Intermodulation in Subharmonic Diode Upconverter for LMDS

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Abstract

A simple approach for the prediction of conversion gain and so far not numerically determined intermodulation behaviour of subharmonic diode mixers is presented. The simulated results are verified with measured results of an upconverter for the frequency range of 38 – 42 GHz. The mixer has a conversion gain of –9 dB with an 1 dB compression point of 2 dBm. For an output power of –10 dBm, the third order intermodulation suppression is –32 dBc.

Introduction

Subharmonic diode mixers, built as hybrid circuits, are used in mmwave and submmwave systems for many years [1]. The fundamental conversion behaviour of subharmonic mixers is well understood [2,3,4]. Recently, subharmonic diode mixers become popular for mmwave communication systems [5]. Due to the low LO frequency, the required LO output power for the mixer operation can be delivered from low cost amplifier. However, in communcation systems considerations about the intermodulation behaviour cannot be neglected. So far the intermodulation behaviour of subharmonic mixers is not very well understood.

In this paper, a simple approach to investigate the conversion and third order intermodulation behaviour of subharmonic diode mixer is presented. The impedance responsible for the conversion bahaviour is identified. The theoretical calculated results are verified with measurements of a fabricated mixer chip. On a chip size of 1.1x1.1 mm^2, the subharmonic diode mixer was designed as an upconverter for the 36-42 GHz frequency range. It has less than 9 dB conversion loss and an input 1 dB compression point of 2 dBm. The measured third order intermodulation suppression for –10 dBm single tone output power is –32 dBc. The simulation predicts the measured performance accurately. An intermodulation suppression of –30 dBc was simulated.

The Simulatin Approach

The schematic of an ideal subharmonic diode mixer is shown in Fig. 1. The LO signal, fed to the antiparallel diode ring from the LO port, has a short circuit at the RF port side formed by a quarter wavelength open stub (stub 1). As a result, the RF matching network does not influence the LO signal. The RF signal is not influenced by stub 1. In contrast, the quarter wavelength open circuit stub 2, shortening the RF signal, forms an impedance $\underline{Z}$ at the LO frequency at the LO side of the diode ring. The impedance $\underline{Z}$ of the open stub and the matching network determine the impedance applied to the diode ring. This impedance mainly influences the large signal voltage across the antiparallel diode pair applied from the LO signal. Consequently, electrical performances of the subharmonic diode mixer, like conversion gain and intermodulation suppression, can be optimized by choosing the appropriate impedance.

In [6] a method is proposed for the applicability estimation of diodes used in single ended mixers.

The method can be extended for the determination of the optimum impedance $\underline{Z}$ used in subharmonic diode mixer. Fig. 2 shows the schematic of the ideal mixer prototype used in the simulation. Only voltages sources are applied to the diode ring. By avoiding the usage of power sources, the design of matching network can be avoided in the simulation. The voltage drop across the diodes is only determined by the impedance presented to the diodes. For the simplification of the analysis, only a resistance is used for the estimation of the best mixing performance instead of an impedance. The inductance shown only forms a DC return with negligible influency at high frequencies. The power levels at the different frequencies are calculated as the frequency selective products of the currents and the volatges across the diodes.

The Fabricated Mixer

Fig. 3 shows the photograph of a fabricated subharmonic diode upconverter. The chip size is 1.1x1.1 mm^2. For the size reduction, the LO and RF short circuit stubs are realized as a shunt capacitor and microstrip inductor combination. The DC return, realized as a spiral inductor, is visible at the RF port. The RF matching network consists of a microstrip line and an open stub. At the LO side, the spiral inductors provide an on-chip IF matching network. The LO matching network is of lowpass type.

Measured Results and Comparison

The upconversion characteristic of the mixer is shown in fig. 4. In the 38 – 42 GHz frequency band, the mixer has a conversion loss between 7 and 9 dB for the upper and lower side band measured with an IF frequency of 1 GHz. The LO suppression is better than 40 dBc. The simulated and measured compression characteristic at 38 GHz is shown in fig. 5. A conversion loss of 9 dB was measured. The simulation predicts a conversion loss of ca 10.5 dB. The mixer has a measured input 1 dB compression point of 2 dBm. The simulation predicts 3 dBm of input compression point. For the simulation and the measurement the same LO power was used. The discrepancies between measurement and simulation result for the assumption of a resistive load in the simulation estimation. The realised on-chip short circuit lines and matching network provide an impedance with reactive contribution.
The third order intermoduation suppression is shown in fig. 6. The intermodualtion behaviour was measured for a two tone spacing of 10 MHz at 38 GHz with an IF input signal of 1 GHz and a LO frequency of 18.5 GHz. At a single tone output power of –10 dBm a third order intermodulation suppression of –32 dBc is measured for both intermodulation products. The prediction of the simple simulation setup of fig. 2 predicts the measured intermodulation characteristic.

