Measurement of Dielectric Constant of Soils of Marble Mining Areas of Mewar Region, Rajasthan State at X-band

Bapna, P.C. and Joshi, S.

Abstract: **This paper presents the measurement of dielectric constant of soils specific to the Mewar region of Rajasthan state (India) at X-band microwave frequencies. Samples were collected from three different marble mining areas. This mining area extracts different types of marbles viz. White, Green and Pink. Besides, soil samples collected from different marble areas of the region are also used to determine their dielectric constant with varied amount of moisture contents. Measurements of dielectric constants of these soils have been carried out using Waveguide cell method. Further, the data on the physical and chemical properties of these soils are also provided. The results depicted in the paper are important for microwave remote sensing applications.**

Keywords: **Dielectric constant, Marble mines soils, Microwave frequency**

I. INTRODUCTION

Microwave remote sensing techniques are now a days widely adopted and used to estimate the presence of natural resources beneath the ground surface. The Rajasthan state is endowed with a large diversity in soil cover. The sediments on which the soils are developed have originated from rock formation of varied lithological composition. The past history of landscape evolution and age of the soil are the other contributing factors to the local and regional variability. No less important is the present and past gradient of climate and associated vegetation. Red loam soils are found in southern part of Rajasthan i.e. in Dungarpur, Banswara and Udaipur districts and these cover 2.3 per cent. The soils are characteristically reddish in colour and loam in texture. These are invariably non-calcarious.[1]

Several researchers have reported the findings of their studies on dielectric and emissive characteristics of soils from various part of the world at different microwave frequencies. The dielectric constant and emissivity of dry and wet black soils at C-band for three different soils types as a function of moisture content have been determined.[2] The results indicate that dielectric constant are function of moisture content in the soils. Studies on dielectric properties of soils at X-band frequencies using infinite sample method were carried out by several investigators.[3]-[9] The surface emissivity of soils is dependent on both water content and physical characteristics the results indicates that the emissivity values are independent of frequency and texture but shows the strong dependence on the moisture content.[6]

Bapna, P.C. is a PhD Scholar, Department of Electronics & Communication, SGV University, Jaipur (Raj), India and Joshi, S. is working as Professor & Head Department of Electronics & Communication, CTAE, M.P.U.A.T., Udaipur (Raj), India bapnapc@yahoo.com

II. EXPERIMENTAL DETAILS

2.1 Materials

Samples of soils were collected from three different locations of non irrigated Mining area of Mewar region of southern Rajasthan where different colour marbles are mined. Sample 1 is from Kelwa (Rajsamand Dist.), White colour marble is mined. Sample 2 is from Keshriya ji (Dungurpur Dist.), Green colour marble is mined. Sample 3 is from Babarmal (Udaipur Dist.), Pink colour marble is mined.

2.2 Sample Preparation

These soil samples are first sieved by sieve shaker to remove the coarse particles. This fine particles are then oven dried for several hours in order to completely remove any moisture.

Soils samples of various moisture contents are prepared by adding an exact amount of distilled water to dried soil. The moisture content is percentage by dry weight Wc (%) is calculated using following relation.

$$Wc\,(\%) = [(\text{weight of wet soil} - \text{weight of dry soil}) / (\text{weight of dry soil})] \times 100 \quad \text{------- (1)}$$

Soil physical and Chemical properties were obtained from Soil Testing Laboratory, Dept., of Agricultural Chemistry and Soil Science, Rajasthan college of Agriculture, MPUAT, Udaipur (Raj.). Table 1 shows the physical properties of these sample soils. Samples 1 &3 are loamy sands in texture where as Sample 2 is sandy loam. Table 2 shows chemical properties. All soils are Alkaline in nature.

2.3 Dielectric Measurements

There are different methods available for the measurement of dielectric constant at a microwave frequency. 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 TE10 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 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.

