Dielectric Characterization of Soil Samples of Nasik Region by Microwave Measurements

M.D.Dhiware[1], S. B. Nahire[2], Sushant Deshmukh[3]
1 K.V.N.Naik Art's, Commerce& Science College, Nasik, Maharashtra, India
2 Arts, Science and Commerce College, Ozar (Mig) Nasik, Maharashtra, India,
3 J.E.S. Colleges, Jalana, Maharashtra, India.

Abstract :
The Real and Imaginary parts (ϵ & ϵ") of the Complex Dielectric Permittivity (ϵ*) of soil have been determined experimentally using an automated X-band microwave set-up in the TE_{10} mode with Reflex Klystron source operating at frequency 9.5 GHz . The different physical properties of soil such as soil structure, soil water content, soil porosity which depends on bulk density of soil affects the dielectric characteristics of soil. Also, emissivity decreases with bulk density. Soil pH, organic carbon, electric conductivity, calcium carbonate, water holding capacity and bulk density of soil directly affects the dielectric constant and dielectric loss ($\varepsilon' and\ \varepsilon''$).The dielectric constant 0.439 is suitable for grapes, and 0.482 is suitable for rice and soya bean crops. Soil of east Dindori region is good for great production of grapes. These parameters have great importance in remote sensing of soil moisture using microwave signals..

Index Terms - Dielectric constant, Dielectric loss, tangent loss, relaxation time, microwave conductivity.

I. INTRODUCTION

Irrigation plays an important role in the agriculture development. Crop production increases considerably if irrigation is provided to dry lands. Nashik district is well known for the grapes and onion production as well as export. Area under fruits and other cash crops show increase in recent time. One of the main reasons behind this cropping pattern change is the irrigation development in the district [1]. Soils are medium in which crop grows to food and cloth. Soil is not only important for agriculture but also have more useful for living organisms. Soil as a component of the terrestrial ecosystem fulfills many function including those that are essential for sustaining plant growth [2]. Soil, as most people think, is not a dead inert matter of minerals. But a healthy soil is indeed alive and dynamic consisting of microorganisms. The top-most layer of soil is comparatively richer in nutrients and supports maximum bio-farms. The profile character varies distinctly from place to place, particularly with respect to their depth, color and composition. The soil is a natural body of mineral and organic material differentiated into horizons [3].Due to excess use of chemicals soil quality decreases. Small crop also affected due to large use of fertilizers and pesticides. So it becomes essential to analysis of soil parameter [4].Soil formation is a constructive as well as destructive process [5].The mineral composition of soil, the organic matter within it and the environment, all are determined by the chemical properties of soil [6]. It is also of variable depth, which differs from the parent material below in morphology, physical properties and constitution, chemical properties and composition and biological characteristics [7]. Chemistry of soil covers chemical reaction process in the soil pertaining to plant and animal growth and human development [8].Different factors create different type of soil. The properties of soil along with its type have a great importance in agriculture [9]. The soil physico chemical property deteriorates to the change in land use especially from agriculture and forest [6]. The change in physico chemical properties of soil leads to infertile or barren soil that does not support normal growth of vegetation for years [10]. Soil fertility is important factors, which determine the growth of plant. It depends on the concentration of N, P,K organic and inorganic materials, micronutrients and water. In general soil chemical fertility and in particular lack of nutrient inputs is a major factor in soil degradation [11].

The emissivity of soil also varies with different moisture content. Knowledge of emissivity of soil is useful for the efficient use of soil [12].Knowledge of the emissivity of the soil is useful for the efficient use of soil. The experimental techniques of the dielectric measurements can be categorized as reflection or transmission types using resonant or no resonant systems, with open or closed structures for sensing the material samples [13].According to Hallikainen*et al.* [14], the soil texture shown to have an effect on dielectric behaviour of soil, that is moisture retentive capacity of clayey soil, is more than that of sandy soil [15].

The variation in dielectric constant and soil water content with increasing volumetric water for the three samples is very similar to the work of Behari [16], Vyas and Gadani [17], and Srivastava and Mishra [18].The measurements of dielectric constant of soils as a function of moisture content over wide microwave frequency range were carried out in the past by many investigators [19-26].

