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Research Article

VARIATION OF DIELECTRIC AND ATTENUATION PROPERTIES FOR TREE LEAVES WITH MOISTURE CONTENTS AT MICROWAVE FREQUENCY

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ABSTRACT
Present studies report the experimental results on the dielectric and attenuation parameters for leaves of two different tree species at X-Band microwave frequency, 10.5 GHz. Leaves of two different tree species viz., Azadirachta indica (Neem) and Acacia indica (Babool) have been used in these measurements. Complex dielectric constants of these tree leaves have been measured by using waveguide cell method with the help of an automated X-band microwave set-up, whereas attenuation of microwave signal is measured by free space method. Initially, dielectric and attenuation properties of newly plucked leaves are measured. Then the gravimetric moisture content (wet basis) of the leaf sample was gradually reduced by drying it in a hot air oven at 45 to 50^{o}. Our results show dependence of dielectric and attenuation properties of tree leaves mainly on their Moisture Content (MC %) and also to some extent on the shape and size of tree leaves. The complex dielectric constant is found directly proportional to the insertion loss and reflection coefficient, whereas it is inversely proportional to the return loss and transmission coefficient. Possible applications of such studies in remote sensing of forests and mobile communications are discussed.

Key Words: *Complex Dielectric Constant, Insertion Loss, Return Loss, Reflection And Transmission Coefficients, Microwave Frequency***.**

INTRODUCTION
Trees are water-based lifeforms. Water molecules exhibit several different natural resonant frequencies in the microwave spectrum. When signals at these frequencies interact with water molecules, some of the photons transfer energy to the water by exciting various vibratory modes in it. As a result of this, the microwave signal energy gets reduced. The dielectric properties of vegetation samples at microwave frequencies are important parameters to be investigated for they describe the linkage between electromagnetic and physical properties of the samples. The dielectric properties of these vegetation samples, which are hygroscopic in general, vary predominantly with moisture content, but also they depend on the frequency of the applied electromagnetic field, the temperature of the materials, and on density and structure of the materials.

Experimental investigations on the attenuation properties of microwaves passing through tree canopies have been reported by several investigators (Chukhlantsev and Golovachev, 1989; El-Rayes and Ulaby, 1987 and Kirdyashev, 1979). Studies on the microwave dielectric behavior of vegetation material have been reported by several investigators (Calla *et al.*, 2005 and Chuah and Lau, 1995). Their results have shown the strong dependence of attenuation by vegetation on frequency. Measurements of dielectric constant of neem leaves at X-band frequency were carried out (Calla *et al.*, 2005*)*. They have estimated the values of emissivity and scattering coefficients of neem trees and outlined their importance in microwave remote sensing of vegetation canopies. Measurements of dielectric constants of leaves of two tropical crops, as a function of moisture content at X-band were also reported (Chuah and Lau, 1995).

Some of the investigators have developed the models relating to microwave remote sensing of forests (Ferrazzoli and Guerriero, 2002; Tzler, 1994; Kerr and Njoku, 1990). However, present available data on dielectric and attenuation properties for forest canopies in tropical areas is very limited and it is rather difficult to make certain conclusions about these properties and their spectral response. In order to provide more experimental data relating to this area, we have carried out the experiments to study the variation of these parameters at X- band microwave frequency (10.5 GHz) for leaves of two different tree species viz., Azadirachta indica (Neem) and Acacia indica (Babool). Such results will definitely be useful for better understanding of the microwave attenuation and dielectric behaviour of vegetation material.

MATERIALS AND METHODS

Sample Collection and Fabrication of Sample Holder

Samples of leaves from two different tree species viz., Babool, and Neem have been used in our experiments. The naturally collected tree leaves are filled into a suitable sample holder. The sample holder is fabricated from uniform plain Perspex sheet with thickness of about 2.5 mm. It is of rectangular shape having inner dimensions (1.8X20X20) cms. Sample holder is then arranged centrally between the transmitting and receiving horn antenna for measuring the insertion loss of microwave signal due to the corresponding tree leaves samples. The gravimetric moisture content, (MC %, wet basis) of the leaf sample was gradually reduced by drying it in a hot air oven at 45^o to 50^o.

Method of Measurement of Attenuation parameters

The free space method is used to measure the insertion loss of microwave signal upon passing through tree leaves samples having thickness of 1.8 cm. Fig.1 shows X-band microwave set-up in the TE_{10} mode with Gunn source operating at frequency 10.5 GHz. The microwave signal is allowed to incident on the tree leaves sample through transmitting antenna. The undesired insertion loss introduced due to presence of perspex sample holder in the transmission path is eliminated by taking the measurements of Insertion Loss (IL) with and without tree leaves. Then the average values of IL of signal due to leaves having various MC (wet basis) for both the tree species are measured.

