The Design of a 200-240-GHz Sub-Harmonic Mixer Based on RAL's Planar Schottky Diodes

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Abstract: This paper presents the design of a fixed-tuned 200-240-*GHz* wide-band sub-harmonic mixer. The mixer is based on an anti-parallel pair of GaAs Schottky diodes fabricated at Rutherford Appleton Laboratory (RAL). The circuits are fully integrated with the RF/IF filter and flip-chipped onto a suspended quartz-based substrate. A best conversion loss of 5.9*dB* was achieved with 5*mW* of LO power at 207*GHz*. Over an RF band of 200-240*GHz*, the conversion loss is below10*dB*. This state-of-the-art optimization is attributed to lower parasitic devices and a low-loss waveguide circuit.

Keywords: Sub-harmonic mixer, Planar Schottky diodes, Terahertz-wave, Wide-band

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1. INTRODUCTION

Subharmonically pumped (SHP) mixers employing an antiparallel diode pair are key components for millimeter- and submillimeter-wave heterodyne receivers. The antiparallel diode pair used in that type of mixers has many desirable advantages from a system point of view. The local oscillator requirements are easier to meet because the LO frequency is about half that in the corresponding fundamentally pumped mixers, and because SHP mixers have substantial AM local oscillator noise suppression [1-3]. Furthermore, the large difference between the signals and LO frequencies makes it possible that the two frequencies can be well isolated by simple filters within the waveguide cavity, thus avoiding the requirement for a low loss LO injection network.

For most of the SHP millimeter- and submillimeter-wave mixers developed so far, the planar GaAs Schottky diode chip has been widely used. The availability of this type of high-quality low-capacitance planar diodes has improved the current design technology of mixers, because they show good reproducibility of their characteristic parameters and they can easily be mounted on a printed circuit [4-5].

Thanks to the improvement of 3D electromagnetic solvers and nonlinear circuit simulators, tuner-less mixers featuring discrete or integrated planar Schottky diodes have already demonstrated lower conversion loss than traditional mixers using mechanically tunable backshorts [6]. Up to 600*GHz,* discrete planar devices can be used for low conversion loss fixed-tuned mixers while providing significant cost reduction [7].

This paper presents the optimization and the design of a low conversion loss fixed-tuned subharmonically pumped mixers operating in the 225*GHz* band that uses a planar Schottky diodes pair from RAL.

2. MIXER DESIGN

The performance of the mixer has been unite-simulated by Agilent's ADS and Ansoft's HFSS. In this subharmonic mixer design, the non-linearity of the schottky diode is used to generate currents at twice of the LO frequency, that mix with the RF signal. The circuit topology is shown schematically in Fig. 1. The model of the mixer block is presented in Fig. 2.

The subharmonic mixer was to be made as a split block with a single quartz (0.1 *mm* thick, relative dielectric constant of 3.78) microstrip circuit which is consist of a probe in the RF waveguide (WR4) feeding a 50 ohm suspension microstrip transmission line; The diodes are connected with RF and LO as a shunt anti-parallel pair between the center line and ground with the transmission line followed by a low-pass filter to block the RF; a probe crossing the LO waveguide (WR8); and finally the IF output would be via a sparkplug-style K Connector with glass bead and sliding contact through the low-pass IF filter. The filters were designed as a succession of low and high impedance suspension microstrip.

