ISSN (e): 2250 – 3005 || Volume, 07 || Issue, 08|| August – 2017 ||
International Journal of Computational Engineering Research (IJCER)

Effect of Ficus Benghalensis leaf overlaid on thick and thin film Microstrip patch Antenna.

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ABSTRACT
Thick and thin film rectangular microstrip patch antennas have been used to investigate the effect of leaf moisture on their response. This paper reported the effect of Ficus Benghalensis leaf when it was used as overlay on thick and thin film microstrip rectangular patch antennas. An approximate estimate values of the effective dielectric constant of the leaf has been made using overlay technique. It is felt that both thick and thin film microstrip patch antennas can be used to monitor the moisture status of leafy vegetation.
***Keywords*:** Thick film, thin film, Microstrip components, rectangular patch antennas, leaf moisture, dielectric constant, complex permittivity.

Date of Submission: 11-08-2017 Date of acceptance: 31-08-2017

I. INTRODUCTION

Microwaves interact with biomaterials because of presence of water. Leaves are major constituent of the vegetation cover. The dielectric properties of vegetation materials are required for remote sensing applications. The microwaves interact with biomaterials due to presence of water. In the X band water dominates the dielectric properties of leaves. The dielectric properties of the leaves due to presence of water in varying quantities can be detected using microwave methods [1,2]. For studying vegetation canopy, surface and deep soil, microwaves are used [3 – 5]. The microstrip components being in planer form can offer an alternative compact device for biomaterial studies. The use of overlay technique [6, 7] offers further planarization. Microwave transmission lines are extensively used in microwave circuits because they can be fabricated easily by employing printed circuit techniques [8]. Microstrip patch antenna is one of the important microstrip component. Leaves form a major portion of the vegetation available. In remote sensing, these form a canopy when viewed from above. How the microwave transmission is affected by the changes in the leaves is a very important aspect. In this paper efforts have made to study the effect of Ficus Benghalensis leaf conditions on the properties of the microstrip patch antenna.

II. EXPERIMENTAL

The microstrip rectangular patch antennas were fabricated using thick and thin film technology. The thick film technology used was screen printing. The metallization used was silver. The thickness of the thick film was ~ 10 µm. For thin film technology, the metallization used was copper which was deposited on precleaned alumina substrates of size 1″ x 1″ x 0.025″. Vacuum evaporation + electroplating were used to deposit copper thin film of 4 – 6 µm thickness. The transmission was measured point by point in the frequency range 8 - 12 GHz. Ficus Benghalensis leaf was used as overlay. For in touch overlay the leaf was cut to a size of 1.5 X 1.5 cm from the centre, so that central vein was part of overlay. The experiments were conducted for fresh leaves, after 24 hours and 48 hours drying of leaves in air. Two types of measurements were done- 1) USP: Upper surface of leaf in contact, with central vein parallel to the direction of propagation. 2) LSP: Lower surface of leaf in contact, with central vein parallel to the direction of propagation.

The microstrip patch antenna was used as the transmitting antenna and pyramidal horn antenna was the receiving antenna. The distance between two antennas was 6.6 cm which ensured the presence of far field region. The radiated output was measured in terms of voltage.

III. RESULTS AND DISCUSSION

3.1 Microstrip patch antenna without overlay

Figure 1 and Figure 2 shows the characteristics of thick and thin film antenna without leaf overlay. The thick film patch antenna shows resonance peak characteristics at 10.4 GHz having 27.2 mV. There is another small peak at 9 GHz having output voltage of 14 mV. The thin film patch antenna shows single resonance peak characteristics at 10.4 GHz having output voltage of 36.6 mV.

