

Effect of Vegetation Biomass on Emissivity of Loam Soil



Physics

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ABSTRACT

Real and Imaginary parts of the complex Dielectric Permittivity (ϵ' and ϵ'') of Loam soil have been measured in the frequency range 150 MHz – 2.4 GHz using a Vector Network Analyzer at varied moisture contents and vegetation biomass. The Emissivity of the soil for normal incidence is calculated from measured values of complex permittivity. The measured permittivity data shows strong dependence on moisture content as expected. 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.

1. Introduction

The real and imaginary parts of the complex dielectric permittivity of the materials found on earth surface affect the efficiency of the electromagnetic systems especially in the fields of communication, Radar, Remote Sensing and Geophysical Probing [1]. The major path of propagation of electromagnetic waves is affected by dispersion through various naturally occurring specimens on earth surface [2-3]. The dielectric permittivity is the most important parameter in microwave remote sensing studies of dry and wet soils. In active microwave remote sensing one measures the backscatter coefficient of the soil and in passive microwave remote sensing the emissivity of the soil is sensed. 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 [4,5]. Dielectric permittivity and hence emissivity is found to be strongly dependent upon moisture content and soil texture and has been widely studied [6-8]. However studies on the effect of Salinity, Vegetation biomass and Organic matter content on permittivity of geological materials are rare. In this paper the laboratory measured values of ϵ' and ϵ'' and emissivity (e) have been presented for loam soil as a function of moisture, vegetation biomass and frequency in the range 150 MHz to 2.4 GHz. The measurements were made at room temperature using Agilent made Vector Network Analyzer (Model – 8714 ES) by the method suggested by Wei & Sridhar [9, 10].

2. Sample preparation

The soil used in this study was collected from a field of Roop-Pura Village, Bhilwara (Rajasthan). The stones and gravels were removed from the soil and then it was passed through sieve no. 20 with 0.5 mm opening and then oven dried. The texture structure of the soil has been given in Table 1.

Table 1 – Characteristics of soil used for dielectric permittivity measurements

Soil type	Loam
Sand (%)	36.68
Silt (%)	26.39
Clay (%)	36.93
Dry bulk density (pb)	1.34
Wilting point (WP), (cm ³ /cm ³)	0.22079
Transition moisture (Wt), (cm ³ /cm ³)	0.27319

The Wilting point (WP) and Transition moisture (Wt) have been calculated using Wang and Schumge model [11] as

$$WP = 0.06774 - 0.00064 \times \text{Sand} + 0.00478 \times \text{Clay} \dots (1)$$

$$Wt = 0.49 \times WP + 0.165 \dots (2)$$

Where Sand and Clay stand for the sand and clay content in percent by dry weight of the soil. Different proportions of vegetation biomass by weight were added to dry soil separately and then it was moistened till saturation. The gravimetric moisture content in the soil sample was calculated using the formula:

$$Wg = (\text{weight of wet soil} - \text{weight of dry soil}) / \text{weight of dry soil} \dots (3)$$

Hence, the volumetric moisture content was determined as

$$WV = Wg \times pb \dots (4)$$

Where, pb is the dry bulk density of the soil.

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

$$\dots (5) e = 1 - \left[\frac{(1 - \epsilon^{1/2})}{(1 + \epsilon^{1/2})} \right]^2$$

3. Results and Discussion

(a) Dependence of ϵ' and ϵ'' upon vegetation biomass at constant moisture

The measured values of ϵ' and ϵ'' for the soil mixed with vegetation biomass have been shown in fig.1. It appears that both ϵ' and ϵ'' show decreasing trend with increasing vegetation biomass. This may be attributed to increased porosity of the samples due to vegetation biomass which results in reduction of free water molecules and enhance the water holding capacity which decreases both ϵ' and ϵ'' .

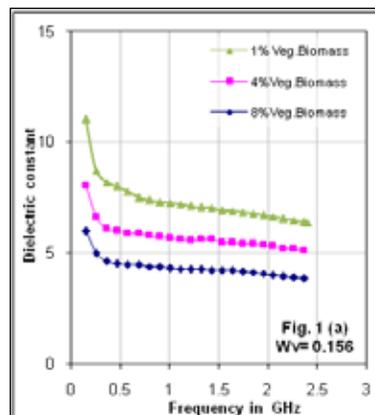
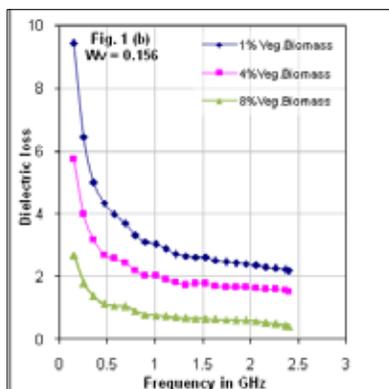


Fig.1- ϵ' and ϵ'' versus Frequency at different vegetation biomass percent



(b) Emissivity of soil for different biomass and moisture

The values of the emissivity calculated from permittivity data at different moisture levels and vegetation biomass are shown in fig.2. The emissivity of soils is found to decrease with increase in moisture content. This may be due to the increase in power reflection coefficient and permittivity. Emissivity appears to follow increasing trend with increasing vegetation biomass as expected, because the permittivity decreases in this case.

