A Novel Conductor-Backed Coplanar-Waveguide Coupled Structure

Chun-Lin Liao and Chun Hsiung Chen
Department of Electrical Engineering,
National Taiwan University, Taipei 10617, Taiwan

ABSTRACT

A new coplanar-waveguide coupled structure is proposed by incorporating a backed conductor on the other side of the substrate. For this new coupled structure, the effective dielectric constants as well as the characteristic impedances of the odd and even modes are calculated by the spectral-domain method. In this study, the proposed coupled structure is characterized by carefully examining the related coupling coefficient and the associated field distributions.

INTRODUCTION

The coplanar waveguides (CPW) receive much attention recently due to the merits of easy in connecting shunt and series components. One disadvantage of conductor-backed coplanar waveguides is the unwanted leakage phenomenon associated with the parallel-plate transmission line structure. In this study, the coupling effect due to finite-width backed conductor is utilized to transfer the power between two coplanar waveguides so that a new coupled structure may be implemented.

Various coplanar-waveguide coupled structures have been proposed. The broadside-coupled coplanar-waveguide structures have the merits of tight coupling and high effective dielectric constant ratio [1]–[2], but these structures are only compatible with multilayer MMIC technology. Edge-coupled structures could not achieve tight coupling as the previous ones but the whole structures are on the same plane [3]–[4]. In this study, a new coupled structure which makes use of a backed conductor to couple two coplanar waveguides on the same side of the substrate is proposed and examined.

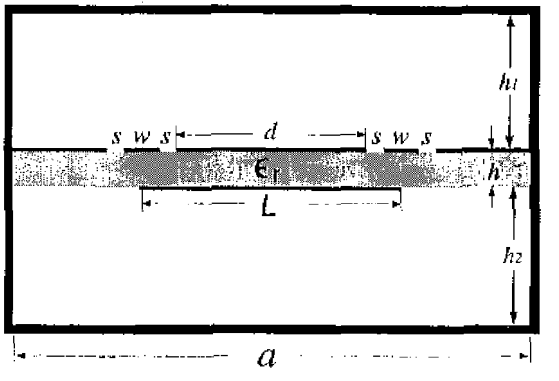

Fig. 1. Cross section of conductor-backed coplanar-waveguide coupled structure. ($w = 1mm$, $s = 0.5mm$, $\epsilon_r = 2.5$, $h = 0.635mm$, $h_1 = h_2 = 60mm$, $a = 1000mm$).

FORMULATION

Consider a symmetric conductor-backed coplanar-waveguide coupled structure as shown in Fig. 1 in which a backed conductor of width L is introduced in the other substrate side of two coplanar waveguides. Two coplanar waveguides have identical strip width w and slot width s, and the dielectric constant and thickness of the substrate are ϵ_r and h, re-

0-7803-5761-2/99/$10.00 ©1999 IEEE

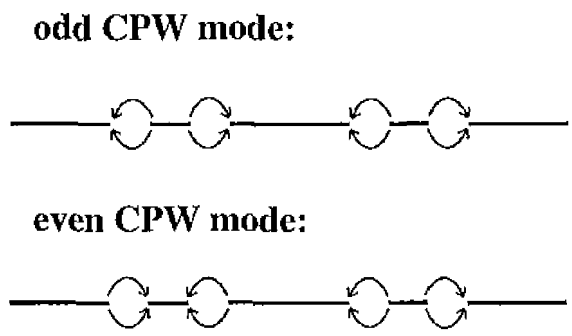

Fig. 2. Electric field distributions for odd and even CPW modes.

spectively. The coupling mechanism is mainly controlled by the width L of backed conductor (Fig. 1). To simplify the analysis, our coplanar-waveguide coupled structure is enclosed by a conducting box.

Although many fundamental modes may be supported by the multi-conductor system (Fig. 1), we are mainly concerned with the odd and even CPW modes with field distributions as shown in Fig. 2. These two modes are responsible for the coupling mechanism associated with two coplanar waveguides. By using the spectral-domain method, the effective dielectric constants ϵ_{eff} as well as characteristic impedances Z_o of odd and even CPW modes are calculated, from which the coupling characteristics of the structure may be examined.

NUMERICAL RESULTS

Fig. 3 shows the effective dielectric constants and characteristic impedances of odd and even CPW modes, as well as the related coupling coefficient C under the condition of $L = 0$. Without backed conductor on the other side of the substrate, the effective dielectric constants of the two modes are almost identical as $d > 5mm$, and the coupling coefficient is smaller than -50dB when $d > 5mm$, showing that the coupling between two coplanar waveguides is not significant.