TABLE 1 PHYSICAL PROPERTIES

S.No.	Sample	Sand (%)	Silt (%)	Clay (%)	Texture	WHC (%)	PD (%)	BD (%)	Pore specs (%)
1	Kelwa (Rajsamand) White Marble	89	3	8	Loamy sand	14.5	23.34	1.62	53.5
2	Keshriya ji (Dungerpur) Green marble	70	26	4	Sandy loam	6.5	26.45	1.32	52.8
3	Babarmal (Udaipur) Pink Marble	88	9	3	Loamy Sand	74.2	25.4	1.43	51.6

TABLE 2 CHEMICAL PROPERTIES

S.No	Sample	pH	EC (dSm^{-1})	OC (%)	P_2O_5 ($Kgha^{-1}$)	K_2O ($Kgha^{-1}$)	Ca m.eq/ltr	Mg m.eq/ltr	Na ppm	$CaCO_3$ (%)
1	Kelwa (Rajsamand) White Marble	7.55	0.34	0.33	28.2	330.6	3.2	4.3	17.9	48
2.	Keshriya ji (Dungerpur) Green marble	7.26	0.54	0.93	25.1	206.6	6.6	5.7	12.7	15
3.	Babarmal (Udaipur) Pink Marble	7.00	0.42	0.38	21.8	358.1	6.7	2.3	21.1	11

III. Results and Discussions

Our results on the variations of dielectric constant of these three samples soils having different gravimetric moisture content in percentage at different frequencies of X-band varies from 8.8GHz to 12.2 GHz are shown in Fig.(1)- (4).

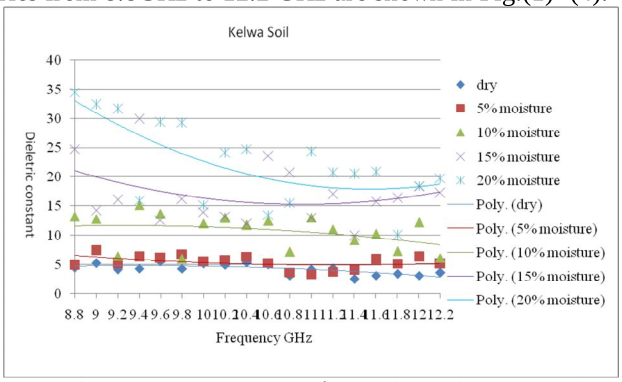

Figure1: Dielectric constant vs Frequency for Sample 1 (Kelwa Mines Soil) with different percentage moisture.

Fig.1 shows the variations of dielectric constant with different gravimetric moisture content (%) for sample1, soil from Kelwa mines area at x-band frequencies which varies from 8.8GHz to 12.2GHz. It is seen that for dry soil dielectric constant varies between 2.53622 to 5.390557. At 5% moisture it varies from 3.271819 to 7.413215, for 10% it varies from 5.970084 to 13.163268, for 15% it varies from 9.887778 to 24.802503 and for 20% it varies from 10.040708 to 34.49804. As moisture increases from 0% to 20% the dielectric constant increases but it decreases with increase in frequency.

Fig.2 shows the variations of dielectric constant with different gravimetric moisture content (%) for sample2, soil from Keshriya ji mines area at x-band frequencies which varies from 8.8GHz to 12.2GHz. It is seen that for dry soil dielectric

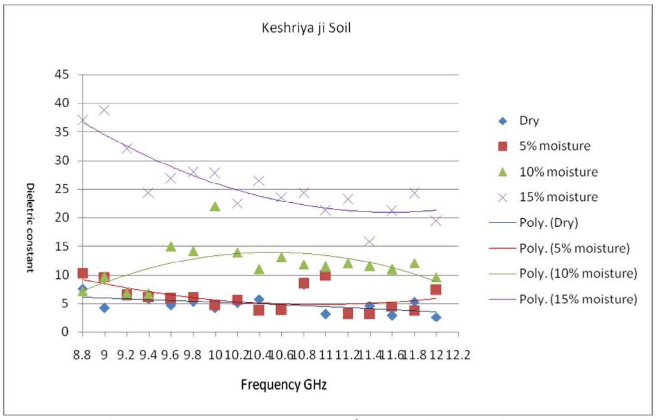

Figure2: Dielectric constant vs Frequency for Sample 2 (Keshriya ji Mines Soil) with different percentage moisture.

constant varies between 2.627586 to 7.603027. At 5% moisture it varies from 3.109193 to 10.313589, for 10% it varies from 6.877245 to 14.97, and for 15% it varies from 15.849696 to 38.81058. As moisture increases from 0% to15% the dielectric constant increases but it decreases with increase in frequency. Fig. 3 shows the variations of dielectric constant with different gravimetric moisture content (%) for sample3, soil from Babarmal mines area at x-band frequencies which varies from 8.8GHz to 12.2GHz. It is seen that for dry soil dielectric constant varies from 0.63355 to 3.9135. At 5% moisture it varies from 0.63335 to 3.9135, for 10% it varies from 2.080383 to 6.64745, for 15% it varies from 2.80383 to 11.0665 and for 20% it varies from 2.30525 to 9.61125. As moisture increases from 0% to 20% the dielectric constant increases but it decreases with increase in frequency.

