A NOVEL COPLANAR TRANSMISSION LINE TO RECTANGULAR WAVEGUIDE TRANSITION

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ABSTRACT

Waveguides (WG) are often utilised for antenna or filter design. This paper presents a new, easy to build transition from a coplanar line to a WG, which is often needed to embed WGs into MMIC designs or vice versa. In contrast to the well known E-plane probe-transitions [1] and ridged waveguide-transitions [2], the proposed waveguide transition does not require modifications of the waveguide and the planar design. The transition was optimised for a low radiation pattern on the top side and for a broadband transmission using the Finite Difference Time Domain Method (FDTD) [3,4]. Measurements for verification are also presented.

INTRODUCTION

The well known planar circuit to waveguide transitions are typically microstrip to waveguide transitions. These transitions often require modifications of the waveguide. The E-plane probe transition [1] consists of a microstrip line on a dielectric substrate inserted into the waveguide. A waveguide backshort must be placed in a certain distance behind the probe to achieve good transmission properties. So the waveguide extends over the top of the planar substrate and puts restrictions upon the layout and the package design. In case of the ridged waveguide transition, the waveguide extends on both sides of the planar design. In addition to this it is rather difficult to incorporate more than one transition in a single design.

The transition introduced in [5] is a new approach to this problem. It uses a substrate placed on the top of the waveguide. On the substrate an open end of a microstrip line radiates through a slot in its ground plane into the waveguide. To improve the transmission, an aperture coupled patch is placed into the waveguide on an additional substrate. The position of this patch is determined by a step in the width of the waveguide. This still requires modifications of standard waveguides.

This paper presents two CPW to rectangular WG transitions for the Ka-Band. One is optimised to achieve a bandwidth of more than 15 percent for less than -15 dB reflection and the other is optimised for low radiation leakage.

The presented transitions are part of a project called "Multifunctional Microwave and Millimeterwave Modules (4M)" which is funded by the BMBF[1]. Its aim is the definition of system concepts, and evolving suitable new technologies like low cost, high efficiency packaging for modern communication systems. Developing these concepts, new technology processes like LTCC multilayer circuits and injection mould plastic or powder injection mould metal are utilized.

TRANSITION DESIGN

The aim of the design was to achieve a simple to build transition requiring no modifications of the waveguide combined with the possibility of hermetic sealing.

[1] Bundesministerium für Bildung und Forschung, Projekt Nummer 16SV418/0

The transition as shown in Fig. 1 consists of a double-sided, structured 635 µm thick Al_2O_3 substrate placed on top of the waveguide. The upper part of Fig.1 shows a top view of the structure, the lower part shows a cut through the plane of symmetry A A'.

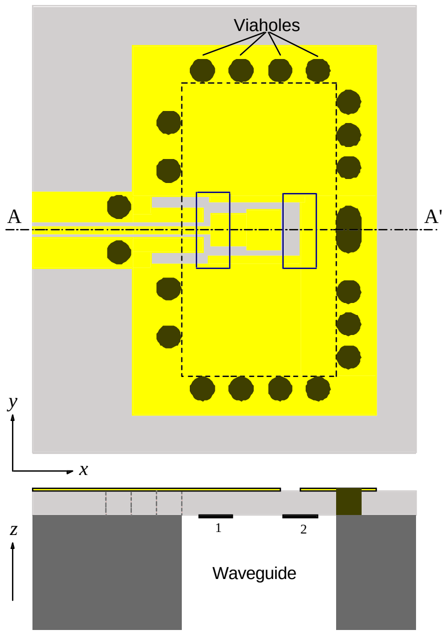

Fig. 1: Top- and sideview of the waveguide-transition.

On top of the substrate the structure on the left side can be interpreted as a coplanar to microstrip transition. Here the electromagnetic field is concentrated between the stripline and the backside metallization. This causes the excitation of the metal strip 1 on the backside. The metal strip 2 is coupled capacitively to the wided microstrip line. So the two metal strips are excited with a phase displacement that yields a strong electrical field in x-direction between the metal stripes as well as in the slots between the metal stripes and the waveguide.
The calculated field distribution of the transversal electrical field on the backside of the substrate (inside the waveguide) at 34 GHz is shown in Fig. 2. It is visible that mainly the TE_{10} mode is excited as desired.

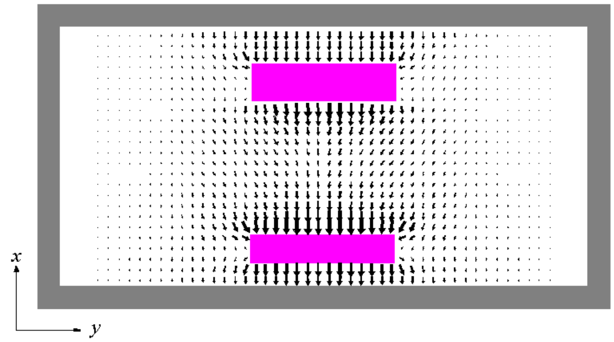

Fig. 2: Transversal electrical field on the backside of the substrate inside the waveguide at 34 GHz.

