INFLUENCE OF BULK DENSITY ON DIELECTRIC PROPERTIES OF SOIL SAMPLES OF KHANDESH AND NORTHERN MAHARASHTRA

[1]Manisha Dhiware, [2]S. B. Nahire, [3]Sushant Deshmukh
[1]Junior College Teacher [2]Associate Professor[3]Associate Professor
[1]Department Of Physics
[1] G.M.D. Arts, B.W. Commerce and Science College, Sinnar, [Nasik]., Maharashtra, India 422 103

ABSTRACT:

At a single microwave frequency 9.56 GHz, dielectric constant and dielectric loss (ε' and ε'') of different soil samples of agriculture land varying with bulk densities are determined at room temperature. At an automated x band microwave set-up in TE_{10} mode operating at 9.56 GHz, dielectric constant, dielectric loss of soils has been measured. From the knowledge of the complex dielectric constant and the surface boundary condition, the Fresnel reflectivity of soil is calculated in microwave remote sensing. Also from Fresnel reflectivity of the surface, using Kirchhoff's reciprocity theorem, microwave emissivity is computed. As bulk density of soil increases, the microwave emission from the soil surface inhibits.

KEYWORDS:

Dielectric constant, Dielectric loss, Tangent loss, Bulk density, Relaxation time

INTRODUCTION:

Soil is an intimate mixture of organic and inorganic materials, water and air. The relative amount of air and water present depends on way the soil particles are packed together. Soil texture is characterized by percentage of sand, silt and clay in it. Soil compaction or high bulk density of soil is important field of research due to agricultural importance. Soil compaction is the main form of soil degradation which alters the extent and configuration of the pore space [1]. It can have adverse effects upon plants by increasing field saturated hydraulic conductivity, mechanical impedance to the growth of roots. Different studies [2–6] predict that the dielectric parameters of soil at microwave frequencies are the function of various properties of soil such as texture, moisture, bulk density, temperature, and salinity. High yielding crop cultivars were highly responsive to fertilizers [7]. Soil characterization in relation to evaluation of fertility status of an area or region is an important aspect in context of sustainable agricultural production [8]. Depending upon the percentage of each constituent, the soil texture is differently named. The measurement of dielectric constant of soil as a function of moisture content has been carried out over wide frequency range in the past several years using soils of widely different texture structures by Wang and Schmugge [9]. Calla et al [10] have studied the dielectric properties of dry and wet soil at microwave frequencies and reported that the dielectric constant of soil is strongly dependent on moisture content. 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 [11]. 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 [12]. According to Hallikainen *et al.* [13], 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 [14]. 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 [15], Vyas and Gadani [16], and Srivastava and Mishra [17].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 [18-25].

MATERIALS AND METHODS:

There are different methods available for measurement of dielectric constant of dry soil at microwave frequency.

a) waveguide cell method
b) Resonance cavity method
c) Network analyser method

Study Area:

Nasik, lying between 19º 33’ and 20⁰ 53’ north latitude and 73⁰ 16’ and 75⁰ 16’, with an area of 15530 Sq. Km North south length is 120 kms. East West length is 200 kms. Dindori is a town and taluka in Nashik district in the Indian state of Maharashtra. Dindori is known for its grape farming. Grapes, tomato, Wheat, Paddy, Sugarcane, groundnut, Ragi, Gram, Brigal are the main crops in Dindori. Soil samples were collected from different agricultural land of Khandesh and Northern 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 to remove the coarser particles. The sieved out fine particles are then dried in the hot air oven to a temperature around 110ºC for about 24 hours in order to completely remove any trace of moisture and stored in properly labelled cloth bags as per the standard procedures. Such dry sample is then called as oven dry sample. Quartering technique was used for the preparation of soil samples.The details of the land are given below.

