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## **3D INTEGRATED NARROWBAND FILTERS FOR MILLIMETER-WAVE WIRELESS APPLICATIONS**

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### **ABSTRACT**

**The TFMS (Thin Film MicroStrip) technology is an attractive solution for Wireless Local Loop equipments, for filtering and interconnects facilities. This is illustrated through the implementation of narrow-band band-pass filters. Original synthesis techniques, consisting in including CPW (CoPlanar Waveguide) to TFMS transitions for loss reduction and reliability, are presented.**

### **INTRODUCTION**

Wireless Local Loop technologies will probably represent the main domain of investigations for telecommunication suppliers and operators in the next 5 years. Indeed, they are potentially considered as the most competitive solutions for emerging markets with respect to wireline networks. Two issues will determine the emergence of these interfaces between subscribers and operators : the cost and the available bandwidth. Therefore, high bit rate services will be proposed by means of millimeter-wave links, which can be considered as a great challenge regarding technologies maturity and reliability at such frequencies [1]. In addition, spectrum occupation will bring severe constraints on RF equipments, especially on passive RF filters (reduced relative operating bandwidth (less than 5% at 41 GHz), losses) and on active components (flip-chip mounted MMIC's). In this paper, we discuss about the integration of narrow bandwidth (4.5%) RF filters at 44.3 GHz,

by means of TFMS (Thin Film MicroStrip) configurations. Then, we emphasize on original approaches for minimizing loss phenomena and solving technological reliability with active modules, by integrating CPW (CoPlanar Waveguide) to TFMS transitions in the filter topologies and considering such structures as complete parts of the input-output resonators.

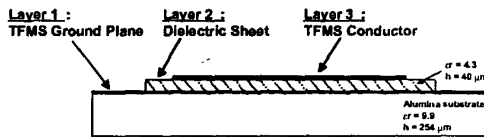
### **NARROW-BAND BAND-PASS FILTERS AT MM-WAVES**

For cost motivations, only integrated configurations are studied here, waveguide or suspended substrate architectures being fundamentally more appropriated under such constraints, but not competitive for cost criteria. The main difficulty when synthesizing lossless narrow-band band-pass filters leads on the ability to design high-Q integrated weakly-coupled resonators [2]. This is a contradictory preoccupation in the present context, because of the operating frequencies resulting in reduced size structures with conductive losses and modelization difficulties.

With classical filter topologies (parallel coupled lines, Stepped Impedance Resonators(SIR)), very low coupling coefficient levels are required for ensuring small bandwidths. This results in a significant spacing between adjacent resonators, and consequently dielectric losses and radiation phenomena, especially with microstrip structures. The problems are quite different with the CPW technology. Indeed, its intrinsic flexibility allows to operate with both restricted spacing between adjacent resonators and reduced metallic losses.

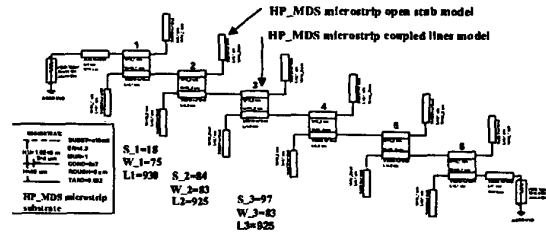
Nevertheless, modelization efforts, packaging constraints and bounding wires for parasitic coupled slotline modes rejection remain fundamental limitations.

The TFMS technology previously proposed by Menzel et Al [3] for integrating low-pass filters appears as a good candidate for implementing millimeter-wave filters. As mentioned on figure 1, we deposit a thin dielectric layer ( $\epsilon_r = 4.3$  / thickness  $h=40\mu\text{m}$ ) on a metallized alumina substrate. Then, microstrip structures can be implemented on this "artificial" substrate, with ratios  $W/h$ ,  $L/h$  or  $S/h$  ( $W$ ,  $L$ ,  $S$  are respectively the Width, the Length and the Spacing between resonators) particularly well-suited for a "transmission line" description of the guiding elements, even at millimeter wavelengths.

