USC Viterbi School of Engineering
Ming Hsieh Department of Electrical Engineering

Integrated Systems Seminar Series

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Power Generation in CMOS from RF to THz: A Spectrum of Challenges and Opportunities

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Technology scaling has enabled CMOS to serve as a platform for the implementation of a wide range of wireless systems operating from radio frequencies to terahertz. However, while we have seen steady (actually, somewhat slowing) increases in speed with technology scaling, this has been accompanied by the inevitable shrinking of supply and breakdown voltages. Consequently, power generation in CMOS is plagued by fundamental trade-offs between output power, efficiency, fidelity and operating frequency. The RF, millimeter-wave and terahertz frequency ranges represent different points in this multi-dimensional trade-off, but each is faced with fundamental challenges dictated by application requirements.

Mm-Wave power amplifiers have traditionally been limited to output power levels that are lower than 100mW and efficiencies lower than 20% due to the need to use scaled technologies with low supply voltages of around 1V. In this presentation, I will describe techniques developed at Columbia University, including device stacking, switch-mode operation at mmWave and low-loss on-chip power combining, that have enabled the first watt-class mmWave PA in CMOS.

At RF frequencies, speed can be traded-off for output power and consequently, watt-level output power is relatively straightforward. However, precision and signal fidelity, manifested as out-of-band emissions, are fundamental challenges, particularly for reconfigurable radios with reduced front-end filtering. This presentation will cover techniques recently developed at Columbia for receiver-band noise filtering in watt-level "digital PAs" and active cancellation of transmitter leakage and noise in reconfigurable receivers. These techniques enable frequency-division-duplexing in reconfigurable radios with relaxed transmitter-receiver isolation.

Finally, terahertz frequencies lie beyond the maximum operating frequencies of today's CMOS devices. I will briefly touch upon techniques that leverage device non-linearity to enable terahertz signal generation in CMOS in the milliwatt power envelope.

Harish Krishnaswamy received the B.Tech. degree in Electrical Engineering from the Indian Institute of Technology-Madras, India, in 2001, and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Southern California (USC) in 2003 and 2009, respectively. He joined the EE department of Columbia University as an Assistant Professor in 2009. His research group at Columbia, funded by various federal agencies, including NSF and DARPA, and industry, focuses on various topics related to devices, circuits and systems for wireless communication, radar, imaging and sensing in the RF, millimeter-wave and terahertz frequency ranges. He received the IEEE International Solid State Circuits Conference (ISSCC) Lewis Winner Award for Outstanding Paper in 2007. He also received the Best Thesis in Experimental Research Award from the USC Viterbi School of Engineering in 2009, and the DARPA Young Faculty Award in 2011.