# 微帶傳輸線合成：近橫向電磁模及第一高階模

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## 摘　　要

本論文係研究合成微帶傳輸線近橫向電磁模及第一高階模，內容為研究一種適合於微波被動電路縮裝應用的新型合成近橫向電磁模傳輸線及提出一種新穎合成的第一高階模傳輸線在波柱掌控天線上的應用。主要內容計包含兩部分，第一部份提出一種新型合成的二維傳輸線，其不僅可承載近橫向電磁傳播模，同時可降低傳統一維微帶線緊密迂迴曲折應用下，在傳播常數與特性阻抗上所遭遇的相關問題之影響。此種二維傳輸線係由一層介質基板及上、下兩層金屬表面所組成。上層金屬表面係由具有中心貼片與連接臂構成之單元細胞迂迴曲折連接而成。底層金屬表面則是一種網孔的二維週期接地面，其網孔部分與上層表面的貼片部分互補，形成一種互補傳導線帶(CCS)傳輸線，其單元細胞係由微帶線及具有調整隔板的微帶線所組成。互補傳導線帶傳輸線在理論及實驗比較研究下，顯示兩者結果吻合，且證實了其在相同迂迴曲折圖案下，對傳播常數及特性阻抗之影響，遠不如微帶線敏感—此種合成的 CCS 傳輸線可提供較寬廣選擇的特性阻抗

及較平坦的傳播特性。在此本論文將提出兩個設計例子，以證實互補傳導線帶傳輸線在極低損耗微波被動電路縮裝設計的潛力。第一個例子係實現於印刷電路 RO4003 基板之 54 億赫的互補傳導線帶四埠混成耦合器(rat-race hybrid)，其需求面積較傳統微帶線型降低約 87 %。第二個例子則是說明了互補傳導線帶傳輸線在單晶化射頻積體電路的應用性，首次即完成 52 億赫之互補金屬-氧化物-半導體(CMOS)振盪器的設計，其係採用台灣半導體製造公司(台積電，TSMC) 0.25-微米 1P5M 互補金屬-氧化物-半導體製程技術、並結合互補傳導線帶傳輸線的一種分佈式諧振器來實現，其整體面積含測試墊僅 $500 \times 600$ 微米平方。

第二部份則提出一種新穎的合成波柱掌控洩漏波天線，其係利用電抗加載電容器沿洩漏線佈置來達成。此電抗加載改變了洩漏線的相位常數，進而改變了主波柱的方向。一種天線原型是被製作及測試，證實在 40 億赫操作頻率下，沿著洩漏線週期加載 0.06527-微微法拉的電容器可獲致 23°波柱掃瞄的角度。經以四個變容器取代 79 個此種金屬-絕緣體-金屬電容器後，更可獲致 13°掃瞄角度之緊湊的電子式波柱掌控天線。

# Microstrip Line Syntheses for
# Quasi-TEM Mode and First Higher-Order Mode

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## ABSTRACT

This dissertation studies microstrip transmission line syntheses for quasi-transverse electromagnetic (Quasi-TEM, $EH_0$) mode and the first higher-order ($EH_1$) mode. The dissertation mainly consists of two parts, investigating a new synthetic transmission line for miniaturizing microwave passive circuits and presenting a novel synthetic beam-steering leaky-wave antenna. The first part presents a synthetic two-dimensional transmission line (2-D TL) that supports quasi-TEM propagation mode and reduces problems associated with compacted meandering of microstrip (MS) on propagation constants and the characteristic impedances commonly observed in conventional one-dimensional MSs. The proposed 2-D TL comprises two layers of metallic surfaces on either side of a dielectric substrate. The top metal surface is a meandered connection of a unit cell with a central patch and connecting arms. The bottom surface is a meshed 2-D periodical ground plane, whose etched portion complements the patch portion of the top surface, forming a complementary-conducting-strip (CCS) TL, enabling a combination of an MS and MS with the tuning septa in a unit cell. Both theoretical and experimental investigations of the CCS TL agree well and demonstrate that it is much less susceptible to the effects of meanderings on the propagation constant and characteristic impedance than an MS for the same meandered pattern, where the synthetic CCS TL can provide wider choice of characteristic impedance and flatter propagation characteristic. Two design examples are presented to demonstrate the potential for a CCS TL for miniaturizing microwave passive circuits with minimal losses. The first example involves a 5.4-GHz CCS four-port rat-race hybrid realized in RO4003 and reduces the area of original MS design by 87 %. The second example illustrates the applicability of a CCS TL to a monolithic RF integrated circuit using a first-pass design of a 5.2-GHz CMOS oscillator incorporating a CCS TL as a resonator with an area totaling 500 × 600μm$^2$ including pads base on Taiwan Semiconductor Manufacturing Company's 0.25-μm 1P5M CMOS process techniques.

In the second part of the dissertation a novel synthetic beam-steering leaky-wave antenna that uses reactive loading capacitors along the leaky line is presented. The reactive loading varies the phase constant of the leaky line, altering direction of the main beam. A prototype was constructed and tested, demonstrating that a beam scanning angle of 23° is obtained by periodically

loading the 0.06527-pF capacitors along the leaky line at 4 GHz. A compacted, electronic beam-steering antenna of scanning angle 13° was established by replacing the 79 MIM capacitors with four varactors.