Figure 1: X- band Microwave Set-up for measuring Attenuation due to Tree Leaves by Free Space Method

From these experimentally measured values of IL, the transmission coefficient (T), reflection coefficient (Γ), VSWR and Return Loss (RL) for different tree leaves samples are then determined from the following relations:

$$IL = -20 \, Log_{10} |T| \quad (1)$$

$$\Gamma = T - 1 \quad (2)$$

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \quad (3)$$

$$RL = -20 \, Log_{10} |\Gamma| \quad (4)$$

Method of Measurement of dielectric Constant

The waveguide cell method is used to determine the dielectric properties of the tree leaves samples by using an automated X-band microwave set-up operating at the same frequency 10.5 GHz. Automation consists of PC-based slotted line control and data acquisition system. It consists of Microcontroller (8051), ADC-12 Bit-MCP (3202) Visual based software. The main advantages resulted due to atomization are increased resolution of output, reduction of backlash error in slotted line, visual representation of standing wave pattern. The solid dielectric cell with this sample is connected to the opposite end of the source (Fig. 2). 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.

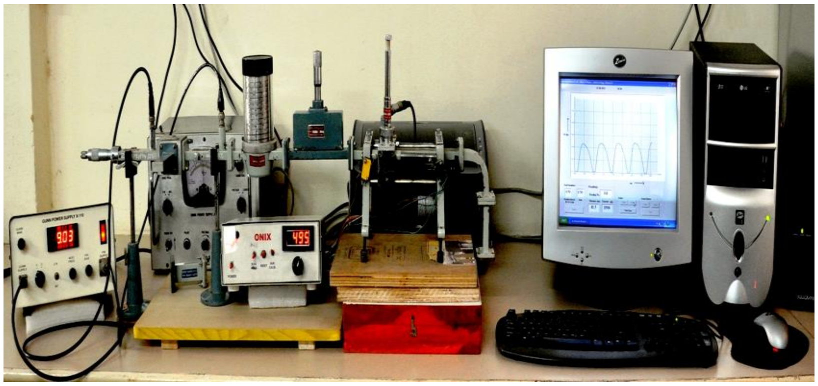


Figure 2: X- band Microwave Set-up for measuring Dielectric constant of Tree Leaves by Waveguide cell Method

The dielectric constant (ε') and dielectric loss (ε'') of the tree leaves are then determined from the following relations:

$$\varepsilon' = \frac{g_{\varepsilon} + (\lambda_{gs}/2a)^2}{1 + (\lambda_{gs}/2a)^2} \qquad (5)$$

$$\varepsilon'' = -\frac{\beta_{\varepsilon}}{1 + (\lambda_{gs}/2a)^2} \qquad (6)$$

Where, a = Inner width of rectangular waveguide,
g_{ε} = real part of the admittance,
λ_{gs} = wavelength in the air-filled guide.
β_{ε} = imaginary part of the admittance

RESULTS AND DISCUSSIONS

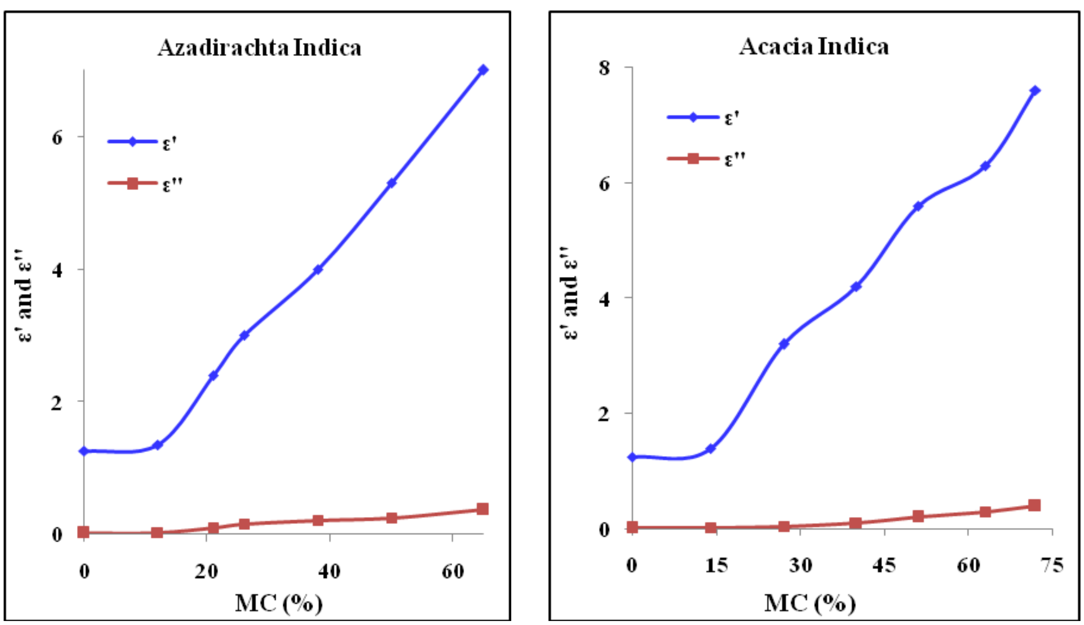
The variation in the values of dielectric constant, dielectric loss, insertion loss, return loss Transmission Coefficient and Reflection Coefficient for leaves samples with gravimetric moisture content, % (wet basis) of both the tree species at 10.5 GHz X-band frequency are summarized in Figs. 3-5.

