Micromachined Split-block Schottky-Diode Mixer for 600 GHz

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Abstract

This paper presents simulation results for a 600 GHz micro-machined waveguide mixer with integrated horn antenna, a hybrid-integrated planar Schottky diode and IF filter structures on a quartz substrate. In addition to the simulated electrical performance we will show first approaches for the manufacturing of the split-block mixer by both micro-mechanical milling and silicon etching technology.

Introduction

In general, accurate measurements of low level signals at THz frequencies require a down-conversion by high performance mixers to a lower IF frequency range where low noise amplification is feasible and signal processing is performed.
Former mixer designs at 600 GHz [1] and 2.5 THz [2] were set up using an open corner cube structure and a whisker contacted Schottky diode. The main problem in this setup was the very fragile whisker contact at the diode. Therefore our current approach concentrates on the development of a miniaturized waveguide mixer in split-block waveguide technology working at 600 GHz using planar diode technology. At 600 GHz it is still possible to compare the manufacturing of the split-block in a conventional micro-mechanical milling process with a silicon etching technology. The advantage of the silicon process is the possibility to scale the whole split-block to even higher frequencies without reaching limits of the manufacturing process with respect to the required waveguide dimensions and the tolerances.
The major advantage of our approach is the opportunity to simultaneously optimize both the geometry of the Schottky diode and its mounting environment on a quartz substrate. This procedure allows optimum coupling of the THz-signal to the Schottky diode and partial compensation of the parasitics of the diode.

Simulation Models

The designed split-block mixer consists of an octagonal horn antenna, a transition from waveguide to microstrip line on a quartz substrate, microstrip filters and the Schottky diode. All these components were simulated using the 3D field solver Microwave Studio (MWS) from CST. Due to the high ratio of the largest to the smallest structures (e.g. 420 μm x 210 μm for the waveguide and 1 μm anode diameter of the diode) the whole split-block model was divided in four sections for the numerical simulation and optimization.

Horn Antenna Model

The LO (600 GHz) and the RF signal (605 GHz) sources are quasi-optically diplexed by Martin-Puplett diplexer and fed via a horn antenna into the waveguide mixer. For an adequate coupling between the quasi-optical Gaussian beams and the split-block waveguide structure an octagonal horn antenna has been developed using the 3D field simulator MWS (Fig. 1). The antenna geometry has been chosen with respect to the etching possibilities on standard silicon wafers. The antenna is realized in a two step etching process utilizing a dry etch process to form the rectangular shapes followed by an anisotropic KOH wet etching process for the diagonal planes. The first dry etching process is used to form the waveguide and the opening of the antenna in the E-plane. The wet-etching process is used to open the H-plane of the antenna in order to form a circular beam profile. Simulations for this octagonal horn antenna showed coupling efficiencies of up to 86%.

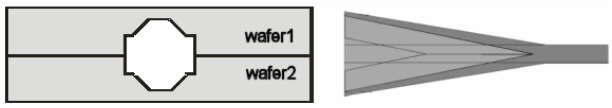

***Fig. 1**: Horn antenna – model for split-block assembled horn antenna (a) aperture view, (b) side view.*

The verification of these promising results has been performed by characterizing a scaled model at 11 GHz in an anechoic chamber. The test results show very good agreement between simulation and the measurement (Fig. 2).

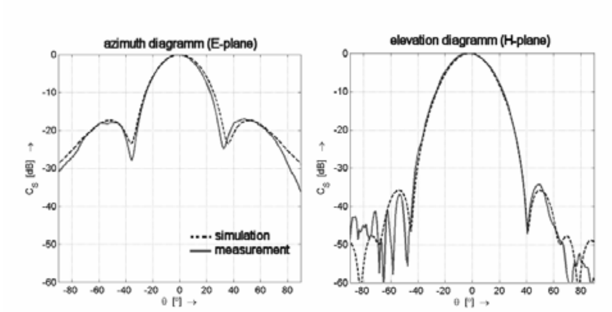

***Fig. 2**: Comparison of the simulated and measured radiation pattern of the scaled octagonal horn antenna.*

Waveguide to Microstrip Transition

After transforming the Gaussian beam to a rectangular waveguide TE_{10} field mode, another transition from the waveguide to a microstrip line is needed. Our approach for a split-block mixer implements a hybrid integrated Schottky diode on a quartz substrate (thickness 40 μm; ε_r=3.8). Therefore we designed a broadband transition from waveguide to microstrip line. The coupling element between the waveguide TE_{10} field mode and the TEM microstrip mode is a radial stub on the quartz substrate. The quartz substrate is placed in a trench parallel to the E-plane of the waveguide (Fig. 3).

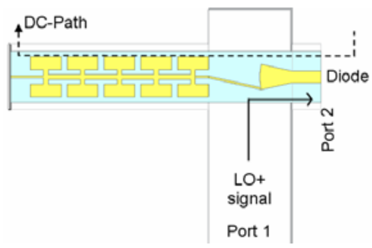

***Fig. 3**: Top view of the waveguide with the transition to microstrip and low pass hammerhead filter for DC bias.*