A New Tool for Slot–Microstrip Transition Simulation

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***Abstract*—We present the specific modelization with the MDS software and its MOMENTUM module, the technology brought into operation, and the obtained measurements for different structures involving the slot–microstrip transition. The experimental results are compared to those achieved by simulation. These works, as a whole, make it possible to evidence the interest of such a topology and the advantages of its simulation.**

***Index Terms*—Microstrip, slotline, transition.**

I. Introduction

THE GROWTH of circuits and systems in the microwave domain has promoted the rise of new microelectronic technologies from the point of view of both microwave monolithic integrated circuits (MMIC's) and integrated systems like hybrid circuits (MCM, thin- and thick-film technology). Topology diversification relative to microwave circuit design was reinforced by the use of new substrates and the transmission line diversity. The various interconnection structures and the associated propagation modes have given rise to many experimental studies as well as multiple analytical approaches. Mixed structures making use of slot lines appear very interesting [1]–[7], while showing technological limits. The use of techniques perfected in microtechnology, as well as the development of present simulation tools, make it possible to easily consider the integration of this type of microwave propagation structure using hybrid thick-film technology.

Microstrips as well as slot lines are both planar structures which can be, under the right conditions, simply modeled by a two-dimensional (2-D) or three-dimensional (3-D) planar approach. The devices under consideration need, however, a more sophisticated modelization which takes into account the different coupling phenomena arising at the level of the slotline–microstrip transitions. The use of the finite-element method allows a complex modelization by numerical resolution of the Maxwell's equations within a meshed structure, but can also be considered too heavy for a fast and efficient microwave circuit design.

We suggest an intermediate approach based on the use of the MOMENTUM module. This specific commercial software module permits the bi-dimensional meshing of several superposed planar structures as well as the study of the couplings taking place between the different levels. In order to validate these theoretical studies, devices were worked out and tested. The study was made in the frequency domain 1 to 20 GHz and applied to filters. Results of measurements are compared to those anticipated by simulation.

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II. Simulation

In a first step the investigated structure opened above and below and surrounded by air is defined as a piling up of successive layers complying with the various level superposition sequences (conducting and dielectric planes) and specifying for each of them its physical and geometric characteristics (permittivity, conductivity, thickness, ...). The simulator nets the general structure, level after level, computes its physical characteristics considering it as a "sandwich" substrate. Then, in a more general computation and for a given frequencial excitation, the simulation determines the different interactions, within the device itself, by a numerical resolution of the electromagnetism equations using the momentum method. In order to reach not only a sufficient accuracy, but also a reasonable calculation time (about 10 min using a Sun work station), the number of cells per wavelength was fixed to 50, for both slot and microstrip lines. The use of the Momentum module makes it possible to specifically simulate the transition microstrip–slot line from the electromagnetic phenomena point of view. The frequency interval selected was (1–20 GHz) and the applications were filters, for which the total computation time duration depends essentially on the number of frequency points and can vary from one to several hours.

Each studied filter was the subject of a specific simulation. For that purpose, the conducting level various geometries were specified and the various measurement ports (50 Ω) settled on the microstrips, hence in the microstrip plane.

The layout graphic output for the various plans given by the simulation made it then possible to manufacture the device for the experimental approach.

III. Designed Structures and Technology Used

In order to validate our approach, we have considered two structures. The first one realizes the function of a rejection filter using slot-line resonators integrated in a microstrip groundplane; the second one is a bandpass filter using the coupling between two slots, respectively, fed by two microstrips. The schematic diagrams of these two devices appear on Fig. 1. Slot lines were reserved in the screen-printed ground plane, while microstrips were deposited on the other side.

Stop-Band Filter: Rejected frequencies are 4 or 10 GHz as the case may be.

