A 320-360 GHz Sub-Harmonically Pumped Image-Rejection Mixer for Earth Observation Applications

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***Abstract*— We report on the development of a 320–360 GHz Sub-Harmonically pumped Image-Rejection Mixer (SHIRM). The device incorporates two anti-parallel pairs of planar Schottky diodes flip-chip mounted onto a single quartz-based microstrip circuit. Measurements provide a best SSB receiver noise temperature of 3300 K and a side-band ratio between 7.2-23.2 dB over the RF bandwidth. This is the first time that the operation of a Schottky diode-based image-rejection mixer has been demonstrated at these frequencies.**

I. Introduction And Background

PASSIVE millimeter-wave limb-sounding from space-borne platforms provides a unique set of observational characteristics of planetary atmospheres. The region of the electromagnetic spectrum sometimes referred to as the Terahertz Gap (0.3–3 THz) is rich in rotational and vibrational molecular states creating spectral signatures of key molecular species. Sounding in the 300 GHz spectral region permits upper tropospheric and lower stratospheric observations to be made in the presence of cloud and in the absence of sunlight.

Due to narrow spectral signatures and low-level quantities of some molecular species, the retrieval process is simplified by performing single side-band (SSB) observations. This can be achieved through a number of techniques. A common method employs a double side-band (DSB) mixer preceeded by a quasi-optical image-rejection filter. A second method employs two DSB mixers with quadrature hybrid components to separate the side-bands. The latter method offers the advantage of rejection at low IF frequencies and broad instantaneous IF bandwidth.

Side-band separating mixers using quadrature techniques have been developed for most of the ALMA bands[1]. These receivers, developed for ground-based astronomy, use SIS devices and operate at cryogenic temperatures. For space-borne Earth Observation missions, cooling receivers to cryogenic temperatures is undesirable leading to an increase in mission complexity and cost. These issues have provided motivation for the development of a Sub-Harmonically pumped Image-Rejection Mixer (SHIRM) using planar Schottky diode technology for operation at ambient temperature. A candidate instrument for the SHIRM is the STEAM-R concept[2], proposed to ESA as part of the PREMIER Earth Explorer mission.

II. SHIRM Architecture And Design

The SHIRM architecture, illustrated in Fig.1, features two DSB sub-harmonic mixers. Coupling to the mixers is provided in-phase for the RF signals and with a 45° phase offset for the LO signals. A 3-port divider is used to split the incoming RF signal; and a quadrature hybrid followed by a stub-loaded 45° phase shifter is used to split and provide the required phase offset in the LO chain. This method provides the required isolation between the LO outputs to enable device optimization. The IF outputs from the mixers are recombined in a connectorized quadrature hybrid, thus completing the image rejection process. The IF bandwidth of the device is governed by the bandwidth of the IF hybrids (from Krytar^{TM}).

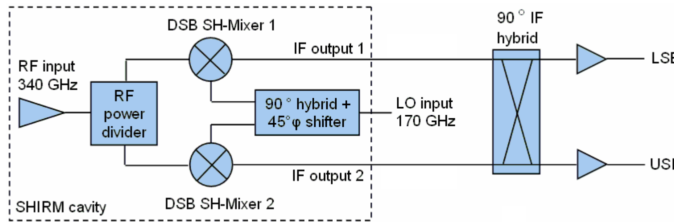

Figure 1: Schematic diagram of the SHIRM. The components in the dotted box are integrated in a micro-machined block.

An internal view of the SHIRM micro-machined block is shown in Fig. 2. The device consists of two anti-parallel pairs of planar Schottky diodes flip-chip mounted onto a single quartz-based microstrip circuit. Each mixer sub-circuit is IF/DC grounded at the centre of the single substrate, with the IF output of both mixers coupled via its endings. The LO WR-05 45° phase shifter is based on previous designs of a quadrature hybrid[3] and stub-loaded phase shifter[4].

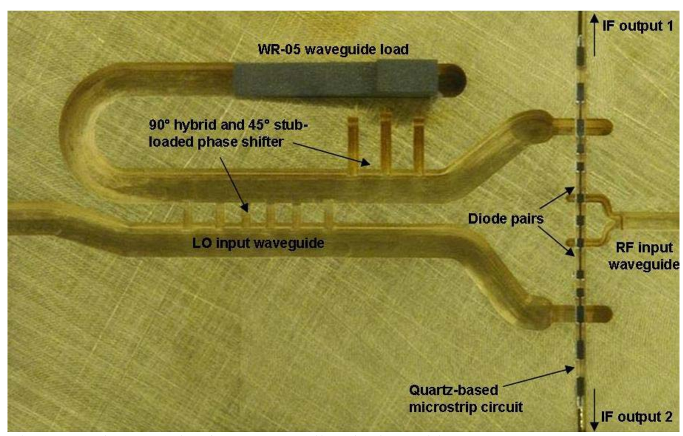

Figure 2: Photograph of SHIRM Split-Block Architecture

Circuit design and optimization were performed using three-dimensional electromagnetic and linear/non-linear circuit co-simulation. The circuit was optimized for best image rejection and lowest conversion losses over an RF bandwidth of 320-360 GHz. Average SSB conversion losses of approx. 9 dB and side-band ratio better than 20 dB are predicted.

