Terahertz On-wafer Metrology for Future Space Applications

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***Abstract*—This report discusses the research project conducted as part of a Ph.D. thesis and IEEE MTT-s fellowship to develop reliable calibration methods for on-wafer measurements in the WR 2.2 band. In this project, the design of the on-wafer calibration standards have been developed, fabricated and tested, while a new method for the assessment of on-wafer standards have been proposed.**

***Index Terms*—metrology, terahertz radiation**

I. INTRODUCTION

Accurate on-wafer measurement is essential for producing cost-efficient, high-quality integrated circuits for communications, electronics, security imaging, radio astronomy, and medical and healthcare applications. While advances have been made in developing THz and millimeter-wave circuits, metrology techniques still need to be developed. As a part of my Ph.D. thesis and the IEEE MTT-s fellowship, I have been researching reliable calibration methods for the on-wafer measurements in WR 2.2 band (330-500 GHz). In this report, I would like to highlight the results of the research project.

The theoretical models based on 12 (Thru-Reflect-Line, TRL) and 16 error terms (Line-Reflect-Reflect-Match) have been studied and compared with ADS and AWR software. This allowed designing the calibration standards for WR-2.2 in the HFSS software. The graduate fellowship helped me to have several research visits to the Chalmers University of Technology, where I gained experience in different aspects of microwave and THz technology and on-wafer measurements in general. Also, there I tested the devices which have been fabricated based on my simulations (Fig. 1). This experience allowed me to modify a similar experimental setup at Aalto University.

The obtained results allowed us to offer a method for calibration testing of the calibration structures based on numerical simulation and non-calibrated measurement data. This approach can also be extended to other passive two-port devices. The theory behind it is based on matrix similarity and tested both numerically and experimentally. The result has been presented at the International Conference on Infrared, Microwave, and Millimeter (THz) waves[1].

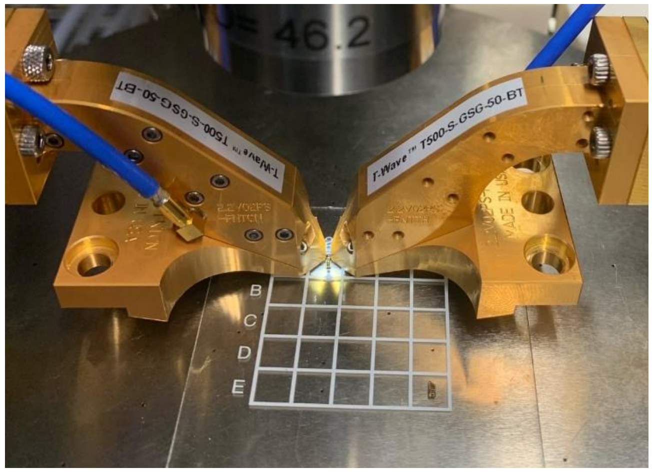

Figure 1. The on-wafer measurements of the calibration structures. Reprinted from [1] and the corresponding poster.

Nevertheless, further research within the project has shown that the coplanar waveguide design is not the best solution for terahertz applications, at least for those which require high precision. Combined with the required vias holes, this solution does not provide a single-mode propagation, and fabrication inaccuracy might lead to improper results. An alternative solution has been found in the microstrip-based calibration lines, and currently, we are working toward the calibration standards based on them. While they have been used for the TRL calibration at THz frequencies, the LRRM-16 version of such calibration standards has never been implemented. The LRRM-16 calibration algorithm will eliminate the error terms that cannot be tacked by the TRL one, so this task is currently on my agenda.

Working on this project was a very interesting journey. I want to continue my research in millimeter-wave technologies for space applications since there are plenty of things to be done. Outside of purely scientific results, managing a small research project and working in different environments helped me a lot to build my own network and get experience in different aspects of academic life. I would like to continue my research way in academia, doing a postdoc in one of the leading US universities, presumably on the cryogenic devices for microwave and millimeter-wave applications. After that, I would like to become a professor or a staff scientist at an academic institution.

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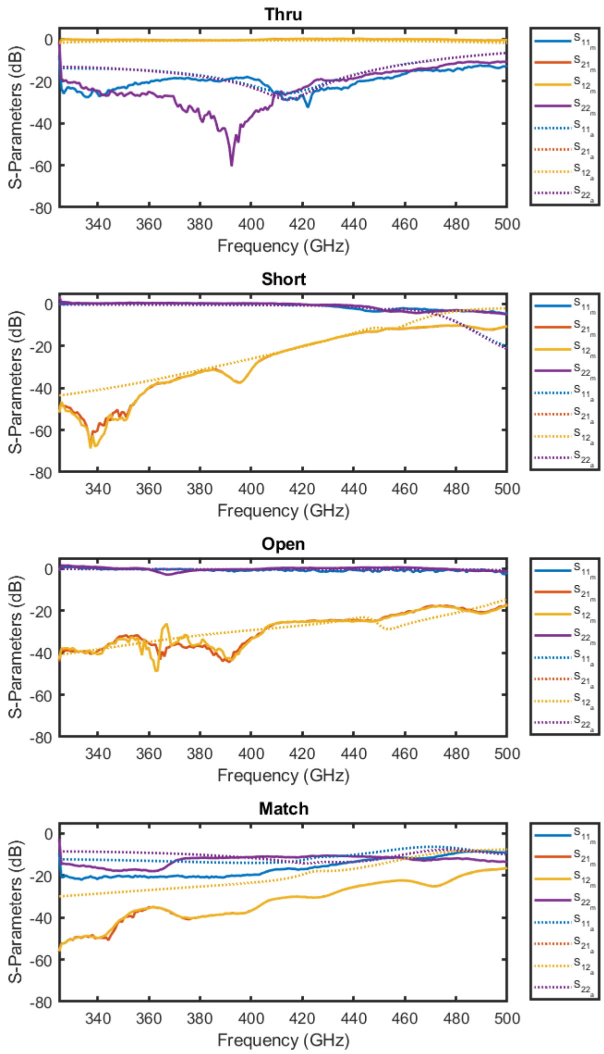

Figure 2. S-parameters for the actual (a) and measured (m) device performance . Reprinted from [1] and the corresponding poster.

REFERENCES

[1] M. Masyukov et al., "A calibration-free method to assess the quality of standards for THz on-wafer measurements," 2022 47th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), Delft, Netherlands, 2022, pp. 1-2, doi: 10.1109/IRMMW-THz50927.2022.9895704.