COMPARISON OF THE SOIL MOISTURE OBTAINED DIRECTLY FROM RADIOMETER AND THE ESTIMATED SOIL MOISTURE FROM MEASURED DIELECTRIC CONSTANT

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ABSTRACT

The emissivity of dry and wet soil depends on dielectric constant, surface roughness, physical properties, polarization and the angle of incidence of microwaves. This study shows the comparison of emissivity obtained from ground-based radiometer with the estimated value from measured dielectric constant. The dielectric constant of dry and wet soil is measured using waveguide cell method at different physical temperatures and emissivity is estimated. A radiometer is used to obtain the emissivity from brightness temperature and physical temperature for variable angle of incidence and both polarization. This study will provide methodology for validation of sensor data with ground-based measurements.

INTRODUCTION

The emissivity is an important parameter for microwave remote sensing, which provides information about soils. All substances at a finite absolute temperature radiate electromagnetic energy, which depend upon the physical properties and as well as the environment in which it exists. Detection & analysis of radiated energy emitted by the soils in the near surface are possible by passive microwave remote sensing techniques by measuring the emissivity of the soil. The emitted radiation from the soil depends upon the dielectric constant, surface roughness, chemical composition, physical temperature, frequency, polarization and angle of observation. The knowledge of emissivity is useful for the efficient indication about soil moisture presence in the soil & also very helpful for building passive microwave instruments for application in agriculture and others[1].

In present paper, the soil from the test site in Rajasthan has been taken to laboratory and the data of emissivity obtained from ground-based radiometer and the estimated emissivity data obtained from the measured dielectric constant has been compared.

RADIOMETER

Passive microwave sensors i.e. Radiometers are highly sensitive receivers designed to measure thermal electromagnetic emission by material media. The function of a radiometer is to measure antenna temperature (TA'), where (TA') represents the average value of a fluctuating noise like signal. Radiometer sensitivity or radiometric resolution is the key quantity characterizing the performance of a microwave radiometer. When a scene, such as terrain, is observed by microwave radiometer (through its antenna beam), the radiation received by the antenna is partly due to self-emission and partly due to reflected radiation originating from the surrounding, such as atmosphere. The magnitude energy received by radiometer is depends on wavelength, polarization and viewing angle. When radiometer observe of bare soil surface, the magnitude of energy depend on soil moisture. Such dependence can be used over large areas to remotely map soil moisture content, an important physical parameter in many hydrological, agricultural, and meteorological application.

SOIL

Soils are composed of solids, liquids and gases mixed together in variable proportions. The relative amount of air and water present depends on the way the soils are packed together. The soil texture depends upon the size of the particle and the structure of soil depends on the way particles are arranged. Both of them influence the amount of the pore space and its distribution of the soil.

Soil has physical as well as electrical properties. Colour, texture, grain size etc comprise the physical property, where the electrical properties include dielectric constant, conductivity and permeability. For passive microwave remote sensing, dielectric constant is the primary electrical property, which is used to estimate emissivity and brightness temperature of the soil.

In present paper, ground based measurements of brightness temperature T_B is carried out using radiometer for both horizontal and vertical polarization at 45^0-incidence angle at 9GHz. Then emissivities are estimated from the T_B. And also, in laboratory the dielectric constant is measured at same frequency of same sample using waveguide cell method. The emissivities using the measured dielectric constant is estimated at 45^0 incidence angle and compared T_B with the emissivities obtained directly from radiometer.

Preparation of Samples

Dry soil samples are prepared from the samples before the experimental observations are carried out. The raw samples are first evenly crushed into fine grains and then the larger particles of the samples are sieved out. The sieved sample is heated to 110° C for half an hour. This dries out the sample completely and the sample is ready for the experimental observations. Wet soils are prepared from the dry soil sample by adding the water drops till it completely saturates. The dielectric constant is measured along with the moisture content of wet soils at different time interval and also these samples are studied directly by the passive microwave sensors.

DIFFERENT METHODS OF MEASUREMENT OF DIELECTRIC CONSTANT[2]

There are basically four methods for measurement of dielectric constant viz. transmission line method, cavity method, free space method and waveguide cell method. In this paper the dielectric constant is measured using waveguide cell method and used for estimation of emissivity.

Wave-Guide Cell Method

In the waveguide cell method, the dielectric constant is measured by calculating the shift in minima of the standing wave pattern in a rectangular waveguide. This shift takes place due to the change in the guide wavelength when a dielectric material is introduced in waveguide. The relevant equations 1 and 2 which are used for calculating ε are given as

$$\varepsilon_r = (\lambda_a/2a)^2 + (\lambda_a/\lambda_{g\varepsilon})^2 \tag{1}$$

Where, $\lambda_{g\varepsilon}$ is found by solving the following equation:

$$\frac{\tan(2\pi(d+L)/\lambda_{ga})}{2\pi L/\lambda_{ga}} = \frac{\tan(2\pi L/\lambda_{g\varepsilon})}{2\pi L/\lambda_{g\varepsilon}} \tag{2}$$

Where, a= Width of the waveguide.

λ_a= Wavelength in the free space

λ_{ga}= Guide wavelength filled with air.

$\lambda_{g\varepsilon}$= Guide wavelength when filled with loss less dielectric material.

d= Displacement of the minima of air after insertion of the dielectric.

L= Length of the plane position where the impedance to be measured.

