ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Dependence of Emissivity on Physical Properties of Roorkee Soils

P. R. Chaudhari*[1], D. V. Ahire[2]

Microwave Research Laboratory, Z. B. Patil College, Dhule, India

ABSTRACT: The dielectric constant of six dry soil samples from the Roorkee (State- Uttarakhand, India) have been measured at microwave frequency in the C-band (f= **5.3** GHz, λ=2.8 cm) region using waveguide cell method. The Emissivity of dry soil samples for normal incidence has been calculated from measured values of dielectric constant. The soil samples were analyzed for physical properties viz texture, bulk density, wilting point. The dependence of emissivity of soils on their physical constituents was presented. The results were analyzed statistically, which showed no linear significant correlation between emissivity of soils and physical constituents. While strong significant fourth order polynomial correlations were observed between them.

KEYWORDS: Physical properties, Dielectric Constant, Emissivity

I. INTRODUCTION

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. Conventional tillage practice and the use of heavy machinery and vehicular traffic on farmlands are important reasons for increasing bulk density of agricultural soil. The increasing bulk density of soil affects the dielectric properties of dry and moist soil. Different studies 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. Microwave emissivity of soils is dependent both on the water content and the physical characteristics of the soil. Since for many research applications in agriculture, hydrology, and meteorology, the amount of moisture in the soil is of primary interest, the significance of soil properties must be quantified if useful soil moisture information is to be extracted from measurements of microwave emissivity. The physical properties of the soil like texture and structure influence the amount of pore space and the distribution of pore space within soil matrix. Thus, pore space and bulk density significantly affect the dielectric constant and hence emissivity of the dry soil. Knowledge of dielectric constant and emissivity of soils is essential in the interpretation of microwave airborne radiometer data of the Earth's surface.

II. LITERATURE REVIEW

Several recent investigations have studied the importance of different soil properties. Emissivity is an important parameter, which provides information about soil. All natural objects including soil are capable of emission, absorption and transmission of electromagnetic energy at all temperature. The emitted radiation from soil depends upon its dielectric permittivity, surface roughness, chemical composition, physical temperature, frequency of polarization, and angle of observation Alex and Behari [1], Kraszewski [2]. Dielectric permittivity and hence emissivity is found to be strongly dependent upon moisture content and soil texture and has been widely studied Vyas [3], Jackson [4], and Vyas [5]. Dobson et al. [6] and Wang and Sehmugge [7] considered the effects of soil texture and bulk density. Their efforts resulted in models for these effects that could be applied using soil survey information. Jackson and O'Neill [8] evaluated the impact of soil tillage on soil structure. They found that knowledge of soil structure conditions was very important to an accurate determination of soil. At a given microwave frequency, the emissivity of the soil was observed to decrease with increase in moisture level, but it increases with increase in vegetation biomass in the soil.

III. MATERIAL & METHODS

a. Study Area: The study was conducted in Haridwar region of the state of Uttarakhand, India. Haridwar district is located in south – western part of Uttarakhand State. It lies from 290 35' to 300 40' North latitude and 770 43 ' to 780 22' East longitude. The geographical area of the district is 2360 km2.Haridwar district has been divided into three Tehsils viz. Roorkee, Bhagwanpur and Laksar and six Development Blocks namely Roorkee, Bhagwanpur, Laksar, Khanpur, Bahdarabad and Narsan. The topography of Haridwar is characterized by sandy soils which do not retain

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

water for long time. Due to unavailability of moisture in the soil the crop productivity is not very good in the region. Also, due to variation in altitude the rainfall also differs from place to place affecting the crop production.

b. Soil Sampling: The aim of this study was to obtain the relationship between emissivity of soil samples from Roorkee with their physical properties. Before sampling 15 mm topsoil was removed. Soil samples were collected from five different locations at the depth of 15cm. in zigzag pattern across the required areas in the development block. Five pits were dug for each sample. A composite sample of about 2 Kg. was taken through mixing of represented soil sample. These soils were first sieved by gyrator sieve shaker with approximately 2 mm spacing to remove the coarser particles and then allowed to dry in air for 1 hour.

c. Soil Physical and Chemical Properties: The samples were analyzed for physical parameters. The physical parameters of soil samples are represented in **Table 1**.
The Wilting Point (WP) and Transition Moisture (Wt) of the soils are calculated by using the Wang and Schmugge model as follows:

$$WP = 0.06774 - 0.00064 \text{ X Sand (\%)} + 0.00478 \text{ X Clay (\%)} \qquad (1)$$

$$Wt = 0.49 \text{ X } WP + 0.165 \qquad (2)$$

Bulk density is a measurement of the volume of soil composed of solid particles versus air space. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil.

