CHAPTER 2

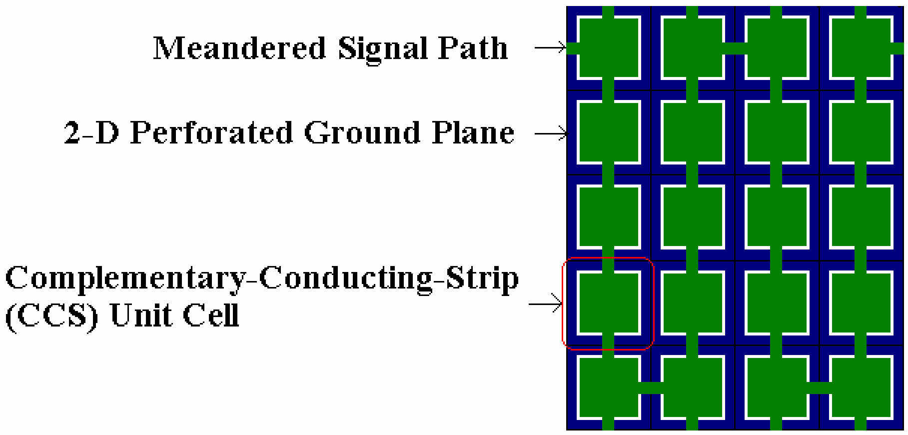
Introduction

This dissertation is composed of two parts. The first part proposes new synthetic quasi-TEM meandered transmission lines for compact microwave integrated circuits, and the second part presents novel synthetic phase-shifterless beam-steering leak-wave antennas for compact microwave scanning antennas.

2.1 New Synthetic Quasi-TEM Transmission Lines

In the first part of this dissertation, Chapter 3 will introduce a two-dimensional transmission-line (2-D TL) concept that will advance the art of the conventional one-dimensional microstrip (1-D MS) lines. The conventional 1-D MS guiding structure is uniform in cross section along the longitudinal direction. The proposed 2-D synthetic TL is non-uniform in cross section along the propagating axial direction. The comparison of the conventional 1-D MS and the synthetic 2-D TL structures is shown in Fig. 2.1 (a) –(b).

(a) Conventional 1-D MS Structure



(b) Synthetic 2-D TL Structure

Fig. 2.1. Comparison of conventional 1-D MS and synthetic 2-D TL structures.

In the Fig. 2.1(a), the conventional 1-D MS structure is composed of the uniform signal path and the uniform ground plane. The guiding properties of the conventional 1-D MS structure are only controlled by the width of the signal path in the longitudinal direction when the substrate parameters (thickness h, relative permittivity ε_r and permeability μ_r etc.) are defined in the vertical direction. On the contrary, the synthetic 2-D TL structure is composed of different shapes. The periodic structures in the signal path and the ground plane are different from those of the UC-PBG and EME MS structures, where the elements of the periodic structure are only put in the ground plane or the signal path as in Fig. 1.8 and Fig. 1.9. The guiding properties of the synthetic 2-D TL are controlled by many planar structural parameters of the complementary-conducting-strip (CCS) unit cell in the signal path and the ground plane shown in Fig. 2.1(b) with the prescribed substrate parameters.

Such an additional degree of freedom in the guiding structure makes the equivalent quasi-TEM EH_0 mode of propagation able to synthesize a wide range of characteristic impedances and place passive TL circuits in a compact area concurrently.

Chapter 3 is organized as follows. A qualitative description of how the synthetic guiding structure works is given in Section 3.1. In this section, a figure-of-merit, called the area reduction factor (ARF), is also introduced to explain how the synthetic 2-D TL significantly reduces the size of a four-port hybrid by the proposed guiding structure. Section 3.2 investigates the guiding characteristics of the proposed guiding structure meandered in a 2-D periodical surface. It indicates that much wider range of characteristic impedance is necessary for designing TL circuits as opposed to those realized by MS meandered in the same way. Section 3.2 also illustrates the dispersion characteristics of 2-D CCS TL with different meandering paths and operational frequencies. It shows that the 2-D CCS TL possesses almost identical propagation characteristics and characteristic impedance as the 2-D TL does. And these properties are quite favorable for practical applications.

Chapter 4 presents the practical design using the synthetic 2-D CCS TL. This kind of design can be applied in the compact HMIC and monolithic CMOS radio frequency integrated circuit (RFIC). A design example for making a miniaturized rat-race HMIC using the synthetic TL designs reported in Section 3.2. is given in Section 4.1. An investigation of the applicability of the synthetic TL to replace the lumped LC resonators in a monolithic RF CMOS oscillator is included in Section 4.2. It demonstrates the potential use of the synthetic TL in RF integrated circuits (RFICs).

2.2 Novel Synthetic Beam-Steering Leaky-Wave Antennas

For CCS TL syntheses, the guided properties of the Quasi-TEM mode are varied by tuning the shapes of planar patterns. Therefore, the distributed inductance *L* and distributed capacitance *C* of the CCS TL can be varied. And, the characteristic impedance Z_c can also be steered. Here, in the second part of this dissertation, the methodology of placing the varactors or lumped capacitors to vary the distributed *C* of TL is proposed. This scheme is utilized to synthesize a novel leaky-wave line that can be used to provide a physical application.

Chapter 5 introduces a novel approach to produce a steerable beam varied by the external loading capacitance (or inductance). In this approach, a periodic, capacitor-loaded micro-slotline leaky wave antenna is incorporated. The phase-shifterless, reactance loaded, micro-slotline leaky wave antenna can then be designed. And this antenna does exhibit low cost, simple making, beam steerable and compactness properties concurrently.

The structure of a periodic, capacitor-loaded micro-slotline leaky-wave antenna is presented in Sectioin 5.1. The complex propagation constants of the first higher-order EH_1 mode of uniform, unloaded micro-slotline structure is also discussed in this Section. The equivalent lossy transmission line model of the leaky-wave antenna is described in Section 5.2. This model qualitatively describes the operational principle of beam-steering. Section 5.3 verifies the beam-steering concept by both the experiments and the theoretical analyses. The structure of a periodic, varactor-loaded micro-slotline leaky-wave antenna is presented. And its input reflection coefficient S_{11} and the input impedance Z_{in} with different reverse bias condition are displayed. Its ability of electronic beam-steering without phase-shifter is also demonstrated in this Section.

Conclusions and suggestions for future studies are given in Chapter 6.