POSTER SESSION n°2

Presentation on
Friday 12 May 09:00-09:30

by Dr. Heribert Eisele & Dr. Imran Mehdi

Poster session n°2 from 11:00 to 12:30

Design & test of a 380 GHz sub-harmonic mixer using American and European Schottky diodes

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Abstract— **We present here the development of a broadband fixed-tuned 360-400 GHz sub-harmonically pumped mixer, featuring an anti-parallel pair of planar Schottky diodes from VDI (Virginia Diodes Inc.). Simulations show that replacing the VDI discrete device by an optimized anti-parallel pair of planar Schottky diodes based on the BES fabrication process of UMS (United Monolithic Semiconductors) onto the same circuit would lead to similar performances. A comparison between the expected performances of both devices used with the same mixer circuit is presented. Measurements on a prototype featuring VDI diodes exhibit best DSB mixer noise temperature of 950 K and conversion losses of 8.5 dB at 380 GHz.**

***Index Terms*— Submillimetre wave receiver, sub-harmonic mixer, planar Schottky diodes.**

I. Introduction

In the framework of future ESA missions dedicated to the remote sensing of the Earth atmosphere in the millimetre and submillimetre wave domain [1], several frequency bands up to at least 380 GHz are highlighted as key priority for the development of highly integrated heterodyne receivers exhibiting high sensitivity at room temperature over a broad instantaneous bandwidth.

In that context, we report here on the development of a broadband fixed-tuned 360-400 GHz sub-harmonic mixer, featuring an anti-parallel pair of planar Schottky diodes. The simulated performances of the designed mixer circuit using two different models of an anti-parallel pair of planar Schottky diodes are presented, and compared with measurements on a prototype fabricated and tested.

II. Design of the 380 GHz sub-harmonic mixer

The design of the 360-400 GHz fixed-tuned sub-harmonic mixer is presented in Fig.1. It features an anti-parallel pair of planar Schottky diodes flip-chip mounted and silver-epoxy glued onto a quartz-based microstrip circuit. The 50 μm thick quartz circuit is then directly reported and glued inside the microstrip channel. A gold beam-lead is formed at the RF end during the circuit fabrication, providing a precise grounding of the diode pair at IF/DC frequencies. The LO/RF waveguides, the microstrip channel and the IF connector socket are milled into two split-waveguide metal blocks. A diagonal horn antenna, similar to [2], is also integrated to the mixer block.

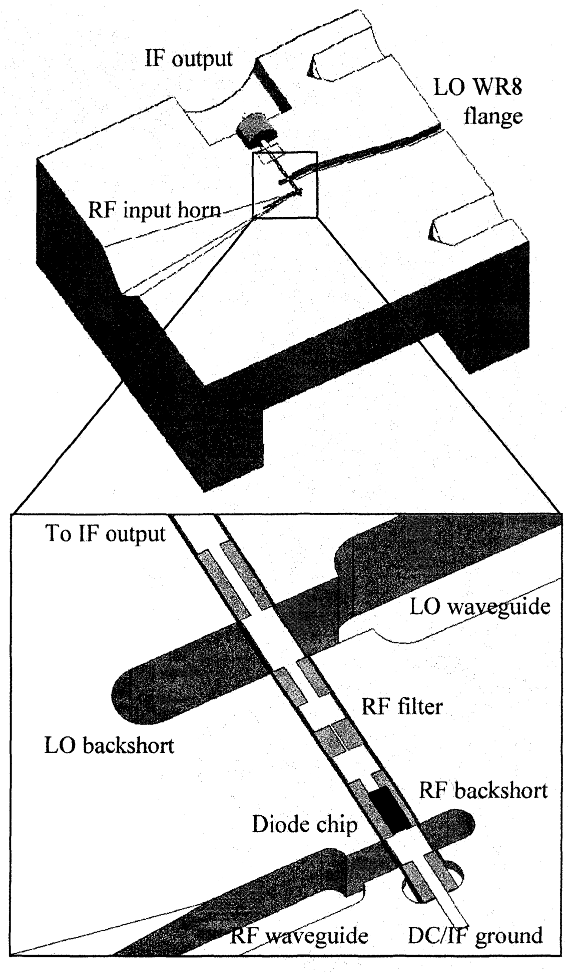

Fig.1. Schematic view of the 380 GHz SHP mixer circuit mounted into the lower half of the mechanical waveguide split block. The circuit has been optimized for best performances with an anti-parallel pair of planar Schottky diodes from VDI.

The mixer circuit has been initially designed to incorporate an anti-parallel pair of planar Schottky diodes from VDI (Ref. SC1T9-D20). However, a study in collaboration with the LERMA department at the Observatory of Paris has been done to test the mixer design using a novel anti-parallel pair of planar Schottky diodes compatible with the BES process

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of the company UMS. The structure has been optimized by the LERMA for operation at 380 GHz and tested in simulation inside the mixer model developed at RAL. The novel designed pair of diodes does not include air-bridges, on the contrary of VDI diodes. Fig. 2a&b show both components' 3D model with their physical and electrical characteristics.