Table 1: Physical Parameter Analysis of Roorkee (Uttarakhand) Soil Samples

Sample No.	Emissi-vity	DC	Sand	Silt	Clay	Porosity	CaCO3	BD (Mg m^{-3})	WP	EC (dSm^{-1})	pH
			%								
1	0.7498	2.78	60	22	18	50.184	1.5	1.35	0.1154	0.16	8.34
2	0.7171	3.2	68	18	14	48.828	1.25	1.31	0.0911	0.26	6.88
3	0.7360	2.95	61	22	17	44.656	1.25	1.45	0.1099	0.12	8.27
4	0.7171	3.2	62	22	16	53.818	1.25	1.27	0.1045	0.12	8.11
5	0.7846	2.4	58	24	18	55.212	2	1.16	0.1167	0.13	8.05
6	0.7481	2.8	67	20	13	49.624	1.25	1.34	0.0870	0.1	6.88

D. Measurement of Dielectric Constant of dry Soil Samples: The waveguide cell method is used to determine the dielectric properties of the dry soil samples. An automated C-band microwave set-up in the TE10 mode with Gunn source operating at frequency 4.5 GHz, PC-based slotted line control and data acquisition system is used for this purpose. The solid dielectric cell with soil sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the soil sample. The sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. Experiments were performed at room temperatures ranged between 25^0 - 35^0 C. Block diagram of microwave bench setup for measurement of dielectric constant of Soils **Fig.1.** The dielectric constant ε of the soils is then determined from the following relation:

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

Where, a = Inner width of rectangular waveguide. λ_{gs} = wavelength in the

DOI: 10.15680/IJIRSET.2014.0312064

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

air-filled guide. $\mathbf{g}_\epsilon$ = real part of the admittance

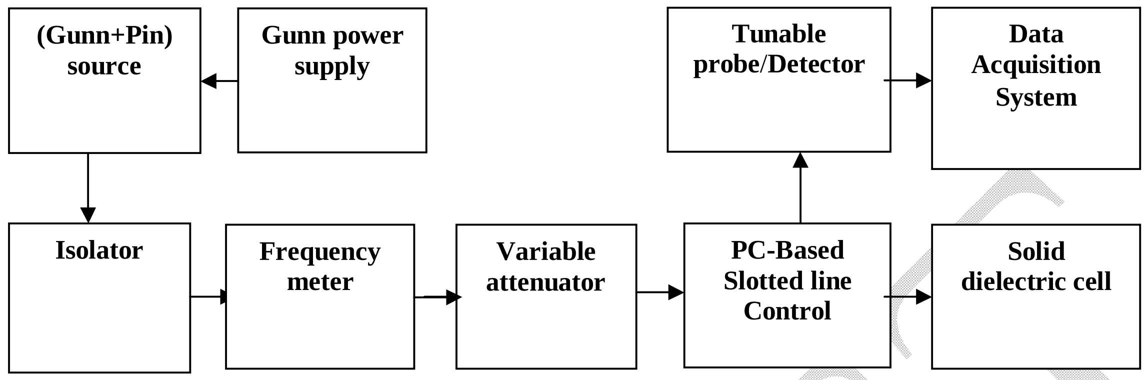

Figure 1: Block diagram of microwave bench setup for measurement of dielectric constant of Soils

e. Determination of Emissivity : The emissivity (e) of the soil can be calculated from the measured values of the permittivity of the soil [12]. For normal incidence (θ = 0) we get the emissivity as -

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

f. Correlation Coefficient: **Statistical analysis:** The relationships of bulk density and dielectric constant with physical parameters of soils were determined using correlation coefficient "r". Correlation coefficients (r) of emissivity of soil samples with physical parameters of soils along with respective regression equations are listed in **Table 2.** This table also gives an idea about the level of significance between various parameters.

