STUDY OF THE ELECTRICAL PARAMETERS LIKE DIELECTRIC CONSTANT, EMISSIVITY AND SCATTERING COEFFICIENT OF ICE AT DIFFERENT PHYSICAL TEMPERATURES AT MICROWAVE FREQUENCIES

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ABSTRACT

The electrical properties like dielectric constant, permeability and the conductivity are very important to study the behaviour of snow. In this study the dielectric constant of ice is measured using wave guide cell method at physical temperature from -10^oC to $+10^oC$ and emissivity is estimated using emissivity model for smooth surface. The perturbation model is used for estimating scattering coefficient assuming ice as slightly rough surface at different physical temperature. The variation of emissivity as well scattering coefficient for different microwave frequencies will be studied for angle of incidence, physical temperature and the polarization.

INTRODUCTION [1]

All natural materials are characterized by the physical and electrical parameters. In general there are three natural materials, soil, water and snow. In the present communication the snow has been studied for electrical properties they are the dielectric constant, permeability and conductivity. Out of these three properties the dielectric constant is very important parameter on which the emission property for passive microwave remote sensing depends. Similarly for active microwave remote sensing the scattering coefficient is a important parameter, which also depends upon the dielectric constant. Here the dielectric constant of ice will be measured for temperature -10^o C to $+10^o$ C in C band using waveguide cell method. Using the measured values of dielectric constant at microwave frequencies the emissivity will be estimated for different angles of incidence and for both polarizations using emissivity model applicable for smooth surfaces. The variation of emissivity as well as the brightness temperature will be studied for angles of incidence, physical temperature and the polarization. For slightly rough surface the perturbation model is applicable for estimation of scattering coefficient. These will be estimated for physical temperatures from -10^o C to $+10^o$ C and the results are will be presented and discussed.

All natural earth materials are characterized by their physical and electrical parameters. The microwave remote sensing of the snow suggest the water contents available in the snow. The measurement of dielectric constant of the snow at different physical temperature will help in predicting formation of glaciers snow avalanches, and flood situation in hilly areas. These estimated values of the emissivity and scattering coefficient can be used for designing passive and active sensors at microwave frequencies.

MEASUREMENT OF DIELECTRIC CONSTANT [4]

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.

For measurement of dielectric constant Ice samples of are prepared and placed in a ice packed thermocol box with a thermometer in which the sample is placed and temperature is monitored. 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 SCATTERING COEFFICIENT [7]

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:

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

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

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

and for vertical Polarization,

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

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,

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

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

ESTIMATION OF EMISSIVITY [6]

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

$$e_p(\theta) = 1 - r_p(\theta) \tag{7}$$

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

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

And, for vertical polarization

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

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

Dielectric Constant of ice at different temperature is measured at frequency 5 to 7 GHz in microwave C band and Scattering Coefficient and emissivity estimated.

Fig.1 show the variation in dielectric constant with frequency, at different physical temperature. The graph suggests that as frequency increases dielectric constant reduces and as temperature increases dielectric constant reduces.

The variation of scattering coefficient on different angle of incidence for both polarization at temperature -10^o C and +10^o C is shown in fig.2. It suggests that scattering coefficient decreases initially at a very slow rate on increasing the angle of incidence upto 20^o after that it decreases quickly and drops down very fast at 80^o for horizontal polarization. For vertical polarization it almost remain same upto 50^o C & slowly tends to drop at 80^o. The trends show that temperature has effect on scattering coefficient.

The graphs for emissivity with angle of incidence for HH & VV with different temperature are plotted in figure 3. The graph fig. 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 curve becomes 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 80^o. At 82° angle there is change in the value of emissivity and the trend changes. The trend of the emissivity curve changes for vertical polarization at 82°. Instead of increasing, the emissivity decreases as shown in the fig. 3. The change over is taking place above 80° and at an angle of 84^o, which is the Brewster angle. Theoretically, the Brewster's angle is given by the following relation

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

SUMMARY AND CONCLUSION

Result of this study concludes that the estimated value of emissivity and scattering coefficient of ice with different temperature depends on the dielectric constant and surface roughness. It 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 will help in treating today's most dangerous situation of glaciers, avalanches and flood in hilly areas especially in Northern Himalayas.

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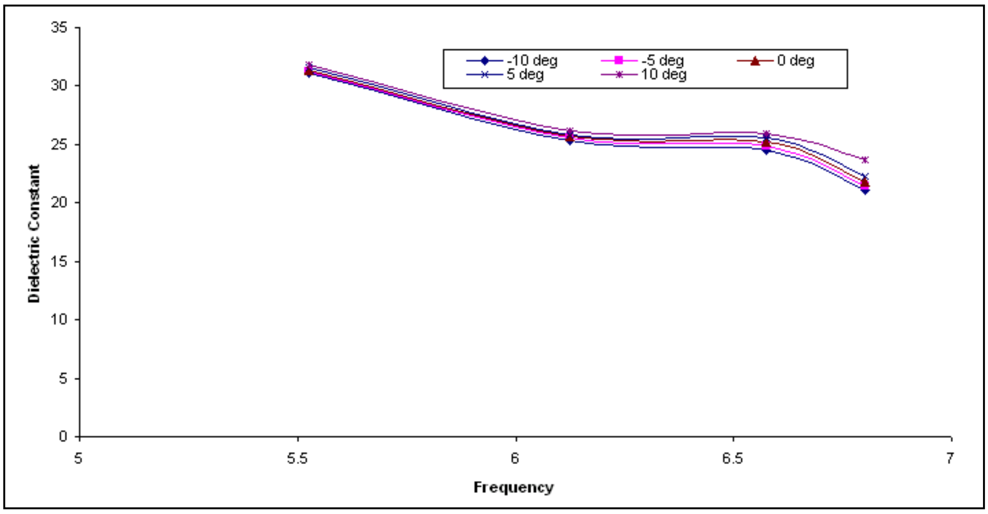

Fig 1 Variation in Dielectric constant with ICE with frequency at different Temperature

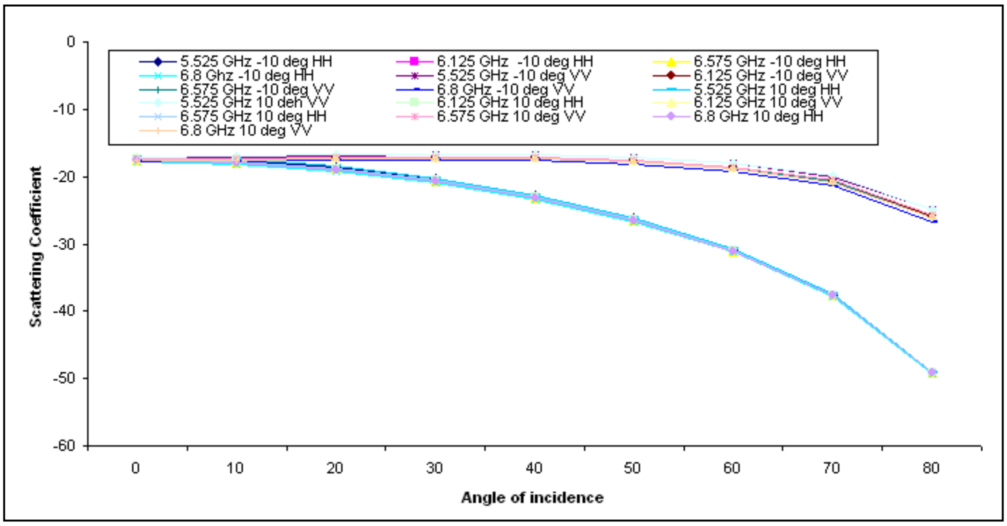

Fig 2 Variation of Scattering Coefficient of ICE with angle of incidence at different polarization and frequencies at –10 deg c and 10 deg c

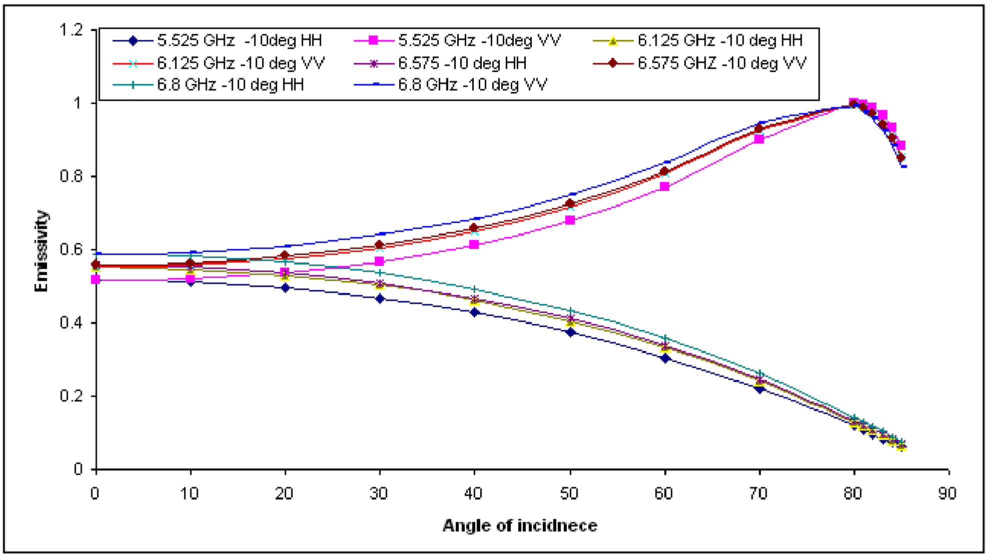

Fig 3 Variation of Emissivity of ICE with angle of incidence for different polarization and frequencies at –10 deg C and 10 deg C