86th ARFTG Microwave Measurement Conference


# ARFTG 86th WORKSHOP

# Microwave Measurements with Applications to Bioengineering and Biomedicine

December 1-4, 2015

Atlanta, Georgia
Georgia Tech Hotel and Conference Center

86th ARFTG
Topic: *Microwave Measurements with Applications to Bioengineering and Biomedicine*
December 1-4, 2015, Atlanta, Georgia
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**Workshop Title: "Microwave Microfluidics"**

**Workshop Organizer**:
Name: James Booth
Affiliation: NIST Boulder
Email: james.booth@nist.gov

**Workshop Description**:
The interaction of electromagnetic fields with biological systems at microwave frequencies has been studied for more than a century. In general, such interactions can be quite complex, as the inhomogeneous nature of biological systems can make quantitative interpretations of microwave measurements quite challenging. The emergence of microfluidic approaches over the past decade has provided an excellent opportunity to employ accurate chip-scale measurements and calibrations to very small volumes of fluid samples that can be precisely located within planar microwave structures. This workshop explores recent developments at the intersection of microfluidics and microwave measurements, where the higher level of control of fluidic systems enables accurate manipulation and microwave measurements of fluid samples, such as single cells, cell suspensions, and biomolecules. Such measurements are demonstrating how microwave measurements can provide biologically relevant information, and hold the promise of rapid, sensitive, multiplexed, high-throughput electronic measurements of biological systems in the near future.

**Schedule** (Wednesday, Dec. 2nd, 2015):

- 13:20 – 13:25: Welcome
- 13:25 – 14:05: Song Liu, KU Leuven
- 14:05 – 14:45: James Hwang, Lehigh University
- 14:45 – 15:25: Pingshan Wang, Clemson University
- 15:25 – 15:40: Coffee Break
- 15:40 – 16:20: Katia Grenier, LAAS-CNRS
- 16:20 – 17:00: Jun-Chau Chien, University of California, Berkeley

**List of Speakers**

| **1. Speaker's Name: Song Liu** | **Confirmed: Yes** |
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| **Affiliation: KU Leuven** | |
| **Presentation Title: Permittivity Measurements Using Microwave Microfluidic Devices - Measurement Techniques and Uncertainty Analysis** | |
| **Email:** song.liu3000@gmail.com | |
| **Abstract:** Microwave microfluidic devices are promising tools for life sciences studies. They allow non-invasive and quantitative monitoring of fluid samples over an ultra broad bandwidth, i.e., from MHz to hundreds of GHz. This presentation discusses dielectric fluids measurement techniques based on transmission lines. An uncertainty analysis addresses the sources of errors, and it will be shown that different extraction techniques have to be selected for different frequency ranges. Other techniques to improve the measurement accuracy, or to reduce the measurement complexity will be discussed also. | |
| **Bio:** Song Liu is working towards a PhD degree in Div. ESAT-TELEMIC, KU Leuven, on millimeter wave biomedical applications. He has experimented on millimeter wave resonator sensors realized with commercial ceramic chip modules, i.e., LTCC. He has worked mostly on quantitative measurements of biological fluids using transmission lines. From Sep. 2014, He spent six months in Dr. James Booth group in NIST, Colorado, USA, working on microwave microfluidics measurements. He has also worked on vector network analyzer calibrations. | |

| **2. Speaker's Name: James C. M. Hwang** | **Confirmed: Yes** |
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| **Affiliation: Lehigh University** | |
| **Presentation Title: Broadband Electrical Detection of Individual Biological Cells** | |
| **Email:** jh00@lehigh.edu | |
| **Abstract:** To resolve the dilemma of cell clogging or solution parasitics encountered by Coulter counters and to evolve a general-purpose electrical detection technique, we used broadband microwave measurements to overcome electrode polarization, AC dielectrophoresis to precisely trap cells between narrowly spaced electrodes, relatively wide microfluidic channels to prevent cell clogging, and cells resuspended in sucrose to reduce solution conductivity. This unique combination of approaches resulted in reproducible sensing of single human cells, both live and dead, of different cultures at different times. Details of the approaches will be discussed in the workshop. | |
| **Bio:** James Hwang is Professor of Electrical Engineering and Director of Compound Semiconductor Technology Laboratory at Lehigh University. He graduated with a B.S. degree in Physics from National Taiwan University in 1970, and completed M.S. (1973) and Ph.D. (1976) studies in Materials Science at Cornell University. After twelve years of industrial experience at IBM, Bell Labs, GE, and GAIN, he joined Lehigh in 1988. He cofounded GAIN and QED; the latter became the public company IQE. He was a Nanyang Professor at Nanyang Technological University, Singapore from 1999 to 2000, and a Program Manager for GHz-THz Electronics at the U.S. Air Force Office of Scientific Research from 2011 to 2013. He is a Life Fellow of the Institute of Electrical and Electronic Engineers. He has published more than 300 refereed technical papers with the citation index h = 36 and has been granted eight U.S. patents. His current research interest includes biosensing, two-dimensional atomic-layer materials, microwave devices and circuits, optoelectronics, and micro-electromechanical systems. | |

| **3. Speaker's Name: Pingshan Wang** | **Confirmed: Yes** |
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**Affiliation: The Department of Electrical and Computer Engineering, Clemson University**

