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MICROWAVE DIELECTRIC STUDY OF SOILS FROM JALNA REGION OF MAHARASHTRA STATE AT X-BAND FREQUENCY

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ABSTRACT:
Measurements of real (ε') and imaginary (ε'') parts of the complex dielectric constant (ε*) of dry and moist soils with varied moisture percentage were made at 9.44 GHz, at room temperature using waveguide cell method. Samples were collected from different locations. From the soil texture, physical parameters such as field capacity, wilting coefficient and transition point are determined. The value of dielectric constant (ε') and dielectric loss (ε'') first increases slowly upto transition point and then increase rapidly with moisture content. This data is used to estimate the a.c. electrical conductivity and relaxation time. The result shows the variation in dielectric properties of dry and moisture added soils. The measured values of complex permittivity of dry and wet soils are in good agreement with work reported earlier.

KEYWORDS: Microwave**,** Dielectric constant, Dielectric loss, a.c. electrical conductivity, Relaxation Time.

1. INTRODUCTION

Microwave remote sensing techniques are now a days widely adopted and used to estimate the presence of natural resources underneath the ground surface. The study of dielectric properties of earth constituents at microwave frequencies plays vital roll as they provides interpretation of various remote sensing data. Dielectric properties are primarily a function of frequency, water saturation, porosity, texture, geometry of componants and electrochemical interactions. Dielectric dispersion in low frequency region is helpful to understand the behaviors of induced polarization in the materials, while high frequency dielectric measurements are useful in planning ground penetrating radar survey. Many researchers working with this aspect, studied dielectric parameters of different materials with various methods. The dielectric properties of black and red soil collected from different locations of Karnataka state as a function of its moisture content are repored[1]. The dielectric properties of soils of different texture collected from different locations of Maharashtra state as a function of its moisture content are repored by Chaudhari and Shinde[2]. Roberts and Von Hipple method is used for measurement of dielectric properties of black soils with organic and inorganic matters[3]. Measurement of complex dielectric constant of soils of Gujrath at X- and C-band microwave frequencies by Gadani and Vyas[4]. Dawood et al[5]. have evaluated the dielectric constant by clay mineral and soil physico – chemical properties and showed that texture and mineral content of soil had different impact on dielectric constant. In a study, Sengwa and Soni[6] have reported the variation of dielectric constant with density of dry minerals of soil at 10.1 GHz . Ahire[7] et al. reported oorelation of electrical conductivity and dielectric constant with physico-chemical properties of black soils. The variation of dielectric constant of dry soils with their physical constituents and naturally available nutrients, micronutrients are repored by chaudhari et al[8]. They have used microwave C-band for this study. On this basis, the present study has been undertaken to have an idea of dielectric properties of different soil texture of the Jalna region of Maharastra State. In this paper, the experimentally determined values of the real and imaginary parts of the complex dielectric constant have been shown for soils under study at different moisture content. This data is used to estimate a.c. electrical conductivity and relaxation time.

2. MATERIALS AND METHODS

Soils are composition of solids (particals), liquids (water) and gases(air) mixed in variable proportions. Relative amounts of water and air present depend upon the way these soil particles are packed together. The soil texture depends upon the size of the particle and the structure of soil depends on the way the particles are being arranged. This influence the amount of pore space; its distribution in the soil. The texture is characterized by percentage of sand, silt and clay in particular soil. Depending upon the percentage of each of these constituents, the soil texture is differently recognized. Each soil has its own set of constituents depending upon its origin, location, nature etc. It is observed that the sandy soil lacks the water holding capacity while clay soil has very good water holding capacity.

The field capacity (FC) can be approximated by the empirical formula on soil composition.

FC= 25.1-0.21 (% sand)+0.22(% clay)

Wilting coefficient (Wp) and transition point (Wt) are calculated by using the Wang and Schmugge model[9].

