Development of a 220-GHz Schottky Diode Subharmonic Mixer

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Abstract- **In this paper, the design of a waveguide fix-tuned 220GHz subharmonically pumped mixer using Schottky planar diodes is demonstrated. It is supposed to be applied in an experimental short-range and high-speed communication system. The anti-parallel pair of planar Schottky diodes from the Rutherford Appleton Laboratory (RAL) was flip-chip mounted and soldered onto a suspended 75μm-thick quartz microstrip circuit. Initial measurements yielded a double sideband (DSB) equivalent noise temperature below 2500K and conversion loss less than 10dB over the range from 200GHz to 235GHz with the IF frequency fixed at around 3GHz and LO power lower than 6mW. The optimum DSB noise temperature of 1368K and conversion loss of 6.5dB were obtained at 204GHz.**

***Index Terms*–Planar Schottky diodes, subharmonic mixer, 220GHz.**

I. INTRODUCTION

Terahertz (THz) waves fall between 100GHz to l0THz in the frequency region of the electromagnetic spectrum. Their corresponding wavelengths range from 30cm to 30μm. Sandwiched between the millimeter wave and light wave range, this field possesses some valuable properties and has recently elicited increasing interest [1-3].

In the lower range of THz frequency band, there are several useful frequencies. 220 GHz is an atmospheric window frequency, thus it offers a large potential to implement short-range and high-speed communication. In most THz applications including communication application, the receiving of THz waves is bound to be involved. Since state-of-the-art electronic amplifiers are rarely reported in frequencies above 300GHz, THz receivers are mostly of the heterodyne type, which employs mixers as the first stage. So their performance plays a critical role in the overall receivers. Mixers based on Schottky diodes have the advantage of operating well at either cryogenic or room temperatures, although not with the sensitivity of SIS or HEB mixers applied in low temperature environment for radio astronomy application. Due to this, heterodyne receivers incorporating Schottky diode mixers are simpler to integrate into compact systems. They are also easy for taking long term or repeated measurements since they operate at room temperature. In a word, for our application, Schottky diode mixers are able to be regarded as a flexible and reliable device with moderate performance at THz band. Mixers with subharmonic pump utilizing an anti-parallel pair of Schottky diodes are widely applied in THz band, since the LO frequency is about only half of that in the corresponding fundamentally pumped ones, which could greatly ease the requirement for LO source.

This paper presents the development of a waveguide fix-tuned 220GHz subharmonically pumped mixer using Schottky planar diodes as a key component of an experimental short-range and high-speed communication system in the future.

II. MIXER DESIGN AND ITS PERFORMANCE

The Schottky diodes play a vital role in the performance of mixers. For the past ten years, planar Schottky diode technology has made great progress. The diodes applied in this paper are from RAL, featuring a low parasitic capacitance and series resistance [4] and in an anti-parallel configuration. The architecture of the subharmonic mixer based on a traditional E-plane split-block waveguide architecture [5] is showed in Fig.1. The architecture is also partly in light of B. Thomas's design [6]. A grounded RF probe, the antiparallel diode pair in series with the transmission line, the LO filter to block the RF signal, a probe crossing the LO waveguide and the IF filter are included. The pair of planar diodes is flipped-chip mounted onto the suspended 75μm-thick quartz microstrip. The gold track at the RF end is grounded by contacting the RF waveguide wall, which provides the return ground for DC current from any imbalance between the diode pair without biasing the diode pair asymmetrically [7]. At the other end, the microstrip circuit is connected to a K-connector as the IF output port. The reduced height waveguide configuration at both RF and LO ports is for broadband operation.

The non-linear behavior of the diodes was analyzed using the standard diode model provided in the Advanced Design System (ADS) suite [8]. The performance of the mixer was simulated using a combination of Agilent's ADS and Ansoft's HFSS [9]. The electromagnetic (EM) fields of passive elements of the mixer were solved in HFSS. The EM simulated results were then imported to ADS to perform the circuit optimization.

