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Complex Dielectric Behavior of Soil from Nasik Region at X-Band Microwave Frequency

M.D.Dhiware[1], S. B. Nahire[1], Sushant Deshmukh[2]

[1] G.M.D. Arts, B.W. Commerce and Science College, Sinnar, [Nasik]., Maharashtra, India 422 103
[2] J.E.S. College, Jalana, Maharashtra, India 431 203

E-mail:- sushant.d59@gmail.com

ABSTRACT

Electrical properties such as dielectric constant, dielectric loss of soils has been measured at an automated x band microwave set-up in TE_{10} mode operating at 10 GHz. It is measured for different moisture content. Soil samples are collected from agricultural land of Nasik region. Soil samples were analyzed for physical and chemical properties for the status of available micro nutrients. Correlations between electrical and physical properties of soil samples were reported. It is observed that dielectric constant increases with increase in moisture content slowly up to transition moisture then it increases rapidly with increase in moisture content. Also dielectric loss is directly proportional to the ac microwave conductivity and transition temperature. It has been found that emissivity decreases with increase in moisture content. In the field of remote sensing and agriculture, results obtained are useful.

KEYWORD

Dielectric constant, moisture content, emissivity, relaxation time

I. Introduction

The dielectric constant of soil is a measure of the response of a soil to electromagnetic waves. This response is composed of two parts, real & imaginary, which determine wave velocity and energy losses respectively [1]. The dielectric constant of soil is a function of its moisture content [2]. Knowledge of the dielectric constant properties such as emissivity and permittivity of the soil is useful for the efficient use of soil and for sensor design in microwave remote sensing [3]. In microwave soil moisture remote sensing, determining the soil moisture by measuring the value of dielectric constant is important. The base for microwave remote sensing of soil moisture is strongly dependence on its water content due to the large contrast between the dielectric constant of air, water and dry soil. The dielectric constant of soil is the physical property being very sensitive on water content. Soil moisture plays a key role in hydrological and climate studies.

When microwaves are directed towards a material, energy gets reflected or transmitted through the surface or absorbed by it. The proportions of energy, which fall into these three categories, have been defined in terms of material properties. Permittivity ϵ and permeability μ are the key parameters describing the interaction of materials with electromagnetic fields [4]. Soils are composed of solids, liquids and gases mixed together in variable proportions. Various percentages of soil-water mixtures give rise to a large dielectric constant variation. So the knowledge of dielectric properties of different soils is necessary for efficient use of microwave sensing techniques for soil moisture estimation.

Emissivity is the important parameter, which provides information about soil. The emissivity of soil also varies with different moisture content. Knowledge of emissivity of soil is useful for the efficient use of soil [5].

THEORY

Basic theory of wave-guide cell method/von-Hipple wave-guide method

The method consists of reflecting microwaves at normal incidence in TE_{10} mode from a dielectric sample placed against a perfectly reflecting surface. The reflection sets up standing waves in space in front of the sample. The separation of the first minimum from the face of the sample will depend upon wavelength of the EM wave in the sample and on sample dimensions [thickness]. and hence on dielectric constant. Further, the change in wavelength shall cause shift in the minima and in turn a change in half power width of the standing wave pattern. Also, losses in the dielectric shall decrease to VSWR [E_{max}/E_{min}]. and so tan δ may be related to this decrease in VSWR.

To proceed, consider that an EM wave travelling through medium 1 [air]. strikes normally to the medium 2 [dielectric]., a part of it is reflected and the rest gets transmitted. A standing wave pattern is thus produced in medium 1. The transverse electric field component in this partial reflection case is given by

$$E_y = [E_0 e^{j\omega t - \gamma_1 x}]\,[1 + \Gamma_0 e^{2\gamma_1 x}] \qquad .... \quad (1)$$

Where γ_1 is the propagation constant in medium 1 and is the sum of attenuation constant α_1 and phase shift constant β_1.

$$\gamma_1 = \alpha_1 + j\,\beta_1 \qquad .... \quad (2)$$

The reflection coefficient Γ_o is given by

$$\Gamma_o = |\Gamma_o|\, e^{-j\psi} \qquad .... \quad (3)$$

Where ψ is the phase of reflection coefficient.

The input impedance $Z_{[0]}$ at the boundary [x = 0]. is given by

$$Z_{(0)} = Z_1 \frac{1+\Gamma_0}{1-\Gamma_0} \quad ....(4)$$

Z_1 is the impedance of medium 1

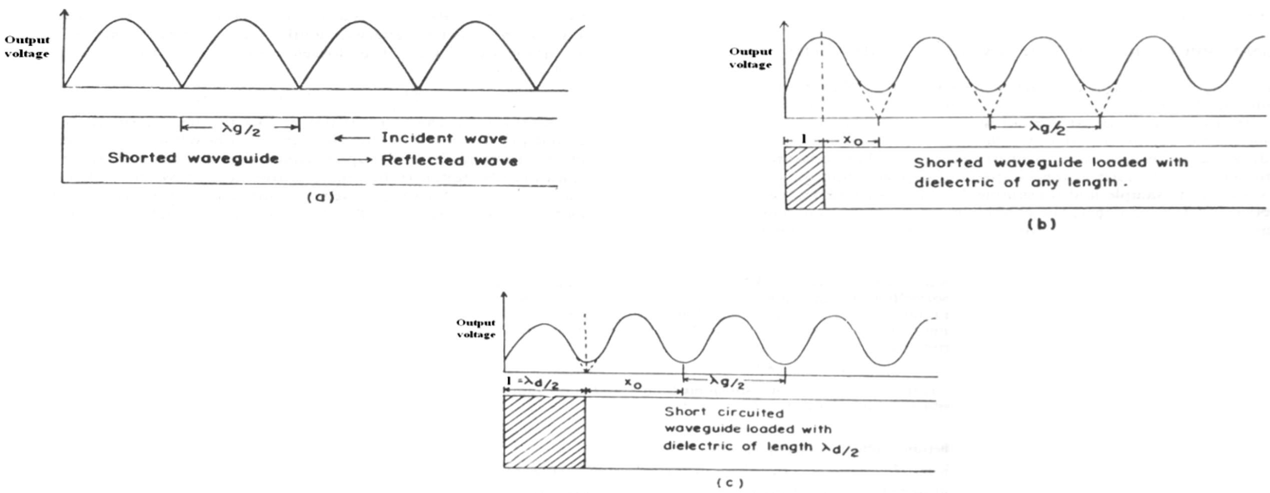


Fig.1 Standing Waves in a waveguide [a]. without dielectric [b]. loaded with dielectric of any length [c]. loaded with dielectric of length $\lambda_d/2$ [λ_d is the wavelength of microwaves in the dielectric]..