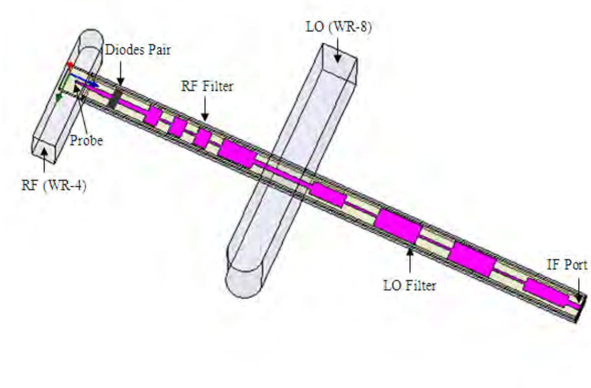


Fig. 1 The circuit topology of the subharmonic mixer

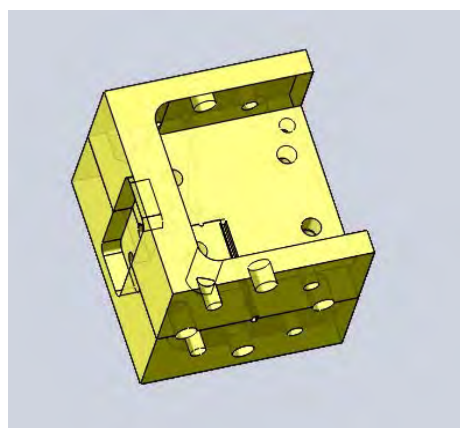


Fig. 2 The model of the mixer block built in solidworks

3. MIXER PERFORMANCE

The simulated results show a very good coupling between waveguide and probe. The circuit topology of the RF probe is presented in Fig.3 and the simulated transition result is presented in Fig. 4. The RF filter and the LO filter also show good band rejection to corresponding frequency.

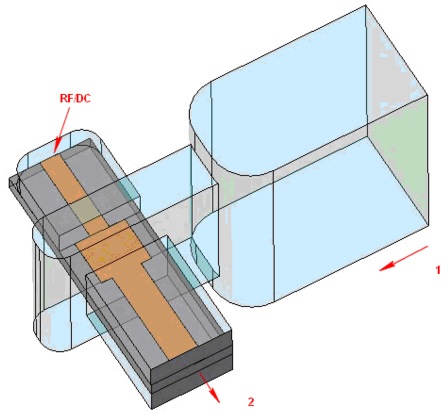


Fig. 3 The circuit topology of the RF probe modeled in HFSS

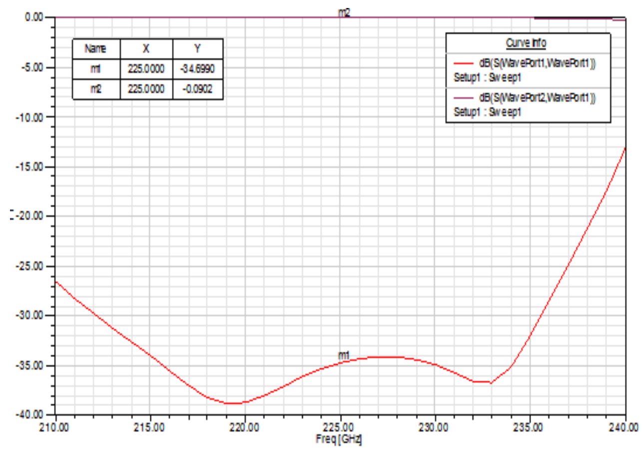
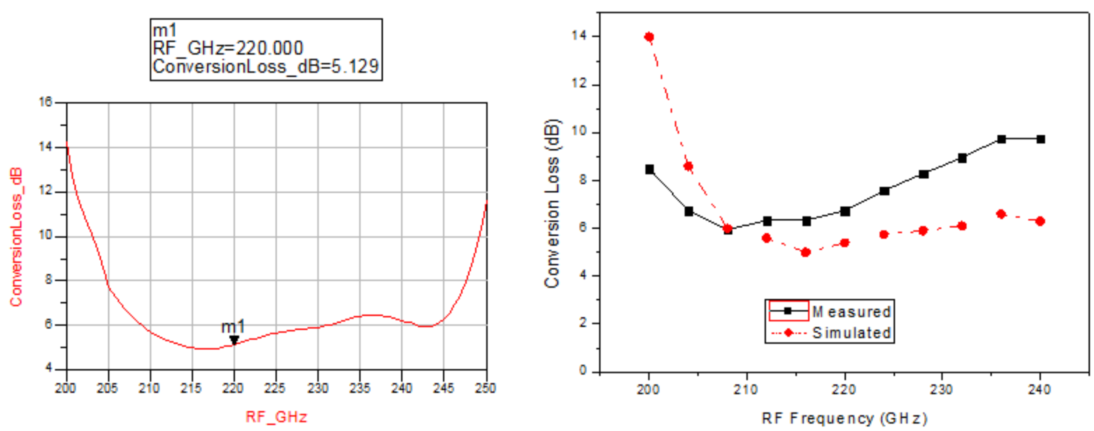


