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Emissivity of Moist Soil at Microwave Frequency

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Abstract: In view of passive microwave remote sensing, microwave emissivity (e) of moist soil estimated using emissivity model. Values of real and imaginary parts of dielectric permittivity ('εand "ε) for artificially moistened soil of Alwar at microwave frequency 9.78 GHz and at 35.0 ^{0}C, Experimental determined complex permittivity of soil is used as input parameter.
The polarized microwave emissivity $_he$(horizontal), $_ve$(vertical) are determined Emissivity Model. The and exhibit a negative correlation with SMC in the soil.

Key words — Dielectric constant, microwave remote sensing, microwave emissivity.

1. Introduction

Study of temporal variation and spatial distribution of the soil moisture profiles through microwave remote sensing studies is an important emerging field of research. Microwave remote sensing provides a unique capability for direct observation of soil moisture or microwave technology is the only remote sensing method that measures a direct response to the absolute amount of water in the surface soil. Remote measurements from space afford the possibility of obtaining frequent, global sampling of soil moisture over a large fraction of the Earth's land surface.

2. Passive Microwave Remote Sensing Parameters

The basic observable parameter of passive microwave remote sensing is microwave emissivity (e) strong function of dielectric constant of target material (soil). Further, emissivity ( ) also depends on sensor properties such as frequency, polarization of microwaves and the angle of observation.

2.1 Microwave Emissivity ()

Calla *et al* [1] describe that the emission of thermal microwave radiation from soils is strongly dependent on the soil moisture content because SMC is prime factor that affects the emissivity of soil. Njoku *et al* [2] described that in case of bare soil the effect of soil moisture on the received passive microwave signal is dominant than surface roughness. An empirical relation between emissivity of soil and SMC (volumetric) is formulated by Alex and Behari[3] as given by equation (1).

$$M_v = -0.8317 e^{-2} + 2.739 e^{-1} - 2.04 \qquad (1)$$

Where, $_vM$ is the SMC (volumetric) and e is the emissivity of soil.

The majority of models for emission of microwaves presented in the literature are based on the simplified Rayleigh approximation. These models are based on Peake's approach[4] which assumes that in thermal equilibrium energy absorbed is equal to energy emitted. The emissivity model assumes a grey body approximation by assigning a constant soil temperature with depth. Since, the temperature and moisture contents of soils exhibit natural variability as a function of depth. Therefore, it is not strictly correct to represent emissivity by such approximations. But for X-band microwaves frequencies the penetration depth is not more than few millimeters[5]. So that uniform profile of temperature is considered for top layer soils and Emissivity model is applicable. Treating uniformity of soil subsurface temperature profile, Kirchoff's reciprocity theorem relates the emissivity (e) to the reflectivity (R) of the surface as equation (2).

$$e = 1 - R \qquad (2)$$

R_h and R_v are the horizontal and vertical Fresnel reflection coefficients and is given by the equations (3) and (4) respectively.

$$R_h = \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \qquad (3)$$

$$R_v = \frac{\varepsilon_r \cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\varepsilon_r \cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \qquad (4)$$

The horizontal and vertical components of surface reflectivity (R) may be computed from the knowledge of the dielectric constant of the medium and the surface boundary condition given by the equation (9) and (10) respectively.

3. Experimental Procedure and Theory

Soil sample from superficial horizons (0-15 cm) of Alwar region has been selected for the experimentation. For sample preparation oven dried for soil is divided in the seven groups and desired amount of conductivity water was mixed to obtain volumetric soil moisture content having the values 3.0% 6.0% 9.0% 12.0% 15.0%, 18.0% and 21.0%. These soil samples are kept in air tight plastic container for twenty four hours for proper mixing (homogeneous distribution of SMC within the entire volume of soil) and to avoid any evaporation from soil. Due to saturated and unsaturated flow of SMC and its vapor in mixture, homogeneous distribution of SMC within the entire volume is obtained.

3.1 Estimation of Microwave Emissivity

Microwave emissivity of bare soil surface are determined by Emissivity model of Peake[4] using experimentally determined values of dielectric permittivity as input parameter. The estimation at range of observation angles varies from 10^0 to 60^0 is optimum because soil moisture measurement using active microwave remote sensing observations is difficult at higher observation angles due to the competing effects of surface roughness.

At X-band microwave frequencies subsurface dielectric and temperature profile is uniform (isothermal), so that emissivity at any given location is related to the Fresnel reflectivity. Variation in SMC leads to change in the soil dielectric constant affecting the soil reflectivity (from the Fresnel equations), which eventually leads to a variation in the emissivity. The surface reflectivity is computed from the knowledge of the dielectric constant of the medium and the surface boundary condition.The horizontal and vertical components of emissivity $_{h}e(\theta)$ and $_{v}e()$ at different view angles varies from 10^0 to 60^0 for bare, smooth and moist soil surfaces are determined.

4. Results and Discussions:

The variations of $_{h}e$ and $_{v}e$with respect to SMC at different observation angles varies from 10^0 to 60^0 are shown in figures: 1 and 2 respectively. Estimated values of emissivity are similar to data of different Indian soils at various moisture levels[3]. It is evident from figures 1 and 2 that:

(i) and both decreases as SMC in the soil increases. Here, emission of microwaves from soil is the conversion of molecular excitation energy (thermal energy) of soil particle into electromagnetic energy and this is due to molecules are activated by solar or any other type sky radiation or interaction of molecule with each other. Activation energy is converted into emitted microwaves due to de-activation of molecules. The radiation emitted during repeated energy transmission comprises a spectral distribution depends on the temperature and dielectric properties of soil. Moist soil and air have very different electrical properties (large contrast between dielectric constant of air & water) but dry soil and air have alike dielectric properties. So that dry soil air interface is homogenous and in case of moist soil thermal radiations generated within the volume beneath the surface, more of radiations are reflected back and less is transmitted into air.