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III. Manufacture and Test

Two anti-parallel pairs of planar Schottky diodes fabricated at RAL[5] were selected on the basis of similar DC characteristics, flip-chip mounted and soldered to the quartz-based microstrip transmission line. The line is then inverted-suspended into the waveguide channel as previously described[6]. A WR-05 waveguide load scaled from a previous design[7], machined from MF116 Eccosorb material[8], is inserted into the isolated port of the quadrature hybrid. The assembled SHIRM block, shown in Fig. 3, includes an integrated diagonal horn. The dimensions are approx. 20 mm × 20 mm × 25 mm.

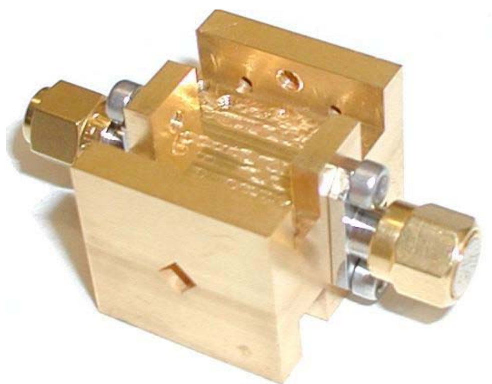

Figure 3: Photograph of the assembled SHIRM Block

The SSB receiver noise temperature and side-band ratio were measured for two IF bandwidths: 2-8 GHz and 6-14 GHz, according to a previously devised method[9]. The IF chains consisted of amplification and IF band filtering, and included isolators in each path. The noise figures of the IF chains were 0.94 dB (2-8 GHz) and 1.64 dB (6-14 GHz). The LO source for the SHIRM comprises a Gunn diode oscillator followed by an isolator, a rotary vane attenuator and a 166 GHz VDI frequency doubler (Ref D154)[10]. A Y-factor measurement was undertaken to determine the receiver noise temperature, then a spectral line was injected into the SHIRM and tuned inside the RF bandwidth. The line is provided by a photo-mixer developed at RAL[11]. The output IF signal is observed on a spectrum analyzer with a resolution bandwidth of 300 kHz and a sample averaging of 50.

Test results of the sideband ratio are presented in Fig. 4 for three different LO frequencies covering the complete RF bandwidth. For IF=2-8 GHz the sideband rejection varies between 7.2-23.0 dB with a SSB receiver noise temperature <3800 K (best 3300 K). For IF=6-14 GHz the sideband rejection varies between 10.3-23.2 dB with a SSB receiver noise temperature <5000 K (best 3900 K). The LO power required to pump the SHIRM varies between 6.6-15 mW for the different LO frequencies.

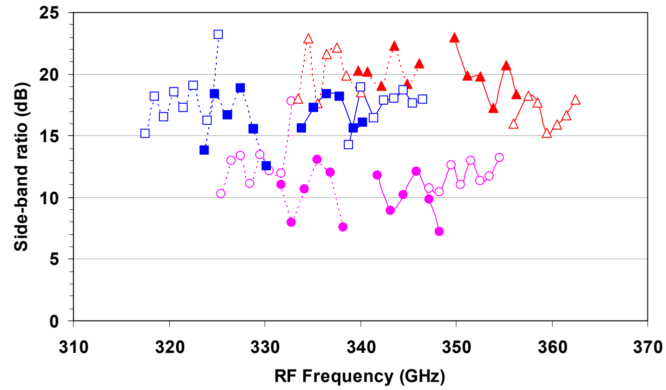

Fig. 4: Measured side-band ratio performance of the SHIRM as a function of RF frequency. Full dots: IF=2-8 GHz, empty dots: IF=6-14 GHz. Dotted lines: LSB, Continuous lines: USB. Blue trace: LO=166 GHz, Pink trace: LO=170 GHz, Red trace: LO=174 GHz

IV. Conclusions

The development and performance of a 320-360 GHz sub-harmonically pumped image-rejection mixer using planar Schottky diodes is presented. The work demonstrates the suitability of this device for future Earth observation instrumentation requiring SSB operation. Further developments are planned to improve the integration of the SHIRM into arrays of receivers.

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