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"Dielectric and Emissivity Behavior of soil of Rehand River of Surajpur Chhattisgarh at X-Band Microwave Frequency"

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Abstract: Microwaves are a form of electromagnetic radiation consisting of electric and magnetic fields oriented at right angles to one another. They operate within a frequency range of approximately 0.3 GHz to 300 GHz, corresponding to wavelengths from 1 meter to 1 millimeter. This paper explores a theoretical model for estimating the emissivity and dielectric constant of soil samples as they relate to moisture content. The emissivity of these soil samples was measured at X-Band frequencies for both vertical and horizontal polarizations. The results indicate that emissivity is higher for vertical polarization than for horizontal polarization. Additionally, the dielectric constant shows a gradual increase with rising moisture content.
Keywords: Physical properties of soil, Dielectric Constant, emissivity.

I. INTRODUCTION

This review covers soil dielectric constant measurements, examining how the dielectric constant depends on various soil parameters, with moisture content identified as the most critical factor affecting dielectric properties. D.H. Gadhani et al. measured the dielectric constant and dielectric loss of soil samples from several districts in Gujarat at different moisture levels using X and C-band microwave frequencies. Their findings showed that the dielectric constant of soil is influenced by both its moisture content and the frequency at which measurements are taken. Ghosh et al. observed that the dielectric constant of soil increases gradually with moisture content up to a certain transition point, after which it rises rapidly with further moisture. Calla O.P.N. et al. studied the emissivity of dry and wet loamy sand soils at microwave frequencies, noting the importance of emissivity data for soil moisture assessment in agriculture, hydrology, and meteorology.

In this study, the complex dielectric constant and emissivity of soil samples collected from various locations along the Rehand River in Surajpur (C.G.) were calculated as a function of moisture content. S.K. Shrivastava et al. also investigated soil dielectric constant measurements at microwave frequencies. Hafid Taha et al. examined the complex dielectric constant of sand and dust particles at 11 GHz in relation to moisture content.

II. MATERIALS AND MEASUREMENT

Soil samples were collected from the Rehand River in the Surajpur district, located in the northern part of Chhattisgarh, India. The samples were taken from the topsoil layer at depths of 0-10 cm. To prepare the samples, they were sieved using a gyrator sieve shaker to remove larger particles. The sieved samples were then dried in a microwave oven at around 110°C for 30 minutes to ensure complete removal of moisture, creating what are known as oven-dry or dry-base samples.

To adjust the moisture content, precise amounts of distilled water were added to the dry samples. These soil-water mixtures were thoroughly blended and stored in a closed container to allow for uniform settling. Finally, the prepared soil samples were placed into a solid dielectric cell to measure their dielectric properties using a microwave test bench.

A. Physical Properties of Soil Sample

The physical properties of soil samples are described as shown in table 1. Table 1 represents the physical properties of the soil samples Rehand River of surajpur of Chhattisgarh (India). The wilting point (Wp) and transition moisture(Wt)of soil in terms of volumetric water content (cm^3/cm^2)are calculated by using the Wang and Schmugge model

Wp= .06774-.00064*Sand%+.00478*clay%.................. (1)

Wt=.49*wp+.165………………………………………………………. (2)

ϒ=-0.57*wp+0.481……………………………………………………(3)

Table 1 : Physical properties of soil sample

SN	sand	silt	clay	Wp	Wt	ϒ	Density
S1	41	38	16	0.118	0.2228	0.4138	1.8
S2	43	39	15	0.1119	0.2198	0.4172	1.79
S3	45	40	14	0.1059	0.2169	0.4207	1.7
S4	47	41	13	0.0998	0.2139	0.4241	2.03
S5	48	42	12	0.0944	0.2112	0.4272	2.00

B. *Evaluation of Complex Dielectric Constant*

Dielectric constant of soils are measured using infinite sample method described in equation (1). Horizontal polarization and Vertical polarization are calculated from equation (2) and (3) . Hence Emissivity of soil sample can be calculated from its dielectric constant with moisture content.

The complex Dielectric constants of dry soils and different percentage of moisture content are calculated from S.M. Sharief (6) arrived at the following empirical relation for the variation of complex permittivity with relation humidity .

