An All Solid-State 640 GHz Subharmonic Mixer

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ABSTRACT

This paper reports on the first all solid-state two-diode subharmonically pumped (SHP) mixer operating at 640 GHz. The required local oscillator (LO) power is less than 4 mW at 320 GHz for optimum performance. Two approaches are used to generate the required LO power. The first approach utilizes a 107 GHz InP Gunn diode followed by a whisker-contacted tripler while the second employs an IMPATT diode at 80 GHz followed by two planar diode frequency doublers. The best measured mixer noise temperature is 2500K double sideband with a conversion loss of 9 dB at an IF of 2 GHz. An IF-frequency scan of the mixer shows a noise temperature of no worse than 3700 K across the 1.5 to 15 GHz band. Extraneous LO noise from the IMPATT is not evident for the SHP mixer, even at those frequencies and with low IF's. This performance represents the state-of-the-art for room temperature subharmonic mixers operating at these frequencies. The mixers are being developed for NASA's Mission to Planet Earth.

I. INTRODUCTION

The subharmonically pumped antiparallel-pair Schottky diode mixer [1-4] is a versatile down-converter concept that has a number of practical advantages over its single diode fundamental mixer counterpart. For submillimeter-wave applications where local oscillator (LO) power is scarce the fact that the required LO frequency is one half the signal frequency is a great advantage. Also, for applications requiring wide IF bandwidths, the approximately 100 ohm IF output impedance of the SHP mixer makes amplifier matching much easier. The Earth Observing System-Microwave Limb Sounder (EOS-MLS) platform to be launched early next century for ozone monitoring has baselined subharmonic mixers for its 190, 240 and 640 GHz channels. One drawback of the SHP mixer is that the antiparallel-pair diodes must be pumped at substantially higher LO power levels unless separate bias for each device can be provided [5]. To date, two diode SHP mixers at 600 GHz have relied on bulky BWO power sources for their LO [6]. In this paper we report the first demonstration of optimum SHP mixers at 640 GHz with excellent noise performance and requiring less than 4 mW of LO power. This LO power reduction has enabled us to utilize solid state sources for the first time.

II. PLANAR SCHOTTKY DIODE MIXERS

The 640 GHz Schottky diode mixers are based on technology that has been described previously [6,7,8]. The fabrication procedure involves T-anode Ti/Pt/Au Schottky anodes and a surface channel etch [9] to isolate the two devices in the pair. Fig. 1 shows the diode configuration.

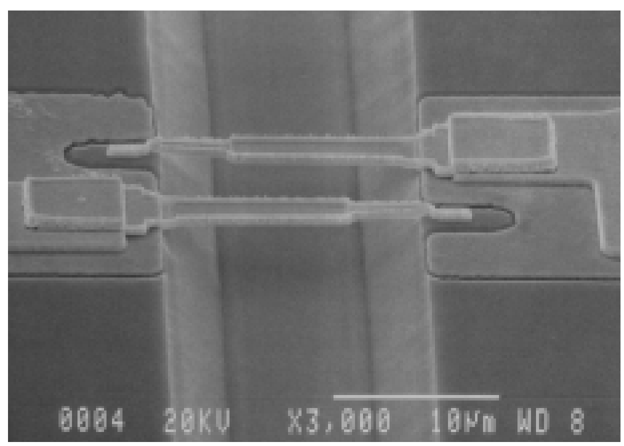

Figure 1: A SEM of the antiparallel pair Schottky diodes after the isolation etch.

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Once the top side processing is completed QUID (Quartz-substrate Up-side-down Integrated Device) technology is used to mount the chips up-side-down on a 50 micron thick quartz substrate. The GaAs substrate is then completely etched away everywhere except for a small region around the active devices. After the backside process, individual circuits are diced and glued into a microstrip housing in the waveguide block. Two wire bonds to the circuit metalization provide a DC return on one side of the diodes and an IF output line to a standard K-connector bead on the other. The 640 GHz circuits are about 100 microns wide by 2500 microns long.

The 640 GHz waveguide mixer mount uses a traditional crossed-guide split-block configuration with the local oscillator waveguide perpendicular to the signal guide and electrically coupled via a shielded quartz microstrip. Hammerhead filter elements are used for frequency separation and matching. A more detailed description of the block that was used at 215 GHz has been reported elsewhere [7]. The waveguide block used for the 640 GHz work is a scaled version of the 215 GHz design with some minor modifications to the input signal port and LO and IF filter structures.