Study Area:

The fertile soil of Dindori (fig.1) is one of the best for producing optimum quality grapes for wine. The soil quality is of lateritic type and has tiny gravel in it to make it well drained. The gravel assists the roots of the vines to go deeper into the soil and reach the micronutrients embedded deeper in the rich soil.The world Cultivated area is around 56% of the total land area. Nashik is situated 2,000 feet above sea level in the Western Ghats of India. Located in northern Maharashtra approximately 200 km from Mumbai and Pune-it is an important industrial and agricultural area. The climate of the area is mild throughout the year, ranging from winter lows of 8-10°C to summer highs of 32-35°C. The Nashik region consists of two rainfall zones. The first is the high rainfall (80-100 cm) hilly Konkan area in the west, and the second is the low rainfall fertile plain to the east.

Fig. 1: Study Area

Materials and methods:

Soil samples were collected in the depth of 0-20cm from 10 sites from Dindori tehsil of Nasik District. Soil samples were completely air dried and passed through 2mm sieve and stored in properly labelled cloth bags as per the standard procedures. Quartering technique was used for the preparation of soil samples. The sieved out particles are then oven dried to a temperature around 110^{o} C in order to completely remove any trace of moisture.

In the present study, Two Point Method has been used to measure the complex dielectric constant of soils. The wave guide cell method is used to determine dielectric constant of these soil samples. The X-band microwave bench is setup in TE_{10} mode with Reflex Klystron source operating at frequencies 9.56 GHz is used for this purpose. The dielectric cell shorted with matched load is connected at load end. The reflected wave combined with incidental wave to give standing wave patterns. These standing wave patterns used to determine the values of shift in minima resulted due to before and after inserting the sample. The Dielectric constant (ϵ') is determined. Fig.2 shows experimental set-up of microwave X-band waveguide transmission line.

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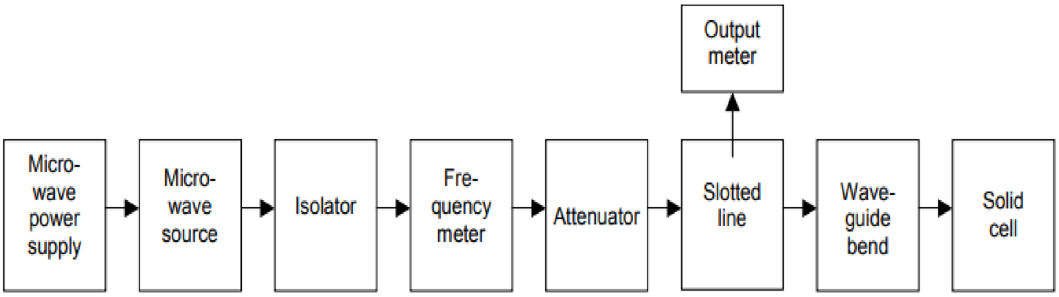

Fig. 2: Experimental set-up of microwave X-band waveguide transmission line

The dielectric constant ε' of the soils is then determined from the following relation:

$$\varepsilon' = \frac{g_e + (\lambda_{gs} / 2a)^2}{1 + (\lambda_{gs} / 2a)^2}$$

and

$$\varepsilon' = \frac{\beta_\varepsilon}{1 + (\lambda_{gs} / 2a)^2}$$

Where, a = Inner width of rectangular waveguide.

λ_{gs} = wavelength in the air-filled guide.

g_ε = real part of the admittance

β_ε = imaginary part of the admittance

Results and Discussion:

Bulk Density Effects:

Bulk density is most important in converting gravimetric soil moisture to volumetric soil moisture. In the Wang and Schmugge[27] model the bulk density is insignificant. The Dobson et al.[28]model uses the bulk density in its calculations of the conductance properties of the soil water that, in turn, affect the dielectric constant. In remote sensing, early research on soil water-dielectric relationships was hindered by different opinions on exactly which soil water property should be used. Many studies used the gravimetric soil moisture and others related dielectric and emission parameters to moisture-tension characteristics. These approaches have been abandoned in favour of volumetric soil moisture.