**Presentation Title: Tunable interferometers for high sensitivity measurements of cells and molecules in microfluidic channels**

**Email**: pwang@clemson.edu

**Abstract:** We present our recent work on the development of microwave interferometers for high sensitivity measurements of cells and molecules in microfluidic channels. The use of tunable attenuators enables sensitivity tuning to measure single cells and 10 fg DNAs in liquid. The use of tunable phase shifters enable frequency coverage from ~ 1 MHz to ~ 40 GHz. Additionally, different spectrum engineering techniques are used to enhance the interactions between probing waves and cells and molecules. Thus, interferometer sensitivity is further improved.

**Bio:** Dr. Pingshan Wang graduated from the School of Electrical and Computer Engineering, Cornell University, Ithaca, NY in 2004. He served as an assistant professor at Southern Illinois University, Carbondale, IL for two years and moved to Clemson University in 2006.

Dr. Wang and his group are currently focusing on high-frequency lab-on-chip (HiF*i*-LoC) techniques, i.e. high-frequency microsystems, for which they study and develop electronic devices, circuits, and systems at radio and terahertz frequencies. They also develop high frequency microfluidic & nanofluidic devices and study the high-frequency properties of biological and chemical substances.

| 4. Speaker's Name: Katia Grenier | Confirmed: Yes |
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**Affiliation: LAAS-CNRS**

**Presentation Title: Miniaturized microwave and millimeter wave biodetection for molecular and cellular characterization**

**Email:** grenier@laas.fr

**Abstract:** Microwave and millimeterwave dielectric spectroscopy is a powerful technique for non-ionizing and non-destructive material characterization. Therefore, its development for the analysis of the living at the molecular and cellular levels is very attractive for biological research and biomedical applications, where non-invasivity, label-free and contact-less abilities as well as in-liquid measurements constitute important leitmotivs.

The talk will consequently present miniature biosensors and associated techniques, which have been developed to characterize different biological materials in aqueous solution. Issues in terms of broadband and narrow band measurements, sensitivity, specificity and repeatability of measurements with standard deviations will notably be highlighted on different biomaterials, such as carbohydrates and amino acids for biomolecules, as well as human cells in suspension and at the single cell level.

**Bio:** Katia Grenier received her Ph.D. degree in electrical engineering from the University of Toulouse, France, in 2000.

After a Postdoctoral Fellowship at Agere Systems (Bell Labs) in 2001, she joined the LAAS-CNRS lab, in France and was engaged in RF MEMS circuits on silicon. From 2007 to 2009, she was with the Laboratory for Integrated Micromechatronic Systems of CNRS (LIMMS-CNRS) in the University of Tokyo, Japan, where she was engaged in launching research activities on microwave-based biosensors. Her research interests in LAAS-CNRS are now focused on the development of fluidic-based micro/nanosystems for biological and medical applications as well as for reconfigurable wireless. Katia is a member of the IEEE MTT-10 Technical Committee on Biological effect and medical applications of RF and microwave of the IEEE Microwave Theory and Techniques Society.

| **5. Speaker's Name: Jun-Chau Chien** | **Confirmed: Yes** |
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**Affiliation: University of California, Berkeley**

**Presentation Title: CMOS Flow Cytometry using Multi-GHz Dielectric Spectroscopy**

**Email:** jcchien@eecs.berkeley.edu

**Abstract:** Rapid cell identification using microfluidics and CMOS technology has the potential to reduce costs and testing time, and perhaps enable point-of-care diagnostics. In this talk, the design and implementation of distributed sensor array for rapid capacitance measurement at microwave frequencies will be discussed. Experimental results on polystyrene beads, insect cells, and molecular sensing on glucose and protein solutions will be presented. Such dielectric-based electrical measurements can potentially enabled label-free single-cell identification.

**Bio:** Jun-Chau Chien received the B.S. and M.S. degrees in electronics engineering from National Taiwan University, Taipei, Taiwan, in 2004 and 2006, respectively, and Ph.D. degree in electrical engineering from University of California, Berkeley, in 2015. He is currently a research associate at University of California, Berkeley, and a circuit design consultant at HMicro Inc. He held positions at Xilinx and InvenSense in 2012 and 2015, respectively. His research topics include CMOS bio-sensor designs for single-cell analysis, VNA calibration techniques at sub-THz frequency, and mixed-signal clock generation.