ESTIMATION OF EMISSIVITY AND SCATTERING COEFFICIENT OF VEGETATION FROM MEASURED DIELECTRIC CONSTANT AT MICROWAVE FREQUENCIES

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ABSTRACT

The emission from the vegetation canopy depends on the type of vegetation and the frequencies at which the emission is measured. For studying the vegetation canopy of a tree, the dielectric constant of its constituent is measured at microwave frequencies. In this study the dielectric constant is measured using waveguide cell method and its scattering coefficient is estimated using perturbation model for slightly rough surface. The emissivity is estimated using emissivity model. The results obtained are useful for microwave remote sensing of vegetation canopy.

INTRODUCTION

The vegetation canopy has to be studied before one can predict moisture content in the soil. The vegetation emits radiation at microwave frequencies. The emission depends upon the type of vegetation and the frequency at which the emission is measured. There is a correlation between the type vegetation and frequency at which emission takes place. Similarly the vegetation canopy scatters the radio waves, which are incident on the canopy. The scatter also depends upon the frequency of radio wave, the angle of incidence, the polarization and surface roughness of the canopy. In the present study the vegetation canopy of the tree, which is available in abundance in Rajasthan, has been studied and results will be presented. The dielectric constant of the constituent of a tree has been measured at microwave frequencies using waveguide cell method. As the constituent of the tree is slightly rough the perturbation model is used for estimating scattering coefficient and emissivity will be estimated using emissivity model, which is applicable to similar surfaces. In the present communication the dielectric constant of neem leaves is measured and emissivity and scattering coefficient is estimated at microwave frequencies in C- band.

The study of vegetation canopy helps in predicting the moisture contents of the soil and the fertility of the land. The vegetation emits radiation at microwave frequency as well as it scatters the radio waves that are incidence on the canopy. The scatter also depends on the frequency of radio waves, angle of incidence, polarization and the surface roughness of the canopy. In desert areas the vegetation canopy at different locations consists of Neem trees, which are found in large numbers in arid climate zone, and so the study of electrical properties of Neem tree is required when one is to study the desert terrain using microwave remote sensing techniques. . Neem has emerged as a single plant species possessing both pesticidal and medicinal properties. The roots absorb the moisture from the underlying soil and transport it to the various parts of the tree by capillary action.

Here the measurement of the storage factor of the dielectric constant of the vegetation (Neem leaves) is done at a frequency in the microwave range, estimation of emissivity using emissivity model and estimation of scattering coefficient using the perturbation model has been presented. These values can be used for designing passive and active microwave sensors to be used for study of vegetation canopy of trees found are the desert area.

MEASUREMENT OF DIELECTRIC CONSTANT [1,5]

Dielectric Constant of the natural earth material is defined as the ability of a material to absorb, emit, scatter, and reflect a portion of electromagnetic field. It depends upon the physical properties of the material, which includes shape & size of the sample, humidity, temperature, frequency and the field of measurements.

Neem leave samples are prepared using raw leaves that cut exactly fit to the internal dimensions of waveguide & placed tightly in to the dielectric cell of 6 mm thickness. 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

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

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

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

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 SCATTERING COEFFICIENT [8]

Different models are available for the estimation of scattering coefficient and emissivity. For estimation of scattering coefficient, Physical Optics Model, Geometric Optics Model, Perturbation Model and IEM Model are available. The selection of a model depends upon the surface roughness and the validity conditions, both of which must be satisfied and are based on the values of standard deviation of surface height or r.m.s surface height (σ), surface correlation length (ℓ), value of wave number k= ($2\pi/\lambda$) and r.m.s. surface slope (m).

Any surface can be distinguished as rough surface, smooth undulating surface and two scale composite rough surface. When both the surface standard deviation and the correlation length are smaller than the wavelength, then the surface is slightly rough and small perturbation model is used. We have considered the neem leaves as slightly rough surface and hence used the perturbation model. The Validity conditions for perturbation model to be satisfied are

$k\sigma < 0.3$

and

$\frac{\sqrt{2}\sigma}{\ell} < 0.3$ where, k = Wave length number = $2\pi/\lambda$, σ = Surface standard deviation, ℓ = Surface correlation length

In the present case

$k\sigma = 0.1$

$k\ell = 1.0$

The backscattering coefficient in this model is calculated using the equation:

$$\sigma^0_{ppn}(\theta) = 8k^4\sigma^2 Cos^4\theta x\left|\alpha_{pp}(\theta)\right|^2 W(2kSin\theta), \quad (3)$$

Where pp==vv or hh i.e. like polarizations.

