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COMPLEX DIELECTRIC PERMITTIVITY OF SALT AFFECTED SOIL AT LOWER MICROWAVE FREQUENCIES

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ABSTRACT

The Real and Imaginary parts (ε' & ε") of the Complex Dielectric Permittivity (ε*) of Loamy sand soil with varied salinity levels have been determined experimentally using a Vector Network Analyzer in the frequency range 150 MHz to 2.2 GHz. It has been observed that the effect of salinity in the soil is more pronounced in the dielectric loss as compared to dielectric constant. The Power reflection coefficient(R) and Emissivity(e) of Microwaves for the soil were also calculated from the measured value of complex dielectric permittivity. These parameters show expected variation with soil salinity and microwave frequencies used and have great importance in remote sensing of soil moisture using microwave signals.

KEYWORDS: Complex Dielectric Permittivity, emissivity, soil moisture, salinity

When microwaves are incident on the surface of the earth, part of the energy is reflected, part is transmitted through the surface and rest is absorbed. The distribution of the incident energy in these proportions is defined in terms of dielectric properties. The complex dielectric permittivity is the fundamental electrical property which describes these interactions, which is mathematically expressed as

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

Where :

ε' = Dielectric Constant

ε'' = Dielectric loss factor

The dielectric constant and dielectric loss of a soil depends on the moisture, frequency, texture, temperature and salinity of the soil. The measurement of soil moisture is a key challenge to understand various environmental processes.

The measurement of soil moisture by means of microwave remote sensing system has been widely studied by numerous researchers (Gadani and Vyas, 2008; Chaudhari and Shinde, 2010 and Pancholi and S.M. Khameshra, 1994).In comparison, the effect of salinity on the dielectric properties of the soil is less studied. Since the dielectric constant of a soil depends on the moisture, the presence of salts in water will also affect its dielectric properties. In irrigation, soil salinity makes it more difficult for plants to absorb soil moisture which affects the plant growth and ultimately crop yield. To keep track of changes in salinity and anticipate further degradation, monitoring is needed (Abdelfattah et al.,2009). The present study has been undertaken to have an idea of electrical properties of soil of Rajasthan state. In this paper, the experimentally measured values of the dielectric constant and dielectric loss have been shown for soil with varied salinity levels. From this, the Reflection coefficient(R) and Emissivity(e) is determined.

SAMPLE PREPARATION

The soil sample used in this study was collected from the field of Harni farm, Bhilwara (Rajasthan). Stones and gravels were removed from the soil, and then it was oven dried. The texture structure of the soil has been given in table 1. The Wilting Point (WP) and Transition moisture (Wt) have been calculated using the Wang and Schmugge model (Wang and Schumugge, 1980) as

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

$$\mathrm{Wt} = 0.49 \times \mathrm{WP} + 0.165 \qquad \text{...............(2)}$$

Where, Sand and Clay stand for the sand and clay contents in percent by dry weight of the soil.

Wet soil samples were prepared with distilled water and the saline water solutions of 10000, 20000, 40000 and 60000 ppm were prepared by adding table salt in the distilled water. The gravimetric soil moisture content in percentage Wg (%) is calculated using wet (W_1) and dry (W_2) soil masses using the relation

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$$Wg(\%) = \frac{W_1 - W_2}{W_2} \times 100 \quad (3)$$

Hence, the volumetric moisture content was determined as

$$Wv = Wg \times \rho_b \quad (4)$$

Where, ρ_b is the dry bulk density of the soil

Table 1: Texture structure of soil used for permittivity measurement

Soil Type	Loamy sand
Sand (%)	78.625
Silt (%)	18.110
Clay (%)	3.265
Dry Bulk Density ?_b	2.290
Wilting Point (WP), cm3 per cm3	0.0330
Transition moisture (Wt), cm3 per cm3	0.1812

EXPERIMENTAL DETAILS

Complex Permittivity of soil samples for various salinity levels in the frequency range 150 MHz to 2.2 GHz were measured using Agilent made Vector Network Analyzer (Model-8714 ES). All measurements were carried out at room temperature. For measurement of complex dielectric permittivity a coaxial probe of size 0.141 inch with N-type male connector is connected to the VNA. The Reflection coefficient (R) and Emissivity(e) for soil sample

$$R = \left[\frac{1-\sqrt{\varepsilon}}{1+\sqrt{\varepsilon}}\right]^2 \quad \text{............. (5)}$$

$$\text{Where } \varepsilon = [\,\varepsilon' - j\varepsilon''\,] = \sqrt{(\varepsilon')^2 + (\varepsilon'')^2} \quad \text{......... (6)}$$

The Emissivity is related to R and given by

$$e = 1 - R \quad \text{............. (7)}$$

were also calculated from the measured permittivity data. The power reflection coefficient of the EM waves at the air dielectric interface is given by (Ho and Hall, 1973)

RESULTS AND DISCUSSION

The measured values of dielectric constant and dielectric loss of loamy sand soil with varied salinity levels have been plotted in Fig. (1). It can be observed that the effect of salinity in the soil is more pronounced in the dielectric loss as compared to dielectric constant which may be attributed to higher conductivity of saline samples causing high losses. The dielectric constant which governs the propagation characteristics & storage of energy of electromagnetic wave does not vary much by soil salinity.