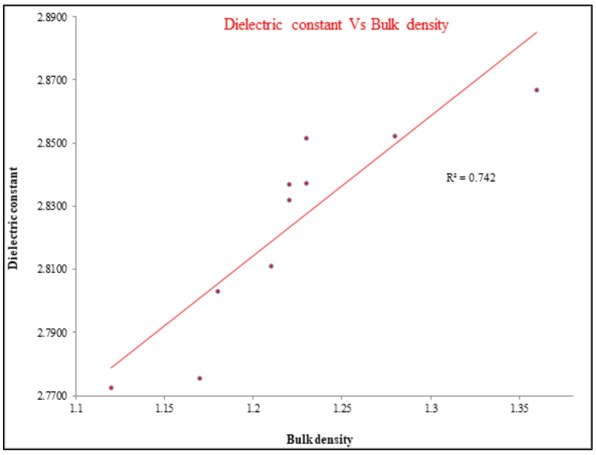

Fig.3: Variation of dielectric constant with bulk density

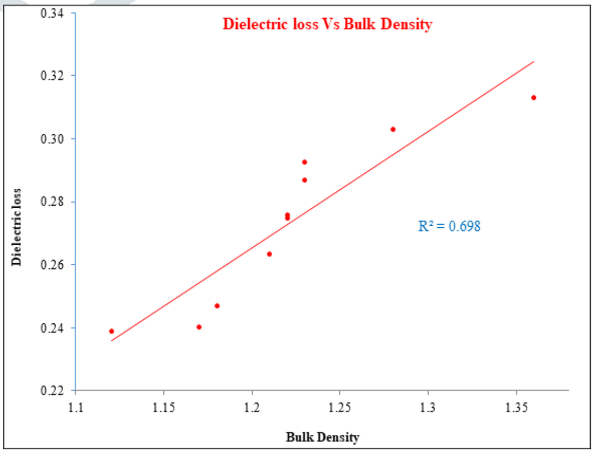

Fig.4: Variation of dielectric loss with bulk density

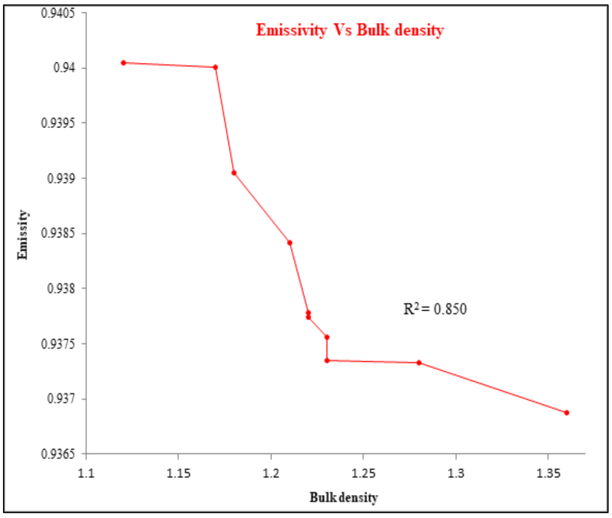

Fig.5: Variation of Emissivity with bulk density

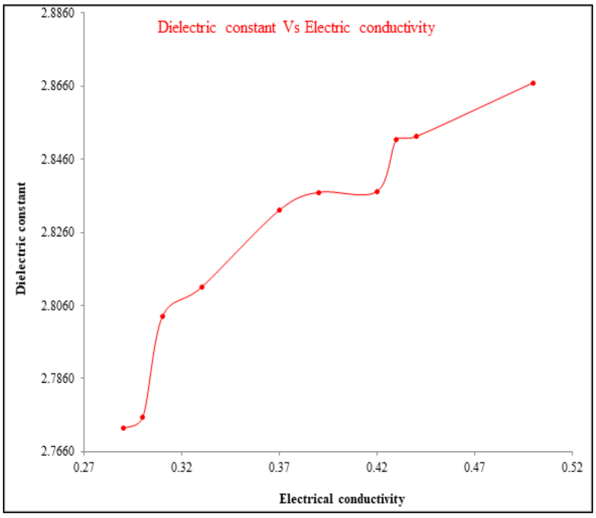

Fig.6: Variation of dielectric constant with Electric Conductivity

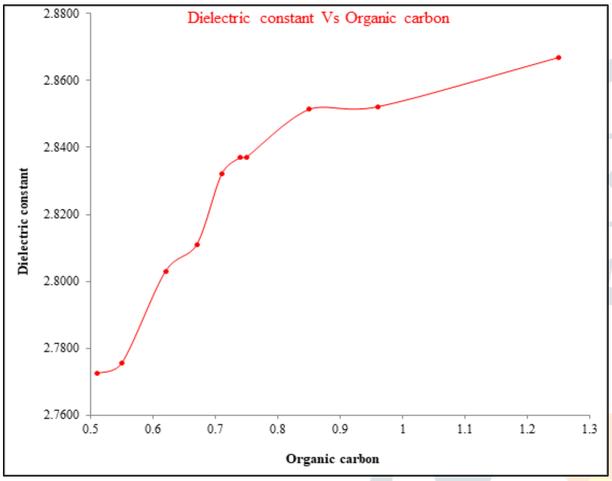

Fig.7: Variation of dielectric constant with Organic carbon

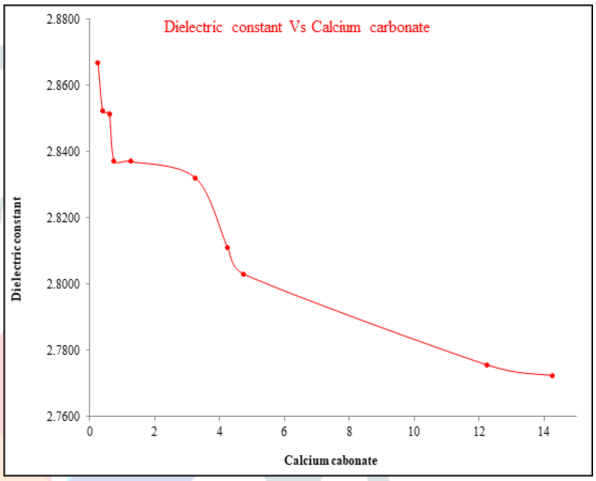

Fig.8: Variation of dielectric constant with Calcium carbonate

Soil texture, density, and structure have important effects that must be accounted for if soil moisture is to be estimated. Recent research has examined the effects of a number of soil characteristics on the relationship between soil moisture and dielectric properties or emissivity Soil salinity, temperature, and organic matter content are not important at longer wavelengths. Dielectric permittivity of a material is its bulk property which defines the interaction of electromagnetic wave with material. For a given value of the gravimetric moisture content, increase in the bulk density will increase the soil dielectric constant. Fig. 3 gives variation of dielectric constant with bulk density. Further, dielectric loss increases with increase in bulk density.Fig.4 shows variation of dielectric loss with bulk density.

Emissivity is the important parameter, which provides information about soil. All the natural objects such as soil with ^{0}C temperature absolute are capable of emission, absorption and transmission. Fig.5 gives relation between bulk density and emissivity and fig. 6 gives the relation between electric conductivity and dielectric constant.

Fig. 7 shows the variation dielectric constant with organic carbon and Fig. 8 gives the variation of dielectric constant with $CaCO_3$ of soil samples. It further show a positive significant correlation of dielectric constant with organic carbon content and negative significant correlation with $CaCO_3$ content for soil samples.