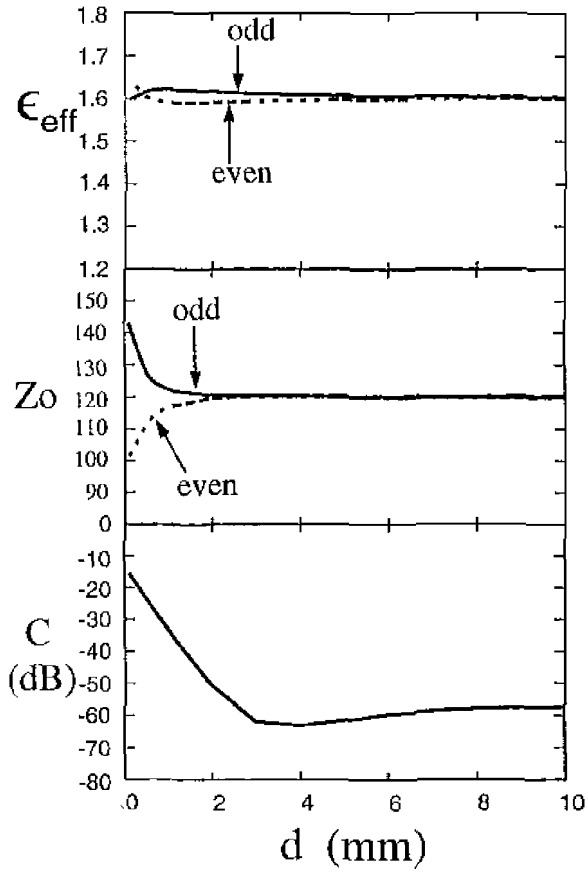

Fig. 3. Effective dielectric constants, characteristic impedances of odd and even modes, and related coupling coefficient ($L = 0$).

For the case with $d = 5mm$, and the width L of backed conductor varying from $2mm$ to $12mm$, the results for ϵ_{eff}, Z_o and C are shown in Fig. 4. For $L > 5mm$, the backed conductor under the substrate is wide enough to cover the two transmission lines, and this makes the difference between the two ϵ_{eff} become obvious. With obvious difference between the characteristic impedances Z_o, the coupling coefficient reaches -12dB as $L > 9mm$, much larger than the case of $L = 0$. For this case of $L > 9mm$, the two conductors of widths d and L may be regarded as a parallel-plate transmission line and the coupling effect associated with the TEM wave becomes significant.

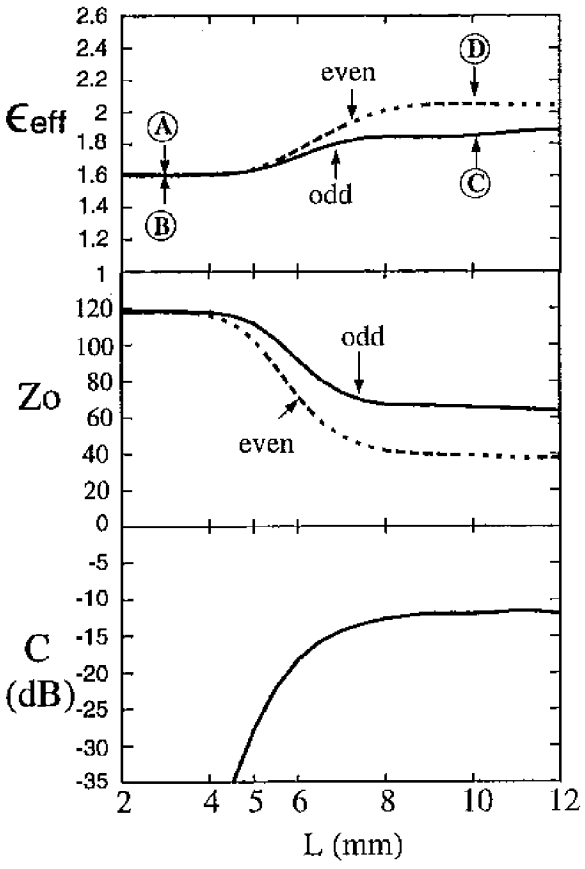

Fig. 4. Effective dielectric constants, characteristic impedances of odd and even modes, and related coupling coefficient ($d = 5mm$).

This effect makes the power transfer from one coplanar waveguide to the other easily even in the lower frequency range.

Fig. 5 shows the electric field distributions corresponding to the cases A, B, C, D of Fig. 4. The cases A and B are for the odd and even CPW modes with $L = 3mm$. Since the width L of backed-conductor is narrower than the line spacing ($d = 5mm$), the coupling effect is weak and the electric fields between two central conductors of widths d and L are very small. For the case with $L = 10mm$, the electric fields for odd and even CPW modes are shown as C and D in Fig. 5. The coupling effect between two coplanar waveguides is more obvious than the previous one and the fields for odd CPW mode between the central conductors are stronger than those for $L = 3mm$, a consequence of the excited TEM wave in the parallel-plate structure.

CONCLUSIONS

In this work, the coupling effect due to backed conductor is utilized to implement a new coupled structure composed of two coplanar waveguides. Without backed conductor on the other side of the substrate, the coupling phenomenon is not obvious. The proposed coupled structure shows significant coupling when the backed conductor width L is wider enough to cover the two coplanar waveguides.