$\varepsilon' = 6.3485+.04\,H\% - 7.78*10^{-4}\,H^2\% + 5.56*10^{-6}\,H^3\%$...............(4)

$\varepsilon'' = .0929+.02H\% - 3.71*10^{-4}H^2\% + 2.76*10^{-6}H^3\%$.....................(5)

Where H is the moisture content (%)

$\varepsilon = \varepsilon' - j\varepsilon''$……………………………………………………..(6)

Table 2 : Dielectric constant of soil sample

SN	Dielectric constant
S1	3.2840+j0.0644
S2	3.2779+j0.0558
S3	3.1738+ j0.04853
S4	3.3014+j0.08143
S5	3.3113+j0.08444

C. *Evaluation Of Emissivity*

The emissivity $e_p(\theta)$ can be calculated by

$e_p(\theta)=(1-r_p(\theta))$……………………………………………………………(6)

$r_p(\theta)$ can be obtained from the Fresnel Reflection coefficient $R_p(\theta)$ as

$r_p(\theta)=|R_p(\theta)|^2$……………………………………………………..(7)

For horizontal polarization

$R_p(\theta)=\frac{\cos\theta-\sqrt{(\varepsilon'-\sin^2\theta)}}{\cos\theta+\sqrt{(\varepsilon-\sin^2\theta)}}$………………………………………………*(8)*

For vertical polarization

$R_v(\theta)=\frac{\varepsilon'\cos\theta-\sqrt{(\varepsilon'-\sin^2\theta)}}{\varepsilon'\cos\theta+\sqrt{(\varepsilon'-\sin^2\theta)}}$…………………………………………(9)

Where θ is the angle of observation from nadir, $\varepsilon'$is dielectric constant of the soil and $e_p(\theta)$ is emissivity of the surface layer and $r_p(\theta)$ is reflection coefficient.

III. RESULT AND DISCUSSION

The results obtained are shown in table 1. It is found that w_p varies from 0.0943 to 0.117.It indicates that sample posses low wilting point and vice versa. Transition moisture w_t values varies from 0.211 to 0.222 and γ values varies from 0.413 to 0.427 , it is observed that transition moisture are higher for soil with low clay content as compared to sandy soil sample. The dielectric constant with moisture content are measured by S.M.Sharief () empirical relation.

It is found that dielectric constant (real and imaginary) increases slowly with moisture content. Emissivity is calculated using equation (6) and equation (7),(8) for Horizontal Polarization and Vertical Polarization at 30^0 for different moisture content. Results are shown in Table 2 and Table 3.It is found that emissivity of dry soil is around unity. Its value decreases with increasing moisture content. Emissivity value of vertical polarization is greater than that of horizontal polarization. Emissivity with vertical polarization varies from 0.9456 to 0.9247. Emissivity with horizontal polarization varies from 0.8929 to 0.8422.

Table 3 : Dielectric constant with moisture content

Moisture(%)	S1	S2	S3	S4	S5
0	3.2840+j0.0644	3.2774+j0.0558	3.1738+j0.0485	3.3014+j0.0814	3.3113+j0.0844
4	3.4319+j0.1386	3.3137+j0.1300	3.2096+j0.1227	3.4493+j0.1556	3.4592+j0.1587
8	3.5570+j0.2020	3.5509+j0.1934	3.4468+j0.1861	3.5744+j0.2190	3.5843+j0.2221
12	3.6615+j0.2557	3.6554+j0.2471	3.5514+j0.2398	3.6789+j0.2727	3.6888+j0.2758
16	3.7476+j0.2936	3.7187+j0.2921	3.8166+j0.2848	3.7650+j0.3177	3.7749+j0.3208
20	3.8172+j0.3380	3.8111+j0.3294	3.9871+j0.3222	3.8346+j0.3551	3.8445+j0.3581

Table 4 : Emissivity with horizontal polarization:

SN	0%	4%	8%	12%	16%	20%
S1	0.8872	0.88	0.8741	0.8692	0.8532	0.8422
S2	0.8875	0.8857	0.8743	0.8695	0.8666	0.8624
S3	0.8927	0.8909	0.8793	0.8744	0.8622	0.8546
S4	0.8863	0.8792	0.8733	0.8685	0.8645	0.8614
S5	0.8858	0.8787	0.8728	0.868	0.864	0.8609

Table 5 : Emissivity with vertical polarization:

SN	0	4%	8%	12%	16%	20%
S1	0.9422	0.9375	0.9336	0.9303	0.9284	0.9255
S2	0.9424	0.9413	0.9338	0.9306	0.9286	0.9257
S3	0.9456	0.9447	0.937	0.9338	0.9255	0.9203
S4	0.9417	0.937	0.9331	0.9298	0.927	0.9250
S5	0.9413	0.9367	0.9328	0.9295	0.9268	0.9247

IV. CONCLUSION

The result shows complex dielectric constant increases with increase in moisture content. At low moisture content, there are more bound water molecules. Hence the dielectric constant of soil at lower moisture content is low and for increasing moisture content dielectric constant of soil are also increases. It is found that emissivity decreases with increasing moisture content. Emissivity value of vertical polarization is greater than Horizontal polarization.