Loss-less dielectric

Consider a solid sample [oven-dry black soil]. of length l_ε loaded in a rectangular waveguide against short circuit that touches it well. In Fig. 2 (b) and (c), D and D_R are respectively the positions of first minimum of the standing wave pattern when waveguide is loaded and unloaded with the dielectric sample. The respective distances from the short circuit will be $[l + l_\varepsilon]$. and $[l_R + l_\varepsilon]$.. Now looking from A towards right and left, the impedances are equal, so

$$Z_0 \tan \beta l = - Z_\varepsilon \tan \beta_\varepsilon l_\varepsilon \qquad \text{....} \qquad (5)$$

Where, Z_0 and Z_ε are respectively the characteristic impedance of empty and dielectric-filled waveguides. Also, the β and β_ε are their respective propagation constants. Similarly from Fig. 2 (b),

$$Z_0 \tan \beta (l_R + l_\varepsilon) = 0 \qquad \text{....} \qquad (6)$$

Now, consider the expression

$$\tan \beta (D_R - D + l_\varepsilon) = \tan \beta \{(l_R + l_\varepsilon) - (l + l_\varepsilon) + l_\varepsilon\}$$
$$= \tan \beta \{(l_R + l_\varepsilon) - l\}$$

Expanding the tangent sum angle and making use of Eq(6), we get,

$$Z_0 \tan \beta (D_R - D + l_\varepsilon) = Z_\varepsilon \tan \beta_\varepsilon l_\varepsilon \qquad \text{....} \qquad (7)$$

Again recalling the relation

$$\frac{\tan \beta (D_R - D + l\varepsilon)}{\beta l \varepsilon} = \frac{\tan \beta \varepsilon l \varepsilon}{\beta \varepsilon l \varepsilon} \qquad \text{..................(8)}$$

Eq(1) suggests a method for measuring dielectric constant. Quantities on the LHS are all experimentally measurable $[\beta = 2\pi/\lambda_g]$.. Thus value of $\tan \beta_\varepsilon l_\varepsilon / \beta_\varepsilon l_\varepsilon$ is known and hence value of $\beta_\varepsilon l_\varepsilon$ can be known from the standard tables. Since $\tan [\beta_\varepsilon l_\varepsilon]. / [\beta_\varepsilon l_\varepsilon]$. is a multivalued function, so correct value has to be selected. This is done in two ways.

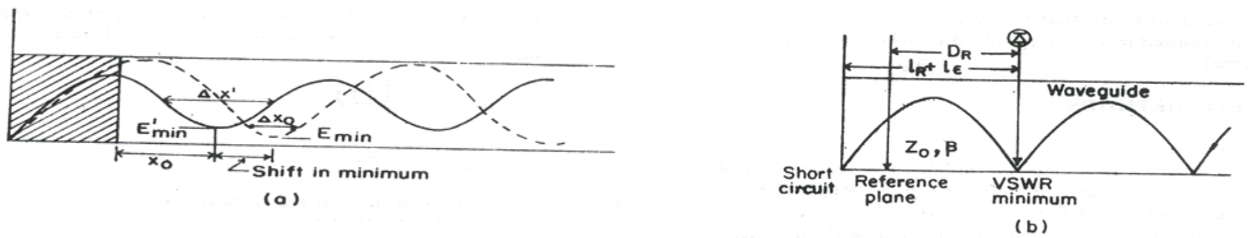
(i) When approximate value of dielectric constant is known, select that value, say β_ε, and compute dielectric constant from the relation

$$\beta_\varepsilon = \frac{2\pi}{\lambda_0}\left\{\varepsilon' \mu_r - \frac{(\lambda_0)^2}{(\lambda_c)^2}\right\}^{1/2} = \frac{2\pi}{\lambda_d} \qquad \text{....................(9)}$$

Where $\lambda_c = 2a$ is cut-off wavelength, λ_0 is free-space wavelength, λ_d is guide wavelength when it is filled with the dielectric. ε' is relative dielectric constant and μ_r is the relative permeability.

$$\varepsilon' = \frac{\left(a/\pi\right)^2 \left(\beta_\varepsilon l_\varepsilon / l_\varepsilon\right)^2 + 1}{\left(2a/\lambda_\varepsilon\right)^2 + 1} \qquad \text{...........................(10)}$$

If this value is close to the approximately known value, then the value obtained is true value, otherwise try another solution and so on.



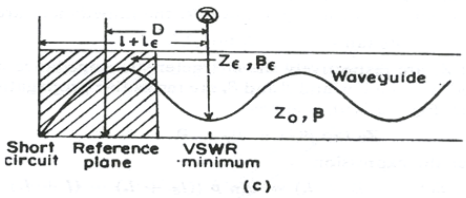


Fig 2 Illustration of Wave-Guide Cell Method for measuring dielectric constant [a]. Double minimum width [b]. Position of minimum with shorted waveguide without dielectric [c]. Position of minimum with shorted waveguide with dielectric sample.

[ii]. If approximate value of the dielectric constant is not known, a second identical experiment is to be performed with the sample of a different length. The proper solution of the transcendental Eq(7) is common to the two sets of solutions and is thus the point of intersection of the two curves drawn for each sample between dielectric constant ε' and the solutions for $\beta_\varepsilon l_\varepsilon$. Eq (8) is used to find out the values of dielectric constant of oven-dry soil samples.

For lossy dielectrics

Eq(7) can be modified for lossy [complex]. dielectrics. In these cases, we determine voltage standing wave ratio and compute reflection coefficient in complex form. The phase difference [Φ]. in the waves travelling in the guide with and without dielectric is

$$\Phi = 2\beta(\Delta x - l_\varepsilon) \quad \ldots \quad (11)$$

Δ x is the shift in minimum. Now reflection coefficient is given by

$$|\tau| = \frac{S-1}{S+1} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

Where S is VSWR. Further, if we define

$$C = \frac{1}{j\beta l_\varepsilon} \frac{1-|\tau|e^{j\theta}}{1+|\tau|e^{j\theta}} = \frac{\tan X\angle\theta}{X\angle\theta} \quad \ldots\ldots\ldots\ldots (13)$$

Then admittance is given by

$$Y_\varepsilon = \frac{(X)^2\angle 2(\theta-90^0)}{(\beta l_\varepsilon)^2} = g_\varepsilon + j\beta_\varepsilon \text{ (say)} \quad \text{\_\_\_\_\_\_} (14)$$

g_ε and β_ε are related to ε' and ε'' as

$$\varepsilon' = \frac{g_\varepsilon + (\lambda_g/2a)^2}{1+(\lambda_g/2a)^2} \quad \ldots\ldots\ldots \quad (15)$$

and

$$\varepsilon'' = -\frac{\beta_\varepsilon}{1+(\lambda_g/2a)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

However, it is to be noted that quantities ψ, θ and $[X/\beta l_\varepsilon]^2$ fall into ranges $0 < \psi < 180°$, $45° < \theta < 90°$, $[X/\beta l_\varepsilon]^2 > 1$, proper values of $X\angle\theta$ is that value which yields the same value of Y_ε for the two samples. Eq(15) and (16) are mainly used to determine the values of dielectric constant and dielectric loss of the black soils. By knowing these two dielectric parameters, the other parameters can easily be estimated.