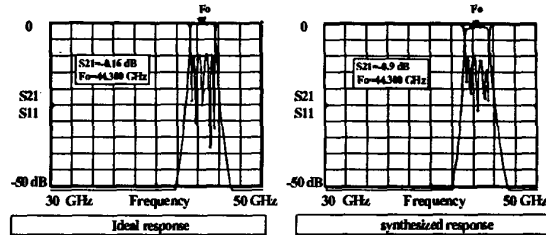


**Figure 1** : TFMS technology

TFMS SIR and parallel coupled lines filters have been synthesized using standard CAD microstrip models from HP-MDS software. Low coupling levels involved by narrow-band specifications are easily obtained with small spacing between resonators because of the ground plane proximity. Figure 2 describes the equivalent TFMS filter model and the correspondence between ideal and synthesized responses. Common microstrip discontinuity models can be employed on this thin substrate despite the operating frequency, thanks to the appropriate shape of the resonators for quasi-TEM propagation conditions. So, the TFMS configuration is quite attractive for developing millimeter-wave filters, both for CAD facilities and design flexibility.



**Figure 2.a** : TFMS equivalent filter (parallel coupled lines topology)

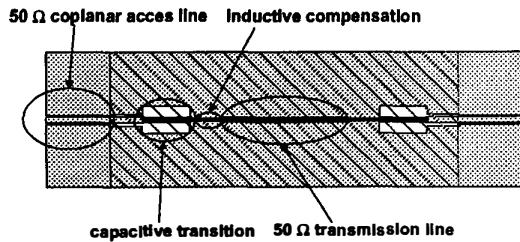


**Figure 2.b** : Ideal and synthesized TFMS equivalent filter responses

### III. INTRODUCING CPW TO TFMS TRANSITIONS FOR TEST AND RELIABILITY

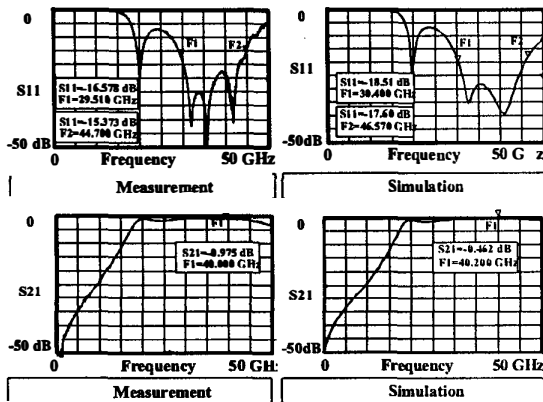
One main preoccupation concerns the excitation of the TFMS feeding lines of the filter. This has been performed by means of TFMS to CPW transitions implemented at both ends of the filters.

A back to back CPW to TFMS transition is presented on figure 3. It is based upon a capacitive coupling between the main conductors of the TFMS and the CPW guides, through the thin dielectric sheet. An inductive compensation is located at each side of the coupling high pass sections to control the cut-off frequency.



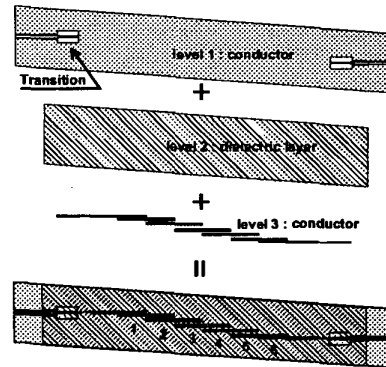
**Figure 3** : CPW to TFMS transition

We have developed 40 % and 65 % CPW to TFMS transitions centered at 40 GHz. As mentioned on figure 4 (40 % bandwidth), quite a good agreement between MDS simulations and measurements is observed. Insertion losses of about 0.8 dB/0.5 cm only have been registered inside the -15 dB return loss bandwidth.

