Evolutionary Planar Transmission-Line Structures:
Their Physics and Practicality

Professor Ching-Kuang Clive Tzuang
Tianjin University, Tianjin, China

This presentation will review the milestones in the development of planar transmission-line structures and discuss their impact on modern integrated circuit technology and system applications. The microstrip transmission line was first reported by Grieg and Engelmann 60 years ago. It consists of a conducting strip supported by a dielectric substrate above a much wider ground plane. This invention led to the subsequent development of many new types of guided-wave structures including slotlines, coplanar waveguides, and other uniplanar configurations for a variety of applications. In 1971, rigorous field-theoretic techniques made possible the accurate determination of the dispersion characteristics of a microstrip. The spectral-domain immittance approach to the Green's function derivation explicitly revealed the hybrid nature of the TE and TM waves propagating within the structure. The fast formalism together with efficient numerical algorithms allowed deeper insights into the complex modes in such structures. Another important domain of knowledge is leaky-mode phenomena, which exist in nearly every planar transmission-line structure known to date. This line of investigation led to the development of a class of large antenna arrays that can be readily designed by the modal theory. In 1997, the study of a microstrip with a periodically perturbed ground plane opened the era of synthetic planar transmission-line structures. The periodically loaded microstrip can support additional complex and leaky modes in the form of space and/or surface waves. Furthermore, it can achieve a slow-wave factor exceeding the square root of relative dielectric constant of the supporting substrate, facilitating the miniaturization of a microwave device without introducing substantial losses. Another form of the non-uniform periodic guided-wave structure, the so-called composite right-left-handed (CRLH) transmission-line metamaterial, represents a new advancement in planar transmission-line development, enabling the synthesis of exotic passive components. Recent studies have shown that non-resonant CRLH transmission-line metamaterials can exhibit a slow-wave factor larger than 20 on a typical monolithic integrated-circuit substrate, thus can be a potentially powerful candidate for terahertz electronic apparatus.