MEASUREMENT OF DIELECTRIC CONSTANT OF SALINE WATER AND ESTIMATION OFEMISSIVITY AND SCATTERING COEFFICIENT AT DIFFERENT PHYSICAL TEMPERATURESAT MICROWAVE FREQUENCIES

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ABSTRACT

The salinity and the physical temperature of ocean water vary from place to place and with depth of sea. This communication suggests microwave remote sensing of oceanic surface, by measuring dielectric constant of saline water with variable salinity at different physical temperatures using waveguide cell method. The scattering coefficient is estimated using perturbation model of slightly rough surface and emissivity of saline water is estimated using emissivity model at different angles of incidence and at different polarization with measured value of dielectric constant. This database is useful for designing of passive and active microwave sensors for remote sensing of oceanic surfaces.

INTRODUCTION [1]

The salinity in the ocean water varies from place to place. The physical temperature also varies. The salinity and physical temperature also varies with depth of sea. Thus for microwave remote sensing of oceanic surface, the study of electrical parameter of the saline water with variable salinity will give useful input for designing the passive and active microwave sensors. The electrical parameters that will be studied are – the dielectric constant, emissivity and the scattering coefficient. The dielectric constant of saline water with variable salinity will be measured using waveguide cell method. The dielectric constant at different physical temperatures and with variable salinity in parts per million (ppm) will be measured using shift in minimum method on a slotted section of waveguide. By solving the transcdental equation and from the value of guide wavelength obtained in the presence of dielectric material, the dielectric constant will be calculated. Another electrical parameter emissivity will be estimated using the measured value of dielectric constant assuming that sea is calm the emissivity model will be used for estimation of emissivity for both polarizations and angles of incidences and the Brewster angle will be determined for vertical polarization. The Brewster angle will also be determined from the measured value of dielectric constant and both the values of Brewster angles for different salinity and the physical temperatures will be compared. The scattering coefficient is the third electrical parameter and this will be estimated using the measured value of the dielectric constant for different physical temperatures and salinity. Using slightly rough surfaces, perturbation model scattering coefficient will be measured for variable angles of incidence from 0^o to 85^o. Thus the database for scattering coefficient will be generated for variable salinity, variable physical temperatures, and different angles of incidence and for both polarizations.

In the laboratory, different models are used to estimate emissivity and scattering coefficient of saline water, whose values can be used to design the microwave sensors so that they can directly measure the same. Thus using these parameters it will be possible to design passive and active microwave sensors for microwave remote sensing of calm sea.

MEASUREMENT OF DIELECTRIC CONSTANT [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.

The value of dielectric constant depends on the amount of salt present in the water, thus different samples of saline water are prepared with different salinity of 10 k ppm, 20 k ppm and 30 k ppm. The measurement has been maid at 29^o C and 15^o C 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_r are given as

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

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

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

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. The validity condition for this model is given in the Table1.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:

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

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

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

and for vertical Polarization,

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

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,

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

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 saline water, different models can be used. Here we are using emissivity model to estimate the microwave emission from the ocean. The basic expression for emissivity is

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

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

$$r_p(\theta) = \left| R_p(\theta) \right|^2 \quad (8)$$

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

Fig. 1-3 suggest the result of this study. Fig.1 shows the variation in dielectric constant of saline water with frequency at different physical temperature and 10 k, 20 k and 30 k salinity. The graph clearly suggests that dielectric constant decreases as frequency increases and as salinity increases dielectric constant decreases.

From fig.2 where the scattering coefficient is plotted against the angle of incidence, with different salinity at different temperature, 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°. After that, it decreases somewhat quickly upto 60° and drops down much faster from 70° to 80°. For vertical polarization, we see that the value of scattering coefficient remains almost constant between the angles of incidence 0° to 20° and decreases at extremely slow rate upto 50°. After that, it drops down quickly from 60° to 80°. 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° 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 fig. Suggests that for HH polarization emissivity reduces very fast as angle of incidence increases for HH polarization whereas it increases as angle of incidence increases. The curve for horizontal polarization shows a decrease in emissivity at a slow rate initially up to 30°, 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° to 80°. At 82° angles there is change in the value of emissivity and the trend changes. The trend of the emissivity curve changes for vertical polarization at 84°. Instead of increasing, the emissivity decreases as shown in the fig. 2. The change over is taking place at an angle of 84°, which is the Brewster angle. Theoretically, the following relation gives the Brewster's angle

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

SUMMARY AND CONCLUSION

We conclude that dielectric constant is a function of frequency and temperature and it decreases as frequency increases. The dielectric constant as salinity of water increases. The change over angle is a function of dielectric and for saline water it is 82°. The database of thus study will helps in determining the behaviour of seawater, sea ice and icebergs. The study will provide good results in designing of microwave sensors for remote sensing of ocean and ice. An extensive study on this subject is required for monitoring the spatial and temporal variations of seawater and sea ice and ocean navigation.