Wp = 0.06774 – 0.00064 Sand (%) + 0.00478 Clay (%)

Wt = 0.49 Wp + 0.165

For measurements of dielectric properties, the infinite sample method described by Altshuler[10] is used. An X-band microwave bench operating at 9.44 GHz with slotted section and a crystal detector is used for measurement of complex dielectric constant. The complex dielectric constant is calculated using the relation,

$$\varepsilon^* = \varepsilon' - j\varepsilon''$$

$$\varepsilon^* = \frac{1}{1+\left[\frac{\lambda_c}{\lambda_g}\right]^2} + \frac{1}{1+\left[\frac{\lambda_g}{\lambda_c}\right]^2}\left[\frac{r - j\tan[k(D-D_R)]}{1 - jr\tan[k(D-D_R)]}\right]^2$$

(1)

Separating the real and imaginary part of dielectric constant form equation (1) the equation for dielectric constant ε’ is given by

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

(2)

and dielectric loss ε” is given by

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

(3)

where, $E = \tan[k(D-D_R)]$, λ_c, λ_g and k cut-off wavelength, guide wavelength and wave vector respectively, r is voltage standing wave ratio (VSWR) and D is the position of first minima with sample and D_R is the position of first minima without sample. The samples were filled and pressed manually in 40 cm long wave-guide, which was terminated with matched load. The measurements of D, D_R and λ_g were made using a slotted line. The VSWR was determined using double minimum power method. The soils for present study belongs to the Jalna region of Maharastra state. Soil samples were collected from both irrigated and non-irrigated areas. The locations are recorded using Garmin make GPS 60. The soils from this region are generally black colored and having different textures. Number of samples of different soil textures, physical and chemical properties are used for study. Out of these, two samples with different textures are reported.

The gravimetric soil moisture content in percentage W_c (%) using wet (W_1) and dry (W_2) soil masses can be obtained Srivastawa and Mishra[6]. Measurements have been carried out at 9.44 GHz fixed frequency. The experimental set-up consist of a 2K25 reflex klystron as the microwave source, with maximum output power of 25 mW and frequency range 8.2-12.4 GHz. The source was connected with a broadband isolator,to avoid the interference between source and reflected signals. To control the power at desired level, a variable attenuator is connected after the isolator,. Frequency meter was used to measure frequency of the signal. The slotted line was used to measure VSWR and distance. For accurate measurements of minima and VSWR, the probe carriage was mounted with a dial gauge having least count one micron. From the measurement of dielectric constant and dielectric loss, a.c.electrical conductivity and relaxation time can be obtained. The values of dielectric constant and dielectric loss are used to estimate the a.c electrical conductivity and relaxation time using the relation[11]

$$\sigma = \omega \varepsilon_0 \varepsilon''$$

and

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

where, ω is angular frequency, ($\omega = 2\pi f$; $f = 9.44$ GHz)

and ε_0 is permittivity of free space, ($\varepsilon_0 = 8.85 \times 10^{-12}$ F/m)

3. RESULTS AND DISCUSSION

The Texture, Physical and Chemical constituents of the samples under study are reported in table 1. The soil parameters field capacity (FC), Wilting coefficient (Wp) and transition point (Wt) calculated using the empirical model are tabulated in table 2. The variations in the values of dielectric constant and dielectric loss with percentage moisture content are measured and plotted in figures 1 and 2 for Clay and Sandy loam Sample respectively. The a.c. electrical conductivity and relaxation time with variation of percentage moisture content are plotted in figure 3 and 4. Here it is observed that, the relative permittivity of the soils increases slowly with moisture content initially, this may be due to *bi*-phase dielectric behavior of water molecule in soil that have smaller permittivity values as compared to free water molecules below transition point and after reaching a transition point they increase rapidly. It is worth to mention that, the relation between the dielectric constant and the moisture content is non-linear. The a.c. electrical conductivity (σ) and relaxation time (τ) shows a systematic change with increase in moisture content. According to Debye theory, when polar molecules are very large, then under the influence of electromagnetic field of very high frequency, the rotary motion of the polar molecules of a system is not sufficiently rapid to attain equilibrium with the field. Due to this, polarization acquires a component out of phase with the field and the displacement current acquires conductance dissipation energy. Thus, the dielectric loss is proportional to the a.c. electrical conductivity. The increase in relaxation time due to increase in moisture content is due to increasing hindrance to the process of polarization. The results are in good agreement with the work reported by earlier researchers.

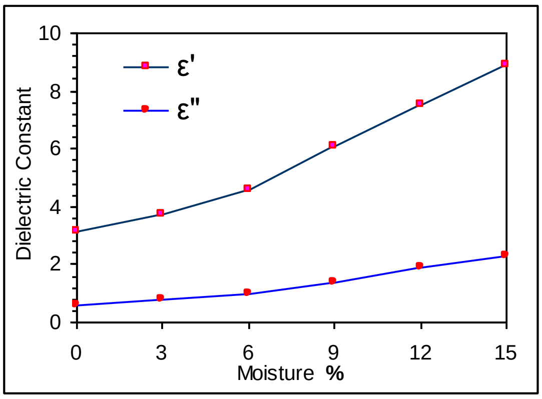

Fig.1-Variation of Dielectric constant and Dielectric loss with moisture content for Clay sample.

