Broadband Microfabricated Waveguide Terminations for Low-power Applications at Terahertz Frequencies

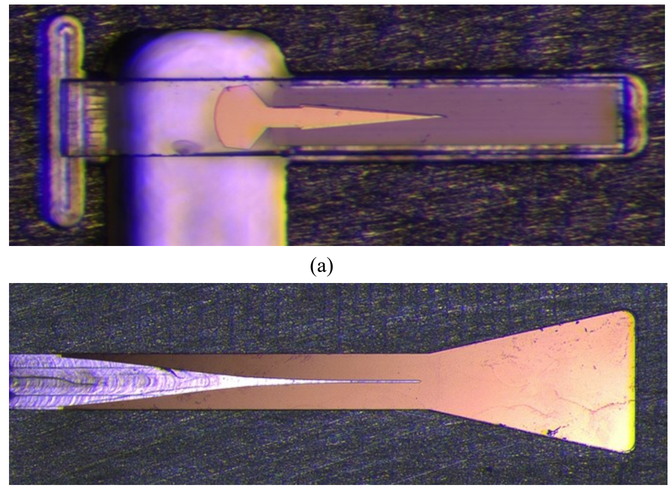
Karl Birkir Flosason, Cristian López*, Denis Meledin, Leif Helldner, Sven-Erik -Ferm, Victor Belitsky and Vincent Desmaris

***Abstract*— We present the design of broadband microfabricated waveguide terminations, for prospective use as drop-in components in waveguide blocks. Two types of terminations were designed and characterized using frequency extension modules. The first type of termination is based on quartz substrate, employing an E-probe to couple to a waveguide and on-substrate Ti-N alloy resistive absorber integrated with broadband tuning circuitry, exhibiting a return loss better than 20 dB over the 260-370 GHz frequency range. The second type of load features a finline to slot-line transition made of a 30 µm thick Si membrane covered with high resistivity Ti-N alloy. This termination exhibits a measured return loss better than 20 dB at all frequencies in the 200-380 GHz band.**

***Keywords*—Microfabrication, termination, waveguides, Terahertz.**

I. Introduction

Waveguide terminations are an important component used in, e.g., power combining waveguide circuits with 3-dB hybrids, directional couplers for LO injection, etc. The terminations load the idle port of such hybrids or directional couplers and absorb unwanted signals [1]. In receiver systems based on 2SB mixers, having high-quality terminations has been shown to be crucial to the mixers' sideband rejection performance [2]. The traditionally used of absorbing material, e.g. Eccosorb™ [3], becomes difficult to machine at high frequencies because o very small dimensions and the material performance at cryogenic temperature is not accurately known. Furthermore, distributed loads [4] require a bigger space for longer waveguides that make the mixer block bulkier and additionally complicates the fabrication of the mixer block by requiring special RF absorbing coating, e.g., high resistivity Titanium film on the milled structures, along with conventional gold plating. The matched loads in the instrumentation applications are exposed to quite low power and thus could be engineered without special considerations for heatsinks. In addition, with a specific design of the loads, the performance of the waveguide terminations becomes predictable and reliable even at cryogenic temperatures. In this paper, we present 2 novel wideband waveguide terminations, Fig. 1, based on chips with E-probe and finline designs. These drop-in chips can be easily integrated into existing systems, achieving return loss levels of better than 20dB over the designed frequency range.



(a)

(b)

Fig.1 Fabricated Waveguide terminations. (a) E-probe chip. (b) Finline based load. The waveguide dimension are 380 µm x760 µm.

II. Termination Design and Simulation

The proposed waveguide terminations were designed and optimized in Ansys HFSS employing realistic parameters for the materials.

The first waveguide load is designed to cover the frequency range 260-370 GHz. The design employs a quartz substrate and resembles a mixer chip, comprising an E-probe to couple the power from the waveguide. Moreover, it includes a simple matching microstrip circuitry made of Gold, and a thin film absorber based on Ti-N alloy, with resistivity 30 Ω/□.

In order to achieve a broader bandwidth, 210-380 GHz, the second type of termination employs a waveguide to slotline transition using a finline profile described in [5]. The load is made off the 30 µm thick Si membrane covered with Ti-N alloy with a resistivity of 30 Ω/□. In Fig. 1 both types of loads are depicted.

All authors were with the Group for Advanced Receiver Development, Department of Space, Earth and Environmental Sciences, Chalmers University of Technology, Gothenburg, SE-41296, Sweden. *Corresponding author *Cristian Lopez, cristian.lopez@chalmers.se*.

