Vol. I No.13 Dec-Jan 2018 (Online) ISSN 2277-3339 (Impact Factor 2.119) IIFS UGC Journal No.: 6437

Estimation of Errors in Calculating Dielectric Constant of Agricultural Soil Samples

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Introduction: In any research work, accuracy of the measured data is very important. It determines the accuracy of the estimated values and is helpful in comparing the obtained values with the standard values. The obtained values never comes to be exact with the standard values due to errors that are incorporated with the experiment. There are different types of errors[1] that can be minimized but not eliminate completely The types of errors are instrumental errors, systematic errors random errors, personal errors, etc. Errors[2] are always present in any of the observations. They can not be removed completely. But one can reduce the degree of error by increasing the number of trails or observations of the data. The different formulae for the estimation of errors are ,

Let $a_1 , a_2, a_3 ,a_4 ,a_5 ,\ldots\ldots\ldots a_n$ are the n number of observations then the mean value of the observation is a_{mean}

$a_{mean} = \frac{a1 ,a2,a3 ,a4 ,a5 ,\ldots\ldots\ldots an}{n} = \frac{1}{n} \square\, a_i$ summation is over all the values , i is from 1 to n.

The difference between the mean value and each individual value is the absolute error

Absolute error $= \Delta a_i = a_{mean} - a_i$

The arithmetic mean of all the absolute errors is called mean absolute errors [3] .

$\Delta a_m = \frac{1}{n} \square \Delta a_i$ summation is over all the values , i is from 1 to n.

The ratio of the mean absolute error in the measurements of a physical quantity to its mean value is called relative error.

Relative error $= \frac{\Delta am}{am}$

Percentage Relative error $= \frac{\Delta am}{am}$ x 100 %

Dielectric Measurements: Study of dielectric parameters[4] of the materials has gained quite significance due to its wide applications in different fields . Study of novel dielectric materials for electronic industry , in microwave heatings and in active and passive remote sensing , dielectric measurements have found different uses. Dielectric study of materials also give structural and compositional information of the materials[6]

Experimental Details: The soil samples were collected from agricultural land of different regions of Marathwada region in the month of April. The soil under study was grated and sieved using standard sieves to cutoff the larger size of the soil particles. The work was carried at room temperature at atmospheric pressure and the natural humidity of the climate of that summer days. Wave guide cell method[7] , particular infinite sample method was employed for the practical work. Klystron power supply generated the required microwaves of frequency 9.76GHz and the micro ammeter connected to the probe of the slot line provided the current of the standing wave generated in the wave guide due to the incident and the reflected wave. The block diagram of the setup used during the work is as shown below:

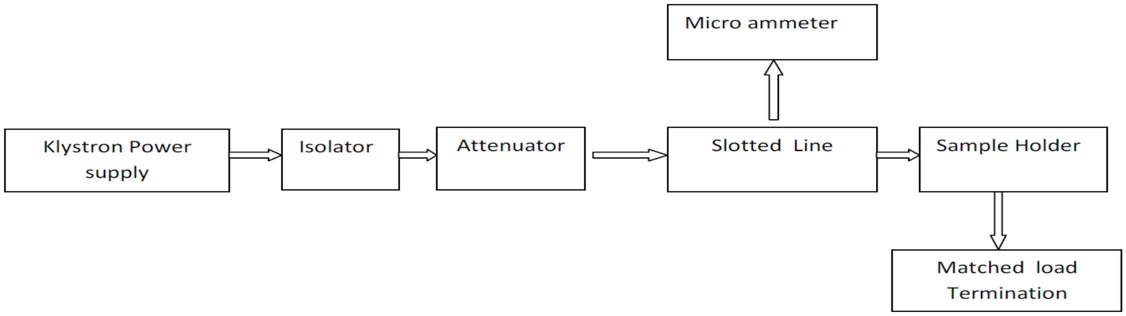
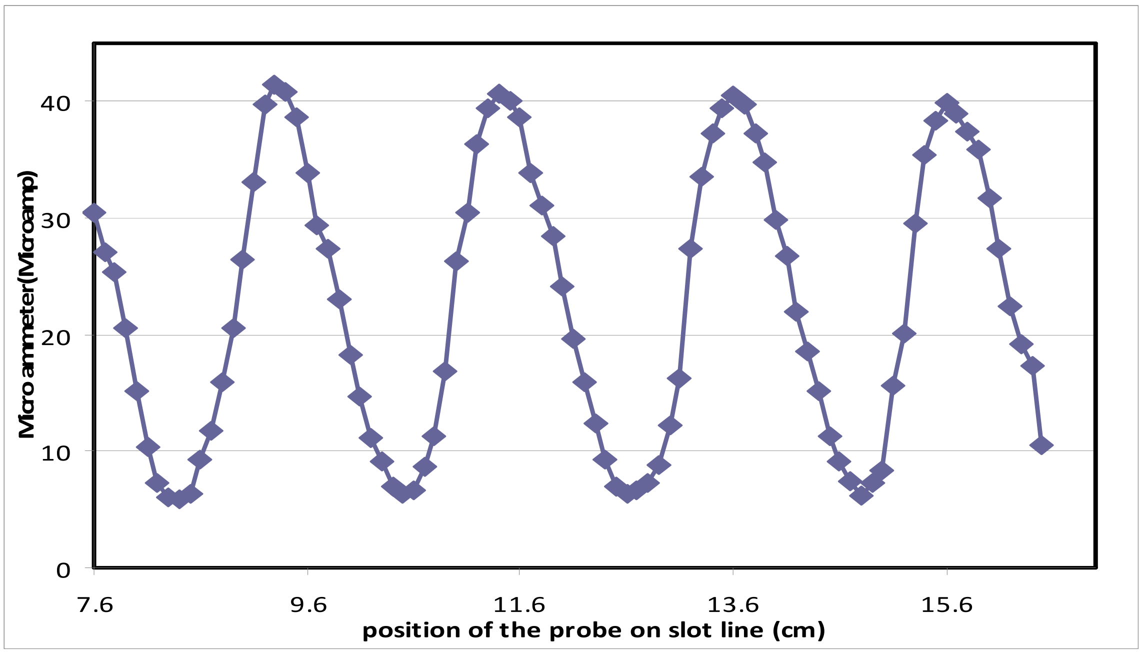