Slot lines represent $\lambda_s/2$ resonators, where λ_s is the guided wavelength in the slot at this frequency, taking into account

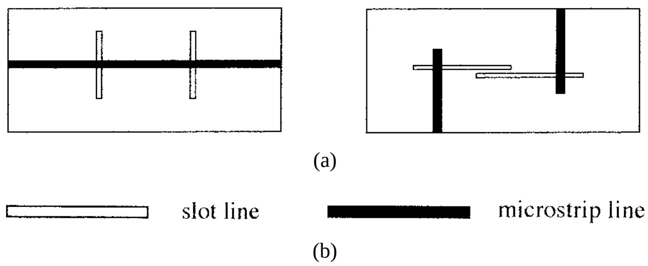

Fig. 1. (a) Stop-band filter. (b) Bandpass filter.

the geometric parameters of the structure. The two slots are separated by $n\lambda_m/4$ where λ_m is the guided wavelength in the microstrip, and n an integer greater or equal to 3. A lower value of n would indeed lead to a double peak rejection due to reciprocal coupling between the two slots [8], [9]. Moreover, the crossing point between microstrip and slot is situated at distances of $\lambda_m/4$, and $\lambda_s/4$ from the free ends of the microstrip and the slot, respectively, in order to insure a maximum energy transmission.

Bandpass Filter: Designed to be centered at 4 GHz, this filter structure uses the coupling between two slots separated by 200 μm over a length $\alpha = \lambda_s/4$. Two perpendicular microstrips, situated on the opposite side of the substrate and crossing each slot at a distance $\lambda_s/4$ of their free end, feed the structure and make it possible to test it [9]. The slotline–microstrip transition occurs at a distance $l = \lambda_s/4$ of the coupling slot-line section.

These different devices were designed and simulated. The circuits were then screen-printed on 99.6 % alumina substrates ($\varepsilon = 9,9$; microwave quality), using high-resolution commercial gold ink. The different steps of the process (screen-printing, drying, and firing) refer to the standards defined by the supplier. The devices were then tested.

IV. Results and Discussion

Measurements were made with a computer-controlled bench. The measurement set assembly mainly includes a network analyzer and a measurement socket allowing the interchangeability of the structures to be tested, all connected to a SUN workstation. The measurement apparatus were monitored through an IEEE bus with a software which also enables the data acquisition and processing. Simulation and measurement results may then be compared and analyzed.

Rejection Filters: The experimental results obtained with the network analyzer and those coming from the simulation are presented and compared Figs. 2 and 3 for the transmission and reflection curves of 10-GHz center frequency filter.

The rejection frequency occurs at 9.6 GHz both for the simulated as well as measured rejection peak (S_{21} parameter) (see Fig. 2). And the rejection levels are very similar (−27 dB).

A possible explanation for the jagged measured data, on the Fig. 3, might be calibration error.

For frequencies higher than 12 GHz, the frequency responses, simulated and measured, go through a clear attenuation (between 3 and 5 dB for simulation, from 5 to 10 dB for measurements). This phenomenon may be due to the sensitivity of measurements beyond 10 GHz, which can be understood by the multiple reflection cumulative effects arising from the different connections, but also by phenomena inherent to the structure (radiation, end effects, among others), which were partially neglected in a first approach.

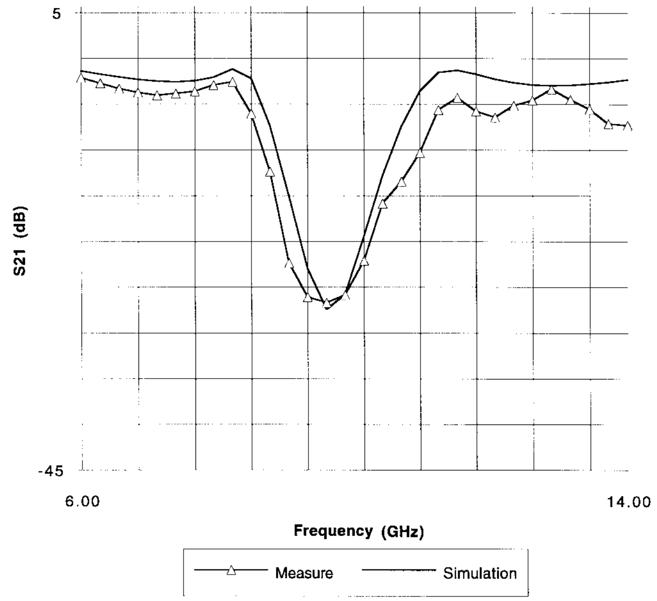

Fig. 2. 10-GHz stop-band filter S_{21} parameter.