The calculated values of Reflection coefficient(R) and Emissivity (e) with frequency have been plotted in Fig. (2) respectively. It is found that Reflection coefficient follows the same trend as the permittivity but emissivity follows a reverse trend i.e. it shows increasing tendency with frequency. Further, the reflection coefficient increases with moisture content due to the increase in permittivity, which causes a total change in reflected energy. The Emissivity decreases with moisture content consequently.

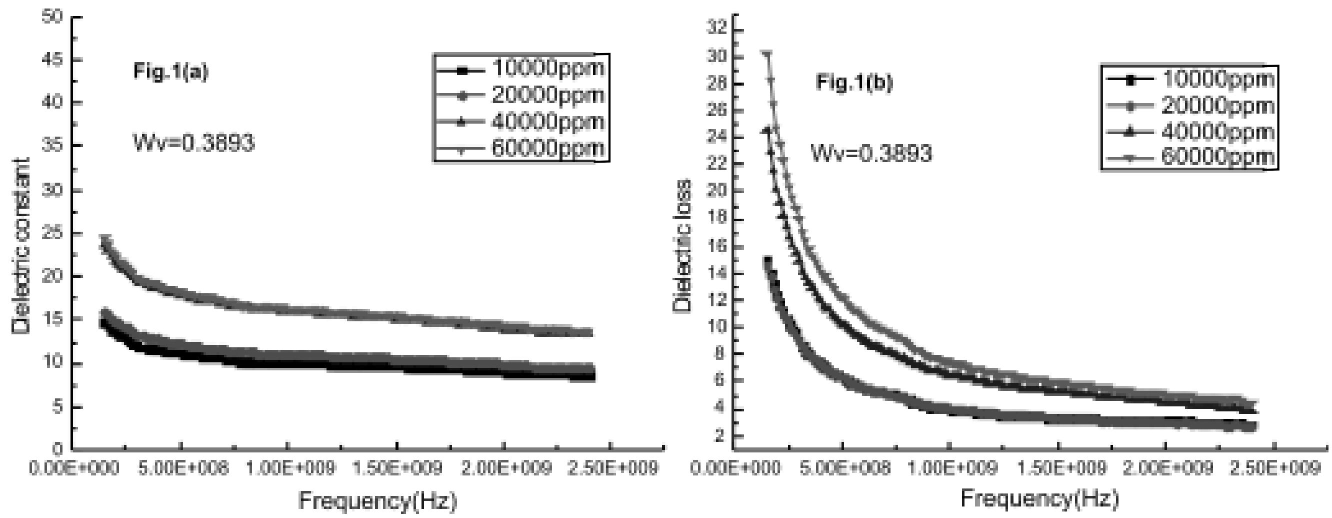

Fig.1: ε' & ε" versus frequency at different salinity levels

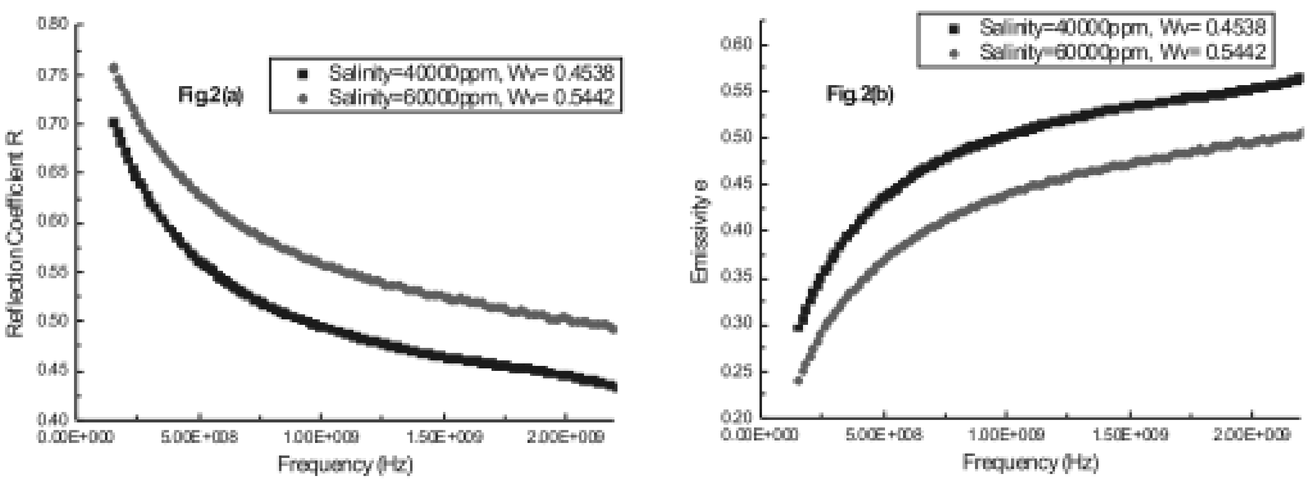

Fig.2: R & e versus frequency for loamy sand soil

CONCLUSION

From the above results it is concluded that the salinity has little influence on the dielectric constant however dielectric loss is strongly affected by the soil salinity. The effect of salinity is to add to the conductivity of the samples and thus causing higher loss. The Reflection coefficient and Emissivity also show expected variations with soil salinity.

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