Design of Feed Horn Integrated 380 GHz Sub-Harmonically Pumped Mixer Cavity

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***Abstract*- This paper presents the design and fabrication of feed horn antenna integrated 380 GHz sub-harmonically pumped mixer's split cavity block. The mixer circuit is fully integrated with the microstrip circuit and the flip-chipped diode (planar GaAs air-bridged Schottky anti-parallel diode, which was designed and fabricated by millimeter technology group, Rutherford Appleton Laboratory, UK) on suspended 50μm thick quartz substrate. The mixer's split cavity block is designed using ANSOFT's three-dimensional full-wave electromagnetic simulation software HFSS, as well as 3D CAD design software SOLIDWORKS. The mixer cavity and its circuit are fabricated and assembled at MMT's Precision Development Facility, UK Rutherford Appleton Laboratory. Mixer circuit configuration and cavity block are detailed in the paper. The simulation investigation shows state-of-the-art results obtained. A best conversion loss of 6.5dB is achieved with 3mW LO power at 383 GHz.**

I. INTRODUCTION

Terahertz (THz) technology is a new research area which developed rapidly during last two decades. This topic involves electromagnetism radiation [1], spectroscopy [2], imaging [3], semiconductor physics [4], materials science [5], and biology [6] etc. THz covers wideband electromagnetic radiation area from 100 GHz to 10 THz, which ends connect to the microwave/millimeter wave and infrared/visible light, respectively. For a long time, there formed the "THz gap" in the application electromagnetic spectrum due to the lack of effective THz sources and detection methods.

When THz wave propagates in the atmosphere, there would be certain attenuation due to resonance with gas molecules, thus formed THz atmospheric attenuation characteristics. Between the atmosphere THz wave absorption lines as shown in Fig. 1, there are some relatively minor atmospheric absorption bands, these minimum value attenuation peaks are called atmospheric window. In the millimeter/THz band, there are several atmospheric windows, distribute at the center frequencies of 94 GHz, 118 GHz, 140 GHz, 183 GHz, 225 GHz, 380 GHz etc., and the relative bandwidth reaches about 20%, even 70% [7]. These bands will make great potential application in receivers. In this paper, 380 GHz was selected as our sub-harmonic mixer's working frequency.

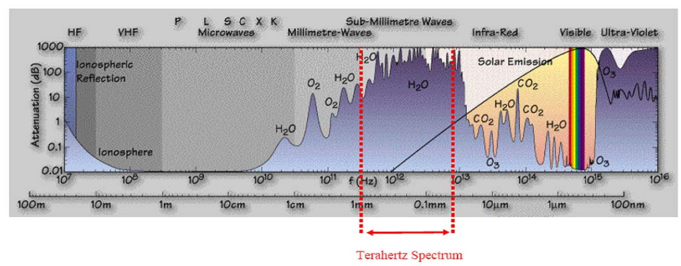

Fig. 1 THz Gap and atmosphere window frequencies

As shown in Fig. 2, among various THz application systems, such as communication, radar, astronomical observation System etc., the most important and also the first problem should be solved is how to realize THz signal down-transformation, which requires THz receiver front-end. Sub-harmonically pumped (SHP) mixers employing an anti-parallel Schottky diode pair are key components for millimeter/ THz wave heterodyne receivers, which using non-linear effect to realize THz signal down-transformation.

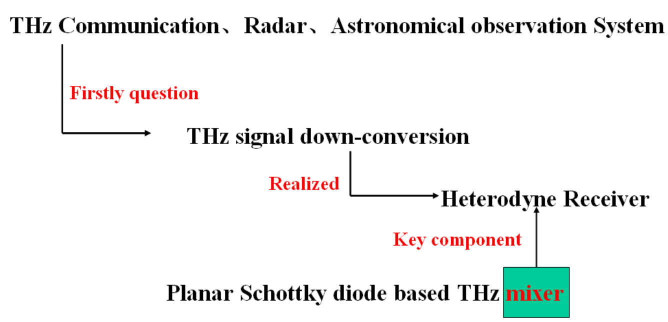

Fig. 2 THz system signal down-transformation using mixer

This paper presents the design and fabrication of feed horn antenna integrated suspended low-loss fixed-tuned 380GHz sub-harmonically pumped mixer's split cavity block. A best double-sideband mixer simulation loss of 6.5dB was achieved at 383GHz with 3mW LO power.

