Wednesday, January 25th, 8:00 am – 12:00 pm

Workshop on Emerging millimeter-wave & THz measurement for 6G communication

Organizer: Masahiro Horibe, Former AIST

Chairs: Joe Gering (Qorvo), Jean-Pierre Teyssier (Keysight Technologies)

Millimeter-wave and THz technologies shall be mainstay technologies in 6G communications. These technologies also play a prominent role in RF, microwave, and millimeter-wave applications for 5G and 6G communications. This workshop will address some of the measurement challenges in millimeter-wave and THz frequency regions. It will start from a user's perspective with talks on the needs in measurement method and design for circuits and antenna devices. It will then shift to a measurement perspective with presentations on material characterization, silicon RF circuit and antenna, and calibration. Taken in entirety, this workshop will be an excellent resource for metrologists and RF circuit and system designers alike.

7:50 am — 8:00 am

Welcome

Workshop Chairs

8:00 am — 8:45 am

Overview of mmW & THz Measurement for 6G Communication

Roger Nichols (Keysight Technologies)

Abstract: The demand for higher data rates and capacity drives new generation of mobile wireless communications to explore and expand the use of new and additional spectrum. In this context, "New Spectrum" refers to spectrum that has *not previously been used for mobile (cellular) wireless communications*. "Additional Spectrum" refers to the incremental spectrum added to what has already been established for use by previous generations. These words may seem to refer to the same thing, but they have distinct meanings. New spectrum requires significant research and engineering to develop transceiver technologies to address the physical challenges of the new frequency and what is often a much wider bandwidth. Given today's crowded airwaves, Additional spectrum means incumbent users are impacted--sometimes with a glancing blow, sometimes with a knockout punch. As a design and measurement company, among our priorities and expertise is to enable the means for quantitative assessment of physical behaviors and radio is one particular focus. This presentation is an overview of how we see the move to 6G impacting the demand for spectrum from 100 to 400 GHz. It will then cover an overview of the measurement challenges we face for materials, radio channels, components, and systems including interoperability and co-existence.

Speaker's Biography: Roger Nichols' 37 years of engineering and management experience in wireless design and measurement at Hewlett-Packard, Agilent, and Keysight Technologies spans roles in R&D, marketing, and manufacturing. He has managed projects, programs, and

	departments beginning with analog cellular radio and on every subsequent standard evolving to 6G. He directed Keysight's 5G program starting in 2014 and has been directing Keysight's 6G program since its inception in 2019. He is a member of the FCC Technical Advisory Council and is also the director of Keysight's work in wireless standards. Roger holds a BSEE from the University of Colorado, Boulder
8:45 am — 9:30 am	Development of D-band Metasurface Reflectors for 6G: Material Characterizations over 100 GHz for Reliable Designs and Antenna Measurements for Performance Evaluations. Yuto Kato (National Institute of Advanced Industrial Science and Technology, AIST). **Abstract:** In this talk, I will present D-band metasurface reflectors at 140 GHz for the application of 6G communication coverage expansion. I will also talk about complex permittivity and conductivity measurement technique at millimeter frequencies for reliable reflector designs using a balanced-type circular disk resonator method, as well as antenna measurement technique for performance evaluations of the reflectors **Speaker's Biography:** Yuto Kato received the B.S. and M.S. degrees in physics from The University of Tokyo, Hongo, Japan, in 2010 and 2012, respectively, and the Ph.D. degree from Osaka University, Toyonaka, Japan, in 2020. Since 2012, he has been with the National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan. His current research interests include material characterizations and electromagnetic metasurfaces at microwave and millimeter-wave frequencies
9:30 am — 10:15 am	Design of Silicon CMOS ICs and Modules for 6G: With Headaches, Possible Cures, and Open Questions in Measurements Shuhei Amakawa (Hiroshima University) **Abstract:** This talk will present 300-GHz-band silicon CMOS ICs and transmitter and receiver modules for high-speed wireless communications. It will also cover behind-the-scenes measurement issues, including some progress that was essential to the successful demonstration of the sub-THz transceivers, and remaining headaches that await treatment. **Speaker's Biography:** Shuhei Amakawa received B.Eng., M.Eng., and Ph.D. degrees from the University of Tokyo in 1995, 1997, and 2001, respectively. He also received an MPhil degree in physics from the University of Cambridge. Since 2010, he has been with Hiroshima University, where he is currently a professor. His research interests include modeling and simulation of nanoelectronic devices and systems, design of RF circuits, and microwave theory and measurement. He currently serves as an International Technical Program Committee member of the International Solid-State Circuits Conference (ISSCC).
10:15 am — 10:30 am	Break
10:30 am — 11:15 am	Millimeter-wave and Terahertz Integrated Circuits to Enable Non-Linear Characterization above 100 GHz Jerome Cheron (National Institute of Standard and Technology, NIST) **Abstract:** Semiconductor foundries have developed technologies that operate above 100 GHz, enabling new and emerging applications. Instrumentation covering ultrawide bandwidths at these frequencies must be developed to accurately characterize the nonlinear response of

active devices and circuits that are currently characterized using only linear scattering parameters and scalar power analyses.

We present and discuss new approaches to millimeter-wave high-precision sources, synthesizers, and on-wafer comb generators, with a focus on innovating InP monolithic integrated circuits designed to enable non-linear characterization above 100 GHz.

Speaker's Biography: Jerome Cheron received his Ph.D. degree in electrical engineering from the University of Limoges, France, in 2011. He joined the National Institute of Standards and Technology (NIST) in Boulder, in 2013. His current research interests include the characterization, modeling and design of millimeter-wave and terahertz active-circuits in III-V technologies.

11:15 am — 12:00 pm

Component Test under Modulated Signals for 6G Communication

Jean-Pierre Teyssier (Keysight Technologies)

Abstract: The upcoming 6G ecosystem at mm frequencies needs all the component test features we are used to at lower frequencies. Wideband modulated signal tests are the most demanding one, and the closest to devices real use.

The multi-ports coherent wideband spectrum analysis approach implemented into modern VNAs allows arbitrary wide vector signal analysis with phase consistency, opening the doors for frequency domain delta Error Vector Magnitude, and time domain Vector Signal Analysis (VSA) demodulation. The same coherent VNA measurement techniques can also be used for wideband source calibration and digital pre-distortion.

Speaker's Biography: Jean-Pierre Teyssier received the Master and Ph.D. degrees from Limoges University, France, in 1990 and 1994, respectively. From 1995 to 2012, he has been a Researcher and Professor with the XLIM Laboratory at University of Limoges, and he has been co-founder of the VTD (Verspecht Teyssier DeGroote) startup company in 2007. He is since 2012 a master research engineer with Keysight Technologies. He is currently the main engineer for the multi-port Spectrum Analyzer capability of the PNA-X VNA at Keysight. His recent contributions include the phase coherent mode of PNA-SA, the wideband phase stitching extended to mm wave frequencies, the PNA link to VSA for wideband signal demodulation.

12:00 pm

End of Workshop