Conclusion:

Colour of soil of Dindori tehsil is black. Soil texture has remarkable effect on the dielectric properties. Study of physical properties, chemical properties, dielectric properties of soils with varied organic and inorganic matter is utilizable in agriculture to prognosticate quality and fertility of soil. Additionally it is subsidiary for the researchers working in the field of microwave remote sensing. The results from such studies are paramount to understand the fundamental nature of the replication of particular soil to high frequency electromagnetic field.

The soil of east Dindori tehsil region has pH range 6.93-7.64, Electrical conductivity has range 0.33-0.43mm, Phosphate has range 0.056-0.061%, Potash has range 0.39-0.4 %, Sand is between 36-44 %, Silt is between 24-46 % and Clay is between 9-22 %.The dielectric constant 0.439 is suitable for grapes, and 0.482 is suitable for rice and soyabean crops. Soil of east Dindori region is good for great production of grapes. Soil pH, organic carbon, electric conductivity, calcium carbonate, water holding capacity and Bulk density of soil directly affects the dielectric constant and dielectric loss ($\varepsilon' and \varepsilon''$). Hence, the different physical properties of soil such as soil structure, soil water content, soil porosity which depends on bulk density of soil affects the dielectric characteristics of soil. Also, emissivity decreases with bulk density.

These results are very useful for the scientists working in the field of microwave remote sensing for soils and also for agriculture scientists.

Acknowledgments:

The authors thank to the Principal, K.V.N.Naik Arts, Commerce & Science College, Nasik and The Principal, JES College, Jalana for providing the laboratory facilities.

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