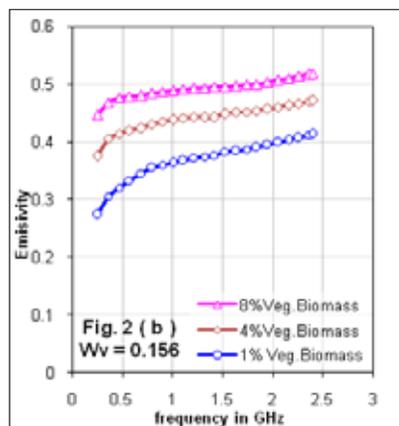
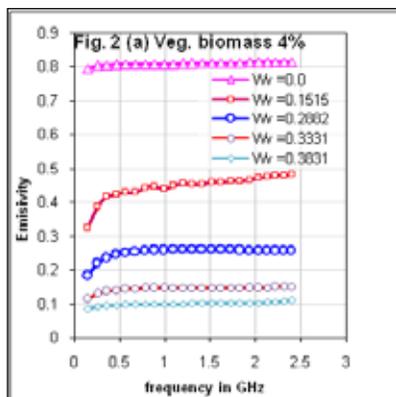


Fig. 2 - Emissivity versus frequency for varied moisture and vegetation biomass

4. Conclusions

The conclusions resulted from this study are as follows:

- (i) The dielectric permittivity (ϵ' and ϵ'') of soils is strongly dependent on soil moisture content.
- (ii) Both ϵ' and ϵ'' show decreasing trend with increasing vegetation biomass in the sample.
- (iii) The emissivity of soils is found to decrease with soil moisture content, but it shows reverse trend with vegetation biomass.

These experimental data of soils are very important in correlating the remotely sensed data with actual field conditions and in distinguishing targets having identical dielectric properties and are in reasonable good agreement with available reports in literature on similar soils [13-16].

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REFERENCE

- [1] Hallikainen M T, Ulaby F T, Dobson M C, El-Rays M A, and Lin-Kun Wu, Microwave dielectric behavior of wet soil Part -I: Empirical models and experimental observations, IEEE Trans Geosci Remote Sens (USA), 13(1), 25 (1985). [2] Sucher M & Fox J, Handbook of microwave measurements (Polytechnic Press, Brooklyn, New York), 504, (1963). [3] Hoekstra P & Delaney A, Dielectric properties of the soils at UHF and microwave frequency, J Geophys Res (USA), 79(11) 1699 (1974). [4] Alex Z C Behari J, Laboratory evaluation of emissivity of soils, Int J Remote sens (UK), 19(7), 1335 (1998). [5] Kraszewski A W, Microwave aquametry - electromagnetic interaction with water containing materials, (IEEE Press, Piscataway, NJ), 1991. [6] Vyas A D, Complex permittivity of sand and sandy loam soils at microwave frequency, India J Radio Space Phys, 11, 168 (1982). [7] Jackson T J, Laboratory evaluation of a field-portable dielectric /soil-moisture prob IEEE Trans Geosci Remote Sens (USA), 28(2), 241 (1990). [8] Alex Z C & Behari J, Complex permittivity of soils as a function of frequency, moisture and texture, Indian J Pure Appl Phys, 34, 319 (1996). [9] Yan-Zhen Wei and Sridhar S, Technique for measuring the frequency dependent complex dielectric constants of liquids up to 20 GHz, Rev Sci Instrum (USA) 60(9), 3041(1989). [10] Yan-Zhen Wei and Sridhar S, Radiation corrected open ended coax line technique for dielectric measurements of liquids up to 20 GHz, IEEE Trans Microw Theory Tech (USA), 39(3), 6301(1991). [11] Wang J R and Schmugge T J, an empirical model for the complex dielectric permittivity of soil as a function of water content, IEEE trans Geosci Remote Sens(USA),18(4), 288 (1980). [12] Jackson T J & O'Neill P E, Salinity effects on the microwave emission of soils, IEEE Trans Geosci Remote Sens (USA), 25(2), 214 (1987). [13] Panchoi K C and Khameshra S M, Complex dielectric permittivity of some Rajasthan soils at 7.114 GHz, Indian J Radio Space Phys, 23, 201 (1994). [14] Gadhani D H and Vyas A D, Measurement of complex dielectric constant of soils of Gujarat at X and C band microwave frequencies, Indian J Radio Space Phys, 37, 221(2008). [15] Calla O P N, Borah M C, Vashishtha P, Mishra R, Bhattacharya A and Purohit S P, Study of the properties of dry and wet loamy sand soil at microwave frequencies, Indian J Radio Space Phys, 28, 109 (1999). [16] Khele Navar V V, Shaikh A A and Ramshetti RS Indian J. of Radio and Space Phys., 38, 112- 115, (April 2009).