PLANAR SCHOTTKY TECHNOLOGY FOR SUBMILLIMETER WAVE RADIOMETRIC APPLICATIONS

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***Abstract*-**Planar Schottky diodes have been the workhorse of room temperature mixers and LO power generation for the past two decades. Continuous progress in semiconductor processing, EM software tools and rpm machining has contributed to push the performance of the technology into the THz regime. This paper highlights the current status of the planar Schottky technology for radiometric applications in the submillimeter wave range.
***Keywords*:** Schottky diode, radiometer front-end, terahertz, planar technology.

INTRODUCTION

For many decades the THz range of the electromagnetic frequency spectrum has been receiving considerable interest from astronomers and planetary scientists. More recently, the advances in THz technology have opened doors to a vast range of ground-based opportunities and applications such as plasma fusion diagnostics, gas spectroscopy, medical imaging, security [1] The most common technologies used to produce receivers in the THz range are the hot electron bolometer (HEB) [2], the superconductor-insulator-superconductor (SIS) receiver [3] and the Schottky diode receiver. Both HEB and SIS receivers exhibit extremely high sensitivity but require cooling at liquid helium temperatures, increasing complexity and cost. Schottky diodes receivers show acceptable performance at room temperature and are ideal candidates for spaceborne applications. The current status of Schottky technology for radiometric applications in the submillimeter range is explored in the current paper.

THZ SCHOTTKY TECHNOLOGY

GaAs Schottky diode is one of the fastest semiconductor devices known at present due to the absence of minority carriers, high electron mobility and the simplicity of the structure. The early instances of Schottky diodes were relying on the so-called whisker-contacted honey comb structure [4], which presents the advantage of extremely small junction capacitance and parasitics and suitability for applications up to a few THz [5]. However, mixers based on whisker-contacted diodes depend on complex assembly procedures, mechanical reliability issues and limited IF bandwidth, which is why planar Schottky diodes have received considerable interest over the past two decades. Continuous progresses in semiconductor processing combined with advances in EM software and rpm machining accuracy has enabled American research groups such as the Jet Propulsion Laboratory and the University of Virginia to demonstrate excellent performance of planar diodes in the THz range [6-7]. Figure 1 presents a schematic of a typical THz Schottky diode. The main technological features required for submillimeter operation include air-bridge fingers for lower fringing fields around the anode, use of e-beam lithography to reduce the anode diameter below 1 μm, etching of the GaAs substrate thickness down to a few microns (membrane) to prevent the propagation of modes in the substrate itself and monolithic integration of the diode with the embedding circuit.

In Europe some significant advances have been recently performed by several research institutes. Interestingly, the three main European actors (namely, Rutherford Appleton Laboratory, UK [8], Tyndall National Institute, Ireland [9], and Advanced Semiconductor Tech-

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nologies, Germany [10]) in the field have contributed to develop unique structures with specific advantages in terms of parasitic reduction, integration level, ease of fabrication and heat dissipation.

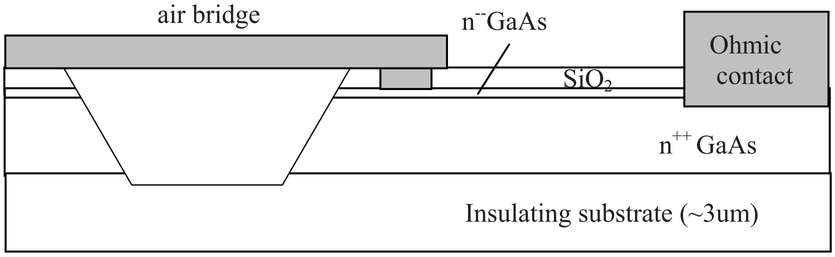

Figure 1: Schematic representation of the planar Schottky diode used at THz frequencies.

MIXER PERFORMANCE

Radiometric applications requiring high spectral resolution heavily rely on heterodyne mixing and IF amplification. The mixer and the local oscillator (LO) source are therefore key elements of heterodyne receiver front-ends. Both fundamental [11-12] and subharmonic [13] Schottky mixers have been demonstrated with good performance in the submillimeter range.

Figure 2a presents a compilation of measured double side band noise temperatures of (sub)millimetre planar Schottky mixers (collected from recently published data). The noise temperature increases with frequency at a rate that is found to be 50 times higher than the quantum limit of mixer noise (=hf/k), which is, respectively, 5 and 25 times more than for cryogenic HEB and SIS receivers [14]. However it is worth noting that this value is lower than the one reported in [15] (i.e, 87.5), which was based on the best submillimeter Schottky mixer results available in the early nineties. This improvement outlines the continuous progress that has been achieved over the past two decades in the design and fabrication of Schottky THz mixers.

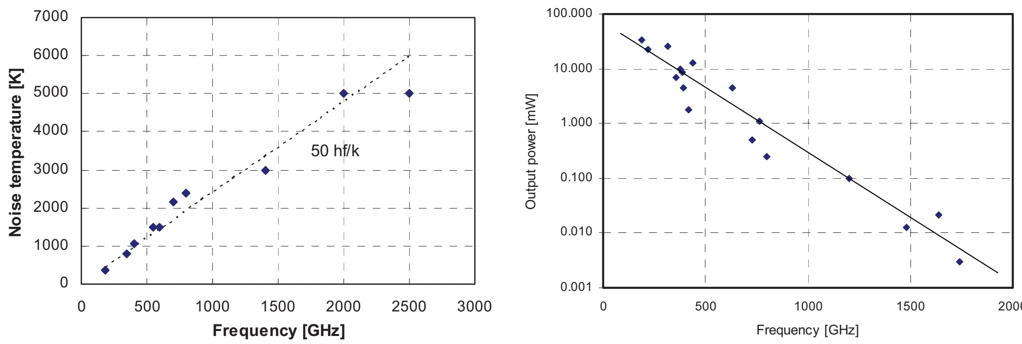

Figure 2: (a) Mixer DSB noise temperature of Schottky planar mixers and (b) output power of Schottky planar multipliers vs frequency (published data).

SOLID STATE LO SOURCE

The other key element of the front end is the LO source. Chains based on solid state amplifiers and Schottky multipliers are preferred over conventional sources in the submillimeter such as backward wave oscillator and far infrared lasers, which are bulky and have limitations in terms of signal purity and bandwidth [16]. Figure 2b outlines the output power performance achieved by planar Schottky multipliers. It is estimated that 1 mW at 1 THz of output power is required to drive a THz planar Schottky mixer [17], which has not been achieved yet. However, the persisting improvement in the performance of Ka and W band power amplifiers (it is now possible to drive initial stage multipliers with hundreds of mW in the W band) will continue to push upwards the level of power produced by THz solid state multiplier chains.

Conclusion

Planar Schottky devices are the workhorse of heterodyne receivers operating at room temperature. The continuous improvement achieved in semiconductor processing, EM software tools and rpm milling machine has now enabled research groups to demonstrate functional planar Schottky mixers in the THz range. Solid state sources based on Schottky multipliers still require further development to produce enough power to drive THz Schottky mixers but benefit from the continuous improvement in the performance of Ka and W band power amplifiers.

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