Sample No.	Name of the farmer	Survey No.	Area	Latitude	Longitude
1	Rangnath Haribhau Bunge	159	Dhakambe	20°09"55'	73°80"70'
2	Ranganath Kandrao Shelke	10	Manori	20°10"24'	73°78"62'
3	Chintaman Bhikaji Khandave	217	Pimpalner	20°12"30'	73°81"47'
4	Hiraman Pundalik Dargode	41/2	Indore	20°16"28'	73°79"25'
5	Gangadhar Govind Gaikwad	144	Akrale	20°14"15'	73°85"56'
6	Shamrao Nivrutti Tidke	1079/B	Ianori Janori	20°11"85'	73°89"13'
7	Ramnath Daguji Gaikwad	98	Palkhed (Dam)	20°18"02'	73°88"72'
8	Pandurang Punjaji Ugale	305	Jopul	20°20"16'	73°91"57'
9	Sampat Sankar Uphade	114	Warkhede	20°23"72'	73°90"71'
10	Sushilabai Tanaji Gaikwad	271	Awankhed	20°24"70'	73°84"59'

Table no.1 The details of the land

Soil Physical and Chemical Properties:

The analysis of soil physical and chemical properties is usually carried out in the well reputed soil testing laboratories. The soil parameters like pH and EC are measured in our laboratory by using 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. These soil analysis reports includes the chemical analysis of OC, available macronutrients N, P, K, Ca, Mg and micronutrients Fe, Mn, Zn, Cu also includes properties like texture, structure, pH, bulk density. 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

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

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

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

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

Measurement of Dielectric Constant of dry Soil Samples:

To determine the dielectric properties of the soil samples of agricultural land of desired location, wave-guide cell method is used. An automated X -band microwave set-up in the TE_{10} mode with Reflex Klystron source operating at frequencies 9.56 GHz is used for this purpose. The sample lengths are usually taken in the multiples of λ/4. To the opposite end of the source, the solid dielectric cell with soil sample is connected. The soil sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. In determining the values of shift in minima resulted due to before and after inserting the sample, these standing wave patterns are used. By measuring the standing wave ratio of the dielectric material and the shift in minima of the standing wave pattern in a rectangular waveguide, the dielectric constant of soil is calculated.The dielectric constant ε' of the soils is then determined from the following relation:

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

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

By using the emissivity model [26] treating uniformity of soil subsurface temperature and dielectric profile, Kirchoff's reciprocity theorem relates the polarized emissivity (*ep*) for bare and smooth soil surfaces which can be given by,

$$e_{p(\theta)=1-R_{p(\theta)}}$$

where $Rp(\theta)$ is the polarized Fresnel reflectivity derived from electromagnetic theory [27]. The horizontal and vertical components of reflectivity are given by :

$$\mathrm{ep}(\theta) = 1 - \frac{\varepsilon' cos\theta - \sqrt{\varepsilon' - sin^2\theta}}{\epsilon' cos\theta + \sqrt{\varepsilon' - sin^2\theta}}$$

For horizontal polarization,

$$\mathrm{ep}(\theta) = 1 - \frac{cos\theta - \sqrt{\varepsilon' - sin^2\theta}}{cos\theta + \sqrt{\varepsilon' - sin^2\theta}}$$

Where, θ = Angle of observation.

$e_p(\theta)$ = Emissivity of the surface layer.

$r_p(\theta)$ = Reflection coefficient.

$R_p(\theta)$ = Fresnel reflection coefficient

Figure shows Experimental set up of x-band microwave bench set up.

Fig.1 Experimental set up of x-band microwave bench

Results and Discussions:

Bulk Density Effects:

Bulk density is most important in converting gravimetric soil moisture to volumetric soil moisture. In the Wang and Schmugge [28] model the bulk density is insignificant. The Dobson et al.[29] 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.

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. When a dielectric media are placed in electric field, the number of induced dipoles per unit volume defines the real part of dielectric constant. In presence of oscillating electric field, these dipoles try to align themselves with the field direction. For a given value of the gravimetric moisture content, increase in the bulk density will increase the soil dielectric constant. Further, dielectric loss increases with increase in bulk density. On the other hand dielectric constant has negative significant correlation with its wilting point. Wilting point of the soil which helps to indicate the water holding capacity of soil.