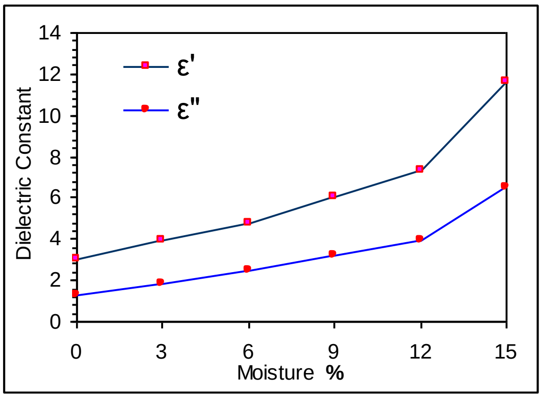

Fig.2-Variation of Dielectric constant and Dielectric loss with moisture content for Sandy loam sample.

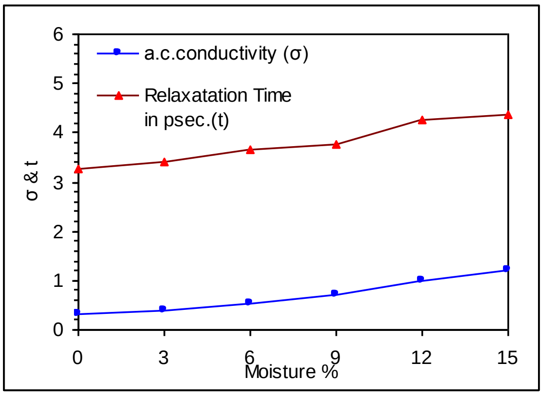

Fig.3-Variation of conductivity and Relaxation time with moisture percentage for Clay sample

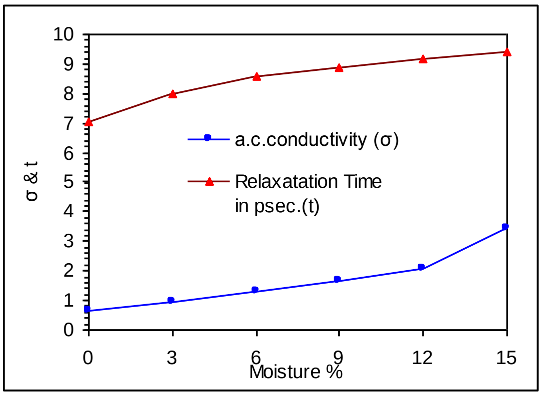

Fig.4-Variation of conductivity and Relaxation time with moisture percentage for Sandy loam sample

Table 1. The Texture, Physical and Chemical properties of soil.

Soil	Chemical Properties						
	pH	E.C. mS/cm	Organic Carbon	Ca %	Mg %	Na %	$CaCO_3$ %
I	8.41	0.40	0.91	29.13	19.72	0.63	6.60
II	6.33	0.40	0.27	25.12	18.50	0.67	4.95
III	7.69	0.57	0.87	37.58	27.98	1.25	2.64
IV	7.82	0.45	0.45	33.76	24.96	0.56	2.45
V	7.14	0.29	0.61	41.40	35.01	0.36	3.75
VI	8.53	0.34	0.89	27.19	19.74	0.85	9.18

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IV	7.82	0.45	0.45	33.76	24.96	0.56	2.45
V	7.14	0.29	0.61	41.40	35.01	0.36	3.75
VI	8.53	0.34	0.89	27.19	19.74	0.85	9.18

Table 2. The physical parameters of soil

Sample	FC	Wp	Wt
I	32.37	0.2602	0.2925
II	35.92	0.3296	0.3265
III	21.18	0.1484	0.2377
IV	30.35	0.2656	0.2951
V	38.03	0.3584	0.3406
VI	16.79	0.1046	0.2162

4. CONCLUSIONS

The bound water exist in soil-water mixtures noticeably affects the dielectric properties of mixture. The relationship between dielectric property and gravimetric water content is non-linear. The a. c. electrical conductivity and relaxation time depends upon the dielectric loss, which represents attenuation and dispersion. The laboratory study of dielectric property of soils with varied moisture as well as other physical and chemical properties with actual field conditions are very important in correlating the data recorded by remote sensing technique.

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