A FIXED-TUNED 400 GHZ SUBHARMONIC MIXER USING PLANAR SCHOTTKY DIODES

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Abstract

The design and testing of a 400 GHz fixed-tuned subharmonic mixer using anti-parallel planar Schottky barrier diodes is presented. Fixed-tuned, two-sided waveguide-to-microstrip transitions are used to couple power into a microstrip channel, in which the diode is mounted. A low-pass filter is used to block the RF signal, and a short-circuited half-wave stub is used to terminate the LO. The first tests of the mixer yielded a double-sideband mixer noise temperature of 1120 K and a mixer conversion loss of 8.0 dB at 420 GHz using 5 mW of local oscillator power.

Introduction

This paper describes the design and testing of a 400 GHz anti-parallel planar-diode subharmonic mixer. The main goal of this research is the development of robust solid-state room-temperature mixers at 380 GHz and 425 GHz with broad IF bandwidth for space-based microwave sounding. In addition to this goal, we desire to develop a sensitive fixed-tuned room-temperature mixer with broad RF and IF bandwidths that is rugged and uses a relatively simple block geometry, in particular one that is compatible with molding and micromachining block fabrication techniques [1]. The use of an E-plane split block design, with the RF and LO guides machined in the same plane of the block makes this design amenable to these inexpensive block fabrication techniques. The mixing element used for this mixer will be a planar Schottky diode [2], which is mechanically robust and can give excellent sensitivity without the need for cooling. Subharmonically pumped anti-parallel diodes will be used because this configuration suppresses LO noise and eliminates the need for an external diplexer since the RF and LO signals are coupled through different ports [3]. Finally, the use of the anti-parallel diode configuration tends to reduce the diode's IF impedance, thus simplifying broadband IF matching.

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Mixer Block Configuration

The mixer block is split in the E-plane of the RF and LO waveguides, which simplifies mixer assembly and reduces the losses in the waveguides. The planar diode is mounted on a 35 μm thick fused-quartz substrate and then placed in a shielded microstrip channel which runs perpendicular to the RF and LO waveguides. A schematic of the mixer block circuit configuration is shown in Fig. 1. Fixed-tuned waveguide-to-microstrip transitions, with the microstrip running through the waveguide, are used to couple power into the microstrip channel, where the diode is mounted. The use of two-sided waveguide-to-microstrip transitions required the use of reduced height RF and LO waveguides to achieve reasonable bandwidths. For this mixer, half height waveguide was used for the RF, and third height guide was used for the LO.

A low-pass microstrip filter is used to prevent the RF signal from coupling to the LO guide, and a short-circuited half-wave stub is used to provide the LO termination. The RF embedding circuit is conceptually similar to that of a successful 700 GHz fundamental planar-diode mixer [4], indicating that this design can be readily scaled to higher frequencies using existing flip-chip type planar diodes.

Block Design

The mixer was designed using Ansoft's Maxwell finite-element simulator to model the waveguides, planar diode chip, and quartz circuit. Coaxial probes were artificially introduced at the two diode junctions during the finite element modeling to allow the direct prediction of the diode embedding impedance. The circuit was designed to present an LO embedding impedance of $70+j130\Omega$, and an RF impedance of $65+j40\Omega$. Harmonic balance simulations were performed for the University of Virginia SD1T7-D20 planar diode (η=1.26, $I_{sat}=2\cdot10^{-16}$ A, R_s=18 Ω, and C_{j0}=1.3 fF), and for the above embedding impedances the simulation predicted a mixer conversion loss of 5.0 dB (DSB) and noise temperature of 250 K (DSB) using 1 mW of LO power. The total conductor and dielectric loss for the horn, waveguide, microstrip, and diode was estimated to be about 2 dB. Using this loss, the predicted performance is a mixer conversion loss of 7 dB (DSB) and mixer noise temperature of 600 K (DSB). Fig. 2 shows a plot of the RF embedding impedance as a function of frequency. It is seen that the fixed-tuned RF bandwidth of the mixer is predicted to be about 70 GHz, or about 18%. The fixed-tuned LO bandwidth is expected to be only about about 5%, with the smaller bandwidth caused by the presence of the half-wave stub terminating the LO circuit.