Fig (i) Block Diagram of the experimental Setup

The probe has an inbuilt crystal detector that rectifies the ac wave and gives the value in dc that is read by the micrometer as a function of the position of the probe on the slot line.



Fig(2) graph showing the variation of micro ammeter current with position of the slot line.

Initially the slot line was terminated by the short and the positions of first minima and the second minima are noted. Twice of the difference between these values gives the waveguide wave length. Next, the sample holder is filled up with the soil and a mechanical system is used to press the soil in the holder and remove any discontinuities in it. The sample holder is terminated with matched termination and is held in line with the slotted waveguide. Now the position of first minima and the points corresponding to twice of minima are noted.

The VSWR is measured by twice minima method for high VSWR measurements. From these values the dielectric constant of the soil is determined using the formulas below:

$$\varepsilon_r = \frac{1}{1+(\lambda_c/\lambda_g)^2} + \frac{1}{1+(\lambda_c/\lambda_g)^2}\left[\frac{r - j\tan\left(k(D-D_R)\right)}{r - jr\tan\left(k(D-D_R)\right)}\right]^2 \quad \text{............ (1)}$$

Where ,
$K = 2\Pi / \lambda_g$
λ_g = guide wavelength
λ_c = cutoff wavelength in the waveguide = 2a , a = wider dimension of the waveguide
r = VSWR
D = Position of first minima with sample
D_R = position of first minima without sample

Separating the real and the imaginary parts of the dielectric constant from the equation (1) , we get,

$$\varepsilon' = \frac{1}{1+(\lambda_c/\lambda_g)^2} + \frac{(\lambda_c/\lambda_g)^2}{1+(\lambda_c/\lambda_g)^2}\left[\frac{(r^2-E^2)(1-r^2E^2)+(2rE)^2}{(1-r^2E^2)^2+(2rE)^2}\right]$$

Ten trails were taken for each soil sample under test and the mean value, absolute error , mean absolute error , relative error and percentage relative errors are tabulated as shown below:

Soil no	Dielectric constant					Mean value	Absolute error					Mean absolute error	Relative error	% error
	Trail 1	Trail 2	Trail 3	Trail 4	Trail 5									
1	1.745	1.795	1.721	1.8542	1.823	1.824	0.079	0.029	0.103	-0.030	0.001	0.036	0.0197	1.97
2	2.027	2.015	1.996	2.0014	2.025	2.013	-0.014	-0.002	0.017	0.012	-0.012	0.000	0.0000	0
3	2.347	2.232	2.415	2.1236	2.2345	2.258	-0.089	0.026	-0.157	0.134	0.023	-0.013	0.0058	0.57
4	2.270	2.196	1.956	1.8745	2.145	1.992	-0.278	-0.204	0.036	0.117	-0.153	-0.096	0.0482	4.81
5	2.127	2.126	2.126	2.2356	2.3145	2.275	0.148	0.149	0.149	0.039	-0.04	0.089	0.0391	3.91
6	2.233	2.273	2.145	2.345	2.178	2.223	-0.01	-0.05	0.078	-0.122	0.045	-0.012	0.0054	0.53
7	1.953	2.428	1.965	2.0786	2.036	2.057	0.104	-0.371	0.092	-0.022	0.021	-0.035	0.0170	1.7
8	1.953	2.126	2.509	2.315	2.214	2.265	0.312	0.139	-0.244	-0.059	0.051	0.040	0.0177	1.77
9	2.098	2.098	1.996	2.145	1.845	1.995	-0.103	-0.103	-0.001	-0.15	0.15	-0.041	0.0206	2.05
10	2.506	2.595	2.595	2.654	2.415	2.535	0.029	-0.06	-0.06	-0.119	0.12	-0.018	0.0071	0.71

Table (1) estimation of errors

Conclusions: Errors are the inevitable part of any measurements . They cannot be removed completely but can be reduced by some extent. One of the technique to reduce the errors is to take large number of observations of any experiment.

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