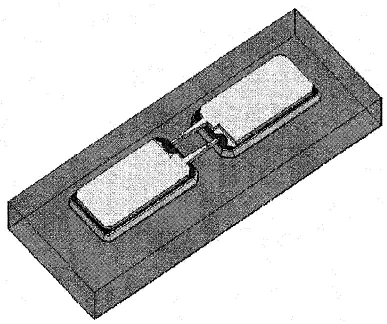

Fig.2a. Schematic view of the planar Schottky diodes from VDI (Ref. SC1T9-D20). The chip includes two air-bridges. Electrical parameters are: R_S=10 Ω, η=1.25, C_{jo}=2.5 fF, I_{sat}=30 fA, V_{bi}=0.8 V, A=1.76 μm^2.

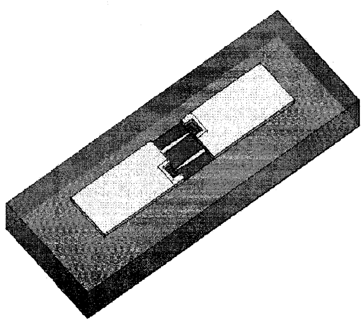

Fig.2b. Schematic view of the planar Schottky diodes based on the BES process from UMS. The chip has no air-bridge. Electrical parameters are: R_S=10 Ω, η=1.2, C_{jo}=2 fF, I_{sat}=4 fA, V_{bi}=0.85 V, A=1.5 μm^2.

III. Design Methodology and Computed Performances

The methodology used to design and optimize the mixer circuit uses a combination of linear/non-linear circuit simulations (Ansoft Designer [3]) and 3D EM simulations (Ansoft HFSS [3]) and is described in detail elsewhere [4]. From a first set of non-linear simulations of the diodes pair, considering an optimum LO power level of 1.5 mW, ideal embedding impedances of approx. Z_{RF} = 47+j.46 at RF frequencies and Z_{LO} = 63+j.121 at LO frequencies are found for the VDI diodes. The IF load impedance is set to 100 Ω. Then, the microstrip circuit, as well as the fixed backshort positions and the waveguide-to-microstrip transition, are optimized to synthesize an embedding impedance as close as possible to these values. Additional losses from the horn antenna (≈ 1dB) and the IF mismatch with the first LNA (≈ 1dB) have been taken into account during the simulations.

The simulated performances of a SHP mixer using VDI and UMS-like diodes are presented in Fig.3. Despite the fact that they appear to be fairly similar, the centre frequency of the mixer using UMS-like diodes is slightly shifted towards 370 GHz, compared to the optimal centre frequency of 380 GHz obtained using VDI diodes. This difference is attributed to slightly superior parasitic capacitance exhibited by the UMS-like diodes. A slight re-optimisation of the mixer circuit using UMS-like diodes would be necessary to achieve the optimal 360-400 GHz bandwidth.

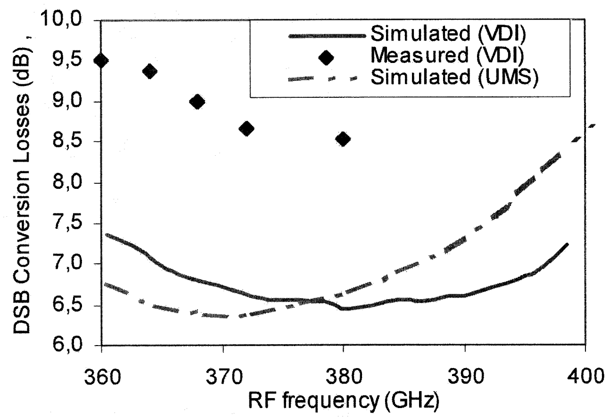

Fig.3. Predicted DSB conversion losses of the 380 GHz SHP mixer designed to incorporate an anti-parallel pair of Schottky diodes from VDI (full curve), along with the predicted performances of a similar mixer circuit incorporating UMS-type anti-parallel pair of planar Schottky diodes (dashed curve). Measured mixer conversion losses using a VDI diodes pair are shown (dots) for comparison.

IV. Test of the 380 GHz Fixed-Tuned Receiver Including the Sub-Harmonic Mixer

In order to pump the subharmonic mixer using a fundamental Gunn oscillator source, a 190 GHz fixed-tuned doubler using an anti-series pair of 6 planar Schottky Varactor diodes from VDI has been developed in the framework of this project, and is described elsewhere [5]. The 190 GHz doubler is pumped by a Gunn oscillator from Carlstrom, which outputs 100 mW of LO power between 84 GHz and 92 GHz, and drops bellow 60 mW for frequencies above 96 GHz. The output power of the doubler reaches a maximum of 7 mW at 176 GHz and outputs an LO signal with a power greater than 2.8 mW between 172 GHz and 190 GHz. The power levels are measured with a PM3 Erickson power meter [6].