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III. Results and Discussion

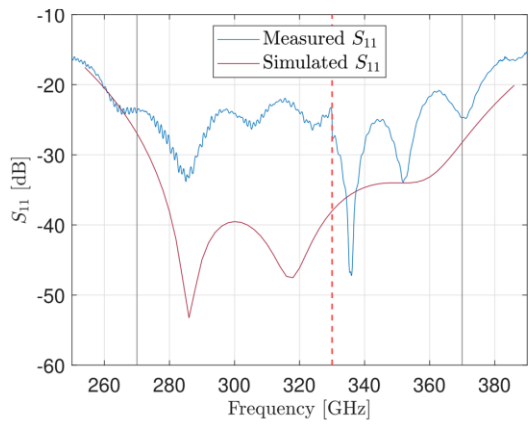
The designs were characterized using a Keysight PNA-X VNA and frequency extension modules. To cover the designed frequency range, two extension modules were employed: WR 3.4 (200-330 GHz) and WR2.2 (325-500 GHz). In both cases, a 1-port TRL calibration was performed. Additionally, waveguide adapters were used to accommodate the waveguide dimensions for each extension module. These adapters were de-embedded through post-processing.

Fig. 2 displays the simulated and measured performance for each termination. Since the measured return loss levels are below 20 dB for most of the band, small discrepancies in positioning could have a significant impact on the measured performance, particularly for the design based on E-probes, which are more sensitive to their position relative to the backshort. However, finlines are less sensitive to their position within the waveguide. In this case, the misalignment between the input waveguide and the extension modul also plays a role in performance, as demonstrated in Fig.2b, where a 30 µm misalignment is introduced in the simulation. The simulations shows a reasonable agreement with the measurement results.

From the graphs, it is clear that the E-probe waveguide load shows a return loss of better than 20 dB over the entire frequency band of 260-375 GHz. Meanwhile, the finline-based waveguide load outperforms the former with a return loss of better than 25 dB over a broader frequency range of 210-380 GHz.

IV. Conclusion

In this paper, we have presented the design, fabrication and characterization of two types of broadband microfabricated waveguide terminations for low-power applications at terahertz frequencies. The first design, based on an E-probe and Ti-N alloy resistive absorber, achieved a return loss better than 20 dB over 260-375 GHz. The second design, featuring a finline to slot-line transition on a Si membrane covered with Ti-N alloy, demonstrated superior performance with a return loss of 25 dB over a broader frequency range of 210-380 GHz. These results indicate that the proposed waveguide terminations are suitable for integration into existing systems, offering reliable and predictable performance even at cryogenic temperatures and with appropriate scaling to even higher frequencies.



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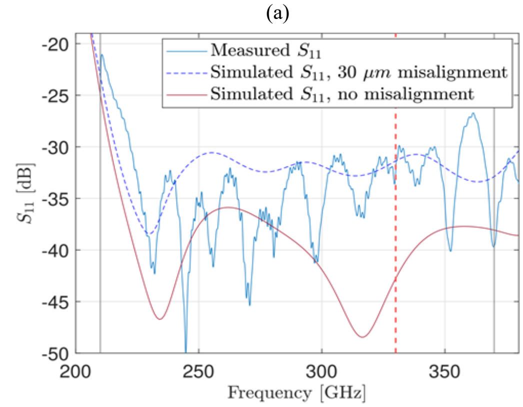

(b)

Fig.2 Simulated and measured performance of the waveguide terminations. (a) Simulated and measured performance for E-probe termination (b) Simulated and measured performance for finline based termination. A simulation with 30 µm misalignment beteween the upper and lower parts of the split-block is included.

References

[1] A. Gouda et al. “Millimeter-wave wideband waveguide power divider with improved isolation between output ports”, IEEE TST Science and Technology vol. 11, no. 4, pp. 686-693, Jul. 2021, doi:. 10.1109/TTHZ.2021.3078876

[2] A Khudchenko et al., “Efficiency of the Image Band Suppression in Sideband Separating SIS Receivers for Radio Astronomy”. In: *2020 7th All- Russian Microwave Conference (RMC)*. Nov. 2020, pp. 19–20. doi: 10.1109/RMC50626.2020.9312246.

[3] G.A. Ediss et al., “FTS measurements of Eccosorb MF112 at room temperature and 5 K from 300 GHz to 2.4 THz”. In: *ALMA memos* #273 (Sept. 1999).

[4] R. Hesper, et al., "A High-Performance 650-GHz Sideband-Separating Mixer—Design and Results," in IEEE TST and Technology, vol. 7, no. 6, pp. 686-693, Nov. 2017, doi: 10.1109/TTHZ.2017.2758270.

[5] C. López et al., “Waveguide-to-Substrate Transition Based on Unilateral Substrateless Finline Structure: Design, Fabrication, and Characterization”. In: IEEE *TST* (Nov. 2020), pp. 668–676. issn: 2156-3446. doi: 10.1109/TTHZ.2020.3020683

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