Broadband Frequency Triplers for Radar Applications in the THz Range

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***Abstract*—We report the design and characterization of Schottky diode-based frequency triplers at 75-105 GHz and 225-315 GHz for the development of frequency multiplied signal sources to be used in a space-borne radar prototype for orbital debris detection at 94 GHz, a ground-based cloud profiling radar at 94 GHz, and a 3-D imaging radar at 300 GHz. The frequency triplers are designed with the aim of optimizing the bandwidth and conversion efficiency for a wide range of input powers, allowing the configuration of versatile sources able to fulfill the bandwidth and power requirements of diverse applications. For the 75-105 GHz frequency tripler, the measured room-temperature conversion efficiency is over 5% between 75 GHz and 102 GHz and over 8% across the 87-99 GHz band for an input power of 100 mW. For the 225-315 GHz frequency tripler, measurements across the 252-303 GHz band show a room-temperature conversion efficiency above 3% for an input power of 100 mW.**

I. Introduction

Millimeter-wave radars are being developed at the Universidad Politécnica de Madrid for diverse applications: A space-borne orbital debris radar at 94 GHz [1], a ground-based cloud profiling radar at 94 GHz [2-3], and a 3-D high-resolution imaging radar at 300 GHz [4]. In all these systems, the transmitted signal is generated by direct digital synthesis and several stages of frequency multiplication and power amplification. This work focuses on the design and characterization of two frequency triplers at 75-105 GHz and 225-315 GHz based on Schottky diodes for the transmitter chains of these radars.

Since self-heating is a significant limiting factor for the performance of high-power millimeter-wave frequency multipliers, the design procedure focuses on thermal management. Section II describes the design methodology, where an analytical electro-thermal model implemented into commercial circuit simulation software has been added to the design methodology presented in [5]. Section III displays the design and characterization of the 75-105 GHz frequency tripler, whereas Section IV presents the design and characterization of the 225-315 GHz.

II. Design Methodology

A physics-based numerical self-consistent electro-thermal model is developed to optimize the Schottky diode electrical and geometrical parameters together with the multiplier circuit performance from a joint electrical and thermal point of view [6]. For the purpose of improving the power handling capability, the multiplier circuit layouts are optimized via 3-D thermal modeling to maintain low operating temperatures. To complement the numerical approach, an analytical electro-thermal model is implemented into Keysight ADS to optimize the overall multiplier circuit performance accounting for the thermal effects. Fig. 1 shows the iterative design process, which can be divided into three steps [5]. The incorporation of thermal aspects into the design procedure provides an integrated thermal management approach that allows optimizing the device and circuit performance and designing for reliability.

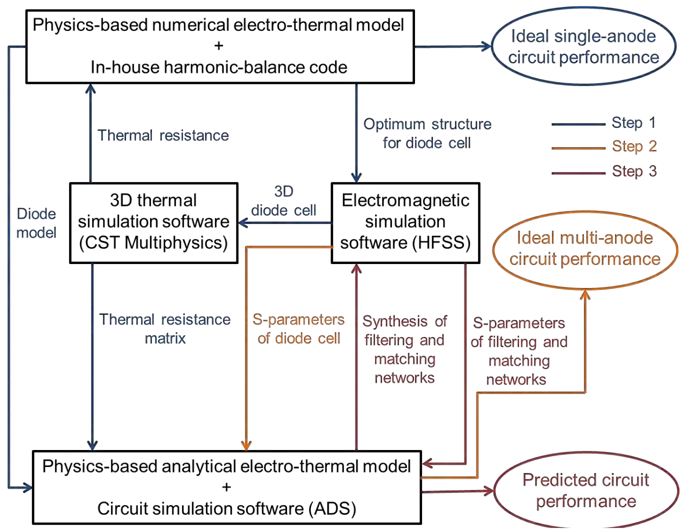

Fig. 1. Iterative design process utilized to optimize circuit performance.

III. Design and Characterization of a 75-105 GHz Frequency Tripler

For the 75-105 GHz frequency tripler, the predicted room-temperature conversion efficiency is over 9% across the 87-102 GHz band for an input power of 100 mW, with a peak efficiency above 12% at 99 GHz.

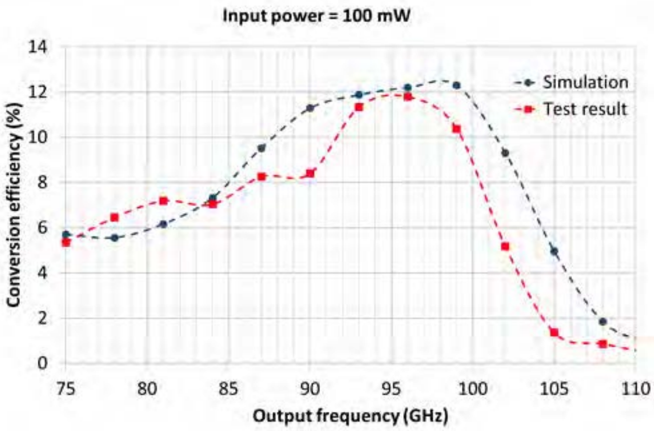

Fig. 2. 75-105 GHz frequency tripler: Conversion efficiency as a function of output frequency for an input power of 100 mW.

The designed frequency tripler is fabricated and assembled by Teratech Components Ltd. (UK) and uses a discrete GaAs diode chip with six planar Schottky varactors in a series configuration. The measured room-temperature conversion efficiency is over 5% between 75 GHz and 102 GHz and over 8% across the 87-99 GHz band for an input power of 100 mW (Fig. 2).

IV. Design and Characterization of a 225-315 GHz Frequency Tripler

For the 225-315 GHz frequency tripler, the simulated room-temperature conversion efficiency is over 3% across the 246-306 GHz band for an input power of 100 mW, with a peak efficiency of 4.5% at 294 GHz.

The designed frequency tripler is fabricated and assembled by Teratech Components Ltd. (UK) and features four anodes integrated into a GaAs membrane. Measurements across the 252-303 GHz band show a room-temperature conversion efficiency above 3% for an input power of 100 mW (Fig. 3).

Conclusions

Two broadband frequency triplers at 75-105 GHz and 225-315 GHz for radar applications have been designed and characterized. The incorporation of thermal aspects into the design procedure provides an integrated thermal management approach that allows optimizing the device and circuit performance and designing for reliability.

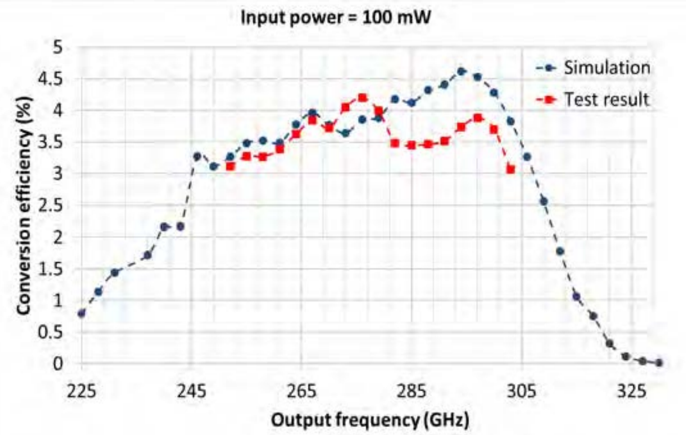

Fig. 3. 225-315 GHz frequency tripler: Conversion efficiency as a function of output frequency for an input power of 100 mW.

Acknowledgment

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