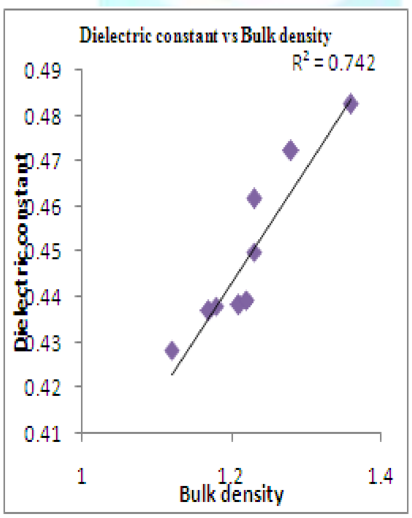

Fig.2 Variation of dielectric constant with bulk density

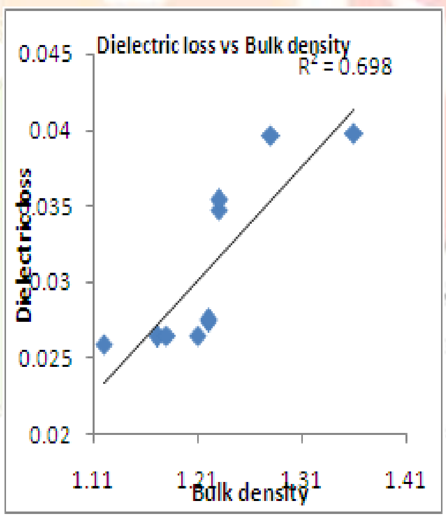

Fig.3 Variation of dielectric loss with bulk density

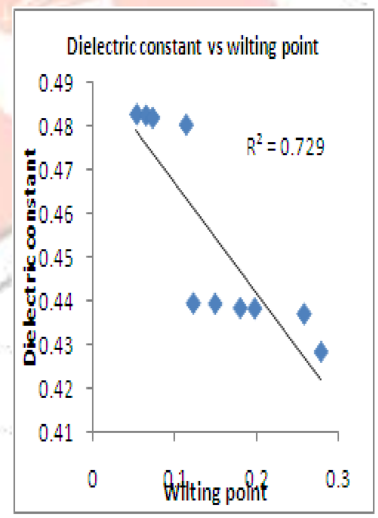

Fig.4 Variation of dielectric constant with wilting point

The values of dielectric constant and dielectric loss are used to estimate relaxation time (τ), in picoseconds, using the relation

$$\tau = \frac{\epsilon''}{\omega\varepsilon'}$$

where, ω is angular frequency

The emissivity of soil for normal incidence were calculated using the relation

$$e = 1 - \left|\frac{1 - \varepsilon^{1/2}}{1 + \varepsilon^{1/2}}\right|^2$$

Where $\varepsilon =$ dielectric constant of soil

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. The emitted radiation from soil depends upon its dielectric constant, surface roughness, chemical composition, physical temperature, frequency of polarization, and angle of observation. The emissivity of the soil also varies with different moisture contents. A knowledge of the emissivity of the soil is useful for the efficient use of soil [11].