Earlier work at these frequencies required LO power of more than 30 mW for optimum mixer performance. By utilizing a number of technologies described in [6-8] we have been able to reduce the power requirements to below 4 mW at 320 GHz and below 2mW at 120 GHz. This has enabled us to use, for the first time, solid-state LO sources.

III. SOLID STATE 320 GHz SOURCES

Two approaches have been utilized to obtain the required power at 320 GHz to drive the mixers. The first approach is based on using a custom designed 107 GHz high power InP Gunn diode followed by a whisker contacted varactor tripler [10]. The Gunn diode technology has been described in [11] while a similar tripler has been described in [12]. A picture of this source connected to the mixer block is shown in Fig. 2. The measured output power at 322 GHz from this source is shown in Figure 3. The output was measured on a WR-5 Anritsu power sensor calibrated using a calorimeter [13]. A straight WR-3 waveguide is used to connect to the mixer block which adds about 0.9 dB of extra insertion loss.

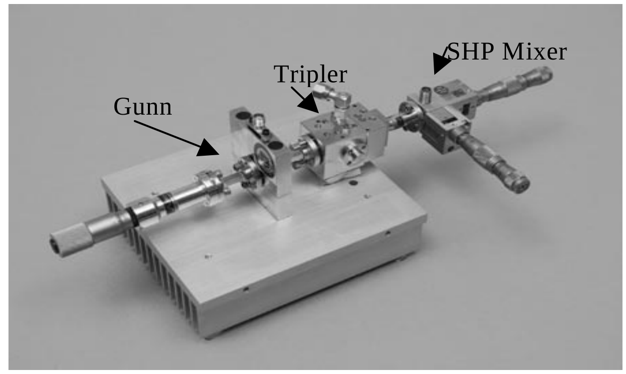

Figure 2: A picture of the 107 GHz Gunn diode oscillator followed by the tripler block and the subharmonic mixer.

The second LO approach involves the use of a Si IMPATT source at 80 GHz (commercially available) followed by a first stage doubler to 160 GHz and a second stage doubler to 320 GHz. Both doublers use planar varactor diodes and their designs and technology have been described in [14,15]. The picture of the source and mixer is shown in Fig. 4 while the measured output power is shown in Fig. 5 as a function of input power.

The output power of the IMPATT source is more than sufficient to drive the first doubler stage and thus an attenuator is used to control the input power to the doubler. Again the output power is measured both with an Anritsu power head and cross compared to a calorimeter [13].

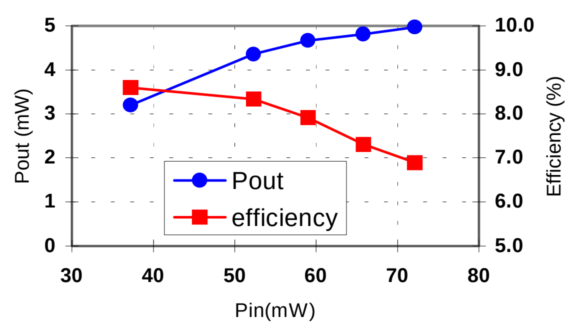

Figure 3: Measured output at 322.1 GHz from the Gunn based LO source. Maximum available power from the Gunn diode is around 100 mW. The tripler was biased at -5.4 V and drew 1.8 mA. The Gunn diode was biased at 5.4 V and 900 mA.

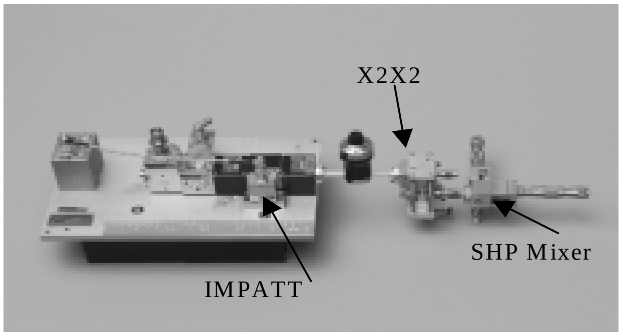

Figure 4: The Si IMPATT is part of the LO circuit that includes Gunn diode injection for phase locking. The input power to the first doubler is controlled via the attenuator.

