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Thick And Thin Film Microstriplines For Sensing Moisture In Croton Leaf Overlay

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Abstract: *Thick and thin film microstriplines have been used to investigate the effect of leaf moisture on their response.The results reported in this paper are in the form of study of Ku band response of the simple microstriplines. The overlay technique was used. An approximate estimate of the effective dielectric constant of the leaf has been made using overlay technique. It is felt that both thick and thin film microstriplines can be used to monitor the moisture status of leafy vegetation in Ku band frequency range.*

***Keywords**: Microstriplines, thick film, thin film, leaf moisture,Ku band.*

I. Introduction

Microwaves interact with biomaterials because of presence of water in almost all of them, offering a variety of applications. For remote sensing applications of vegetation cover and water content measurement, the precise dielectric properties of the vegetation materials is required. Several authors [1, 2] have attempted to study the vegetation materials as a function of moisture content at microwave frequencies. The moisture content of materials is an important parameter in industrial and research applications. The numbers of techniques have been used for determining the quantity of water. Various attempts have been made to correlate the electrical properties of agricultural products with moisture content. Microwave techniques are attractive because at these frequencies the electrical energy is strongly absorbed by water due to dipole character of water molecules. Recent developments of reliable low cost and reduced size microwave components make microwave methods competitive with other techniques. The microstrip components being in planer form can offer an alternative compact device for biomaterial studies. The use of overlay technique [3, 4] offers further planarization. Microwave transmission lines are extensively used in microwave circuits because they can be fabricated easily by employing printed circuit techniques [5].

II. Experimental

The microstriplines 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 13.4 – 18 GHz. 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. Six 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. 3) USPR: Upper surface of leaf in contact, with central vein perpendicular to the direction of propagation. 4) LSPR: Lower surface of leaf in contact, with central vein perpendicular to the direction of propagation. 5) USMA: Upper surface making angle 45° with the main strip. 6) LSMA: Lower surface making angle 45° with the main strip.

III. Results And Discussion

The transmittance characteristics of thick and thin film microstriplines in the Ku band is shown in Fig. 1 and 2.

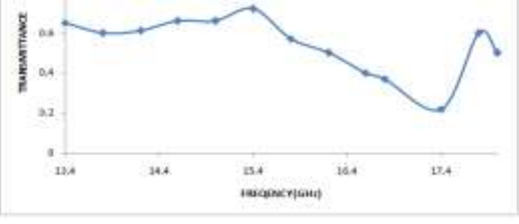

Fig. 1: Characteristic of thick film microstripline without overlay.

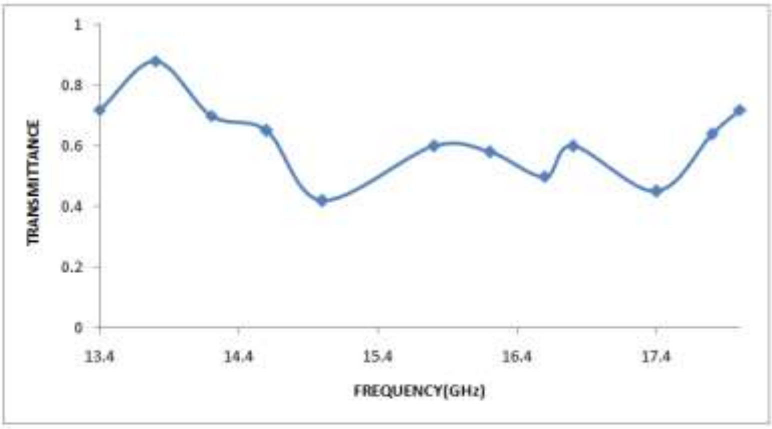

Fig. 2: Characteristic of thin film microstripline without overlay.