2. EXPERIMENTAL DETAILS

2.1. Materials

Soil samples were collected from ten different agricultural land of Sinnar Tahsil, Nasik, Maharashtra. Soil samples were collected in the depth of 0-20cm from desired location. Soil samples were completely air dried and passed through 2mm sieve and stored in properly labeled cloth bags as per the standard procedures. Quartering technique was used for the preparation of soil samples.

The details of the land are given below.

No.	Name of Farmer	Survey No.	Area	Location	
1	Anil Warungse	790	Dubare	N 19^{o} 46$^{'}$ 21.3204"	E 73^{0} 58' 2.3736"
2	Sakubai Warugse	667	Dubare	N 19^{o} 46$^{'}$ 25.0896"	E 73^{0} 58' 8.0256"
3	Sudam Shinde	29	Thangaon	N 19^{o} 41$^{'}$ 38.4612"	E 73^{0} 56' 32.5464"
4	Bhimaji Shinde	1442	Thangaon	N 19^{o} 42$^{'}$ 34.6752"	E 73^{0} 56' 2.6880"
5	Narayan Pawar	907	Sonambe	N 19^{o} 46$^{'}$ 32.178"	E 73^{0} 56' 11.418"
6	Ravindra Kanadi	199	Komalwadi	N 19^{o} 57' 52.8804"	E 74^{0} 8' 3.5628"
7	Mandakini Thorat	107	Panchale	N 19^{o} 53' 47.8176"	E 743^{0} 12' 17.73"
8	Jagannath Gadakh	165	Deopur	N 19^{o} 52 $^{'}$ 28.2504"	E 74^{0} 9' 26.7588"
9	Balkrishna Kanadi	177	Sinnar	N 19^{o} 57$^{'}$ 29.8908"	E 73^{0} 50' 12.0264"
10	Chandrakant Zagade	50/2	Lonarwadi	N 19^{o} 51' 15.5052"	E 74^{0} 0' 35.9172"

2.2. Sample Preparation

These soil samples are sieved by sieve shaker to remove the coarse particles. This fine particles are then oven dried for several hours to remove moisture. Soil samples of various moisture are prepared by adding an exact amount of distilled water to dry soil. The gravimetric soil moisture content in percentage Wc [%]. is calculated using wet [W_1]. and dry [W_2]. soil masses using the following relation

$$W_c(\%) = \frac{W_1 - W_2}{W_2} x\, 100 \quad \text{.....................(1)}$$

Physical and Chemical characteristics of the soil were measured at Soil Analysis Laboratory, Department of Agriculture, Government of Agriculture Pune. The wilting point [W_p]. have been calculated using the Wang and Schmugge Model [Wang and Schmugge, 1980]. as

$$W_p = 0.06774 - 0.00064 \times sand + 0.00478 \times clay \quad \text{..........(2)}$$

$$W_t = 0.49 \times W_p + 0.165 \quad \text{...(3)}$$

where sand and clay stand for the sand and the clay content in percentage by dry weight of the soil.

2.3. Dielectric Measurements

The experimental technique used to measure the dielectric constant and water content is credited to Roberts and Von Hipple [6]. There are different methods for the measurement of dielectric constant at microwave frequency. At microwave frequencies, the effect of ionic conductivity gets negligible as compared to dielectric losses [7]. The choices of measurement technique, equipment, and sample holder design depend upon the dielectric materials to be measured, and the frequency or frequency range of interest [8].

In the present paper, Two Point Method has been used to measure the dielectric constant of the soil. The waveguide cell method is used to determine dielectric constant of the soil samples. The X band microwave bench is set up in TE_{10} mode with Gunn Source operating at X band frequencies at room temperature. The dielectric cell shorted with matched load is connected at load end. The reflected wave combined with incidental wave to give standing wave pattern. These standing wave patterns are used to determine the values of shift in minima resulted due to before and after inserting the sample. In this measurement the technique used is the infinite sample method [9]. An X band microwave bench operating at 9 GHz in the TE_{10} mode with slotted section and crystal detector are used for measurement of VSWR and the shift of minima is needed in this technique.

Table no.1 PHYSICAL PROPERTIE

Sample No.	Sand [%]	Silt [%]	Clay [%]	Textural class	Bulk density [mgm-3]	Particle density [mgm-3]	Maximum water holding capacity [%]	porosity	Wilting point	Transition moisture	Field capacity	Γ
1	28.75	37.5	32.75	Clay loam	1.14	2.54	34.27	55.11811024	0.481	0.40069	26.2675	0.20683
2	23.25	55.25	20.75	Silt loam	1.14	2.55	47.14	55.29411765	0.152045	0.23950205	24.7825	0.394334
3	21.5	63.75	14	Silt loam	1.37	2.64	39.36	48.10606061	0.1209	0.224241	23.665	0.412087
4	43.22	23.85	32.35	Clay loam	1.19	2.57	40.16	53.69649805	0.194712	0.260408978	23.1408	0.370014
5	35.4	50.8	13.4	Silt loam	1.29	2.62	33.19	50.76335878	0.109136	0.21847664	20.614	0.418792
6	40.6	51.09	7.8	Silt loam	1.34	2.63	35.49	49.04942966	0.07904	0.2037296	18.29	0.435947
7	41.4	52	6.2	Silt loam	1.33	2.61	38.8	49.04214559	0.07088	0.1997312	17.77	0.440598
8	23.75	36.5	38.75	Clay loam	1.26	2.59	37.57	51.35135135	0.237765	0.28150485	28.6375	0.345474
9	42	25.5	31.75	Clay loam	1.19	2.57	48.01	53.69649805	0.192625	0.25938625	23.265	0.371204
10	39.5	32	28	Clay loam	1.27	2.59	44.17	50.96525097	0.1763	0.251387	22.965	0.380509