Conclusion

A simulation apporach is presented that can be used for the prediction of conversion gain and intermodulation level of subharmonic diode mixers in upconverter configuaration. The impedance at the LO frequency must be accurately chosen for the optimum performacne of the mixer.
For the frequency range of 38 – 42 GHz, the measured results of a small size mixer with an area of 1.1x1.1 mm^2 were used for verification of the simulation. The mixer has a conversion gain of –9 dB with an 1 dB compression point of 2 dBm. For an output power of –10 dBm, the third order intermodulation suppression is –32 dBc. The simulation predicts the perfomrance accurately.

References

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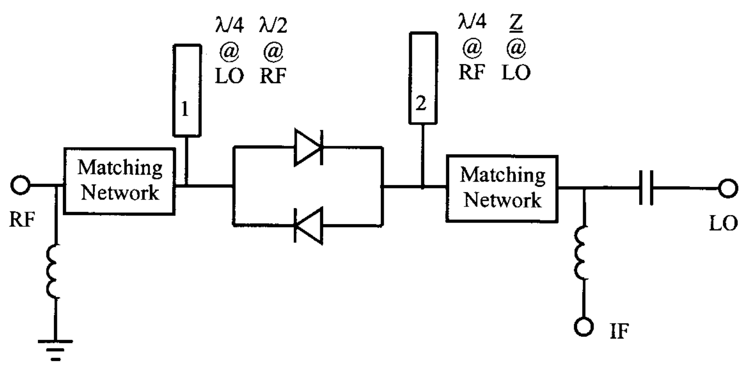

Fig. 1: Schematic of a subharmonic diode mixer

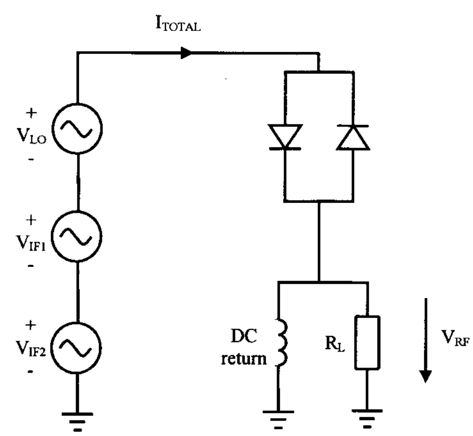

Fig. 2: Schematic of the simulation setup

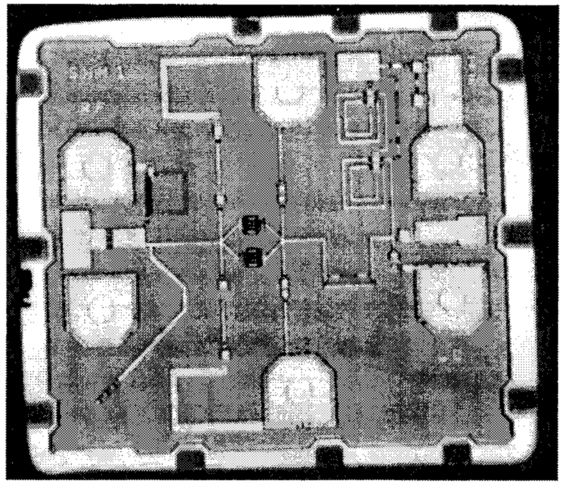

Fig. 3: Photograph of the subharmonic diode mixer

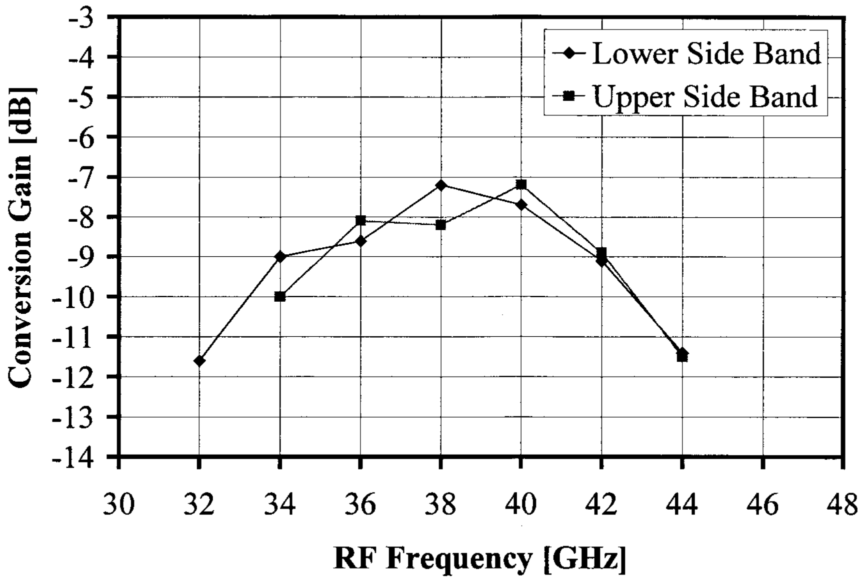

Fig. 4: Conversion gain of the subharmonic diode mixer as upconverter with $f_{IF} = 1$ GHz