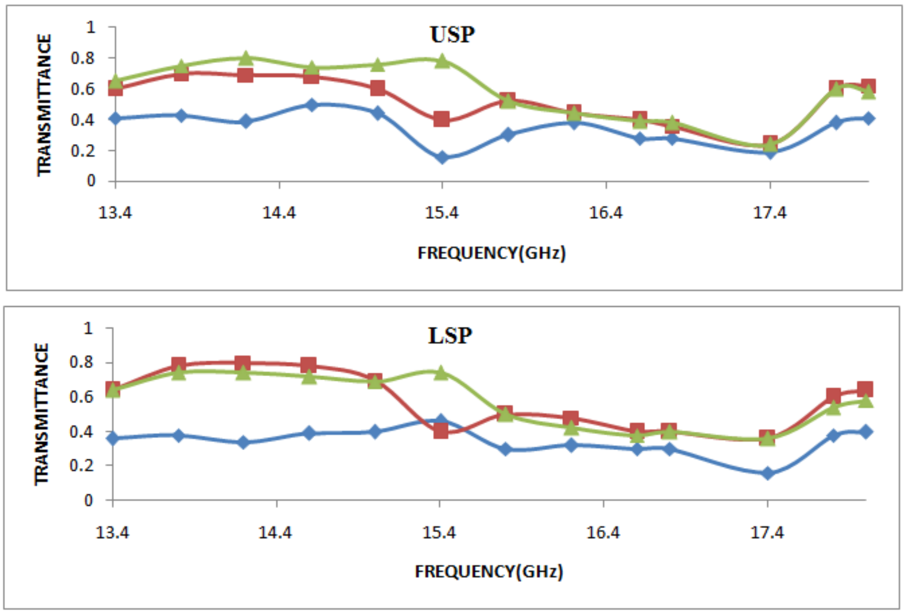

Fig. 3: Thick film microstriline with croton leaf overlay.

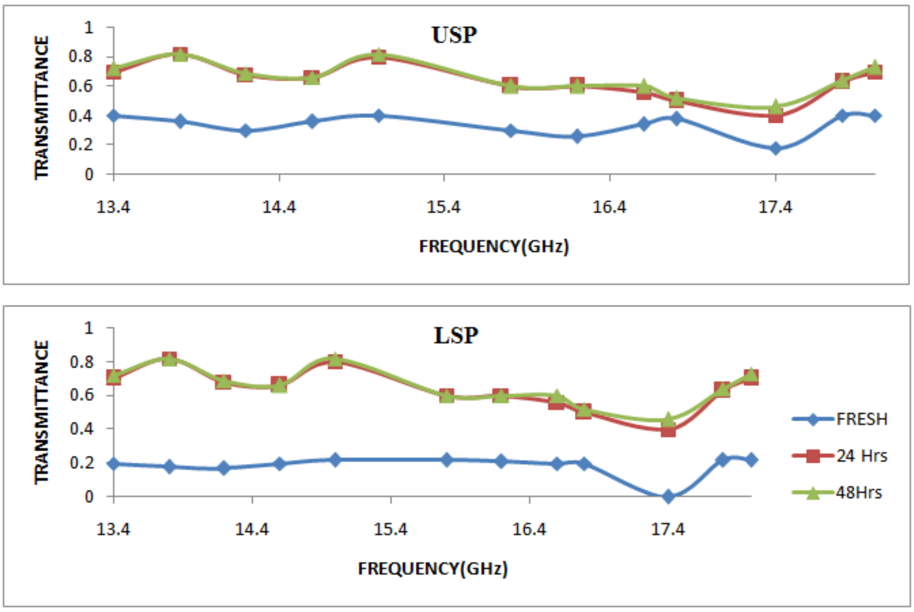

Fig. 4: Thin film microstriline with croton leaf overlay.

The average transmittance for thick film microstriline is ~0.52 and for thin film microstriline it is ~0.64. The transmission shows decreasing tendency up to 17.4 GHz. Fig. 3 and 4 shows the effect of Croton on thick and thin film microstriplines respectively. When fresh Croton is kept, in both USP and LSP positions the transmittance decreased. After 24 hours and 48 hours drying of leaf, the curves are similar to no overlay position. The data of transmittance at different frequencies for other positions is shown in table 1.