Table no.2 CHEMICAL PROPERTIES

Sample No.	PH[1:2.5]	E.C [dSm-1	Organic Carbon [%]	Calcium carbonate [%]	Available nitrogen [Kg/ha]	Available phosphorous [Kg/ha]	Available Potassium [Kg/ha]	Available iron [ppm]	Available manganese [ppm]	Available zinc [ppm]	Available copper[ppm]
1.	7.6	0.13	0.46	2	56	11.64	333	5.84	7.34	0.37	1.34
	Midly alkaline	Normal	Medium	Slightly calcareous	Very Low	Low	Very High	High	High	Low	High
2.	6.5	0.13	0.31	2.5	203	38.53	339	5.04	7.35	0.45	2.45
	Slightly acidic	Normal	Low	Moderately calcareous	Low	Very High	Very High	High	High	Low	High
3.	6.9	0.12	0.42	1.5	158	16.08	343	4.9	7.35	0.45	1.85
	Neutral	Normal	Low	Slightly calcareous	Low	Medium	Very High	High	High	Low	High
4.	6.7	0.13	0.43	0.75	158	13.58	240	6.03	5.72	0.37	2.93
	Neutral	Normal	Medium	Barely calcareous	Low	Low	Moderately High	High	High	Low	High
5.	7.1	0.1	0.53	0.75	147	10.81	221	8.3	5.21	0.24	1.6
	Neutral	Normal	Medium	Slightly calcareous	Low	Low	Moderately High	High	High	Low	High
6.	6.7	0.2	0.45	2.75	169	31.88	355	11.65	7.35	0.41	1.71
	Neutral	Normal	Medium	Moderately calcareous	Low	High	Very High	High	High	Low	High
7.	8.3	0.25	0.55	22.75	158	2.22	185	0.18	2.3	0.15	1.04
	Moderately alkaline	Normal	Medium	Highly calcareous	Low	Very Low	Medium	Low	High	Low	High
8.	8.4	0.25	1.86	23	169	7.76	228	0.64	0.95	0.22	0.96
	Moderately alkaline	Normal	Very High	Highly calcareous	Low	Low	Moderately High	Low	Low	Low	High
9.	8.5	0.2	1.18	22.75	158	25.23	375	1.27	3.56	0.19	2.28
	Strongly alkaline	Normal	Very High	Highly calcareous	Low	Moderately High	Very High	Low	High	Low	High
10.	8.5	0.19	1.71	22	158	3.33	286	0.66	2.11	0.11	1.49
	Strongly alkaline	Normal	Very High	Highly calcareous	Low	Very Low	High	Low	High	Low	High

RESULT AND DISCUSSION

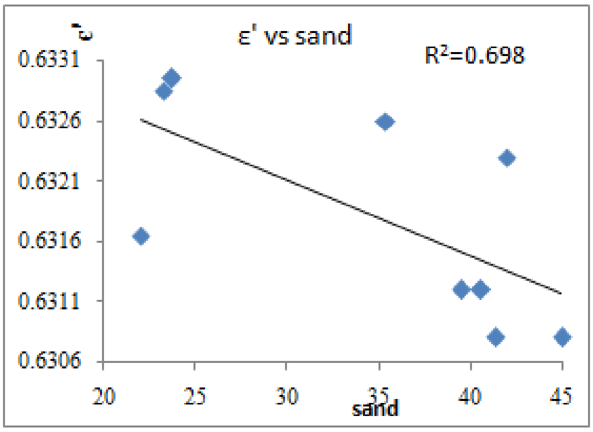


Figure 1: variation of dielectric constant with % of sand in soil

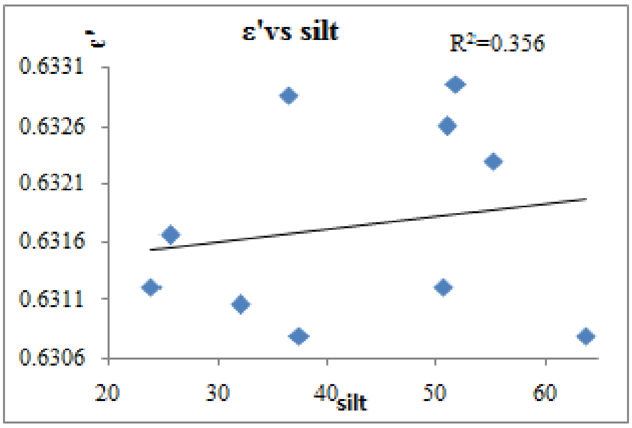


Figure 2: variation of dielectric constant with % of silt in soil

Soil texture can be expressed significantly by its electrical conductivity and dielectric constant. Clay textured soil is highly conductive while sandy soils are poor conductors; reported by Marx et al [10]. Kumar M.and Babel A.L.[11] reported that the availability of micronutrients increased significantly with increase in finer fractions that is silt and clay. From graph1,2 and 3, it is observed that dielectric constant decreases with increase of sand percentages whereas it increases with the increase in percentage of silt and clay in soil.

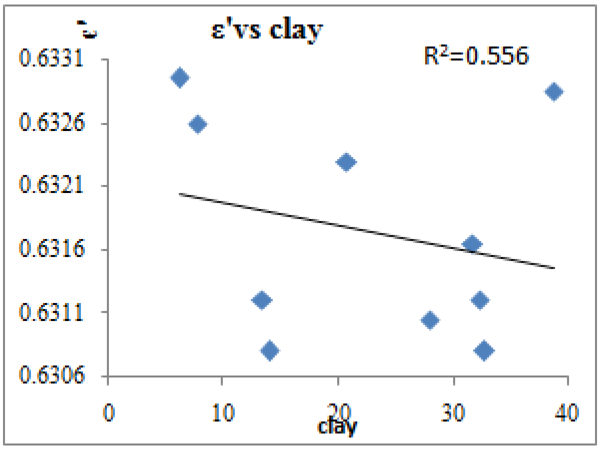


Figure 3: variation of dielectric constant with % of clay in soil

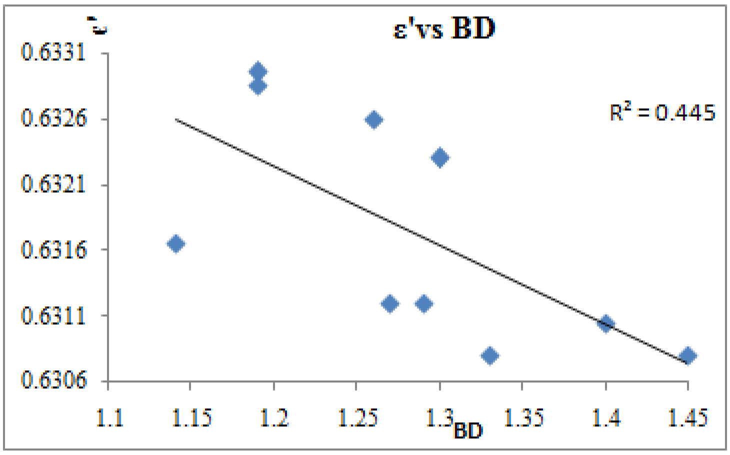


Figure 4: variation of dielectric constant with bulk density of soil

Dielectric constant was found to be dependent on bulk density of soil. From graph 4, it is observed that dielectric constant has positive correlation with bulk density. Similar results were reported by Wagner et al.[12] in which dielectric constant was evaluated at different moisture conditions.