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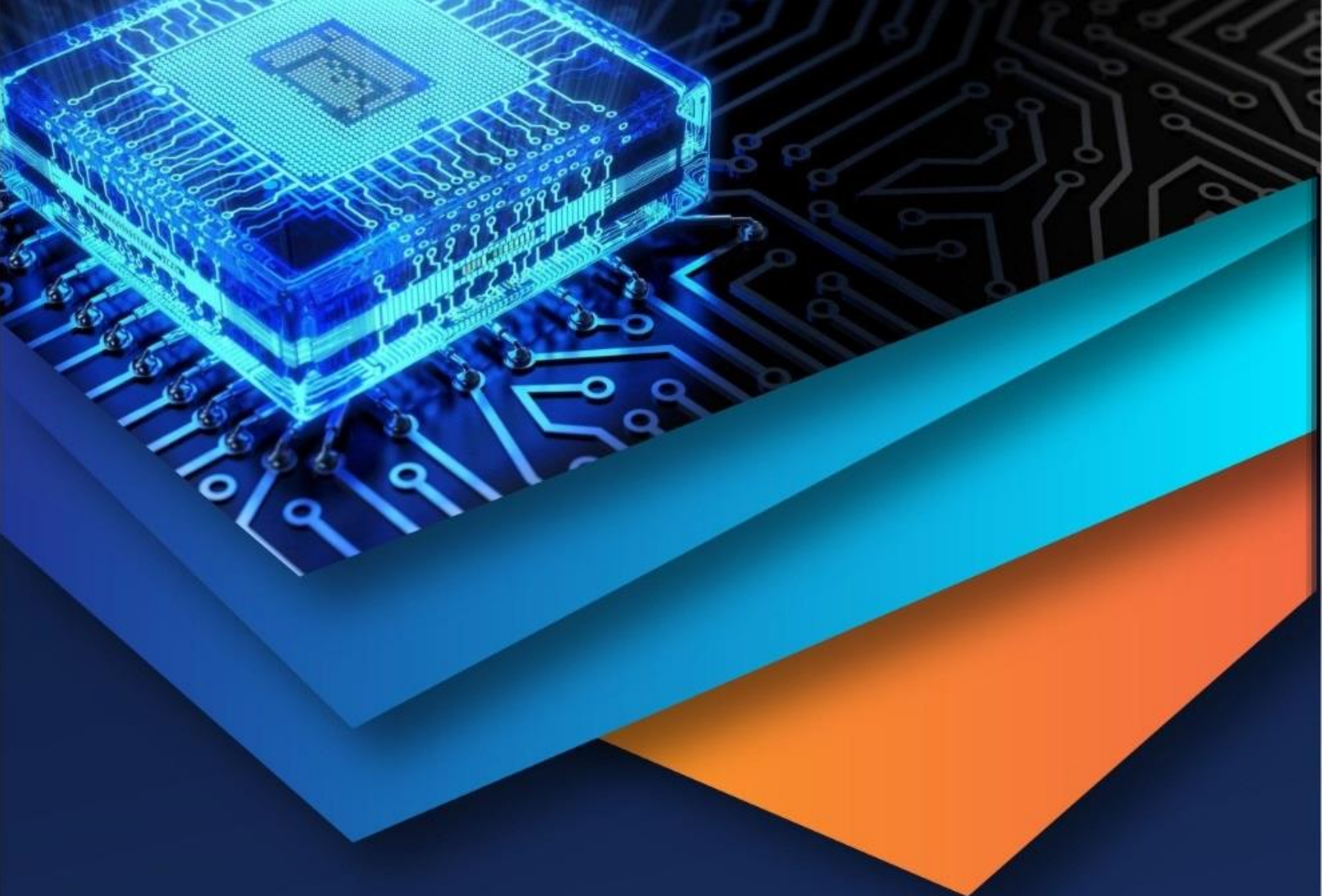

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