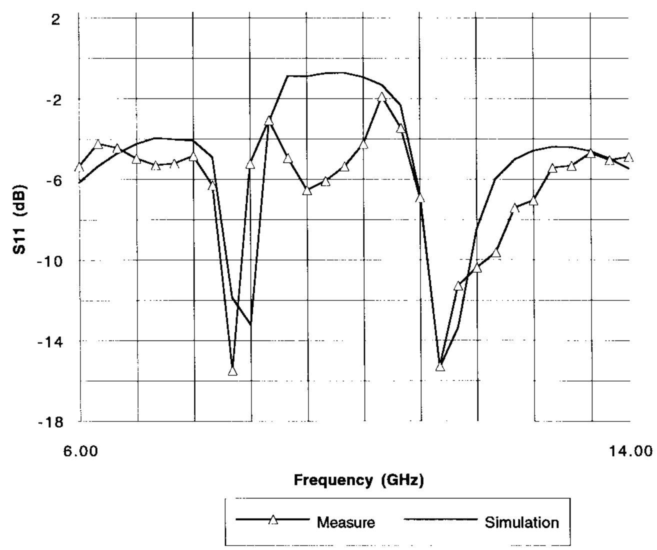

Fig. 3. 10-GHz stop-band filter S_{11} parameter.

Analogous results were obtained for the 4-GHz stop-band filter. The rejection occurs at 3.9 GHz and is higher (−40 dB) for the real filter than for the simulated one (−27 dB). Taking into account the frequency range (2–6 GHz), this difference could be attributed to the effect of simulation or/and measurement steps.

Bandpass Filter: The experimental and simulated results are given Fig. 4.

The two transmission curves (S_{21} parameter), simulated and measured, are in good agreement and accurately centered at 4 GHz.

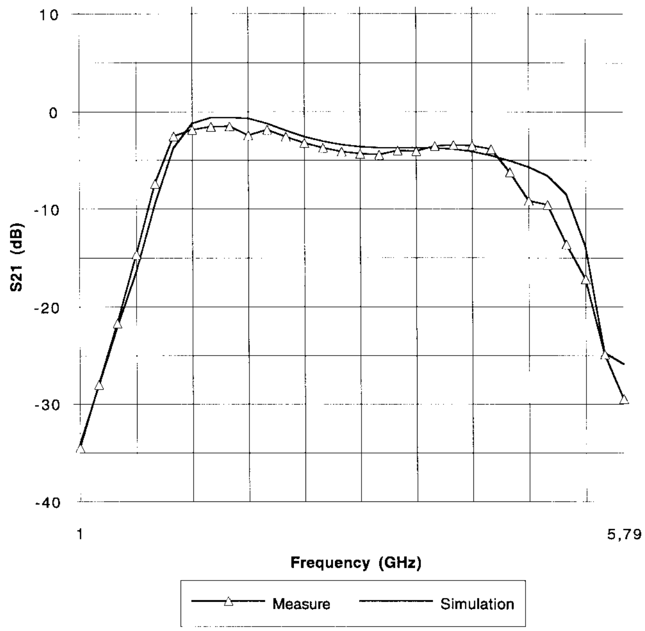

Fig. 4. Pass-band filter S_{21} parameter ($fc = 4$ GHz).

As for the previous structure a significant attenuation can be noted in the transmission band toward the high frequencies.

V. Conclusion

An alternative modelization method has been used to solve the specific structure formed by the microstrip–slot-line transition. This method, based on the use of a specific module, has made it possible to predict the behavior of these transitions when they are used to feed coupled slot-line filters. The corresponding devices were worked out using screen-printing thick-film technology. Their working frequencies were chosen at 4 and 10 GHz. Their electrical characterizations were performed with a S-parameter computer-controlled acquisition bench in the 1–20-GHz range. Satisfying agreements between computed and measured parameters were achieved.

Finally, we have been able to point out, through several examples, the interest of this simulation method, including its easy accessibility, which should allow to anticipate the behavior of more sophisticated circuits including multilayer structures.

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