AN EFFICIENT FDTD ANALYSIS OF A WAVEGUIDE-TO-MICROSTRIP TRANSITION

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ABSTRACT

In this paper, modifications in the basic FDTD for a fast analysis and optimization of a microstrip-to-waveguide transition are proposed and illustrated. The bandwidth of such an interconnect is increased by a probe in the shape of a rectangular patch. Furthermore, via-holes for a better integration with extended planar circuits are considered, and their electrical influence is investigated. Finally, the FDTD results are compared with the measurements.

INTRODUCTION

Modern mm-wave communication front ends for LANs, tie lines etc. require high performance but low cost production. To this end, a combination of planar transmission line circuits with metal waveguide for low loss filters and diplexers is used. The waveguide components are commonly realized in the H-plane. Components like the local-oscillator or the transmitter and receiver modules usually are designed in planar technique. For this reason, interconnects between the rectangular waveguide and the planar circuits are necessary. Such transitions should be manufactured easily and should avoid complicated matching networks. Therefore, a concept for a broadband interconnect in the E-plane with low effort in manufacturing and small size is presented.

DESCRIPTION OF THE TRANSITION

In this interconnect, a dielectric substrate supporting the microstrip line is placed on the open end of a rectangular waveguide. A waveguide cap acting as a short circuit is placed on top of the planar circuits, while the waveguide and waveguide cap are connected by vias in the planar substrate (Fig. 1). In this way, and in contrast to other transitions of this type, e.g. [4], the substrate can extend beyond the waveguide cross section, and no (partly difficult and expensive) cutting of the substrate (e.g. aluminia) is necessary. With a simple probe at the end of the microstrip line, this structure would have a very narrow operation bandwidth. Thus, a rectangular patch as shown in Fig. 1 is used to achieve a larger bandwidth. Investigations have shown that the via-holes in the substrate have a non neglible influence on the electrical behavior, therefore a full wave analysis including these details is necessary.

EFFICIENT OPTIMIZATION

Due to the complex geometry, an optimization of the transition requires several FDTD simulations with different values for the geometry and position of the probe and the height of the waveguide cap. With increasing number of parameters, which influence the electrical behavior, a full wave optimization gets rather expensive like in this case. Therefore, for a quick and effi-

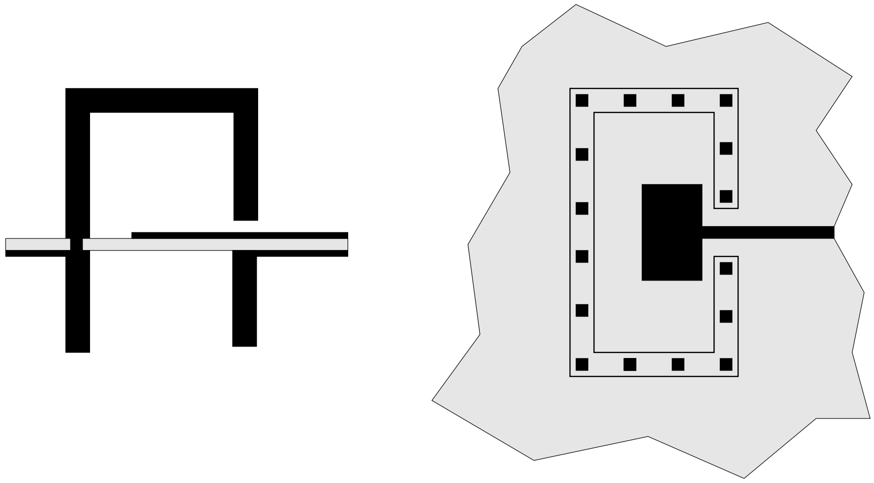

Figure 1: Structure of the transition.

cient optimization a reduction of the computation time is necessary. To reduce the simulation effort, some extensions to the basic FDTD method are inserted.

Excitation method

The starting point was the standard FDTD scheme according to [1] with absorbing boundary conditions as described in [2]. An important improvement in this contribution is the choice of a short feeding line by using a novel excitation of the structure. Normally, the structure is excited with a modulated Gaussian pulse at the outer boundary with a field distribution, which is only a rough approximation of the basic mode of the transmission line. But such an excitation requires a long feeding line, because the natural field distribution is not available until far away from the incident wall. Another disadvantage of this method lies in the fact that the incident and reflected pulse have to be separated

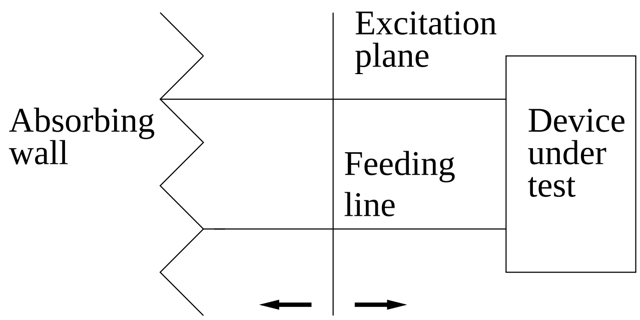

Figure 2: Excitation principle of the structure.