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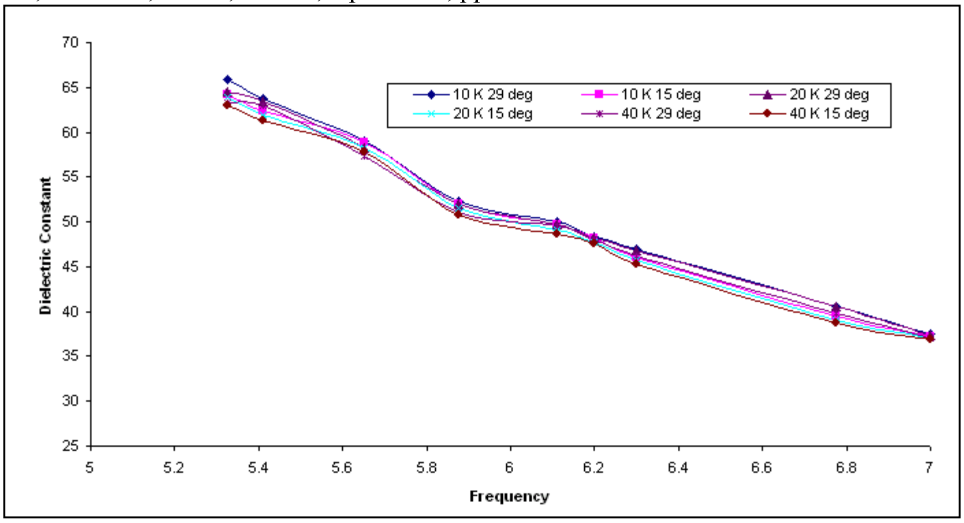

Fig 1 Variation in dielectric constant of saline water with frequency at different physical temperature and salinity

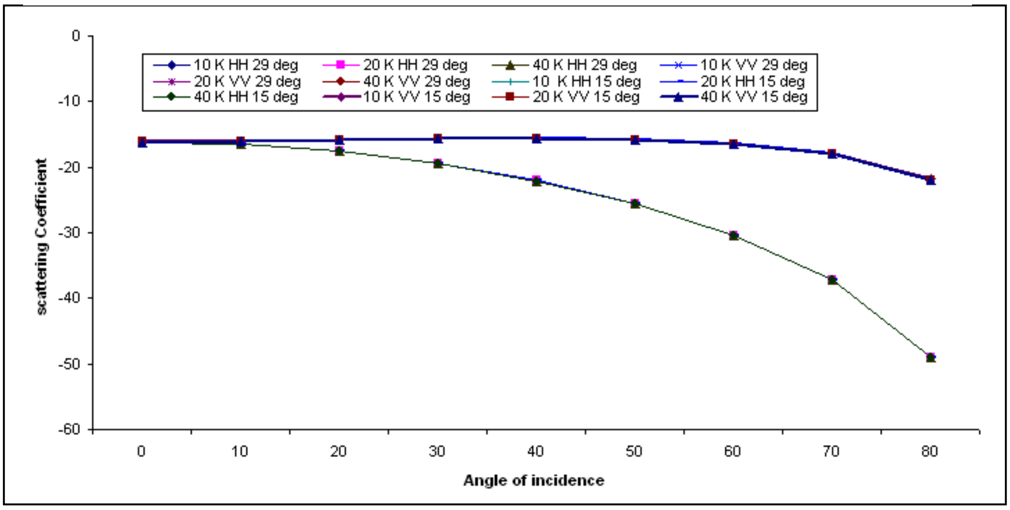

Fig 2 Variation of Scattering Coefficient with Salinity and angle of incidence with different polarization at frequency 5.325 GHz for 29 deg C and 15 deg C

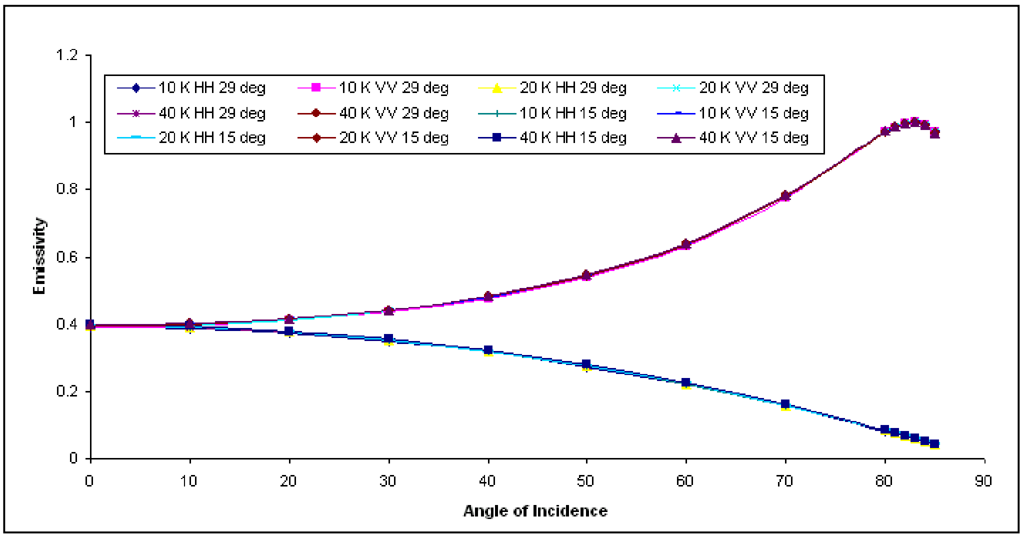

Fig 3 Variation of Emissivity with Salinity and angle of incidence with different polarization at frequency 5.325 GHz for 29 deg c and 15 deg C