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Investigation of a simple Model for Conductor loss calculations in Microwave Range for TFML on Polyimide substrate

[1]Ritu Bansal, [2]Sanjay Kumar Mishra

[1]Assistant Professor, [2]Professor
[1]Department of Electronics,
[1]ARSD College, Delhi University, India

Abstract: This paper presents an investigation of a simple model given in literature to detrrmine conductor loss of thin film microstrip line structure on Dupont PI- 2611(Polyimide).The analytical results are compared with simulator and measured results. The model is in good agreement with experimental results. The presented model is investigated in 1-110 GHz frequency range.

Index Terms - Thin Film Microstrip Line(TFML), Microwave range, Conductivity, Conductor loss

1. INTRODUCTION

In today's world MIC and MMIC are much in demand due to its small size, fast speed and durability. Hence it is desired to minimize the losses in small size modules.

Wireless Communication, personal communications, direct broadcast television, local multipoint distribution systems (LMDS), and many more industries are relying on small, low cost RF and microwave components. This has led to the increased use of multichip modules (MCMs) that incorporate analog and digital circuits within a single package. Although conventional microwave transmission lines and control lines on ceramic substrates with wire bonds can be used in MCMs, this does not lead to either low cost or smaller components. Instead a preferred approach is to integrate all of the circuits together onto a single carrier substrate i.e. GaAs, Si and Alumina using Thin Film Microstrip lines (TFML) and small via holes. This increases the packaging density within MCM and decreases the parasitic reactances compared to conventional circuits.

Typical substrate height in TFMS is from 1 to 25 um, whereas in conventional lines it is from 100 to 500 um (Generally). The most common dielectrics used in MMIC are Polyimide [1], BCB (bis-benzocyclobutene) [2], SiON those having low dielectric constant of 3, 2.7 and 5 respectively compared to 9.9, 11.9 and 12.9 for Alumina, Si, GaAs respectively used in conventional Microstrip lines. Typically conductor thickness is $t \leq 1.5$ um and lastly line width is in the range of 1um to 40 um usually. These dimensions are desirable in small size modules.

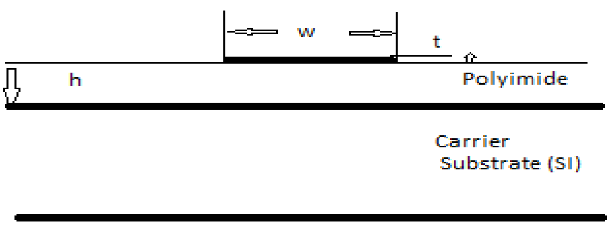

Figure 1: Schematic of TFMS

2. Conductor loss Model

There are saveral type opf losses in Microsrip line i.e. Conductor loss (loss due to Conductor strip), Dielectric loss(loss due to lossy dielectric), surface wave loss and Radiation loss etc. Among these Conductor loss and dielectric losses are significant. Out of which Conductor loss is dominant and contributing for about 90% of the total loss. That's why we have investigated a simple formula given in literature[3] (given in (1)) to account for conductor loss of Thin Film Microstrip Line (TFML). Moreover this Formula requires critical calculations of stopping distance of conductopr stip[4]. In various research papers you can find various closed form formulas for conductor loss but this formula is simple in a way as no trigonometric function and no complex quantity. In literature this formula is given for conventional Microstrip lines but as this formula gives less value in camparison to measured conductor loss hence it was modified by reaserchers[4](given in (2)). We have also used those closed form formula earlier for TFML for calculating loss in terahertz range.