The viaholes extend the waveguide into the substrate and prevent the transition from lateral radiation. By the two viaholes at the sides of the coplanar line the suppression of the unwanted odd coplanar modes is obtained.
The design was done using EMPIRE™, a versatile 3D fieldsimulator based on the FDTD method [2]. Design parameters used are the dimensions of the patches on the backside and the structure of the coplanar to microstrip transition on the top. To reduce simulation time and computer memory usage, only the half structure has been simulated. This is possible by taking into account the symmetry of the structre and the modes in the waveguide to the xz-plane defined by the line A-A' in Fig.1. The simulator takes care of this symmetry, if a magnetic wall is placed at A-A'.
To verify the design, a test structure has been realised (Fig. 3), and measured. It consists of two coplanar-waveguide transitions to allow the use of waveguide NWA for measurement.
For the test structure the substrate is fixed on the waveguide flange using conductive glue. The measurements compared with simulation results are shown in Fig. 4.

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[2] EMPIRE™ is a commercial fieldsimulator developed at the IMST.

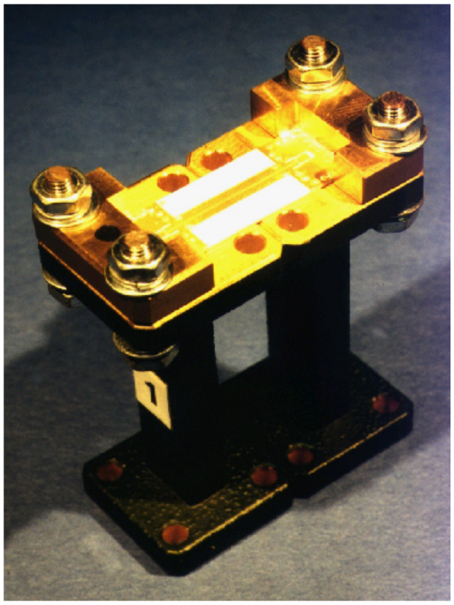

Fig. 3: Photo of the teststructure.

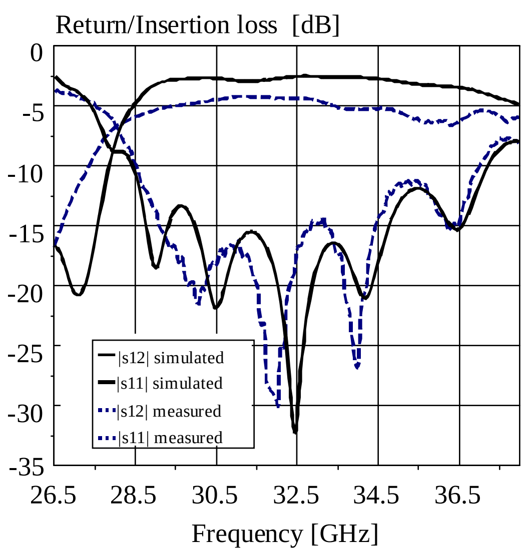

Fig. 4: Scattering parameters of the transition.

Simulation results and measurements correspond well with each other. The differences between them can be explained by the fact that dielectric losses as well as the finite conductivity of the metal structure and the waveguide walls are neglected in the FDTD simulations. The differences between the reflection losses are presumably caused by mechanical tolerances or failure of some viaholes and placement inaccuracies.

It can be seen that the transition achieves a bandwidth of 5 GHz at a minimum return loss of 15 dB. The insertion loss of about 4 dB for two transitions (back to back) is an indication for a slight radiation leakage.

Therefore another transition was developed attaining a lower insertion loss. This design was made for an antenna feed at 34 GHz. Basically the structure is the same as in the design described above. A four layer LTCC-substrate was used, each layer had a thickness of 150 µm and a permittivity of $\varepsilon_r = 7.8$. To achieve a low radiation leakage, the metal structure at the top of the transition was modified. Additionally, the position and dimensions of the patches on the side of the waveguide have been optimised with several FDTD simulations. The resulting transition is shown in a detailed view in Fig. 5.

