frequency depends on the frequency range as well as the type of system under consideration. A convenient method of measurement the dielectric properties of material is electromagnetic standing wave within the test material or in front of material.

When the sample extends over an appreciable part of wavelength, the electric and magnetic fields vary over the sample dimensions. In such cases an analysis based on maxwell's equations of the waves travelling along a transmission line, containing the sample is required. Apparatus employing co-axial line may be used over a frequency range of some MHz to 5 GHz. Hallow pipe (wave-guide) is useful over the range 2 to 60 GHz. The experimental determinations of dielectric rests on the observation of the waves transmitted through or reflected from length 'L' of dielectric. The procedure followed depends mainly on whether the sample is liquid or solid and on whether the loss is large or small.

If solids are to be measured then solids may be machined or die-pressed to fit the waveguide and some adjustments of length is necessary. But measurements as a function of length is not practicable solids have the real advantage that, a window is not required for sample holder, and the disadvantage is that they may not fit the sample holder snugly.

Recent improvements like sampling of the standing wave pattern at regular intervals and automated data processing improves the experimental sensitivity. In our work we have employed X-band microwave bench to measure dielectric constant and loss factor. In this method the length of sample column in the cell. Changed in steps and the corresponding output from the crystal detector is recorded the data obtained is used to determine the valency of propagation constant in the sample.The values of ∈'and∈"can beobtained from propagationconstants.

TECHNIQUE'S

1) Histon and Polly's Method:

For low loss materials, the standing wave method is advantageous, W.M. Histone et. al[1] has considered the case of low loss materials. The dilute solution of polar solute in non-polar solvent. For short circuit termination they used sample length in the steps of $\frac{\lambda_d}{2}$ and measured VSWR. Thus for material sample of length equal to $\left[\frac{n\lambda_d}{2}\right]$ where n=1,2,3,……. placed in contact with short circuit. Then the value of X0 the distance of first minima for the interference is zero.

The values of the desired parameters are found by following relation (for low loss material)

$$\varepsilon' = \left[\frac{\lambda_0}{\lambda_c}\right]^2 + \left[\frac{\lambda_0}{\lambda_d}\right]^2 \text{....................(1)}$$

$$\varepsilon'' = \left[\frac{1}{\pi}\right]\left[\frac{\lambda_0}{\lambda_d}\right]^2 (\alpha_d \lambda_d) \text{...................(2)}$$

For high loss materials, Polly's considered the case of high loss materials[2] the method requires the determination of standing wave ratios using slotted line far various sample lengths, which are integral multiple of $\left[\frac{\lambda_d}{2}\right]$.

The dielectric constant (∈') and dielectricloss (∈'') can be computed by using following relation.

$$\varepsilon' = \left[\frac{\lambda_0}{\lambda_c}\right]^2 + \left[\frac{\lambda_0}{\lambda_d}\right]^2 + \left[1 - \tan^2\frac{\Delta}{2}\right] \text{..................(3)}$$

$$\varepsilon'' = 2\left[\frac{\lambda_0}{\lambda_d}\right]^2 \left[\tan\frac{\Delta}{2}\right] \text{..................(4)}$$

2) Serber's Technique:

In case of Serber's method[3] $\alpha_d \lambda_d$ is found by computing variation in the reflected power, when the length of sample is varied by moving a shorting plunger. The reflection co-efficient $|\Gamma|$ at two face of dielectric sample of length (L) enclosed in a wave guide cell and terminated by perfectly reflecting short circuit

The ∈' and ∈'' may he computed from the following relations.

$$\varepsilon' = \left[\frac{\lambda_0}{\lambda_c}\right]^2 + \left[\frac{\lambda_0}{\lambda_d}\right]^2 \left[1 - \left(\frac{\alpha_d \lambda_d}{2\pi}\right)^2\right] \text{..................(5)}$$

$$\varepsilon'' = \left[\frac{1}{\pi}\right]\left[\frac{\lambda_0}{\lambda_d}\right]^2 (\alpha_d \lambda_d) \text{...................(6)}$$