Fig. 4 The simulated transition result of the RF probe showing good matching RF probe modeled in HFSS

The waveguide to microstrip transition and filters are simulated by HFSS. A harmonic balance simulation is undertaken with the ADS standard diode model, modified by using the parameters given by RAL. For each diode of the pair, the junction capacitance Cj_0 of 3.4*fF* (without its parasitic capacitance), the ideality factor n of 1.185, the series resistance R_s of 11ohm, the anode diameter d of 1.7*um*.

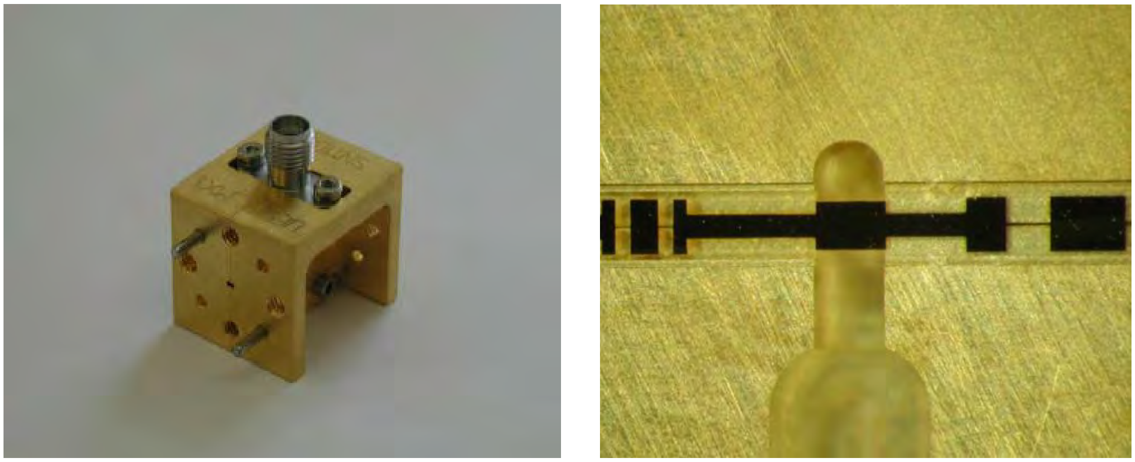
This process is to optimize the parameters of the designed low and high impedance microstrip for best matching of the diodes to get lowest conversion loss.

Motivated by the LO of 2*mW*, the simulated conversion loss of the sub-harmonic mixer is shown in Fig. 5. The lowest conversion loss is 5*dB*. The measured result is below 8*dB* between 202 *GHz* to 224*GHz*, but the center frequency is shifting to 214*GHz*. Over an RF band of 200-240*GHz*, the conversion loss is below 10*dB*.The mixer block and the circuits are showing in Fig.6.



(a) (b)

Fig. 5 The simulated and measured conversion loss of the subharmonic mixer



(a) (b)

Fig.6 Pictures show the three completed mixer blocks and the circuit

4. CONCLUSION

This paper describes the design of a 200-240*GHz* sub-harmonic mixer. It demonstrates that submillimeter-wave mixer can be realized by RAL's GaAs flip-chip Schottky diodes pair. Using unite-optimization of ADS and HFSS, the measured result show state-of-the-art performance with a minimum conversion loss of 5.9*dB* driven by 5*mW*. Over an RF band of 200-240*GHz*, the conversion loss is below 10*dB*.

5. ACKNOWLEDGMENT

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