Table 2: Correlation coefficients between Emissivity and Physical Parameters of Soil

Sr. No.	Parameters (y) With Emissivity (E)	Prediction Equations	Correlation Coefficient (r)	Level of Significance
1	Sand	$y = 3E+08x^4 - 9E+08x^3 + 1E+09x^2 - 5E+08x + 9E+07$	0.879	Strong Significant
2	Silt	$y = -9E+07x^4 + 3E+08x^3 - 3E+08x^2 + 1E+08x - 3E+07$	0.791	Strong Significant
3	Clay	$y = -2E+08x^4 + 6E+08x^3 - 7E+08x^2 + 4E+08x - 7E+07$	0.953	High degree significant
4	Bulk Density	$y = -1E+06x^4 + 4E+06x^3 - 4E+06x^2 + 2E+06x – 37$	0.991	High degree significant
5	Porosity	$y = 1E+07x^4 - 4E+07x^3 + 5E+07x^2 - 2E+07x + 5E+06$	0.908	High degree significant
6	Wilting Point	$y = -1E+06x^4 + 4E+06x^3 - 4E+06x^2 + 2E+06x – 37$	0.940	High degree significant
7	Dielectric Constant	$y = -11.94x + 11.75$	- 0.998	High degree negative significant
8	Electrical Conductivity	$y = -2E+06x^4 + 7E+06x^3 - 8E+06x^2 + 4E+06x – 71$	0.647	Significant
9	pH	$y = -6E+07x^4 + 2E+08x^3 - 2E+08x^2 + 1E+08x - 2E+07$	0.823	Strong Significant

DOI: 10.15680/IJIRSET.2014.0312064

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

IV. RESULT AND DISCUSSION

The sand, silt and clay of collected samples ranges from 58- 67, 18 - 24 and 13 - 18 % respectively and these soils were categorized as sandy loam. All samples were slightly calcareous (1.25 - 2 %) in nature. The pH (6.88 - 8.34) values indicated that four soil samples were moderately alkaline and two were neutral. While the electrical conductivity (0.1 - 0.26 ds/m) values showed that all soil samples were non saline in nature.

The emissivity of soil samples were obtained from the measured values of dielectric constant. These values were then correlated with different physical parameters of soil. High degree negative significant but linear correlation (r = - 0.998) between dielectric constant and emissivity of soil samples was observed. Strong significant correlation of Emissivity of soil samples with sand (r = 0.879), silt (r = 0. 791) and pH (r = 0.823) was found. While high degree significant correlation of emissivity with clay (r = 0.953), bulk density (r = 0.991), porosity (r = 0.908) and wilting point (r = 0.940) was observed.

V. CONCLUSION

1. No linear correlation was observed between emissivity and physical parameters of soil.
2. High degree significant fourth order polynomial correlation of emissivity of soil was observed with clay content of soil while strong significant fourth order polynomial correlation was observed with sand and silt content of soil i.e. emissivity of soil sample was dependent on texture of soil.
3. Emissivity was also found to be dependent pore space and hence on water holding capacity of soil.

Laboratory studies on emissivity of soils varied with physical properties of soils are very important in correlating remotely sensed data with actual field conditions and in distinguishing targets having identical dielectric properties.

REFERENCES

[1] Alex Z C and Behari J, "Laboratory evaluation of emissivity of soils", Int J Remote sens (UK), 19(7), pp.1335-1340,1998.

[2] Kraszewski A W, "Microwave aquametry - electromagnetic interaction with water containing materials", (IEEE Press, Piscataway, NJ), ol. 47 2005, 1991.

[3] Vyas A D, "Complex permittivity of sand and sandy loam soils at microwave frequency", India J Radio Space Phys, 11, 168 1982.

[4] Jackson T J, "Laboratory evaluation of a field-portable dielectric /soil-moisture probe", IEEE Trans Geosci Remote Sens (USA), 28(2), pp. 241-245 ,1990.

[5] Alex Z C & Behari J, "Complex permittivity of soils as a function of frequency, moisture and texture", Indian J Pure Appl Phys, 34, pp. 319 - 325 , 1996.

[6] Dobson, M. C., Ulaby, F. T., tlallikainen, M. T., and El-ttayes, M. A., "Microwave dielectric behavior of wet soil--Part lI: Dielectric mixing models", *IEEE Trans. Geosci. Remote Sens.* GE-23:pp. 35-46, 1985.

[7] Jackson, T. J., and O'Neill, P. E., "Microwave dielectric model for aggregated soils", IEEE Trans. C, eosci. Remote Sens'. GE-24:pp. 920-929, 1986.

[8] Wang, J. R., and T. J. Schmugge, "An empirical model for the complex dielectric permittivity of soil as a function of water content", *IEEE Trans. Geosci. Remote Sens.*, Vol. 18, No. 4, pp 288-295, 1980.