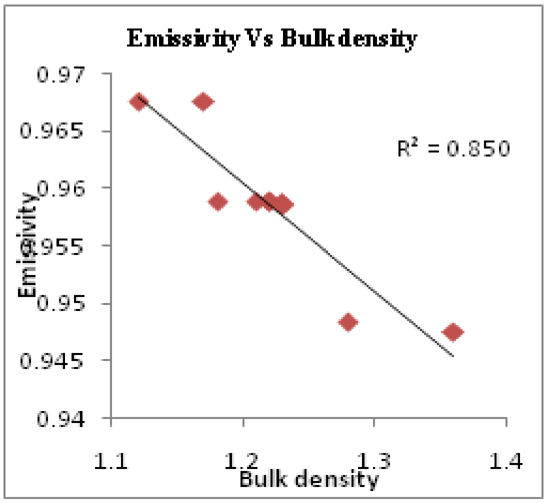

Fig.5 Variation of dielectric constant with wilting point

Grape is the most important fruit crop in the Nashik district. This crop is cultivated for more than a century in this district. Although the share of fruit in the gross area is very small in the district, grapes occupy leading position in various fruit that are grown in the study area. The grape growing regions of the world have soils ranging from gravelly sand to heavy clays, from shallow to very deep and from low to high fertility. According to KhiLari (1979) the most favourable soil pH for grapevine ranges from 6,5 to 7.5 that is to say soils should be neutral. Khilari (1979) suggests that the most favourable soils for grape cultivation are clay and silt loam soils with fine sand. The proportion of these constituents is 35 to 45% of fine sand. 25 to 40 % of silt and 10 to 25% of clay. He has also made a diagrammatic representation of these soils which suggests that the structure of the soil is the most important factor in grape cultivation. Clay should be much less in these soils so that they are well drained. The field observation showed that Dindori tahsil has shallow soils and produce good quality grapes.

PHYSICAL PROPERTIES		CHEMICAL PROPERTIES	
Sand (0.1-0.25mm)	35-45 %	pH	6.5-8.2
Silt (0.002-0.1mm)	25-45 %	Lime Content	3-5 %
Clay (< 0.002mm)	10-25 %	Elect. Cond.	Around 0.4 mm

Colour	Dark brown-black	Phosphate	0.06%
Thickness	60-120 cm	Potash	0.4%

Table no.2 Requirement of good soil for grapes

Conclusion:

The soil of Dindori tehsil has pH range 6.93-7.64, Electrical conductivity has range 0.33-.043mm, Phasphate 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 %.Colour of soil of Dindori tehsil is black. Soil of Dindori is good for great production of grapes. Bulk density of soil directly affects the dielectric constant and dielectric loss (ε' *and* ε'').Hence, the different physical properties of soil such as soil structure, soil water content, soil porosity which depend 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, GMD Arts, BW Commerce & Science College, Sinnar and The Principal, JES College,Jalana for providing the laboratory facilities.

References:

1. V. K. Gupta and R. A. Jangid ,“The Effect of Bulk Density on Emission Behavior of Soil at Microwave Frequencies”, International Journal of Microwave Science and Technology, Volume 2011,pp 1-6.
2. M. C. Dobson, F. T. Ulaby, M. A. El-Rayes, and M. T. Hallikainen,“Microwave dielectric behavior of wet soil—part II: dielectric mixing models,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. GE-23, no. 1, pp. 35–46, 1985.
3. N. R. Peplinski, F. T. Ulaby, and M. C. Dobson, “Dielectric properties of soils in the 0.3–1.3-GHz range,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 33, no. 3, pp. 803–807, 1995.
4. M. T. Hallikainen, F. T. Ulaby, M. C. Dobson, and M. A. El-Rayes, “Microwave dielectric behavior of wet soil—part I: empirical models and experimental observations,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. GE-23, no.1, pp. 25–34, 1985.
5. P. Hoekstra and A. Delaney, “Dielectric properties of soils at UHF and microwave frequencies,” *Journal of Geophysical Research*, vol. 79, pp. 1699–1708, 1974.
6. J. R. Wang and T. J. Schmugge, “An empirical model for the complex dielectric permittivity of soils as a function of water content,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. GE-18, no. 4, pp. 288–295, 1980.
7. S.V.Lamture,S.S.Patil,Micronutrients status in soil under command area of Upper Kundalika project Beed District [Maharashtra],International Journal of Scientific Research,Vol.4,Issue:2 February 2015,pp 120-122
8. S.L.Waikar,A.L.Dhamak,V.D.Patil,P.R.Jarrakar,Assessment of Soil Properties of Central Farm-B-Block of MKV, Parbhani, Journal of Research in Agriculture and Animal Science,Vol.2 Issue10 pp:28-34, 2014
9. J. R. Wang and T. J. Schmugge, “An empirical model for complex dielectric permittivity of soils as a function of water content”, IEEE Transactions on Geoscience and RemoteSensing, 18, pp.288- 295,1980.
10. OP N Calla, M. C. Borah, P. V.ashishtha, R. MIshra , A. Bhattacharya and S. P. Purohit , Study of the properties of dry and wet loamy sand soil at microwave frequencies, Indian J Radio Space Phys, 28, pp. 109-112, 1999.

