平面波導之特殊基板及電磁干擾

On Special Substrate and Interference of Planar Waveguides

計畫編號: NSC 89-2213-E-002-101
執行期限: 88 年 8 月 1 日至 89 年 7 月 31 日
計畫主持人: 江簡富　　台灣大學電信研究所

中文摘要 (關鍵詞: 共面帶線、電磁共容、積分方程、矩量法。)

在本計畫中，藉著計算共面帶線上的感應電流來研究入射平面波造成的干擾。首先推導以感應電流爲未知數的積分方程式，再以矩量法求解。考慮與共面帶線同向或垂直的 TM 及 TE 極化平面波，並考慮共面帶線的各式幾何參數對感應電流的影響。感應電流在共面帶線上造成雜訊而降低傳導信號的完整性，應在設計初期早做考慮。

Abstract (Key words: coplanar line, electromagnetic compatibility, integral equation, method of moments.)

In this project, we study the interference on coplanar lines and microstrip lines caused by an incident plane wave by calculating the induced current on their surfaces. Integral equations in terms of the induced currents are formulated, then solved by applying method of moments. Both the TM and TE polarized plane waves incident from directions aligned and prependicular to the transmission lines are considered. The distributions of induced currents on the transmission lines with different geometrical parameters are presented. The induced current distributions incur noise on the transmission lines and deteriorate signal integrity significantly. Hence, they should be considered in the design phase.

1 Introduction

Coplanar lines are useful in MIC and MMIC design where components can be easily mounted without using vias. The scattering problems of coplanar lines and similar transmission lines have been studied by using integral equations of Sommerfeld-type [1]. In [2], the scattering properties of a single strip or coplanar strips are investigated by combining the Fourier transform with singular integral equation methods. In [3], the scattering problem of a symmetric double-strip grating is solved by deriving a Carlemen's integral equation and a Cauchy-type singular integral equation.

Coplanar lines are useful component for microwave circuits for the ease of fabrication and no need for vias. Due to size reduction of integrated circuits, coupling between neighboring lines caused by external field becomes more serious. The current induced on the victim lines may lead to a malfunction in the connected loads. Hence, it is important to analyze the induced currents on the coplanar lines.

In this paper, four situations associated with different incident directions and plane wave polarizations are formulated. Referring to Figure 1, they are (1) TM-polarized wave incident in a direction aligned with the coplanar lines (in the yz-plane), (2) TE-polarized wave incident in a direction perpendicular to the coplanar lines (in the xz-plane), (3) TE-polarized wave incident in a direction aligned with the coplanar lines (in the yz-plane), and (4) TM-polarized wave incident in a direction perpendicular to the coplanar lines (in the xz-plane). Both single strip line and two coplanar lines are considered. The variation of induced currents with different parameters such as frequency, incident angle, strip width, strip seperation, and substrate dielectric constant are analyzed.

2 Solution Procedure

Figure 1 shows a plane wave incident upon two coplanar lines which are laid along the y direction. A plane wave is defined to have an aligned incidence when the wave number vector is in the yz plane, and is defined to have a side incidence when its wave number vector is in the xz plane.

The field components in each region can be expressed as integrals in the spectral domain plus the incident and reflected plane waves. Applying the boundary conditions that (1) $H_{0x} - H_{1x} = K_y$, $H_{0y} - H_{1y} = -K_x$, $E_{0x} = E_{1x}$, $E_{0y} = E_{1y}$ at $z_0 = 0$, and (2) $E_{1x} = E_{2x}$, $E_{1y} = E_{2y}$, $H_{1x} = H_{2x}$, $H_{1y} = H_{2y}$ at $z_1 = 0$, the field coefficients inside the integrals can be expressed in terms of the surface current coefficients. Impose the last boundary condition that the tangential electric fields vanish on the coplanar line surface to obtain two coupled integral equations. To solve the integral equations by using method of moments, first choose sets of basis functions to expand the surface currents, then substitute these expansions into the integral equations. Next, choose the same sets of basis functions as weighting functions, then take the inner product of each weighting function with the integral equations to obtain a matrix equation.

The current distribution is obtained by solving this matrix equation. For the microstrip structure which has a ground plane, the fields in layer (2) vanish, and the continuing conditions at $z = -d_1$ is replaced by the condition that the tangential electric field components vanish at $z = -d_1$.

The other three situations are formulated in similar manners.

3 Results and Discussions

The induced current is normalized with respect to the magnitude of the incident magnetic field (H_o) in all the cases. We have verified the accuracy of our approach by comparing results in [1], and the results matched reasonably well.

Figure 2 shows the total induced currents as a function of strip width when the incident angle is near grazing. Near grazing incidence, both the I_x and I_y components induced by the TM mode are close to those at normal incidence. The magnitude of the I_x component induced by the TE wave is about two order smaller at grazing incidence.