Where $\alpha_d \lambda_d = \frac{d}{dn}\log(M_n - 1)$

3) Slot Line Technique:

The electromagnetic field at any point of a transmission line may be considered as the sum of two travelling waves. Waves from generator due to mismatch. The reflected wave to give a standing wave pattern[2,4]. The maximum field strength is found where two add in phase and the maximum occurs where two wave add in opposite phase. The ratio of the amplitude of maxima to the minima field strength of the wave is called the ``voltage standing wave ratio'' and is given by

$$VSWR = \frac{E_{max}}{E_{min}} = \left[\frac{E_1 + E_2}{E_1 - E_2}\right] \text{.................(7)}$$

$$VSWR = \frac{\left[1+\frac{E_2}{E_1}\right]}{\left[1-\frac{E_2}{E_1}\right]} = \frac{\left(1+\Gamma r\right)}{\left(1-\Gamma r\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where $\Gamma r = \frac{E_2}{E_1}$ is called reflection co-efficient

The standing wave patterns are usually studied by means of travelling detractor, which protres the electric field intensity along the axis of propagation.

MEASUREMENT OF $\alpha_d \lambda_d$

To sample the standing waves within a wave guide, a narrow longitudinal slot with ends tapered to provide smoother impedance transformation and thereby providing minimum mismatch, is milled on the top of broader dimension of the wave guide. Such section is known as slotted wave guide section. The necessary experiment setup is shown

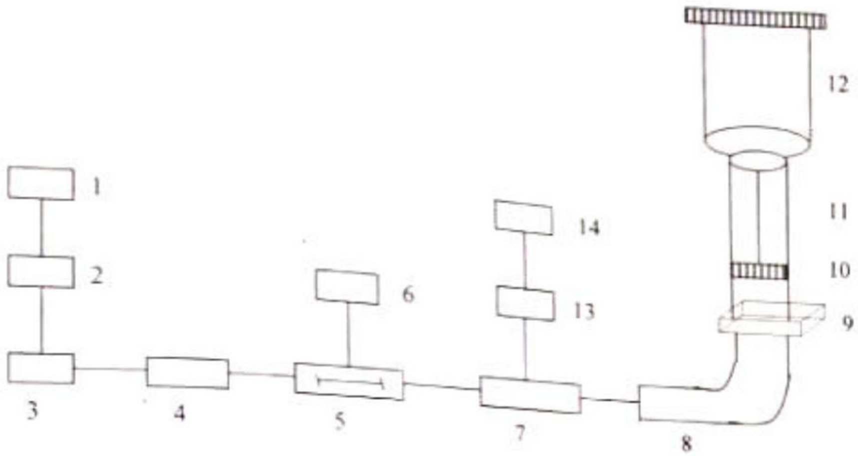

Fig 1: Setup for measuring dielectric constant of a material using slot line.

1) Power supply
2) Microwave source
3)Isolators
4) Frequency meter
5)Directional couplers
6) Frequency meter
7) Slot line
8) 90 degree- waveguide bend
9) Mica joint
10) Short circuiting
11) Dielectric cell
12) Micrometre screw to drive plunger
13) Tuned detector
14) Indicating mete

Plotting curve between , meter reading versus distance along the slot line we get standing wave pattern. From plot we get guide wavelength (λg), writing wave in the line. The dielectric wavelength (λd) is

$$\lambda_d = 2l$$

Where l is the spacing between adjust minima of standing wave pattern

$$VSWR = S_n = \left(\frac{\lambda_d}{\pi \Delta x_n}\right)$$

$$VSWR\left(\rho_n\right) = \frac{1}{S_n} \text{ where n = 1,2,3,………}$$

The graph between (ρ_n) versus n gives straight line and slope of this line gives αd

$$\alpha_d = \left[\frac{2\lambda_g}{\lambda^2 d}\right]\left[\frac{d\rho_{mean}}{d_n}\right]$$

The loss factor can be compute by using the relation

$$\varepsilon'' = \left[\frac{1}{\pi}\right]\left[\frac{\lambda_0}{\lambda_d}\right]^2 \alpha_d\, \lambda_d ....(9)$$

The loss tangent value is given by

$$\Gamma\ and\ \delta = \frac{\varepsilon''}{\varepsilon'} ....(10)$$

4) Reflectometer Technique :

It is a special system, which permits rapid measurement of VSWR. since there is a direct relationship between the VSWR and reflection coefficient (Γr) of a wave – guide, by measuring the ratio of relative amplitudes of reflected and incident signal's, VSWR can be measured.

