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Microstrip losses with Al_2O_3 overlay

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Abstract. Microstriplines were coated with Al_2O_3 by chemical vapour deposition to get homogeneous thin film overlay. The paper reports the decrease in the total power loss in such microstrips. The frequency response from 2–6 GHz is studied for the overlay effect.

Keywords. Microstrip; attenuation; microwave power; overlay; aluminium oxide; chemical vapour deposition.

1. Introduction

Open microstrip is the most convenient type of transmission line for fabricating hybrid and monolithic microwave integrated circuits (MICs). This inhomogeneous, open structure has quasi-TEM mode of propagation with electric lines of force dispersing into air which contribute to radiation losses. Pucel *et al* (1968) has given an expression for conductor and dielectric losses of microstrips. Denlinger (1969) expressed radiation loss from microstrip resonator as a function of effective dielectric constant (ε_{eff}), substrate thickness (h) and a free space wavelength (λ_0). The ε_{eff} depends on the substrate dielectric constant and the distribution of field between substrate and air. This distribution is a function of frequency due to contribution of higher order modes propagating which are unavoidable because of its structure (Young and Sobol 1974).

The fringing fields from microstrip are often used for coupling the power between two close-by strips. The dielectric overlay technique can be used to improve the coupling and directivity as analyzed by Haupt and Delysh (1974), Speilman (1974) and Lee (1974). Speilman (1974) reported theoretical analysis for machined alumina stuck on overlay on the alumina substrate; this study of course cannot be directly applied to thin film overlay. Experimental observations on thin film overlay of nicrome (Weirather 1974) and Bi_2O_3 (Karekar and Pande 1976) have been reported, the latter showing an improvement in the quality factor (Q) of rejection filter. Both the overlays are inhomogeneous with Al_2O_3 substrate.

Only thin film Al_2O_3 overlay can give a near homogeneous structure which is reported in this study. The improvement in the parameters of microstrip resonators and couplers can be analyzed if the effect of overlay on parameters of a single microstrip (like characteristic impedance (Z_0), attenuation and radiation) is known. The total loss of power which includes attenuation and radiation is studied here using transmission and return loss observations, with swept frequency techniques (2–6 GHz) using WILTRON, computer-aided scalar network analyzer. The effect of overlay on total loss is studied and is further analyzed to distinguish between the effect of overlay on reducing radiation and the effect giving better matching due to Z_0 changes.

2. Experimental

Alumina substrates (1 inch × 1 inch Alsimag 772) were locally metallized (at IIT, Bombay) by Cr-Au successive vacuum evaporation. The thickness of gold film was then increased by electroplating upto 8 μ. The three masks for three-line patterns and one mask for five-line pattern were prepared and photolithographically delineated on the substrate. For each mask three sample sets were taken, out of which sixteen lines could be finally used for this experiment. The Al_2O_3 homogeneous overlay was deposited on these patterns by metal organic chemical vapour deposition (MOCVD). The MOCVD system consisted of a resistively heated horizontal flow system (Dhanvantri *et al* 1985). Aluminium isopropoxide was used as a reactant material. The thickness of the overlay was kept constant at nearly 3000 Å. The microwave measurements of transmission and return loss (RL) were performed on a WILTRON network analyzer with an HP-85 microcomputer for correcting the system errors. This gives high accuracy of 56 dB ± 1·5 dB (i.e. the limiting power level is about $\pm 10^{-6}$ mW).

3. Results and discussion

Figure 1 shows a typical transmission and return loss curves before and after overlay, measured using the same connectors, transitions and other components. The average improvement in transmission measured for 16 lines is 0·3 dB over the frequency range of 2–6 GHz. For the same samples and frequency range the average decrease in RL is 5·6 dB which is further used to calculate the power reflection coefficient (ρ^2).

