行政院國家科學委員會補助專題研究計畫成果報告

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計畫類別：☐ 個別型計畫　☑ 整合型計畫
計畫編號：NSC 89－2213－E－002－048
執行期間：88 年 8 月 1 日至 89 年 7 月 31 日

計畫主持人：陳俊雄
共同主持人：許博文

本成果報告包括以下應繳交之附件：

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執行單位：國立台灣大學電機工程學系

中 華 民 國 89 年 9 月 日

行政院國家科學委員會專題研究計畫成果報告

「毫米波電路與天線Ⅱ」(總計畫) (3/3)
Millimeter-Wave Circuits and Antennas Ⅱ (3/3)

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主 持 人：陳俊雄　　國立台灣大學電機系教授
共同主持人：許博文　　國立台灣大學電機系教授

本整合型計畫的目標為：研發毫米波系統的關鍵性元、組件，整合國內毫米波領域的相關研究，藉研究經驗、成果的交流與結合，來建立國內的毫米波技術，並培養國防單位及工業界急需的微波與毫米波專業人才。

本計畫主要集中於毫米波主、被動元、組件的研究，以平面結構為骨幹，並以主動元件、被動組件、波導、及天線的分析與設計為重點，理論與實驗並重，來發展出相關的電腦軟體程式集等，以作為分析與設計毫米波主、被動元、組件的主要依據。

本跨校整合型計畫含一項總計畫及七項子計畫，分由台大電機資訊學院教授(六位)及中興大學電機系教授(一位)主持。本年度各子計畫的目標及完成項目分述於下，至於詳細的內容，請參閱個別的完整報告。

1. 單面被動組件(3/3)(子計畫一，NSC 89-2213-E-002-047，陳俊雄主持)：

本計畫的目標為：研發三種關鍵性的單面組件（即轉接器、濾波器、混波器），以提升國內毫米波單晶積體電路之技術。本研究內容包括：設計用等效電路模型的建立，分析用電腦軟體程式集的完成，再結合理論分析與實驗量測，進行單面轉接器、濾波器、及混波器各種特性之詳盡探討。

本（第三）年度研究，將統合前二年成果，以共面波導至共面帶線轉接當作平衡器，以共面帶線低通與高通濾波器當作雙工電路與直流截止，來提升混波器的端對端阻隔效應，減少訊號間的干擾，並進而設計與製作出一個新的單面型雙平衡混波器。它的轉換損耗自 6dB 至 10dB，LO 至 IF 與 LO 至 RF 的阻隔，分別大於 30dB 與 20dB，而 LO 埠與 IF 埠的頻寬，也分別為 10 GHz 至 35 GHz 與 0.1 GHz 至 5 GHz。

為方便混波器的設計工作，本研究特提出一等效電路模型，其元組件均可由簡便的近似公式推得，因此可輕易從事設計與模擬工作。而所得模擬結果與量測結果的吻合，不僅驗証等效電路模型的正確性，而且還顯現所提設計過程的實用性。

2. 共面波導饋入式天線陣列(3/3)(子計畫二，NSC 89-2213-E-002-049，許博文主持)：

本計畫是三年期計畫之第三年。本年度主要工作為：綜合前年度之研究成果，並完成共面波導饋入式微帶天線陣列之分析與設計方法。首先利用 Zeland 公司所出品之全波分析軟體 IE3D™，來計算單元天線的自導納以及二單元陣列天線之輸入阻抗，再利用此二者之值，推算出二單元天線之間的互導納，據此再以傳輸線理論，推算出多元素陣列天線的輸入阻抗。利用此方法，我們設計了一個三單元的共面波導饋入式微帶天線，以實驗驗證理論之正確性，並證實單元間互導納對陣列天線輸入阻抗所帶來的巨大影響。

3. 注入鎖定主動天線陣列(3/3)(子計畫三，NSC 89-2213-E-002-050，瞿大雄主持)：

本計畫旨在建立注入鎖定主動天線陣列之理論分析、模擬與實驗量測，以及N-埠網路S-參數之量測原理、校準、裝置與應用。

本報告係敘述第三年之研究成果，包括：1) 建立天線耦合效應之陣列分析方法，2) 使用諧波平衡法，建立分析注入鎖定自我振盪倍頻器，及主動天線陣列之理論、模擬與實驗量測，3) 建立N-埠網路S-參數之降埠量測方法及應用。