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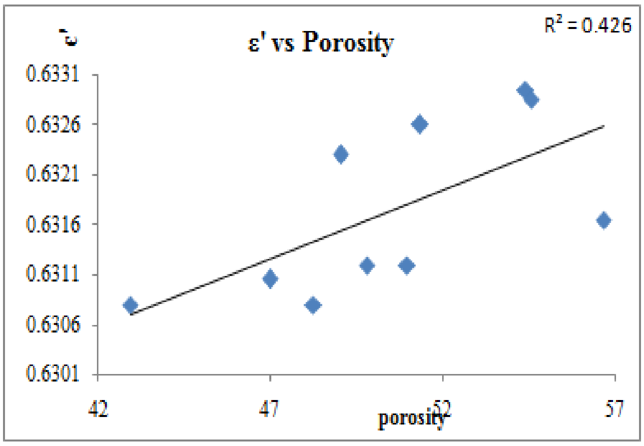

Figure 5: variation of dielectric constant with porosity of soil

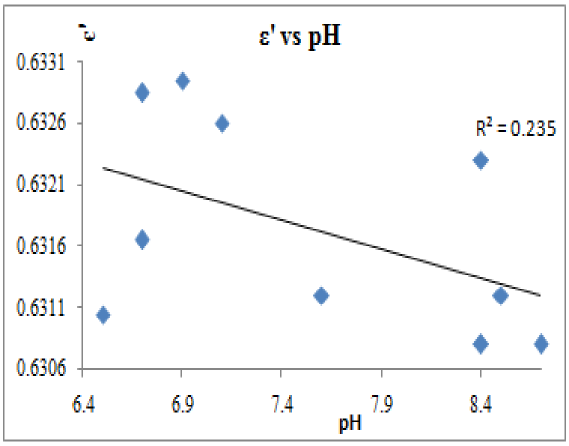

Figure 6: variation of dielectric constant with pH of soil

From graph 5, it is observed that dielectric constant has positive correlation with porosity. Most of the crops grow best in the soil which is neutral (pH =6 to7.5), very few crops prefer acidic or alkaline soils.

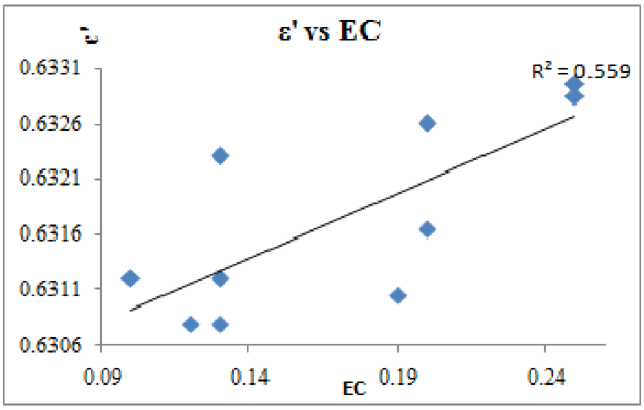

Figure7: variation of dielectric constant with electrical conductivity of soil

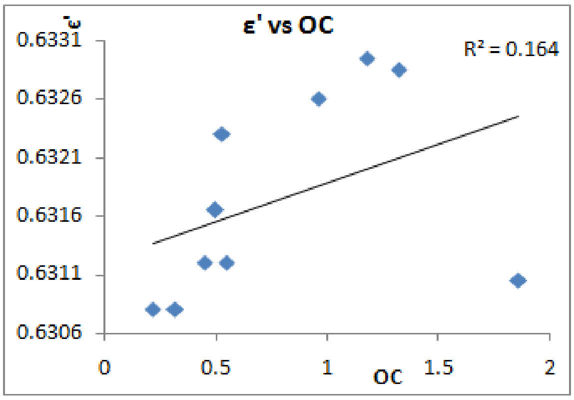

Figure 8: variation of dielectric constant with organic carbon in soil

From graph 7, it is observed that dielectric constant has positive correlation with electrical conductivity. These experimental results are found to agree with theoretical models developed by investigators working in this field [13]. From graph 8, it is observed that dielectric constant has positive correlation with organic carbon.

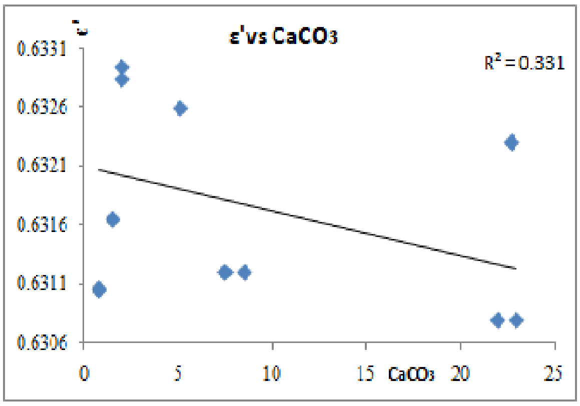

Figure 9: variation of dielectric constant with calcium carbonate in soil

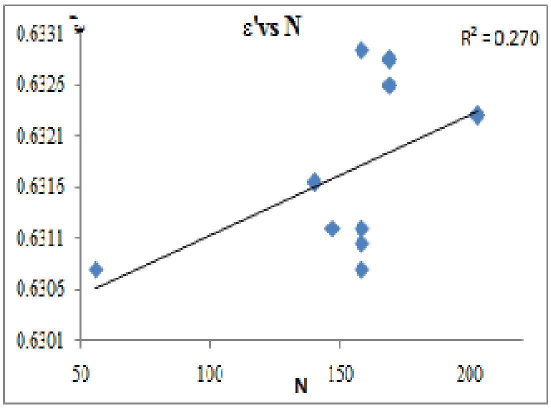

Figure 10: variation of dielectric constant with nitrogen in soil

From graph 9, it is observed that dielectric constant has negative correlation with calcium carbonate. Also from graph 10, dielectric constant has positive correlation with nitrogen available in soil.