in the time domain. To this end, the feed line has to be at least half as long as the pulse spreading on the line. In this contribution, the structure is excited in a plane between the discontinuity and the absorbing wall (Fig. 2) with a precomputed field distribution. In this way, only a short section of transmission line is required, and an overlapping of the incident and scattered pulse can be admitted. This leads to a considerable reduction in computation time (Principally, this method is possible only when the field distribution is independent of frequency. In most practical applications, this is approximated sufficiently). This excitation generates two waves propagation in two directions from the plane. When the wave propagates in z-direction, the equations for the field components tangential to the excitation plane are determined in the following way:

$$E_x^{n+1} = E_x^n + \frac{\Delta t}{\epsilon \Delta y \Delta z}\mathbf{rot}\vec{H}^{n+1/2} * \vec{e}_x - \frac{2\Delta t}{\epsilon \Delta z} H_{inc,y} \quad (1)$$

$$E_y^{n+1} = E_y^n + \frac{\Delta t}{\epsilon \Delta x \Delta z}\mathbf{rot}\vec{H}^{n+1/2} * \vec{e}_y - \frac{2\Delta t}{\epsilon \Delta z} H_{inc,x} \quad , \quad (2)$$

where H_{inc} is the magnetic field of the basic mode of the transmission line. With the value of the H field, the power propagating on the transmission line can be accurately adjusted and is independent of the spatial or time steps as well as of frequency. Also this excitation help to avoid instability at the absorbing boundary conditions at early times. This problem occurs, when the boundary wall switches from excitation to absorption.

One dimensional waveguides

In a second step, the homogenous rectangular waveguide sections are replaced by one-dimensional lines as described in [3]. Both the feeding waveguide and the waveguide-section with the back-short can be replaced in that way, which enormously reduces computer resources. At the interface of the 1D and 3D structure, the modes of the waveguides are sampled and fed into the 1D line. If more modes are considered, the interface can be placed near to the waveguide discontinuity, represented by the substrate supporting the probe.

System identification

The final improvement was achieved in calculation of the scattering parameters. If a FFT or a DFT is used to calculate the s-parameters, the FDTD simulation has to continued until the time signal has approached zero. The convergence of the fourier transformation is very slow, so a long simulation time results. A more effective method for determining the s-parameters is proposed in [5]. In this method, the structure is regarded as a discrete system in time and is identified by an Infinite Impulse Response (IIR) filter. The filter coefficients are calculated by suitable algorithms, also described in [5]. The calculation of the coefficients converges faster than the fourier transformation, so that the FDTD calculation can be aborted earlier without loss in accuracy.

RESULTS

Two transitions with different passbands were designed for the B-band. The center frequencies are 32 and 38 GHz, respectively. The geometries of the probe and the height of the waveguide cap were optimized using a gradient method, included in the FDTD simulator, which modifies the variables and searches for a minimum automatically.

According to the simulation results, the maximum bandwith, which can be achieved with this structure, is 2 GHz at 20 dB return loss and better. In a previous simulation, the via holes were replaced by electric walls. In comparision to the letter investigations,

a deviation in the center frequency of about 300 MHz occurs. For a quick optimization, the simplified model can be used for an first approach to the best parameter values. In a second step, the exact model including the position and dimensions of the via holes leads to the final results.

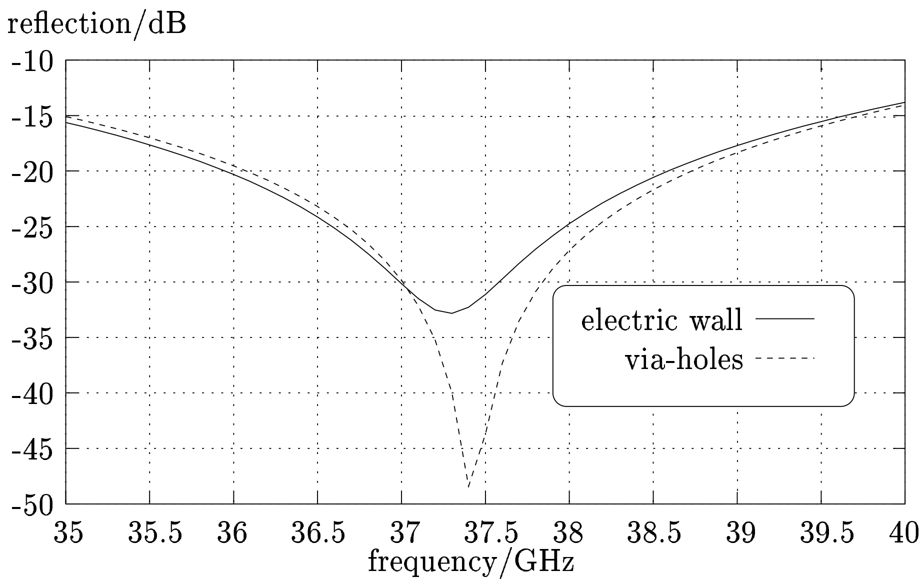

Figure 3: Comparision between simplified model with electric walls and the real structure with via holes.