(ii) It is evident from figures : 2 that decreases as the angle of observation increases because horizontal components of Fresnel reflectivity increase as the angle of observation increases. Kirchoff's reciprocity theorem states that the emissivity is equal to one minus Fresnel reflectivity. has the maximum value near-zero incidence angles and decreases towards grazing direction. Hence, according to Fresnel relation of electromagnetic theory, in normal direction emissivity is maximum (reflectivity is minimum) and decreases as obliquity increases. Hence, emissivity decreases as the observation angle increases.

(iii) Since slope of curves in figure:2 is uniform (parallel lines) so that irrespective of observation angle, sensitivity of with respect to SMC is almost invariable. Separation between adjacent curves increases as the angle of observation increases. Angular sensitivity of horizontal emissivity is independent of moistness (dielectric constant) of soil because observation angle and dielectric constant are two independent variable control the horizontal emissivity. Same trend of variation in emissivity w.r.t SMC at each observation angle or vice-versa is observed.

(iv) Figure: 3 reveals that variation of with respect to observation angles is quite different in comparison to corresponding horizontal components. Here the increases as the observation up to around 60^0. Calla *et al* [6] described that Fresnel reflectivity for vertical polarized microwaves decreases or emissivity increases up to Brewster angle.

5. Conclusion:

Hence, power emitted from moist soil is much less than the power emitted from dry soil. As SMC increases electromagnetic contrast between soil and air increases and soil becomes less bright hence emissivity decreases. decrease as the SMC of the soil increases may be explained as the increase in SMC leads to an increase in the soil dielectric constant resulting into an increase in the soil's horizontal reflectivity (from the Fresnel equations), which eventually leads to a decrease in the horizontal emissivity

Present investigation may be useful regarding, to design of microwave remote sensing sensors for soil moisture studies, develop a algorithm for retrieval of actual value of SMC at particular site, study regarding temporal and spatial distribution of SMC of an area by microwave remote sensing,

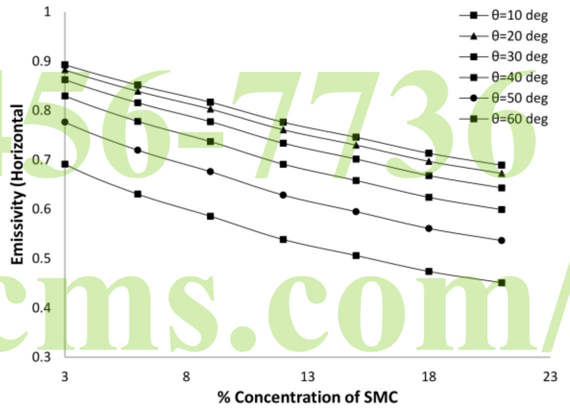

Figure: 1 Variations of horizontal emissivity w.r.t % Conc. of SMC (Volumetric) at different observation angle

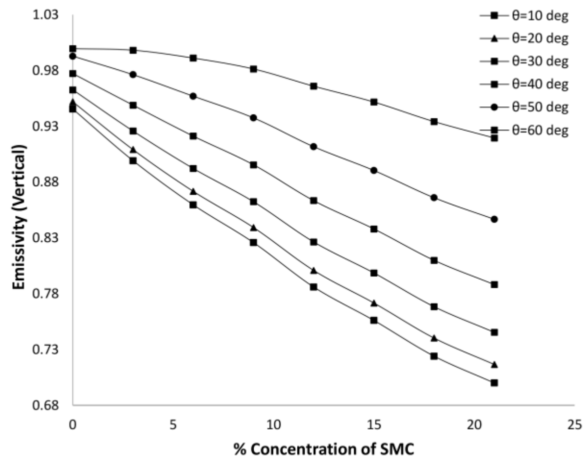

Figure: 2 Variations of vertical emissivity w.r.t % Conc. of SMC (Volumetric) at different observation angle

References

1. Calla O P N, Bohra M C, Vashistha P, Mishra R, Bhattacharya A & Purohit S P, 1999 "Study of the properties of dry and wet loamy sand soil at microwave frequencies" *Indian J. of Radio and space .Phy*. 28 pp 109-112.
2. Njoku E G, Jackson T J, Lakshmi V, Chan T K & Nghiem S V, 2003 "Soil Moisture Retrieval FromAMSR-E". *IEEE Trans. on Geoscience and Remote Sensing (USA)*, 41(2), pp 215-229.
3. Alex Z C& Behari J, 1998 "Laboratory evaluation of emissivity of soils" *International Journal of Remote Sensing(USA)*, 19(7) pp 1335 – 1340.
4. Peake W H 1959 "Interaction of electromagnetic waves with some natural surfaces". *IRE Trans on Antennas and propog (USA)*, 7(5) pp 324-S329
5. Nolan M & Fatland D R, 2003 " Penetration depth as DInSAR observable and proxy for soil moisture". *IEEE Trans. on Geosci. Remote Sensing (USA)*, **41**(3) pp 532 – 537.
6. Calla O P N, Baruah A, Das B, Mishra K P, Kalita M & Haque S S, 2004 "Emission and scattering behavior of dry soils from northeast India " *Indian J. of Radio and space .Phy*. 33 pp321-328.