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스펙트랄 도메인법을 사용한 다층 GaAs 마이크로스트립선로 해석 모델링

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Analysis of MMIC-Microstrip Line Using Spectral Domain method

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Abstract - Multilayer microstrip lines are an integral part of an MMIC. This paper presents an analysis of multilayer GaAs-MMIC microstrip line using a spectral domain method(SDM) taking into account the effect of the variation in the thickness of various layers of substrates on the characteristic impedance and the effective dielectric constant of the line. This work is expected to be useful in GaAs foundries for accurate CAD modelling of the microstrip lines up to 40 GHz.

1. introduction

MMIC technology has been quite popular since last three decades in military, space and mobile applications, due to their better performance, compactness, lightweight and high reliability. Microstrip line is used as interconnects between active and passive components and it also used as matching circuits design at higher frequency. A multi-layer microstrip line (MSL) is the presence of multiple dielectrics, such as thin layers of silicon nitride and polyimide on the GaAs substrate and again silicon nitride on the top of the strip. These additional dielectric layers have a strong influence on the field distribution at microwave frequencies thereby affecting the electrical parameters, namely the effective dielectric constant, e_{eff} and characteristic impedance of the microstrip line. Finlay and Jansen [1] have analysed the GaAs-MMIC multi-dielectric microstrip lineusing spectral domain technique (SDM), showing the variation of attenuation and effective dielectric constant for 200 μm GaAs substrate up to 24 GHz. This paper presents the theoretical analysis of microstrip line using SDM . Here, one effort has been taken to provide experimental and theoretical database for this structure.

The finite conductivity of metallic strip has been accounted in the spectral domain analysis by using the complex resistive boundary condition.

2. Theoretical Model Formulation

Spectral domain method (SDM) provides an elegant tool for the reduction of integral equations describing the electromagnetic field distribution in the devices to ordinary algebraic equations, which are amenable to computer analytical processing. Using the SDM [2,3], following electric field integral equation (EFIE) is obtained for the concerned structure shown in Fig. 1

$$([\tilde{G}(\alpha_n, \beta, \omega)] - Z_S)[\tilde{J}] = [\tilde{E}] \quad (1)$$

where $\tilde{G}$'s are the respective Fourier transformed Green's functions, $\tilde{J}$ and $\tilde{E}$ are the current density and the electric field matrices, respectively, and Z_S is the complex surface impedance that quantifies the finite conductivity of the conducting strip. It is given by the following relation

$$Z_s = \frac{1}{\sigma\delta}(1 + j) \qquad \delta = \sqrt{\frac{1}{\pi\mu\sigma f}} \quad (2)$$

where is the permeability of free space, σ is the conductivity of the metal, δ is the skin depth and f is the frequency in GHz.

Using Galerkin's technique Eq. (1) is transformed into a system of linear homogeneous equations [2]:

$$[C(\gamma)]\begin{bmatrix}[a]\\ [b]\end{bmatrix}=[0] \qquad (3)$$

where [a] and [b] are the unknown series amplitudes matrices of the basis currents.
Solving Eqn. (3) for its eigen values we get $\gamma=\beta-j\alpha$, where is the attenuation constant and β is the phase constant.

Characteristic impedance is evaluated from the following relation

$$Z_0 = P_{av} \big/ I_0^2 \qquad (4)$$

Where P_{av} is the time-average power flow along the z-axis and I_0 is the effective current flow along the z-axis on the strip. P_{av} is given by the following expression [2]

$$P_{av} = \mathrm{Re}\int_S \boldsymbol{E}\times\boldsymbol{H}^{*}.\hat{z}\,dx\,dy$$
$$= \frac{1}{2L}\sum_{-\infty}^{\infty}\left[E_{h1}(\alpha)+E_{h2}(\alpha)+E_{h3}(\alpha)+E_{h4}(\alpha)\right]$$
$$(5)$$

Where the quantities within brackets in Eqs. (5) are calculated as given in reference [2]. I_0can be obtained by integrating J_z along the z-direction. The above computation is the general solution for the geometry of the shielded microstrip line as shown in Fig.1.

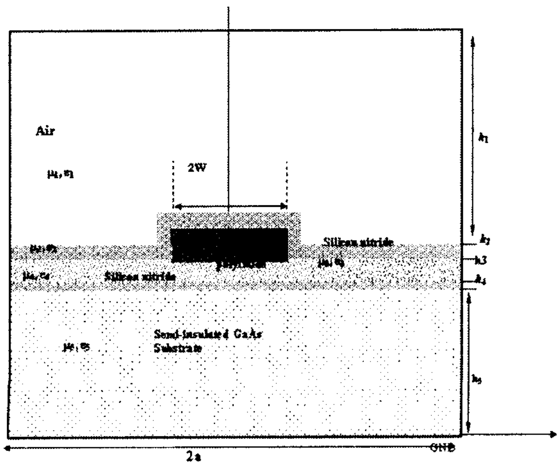
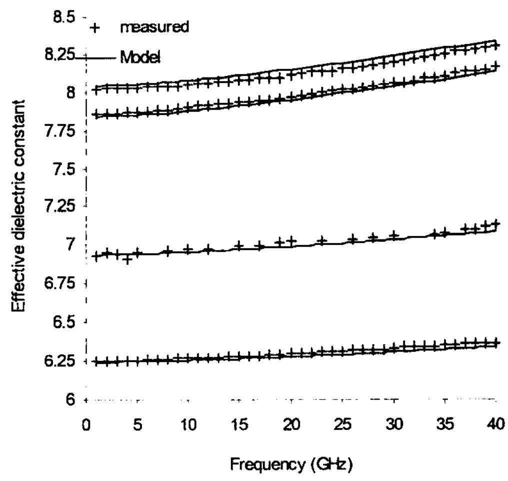


Figure1-Crosssection of multi-dielectric GaAs-MMIC microstrip line

2.1 RESULTS AND DISCUSSION

Using the theoretical formulation presented in section-IV the electrical characterization of the GaAs-MMIC multi-dielectric layers microstrip line has been carried out. The variation of effective dielectric constant and characteristic impedance of the microstrip line has been studied up to 40 GHz. The effect of shielding is negligible in the analysis as the height of the shield is taken almost 10 cm.

Figure 5 shows the variation of effective dielectric constant with frequencies for different widths of microstrip line. The cross show the measured data and solid straight line shows the modeled data of the characteristic impedance 42, 44, 74 and 102 Ω . These figures show good matching between measured and modelled result within 2% accuracy.



resistance Ω, (dielectric constant)
42(8~8.25),44(7.85~8),74(6.9),102(6.25)

Figure 2 Variation of effective dielectric constant with frequencies

3. CONCLUSION

A detailed characterization of multi-dielectric GaAs-MMIC microstrip lines has been carried out using SDM. The theoretical results have been compared with measured data. The measurements have been based on an accurate characterization of the microstrip line parameters at high frequency. The theoretical model predicts the frequency-dependent transmission-line parameters quite accurately over a very broad frequency range of 1 to 40 GHz. This database is expected to be useful in many GaAs foundries for microstrip line modelling up to 40 GHz.

Referances

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