A Compact Low-Power 874 GHz Schottky Receiver for the IceCube Radiometer

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Abstract— **This paper describes a 874-GHz Schottky receiver that uses high-efficiency amplifiers and varactor multipliers in the LO chain to achieve low DC power with uncompromised sensitivity in a compact configuration optimal for CubeSat platforms. The total required DC power for the LO, including the 24.278 GHz dielectric resonator oscillator (DRO), is less than 2W. Despite the low power dissipation, expected mixer noise temperature is 3000K DSB at room temperature.**

I. Introduction

One of the largest uncertainties in predicting climate change on Earth involves the characterization of ice clouds, due to their importance in radiative cloud feedback, precipitation and upper troposphere water cycling [1]. Submillimeter-wave radiometry is a technique that shows considerable promise for remote sensing and characterization of ice cloud properties in the upper troposphere. The CoSSIR instrument was the first flight of a 874-GHz radiometer and has demonstrated the ability of this technique for measuring ice cloud properties [2]. IceCube, funded by NASA's Earth Science Technology Office (ESTO), is a 28-day low earth orbit CubeSat mission currently planned for launch in summer 2016. The primary objective of IceCube is to validate the technological readiness of an 874 GHz commercial receiver for use in future spaceflight missions. The secondary objective of this mission is to demonstrate ~0.1 K Noise Equivalent Temperature Difference (NETD) and 2 K maximum calibration error performance. If successful, it could be a precursor for a network of CubeSats to provide cost-effective and global mapping of ice clouds. In this paper, we describe the 874-GHz Mixer LO Assembly (MLA) designed to be flown on IceCube.

The 874 GHz mixer and LO on CoSSIR was also provided by Virginia Diodes, Inc. (VDI) and consisted of a 36.417 GHz DRO followed by a high-power microwave amplifier, x12 multiplier chain, and second-harmonic mixer. While a highly effective receiver for CoSSIR, the size and DC power requirements of this system (the 36-GHz power amplifier in particular) would be prohibitive for a CubeSat platform where available DC power is very limited. Other 874-GHz receivers previously reported include a fundamental Schottky mixer with less than 4000K DSB from 845 to 888 GHz at room temperature [3]. This system required a high-power LO chain driven by a separate commercial W-band source followed by a series of power-combined W-band power amplifiers. In this work, we utilize an efficient E-band MMIC amplifier followed by high-efficiency varactors specifically tuned for this band to provide a complete LO and mixer, including DRO, with total power dissipation under 2W and no sacrifice of mixer sensitivity.

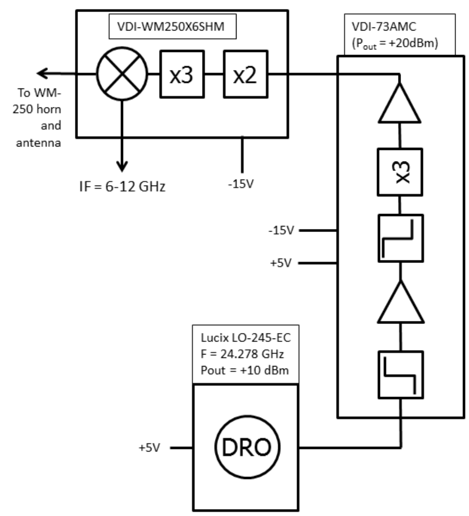

Fig. 1 Block diagram of the 874-GHz IceCube MLA. The MLA is composed of three modules: the 24.278 GHz DRO, 72.8 GHz AMC (73AMC), and 874-GHz subharmonic mixer (WM250X6SHM).

II. LO and Mixer Design

The MLA is a 2nd harmonic mixer assembly that down-converts an 862-886 GHz passband to an Intermediate Frequency (IF) output spanning 6-12 GHz. The entire MLA, including DRO, is required to fit within a 9 cm x 9 cm x 3 cm volume. This prohibited the use of discrete components for each of the LO amplifiers, multipliers, and mixer. It was decided to separate the receiver into three modules (DRO, 72.8 GHz active tripler, and 874 GHz mixer) with the modules custom configured for a compact configuration.

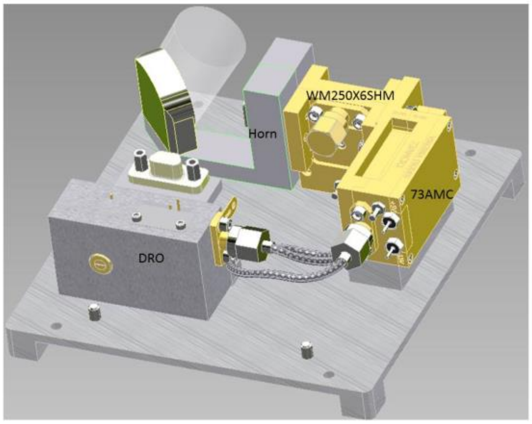

Fig. 2 Model of the 874-GHz IceCube MLA 10 cm x 10 cm science plate.

The block diagram of the MLA is shown in Fig. 1. The model of the MLA on the IceCube science plate is shown in Fig. 2. The 24.278 GHz DRO is procured from Lucix Corporation and runs off a single +5V supply requiring only 55mA bias current. The 73 GHz active tripler module (73AMC, photo shown in Fig. 3) contains a commercial MMIC amplifier at the DRO frequency followed by a WR-13 tripler of VDI design followed by a MMIC E-band amplifier provided by BAE Systems. The 73AMC is powered from a single +5V supply requiring less than 300 mA bias current. The -15V input to the 73AMC acts as an enable for the power amplifier bias, ensuring that RF power is not applied to the subsequent varactor multipliers in the absence of varactor bias. The E-band MMIC amplifier in the 73AMC provides +20 dBm output power at 0 dBm input. The varactor multiplier and mixer module (WM250X6SHM, photo shown in Fig. 4) contains a VDI-designed varactor doubler, varactor tripler, and second-harmonic mixer with a WM-250 (WR-1.0) interface to the horn antenna to be installed by NASA. The varactor multipliers were developed under a successful NASA Phase 2 SBIR ("High Reliability Oscillators for Terahertz Systems") and allow for 100 mW at 72.8 GHz to optimally pump a 874 GHz second-harmonic Schottky mixer. The 146 GHz varactor doubler and 437 GHz varactor tripler have respective efficiencies of approximately 35% and 8%. The IF amplifiers and baseband processing are on a plate above the mixer and LO plate, not shown here.

III. Measurements and Reliability

The WM250X6SHM module is currently in assembly and measurements of this module along with the entire MLA will be presented at the conference. The expected DSB noise temperature, based on previous VDI second-harmonic mixers in this frequency range, is approximately 3000K with 12 dB conversion loss.

Fig. 3 Photograph of 73AMC active tripler module.

Fig. 4 Photograph of WM250X6SHM varactor multiplier and mixer module.

The MLA is required to survive over a -30C to +65C temperature range and is required to meet all specifications over a 20-30C operating range. It is additionally desired that the MLA function with reduced sensitivity over an extended 10-40C range. Initial testing will be performed on a temperature plate over the full 10-40C range to determine the performance over the full extended range. Modifications may then be made to improve sensitivity over the extended range at the expense of optimum performance at standard temperature. This performance versus temperature data will be presented at the conference.

Bellcore thermal cycling tests are also being performed on all modules to optimize reliability. This subjects each module to 500 2-hour cycles over a -40C to +70C range. Results from these tests will also be presented at the conference.

Acknowledgment

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References

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