Investigated Formula:

$$\alpha_c = \frac{27.3\,\sqrt[2]{\epsilon_{reff}}\;\delta_s}{\lambda_o h} \quad dB/legnth$$

$$Where\ \delta_s = \sqrt{\frac{2}{\omega\sigma u_o}} \qquad (1)$$

Earlier Formula:

$$\alpha_C = \frac{R_{SM}}{2\pi^2 Z_0 W}\ln\left(\frac{W}{\Delta}-1\right) \quad \mathrm{Np/m}$$

where

$$R_{SM} = \mu_0 \omega t\,\mathrm{Im}\left(\frac{\cot(k_C t)+\csc(k_C t)}{(k_C t)}\right) \qquad (2)$$

$$k_C = \omega\sqrt{\mu_0\varepsilon_0}\left[1 - j\frac{\sigma_C}{\omega\varepsilon_0}\right]^{1/2}$$

Where Δ is stopping distance

3. Thin Film Conductivity

The conductivity of thin film is less in comparison with Bulk or thick film at the same temperature [5]. This could be understood in a manner that bulk conductivity is more due to more no. of electron density than that of thin film of any metal hence at any frequency at same temperature conductivity will be less for thin film. When we draw a plot of conductivity versus frequency for thick film or bulk metal would show decrease with frequency, whereas when we draw a plot of conductivity of Thin Film versus frequency would show increase with frequency [6]. More recently such conductivity increase with frequency has been measured for the thin gold film (9 -20nm) on 0.04mm thick Kapton substrate in the X-band [7]
Dispersive coductivity of thin film, we have also taken into account. We know bulk Conductivity of Gold is 4.5×107 at 295k temperature. But thin Gold film static conductivity will be less at the same temperature. As frequency increases conductivity of thin film shows a slight incraese with frequency (3), the equation for dispersive Conductivity is suggested by Konno[6]. We have used the highly accurate Hammerstad and Jensen model [8] to compute the static effective relative permittivity and Kirschinning and Jensen model [9] model for dispersive effective relative permitivity are given below.

$$\sigma_c(f) = \sigma_0(f)\sqrt{(1 + C_0\, f_{GHz}} \qquad (3)$$

$$\varepsilon_{r\,eff}(w/h, \varepsilon_r) = 1 + q(\varepsilon_r - 1) \qquad (4)$$

Where ϵ_r is relative permittivity of the substrate and the filling- factor q of the microstrip line is given below.

$$q = \frac{F+1}{2}, \quad F = \left(1 + 10\frac{h}{w}\right)^{-ab} \qquad (5)$$

Where

$$a = 1 + \frac{1}{49} \ln\left(\frac{\left(\frac{w}{h}\right)^4 + \left(\frac{w}{52\ h}\right)^2}{\left(\frac{w}{h}\right)^4 + 0.432} \right) + \frac{1}{18.7} \ln\left(1 + \left(\frac{w}{18.1h}\right)^3\right)$$

$$b = 0.564 \cdot \left(\frac{\varepsilon_r - 0.9}{\varepsilon_r + 3}\right)^{0.053}$$

Kirschning and Jansen dispersion model is given below

$$\varepsilon_{r\,eff}(f) = \varepsilon_r - \frac{\varepsilon_r - \varepsilon_{r\,eff}\left(\frac{w}{h}, \varepsilon_r\right)}{1 + P\left(f_{GHz}, \frac{w}{h}., \varepsilon_r\right)} \quad (6)$$

Where, P is the curve fitted parameter, dependent upon w_{eff}/h, ε_r, t and frequency. Further details of P are given in [9].

However Konno suggested the value of Co=0.045 in Terahertz frequency range, but due to more desire for MICs (Microwave Integrated Circuits) in Microwave range. Thus we investigate this simple conductor loss formula with dispersive conductivity in frequency range 1 to 110 GHz. We suggest the value of Co =0.001 for conductor loss calculation for TFML in this range

4. Results

We have done investigation for TFML on Polyimide substrate having relative permittivity 3.12 of 4.35 um thickness and strip width is varied from 5, 7.1, 9.5, 12.5, 16.4, 21.7 and 34.4 um. We have separated the conductor loss from measured loss by taking % contribution of conductor loss in structures on simulator [10].