Fig. 3 (a, b) shows the variations of dielectric constant and dielectric loss at 10.5 GHz for leaves samples with gravimetric moisture content, % (wet basis) of Azadirachta indica (Neem) and Acacia indica (Babool) respectively. Both these parameters are found to increase with increase in MC (%). Trends are almost similar for leaves of both the tree species, except the relative magnitudes of dielectric constant and dielectric loss are comparatively higher for Acacia indica.

The results on attenuation of microwaves at 10.5 GHz frequency due to leaves samples for two different tree species used have been analyzed and represented graphically in Figs. 4 and 5.Fig.4 (a, b) shows the variations of Insertion Loss (IL) and Return Loss (RL) for the leaves samples of Azadirachta indica and Acacia indica having different (MC%, wet basis) respectively at 10.5 GHz. Initial natural wet basis MC (%) for leaves of Azadirachta indica and Acacia indica are 65% and 72% respectively. The results indicate the behaviour of leaves samples studied for both species is qualitatively similar. In both the cases, variations of IL and RL with MC are nonlinear. It is found that the magnitudes of IL of microwave signal are found to increase with increase in MC (%) for both tree leaves samples studied. This shows that dry leaves are less deleterious than wet ones. Variations of RL of microwave signal with MC show exactly reverse trends than those observed for IL.

Fig.5 (a,b) shows the variations of Transmission Coefficient and Reflection Coefficient for the leaves samples of Azadirachta indica and Acacia indica having different (MC%, wet basis) respectively at 10.5 GHz. The results also indicate the behaviour of leaves samples studied for both species is qualitatively similar. In both cases, variations of T and Γ with MC are nonlinear. It is found that the magnitudes of T of microwave signal are found to decrease with increase in MC (%) for both tree leaves samples studied. Variations of Γ of microwave signal with MC show exactly reverse trends than those observed for T. Thus, dry leaves have more transmissivity and hence less reflectivity than green/wet leaves.

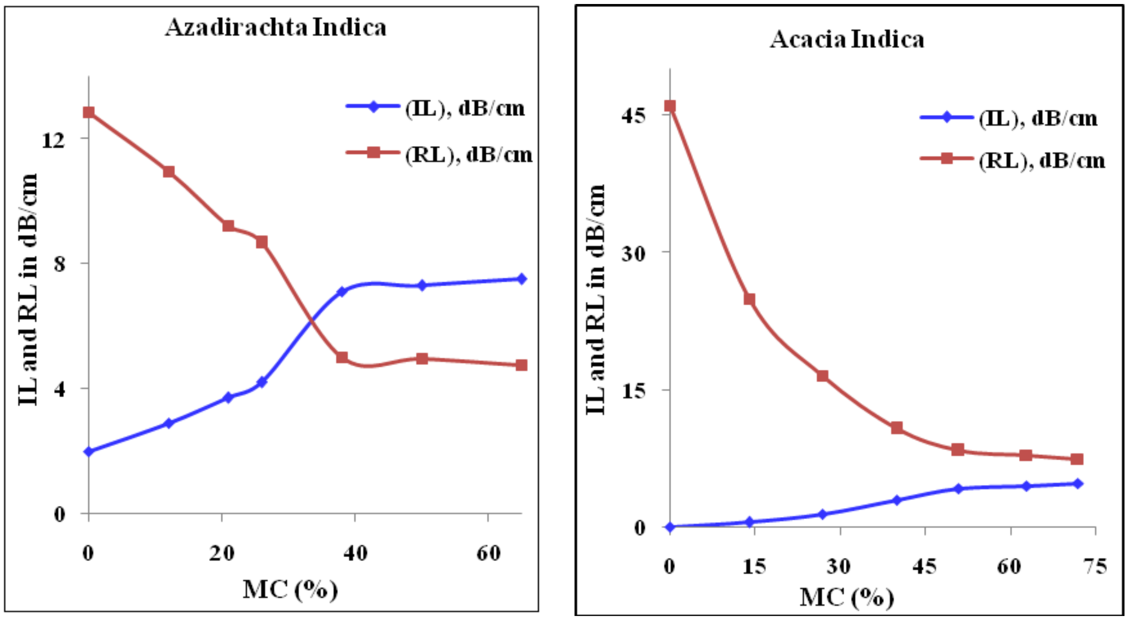
Results presented here (Figs. 3-5), indicate the dominant role of water in determining the dielectric and attenuation behavior of microwaves passing through tree species. Further, it is observed that the initial rate of increase or decrease of these attenuation parameters of microwave signal with different (MC) (%) is comparatively more. Further, our results show relatively lower magnitudes of IL values for Acacia indica leaves which are circular shaped and of relatively smaller size than Azadirachta indica leaves. Further, Transmission and reflection coefficients both attain equal values (0.5 each) at lower values of MC for Azadirachta indica (Neem) leaves than that for Acacia indica (Babool) leaves. Thus, our results also show the dependence of these attenuation factors on shape and size of tree leaves.