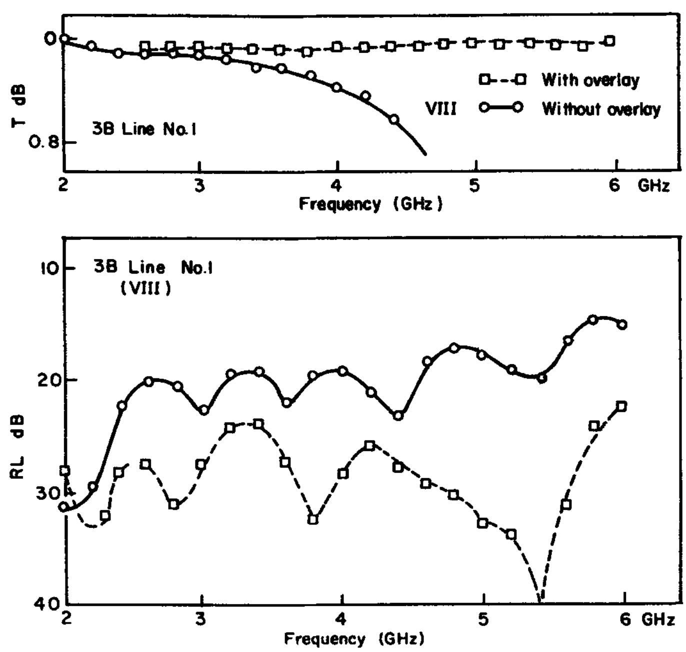

Figure 1. Typical transmission and return loss curves with and without Al_2O_3 overlay.

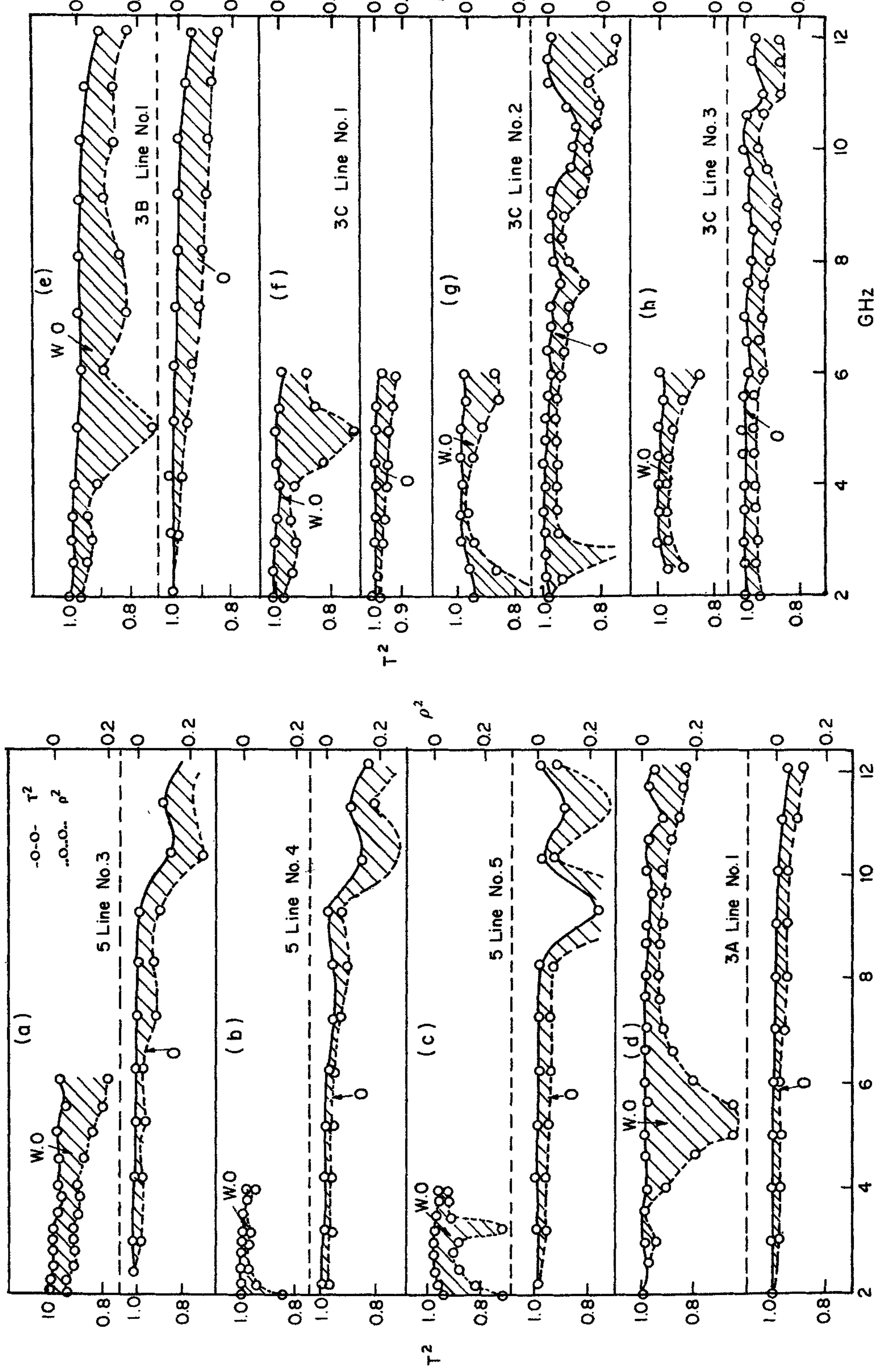

Figure 2. Variation of power reflection (ρ^2) and transmission (T^2) coefficients with frequency. The shaded area shows total loss of power with (O) and without (W.O.) overlay.

