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STUDY OF DIELECTRIC AND EMISSIVE BEHAVIOUR OF EMBLICA OFFCINALIS TREE LEAVES AT X-BAND FREQUENCIES

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Abstract: This study presents the data on dielectric constant, dielectric loss and emissivity of leaves of *Emblica offcinalis* tree species at X-band microwave frequencies (9.63GHz, 10.63GHz and 11.63GHz). Wave guide cell method has been used for measuring dielectric constant and loss of tree leaves. Our result show a little decrease in the values of dielectric constant for the leaves of sample of tree species as the frequency is increased. The estimation of emissivity has been made using the measured values of dielectric constant. Emissivity of tree leaves is estimated by using emissivity model. For both, vertical and horizontal polarizations, at constant value of incident angle, emissivity of tree leaves is found to decrease significantly increase in the values of its Gravimetric Moisture Content (MC%). Also, the values of emissivity for tree leaves at same incident angle are greater for vertical polarization than for horizontal polarization. Such results are useful for microwave remote sensing of vegetation canopy from agricultural and forest areas.

Keywords: Dielectric constant, dielectric loss, tree leaves, microwave frequency, emissivity.

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INTRODUCTION

The dielectric constant is a fundamental property of all materials. The strength of interaction between microwaves and a material is determined by the dielectric constant and is an important determinant of emissivity of a material. The dielectric constant is a complex number. The real part of it determines the propagation characteristics of the energy as it passes through the material and the imaginary part determines the energy losses. In a heterogeneous material, e.g. soil or vegetation/tree leaves material, the complex dielectric constant is a combination of all individual dielectric constants of the constituent parts (e.g. water, air). Other factors that influence the dielectric constant are temperature, salinity and frequency.

The microwave dielectric behaviour of vegetation materials have studied by several investigators. [1-5] Their results have been reported dielectric parameters of plants/vegetations as a function of moisture content at microwave frequencies. The dielectric properties of Bamboo and Canna plants leaves at 9.8 GHz have been studied as a function of moisture content.[6] Emissive and scattering behaviour of neem leaves have been experimentally studied at different microwave frequencies by using emissivity model.[7] Experimental results on complex dielectric constant and emissivity for leaves of different tree species at X-band microwave frequencies have been reported.[8-10] However, some of these investigations have pointed a scarcity of data on the dielectric and emissive properties relating to tropical vegetation/tree canopies.[11]

In order to provide more experimental data relating to this area, we have carried out the experiments to measure complex dielectric constant for leaves of Emblica offcinalis tree species at three different X-band microwave frequencies. These values can be used for designing the passive microwave sensors to be used for study of vegetation canopy of tree.

MATERIALS AND METHODS

Preparation of the tree leaves samples:

Samples of leaves of Emblica offcinalis (Amla) has been used in our experiments. This tree species selected lie within the small area covering about 1 km2 in the Dhule city. Dhule district comes under tropical zone and located in the northern region of Maharashtra state (India). Height of this tree species ranged between 7 to 15 meters. Initially, the newly plucked tree leaves are inserted into the solid dielectric cell and their dielectric constant is measured. Then the wet basis gravimetric moisture content (MC, %) of this tree leaves sample was gradually reduced by drying it in a hot air oven at 45o to 50o C. Moistures of leaves are varied from its natural to oven dry value.

Measurement of dielectric constant:

The waveguide cell method is used to determine the dielectric properties of the tree leaves samples. An automated X-band microwave set-up in the TE10 mode with Gunn source operating at frequencies 9.63 GHz, 10.63 GHz and 11.63 GHz, PC-based slotted line control and data acquisition system is used for this purpose. It consists of Microcontroller (8051), ADC-12 Bit- MCP (3202) Visual-based software. The solid dielectric cell with this sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the tree leaves sample. The sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. The dielectric constant ε' and dielectric loss ε'' of the tree leaves are then determined from the following relations:

$$\varepsilon' = \frac{g_\varepsilon + (\lambda_{gs}/2a)^2}{1 + (\lambda_{gs}/2a)^2} \quad .... (1)$$

$$\varepsilon'' = -\frac{\beta_\varepsilon}{1 + \left(\lambda_{gs}/2a\right)^2} \quad .... \qquad (2)$$

Where, a = Inner width of rectangular waveguide.

