INTEGRATED CIRCUIT DISCONTINUITIES AND RADIATION

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ABSTRACT

A review of the status of integrated circuit discontinuities is presented in the context of Professor A. A. Oliner's contributions. The physical principles involved and the methods of deriving equivalent circuits will be discussed, including radiation effects. In addition, the evolution of Professor Oliner's work to the present modeling methods of discontinuities in a variety of waveguiding structures such as microstrip will be emphasized.

I. INTRODUCTION

The balanced strip transmission line will be considered as the basis of this presentation on Professor A. A. Oliner's contributions on modeling discontinuities (1)-(3). Professor Oliner's early works on balanced stripline discontinuities such as strip open end, gap, step, circular and rectangular slots, as well as bends and T-junctions will be discussed. The methodologies he adopted to derive equivalent circuits for these discontinuities will be elaborated and emphasis will be placed on their evolution to the modeling of integrated circuit guiding structures such as e.g. the microstrip transmission line. By using Babinet's principle, Professor Oliner originated the magnetic sidewall model for the stripline problem. This idea was later on applied to microstrip (4) and associated microstrip discontinuities (5)-(6). This magnetic sidewall approach is a semi-dynamic technique that initiated the full wave analysis of microstrip problems such as the spectral domain method (7)-(8) and transverse resonance technique for enclosed structures (9)-(10) and integral equation method for open (11)-(14) and more recently shielded structures [15].

BALANCED STRIPLINE DISCONTINUITIES AND JUNCTIONS

Professor A. A. Oliner was instrumental in the early investigation of balanced stripline structures, including stripline discontinuities. He contributed in a seminal manner by pointing out at the time that an accurate model must include the reactive properties of the stripline discontinuity. He proceeded to obtain, by combining theoretical and empirical techniques, simple and accurate formulas and equivalent circuits for a variety of stripline discontinuities. Although during the presentation a complete account of Professor Oliner's cotnribution to balanced stripline discontinuity modeling will be discussed, some examples will be briefly cited here as an introduction to the presentation:

Open-end Balanced Stripline

Figure 1 shows a balanced stripline, the inner strip being terminated abruptly at an open end, and the equivalent circuit of the discontinuity.

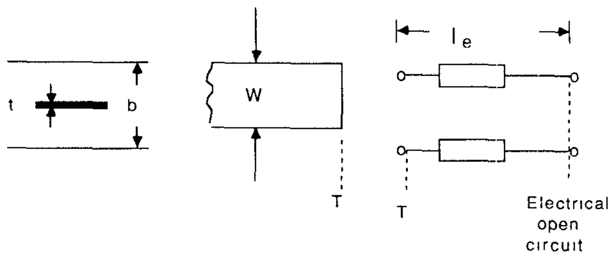

Figure 1 Stripline open end and its equivalent circuit

Combining the formula of excess length due to fringing at the end of a semi-finite strip with empirical data, Professor Oliner derived the following simple formula for the excess length of an abruptly terminated stripline, namely

$$\ell_e = \frac{1}{k}\cot^{-1}\left[\frac{4\ell_{e\infty}+2w}{\ell_{e\infty}+2w}\cot(k\ell_{e\infty})\right] \qquad (1)$$

where $k = \frac{2\pi}{\lambda}$ and $\ell_{e\infty}$ is the excess length of a half plane i.e. $\ell_{e\infty} = \frac{b\ell n2}{\pi}$. The characteristic impedance of the line is given as

$$Z_o = \frac{30\pi(1-t/b)}{D/b} \qquad (2)$$

with

$$W_e = b\frac{K(k)}{K(k')} + \frac{t}{\pi}\left[1 - \ell n\left(\frac{2t}{b}\right)\right] \qquad (3)$$

$$k = \tanh\left(\frac{\pi W}{2b}\right),\ k' = \sqrt{1-k^2} \qquad (4)$$

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In this case, the quantity W_e is the "effective width" of the stripline.

Step Discontinuity

Figure 2 presents a step discontinuity and the equivalent circuit.

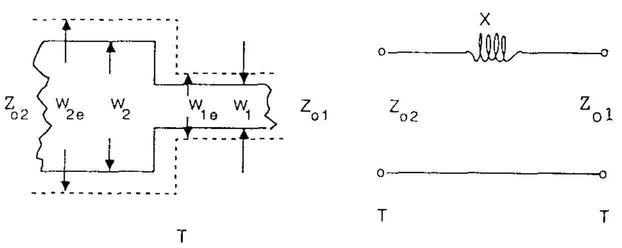

Figure 2 Stripline step junction and its equivalent circuit

The reactance of the equivalent circuit is given by the formula

$$\frac{X}{Z_{o1}} = \frac{2W_{1e}}{\lambda} \ln \csc\left(\frac{\pi W_{2e}}{2W_{1e}}\right) \qquad (5)$$

and

$$\frac{Z_{o2}}{Z_{o1}} = \frac{W_{1e}}{W_{2e}} \qquad (6)$$

Details of the derivation of these simple and practical formulae by Professor Oliner will be elaborated during the presentation. Furthermore, the discussion will expand to include the ingenious development of equivalent circuits by Professor Oliner for gaps, stripline slots, sharp bends and tee junctions.

MODELING MICROSTRIP DISCONTINUITIES

Professor Oliner's work on modeling strip discontinuities has served as the starting point for subsequent researchers in their effort to model other waveguiding structure discontinuities such as e.g. microstrip. To this end Oliner's stripline waveguide model with magnetic side walls has been adopted to model microstrip and microstrip discontinuities (7)-(8). The advent of very high speed computing capacity has recently provided impetus to the development of a variety of dynamic approaches which will also be addressed. The spectral domain method (9)-(10) and transverse resonance technique for enclosed structures (11)-(12) constitute a higher level of sophistication in obtaining accurate results in modeling MICs and MMICs. The spectral domain approach is to find the incident and reflected wave amplitudes in each port to construct the scattering matrix; while the transverse resonance method aims to find the resonant length of the cavity. Based on the resonant length, the impedance parameters are computed from the resonance condition. Dynamic modeling of a variety of integrated microwave and millimeter wave circuit discontinuities can also be achieved with high accuracy by employing the integral equation method (13)-(14). This method applies to shielded as well as open structures and it accounts for the physical effects including radiation, surface waves and higher order modes. In this scheme, the method of moments which determines the current on the strip or electric field on the slot is implemented in the solution of the Pocklington integral equation. The exact Green's function of a grounded dielectric slab in an open or shielded structure, due to either an electric dipole or a magnetic dipole has been used, which includes all the physical phenomena.

CONCLUSION

Professor Oliner's work as it applies to the understanding and modeling of balanced stripline discontinuities is reviewed. The evolution of Professor Oliner's contributions and recommendations to analyze microstrip and microstrip discontinuities is also presented. The current state of the art in the MIC discontinuity modeling is also discussed. Although emphasis will be placed on stripline and microstrip waveguiding structures, if time permits the finline and coplanar waveguide issues will also be addressed.

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