For the side-incidence TE wave, the I_y component is induced by the combined electric field consisting of the incident and the reflected waves. In the absence of the strips, the combined field has a standing wave form which is zero at the ground plane. The pitch of the field pattern in the z direction is much small at normal incidence than at grazing incidence. Thus, the field strength on the position of strip surface when the strip is absent is much smaller at normal incidence than at grazing incidence, so are the induced surface currents.

For the TM waves at normal incidence, both the incident and the reflected field components are large compared with those at grazing incidence, and the cancellation of these two components renders the total electric field to be about the same at normal and grazing incidences.

In the absence of ground plane, the reflected wave by the substrate is much smaller than the incident wave. For the side-incidence TE wave, the E_y component observed at the strip position is almost the same either at normal incidence or grazing incidence. For the aligned-incidence of TM polarization, the E_y component at normal incidence is much larger than that at grazing incidence, so is the induced I_y component. By the same argument, the I_x component induced by the aligned-incidence TE wave is insensitive to the incident angle, while the I_x component induced by the side-incidence TM wave is about one order smaller at grazing incidence than at normal incidence.

Next, consider the structure with two identical coplanar lines. The total induced current can be separated into two modes. One is the common-mode current defined as $I_c = (I_0 + I_1)/2$, and the other is the differential-mode current defined as $I_d = (I_0 - I_1)/2$ where I_0 and I_1 are the total induced currents on the left-strip and right-strip, respectively. Notice that the common-mode current will reradiate and create interference to neighboring circuitries, but the differential-mode current tends to be guided along the strips.

Figure 3 shows the total induced currents I_x with a side-incidence TM plane wave. It is observed that the common-mode current is larger than the associated differential-mode current, and the magnitude of both components increase with frequency. When the incident angle is increased from 45° to 89°, the current is reduced by about two orders of magnitude.

Figure 4 shows the frequency dependence of the induced common mode current with an aligned-incidence TM plane wave. The differential mode current is vanishingly small at both oblique and near grazing incidences due to symmetry. The common-mode current at oblique incidence is larger than that near grazing incidence. The common-mode I_x component increases slightly with frequency. The I_y component of the differential-mode is vanishingly small due to symmetry. The common-mode current decreases monotonically with frequency. The current near grazing incidence is always smaller than that at oblique incidence.

The effect of strip separation on the total induced current I_y with a side-incidence TE plane wave is shown in Figure 5. The strip separation is defined as the distance between the centers of the two strips. It is shown that the total induced current increases with separation for both the common-mode and the differential-mode. The increasing rate of the differential-mode current is larger than that of the common-mode. The discrepancy between the two differential mode curves at oblique incidence and near grazing incidence is smaller than that between the common-mode curves. The discrepancy between the two curves of the same mode is larger when the substrate dielectric constant is increased to, for instance, $\epsilon_1 = 10\epsilon_o$.

4 Conclusions

In this paper, an integral equation approach and method of moments are applied to study the induced current on single strip and coupled coplanar lines. Situations with either TE or TM incident plane wave, either side-incidence or aligned-incidence are considered. Results of induced current are presented to analyze the interference caused by incident plane waves on the coplanar lines. These results are useful in predicting the interference caused by external sources.

References

[1] C. M. Butler, "Current induced on a conducting strip which resides on the planar interface between two semi-infinite half-spaces," *IEEE Trans. Antennas Propagat.*, vol.AP-32, pp.226-231, March 1984.

[2] J. L. Tsalamengas and J. G Fikioris, "TM scattering by conducting strips right on the planar interface of a three-layered medium ," *IEEE Trans. Antennas Propagat.*, vol.41, pp.542-555, May 1993.

[3] D. Filipovic, "A new solution for TE plane-wave scattering from a symmetric double-strip grating composed of equal strips," *IEEE Trans. Microwave Theory Tech.*, vol.44, pp.1990-1996, November 1996.

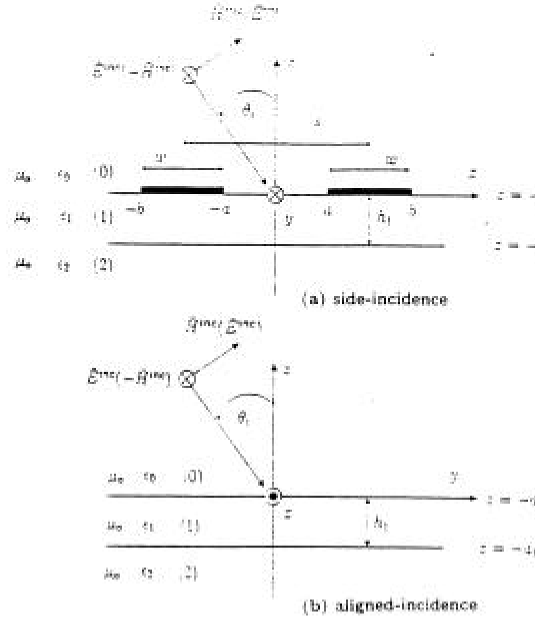

Figure 1: Geometrical configuration of a plane wave incident upon two coplanar lines, (a) side-incidence, (b) aligned-incidence.

