NEW 3D LOW LOSS, WIDE BAND MICROWAVE INTERCONNECTION.

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ABSTRACT

This paper describes a new wide band [0; 40 GHz] vertical interconnection approach between two RF homogeneously grounded coplanar lines. It can be considered as two 90° vertical bends transition. Both electromagnetic simulation and measurement demonstrate very good results on the whole frequency range.

INTRODUCTION

3D microwave modules are ideally suited for applications where complex microwave functions have to be packed in a small volume. This is the case, for example, in active array radars for aerospace at X-band [1]-[2]. In this application, thousands of identical modules have to be stacked very tightly behind the radiating elements. Thus, 3D technology leads to lower size, weight and cost.

For all 3D technologies, the main problem to solve is the vertical electrical interconnection between two RF lines of two different layers. In this paper, we present a new vertical interconnection based on an homogeneous double grounded coplanar line (that is to say a coplanar line which is embedded between two grounded substrates), called homogeneous coplanar line, with a 90° vertical transition which leads to a three dimensionnal structure (cf. Figure 1). The interconnection can be approximated as a two 90° bends transition.

DESIGN OF THE NEW CONCEPT

The design of this structure is divided in two parts :

- first, the conception of the grounded coplanar line.
- next, the analysis of the transition itself.

On a grounded coplanar line, the fundamental mode is the odd mode where the electric field vectors are in opposite direction in the two slots. However, at some special frequencies, the effects of parasitic modes may appear. These modes are the "microstrip like mode" (the electromagnetic energy is not concentrated in the slots but between the strip and the grounded backplane), the "slot line mode", also called the "even mode" (the electric field vectors are in the same direction due to a difference of potential between the two lateral groundplanes) or the "resonator mode" (due to the width of the lateral ground planes [3]).

Under these electrical considerations of the grounded coplanar line, we started a complete analysis of the interconnection. The calculation were based on the commercial three dimensionnal finite elements software HFSS from Hewlett-Packard. In order to minimize the calculation time, we put a magnetic wall in the middle of the structure and the different materials used for this simulation were considered as perfect. The input/output ports were designed to achieve a perfect coplanar propagation in the structure with no parasitic modes.

As we can see in Figure 1, the interconnection can be considered as two 90° bends in the vertical direction. The coplanar line is embedded in an homogeneous material and the two RF levels are separated from each other by a ground plane to improve the isolation. A

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window is designed in the ground plane at the point where the vertical line crosses it to avoid the short-circuit.

Regarding to the simulation results, we can see that along the RF line, there is no coupling between the RF line and the common ground plane as showed in the Figure 3. Figure 4 shows that the electric field stays concentrated in the slots, even in the two vertical coplanar bends. This expresses clearly the quasi-surfacic feature of this kind of propagation. In fact, as the ground planes follow continously the coplanar strip all along the transition, the 3D transition is perfectly impedance controlled. We can see in Figure 2 that the simulation shows excellent results respect to the [S] parameters S_{11} and S_{21} over a large frequency range [0; 35 GHz].

VALIDATION OF THE CONCEPT

Due to some technical problems, such as the difficulty of measurements using coplanar RF probes at two different horizontal levels, the previously described structure has not been measured using exactly the same configuration. In order to validate our approach, a test structure has been designed based on an inhomogeneous coplanar line and two vertical transitions. This structure allows the use of conventionnal coplanar probes on the same horizontal plane. The line parameters are W=70µm (strip) and G=40µm (gap), thus avoiding the effect of the "microstrip like mode". The substrate is a 40 mils thick alumina substrate with no ground plane between the two strips. This is another important difference between the test structure and the theoritically studied structure.

However, we have performed some simulation on this modified structure (cf. Figure 5) with HFSS which have showed that there was a very good isolation between the RF lines at the edge transition.

The problem of testing the circuit with the reference ports located at two different levels is solved by chaining two transitions, so that the connectors are located at the same level. The main technological problems is in the etching of the vertical sections on the alumina substrate and in the upper and lower lines alignement. These problems have been solved by using an UV laser processing technique. The size of the laser spot is 20µm wide with a 10µm recovering area leading to a very good precision on the RF line processing.