λ_{gs} = wavelength in the air-filled guide.

g_ε = real part of the admittance;

β_ε = imaginary part of the admittance

From these measured values of dielectric constants at X-band frequencies for the tree leaves samples having different MC (%), the estimations of emissivity are made at different incident angles by using emissivity models, respectively for vertical and horizontal polarizations.

Estimation of Emissivity from emissivity model:

The emissivity $e_p(\theta)$ for vertical polarization (VV) can be written as

$$e_p(\theta) = 1 - r_p(\theta) = 1 - |R_p(\theta)| \quad .... (3)$$

$$e_p(\theta) = 1 - \frac{\varepsilon'\cos\theta - \sqrt{\varepsilon' - \sin^2\theta}}{\varepsilon'\cos\theta + \sqrt{\varepsilon' - \sin^2\theta}} \quad \ldots.\ (4)$$

and the emissivity $e_p(\theta)$ for horizontal polarization (HH) can be written as

$$e_p(\theta) = 1 - r_p(\theta) = 1 - |R_p(\theta)| \quad \ldots.\ (5)$$

$$e_p(\theta) = 1 - \frac{\cos\theta - \sqrt{\varepsilon' - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon' - \sin^2\theta}} \quad \ldots.\ (6)$$

θ = Angle of observation

$e_p(\theta)$ = Emissivity of the surface layer $r_p(\theta)$ = Reflection coefficient

$R_p(\theta)$ = Fresnel reflection coefficient

RESULTS AND DISCUSSION

Our results on the variations of dielectric constant (ε') and dielectric loss (ε'') of leaves samples of Emblica offcinalis tree species with different gravimetric moisture contents (wet basis) and also the variations of their emissivity for vertical and horizontal Polarizations (VV and HH) at different incident angles are summarized in Figs. 1 and 2. These experiments are performed at microwave frequencies 9.63 GHz, 10.63 GHz and 11.63 GHz and for MC variations from moistures of freshly plucked natural leaves to their oven- dry values.

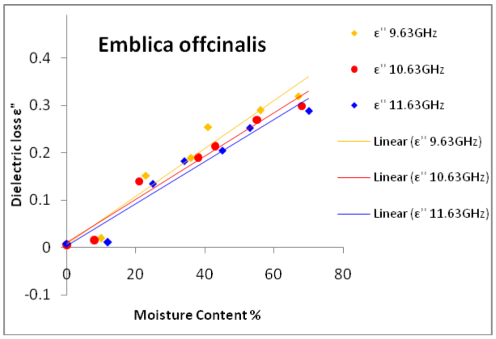

Fig.1 (a)