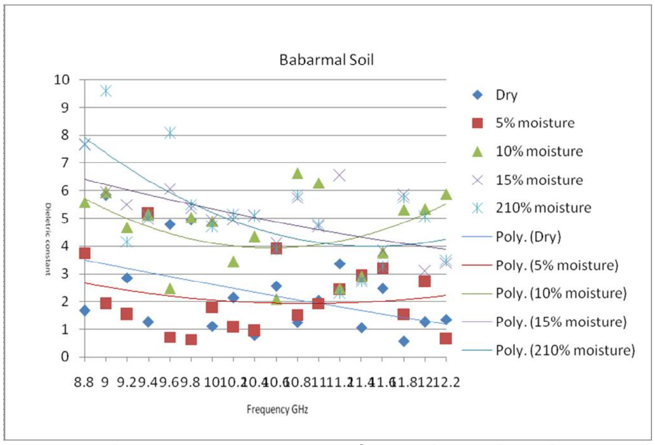

Figure 3: Dielectric constant vs Frequency for Sample 3 (Babarmal Mines Soil) with different percentage moisture

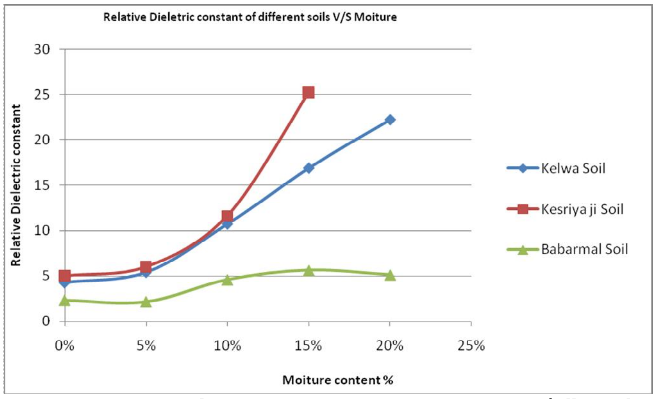

Figure 4: Average Dielectric constant vs Moisture content (%) of all samples

Fig. 4 shows the variations of average dielectric constant variation at X-band with gravimetric moisture content varies from 0% to 20% for all three different samples. It is seen that for sample 1 (Kelwa soil) the dielectric constant slightly increases at 5% moisture, then increases with constant rate with increase in moisture, for sample 2 (Keshriya ji soil) it follows the same as sample 1 till 10%, but it increases sharply after 10% .For sample 3 Babarmal soil the variation is very small in magnitude compare to other two samples, it increases till 15% then it decreases slightly. This variation can be explained very well from the dependence of soil water holding capacity of sample 3 is about 74.2 % (Table 1).

Many important soil processes take place in soil pores. Soil texture and structure influence porosity by determining the size, number and interconnection of pores. Coarse-textured soils have macro pores and they are loosely bound with each other. Whereas Fine –textured soils have micro pores are tightly bound. They have micro and macro pores have higher porosity. Dielectric constant is directly proportional to total porosity of soils [10].

IV. CONCLUSIONS

These plots depicts that whatever be the moisture condition and type of soils, the dielectric constant decreases with increase in frequency. All samples also show the frequency dispersion properties. The polarization of a dielectric when an electromagnetic field is applied takes place over certain relaxation time, the relaxation process depends on physicochemical properties and the texture of the soils. This dispersion gives the different peaks and dips throughout the band of frequency.

Sample 2 has lowest sand percentage, highest silt and comparable clay in its texture, highest particle density and comparable Pore spaces than other two samples , these attributes to higher dielectric constant at all moisture contents.

Sample 1 has higher sand, lower silt, lower particle density than sample1, thus it has low dielectric constant than sample2 at all moisture contents, but higher dielectric constant than sample 3.

Sample 3 has highest sand, lowest silt, lowest particle density than other two sample soils, thus it has lowest dielectric constant in compare to other samples.

Thus results verify that dielectric constant also depends on the physical properties of soil.

Sample 2 has highest Electric conductivity, Organic contents, Mg and lowest Ca, Na and comparable $CaCo_3$ with comparison to other samples attributing to high Dielectric constant.