MEASUREMENTS AND DISCUSSION

The measurements were performed on the [0, 40 GHz] frequency range using a Wiltron 360B network analysor and a Cascade Microtech Summit 10600 test station. An LRM calibration technique has been used in the RF probes planes. The alumina was lying on two small metallic pieces in ordre to separate it from the chuck and to prevent the lower coplanar line from being short-circuited.

The results obtained on the magnitude of the S_{11} and S_{21} parameters are shown on Figure 6 and Figure 7 respectively. They can be considered as very good on the [0, 20 GHz] range (with a reflexion factor below -18 dB), the metallic losses being the major responsible of the insertion losses (-2.2 dB at 5 GHz and -11 dB at 40 GHz for a total length of 53 mm).

These relatively high insertion losses are due to the choice of a very thin cental conductor (W=70µm) in which the current lines are strongly concentrated.

This is clearly visible when the measurements are compared with the theoritically calculated losses of a "normal" (horizontal) coplanar line of the same length and the same dimensions (cf. Figure 7).

Actually, the losses of our two bends structure are even lower than the losses of a "normal" coplanar line. This can be understood by the special effect of the laser etching into the alumina (about 10 to 12µm compared to the 5µm gold plating) which results in an air gap between the central line and the ground plane in an area where the electromagnetic fields are higly concentrated.

It can be also pointed out that the measurement features sharp peaks on the insertion losses in the upper frequency range. This can be explained by the cavity like behaviour of the substrate which is entirely metallised (that is to say the two surfaces and the four edges). Moreover, no air-bridges crossing the RF line have been wired. This could result in a degradation due to the apparition of the "even mode" along the coplanar line on such a long line. At last, as the dimensions of the lateral ground planes are quite huge compared to the width of the strip, this could induce some resonant effects on the propagation.

Further developments have to be undertaken to take into account these two main observations : some air-bridges have to be added along the line and the lateral groundplanes width to be reduced. In addition, we have to solve the problem of extracting from the measurements the [S] parameters of the vertical transition alone (and not of two chained transitions including long RF lines).

CONCLUSION

We present in this article a new concept of a 3D RF interconnection between two horizontal layers based on a RF coplanar line. The first results on this structure show very good characteristics in the [0; 20 GHz] frequency range. Between 20 GHz and 40 GHz, some resonant effects are observed due to parasitic modes not taken into account during the design. Different studies are in progress for a better understanding of the problems revealed by this test vehicle in the upper frequency range. Results should be available at the time of the conference.

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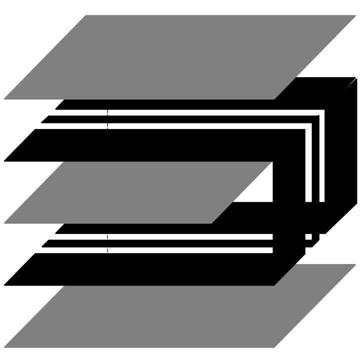


Figure 1 : Schematic of the RF vertical interconnection.

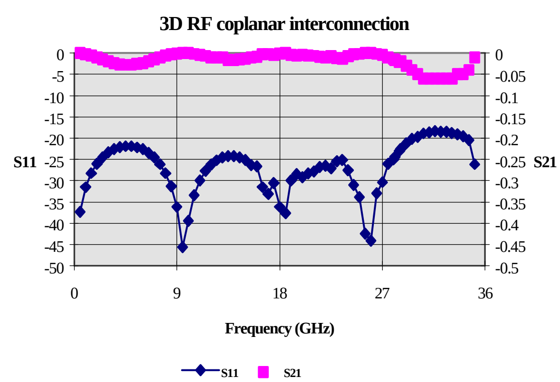
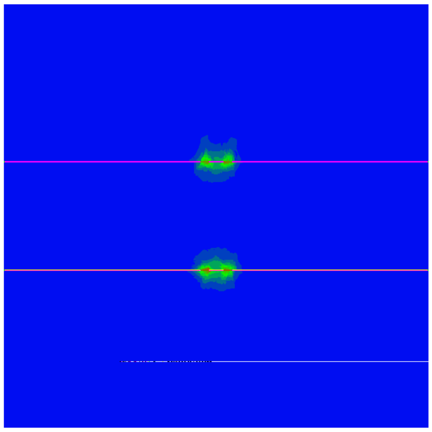