Also, $\left|\alpha_{hh}(\theta)\right|^2 = \Gamma_h(\theta)$ is the Fresnel reflectivity for horizontal polarization, which is given by

$$\alpha_{hh}(\theta) = \frac{Cos\theta - \sqrt{\varepsilon_r - Sin^2\theta}}{Cos\theta + \sqrt{\varepsilon_r - Sin^2\theta}} \quad (4)$$

and for vertical Polarization,

$$\alpha_{vv}(\theta) = (\varepsilon_r - 1)\frac{\sin^2\theta - \varepsilon_r(1+\sin^2\theta)}{\left[\varepsilon_r Cos\theta + \sqrt{(\varepsilon_r - \sin^2\theta)}\right]^2} \quad (5)$$

Where θ is the angle of incidence, ε_r is the dielectric constant of surface, W($2ksin\theta$) is the normalized roughness spectrum, which is the Bessel transform of the correlation function $\rho(\xi)$, evaluated at the surface wave number of $2kSin\theta$. For the Gaussian correlation function,

$$W(2kSin\theta) = \frac{1}{2}\ell^2 \exp\left[(k\ell Sin\theta)^2\right] \quad (6)$$

We have considered the following assumption for estimations $k\sigma = 0.1$ and $k\ell = 1.0$.

ESTIMATION OF EMISSIVITY [2,7]

For the estimation of emissivity of the neem leaves dry soil samples, different models can be used. Here we are using emissivity model to estimate the microwave emission from the neem leaves. The basic expression for emissivity is

$$e_p(\theta) = 1 - r_p(\theta) \quad (7)$$

where, $e_p(\theta)$ = the emissivity of the surface layer, p= polarization either vertical or horizontal, $r_p(\theta)$ = reflectivity coefficient

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

$$r_p(\theta) = \left|R_p(\theta)\right|^2 \tag{8}$$

Where, Fresnel reflection coefficient for horizontal polarization

$$R_p(\theta) = \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \tag{9}$$

And, for vertical polarization

$$R_p(\theta) = \frac{\varepsilon_r \cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\varepsilon_r \cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \tag{10}$$

Where, θ = angle of observation from the nadir and ε_r = dielectric constant of the material. Using the above equations estimation of emissivity is done.

RESULTS AND DISCUSSION [6,9]

The dielectric constant of neem leaves are measured at frequency 5 to 7 GHz in C band: fig.1 shows the variation of dielectric constant of neem leaves with frequencies. The fig.1 suggests, as the frequency increases the dielectric constant of leaves reduces.

From fig.2 where the scattering coefficient is plotted against the angle of incidence, at 6 mm thickness of leaves, the following observations are made.

For horizontal polarization, the scattering coefficient decreases initially at a very slow rate on increasing the angle of incidence upto 20^o. After that, it decreases somewhat quickly upto 60^o and drops down much faster from 70^o to 80^o. For vertical polarization, we see that the value of scattering coefficient remains almost constant between the angles of incidence 0^o to 20^o and decreases at extremely slow rate upto 50^o. After that, it drops down quickly from 60^o to 80^o. From the comparative study of the two polarizations, we see that the scattering coefficient for the vertical polarization is more as compared to the horizontal polarization and the value of scattering coefficient at 0^o angle of incidence is almost same. Thus, we can say that the rate of decrease of scattering coefficient for the vertical polarization is comparatively slower than the horizontal polarization.

Fig.3 plotted for emissivity against the angle of incidence. The graph suggests, that for HH polarization emissivity reduces very fast as angle of incidence increases. The curve for horizontal polarization shows a decrease in emissivity at a slow rate initially up to 30^o, and above this angle the emissivity reduces faster as the angle of incidence increases. The curve for vertical polarization shows a gradual increase in emissivity initially, which becomes faster as the angle of incidence varies from 30^o to 70^o. At 74° angle there is change in the value of emissivity and the trend changes. The trend of the emissivity curve changes for vertical polarization at 74°. Instead of increasing, the emissivity decreases as shown in the fig. 2. The change over is taking place at an angle of 74^o, which is the Brewster angle[4]. Theoretically, the Brewster's angle is given by the following relation

$$\tan\theta = \sqrt{\varepsilon_r}$$

SUMMARY AND CONCLUSION

From the results obtained, it can be concluded that the estimated value of emissivity and scattering coefficients of neem leaves depends upon their dielectric constant and surface roughness. It can be said that it will be desirable to use vertical polarization for study of emissivity and scattering coefficient for microwave remote sensing of vegetation canopies.