(a) (b)

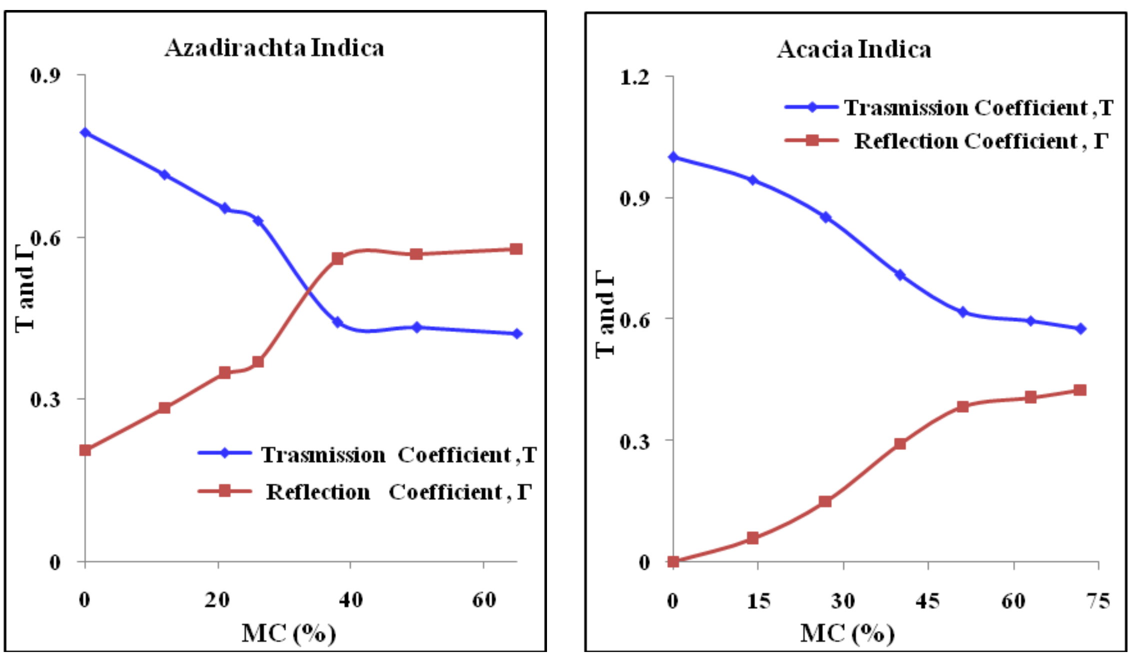
Figure 3: Variation of dielectric constant and loss with percentage moisture content at 10.5 GHz

Thus, results reported here on dielectric constant of leaves and attenuation of microwaves passing through them at microwave frequency have potential applications in remote sensing and mobile communications.



(a) **(b)**

Figure 4: Variation of insertion and return loss with percentage moisture content at 10.5 GHz



(a) **(b)**

Figure 5: Variation of transmission and reflection Coefficient with percentage moisture content at 10.5 GHz

These studies will be useful for remote sensing of forest and also the soil beneath the forest cover. Variation of ε', ε", IL, RL, T and Γ with MC of leaves will help to understand the seasonal variations of remote sensing data from forest areas. Further, attenuation values of the corresponding tree canopies will help in assigning the transmitter power of the mobile station. Besides these, the results reported here may also help in designing the moisture meters for tree leaves. In order to have more appropriate model of tree canopy, the studies reported here should be extended for flowers, stalks, branches and trunks of trees. Moreover, the results should also be repeated for several other microwave frequencies and also in the different environmental conditions. Leaves of both the tree species studied here are also having medicinal uses. Hence our study may also be useful in medicinal field.

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