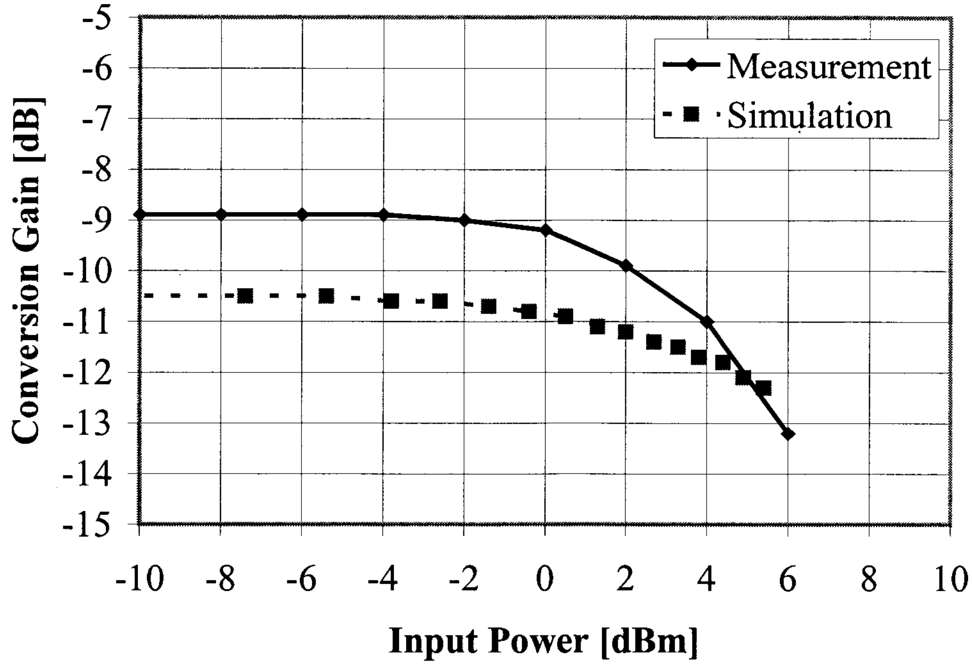

Fig. 5: Measured compression characteristic of the subharmonic diode mixer as upconverter with f_{IF} = 1 GHz and f_{LO} = 18.5 GHz. The simulation was performed with the preditcion setup of fig. 2.

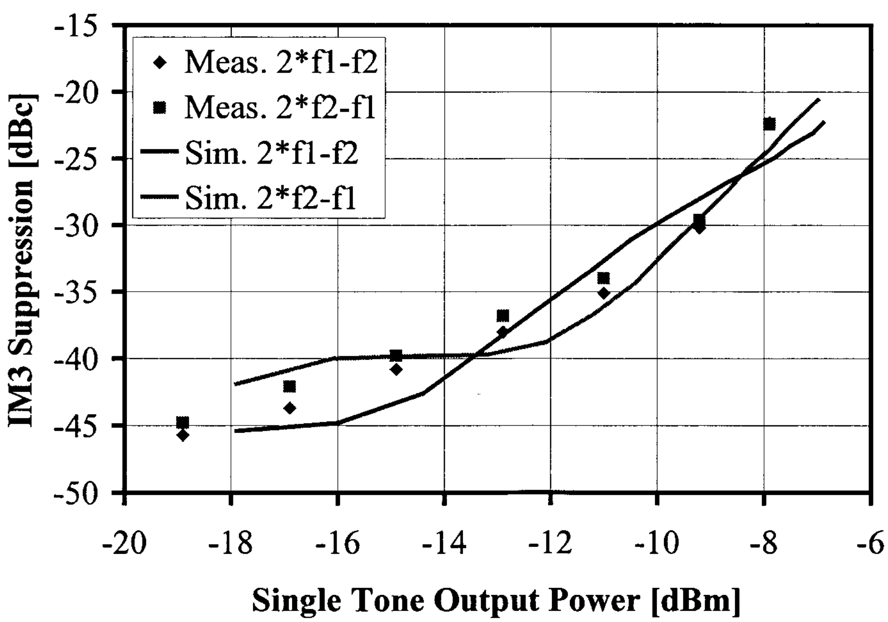

Fig. 6: Measured upper side third order intermodulation suppression of the subharmonic diode mixer as upconverter with f_{IF} = 1 GHz and f_{LO} = 18.5 GHz and 10 MHz two tone spacing. The simulation was performed with the setup of fig. 2.