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Scattering at a Four-Port Vertical Microstrip–Slotline Transition

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Abstract—The rigorous analysis of three types of characteristic oscillations has been conducted in a stripline-slot resonator formed by the mutually-perpendicular strip and slot transmission lines (three-layer structure). Scattering matrix for a four-port vertical microstrip–slotline transition has been built on the basis of the resultant solution of boundary problems for the stripline-slot resonator.

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Planar transmission lines (stripline, slotline, etc.) have been finding wide application in hybrid and monolithic integral microwave circuits representing three-dimensional multilayer structures. One of the basic elements of these structures is vertical microstrip–slotline (MSL–SL) transition. Such transition is used, for example, in designing the circuits of transistor power amplifies operating in parallel (balanced networks consisting of two and more transistors). The analysis of such connection is a rather complex task that cannot be handled by ordinary projection methods (for example, the method of matched modes). In particular cases (for the structures with loops in MSL and SL), solutions of this problem are built either by using the method of moments with the Green function (in quasi-static approximation) [1, 2] or in accordance with the theory of long-distance lines [3], and these solutions feature low accuracy as compared with the results of experiments. In the paper of Schwab and Menzel [4] the scattering matrix of fundamental modes on the MSL–SL transition (two-port network with loops) was calculated to a high accuracy by the transverse resonance method (TRM). In case of TRM [5] the calculation of the scattering matrix on a specific discontinuity in the transmission line is based on using solutions of the boundary problem for the resonator containing this discontinuity. The purpose of the this paper is to design an algorithm for calculating *S*-matrix on the border of the overlap area of mutually-perpendicular strip and slot transmission lines in the three-layer structure.

MSL–SL RESONATOR

The structure under analysis is shown in Fig. 1. A stripline-slot resonator with three-layer filling is considered, the area of which is limited by electric walls. The second layer is a dielectric substrate, at both sides of which the mutually-perpendicular strip and slot lines are found. The size of the shield is $2A\times 2L$, the substrate thickness is h having permittivity ε_r, the strip and slot widths are w and s, respectively. Dimensions along the y-axis are shown in the figure.

Given the symmetry of such structure, three types of oscillations are possible that participate in forming the scattering matrix of a 4-port MSL–SL transition. The first type of oscillations corresponds to the field symmetry with magnetic walls in planes $x = 0$, $z = 0$ (MSL main mode and SL higher odd mode). The second type of oscillations is characterized by the field symmetry with electric walls in planes $x = 0$, $z = 0$ (SL main mode and MSL higher even modes). The third type of oscillations corresponds to the symmetry with the magnetic wall in plane $x = 0$ and the electric wall in plane $z = 0$ ("coupled" stripline-slot mode where the energy transfer proceeds from one transmission line to another). The solution of each of the three boundary problems for hybrid proper resonator modes is sought in terms of the electric and magnetic vector potentials $\mathbf{A}_{e(h)y} = (0, A_{e(h)y}, 0)$ [6, 7].

Let us consider the third type of oscillations in the resonator (Fig. 1, magnetic wall (*m.w.*) at $x = 0$ and electric wall (*e.w.*) at $z = 0$). In each of partial regions $i = 1\ldots3$ (Fig. 1) vector potentials satisfy the Helmholtz equation: