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Christian Person, Laurent Carre, Eric Rius, Jean-Philippe Coupez, Serge  
Toutain

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# ORIGINAL TECHNIQUES FOR DESIGNING WIDEBAND 3D INTEGRATED COUPLERS

Ch. Person, L. Carré, E. Rius, J. Ph. Coupez, S. Toutain

(\*) LEST - ENST de Bretagne/UBO - BP832 - 29285 Brest Cédex - France

## ABSTRACT

In this paper, we propose some original technological configurations for implementing highly coupled wideband structures in a 3D environment. Thanks to a convenient combination of thinkable topologies, difficulties commonly encountered with a classical approach can be solved. Different design examples of couplers are given, and experimental and simulated results are presented.

## INTRODUCTION

In the last few years, a lot of works have been published about the design of microwave couplers, with persistent preoccupations in terms of bandwidth and coupling level possibilities.

On one hand, high coupling levels are reachable by means of Lange structures, or Tandem topologies; nevertheless, limitations are observed in terms of bandwidth because of synthesis considerations (quarterwavelength structures) and electrical perturbations (discontinuities, medium inhomogeneity).

On the other hand, reaching wider frequency bandwidth range is generally performed by using cascaded structures. In this case, as the basic considered elements have intrinsic limitations in terms of reachable coupling levels, discontinuities and bandwidth, great problems are often encountered.

Today, multilevelled microstrip topologies become widespread, then solving problems of high coupling levels (overlapping process) [1]...[5]. Nevertheless, in accordance with involved materials and considered transmission

line topologies, extremely wide operating bandwidths are not thinkable (phase velocity difference  $\gg$  low directivity level).

If the "cascaded" solution seems to be the more attractive opportunity for reaching wide bandwidth, a specific work must be done on each basic structure, concerning topologies, dispersion, and discontinuities. In this way, we propose an original design technique, based upon *multilayer multitechnology concepts*.

## DESIGN OF ORIGINAL BASIC STRUCTURES FOR MULTISECTION COUPLER

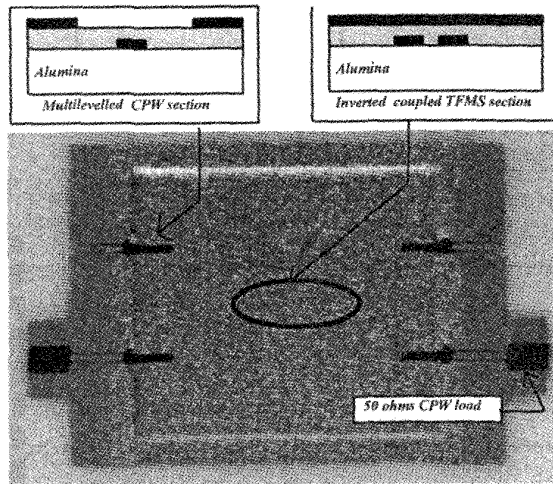
When designing multisection couplers, low coupling levels are generally needed for lateral sections while high coupling values are required for the center sections (respectively about 16.5dB and 1.65dB for a 3dB third order 0.1dB ripple coupler, for example).

Therefore, as the constraints are quite different for each region, specific topologies must be systematically chosen and optimized. Nevertheless, the technological compatibility between each section must be taken into consideration.

### 1) Low coupling level structures

Classical planar coupled lines can be used to implement low coupling level structures. However, this will result in a significant spacing between transmission lines, and thus, in a great difference between phase velocities, reducing the directivity of the coupler. To ensure the phase velocities equivalence, we have

developed an inverted TFMS (Thin Film MicroStrip lines) 16.5dB coupler on alumina substrate, in a multileveled configuration.



**Fig. 1 :** Inverted TFMS 16.15 dB coupler  
(Center frequency : 10GHz)

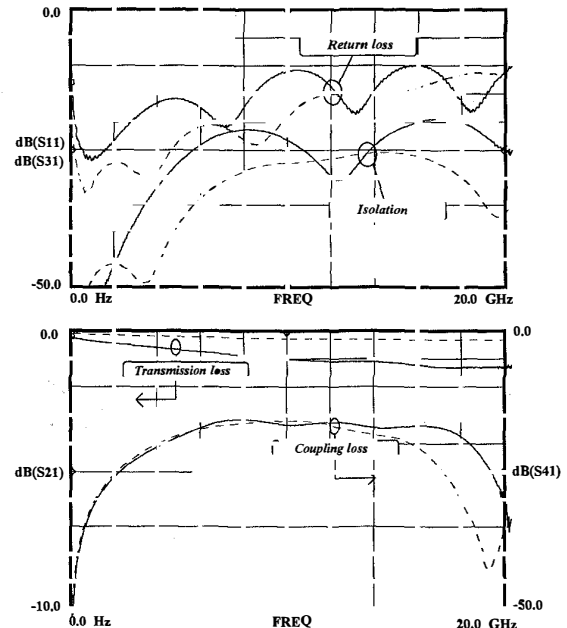
The coupled lines are directly laid down on the substrate (permittivity 9.6), with a 30 $\mu$ m dielectric overlay (permittivity 9.5), and an upper ground plane. The homogeneity of the structure is forced, and the isolation is naturally improved (less than -45dB).

This coupler has been implemented and tested on a probe station; indeed, in relation with the line width (less than 50 $\mu$ m), inverted TFMS to CPW (coplanar waveguide) transitions have been implemented at the different ports. Specific models have been defined to take into account losses and parasitic effects involved by such interconnecting lines.

In addition, as a two-port S-parameters extraction procedure is employed, the two other accesses are terminated by 50 ohms screen-printed CPW loads, which have been characterized (return loss -20dB up to 10Ghz, -10dB above).

Fig.2 shows the corresponding experimental results; Note that the 50 ohms CPW loads significantly degrade the return loss and isolation parameters. When all previously des-

cribed parasitic effects are included in the simulated model (fig. 2), quite a good agreement is observed

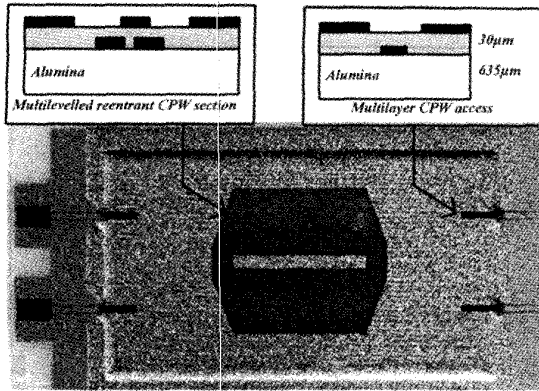


**Fig. 2 :** 16.5dB inverted TFMS coupler  
- Measurements (—) - Simulation (---) -

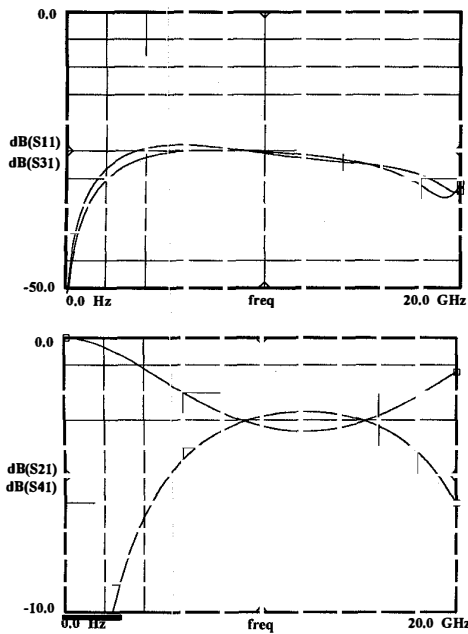
That means that the effective coupling section itself is well-controlled, and gives performance in accordance with the ideal expected ones (16.5dB coupler, isolation less than -45dB).

## 2) High coupling level structures

So as to remain compatible with the previous planar coupler (inverted TFMS coupler), we have investigated new topologies of structures leading to high coupling levels. Fig.3 depicts one basic configuration, based upon the CPW technology in a multilayer medium. High coupling levels are achieved by considering a reentrant CPW topology, the third conductor being located on the upper dielectric layer as well as the ground planes; The modelization is performed by means of HP-MDS models, considering lateral CPW ground planes as conductors with a reduced width.



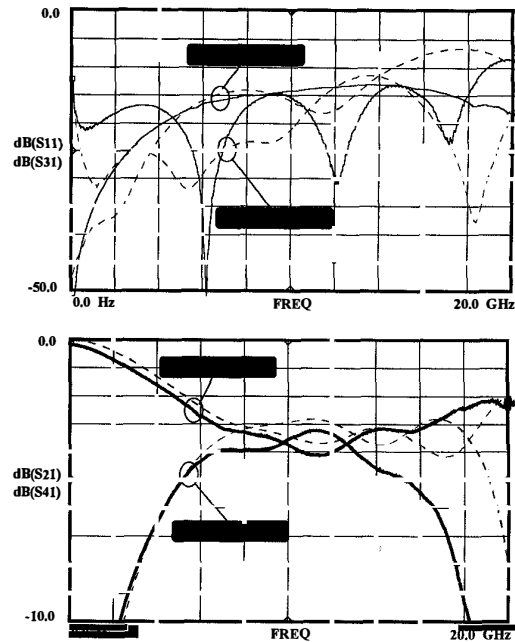
**Figure 3** : 3dB Multileveled CPW coupler :



**Fig.4** : Ideal simulated [S] parameters

Due to the upper reentrant conductor, this second structure is also less sensitive to technological dispersions, and provides better results in terms of directivity, the main part of the signal being concentrated in the dielectric.

3dB couplers have been realized and tested. As mentioned on fig. 5, return loss and isolation are significantly degraded with respect to ideal simulated ones (fig.4) because of reflection coefficients related to 50 ohms loads.



**Fig.5** : 3dB multileveled reentrant CPW coupler  
Measurement (—) / Simulation with parasitic effects(---)

When parasitic effects specific to test conditions are taken into account (fig.5), simulation and experiment become close to each other; the 3dB reentrant CPW coupler is obviously correctly defined and gives performance similar to the ideal expected ones (fig4)

### 3) Wideband high coupling level couplers

Multisection wideband 3dB couplers can be obtained by cascading previous developed coupling topologies. Then, for a 3dB third-order 0.1dB-ripple coupler, lateral sections can be integrated as 16.5dB inverted TFMS coupler, while the center one will be a 1.65dB multilayer reentrant CPW coupler.

Due to the planar configuration of basic structures, the different sections can be easily interconnected, minimizing parasitic phenomena. This is a real improvement with respect to classical multisection coplanar/microstrip couplers.

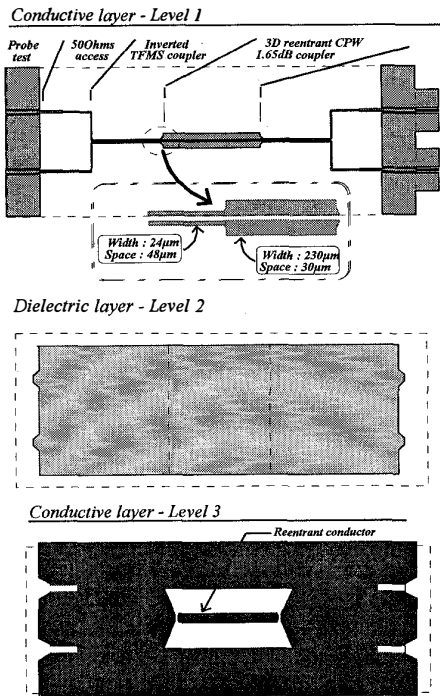


Fig. 6 : 3dB multisections coupler - description

The upper TFMS ground plane for lateral 16.15dB sections is used in order to reject parasitic modes potentially generated by the center CPW structure; here, no bounding operation is required thanks to this configuration.

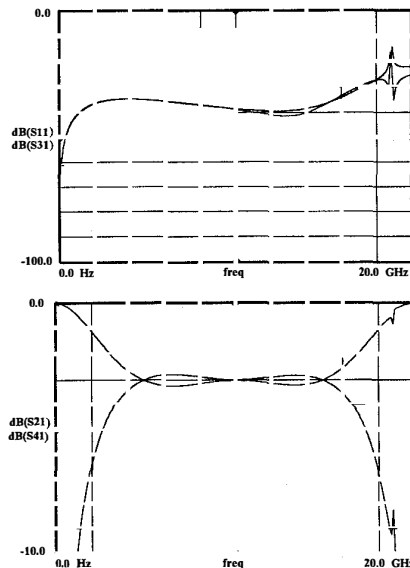


Figure 7 : Multisections 3dB coupler : simulation

We are currently experimenting such wideband multisection tight coupling structures and experimental results will be presented during the conference.

## CONCLUSION

Integrating wideband tight coupling structures often leads to great limitations in terms of electrical performances and physical dimensions. We propose in this work alternative original solutions, based upon design flexibilities inherent to a 3D approach. The main difficulty consists in the ability to make compromises between concepts which currently result in opposite solutions. In particular, it is illustrated here through the possibility of keeping the phase velocity identity between propagated modes under high or low coupling level requirements, by choosing appropriate inverted TFMS or reentrant multilayer CPW structures.

Furthermore, parasitic modes and discontinuities are minimized during interconnection phases, resulting in a better control of the modelization procedure. We intend to use extensively this method to develop miniature integrated circuits in the millimeterwave domain.

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