Figure 2 : Calculated [S] parameters of the vertical transition in the frequency range [0; 35 GHz]



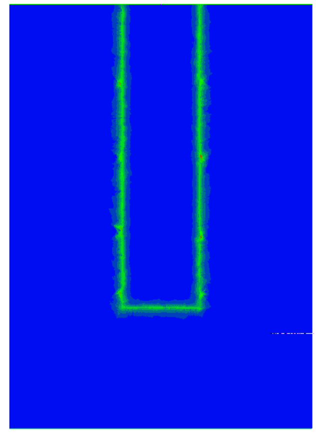


Figure 3 : Representation of the electric field across the RF line.

Figure 4 : Representation of the electric field in the slots of the coplanar line.

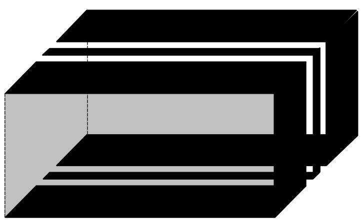


Figure 5 : Description of the test vehicle's transition.

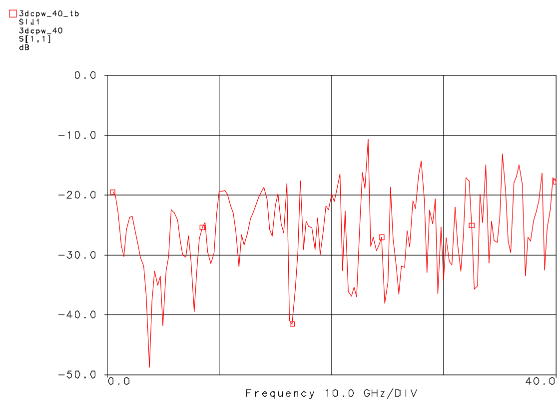
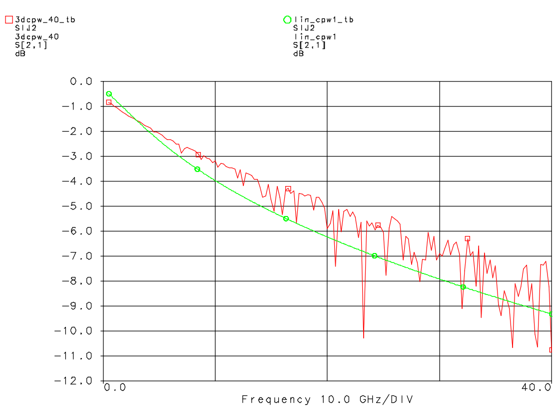
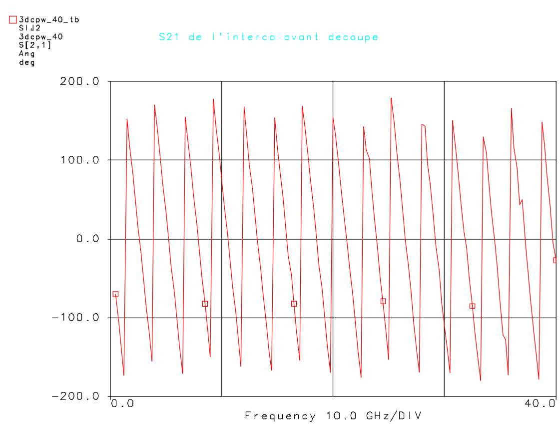


Figure 6 : Return loss.



Insertion losses of the structure and comparison with a grounded coplanar line of the same length.



Phase of the S_{21}

Figure 7 : Measurements of the S_{21} parameter of the vertical interconnection of the modified structure.

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