ESTIMATION OF EMISSIVITY[3]

The choice of model for estimation depends on many factors such as physical properties including shape and size of the sample, physical temperature, polarization, frequency and angle of observation. In present paper, emissivity model is used to estimate the emissivities.

EMISSIVITY MODEL[4]

The emissivity model proposed by Peak (1959), is the simplest to use with reasonable accuracy at higher microwave frequencies, where the radiation arises from within a range close to the surface. In this model the brightness temperature, T_B, of soil is given by:

$$T_B = e_p(\theta)T + r_p(\theta)T_{sky} \tag{3}$$

Where, p refers to the polarization either vertical or horizontal.

T is the surface temperature.

$e_p(\theta)$ is the emissivity of the surface layer i.e. $\mathbf{e_p = 1 - r_p(\theta)}$
$r_p(\theta)$ is the reflectivity at air-soil interface.
T_{sky} is the brightness temperature equivalent of the sky and atmospheric radiation incident on the soil. *It is usually a very small value with respect to brightness temperature. So, the effect of sky temperature in estimation of brightness temperature has been ignored in this present study.*

In the case of smooth surface as well as for a homogenous medium, $r_p(\theta)$ can be obtained from Fresnel reflection coefficient $R_p(\theta)$ as

$$r_p(\theta) = \left|R_p(\theta)\right|^2 \tag{4}$$

Where,

$$R_p(\theta) = \frac{\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \tag{5}$$

for horizontal polarization, and

$$R_p(\theta) = \frac{\varepsilon\cos\theta - \sqrt{\varepsilon - \sin^2\theta}}{\varepsilon\cos\theta + \sqrt{\varepsilon - \sin^2\theta}} \tag{6}$$

for vertical polarization.
Where, θ is the angle of observation from the nadir and
ε is the dielectric constant of the soil.

These equations are used for calculation of emissivity as well as brightness temperature from the measured dielectric constant of the soil.

MEASUREMENT OF T_B USING IMPROVISED RADIOMETER SYSTEM:

A radiometer system was developed using the available equipment. It consists of antenna system and a modulator at 1 KHz. Fig 1 show the experimental setup used for the measurement.

Fig. 1.Experimental set up for direct measurement of T_B using improvised Radiometer system.

The electromagnetic radiation in terms of RF signal generating from soil is modulated by 1KHz-modulated signal. The modulated signal is detected by crystal detector and the VSWR meter detects output received noise power.

CALIBRATION CHART

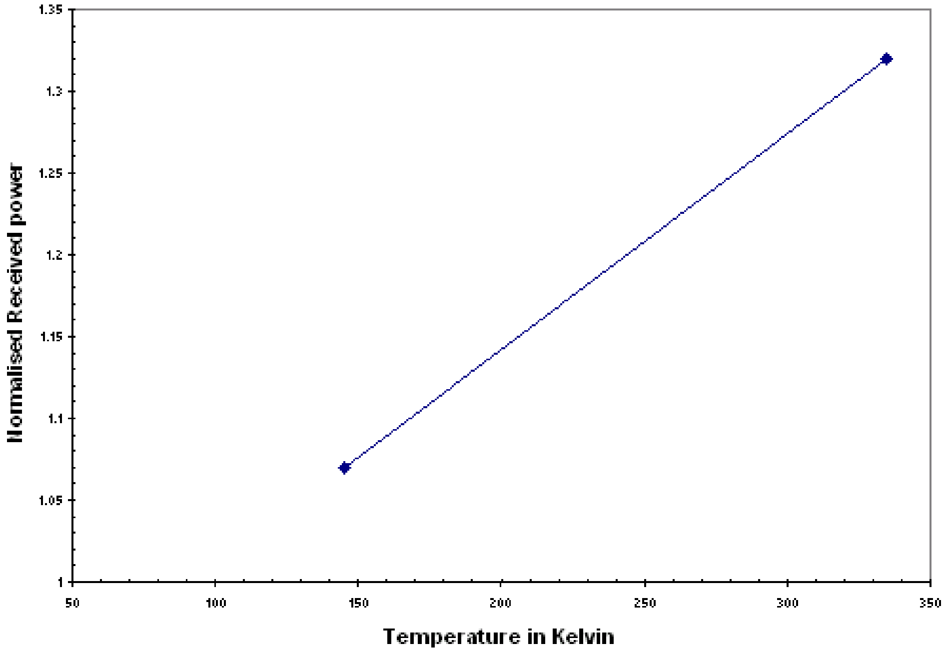

Fig.2. Calibration curve of the Radiometer

RESULTS AND DISCUSSION

Soils	**Emissivity at incidence angle 45deree**			
	Estimated		Measured	
	Vp	**Hp**	**Vp**	**Hp**
Dry soil at T=30C	0.9885	0.8929	0.9939	0.9939
Wet soil at T=28 C	0.5454	0.3258	0.5546	0.5546

The estimated emissivity of dry soil at physical temperature 30^0C and measured value are nearly equal. The measured and estimated values at = 28° C are also nearly equal.

CONCLUSIONS

The emissivity is the electrical parameters of soil, which is function of frequency polarization angle of incidence and the dielectric constant of the soil. The emissivity has been obtained by measuring Brightness temperature and physical temperature. The emissivity has also been estimated from the measured dielectric constant. These two values of emissivity have been compared and presented. The results show that the values are very close thus both the methods gets validated through this examples.

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