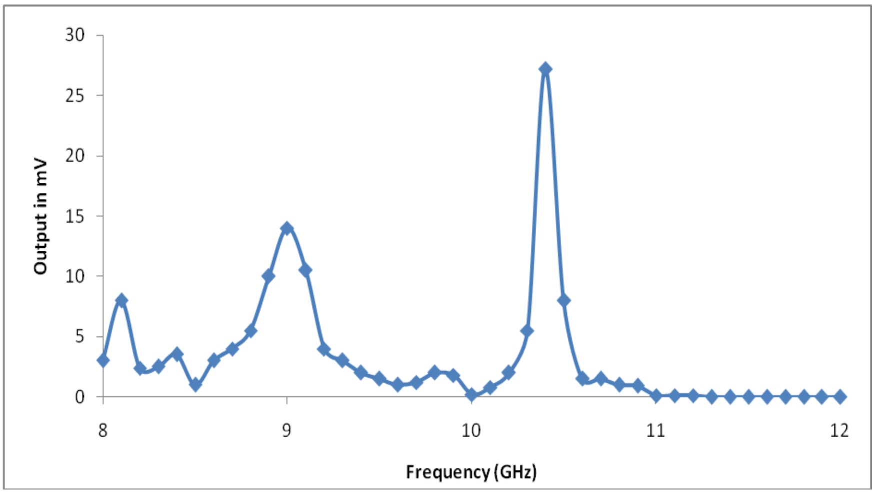

Fig. 1 Thick film microstrip patch antenna without overlay

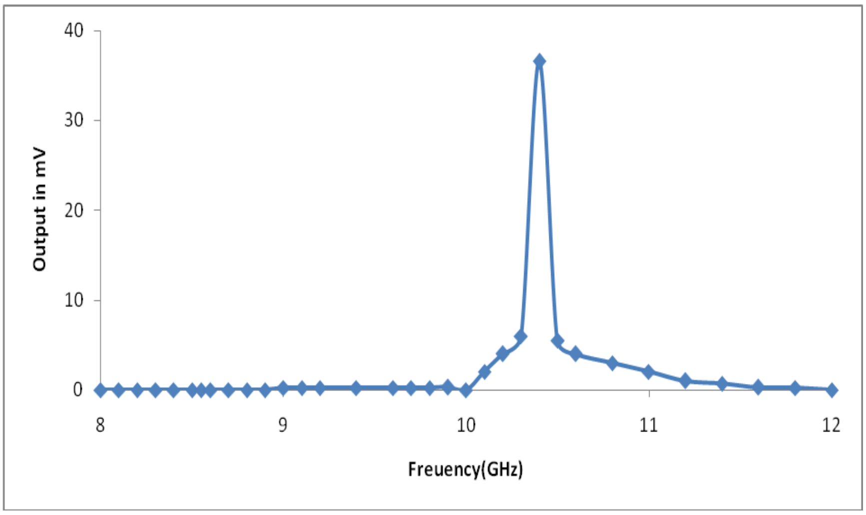

Fig. 2 Thin film microstrip patch antenna without overlay

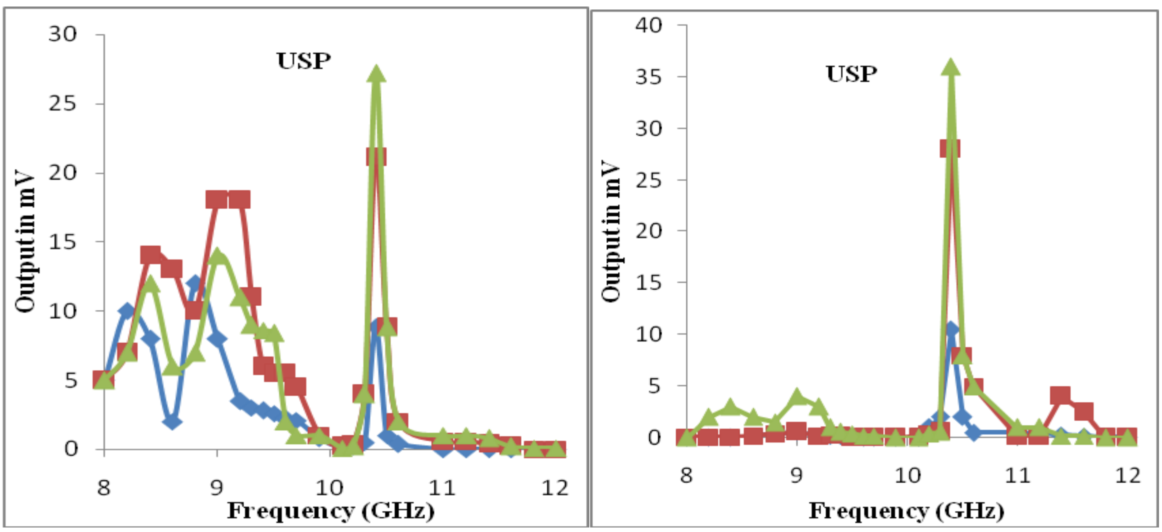

Fig. 3 Thick and thin film microstrip patch antenna with Ficus Benghalensis leaf overlay in USP position

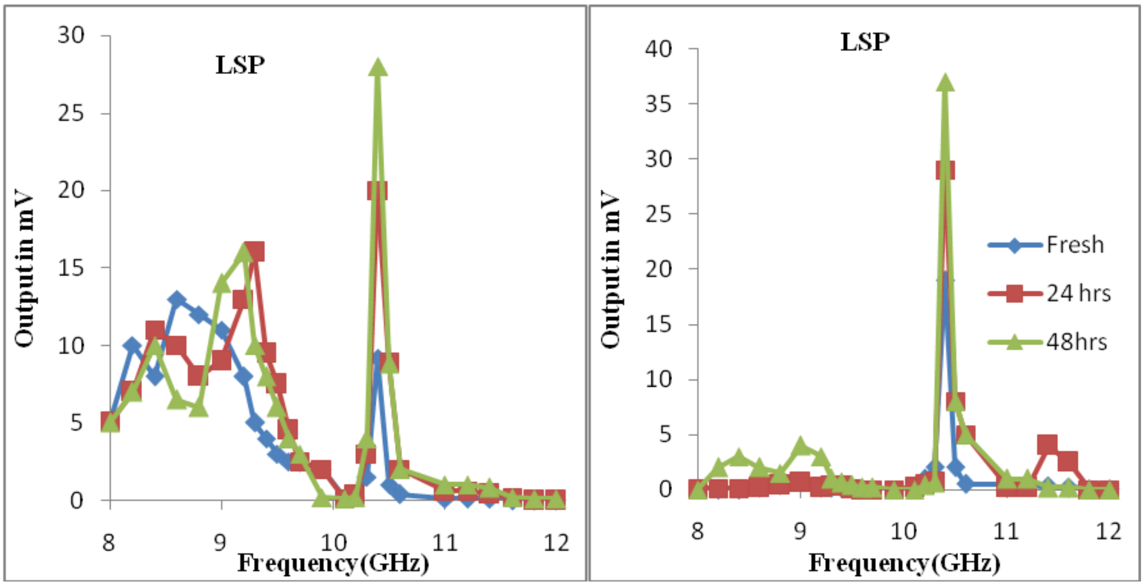

Fig. 3 Thick and thin film microstrip patch antenna with Ficus Benghalensis leaf overlay in LSP position

3.2 Thick and Thin film patch antenna with Ficus Benghalensis leaf overlay

Figures 3 and Figure 4 gives output characteristics of thick and thin film microstrip patch antenna with Ficus Benghalensis leaf overlay. Due to fresh leaf overlay in both positions, the output decreases considerably in the resonance region both for thick film and thin film antenna. The off resonance output has not changed due to the overlay. Due to drying of the leaf the output at resonance increasers and reaches the no overlay value after 48 hours. In the frequency range between 8 – 9.5 GHz for the thick film antenna, the initial peak at 9 GHz shifts to ~8.8 GHz due to fresh leaf overlay also increases the output in this frequency range and there is a tendency for the peak to broaden. The data of output voltage (at resonance) and Q values are given in table 1 below.