II. INTEGRATED FEED HORN DESIGN

The 380 GHz feed horn antenna integrated mixer is fixed-tuned, using least parts to minimize the cost, as well as maximize its potential convenience for circuit and block manufacture. The mixer's RF input port connects to the feed horn. The feed horn antenna modeling is shown in Fig. 3.

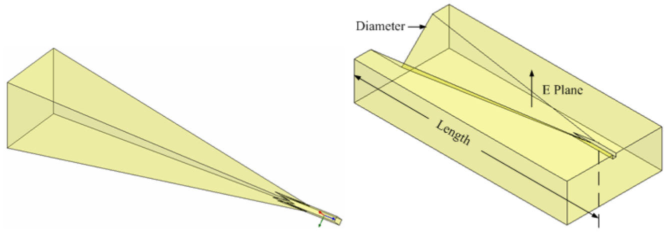

Fig. 3 Feed horn antenna modeling

Tab. 1 VDI feed horn parameters under certain standard waveguide

Waveguide Type	Frequency Range (GHz)	Horn Type	Horn Length (mm)	Aperture Diameter
WR-4.3	170-260	Conical	16.5mm	7.1mm
WR-2.8	260-400	Diagonal	21.4mm	4.6mm
Waveguide Type	**TaperHalf-Angle**	**Full 3dB Bandwidth**	**Gain**	**Beam Waist**
WR-4.3	12.1deg	13deg	21dB	2.7mm
WR-2.8	6.1deg	10deg	26dB	1.9mm

Reference to U.S. Virginia Diodes, Inc. feed horn style and parameters under certain standard waveguide shown in Tab. 1, this feed horn is design and fabricated, using additional special feed horn attached, as shown in Fig. 4.

Fig. 4 Feed horn integrated 380GHz mixer

III. MIXER CAVITY DESIGN

Thanks to the improvement of 3D electromagnetic solvers and nonlinear circuit simulators, fix tuned SHP mixers using discrete or integrated planar Schottky diodes have already demonstrated lower conversion loss than traditional mixers using mechanically tunable back-shorts [8]. The discrete planar diode could be used for low conversion loss fixed-tuned mixers while providing significant cost reduction, up to 600GHz [9].

The SHP mixer cavity would be realized by a two way split block, split among the interface of the 50μm thick quartz substrate (Relative dielectric constant 3.78) is located. The designed SHP Mixer's split cavity block is shown in Fig. 5.

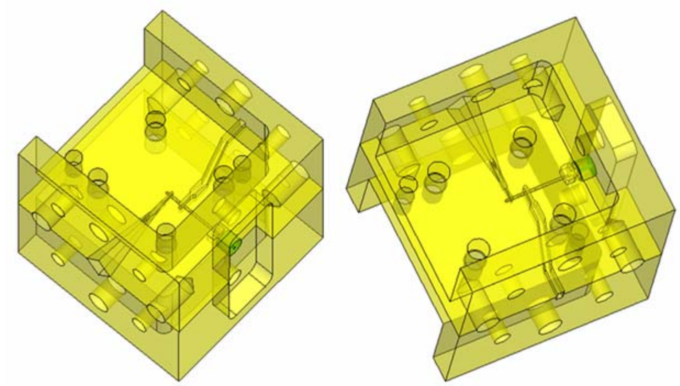

Fig. 5 The designed SHP mixer's split cavity block

The anti-parallel diode pair is flip-chipped onto the quartz substrate, connected with RF/LO relevant circuits. Two step-impedance line low-pass filters are used to block the RF and LO frequency, respectively. The output IF signal would be via a sparkplug-style K connector with glass bead and sliding contact through the low-pass LO filter. This feed horn antenna integrated suspended low-loss fixed-tuned 380GHz sub-harmonically pumped mixer's two ways split block shown in Fig. 6, its circuit configuration shown in Fig. 7.