Auriliary arms of the two directional couplers are connected to the incident and reflected channels of a ratio meter directly computers the reflection co-efficient and display it an therecorder.

The reflect meter method is a superior to slotted line measurements became it measures the two dissimilar magnitudes while as the latter measures the ratio of nearly equal to magnitudes.

The necessary setup for measuring dielectric constant of material using reflectometer method is shown in fig (2)

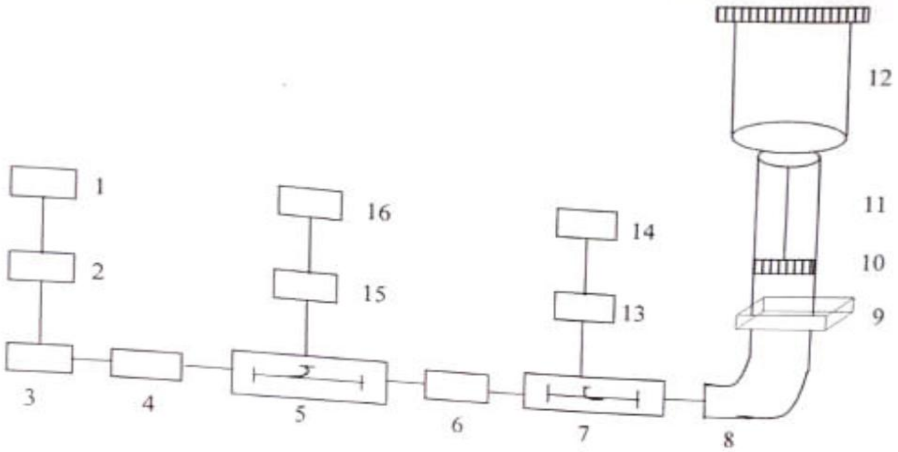

Fig. 2: Setup for measuring dielectric constant of a material using reflectometer principle .

1)Power supply
2) Microwave source
3 & 6) Isolators
4)Variable attenuator
5&7) Directional couplers
8) 90^0 – waveguide bend
9) Mica joint
10) Short circuiting plunger
11) Dielectric cell
12) Micrometre screw to drive plunger
13&15) Tuned identical detectors
14&16) Indicating meters

The VSWR using directional couplers can be written as ..

$$S = \frac{I_F + I_r + 2(I_F I_r)^{1/2}}{I_F - I_r} \text{.................}(11)$$

Where I_F and I_r are the forward and reverse currents respectively.

The Dielectric constant and loss are given by

$$\varepsilon' = \left(\frac{\lambda_0}{\lambda_c}\right)^2 + \left(\frac{\lambda_0}{\lambda_d}\right)^2 \text{....................}(12)$$

$$\varepsilon'' = \frac{2}{\pi}\left(\frac{\lambda_0}{\lambda_c}\right)^2 \frac{\lambda_g}{\lambda_d}\left(\frac{d\rho_{mean}}{d_n}\right)^2 \text{....................}(13)$$

Where

λ_0 is the free space wavelength

λ_d is the wavelength in dielectric

λ_c is the cut off wavelength of waveguide

λ_g is the guide wavelength

The conductivity (σ) and relaxation time (τ) are obtained by using the relation[5,6,7].

$$\sigma = \omega \varepsilon_0 \varepsilon'' \text{........................}(14)$$

$$\tau = \frac{\varepsilon''}{\omega \varepsilon'} \text{...........................}(15)$$

Where ω = 9.85 GHz angular frequency
ϵ_0= permittivity free space.