4. 微帶饋入式槽線天線(3/3)(子計畫四，NSC 89-2213-E-002-051，吳瑞北主持)：

本計畫旨在探討微帶饋入式漸寬槽線天線及其所組成線性陣列之電磁特性。利用吾人發展的柱形網格時域有限元素法，結合傳統時域有限差分法，可以有效地分析此種平面天線結構，並與實驗和商業套裝軟體 Ansoft HFSS 獲得一致的結果。吾人並利用 Ansoft HFSS 來分析兩個天線單元組成天線陣列之特性，包括天線單元間的耦合效應，天線單元間距的影響，以及天線陣列的輻射場型，並實際製作、實驗加以驗證。

5. 毫米波主動元件模型及電路(3/3)(子計畫七，NSC 89-2213-E-005-019，孟慶宗主持)：

結合平面天線和 GaAsMESFET 的主動天線混頻器，已用微波單晶積體電路技術成功的實現，全部的晶片尺寸約為 $5x5mm^2$，此電路接收 10 GHz 的射頻訊號，並降頻至 1 GHz 的中頻訊號，且轉換損耗為 7±2dB，這研究可應用於實現物美價廉的商用毫米波防撞雷達。

6. 平面波導之特殊基板及電磁干擾(3/3)(子計畫八，NSC 89-2213-E-002-101，江簡富主持)：

本研究探討入射平面波對微帶線及共面線造成的干擾，而以線表面上的感應電流衡量。首先推導感應電流的積分方程式，再以矩量法求解。所考慮的入射平面波含TM及TE極性，入射方向包括側向及順向。報告內容包括不同尺寸傳輸線上所感應的電流分布。此種感應電流會導致傳輸線上的雜訊並損壞信號的完整性，因此應在設計時就予以考慮。

7. 毫米波單晶電路元件之設計與模式化技術(3/3)(子計畫九，NSC 89-2213-E-002-052，王暉主持)：

本計畫在於研究毫米波單晶電路元件(MMIC)之設計與模式化技術。單晶電路製程所使用的電晶體為高速場效電晶體(HEMT)，此製程可由國外的工廠提供。所研發的元件包括低雜訊放大器、功率放大器、混波器、及振盪器。

本計畫研究項目包括：開發元件模式、MMIC設計、晶片佈局、製作與驗證。第一年度計畫以 35 GHz 收發模組元件的研製為主，完成了微帶線設計，同時也嚐試以共面波導進行設計，而完成設計及佈局的晶片，已送往代工廠實際製作。在第二年度，晶片已製作完成，並且順利完成電路的量測。除了 35 GHz 收發模組元件的研製，更高頻率的收發元件亦相繼設計完成。

A Novel Conductor-Backed Coplanar-Waveguide Coupled Structure

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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.

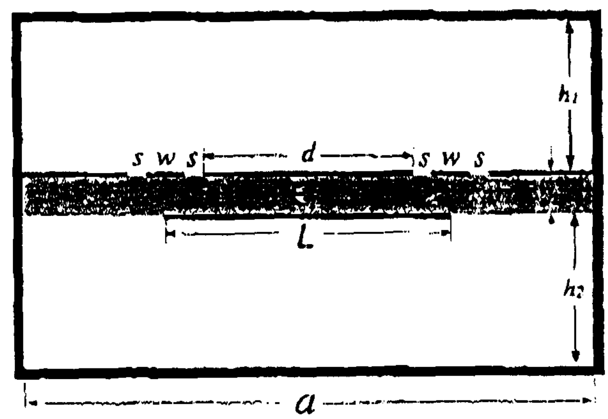

Fig. 1. Cross section of conductor-backed coplanar-waveguide coupled structure. (w = $1mm$, $s = 0.5mm$, $\epsilon_r = 2.5$, $h = 0.635mm$, $h_1 = h_2 = 60mm$, $a = 1000mm$).