The two transitions were manufactured using a ceramic subtrate. The Figures 4 and 5 show a good aggrement of measurement and FDTD results. Also, the predicted bandwith of 2 GHz could be obtained. The deviation between measurements and theory mostly are due to the tolerances in positioning the three parts of the transition.

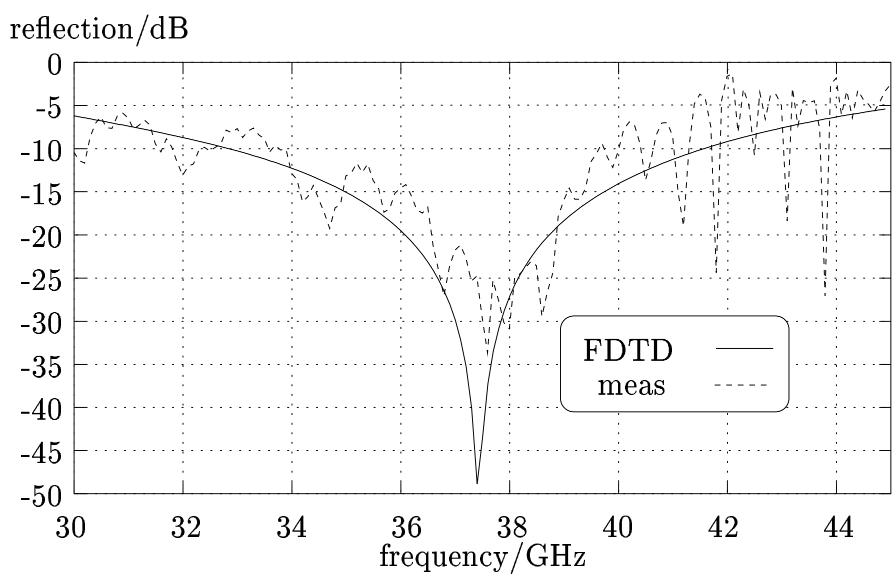

Figure 4: Measurement und simulation results for the transition at 38 GHz.

CONCLUSION

A broadband microstrip-to-waveguide transition is illustrated, considering the influence of the via-holes on the electric behavior. With some modifications and extensions to the basic FDTD method, the interconnect could be analyzed and optimized quickly. A 50% reduction in computational effort can be assigned to the novel excitation method of the structure.

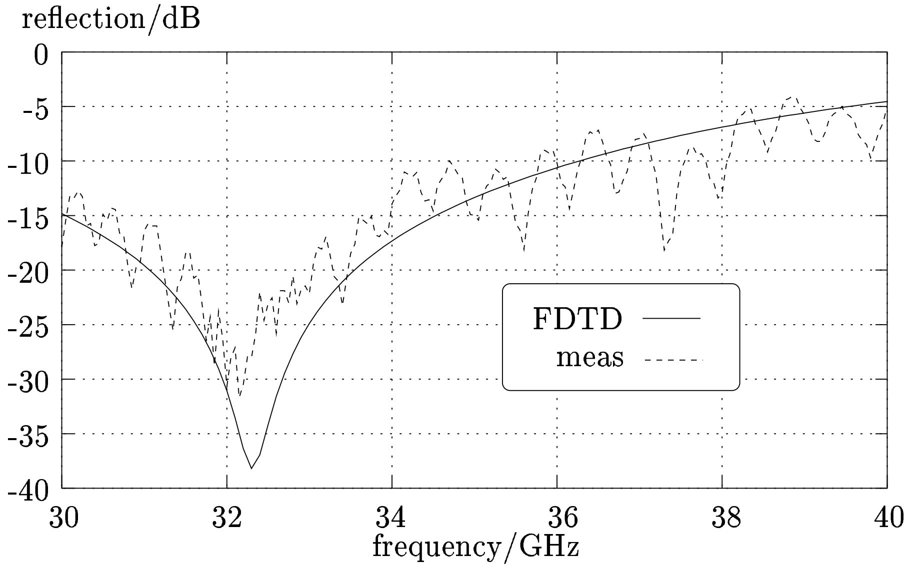

Figure 5: Measurement und simulation results for the transition at 32 GHz.

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