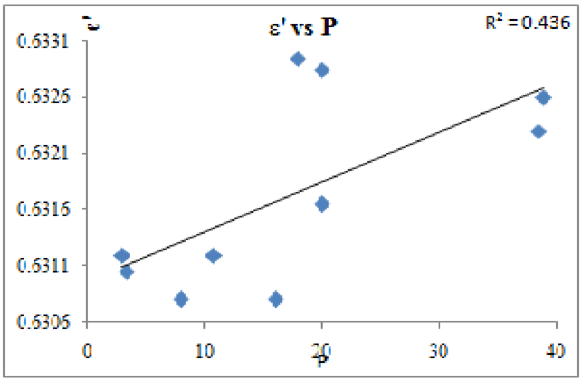

Figure 11: variation of dielectric constant with phosphorous in soil

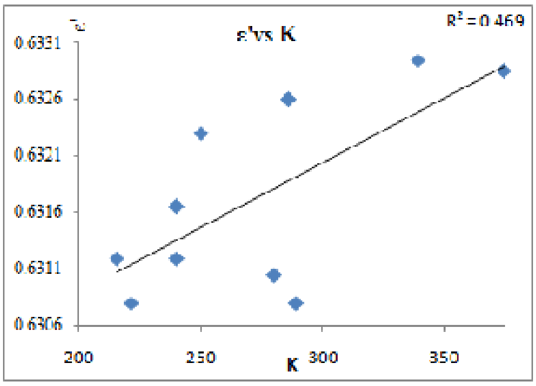

Figure 12: variation of dielectric constant with potassium in soil

From graph ,11 and 12, it is observed that dielectric constant has positive correlation with nitrogen phosphorous and potassium. These results have good agreement with results of earlier investigators [14].

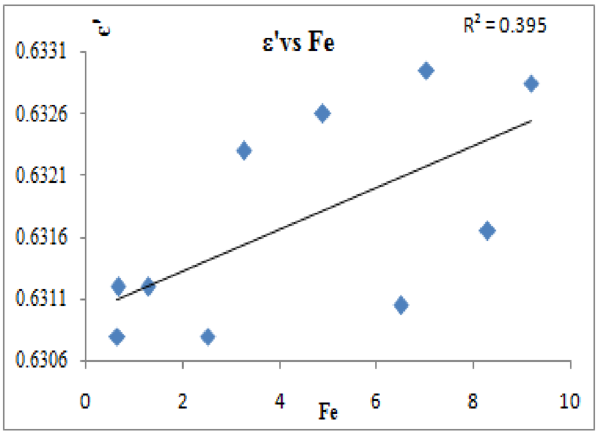

Figure 13: variation of dielectric constant with iron in soil

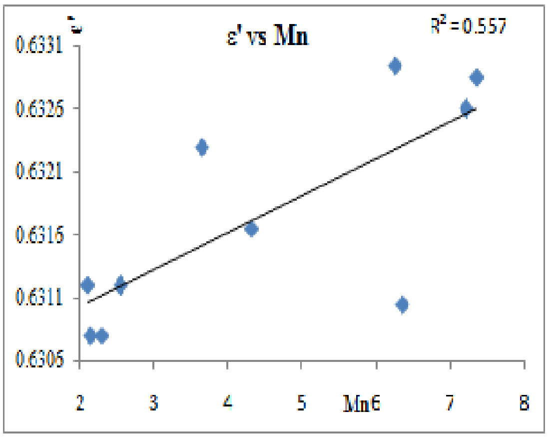

Figure 14: variation of dielectric constant with manganese in soil

From graph 13, dielectric constant has positive correlation with iron available in soil. Also from graph 14, dielectric constant has positive correlation with manganese available in soil.

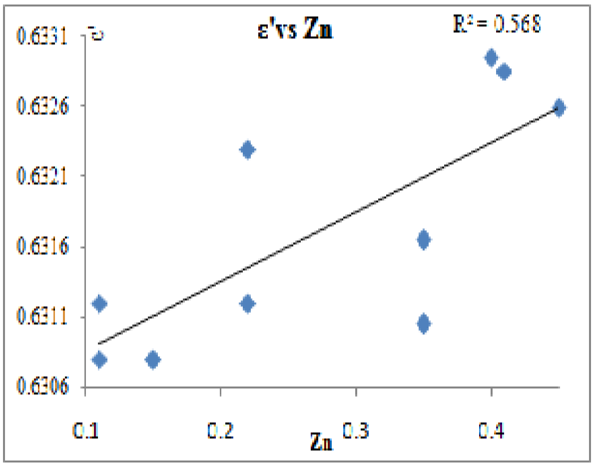

Figure 15: variation of dielectric constant with zinc in soil

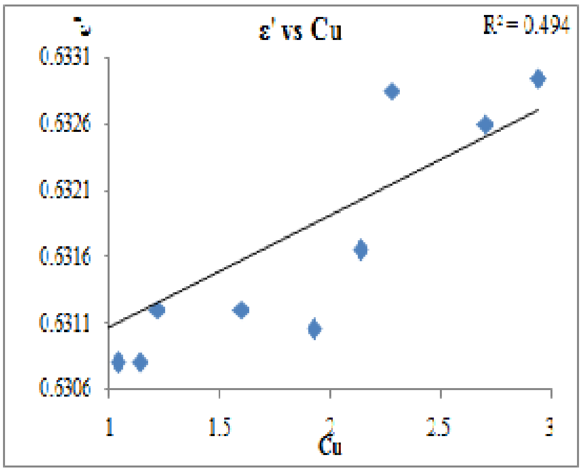

Figure 16: variation of dielectric constant with copper in soil

From graph 15, dielectric constant has positive correlation with zinc available in soil. Also from graph 16, dielectric constant has positive correlation with copper available in soil.Thus we see that the dielectric constant of soils depends on many factors like moisture content and its physical and chemical composition.

From graph 5, it is observed that dielectric constant has positive correlation with porosity. Most of the crops grow best in the soil which is neutral (pH =6 to7.5), very few crops prefer acidic or alkaline soils.