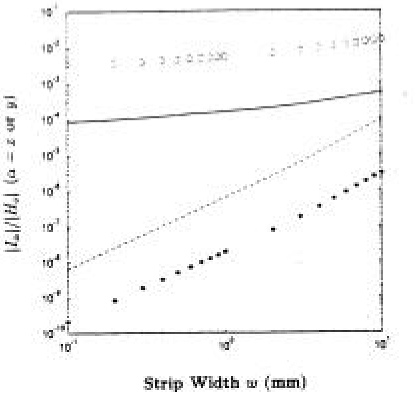

Figure 2: Effects of strip width on the total induced current on a single strip line, f = 1 GHz, h_1 = 2 mm, θ_i = 89°, $\epsilon_0 = \epsilon_2 = \epsilon_o$, $\epsilon_1 = 2\epsilon_o$, ——: I_y of side-incidence TE mode, o: I_y of aligned-incidence TM mode, - - -: I_x of side-incidence TM mode, *: I_x of aligned-incidence TE mode.

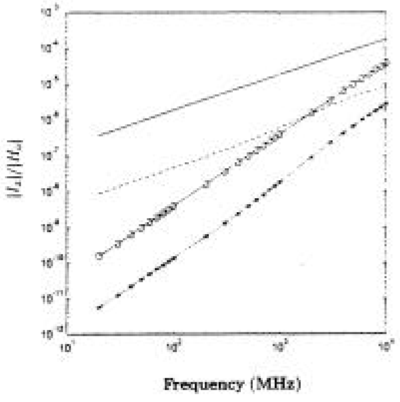

Figure 4: Total induced common mode current on two coplanar lines with an aligned-incidence TM plane wave at different frequencies, w= 1 mm, h_1 = 2 mm, s = 3 mm, $\epsilon_0 = \epsilon_2 = \epsilon_o$, $\epsilon_1 = 2\epsilon_o$, ——: I_x at θ_i = 45°, - - -: I_x at θ_i = 89°, –o–o–: I_y at θ_i = 45°, – * – * –: I_y at θ_i = 89°.

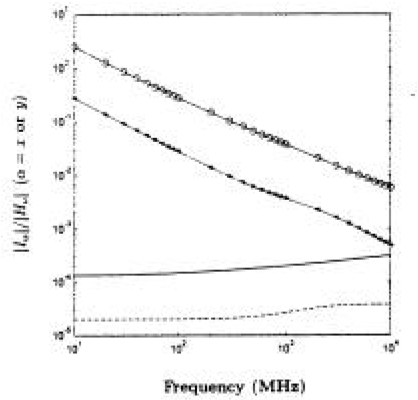

Figure 3: Total induced current I_x on two coplanar lines with a side-incidence TM plane wave at different frequencies, w= 1 mm, h_1 = 2 mm, s = 3 mm, $\epsilon_0 = \epsilon_2 = \epsilon_o$, $\epsilon_1 = 2\epsilon_o$, ——: common mode at θ_i = 45°, - - -: common mode at θ_i = 89°, –o–o–: differential mode at θ_i = 45°, – * – * –: differential mode at θ_i = 89°.

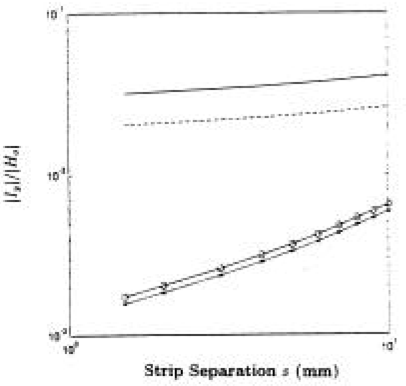

Figure 5: Effects of strip separation on the total induced current I_y on two coplanar lines with a side-incidence TE plane wave, f = 1 GHz, w = 1 mm, h_1 = 2 mm, $\epsilon_0 = \epsilon_2 = \epsilon_o$, $\epsilon_1 = 2\epsilon_o$, ——: common mode at θ_i = 45°, - - -: common mode at θ_i = 89°, –o–o–: differential mode at θ_i = 45°, – * – * –: differential mode at θ_i = 89°.