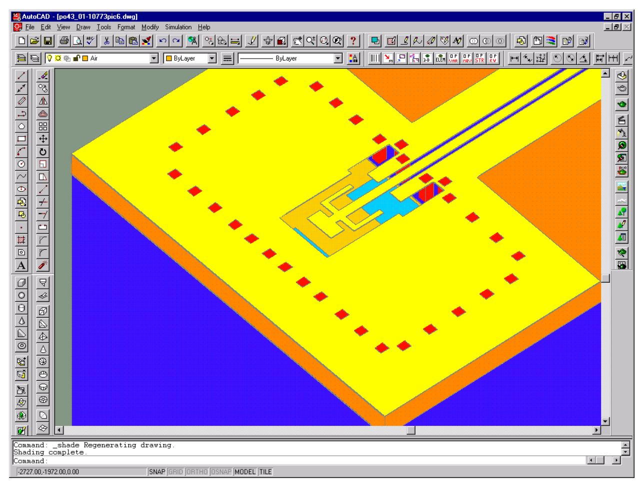

Fig. 5: Transition for a antenna feeding at 34 GHz.

This transition achieves a bandwidth of at least 2 GHz for a return loss of 15 dB as well as an insertion loss of 1 dB for two transitions (back to back) as used for the test structure. The radiation leakage calculated from the insertion loss is lower than -14 dB. Fig. 6 shows the simulation results.

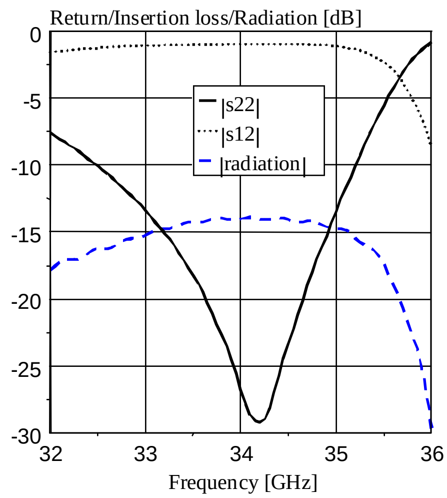

Fig. 6: Reflection and transmission coefficients of the modified transition.

To examine the behavior of the transition in a closed package a metal plate has been placed 2 mm above the substrate.

The insertion loss, as shown in Fig. 7 is similar to the simulation without metal plate. The bandwidth for a return loss of 15 dB decreased slightly, but is still about 1.5 GHz and the radiation leakage is lower than -13 dB. In addition the frequency range of adaption is shifted down about 0.5 GHz, but this can be corrected by modfication of the patches on the side of the waveguide. Thus the transition can also be used in closed packages but the package design effects the behavior of the transition slightly. The coupling between the transition and the metal plate can probably be reduced by placing the metal plate a quarter wavelength above the structure.

CONCLUSION

Two novel transitions from coplanar lines to waveguides have been presented. They are based on the coupling between metal structures on the top of a substrate with metal stripes beneath it. Both transitions do not require any modifications of standard waveguides and can easily be used in integrated circuit design. They can even be used in closed packages by taking care of the package dimensions in the transition desing. It is shown, that it is possible to design the transitions for large bandwidths and low radiation leakage.

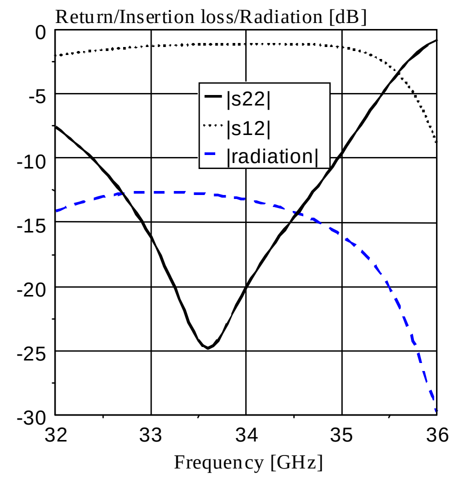

Fig. 7: Reflection and transmission coefficients with metal plate above the structure.

REFERENCES

[1] T.Q. Ho, Y. Shih: "Spectral-domain analysis of E-plane waveguide to microstrip transitions" , *IEEE Trans. Microwave Theory Tech.*, Volume 37, pp. 388-392, Feb. 89

[2] W.Menzel, A. Klaassen: "On the transition from ridged waveguide to microstrip", *Proc. 19th European Microwave Conf.*, pp. 1265-1269,1989

[3] Yee, K. S.: "Numerical solution of initial boundary value problems involving maxwell´s equations in isotropic media." *IEEE Trans. Antennas and Propagation.* Vol. AP-14, S. 302-307, 1966

[4] M.Werthen, M.Rittweger, I.Wolff: "Multi-mode simulation of homogeneous wave-guide components using a combination of the FDTD and FD^2 method" , *Proc. 25th European Microwave Conf.*, pp. 234-237, 1995

[5] W.Grabherr, B. Huder, W.Menzel: "Microstrip to waveguide transitions compatible with MM-wave integrated circuits" , *IEEE Trans. Microwave Theory Tech.*, Volume 42, pp.1842-1843, Sep. 1994