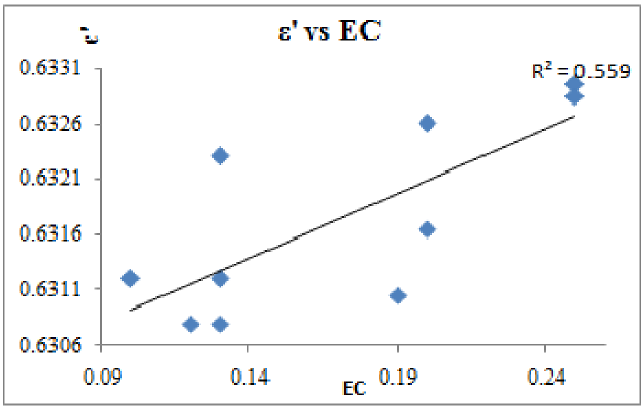

Figure7: variation of dielectric constant with electrical conductivity of soil

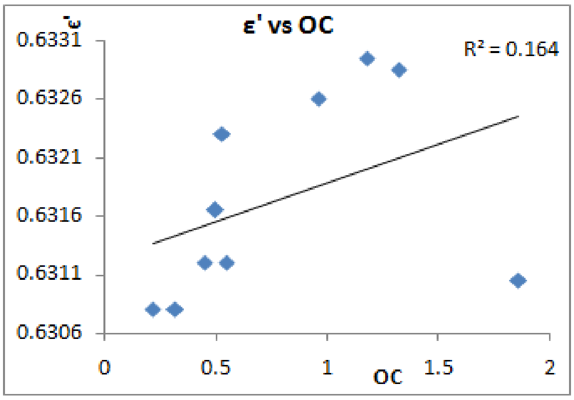

Figure 8: variation of dielectric constant with organic carbon in soil

From graph 7, it is observed that dielectric constant has positive correlation with electrical conductivity. These experimental results are found to agree with theoretical models developed by investigators working in this field [13]. From graph 8, it is observed that dielectric constant has positive correlation with organic carbon.

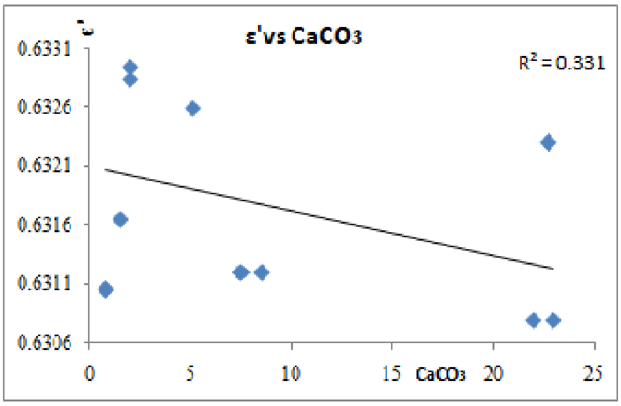

Figure 9: variation of dielectric constant with calcium carbonate in soil

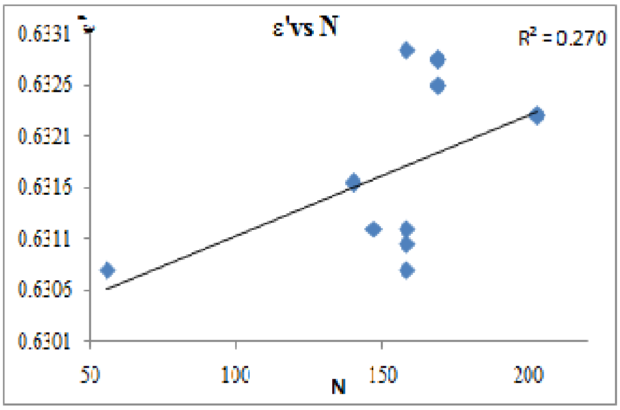

Figure 10: variation of dielectric constant with nitrogen in soil

From graph 9, it is observed that dielectric constant has negative correlation with calcium carbonate. Also from graph 10, dielectric constant has positive correlation with nitrogen available in soil.

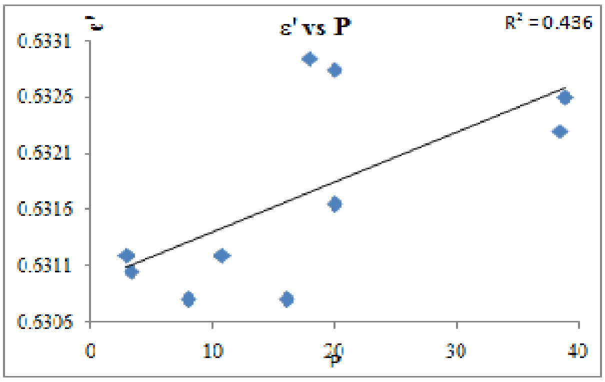

Figure 11: variation of dielectric constant with phosphorous in soil

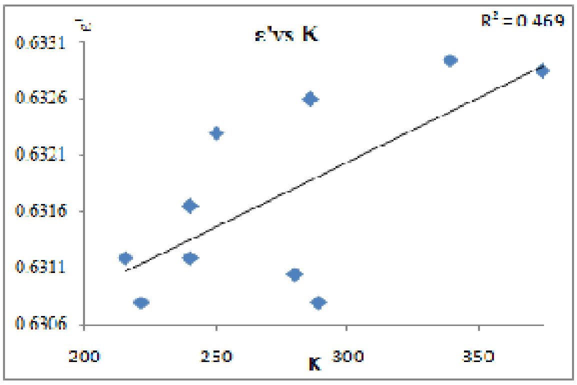

Figure 12: variation of dielectric constant with potassium in soil

From graph ,11 and 12, it is observed that dielectric constant has positive correlation with nitrogen phosphorous and potassium. These results have good agreement with results of earlier investigators [14].