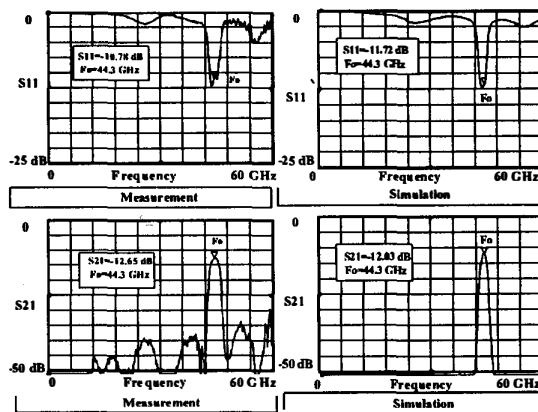


**Figure 4** : Characterization of a back-to-back CPW to TFMS transition

Such transitions have been introduced at both extremities of the previous described TFMS filters (fig. 5). Probe tests can be easily applied under such conditions (fig. 6). In addition, this is also a convenient solution for improving reliability between active and passive modules in future millimeter-wave hybrid front-ends. The -12 dB measured insertion losses are basically related to the finite conductivity and the thin thickness (4 $\mu$ m) of the gold conductors.



**Figure 5** : Layout of the TFMS filter



**Figure 6** : TFMS filter : measurement-simulation

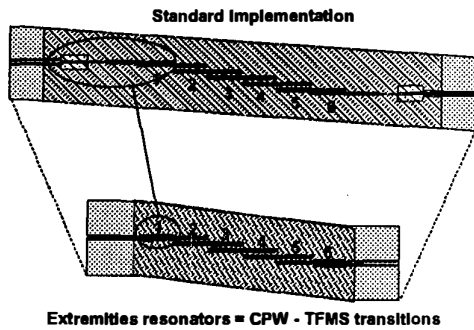
Anyway, this value is quite similar to the one obtained with standard microstrip configurations on Alumina substrate, for which the shape and the limited Q-factor of the resonators strongly affect the effective operating bandwidth and the associated transmission losses.

### CPW -TFMS TRANSITIONS AS FILTER RESONATORS

Lastly, we emphasize on the possibility of considering these transitions as a complete part of the band-pass filter. As illustrated on figure 7, we introduce the CPW to TFMS transitions in place of the extremity resonators of the filter. These

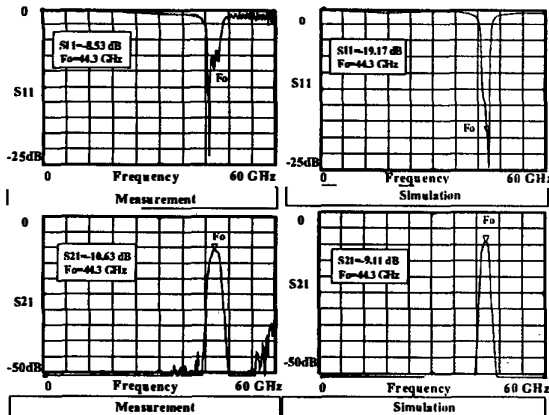
transitions are now designed with respect to the electrical characteristics of the external resonators. This procedure has three consequences :

- Reducing the losses because the order of the filter is artificially decreased in this way
- Ensuring an intrinsic reliability of the passive functions with mm mounting techniques
- Minimizing the technological sensitivity : the critical spacing between the external resonators are suppressed (overlapped approach).



**Figure 7 :** Integration of CPW -TFMS transitions as filter resonators

The measurement and the simulation of such a filter are reported on figure 8.



**Figure 8:** Filter with CPW transitions-experiment

The agreement is correct. Moreover,  $-10.63$  dB insertion losses are observed in this case (to compare to the  $-12.03$  dB obtained with the first structure (figure 5) which uses external transitions). Such original integration technique is undoubtedly interesting for the implementation of complete RF front ends, leading to reduced technological constraints and improved performances.

## CONCLUSION

We investigate on the possibility of designing very narrow-band filters for millimeter-wave wireless equipments. The TFMS technology is basically attractive on several aspects (design possibilities and control, technological sensitivity, ...). One additional effort must be made for improving conductive losses, either by using better materials (silver), or depositing thicker conductive layers (which is now thinkable through the proposed original filter synthesis technique (integration of high performance transitions as resonators) which really contributes to reduce the technological sensitivity).

## ACKNOWLEDGMENT

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