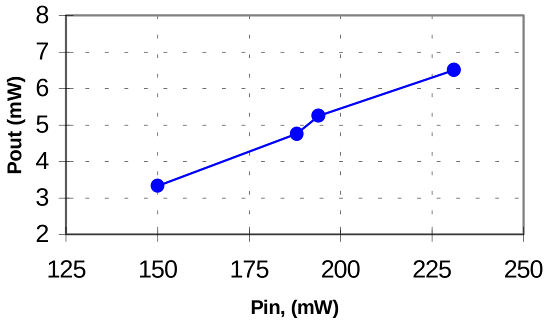

Figure 5: Output power at 320 GHz from the planar diode x2x2 circuit as a function of the input power to the first doubler. The IMPATT is biased at 28 V and 460 mA, the first doubler is biased around 12.5 V and the second doubler is self-biased via a zener diode.

IV. MIXER PERFORMANCE

The Schottky diode pair used for the SHP mixer has an ideality factor of about 1.2 and a series resistance of 8.5 ohms (same for both diodes). The total capacitance of the QUID structure is about 9-10 fF. Each junction is assumed to have a capacitance of about 2 fF and the remaining capacitance is attributed to parasitics. Fig. 6 shows the measured IF bandwidth of the mixer when used with the InP Gunn and tripler source. The measured input power at the mixer port is about 3.4 mW, verified with a calorimeter, an Anritsu power sensor and a Dorado power sensor. The mixer is tuned for optimum performance at 1.5 GHz. The LO frequency is 321 GHz.

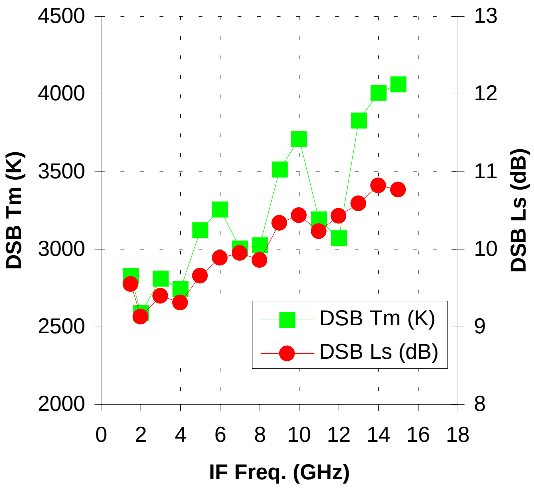

Figure 6: QUID diode mixer performance with the InP Gunn and tripler source.

The performance of the same mixer with the Si IMPATT source followed by the two doublers is shown in Fig. 7. The LO frequency in this case is 320 GHz. The measured input power at the mixer port is between 3.5-3.8 mW. It is believed that the slight improvement observed in this particular configuration is due to the slightly higher available LO power. Note that the LO noise normally associated with IMPATT diodes is not a problem (even at 640 GHz) for these SHP mixers [3,7].

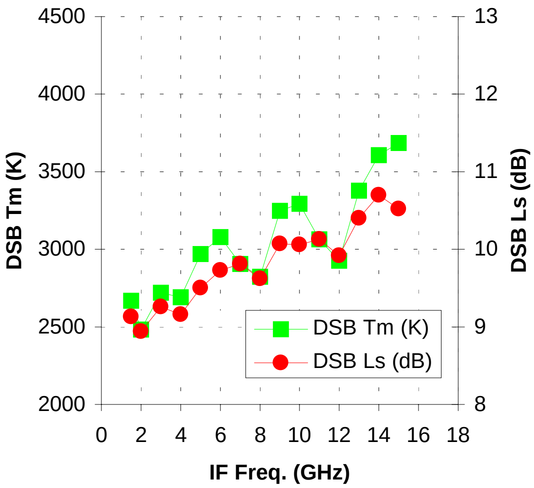

Figure 7: QUID diode mixer performance with the Si IMPATT diode and x2x2 source.

V. CONCLUSION

The SHP mixer performance reported in this paper presents state-of-the-art both in noise temperature and LO power requirements for room temperature Schottky diode mixers. The performance of fundamental mixers at similar frequencies is better [16], however, the bandwidth is more limited and an implementation with all planar devices in the LO chain has not yet been demonstrated. It is worth emphasizing that the results shown in Fig. 7 are based on using planar devices both for the varactor multipliers and the mixer, thus enhancing reliability for space applications. The excellent mixer performance and low LO power required can be attributed to low parasitic devices and low loss waveguide circuitry. The LO noise rejection inherent in the SHP mixer is now demonstrated at 640 GHz.

VI. ACKNOWLEDGMENT

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Authors would like to acknowledge the support of Suzi Martin and Jeff Hong (devices) and Pete Bruneau (mixer block fabrication) all of the Jet Propulsion Laboratory.

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