Mixer Testing

The sensitivity of the mixer was measured at room temperature, yielding an overall system noise temperature of 2930 K (DSB) using 5 mW of LO power. The local oscillator power for this mixer was provided by a 105 GHz Gunn oscillator with about 75 mW output power driving a planar balanced doubler [5]. A variable attenuator was used to vary the IF noise temperature from 100 K to 440 K, thus allowing the measurement of the mixer parameters T_{mix}=2130 K (DSB) and L_{mix}=9.8 dB (DSB). Correction of the IF standing-wave-ratio of 4:1 will improve the performance to

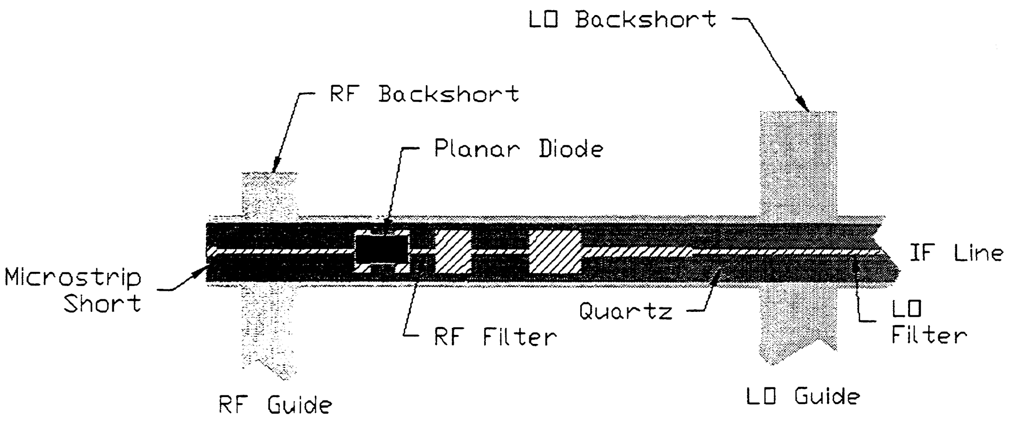

Fig. 1. Schematic of subharmonic mixer block circuit configuration.

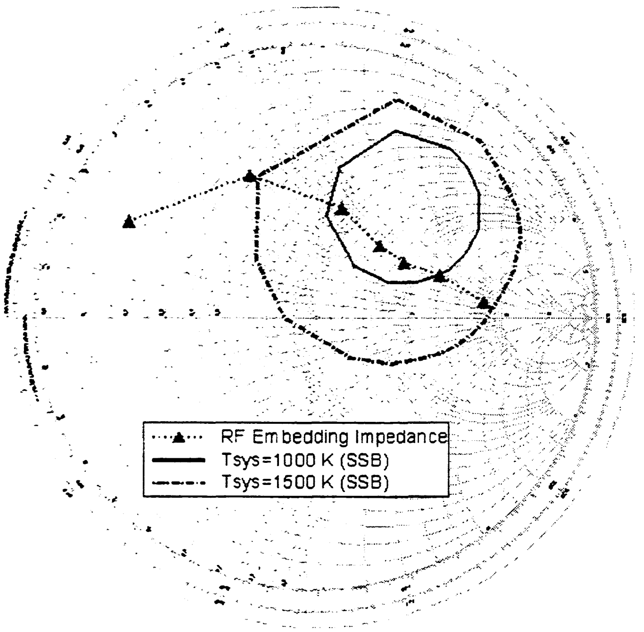

Fig. 2. RF embedding impedance from 360 GHz to 440 GHz (13.3 GHz steps) and computed noise temperature contours (contours calculated with 1.5 mW LO power, 100 Ω IF impedance, and with no transmission line losses).

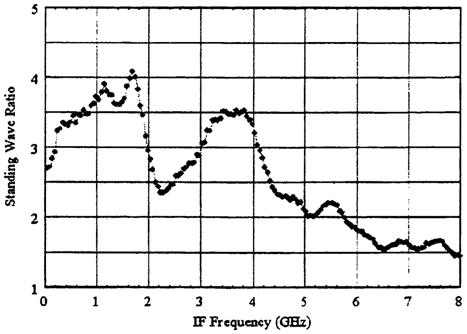

Fig. 3. Measured IF standing-wave-ratio for mixer at 420 GHz with 5 mW of LO pump power.

$T_{mix,c}$=1120 K (DSB) and $L_{mix,c}$=8.0 dB (DSB) (note that a room temperarature circulator was used at the input of the IF amplifier chain). A plot of the IF mismatch versus frequency is shown in Fig. 3.

Conclusions

We have developed an a robust 400 GHz planar-diode mixer with excellent sensitivity which can use an all-solid-state LO source. This mixer block is compatible with micromaching and molding techniques, thus allowing for the possibility of reduced component cost for submillimeter-wavelength mixers. Future testing will examine the experimental RF and IF bandwidths for this mixer. Based of previous results with fundamental mixers, it is expected that this mixer can be scaled to at least 700 GHz using existing planar flip-chip diodes, and can be scaled to THz frequencies by integrating the diode with the mixer circuitry [6].

Acknowledgments

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