# Design of an 874 GHz Biasable Sub-Harmonic Mixer Based on MMIC Membrane Planar Schottky Diodes

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***Abstract*—We report upon the development of a 874 GHz bias-able sub-harmonic mixer using planar Schottky diodes. The MMIC integrates two planar Schottky diodes in a balanced configuration, stripline filtering elements and on-chip capacitor on a 5 microns thick GaAs membrane. Predicted performance gives optimal conversion losses of 10 dB and a 3 dB bandwidth from 820 to 920 GHz. This work represents the highest frequency Schottky based MMIC sub-harmonic mixer development to-date.**

## I. Introduction

Atmospheric remote sensing of stratospheric ice clouds is of key interest in understanding the hydrological cycle of climate systems for life on Earth. Several missions have been proposed that would monitor globally the ice water content of cirrus clouds using passive sub-millimeter radiometer instruments (e.g. CIWSIR/GOMAS Explorer mission proposals to ESA). Studies of such missions have demonstrated that ice clouds' signature is more pronounced and better spatially resolved if high frequency channels (i.e., 664 GHz and 874 GHz) rather than lower frequency sub-millimeter channels are chosen. High frequency channels also allow specific information about small grain size ice particles (typ. < 300 um) to be retrieved [1]. Sensitive heterodyne receivers based on planar Schottky diodes are, so far, the most appropriate for long life, room temperature instruments operating at frequencies up to 2.5 THz.

Despite the fact that several milliwatts of output power from multiplied microwave sources have already been achieved at 440 GHz [2] and higher [3], the provision of the Local Oscillator is still an issue for high frequencies sub-millimeter wave receivers. Therefore, a biasable sub-harmonic mixer is desirable in order to reduce the LO power requirements by forward biasing each diode individually, as already demonstrated at lower frequencies [4].

In that context, we present here the design and development of an 874 GHz biasable sub-harmonic (SHP) mixer featuring a membrane based MMIC using planar Schottky diodes.

## II. 874 GHz SHP Mixer Architecture

A schematic view of the 874 GHz biasable sub-harmonic MMIC mixer is shown in Fig.1. The MMIC circuit is based on the membrane and beam-lead fabrication process developed by JPL, and successfully used for the development of Schottky diode based multipliers for the HIFI instrument onboard HERSCHEL Space Observatory [3][5]. It features a pair of series planar Schottky diodes placed in balanced configuration inside the waveguides cross-channel, as first introduced by Carlson et al. [6]. A beamlead connected to the cathode of the 1st diode provides a DC/RF ground, whereas an on-chip capacitor connected to the anode of the other diode is used to decouple the RF ground from the DC bias line (bottom line shown in red in Fig.1). This configuration is similar to a MMIC frequency tripler developed by Maestrini et al. [7].

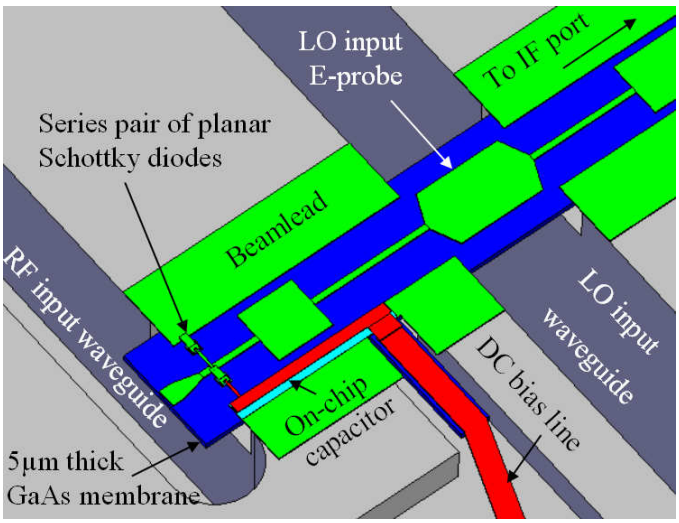


Fig.1: view of the 874 GHz MMIC SHP mixer circuit.