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-

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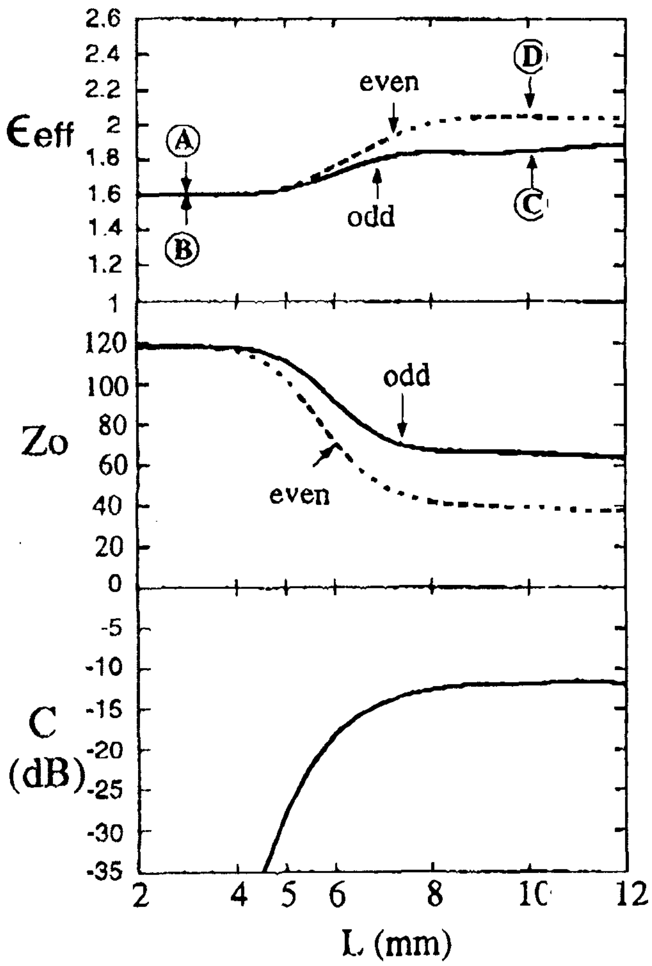

Fig. 4. Effective dielectric constants, characteristic impedances of odd and even modes, and related coupling coefficient ($d = 5mm$).

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.

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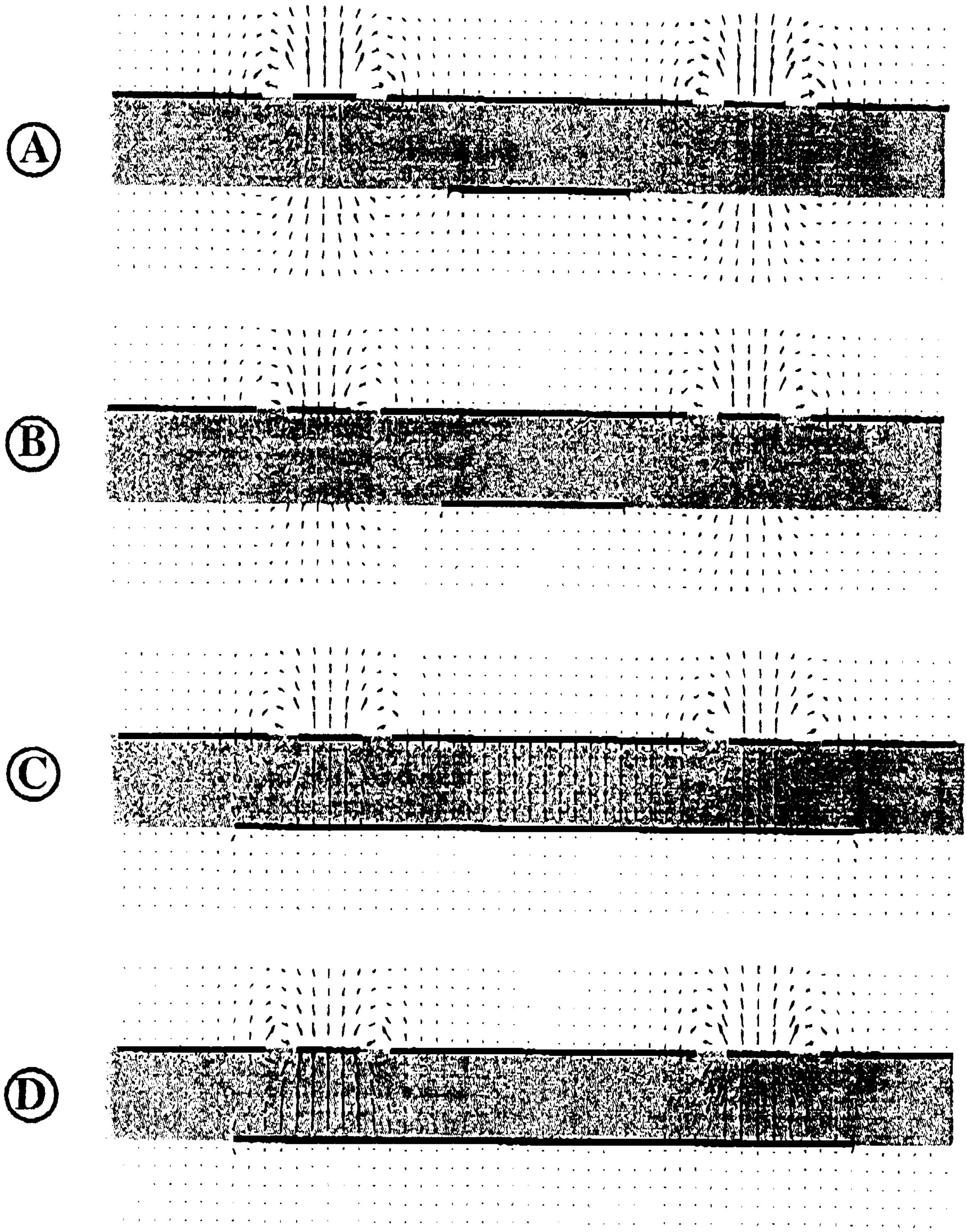

