Project Report "Accuracy Improvement in Broadband Dielectric Measurements of Biological Liquids using Transmission Lines up to 110 GHz"

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I. Project Results

This report documents the temporary outcomes of the MTT-S (Microwave Theory and Techniques Society) graduate fellowship project "Accuracy Improvement in Broadband Dielectric Measurements of Biological Liquids using Transmission Lines up to 110 GHz". The MTT-S graduate fellowship consists of up 1000 USD of travel grant to IMS 2014 and 6000 USD of research funding.

Thanks to the fellowship, the author travelled to IMS 2014, Tampa, Florida, USA. During IMS 2014, the author attended relevant technique sessions and workshops, and had discussions with experts in the field. He also attended the women's in engineering, the young engineer event, and other cultural events. The author also made friends with attendees from other parts of the world. In general, IMS 2014 was a fruitful event for the author.

The proposed project was partly carried out in collaboration with Dr. James Booth from National Institute of Standards and Technology (NIST), Boulder, Colorado, USA. The visit to Dr. Booth's group took place right after the IMS 2014, i.e. at the end of August 2014, and finished at the end of February, 2015. Because of the visit, a large part of the graduate fellowship was kept at the university bank account still. During the visit, part of the funding (500 USD) was spent attending ARFTG 2014 conference [1]. At ARFTG 2014, the author presented a novel broadband microfluidic calibration techniques using reference liquids with unknown permittivity. During the visit to Dr. Booth group, the author has learned about microfluidic fabrication, broadband permittivity extraction using optimization and broadband series-resistor on-wafer calibration. The author also made contact with Dr. Dylan Williams which is an expert on on-wafer measurement and uncertainty analysis. With the help of Dr. Williams, the author made use of an uncertainty analysis software called NIST Microwave Uncertainty Framework to perform uncertainty calculation of the extracted complex permittivity. Based on Dr. Booth extraction techniques, the author has developed an improved measurement technique to extract the complex permittivity and permeability of any fluids from only two measurements. Summary of this new technique and the uncertainty analysis will be submitted to IEEE Transactions on Microwave Theory and Techniques [2].

During the visit, the author also made contribution to series-resistor calibration. The author has developed a method to extract the lumped circuit parameters of the impedance standards for series-resistor calibrations. Compared to the classical calibration comparison technique, the proposed method provides similar series-resistor calibration without the need of performing an additional calibration on a low-loss and dispersionless substrate. The summary of this work will also be submitted also to IEEE Transactions on Microwave Theory and Techniques [3] in the future.

Since the beginning of March, 2015. The author has been back in KULeuven, Belgium to further carry out the proposed project. The author has been involved in cleanroom fabrication of microwave-microfluidic devices and calibration structures for the application of accurate broadband complex permittivity measurement from 10 MHz to 110 GHz. As proposed in the project proposal, a large part of the fellowship will be spent on purchasing the masks and wafers and cleanroom hours. Presently, together with other PhD students, the author is finalizing the layout design and making the glass cover for the microfluidic devices to be fabricated.

Before the visit to NIST, USA, the author was applying for a travel grant from his home institute in Belgium. The MTT-S graduate fellowship was a strong evidence in proving the author's academia competence. During the visit in NIST, the author was exposed to research of a high level, which helped him made his decision to stay in the research field after his PhD.

In the end, the author would like to thank all the relevant people working to make this graduate fellowship possible. This fellowship has been a huge encouragement in the author's PhD research.

References

[1] S. Liu, I. Ocket, P. Barmuta, T. Markovic, A. Lewandowski, D. Schreurs, and B. Nauwelaers, "Broadband dielectric spectroscopy calibration using calibration liquids with unknown permittivity," *ARFTG conference*, pp. 1 – 5, 4 - 5, Dec, 2014.

[2] S. Liu, N. D. Orloff, C. Little, X. Lu, J. Booth, I. Ocket, D. Schreurs, and B. Nauwelaers, "Comparison of model parameter determination methods for series-resistor calibration on lossy silicon substrate," *IEEE Transactions on Microwave Theory and Techniques*, vol. xx, pp. xxx–xxx, to be submitted.

[3] ——, "Single-length method to measure dielectric and magnetic fluids in microfluidic channels," *IEEE Transactions on Microwave Theory and Techniques*, vol. xx, pp. xxx–xxx, to be submitted.

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