The variation of transmission and RL with frequency show resonant dips at harmonic frequencies. Though the coupling effects are not analyzed in detail, the amplitudes of dips decrease with overlay. The complete data of eight different microstrip widths for ρ^2 and T^2 with and without overlay are given in figure 2, where the shaded portion shows the relative power loss ($1-\rho^2-T^2$). Table 1 gives the corresponding average decrease in the loss due to Al_2O_3 overlay but no specific relationship between percentage loss and strip width is observable. Further the decrease, which is present at all frequencies between 2 and 10 GHz, is more prominent at higher frequencies (in some cases where the readings are available). On an average the decrease is 1·7% at 4 GHz and 8·8% at 6 GHz indicating better wide band operations. The results are sometimes over shadowed due to the coupling between neighbouring parallel lines.

The decrease in total loss of power from microstrip leads to increased transmission of power, whereas increase in the return loss (i.e. reflection coefficient) indicates change in Z_0. Characteristic impedance given by $1/V_pC$ is therefore affected by change in effective permittivity. Our observations show increase in transmitted power (T^2) by about 5% and decrease in the reflected power by about 0·8% at 3 GHz. These figures indicate that the increase in transmission is mainly due to the decrease in microstrip losses. If the change in ρ^2 is comparable to the change in transmission (T^2) then it can be attributed to the improvement in matching, which is not the case. Thus the decrease in total loss is attributed to the following phenomenon.

When a homogeneous overlay is placed on a microstrip substrate a layer of air is replaced by the Al_2O_3 thin film. Thus the propagation mode will tend to move from quasi-TEM towards TEM propagation, reducing the surface mode or other higher order modes, due to increased homogeneity of the medium. Secondly, the fringing field otherwise dispersing in air will be compressed, to some extent, into the overlay region because of its high permittivity. Hence the radiating fields will be confined more to the overlay dielectric region which may have manifested in the observed reduction of radiation loss (particularly because the dielectric and conductor losses cannot be expected to decrease with overlay (Pucel *et al* 1968)). Denlinger (1969) predicted a similar decrease in the radiation loss with increase in the effective permittivity. The reported change in ε_{eff} for Bi_2O_3 overlay is 0·9 for the thickness of

Table 1. Actual line widths and average percentage loss for the samples at 4 and 6 GHz.

Width W (cm)	Decrease in percentage loss $(1-\rho^2-T^2)\times 100\%$	
	4 GHz	6 GHz
0·057	4·5	15·0
0·050	−2·0	9·0
0·052	1·0	4·0
0·054	5·0	2·0
0·062	0·0	8·0
0·064	3·5	15·0
0·066	1·0	–
0·069	0·5	–

1·3 μ (Pande 1976). The change in percentage radiation loss is about 1–2% for this change in ε_{eff}, which can be considered as the maximum limit of change in percentage radiation in our study. Hence the rest of the average decrease in loss, especially at a higher frequency, may be attributed to the change in the propagation mode.

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References

Dhanavantri C, Karekar R N and Rao V J 1985 *Thin Solid Films* **127** 85

Denlinger E J 1969 *IEEE Trans. Microwave Theory Tech.* **17** 235

Haupt G and Delysh H 1974 *Electron. Lett.* **10** 142

Karekar R N and Pande M K 1976 *IEEE Trans. Microwave Theory Tech.* **24** 262

Lee Y S 1974 *IEEE Trans. Microwave Theory Tech.* **22** 66

Pande M K 1976 *Studies on microstrip circuits with special reference to thin film Bi_2O_3 overlay* Ph.D. Thesis, University of Poona, 142

Pucel R A, Masse D J and Hertwig C P 1968 *IEEE Trans. Microwave Theory Tech.* **16** 6

Spielman B 1974 *Analysis of Electrical characteristics of edge-coupled microstriplines with a dielectric overlay* NRL Report 7810

Weirather R R 1974 *IEEE Trans. Microwave Theory Tech.* **22** 71

Young L and Sobol H (eds) 1974 *Advances in microwaves* (New York: Academic Press) Vol. 8, p 121