## III. Design Methodology

The design methodology uses a combination of three-dimensional electromagnetic simulations (using HFSS from Ansoft [8]) coupled to linear and non-linear circuit simulations (using ADS from Agilent [9]), as described in [10]. First, the diodes dimensions and doping are chosen for best performances in the desired frequency range from a set of non-linear Harmonic Balance simulations. The resulting electrical parameters of each individual diode are a series resistance of 20 Ω, an ideality factor of 1.3, a built-in potential of 0.8 V, saturation current of $3.10^{-14}$ A, and a junction capacitance of 1.15 fF. The ideal embedding

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impedances for an anti-parallel pair of diodes without bias voltage applied is $Z_{RF}$ = 43 + j.53 at RF frequencies, and $Z_{LO}$ = 55 + j.135 at LO frequencies. Second, a 3-Dimensional model of the diodes cell is simulated electromagnetically using HFSS and tuned for lowest conversion losses. Finally, the rest of the circuit is modeled electromagnetically and tuned to present embedding impedances as close as possible to the ideal values over the broadest bandwidth possible.

Predicted mixer performance is presented in Fig.2. Simulations suggest DSB mixer conversion losses of approximately 10 dB. The simulated 3 dB RF bandwidth extends from 820 GHz to 920 GHz.

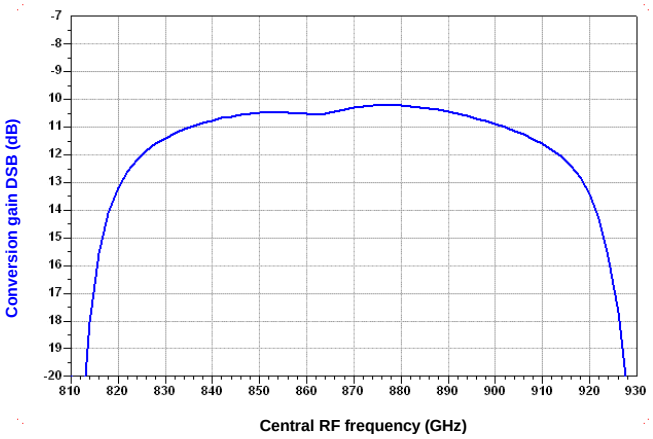


Fig.2: Predicted DSB conversion losses *VS* central RF frequency.

## IV. Mixer Fabrication, Assembly and Test

The MMIC membrane devices fabricated by the SWAT group at JPL are 5 µm thick and approximately 850 µm long A bias-less version of the MMIC chip shown in Fig.3 is mounted inside the lower half of the split-waveguide block and suspended inside the cross-channel by metal beamleads. Another beamlead (not shown in the figure) is connected to the IF output circuit.

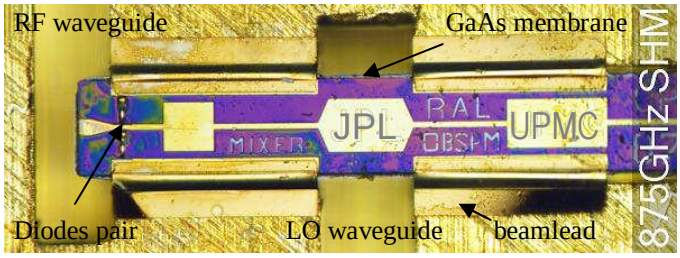


Fig.3: Photo of the 874 GHz sub-harmonic mixer bias-less MMIC mounted inside the lower of the split-waveguide block.

The 874 GHz sub-harmonic mixer block has been machined by the Precision Development Facility group at RAL. It includes a broadband DC-40 GHz IF output K-connector (from Anritsu [11]), a UG-387 LO waveguide flange, and an integral diagonal feed-horn antenna [12].

Preliminary measurements give DSB mixer conversion losses of 10.5 to 12 dB and DSB mixer noise temperature between 3000 K and 4300 K in the frequency range 800-856 GHz.

## V. Conclusion

The design and development of a novel 874 GHz sub-harmonic biasable mixer using MMIC GaAs membrane planar Schottky diodes is presented. A biasable and bias-less version of the MMIC chip have been fabricated. Preliminary measurements show good agreement with the simulations.

## VI. Acknowledgements

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