Fig. 5. Electric field distributions for (A) odd CPW mode with $L = 3mm$, (B) even CPW mode with $L = 3mm$, (C) odd CPW mode with $L = 10mm$, and (D) even CPW mode with $L = 10mm$.

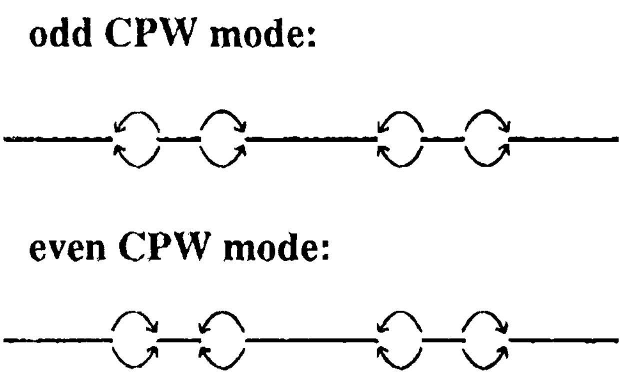

Fig. 2. Electric field distributions for odd and even CPW modes.

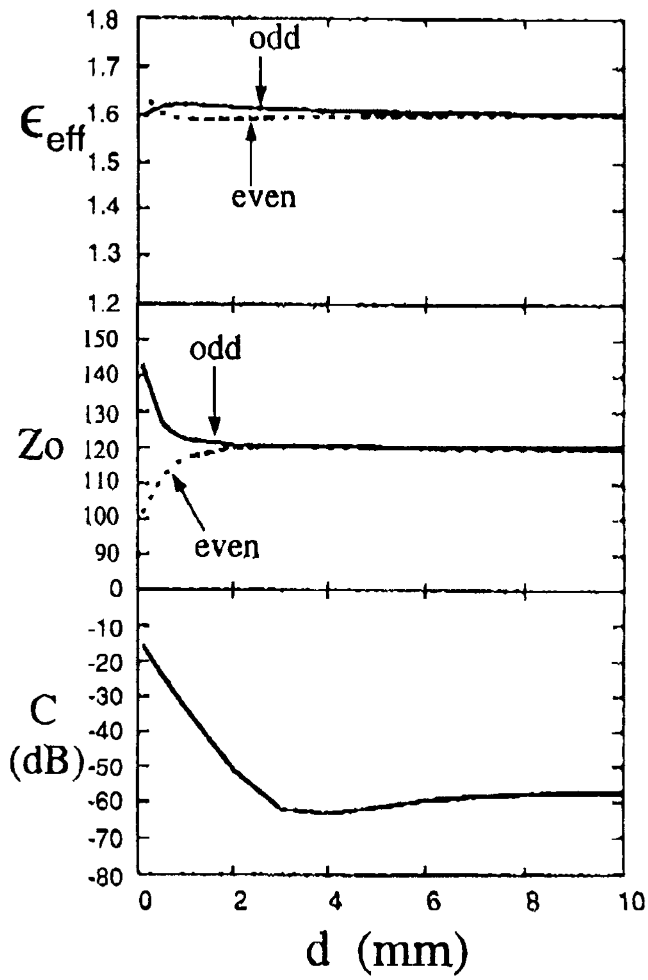

Fig. 3. Effective dielectric constants, characteristic impedances of odd and even modes, and related coupling coefficient ($L = 0$).

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.

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.