Abstract—This paper presents the design and simulation of several fixed-tuned sub-harmonic mixers cover frequencies from 110 GHz to 130 GHz, 215 GHz to 235 GHz, 310 GHz to 350 GHz, and 400 GHz to 440 GHz. Among them, 120 GHz, 225 GHz, 330 GHz subharmonic mixers are designed with flip-chipped planar schottky diode mounted onto a suspended quartz-based substrate, the 225 GHz and 425 GHz subharmonic mixers are GaAs membrane integrated, and the 115 GHz subharmonic mixer has been fabricated and tested already.

Index Terms—Conversion loss, planar schottky diodes, sub-harmonic mixer, terahertz, terahertz monolithic integrated circuit membrane mixer.

1. Introduction

The development of low-loss, heterodyne detection systems operating at terahertz frequency band[1]−[3], is essential for applications including radiometers, radar systems, and communication systems. Despite the progress of submillimeter-wave low-noise amplifiers[4], Schottky mixers are still used as the first element of receiver front-ends to down-convert the signal collected by the antenna to microwave frequencies where it can be amplified and analyzed more easily. Schottky mixers have the advantage over other sensor technologies to work at room temperature as well as cryogenic temperatures for improved noise performance, which make them the technology of choice for long-term applications[5],[6].

2. Design

To design the subharmonic mixer successfully, two circuit simulation tools are implemented, advanced design system (ADS) and high frequency structure simulator (HFSS). For nonlinear circuit analysis, ADS based on the harmonic balance technology is used. And HFSS offers the linear electromagnetic solution to the specified physical structure based on the finite element analysis.

For the linear embedding circuit, aiming to reduce the requirements for the computer memory and computation time during HFSS simulation, the structure was divided into four functional parts which can be solved individually, namely, 1) the local oscillator (LO) input waveguide transition to suspended microstrip including the IF low pass filter, 2) the low band pass filter which will stop RF frequency while pass LO and IF frequency, 3) the anti-parallel planar Schottky diodes and nearby suspended microstrip, and 4) the transition from microstrip to radio frequency (RF) input waveguide. Finally, all the functional parts were integrated in HFSS for a complete linear electromagnetic structure simulation to achieve desired performance. As a consequence, the generalized S-matrix from the four HFSS models were imported into ADS and connected with suspended microstrip lines. In the ADS simulator, harmonic balance analysis was launched to evaluate the simulated performance of the full structure. If the simulation results were not satisfying, the sub-harmonic mixer structure in HFSS should be re-optimized.

3. Mixer performance

3.1 110 GHz to 130GHz Subharmonic Mixer

The simulated and the measured best double-sideband (DSB) conversion loss is shown in Fig. 1. A DSB conversion loss of 4.7 dB was achieved with 8 mW of LO power at 1.2 GHz IF. Over an RF band of 14 GHz, the DSB conversion loss is below 9 dB. The actual photograph of the subharmonic mixer is shown in Fig. 2.
3.2 215-235 GHz Subharmonic Mixer
Motivated by the LO between 5 mW to 10 mW, the simulated conversion loss of the subharmonic mixer is shown in Fig. 3. The lowest conversion loss is driven by 7 mW of the LO power. The mixer block shown in Fig. 4 has been fabricated and is currently waiting to be tested.

3.3 310 GHz to 350 GHz Subharmonic Mixer
Motivated by the LO between 3 mW to 8 mW, the simulated conversion loss of the subharmonic mixer is shown in Fig. 5. The lowest double sideband conversion loss performance of 5.7 dB is driven by 5 mW of the LO. The mixer block shown in Fig. 6 has been fabricated and is currently waiting to be tested.

3.4 225 GHz TMIC Subharmonic Mixer
As the frequency increases, the TMIC technology is adopted. Fig. 7 shows the configuration of the 225 GHz TMIC membrane sub-harmonic pumped mixer circuit. Fig. 8 shows the simulated conversion loss and noise figure over the RF frequency band. The 220 GHz mixer yielded conversion loss and noise figure of 6.7 dB and 2.9 dB respectively and the 3 dB bandwidth is about 16%, operating from 205 GHz to 240 GHz. Fig. 9 shows that both the optimum conversion loss and noise figure can be obtained when the LO drive power is 4 dBm.
3.5 425 GHz TMIC Subharmonic Mixer

The simulated result is shown in Fig. 10. The optimized conversion loss of the 425 GHz mixer is less than 7 dB.

4. Conclusions

Several mixers using planar Schottky diode flip-chipped mounted onto a suspended quartz-based substrate and integrated with GaAs substrate were successfully designed respectively and the 115 GHz subharmonic mixer with flip-chipped diode has been fabricated and tested. A best DSB conversion loss of 4.7 dB of the mixer was achieved with 8 mW of LO power at 1.2 GHz IF. Over an RF band of 14 GHz, the DSB conversion loss is below 9 dB. The simulated and tested results have shown that the technique used in the device above is a feasible approach for sub-harmonic mixer design.

References


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