11. O.P.N Calla & R.K.Singh. Indian Journal of Radio & Space Physics, Vol.31, June 2002, Emission characteristics of dry and wet loamy sand soil layered packed at microwave frequency, pp 285-292
12. A. W. Kraszewski, *Microwave aquametry. Electromagnetic interaction with water-containing materials*,IEEE Press (1996).
13. M. T. Hallikainen, T. U. Fawwaz, C. D. Obson, M. A. El-Rayes, and L.-K. Wu, Microwave dielectric behaviour of wet soil-Part 1: Empirical models and experimental observations, *IEEE Trans. Geosci. Remote Sensing*, **23**, 25–34 (1985).
14. F. N. Dalton, and M. Th. van Genuchten, The time-domain reflectomtery method for measuring soil water content and salinity, *Geoderma*, **38**, 237–250 (1986).
15. J. Behari, Frequency dependent variation of dielectric parameters of wet soil, *Microwave measurement techniques and applications*, pp. 71–79, Anamaya Publishers, New Delhi (2003).
16. A. D. Vyas, and D. H. Gadani, Dielectric properties of dry and wet soils at microwave frequencies, *Microwave measurement techniques and applications*, pp. 80–85, Anamaya Publishers, New Delhi (2003).
17. S. K. Srivastava, and G. P. Mishra, Study of characteristics of the soil of Chhattisgarh at X-band frequency, *Sadhana*, **29**, 343–347 (2005).
18. Hallikainen M. T., Ulaby F. T., Dobson M.C., Elrayes M. A. and Wu L. K., IEEE Transactions on Geoscience and Remote Sensing, 23(1), (1985a), 25-34.
19. Curtis J. O., IEEE Transactions on Geoscience and Remote Sensing, 29(1), (2001), 125.
20. Srivastava S. K. and Mishra G. P., Sadhana , 29 (4), (2004), 343-347.
21. Calla O.P.N., Bohra D., Mishra S. K. Alam M., Hazarika D. and Ramawat L., Indian J. of Radio and Space Physics, 36, (2007), 229-233.
22. Alex Z. C. and Behari J., Indian J. Pure and applied Physics., 34, (1996), 319- 323.
23. Hallikainen M. T., Ulaby F. T., Dobson M. C. and El-Rayes M. A., IEEE Transactions on Geoscience and Remote Sensing, 23(1), (1985b), 35-46.
24. Wang J. R., Radio Sci., 15, (1980), 977-985.
25. Alex Z. C., Behari J., Rufus E. and Karpagam A. V., 22nd Asian Conference on Remote Sensing, SISV, AARS, Singapore, (2001).
26. W. Peake, "Interaction of electromagnetic waves with some natural surfaces," *IRE Transactions on Antennas and Propagation*, vol. 7, pp. 2582–2590, 1959.
27. J. A. Kong, *Electromagnetic Wave Theory*, Wiley-Interscience, New York, NY, USA, 2nd edition, 1990.
28. J. R. Wang and T. J. Schmugge. An Empirical Model for the Complex Dielectric Permittivity of Soil as a Function of Water Content. *IEEE Transactions on Geoscience and Remote Sensing*, Vol. GE-18, 1980, pp. 288-295
29. M. C. Dobson, F. T. Ulaby, M. T. Hallikainen, and M. A. ElRayes. Microwave Dieleccric Behavior of Wet Soil, Part II: Diclcccric Mixing Models. *IEEE Tra11sactio11s 011 Geoscience and Remote Sensing*, Vol. GE-23, 1985, pp. 35-46.