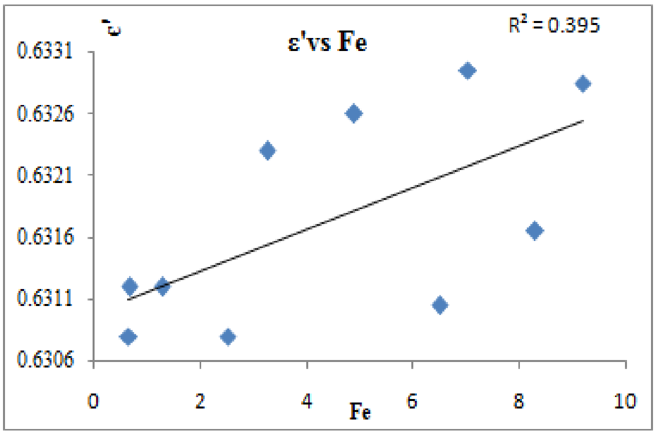

Figure 13: variation of dielectric constant with iron in soil

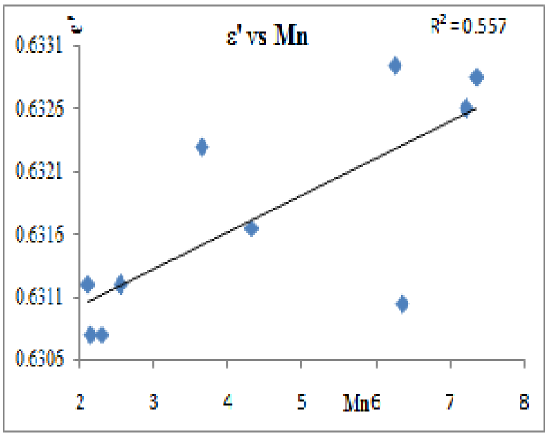

Figure 14: variation of dielectric constant with manganese in soil

From graph 13, dielectric constant has positive correlation with iron available in soil. Also from graph 14, dielectric constant has positive correlation with manganese available in soil.

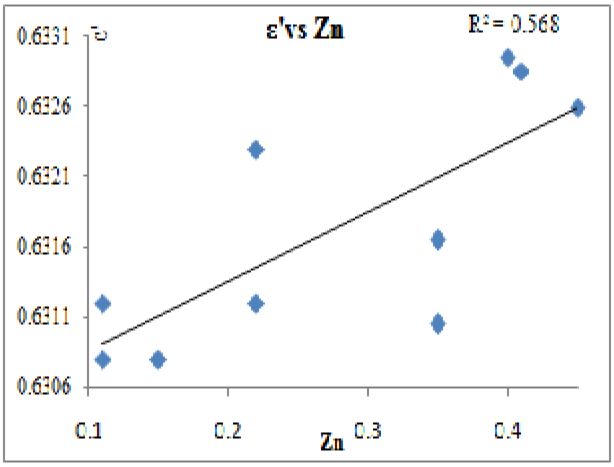

Figure 15: variation of dielectric constant with zinc in soil

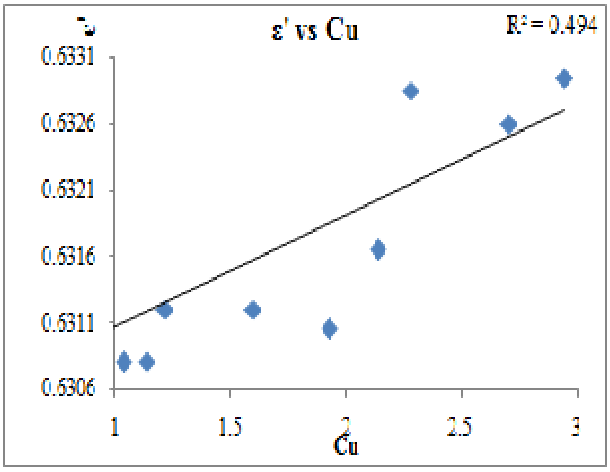

Figure 16: variation of dielectric constant with copper in soil

From graph 15, dielectric constant has positive correlation with zinc available in soil. Also from graph 16, dielectric constant has positive correlation with copper available in soil.Thus we see that the dielectric constant of soils depends on many factors like moisture content and its physical and chemical composition.

The soil parameters like pH and EC are determined by using Digital Soil Testing kit. The detailed soil analysis reports for the remaining parameters of the soil samples used in this study were obtained from Soil Science Division, College of Agriculture, Pune. Important physical properties such as soil texture, bulk and particle density and chemical properties such as pH, EC, OC, $CaCO_3$ available macronutrients N, P, K, Ca, Mg, micronutrients Fe, Mn, Zn, Cu, etc. of the soil samples are determined.

The variations of dielectric constant and dielectric loss of dry soil samples of ten different lands of sinner tehsil have been measured. Also other electrical properties such as ac microwave conductivity, relaxation time, tangent loss, wilting point, transition moisture and field capacity are reported. Dielectric constant represents the ability of a material to store electric energy, while the loss factor represents the loss of electric field energy in the material. The loss tangent is defined as the ratio of loss factor to the dielectric constant.

$$\text{Tan} = \frac{\varepsilon''}{\varepsilon'}$$

The ac conductivity and relaxation time are obtained . [15-16]..

$$\sigma = \omega\, \varepsilon_0 \varepsilon'' \quad \text{and} \quad \tau = \frac{\varepsilon''}{\omega \varepsilon'}$$

Soil texture is characterized by percentage of sand, silt and clay in it [17]. Depending upon the percentage of constituents, soils are classified into twelve types and they are arranged in a triangular form which is known as soil texture classification triangle [18-19].The variation of dielectric constant and dielectric loss respectively as a function of sand content in the soil, the value of dielectric constant increases with increase in content of sand in the soil. It is in good agreement with the earlier work [1].

From our observations, the relation between the dielectric constant and the moisture content is non linear. Because for moist soil, dielectric constant is not a function of individual components. The value of dielectric constant is roughly proportional to sand content and inversely proportional to clay content.

4. CONCLUSION

The behavior of dielectric constant and the percentage of moisture content is non linear. The dielectric constant varies with the status of nutrients available in soil. The ac electrical conductivity, relaxation time and tangent loss are directly proportional to dielectric loss. The dielectric constant of soil at lower moisture content is low. As the moisture content increases above transition moisture in the soil, dielectric constant increases rapidly. The results have importance not only for better understanding of soil physics but also microwave remote sensing application.

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AUTHORS

Particulars	Name of the Authors	Qualifications	Institution	Email address
First Author	**M.D.Dhiware**	**M.Sc, B.Ed., NET**	G.M.D. Arts, B.W. Commerce and Science College, Sinnar, [Nasik]., Maharashtra, India 422 103	manisha.salunke73@gmail.com
Second Author	**S. B. Nahire**	**M.Sc., D.H.E.**	G.M.D. Arts, B.W. Commerce and Science College, Sinnar, [Nasik]., Maharashtra, India 422 103	**Sumadhu29@gmai.com**
Third Author	**Sushant Deshmukh**	**M.Sc., Ph.D.**	J.E.S. College, Jalana, Maharashtra, India 431 203	**sushant.d59@gmail.com**

Correspondence Author:-

Sushant Deshmukh
Guide Teacher
(Associate Professor)
Physics Department
J.E.S. College, Jalana, Maharashtra, India 431 203
sushant.d59@gmail.com
Contact Number : +91-9420416654