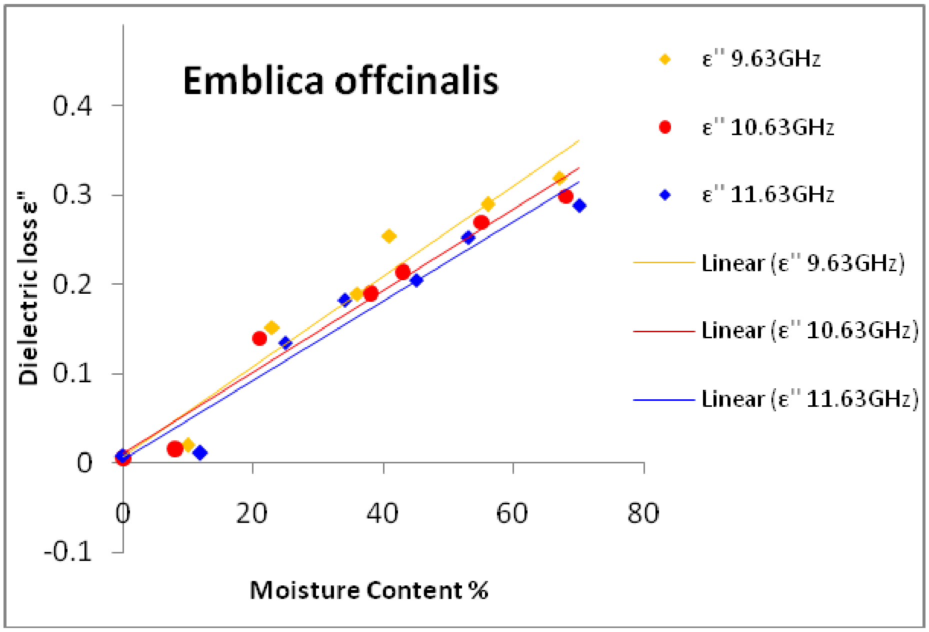

Fig.1 (b)

Fig.1(a)-(b):Variations of dielectric constant and loss of Emblica offcinalis leaves with gravimetric moisture content at three different frequencies.

Fig. 1(a)-(b) show the variations of dielectric constant and loss for Emblica offcinalis (Amla) leaves samples with gravimetric moisture content at microwave frequencies 9.63 GHz, 10.63 GHz and 11.63 GHz respectively. The dielectric constant and loss of the leaves are found to increase with increase in MC (%) over the entire range studied. However, these variations with MC are relatively more nonlinear for (ε') than (ε'') and the general trends are almost similar for these the frequencies, except their relative magnitudes. Further, there is little decrease in dielectric constant and loss with increase in frequency.

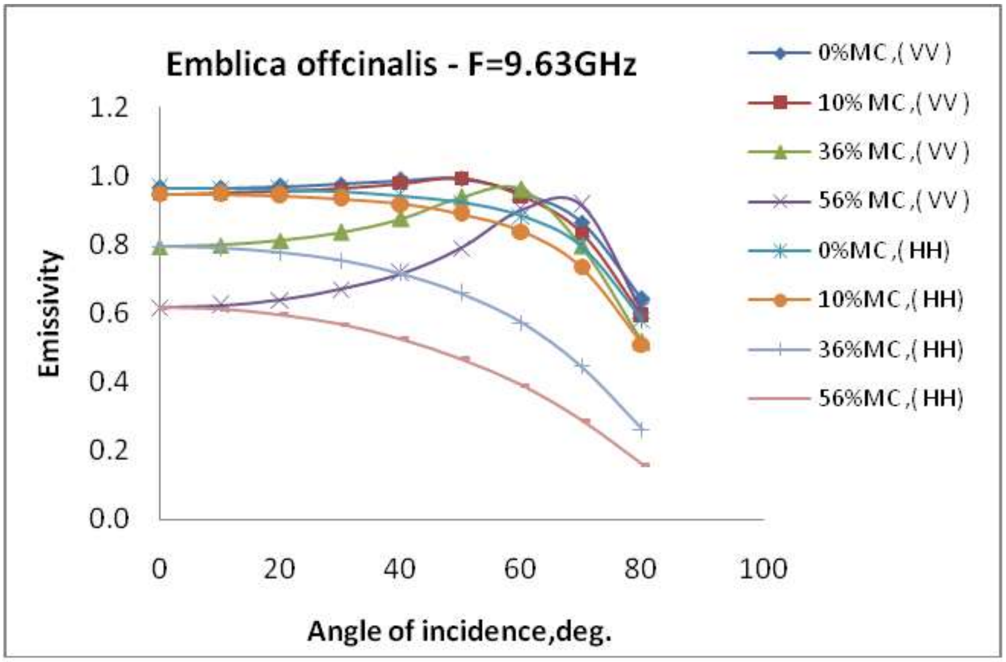
Emblica offcinalis - F=9.63GHz
Emissivity
Angle of incidence,deg.
0%MC ,(VV)
10% MC ,(VV)
36% MC ,(VV)
56% MC ,(VV)
0%MC ,(HH)
10%MC ,(HH)
36%MC ,(HH)
56%MC ,(HH)

Fig.2 (a)