Table 1: Data of output voltage and Q values

Leaf condition	Thick film		Thin film	
	Output voltage mV	Q	Output voltage mV	Q
USP				
Fresh	7.3	92.4	10.6	115.5
24 hrs.	21.4	92.4	27.6	102.7
48 hrs.	26.2	92.4	35.8	115.5
LSP				
Fresh	7.1	115.5	17.8	102.7
24 hrs.	19.3	115.5	27.8	84
48 hrs.	26.6	115.5	36	92.4

When overlay is kept in touch with the antennas, it is the radiated field which interacts with the overlay. The amount of water in the leaf is a dominant factor dictating the dielectric behavior of the leaf. Water has the complex permittivity therefore the permittivity of the leaf is the effective complex permittivity of the mixture $\varepsilon^* = \varepsilon_r' - j\,\varepsilon_r''$ This indicated the wave matter interaction and can be considered as the electrical signature of the material.

The real part of permittivity of pure water is ~60 at 10 GHz but the imaginary part increases in the microwave range and attains maximum value at ~ 20 GHz. The leaves have complex dielectric constant, with real part depending on the phase and imaginary part on amplitude change, the formula suggested by Gouker et al [9] was used to calculate the amount of phase change due to overlay. Using the expression of Kim et al [10], the value ε'and ε'' have been calculated. The following formulae were used.

$$\varepsilon'_{eff} = \varepsilon' = \left(1+\frac{\Delta\phi\lambda_0}{360d}\right)^2$$

$$\varepsilon''_{eff} = \varepsilon'' = \frac{\Delta A\lambda_0\sqrt{\varepsilon'}}{8.686\pi d}$$

From the calculations one can obtain the complex effective permittivity of the leaf as $\varepsilon_{eff}^* = \varepsilon_{eff}' - j\varepsilon_{eff}''$. This represents the wave matter interaction and can be considered as the electrical signature of the material. The real part ε_{eff}' indicates the ability of the material to store energy from the field of the electromagnetic wave and the imaginary part ε_{eff}'' indicates the ability of the material to dissipate energy. Both entities are dependent of frequency, bulk density, moisture content, temperature and composition.

The data of ε' and ε'' for the various leaves after keeping as overlay on thick and thin film microstrip patch antennas are given in table 2.

Table 2: Data of Dielectric constants of the Ficus benghalensis leaf for different conditions

ε_{eff}	$\Delta\varphi$	ε'	**Leaf condition**	**ε'' at resonance**	
				Thick film	**Thin film**
68	123.3	124.8	**Fresh**		
			USP	296.4	188.8
			LSP	326.7	126.7
30.78	94	76.6	**24 Hrs.**		
			USP	156.3	68.8
			LSP	165	68.8
21.6	79.12	56.7	**48 Hrs.**		
			USP	115.8	40.1
			LSP	115.8	40.1

As exected the ε' (real part) is more for fresh leaf and becomes lesser as the leaf dries. The moisture content in fresh Ficus benghalensis leaf was 72 %, after 24 hours it was 54.3% and after 48 hours it was 28.49%. As leaf dried, the value **ε**'' decreases. From this data it is seen that the metallization dependent changes in **ε**'' is obtained. The large changes obtained in **ε**'' due to fresh leaf might be due to contribution of free water and also the physically bound water in the leaf. The chemically bound water might still remain in the leaf even after 48 hours drying which might be the reason why ε' and ε''of dry leaf does not attain the dry matter values. It has been reported that [11] a change of about 8% in moisture content produces on average a variation of 120 % for ε_{eff}''. The values of ε' and ε'' obtained for the Ficus Benghalensis leaf shows very high % change of ε'' with water.

IV. CONCLUSION

The sensitivity to overlay condition of Ficus Benghalensis leaf overlay at different conditions is almost similar in both thick film and thin film components. The sensitivity of thick film patch antenna is more. Thick film antennas have been proved very useful for sensing moisture status of the leaves.

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International Journal of Computational Engineering Research (IJCER) is UGC approved Journal with Sl. No. 4627, Journal no. 47631.

Rajesh Ajit Ghorpade. “Effect of Ficus Benghalensis leaf overlaid on thick and thin film Microstrip patch Antenna.” International Journal of Computational Engineering Research (IJCER), vol. 7, no. 8, 2017, pp. 95–98.