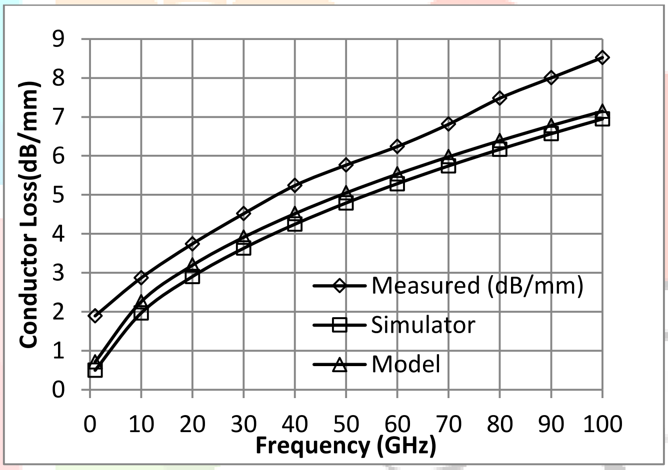

Fig1 Conductor loss for w=5um

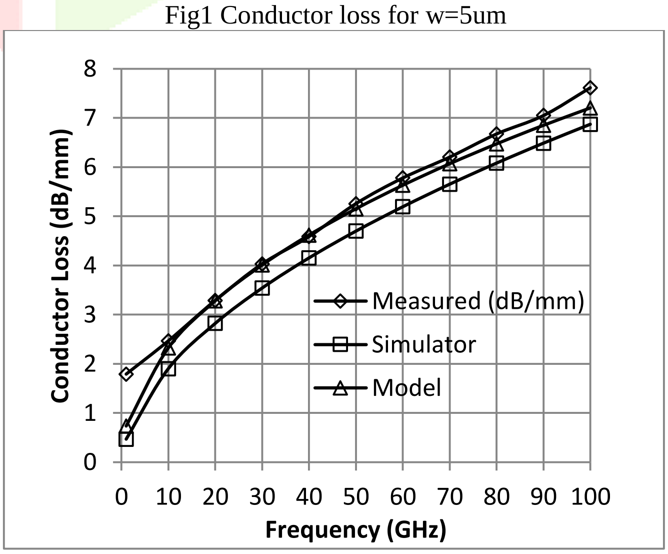

Fig2 Conductor loss for w=12.5um

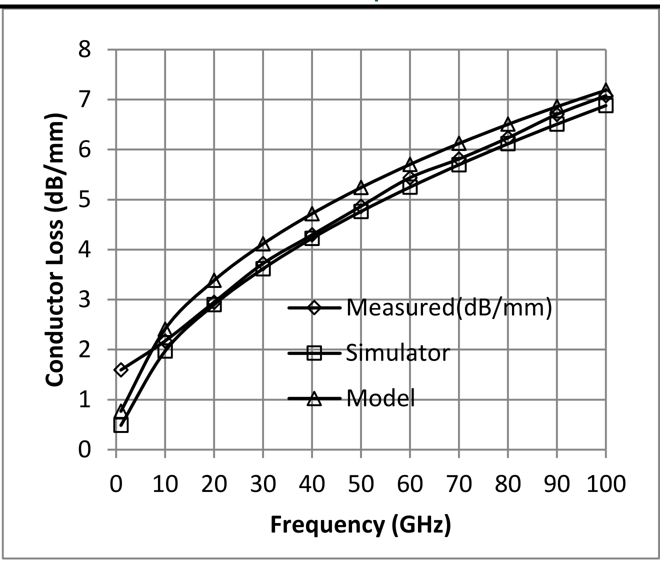

Fig3 Conductor loss for w=34.4um

This paper presents results for strip widths i.e. w=5um in figure (1), w=12.5 um in figure (2) and w=34.4 um in figure (3) with strip thickness 1.3 um on dupont PI-2611(Polyimide) substrate.

5. CONCLUSION

We have presented an investigation of a simple formula for conductor loss calculation for Thin Film Microstrip line in Microwave Frequency range from 1 GHz to 110 GHz on Polyimide substrate of thickness of 4.35um having permittivity of 3.12 for strip width from 5 um to 34.4um. This has been found that this formula is in good agreement with measured results. Also one more thing we have observed here that as width is increasing, loss is decreasing and our Model also follows the same behavior.

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