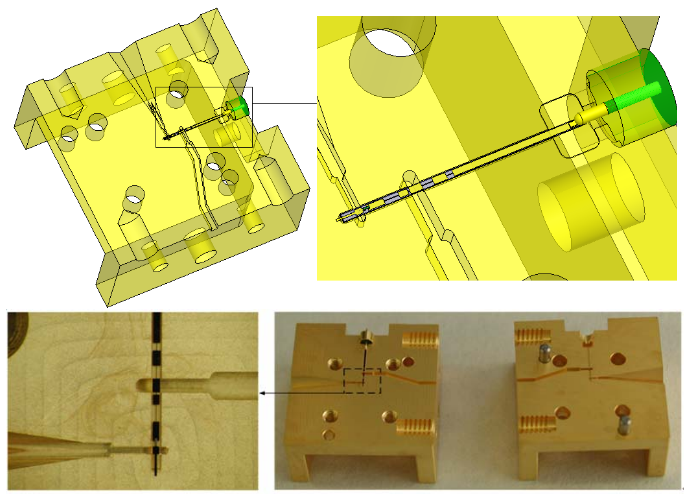

Fig. 6 The suspended quartz circuit in mixer split cavity

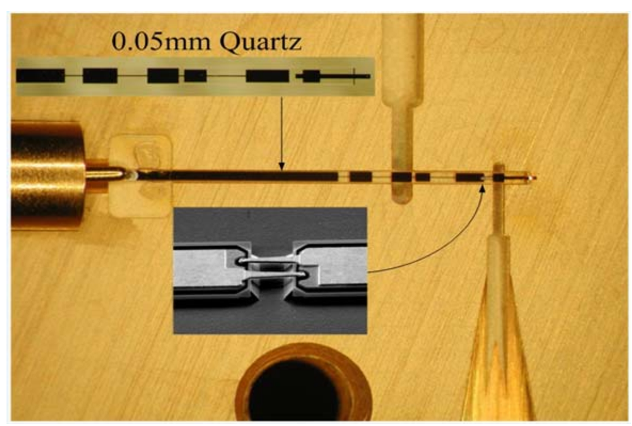

Fig. 7 The designed 380 GHz SHP mixer circuit configuration

IV. SIMULATION RESULTS

The 380 GHz SHP mixer after assemble shown in Fig. 8. The whole mixer cavity block dimension is 20mm×20mm×20mm. Cavity up-side is integrated rectangular RF feed horn antenna, down-side is LO input waveguide and left-side is sparkplug-style K connector to the output IF signal.

Fig. 8 The 380 GHz SHP mixer after assemble

The performance of the mixer has been unite-simulated by Agilent's ADS and Ansoft's HFSS. 380 GHz SHP mixer's system level modeling is studied and the state-of-the-art simulation results are obtained. The best simulation conversion loss achieved is about 6.5dB, at 383 GHz with 3mW LO power, as shown in Fig. 9. This state-of-the-art simulation results [10, 11] are attributed to low parasitic UK RAL planar GaAs air-bridged Schottky anti-parallel pair diode AP1/G2, low-loss quartz suspended microstrip circuit, and system level mixer modeling.

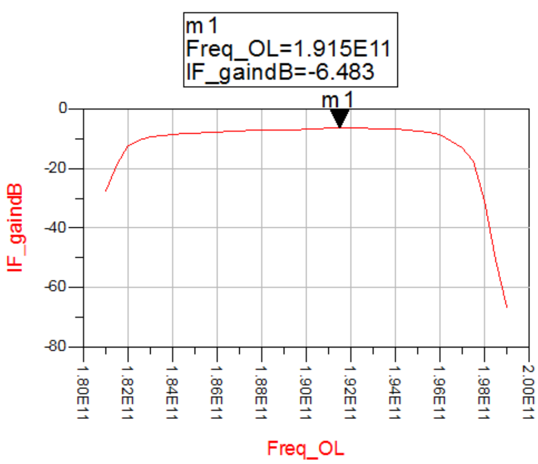

Fig. 9 Conversion loss simulation results of the designed SHP mixer

IV. CONCLUSION

This paper presents the design method of feed horn antenna integrated suspended low-loss fixed-tuned 380GHz sub-harmonically pumped mixer's split cavity block. The assembled mixer cavity and inner circuit are detailed. Simulation results show best double-sideband mixer loss of 6.5dB at 383GHz with 3mW LO power.

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