Sample 2 has lowest bulk density thus has high Dielectric constant

Figure4 reveal that the dielectric constant initially increases slowly with moisture content. After reaching a break point moisture value (transition moisture) increases steeply with moisture content. Transition moisture also depends on the soil texture.

A wet soil is a mixture of soil particles, air voids and water. The water contained in soil usually two types (1) bound water & (2) free water. Bound water refers to water molecules contained in the first molecular layer surrounding the soil particle are tightly held by the soil particles, due to influence of matric and osmotic forces. The matric forces acting on a molecule decreases rapidly with the distance away from soil particles are able to move freely within soil medium called free water. [11].

The sample 2 is sandy loam higher percentage (26%) of silt and water holding capacity about 6.5% has more free water, thus the dielectric constant increases rapidly after the transition moisture up to 38.81058 at 15% gravimetric moisture content.

The sample1 is loamy sand having 3% silt, 8% clay having water holding capacity of 14.5% also shows that dielectric constant increases very slightly till 5% moisture than after it increases with less slope than the sample 2.

The sample 3 is loamy sand having 9% silt but has 74.2 % water holding capacity thus it has physical texture to hold more bound water thus its dielectric constant does not very more as moisture increases as compare to other two samples. The more pore space available in soil, the more air and water the soil can retain. The surface area per unit volume of sand particle is relatively smaller than that for clay particles. Hence at given moisture content the clay particle can hold more bound water than sand particles. [2]

Thus we see that the dielectric constant of soils depends on many factors like frequency, moisture, and its physical and chemical compositions.

.

REFERENCES

[1] The soil of Rajasthan for optimising land use, National bureau of Soil Survy and Lan use planning(ICAR), NBSS Publications,51.

[2] Vidya D. Ahir, D.V. Ahire and P.R. Choudhari " Dielectric constant and emissivity of dry and wet black soils at C-band microwave frequency" Journal of Chemical, Biological and Physical Sciences Fb;, vol 1.2 no. 2 pp 937-946, 2012.

[3] S.K. Shrivastva and G.P.Mishra " Study of the Characteristics of the soil of Chhatishgarh at X-band frequency" Sadhana Vol., 29, part 4, pp 34-347, Aug; 2004.

[4] H.C. Chouhari, S. B. Deshmukh et al Proceedings of International conference microwave and optoelectronics, Aurangabad (Maharastra) pp 891-896, 2007.

[5] H.C. Chouhari and V.J. Shinde " Dielectric study of moisture laden soils at X- band microwave frequency" International journal of Physical sciences , Vol3(3), pp 075-078, March 2008

[6] Z.C. Alex, J. Behari, et al , " Asian conference on Remote sensing ", 5-9 November 2001, Singapore.

[7] OPN Calla, Dinesh Bohra et al, " Comparsion of emissivity and scattering coefficient of two samples of Aravali rocks and dry soils of Rajasthan at frequencies of x-band", Indian Journal of Radio & Space physics ,vol., 36,pp 65-71 Feb., 2007

[8] Vivek yadav, Anil Kumar et al " Measurement of dielectric behaviour of fertilized soil at microwave frequency", Journal of Agricultural scien, vol., no.2. Dec., 2009.

[9] P. Xu and K.S. Chen , " Analysis of microwave emission of exponentially correlated rough soil surfaces from 1.4GHz to 36.5GHz ", Progress in Electromagnetic Research , vol., 108, pp 205-219, 2010.

[10] J.R.Wang and T.J.Schmugge , IEEE Trans. Geosci. Remote sens., 18,pp 288-295, 1980.

[11] Josef Cihlar and Fawwaz T. Ulaby, "Dielectric properties of soils as a function of moisture content CRES Technical Report 177-47, November, 1974.

Bapna,P.C is Associate Professor at the Department of Electronics & Communication, College of Engineering and Technology, Udaipur. He did B.E. and MBA. He is pursuing Ph.D in Faculty of Engineering from SGV University, Jaipur,. His main research areas are microwave remote sensing, Wireless communication. He has 32 Yrs of experience in engineering field

Dr. Sunil Joshi is Professor & Head at the Department of Electronics & Communication, College of Engineering and Technology, Udaipur. He did B.E. and ME from MBM Jodhpur. He has awarded Ph.D in Faculty of Engineering from MNIT Jaipur,. His main research areas are millimeter waves, microwave remote sensing Wireless Broadband Channel Modeling, OFC, MIMO Systems .He has 21 Yrs of experience in engineering field