REFERENCES

[1] C. Nguyen, "Broadside-coupled coplanar waveguides and their end-coupled bandpass filter applications," *IEEE Trans. Microwave Theory Tech.*, vol. 40, pp. 2181–2189, Dec. 1992.

[2] I. P. Hong, Y. K. Lee and H. K. Park, "Dispersion characteristics of a broadside-coupled coplanar waveguide," *Electronics Letters*, vol.33, pp. 965–966, May 1997.

[3] P. Singkornrat and J. A. Buck, "Picosecond pulse propagation in coplanar waveguide forward directional couplers ," *IEEE Trans. Microwave Theory Tech.*, vol. 39, pp. 1025–1028, June 1991.

[4] G. Ghione and C. U. Naldi, "Coplanar waveguides for MMIC applications: effect of upper shielding, conductor backing, finite-extent ground planes, and line-to-line coupling," *IEEE Trans. Microwave Theory Tech.*, vol. 35, pp-260–267, March 1987.

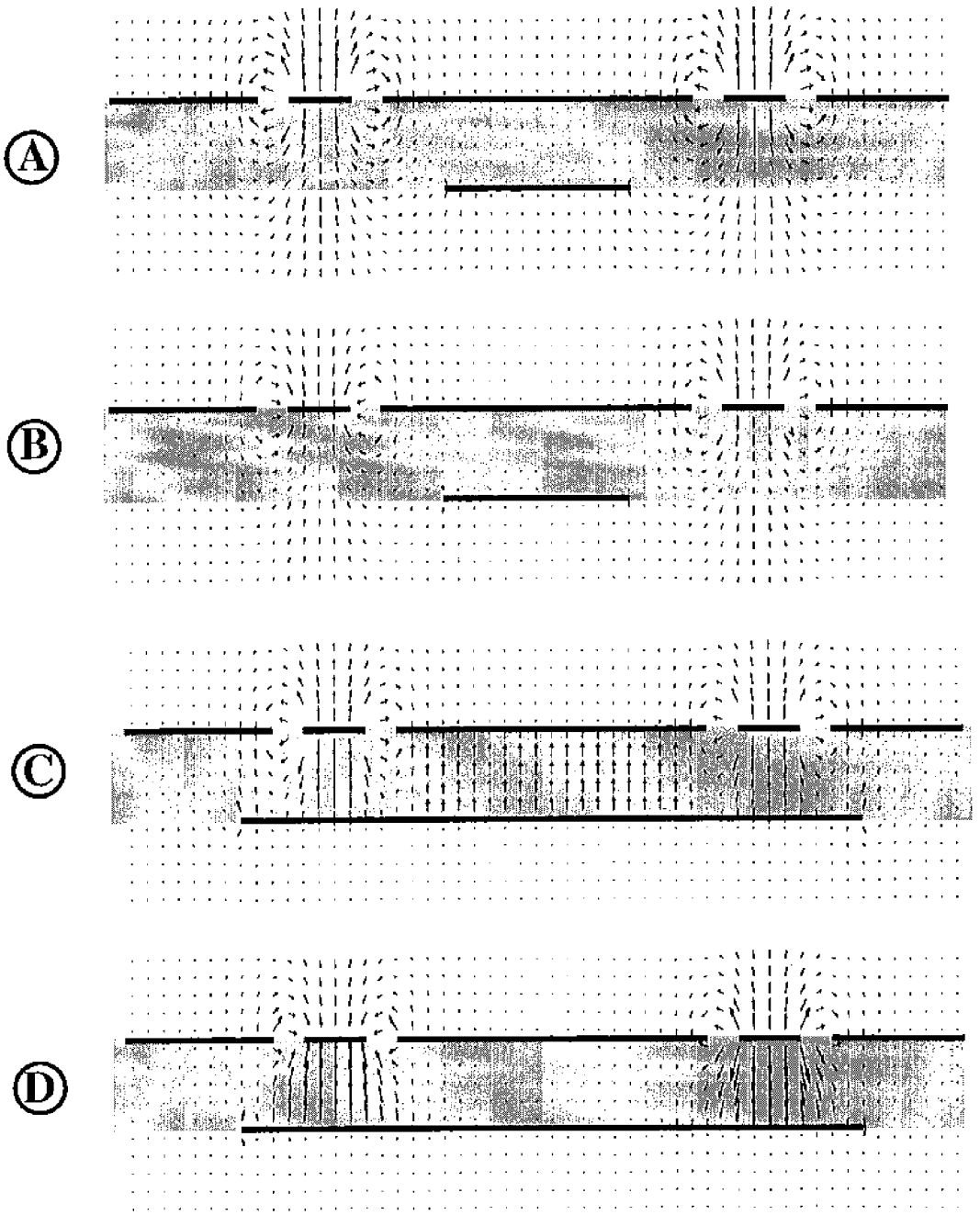

Fig. 5. Electric field distributions for (A) odd CPW mode with $L = 3mm$, (B) even CPW mode with $L = 3mm$, (C) odd CPW mode with $L = 10mm$, and (D) even CPW mode with $L = 10mm$.