The experimental set up of X- Band as shown in fig (3)

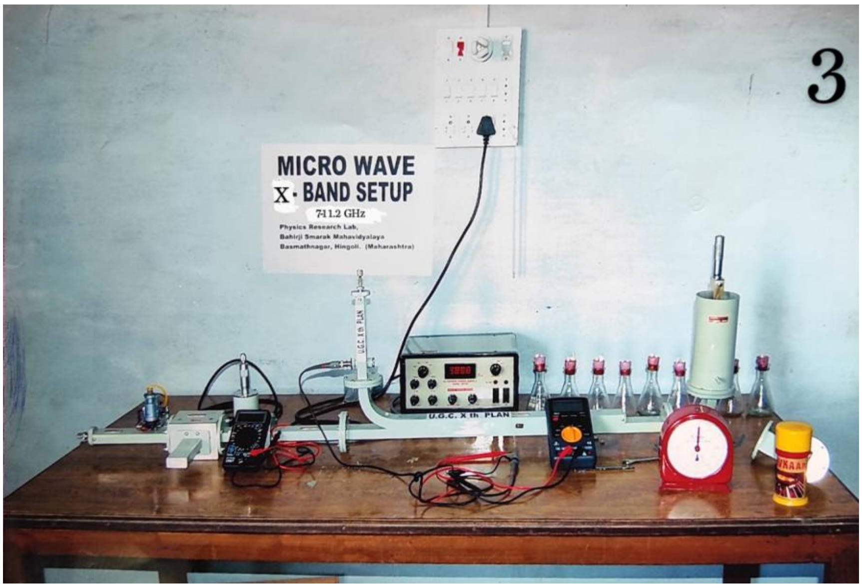

Fig.3: The experimental set up of X- Band

Many researcher[5,8,9,10] have studied the dielectric parameters using using this method of pulses , mustard seeds of powders .

The values of ϵ'and ϵ'' are then verified by mixture formulae given by Landau-Lipschitz -Looyenga and Bottcher[11,12] of powdered to solid.

CONCLUSION

- The microwave reflectometer technique can be used for different types of powdered low loss materials
- This technique is superior than slotted line method because it measures two dissimilar magnitudes.
- The reflectometer technique is more accurate than other techniques.
- In this technique the dielectric parameter values **∈' and ∈''**can be verified by using Co-relation formulae.
- There is fair agreement is found in experimental and computed values.
- It provides accurate estimate of **∈' and ∈''** powdered samples at known bulk densities.

REFERENCES

[1]. W M Heston, E J Hennelly and C P Smyth J.Am.chem.soc.72,3443 (1950)
[2]. M L Sisodia and G S Raghuvanshi, Basic Microwave Techniques & lab manual,Wiley Eastern Ltd. New Delhi (1990)
[3]. W H Surber,J. Appl. Phys. 19, 514 (1948)
[4]. Edgar Hund, Microwave communication, M.C. Graw Hill Book company, (1989)
[5]. P.G. Gawalietal Dielectric behaviour of some pulses using reflectometer technique,(2003) at 9.85 GHz , Indian Journal & applied Research[3].
[6]. B S Narwadeetal ,Journal of chemical sciences of Indian Academy of science , 117(6), 673-677 (2005)
[7]. B K Bonganeetal , International journal of Physics and mathematical sciences .
[8]. A K Bansal etal, Indian Journal Of pure and applied Physics 39, 2001, PP 799-803
[9]. R A Jangidetal" Indian Journal of pure and applied physics" 34, 1996 PP316-318
[10]. J S Yadav etal , Indian journal of pure and applied physics ,30, 1992, 427
[11]. L D Landau and E M Lifshitz Electrodynamics of continues media Pergarnom Press , London , 1960, P-46.
[12]. C J F Bottcher "The Theory of dielectric polarization"
[13]. Elsevierss Amsterdam , 1952, PP415