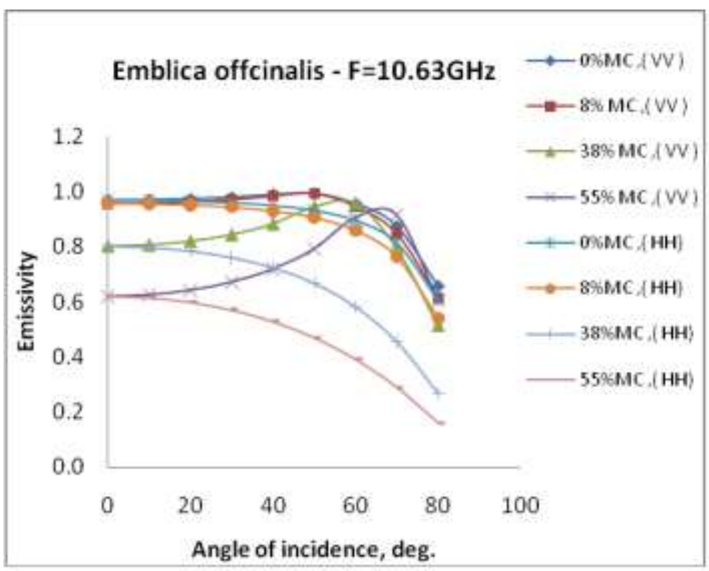
Emblica offcinalis - F=10.63GHz
Emissivity
Angle of incidence, deg.
0%MC ,(VV)
8% MC ,(VV)
38% MC ,(VV)
55% MC ,(VV)
0%MC ,(HH)
8%MC ,(HH)
38%MC ,(HH)
55%MC ,(HH)

Fig.2(b)

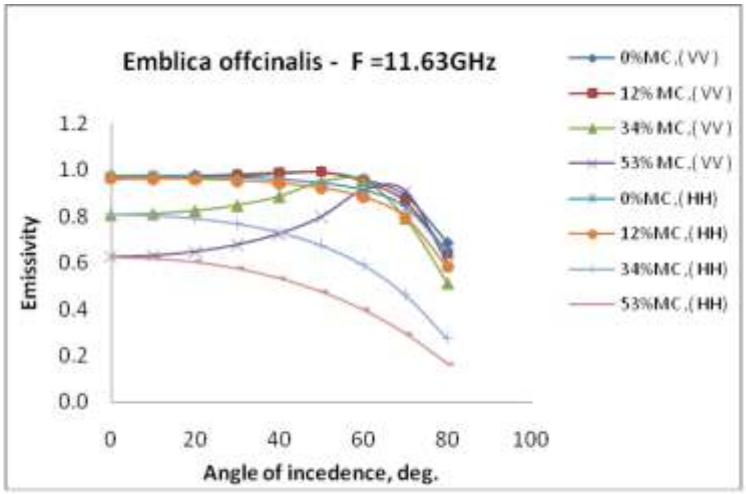

Fig.2 (c)

Fig.2(a)-(c):Variation of emissivity (Vertical and Horizantal Polarizations) for different wet basis gravimetric MC (%) with incident angles in degrees of Emblica offcinalis leaves at 9.63 GHz, 10.63 GHz and 11.63 GHz.

Fig.2 (a)-(c) are plotted for emissivity against the angle of incidence. The graph suggests that for horizontal 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 300, 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 300 to 650. Beyond 650 angles there is change in the value of emissivity and the trend changes. Instead of increasing the emissivity decreases as shown in Fig.2 (a)-(c). Also show almost similar trends except little difference in their magnitudes for different X-band frequencies. Thus, results presented here show fairly good agreement with the experimental and theoretical studies of earlier investigators. [1, 4, 7, 9]

Emissivity of tree leaves is an important parameter needed in designing of passive microwave sensors. Therefore, such study has lot of importance from the point of view of microwave remote sensing for agricultural and forest areas.

CONCLUSIONS

1. The dielectric constant and loss for Emblica offcinalis (Amla) are found to increase with increase in its gravimetric MC (%) at microwave frequencies. However, most of these variations are nonlinear and also show little decrease with increase in microwave frequencies.
2. For both, vertical and horizontal polarizations, at constant value of incident angle, emissivity of tree leaves is found to decrease significantly with increase in the values of its moisture content (%) .
3. The values of emissivity for tree leaves at same incident angle are greater for vertical polarization than for horizontal polarization.

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