The complete 380 GHz fixed-tuned receiver including the 190 GHz fixed-tuned doubler and the 380 GHz fixed-tuned sub-harmonic mixer has been assembled and tested, as shown in Fig. 4a&b. The doubler is fed by a Gunn diode source followed by a variable attenuator. No isolator is inserted between the doubler and the mixer in order to maximize the available LO power. The IF signal is amplified by a low noise amplifier (1st LNA from Miteq) chain including a band-pass filter in between 2.5 GHz and 3.5 GHz. The output signal of the amplifier chain is measured using a HP 8481A power sensor.

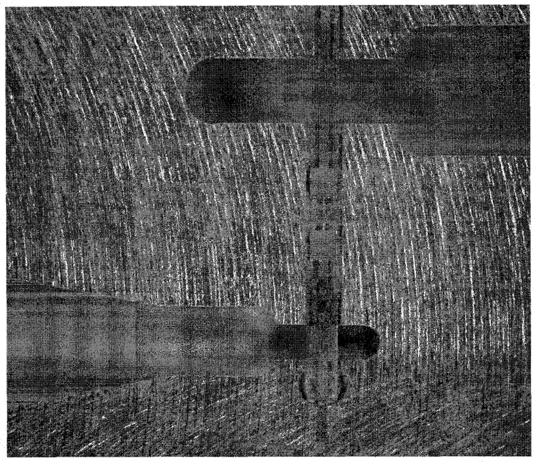

Fig.4a. Detail of the 380 GHz mixer microstrip circuit mounted into the lower half of the mixer block. The mixer circuit includes an anti-parallel pair of planar Schottky diodes from VDI, flipped-chipped and silver-epoxy glued onto the quartz based circuit.

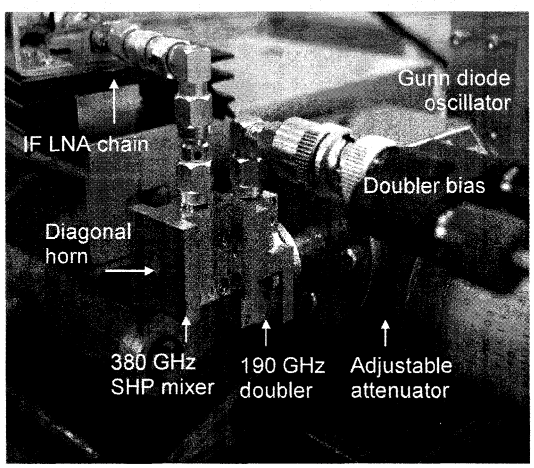

Fig.4b. View of the test setup showing the 190 GHz fixed-tuned doubler connected to the 380 GHz fixed-tuned SHP mixer. A waveguide attenuator is inserted between the doubler and the Gunn oscillator. The IF signal from the SHP mixer is output to a LNA IF chain.

The measured performances of the receiver including the mixer noise temperature are presented in Fig. 5. The best mixer performance is obtained at 380 GHz, with DSB receiver noise temperature of 1693 K. Varying the IF LNA noise temperature from 100 K to 450 K allows to calculate a corresponding DSB mixer noise temperature of 950 K and DSB mixer conversion losses of 8.5 dB. The measured mixer conversion losses are given in Fig.3, and can be compared with the predictions. The DSB mixer noise temperature remains below 1200 K between 360 GHz and 380 GHz. The amount of power required to pump the mixer between 360 GHz and 380 GHz is estimated between 2 mW and 3.5 mW.

Further tests using a more powerful fundamental source above 95 GHz will be necessary to characterise the mixer up to 400 GHz. The performances are indeed expected to be flat up to 400 GHz, as suggested by the results in simulations (Fig.3).

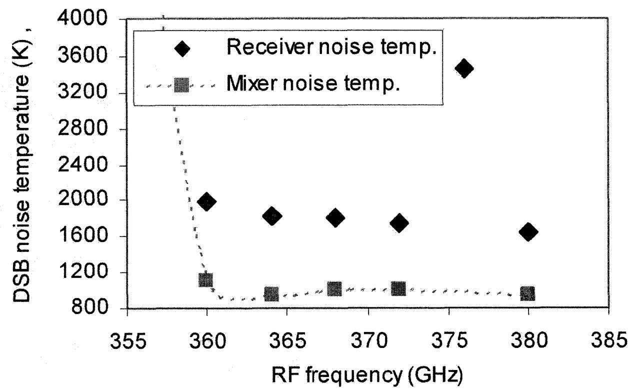

Fig.5. Measured DSB receiver and mixer noise temperature VS frequency. Degradation in the receiver noise temperature noticeable at 376 GHz is due to a sharp resonance in the LO signal coupling between the doubler and the mixer. Inserting an isolator between the mixer and the doubler would cancel the resonance.

V. Conclusion

The design, fabrication and test of a 380 GHz fixed-tuned mixer is presented. The mixer circuit has been designed for VDI diodes, but simulations show that using an optimized pair of planar Schottky diodes compatible with the BES process of UMS would give similar performances, providing a useful bench-mark for discrete American and European planar Schottky diodes. Measurements performed on a mixer using planar diodes chip from VDI give excellent performances, in accordance with the simulations.

Acknowledgements

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