TABLE 1: Transmittance data of thick and thin film microstriplines

Sr. No.	LEAF CONDITION	TRANSMITTANCE			TRANSMITTANCE		
		THICK FILM			THIN FILM		
		13.4 GHz	15.4 GHz	18 GHz	13.4 GHz	15.4 GHz	18 GHz
01	**USPR**						
	Fresh	0.4	0.12	0.4	0.4	0.42	0.4
	24 hours	0.59	0.62	0.54	0.7	0.78	0.7
	48 hours	0.62	0.72	0.53	0.7	0.76	0.66
02	**LSPR**						
	Fresh	0.44	0.52	0.34	0.56	0.6	0.48
	24 hours	0.62	0.6	0.56	0.72	0.8	0.72
	48 hours	0.62	0.7	0.52	0.72	0.78	0.7
03	**USMA**						
	Fresh	0.3	0.1	0.3	0.3	0.32	0.28
	24 hours	0.56	0.6	0.52	0.7	0.7	0.68
	48 hours	0.62	0.7	0.52	0.7	0.8	0.66
04	**LSMA**						
	Fresh	0.4	0.48	0.28	0.48	0.48	0.46
	24 hours	0.62	0.48	0.56	0.76	0.82	0.76
	48 hours	0.6	0.72	0.56	0.74	0.82	0.76

From the table it is seen that, almost for all positions the transmittance decreases when fresh leaf was overlaid. As leaf dries, the transmittance increases.

Leaves are a major constituent of many types of plants. Leaf is heterogeneous media consisting of components with different dielectric behaviours. Leaves are basically water loaded materials. The amount of water in the leaf is a dominant factor dictating the dielectric behaviour of the leaf. Water has the complex permittivity therefore the permittivity of the leaf is the effective complex permittivity of the mixture $\varepsilon^* = \varepsilon_r' - j\,\varepsilon_r''$. The complex permittivity is a measure of the ability of a material to polarize when subjected to an electric field. At microwave frequencies moisture in most substances plays a major role in the polarization phenomenon. The water in the leaves can be either in free State or in bound state. Water in its free liquid state appears very rarely in agricultural products. It is mostly physically absorbed in the capillaries or cavities or chemically bound to other molecules of the material [6]. In the Ku band, the water dominates the dielectric properties of the leaves. Water in the vegetation material is generally found at different binding modes depending on the intensity and nature of the forces acting on water molecules. The propagation of bound and free form is very difficult to determine. The physically bound water is present with leaf throughout its volume either in absorbed or in adsorbed state. It is possible to excite rotational energy level in the water molecule and achieves an energy based attenuation of the microwave signal proportional to the amount of water present. The chemically bound water forms part of the crystal lattice or its hydrogen bonds to another charged species. In this case the microwave beam is not able to make the molecule spin and is not of sufficient energy to break the molecule free from its bond.

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 [6] was used to calculate the amount of phase change due to overlay. Using the expression of Kim et al [7], the value ε' and ε'' have been calculated. The following formulae were used.

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

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

The data of ε_{eff}' and ε_{eff}'' for the various leaves after keeping as overlay on thick and thin film microstriplines are given in table 2.

Table 2. Data of permittivity

ε_{eff}	$\Delta\varphi$	ε_{eff}'	**Leaf condition**	**ε_{eff}'' at 15.4 GHz**
76.6	126.5	130.8	**Fresh** USP,LSP,USPR,LSPR,USMA,LSMA	**Thick film** 159.6,45.4,190.8,32.1,210,40.8 **Thin film** 33.9,84.1,14.1,24.5,43.6,31.2
28.2	91.3	72.9	**24 Hrs.** USP,LSP,USPR,LSPR,USMA,LSMA,	**Thick film** 45.2,37.5,9.8,12.4,12.4,- **Thin film** 28.4,41.5,39.4,41.5,30.7,43.5
17.5	68.6	44.4	**48 Hrs.** USP,LSP,USPR,LSPR, USMA,LSMA	**Thick film** 1.7,1.8,1.79,0.01,0.01,1.79 **Thin film** 24,32.4,29.1,30.8.32.4,33.9

The high value of ε_{eff}'' indicating the circuit become very lossy because of the leaf. As leaf dries the transmittance increases.

IV. Conclusion

The overlay technique offers a useful and easy mode for the measurement of properties of materials in the microwave range of electromagnetic spectrum. Microstrips offers an open structure, the easy loading and unloading of the sample is possible as against the conventional resonant cavities. Since the leaf touched the microstriplines (thick and thin film), surface dependent and orientation dependent effects are observed. The high value of ε_{eff}'' indicating the circuit become very lossy because of the leaf. As leaf dries the transmittance increases.The sensitivity to overlay conditions are almost similar in both thick and thin film microstriplines.The ε_{eff}'' values are different when calculated , means the circuit show different reactions to variations in the moisture content of the leaf overlay. Both thick and thin film microstriplines have been proved very useful for sensing the moisture status of Croton leaf.

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