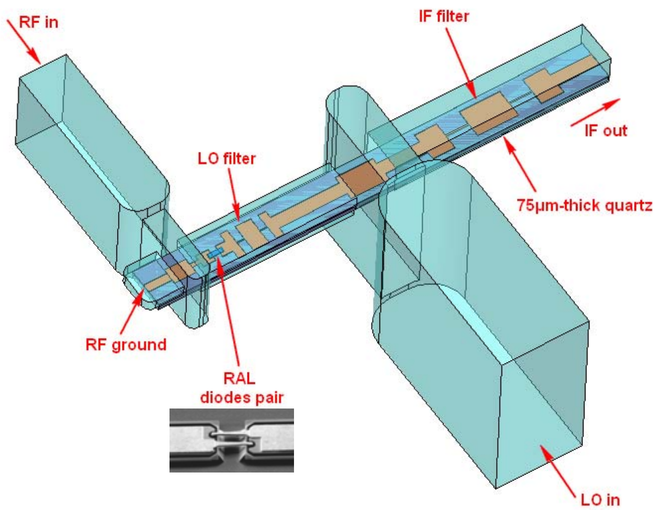

Fig. 1. The architecture of the mixer

Fig. 2 is the inside view of the assembled bottom block and the appearance of the mixer is shown in Fig. 3. The fabrication and measurement of the mixer were also carried out at RAL. The simulated DSB conversion loss is shown in Fig. 4 alongside the measured DSB conversion loss. The LO fundamental source was provided by a 0.05-20GHz synthesizer, which was used to drive a commercial sextupler followed by a power amplifier, both from Radiometer Physics GmbH (RPG). The output power of the LO source chain was calibrated with an Erickson power meter. The mixer was measured using the classic Y-factor method. The equivalent noise temperature of the receiver was measured by presenting alternatively a room temperature and a liquid nitrogen-cooled blackbody in front of the feed-horn. The optimum DSB mixer noise temperature was measured as 1368 K at 204GHz with LO power of 5mW.

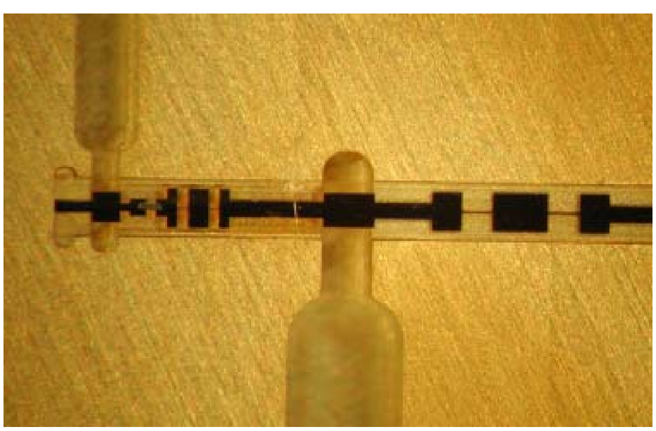

Fig. 2. The inside view of the assembled bottom block

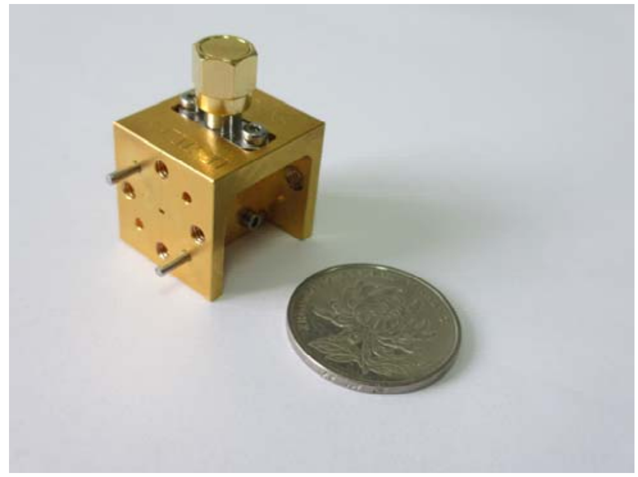

Fig. 3. The photograph of the fabricated mixer

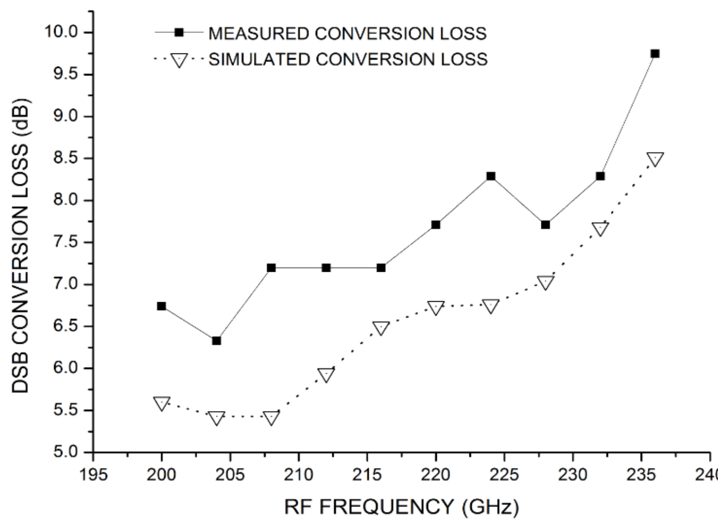

Fig. 4. The mixer's simulated and measured performance

III. Conclusion

This paper presents the development of a 220-GHz subharmonic mixer for a future communication system based on RAL's planar Schottky diodes. Good measured noise and conversion loss performance has been obtained. The measurement results are in accord with the simulation prediction. Work is still in progress to optimize the bandwidth and noise and conversion loss performance. In the future, the methodology for designing this mixer will contribute to the development of terahertz receivers at higher frequencies.

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