This study gives input with regard to the electrical properties of a constituent of neem tree. This study of emissivity and scattering coefficient of neem tree leaves is very important from the point of view of microwave remote sensing as these parameters are required for designing passive and active sensors. This input of emissivity and scattering coefficient is also useful from the point of view of data base generation with regard to neem leaves. This tree is in abundance in Rajasthan and so the study has been initiated and will be useful for microwave remote sensing of vegetation canopies in arid zone.

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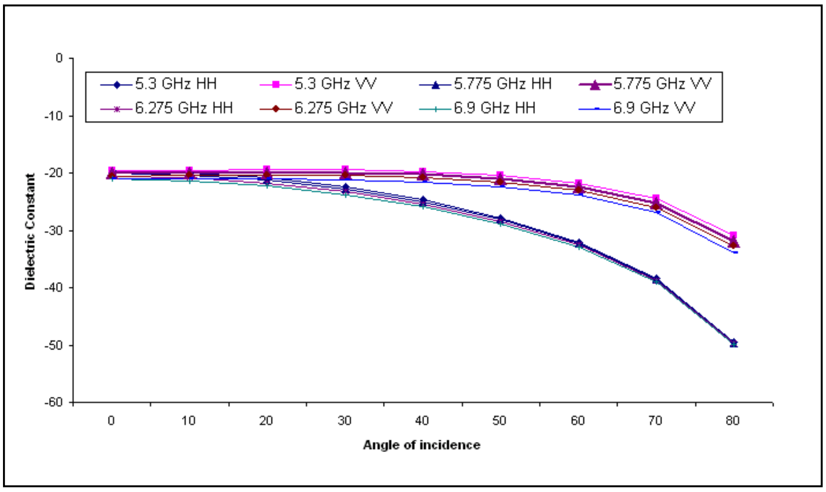

Fig 2 Variation of Scattering Coefficient of Neem Leaves with different polarization and frequencies

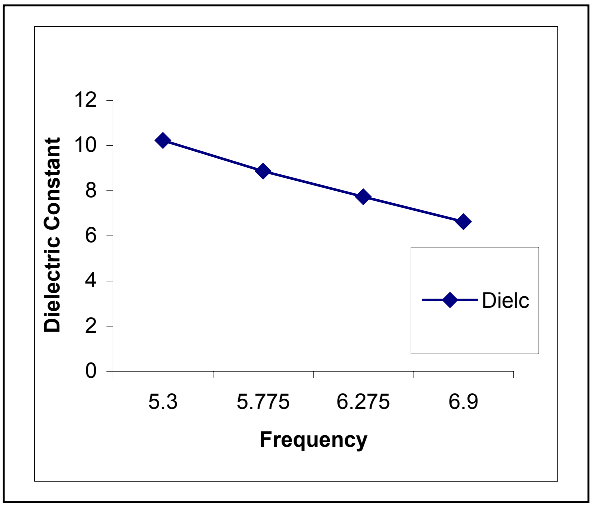

Fig 1 Variation of Dielectric constant for Neem Leaves with different frequencies

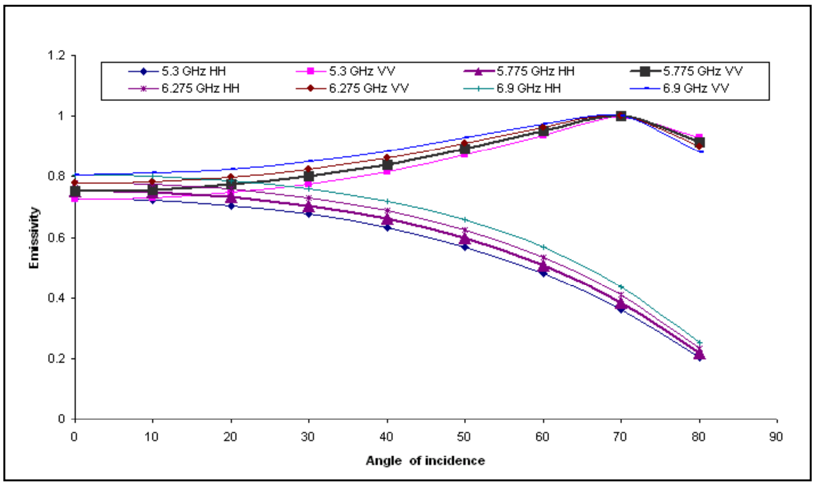

Fig 3 Variation of Emissivity of Neem Leaves with angle of incidence for different polarization and frequencies