Addressing the Challenges of 5G Systems: Research at the Georgia Institute of Technology

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The 5th generation cellular system is expected to incorporate disruptive technologies such as massive MIMO, millimeter-wave frequencies, and active phased array antennas. Several ongoing research projects at the Georgia Tech address 5G issues. These include techniques for improving the energy efficiency of the MIMO system from the transmitter side, 3D MIMO channel modeling, and machine learning for 5G networks. General research in the telecommunication area is in signal processing for improving spectral and energy efficiency of 5G networks. These research topics include massive MIMO, resource allocation for heterogenous networks and device-to-device communications, vehicle communications and fundamental issues in millimeter-wave and Terahertz communications. Ongoing research in the electromagnetics area revolves around antenna technologies, and includes inkjet and 3D printed antenna arrays on flexible substrates, inkjet printed origami frequency selective surfaces, 3D interconnects, and packages for digital phase shifters, and the co-design of multifeed antennas with millimeter-wave transmitters to boost the power and efficiency of operation. This presentation will review some of this work.

As an example in the area of millimeter-wave circuits, a major challenge for low-cost Si-based 5G systems is to support large transmitter output power with high efficiency and linearity from a limited supply voltage, which currently requires extensive power combining. Passive on-chip/on-package networks can combine multiple power amplifiers (PAs), but the lossy combiners degrade the total transmitter output power and lower the efficiency. Spatial power combining using a large antenna array can increase the total EIRP, at the cost of a large panel size, and a complicated Tx/Rx alignment due to exceedingly narrow beamwidths in dynamic/mobile 5G applications. At Georgia Tech, we exploit the unique advantages of circuit-antenna co-designs, as illustrated by a multi-feed antenna (MFA) that performs direct on-antenna power combining from multiple PAs while presenting the same radiation characteristics as its single-feed counterpart. In a previous demonstration, an on-chip MFA is driven by 16 linear on-chip PAs as a 5G Si-based transmitter [1]. The single-element MFA transmitter is implemented in a 45nm CMOS SOI process and generates +27.9dBm saturated power with 23.4% PAE and +33.1dBm peak EIRP at 59 GHz, all of which outperform any reported Si-based mm-wave transmitters [2]. It supports 4Gb/s 16-QAM signal with -21.9dB EVM and 4.8Gb/s 64-QAM signal with -25.4dB EVM. This MFA-based transmitter element can be implemented as an array to further boost the Tx EIRP, and its frequency can be scaled to address various 5G bands. Other examples will be presented for low-cost additively manufactured on-chip non-CMOS components, such as antennas, sensors, microfluidic structures, and high-Q passives for frequencies up to and above 60 GHz.

[1] S. Li, T. Chi, J. Park, and H. Wang, “A Multi-Feed Antenna for Antenna-Level Power Combining”, *Proc. IEEE AP-S/URSI*, June 2016.
[2] T. Chi, F. Wang, S. Li, M. Huang, J. Park, and H. Wang, "A 60 GHz On-Chip Linear Radiator with Single-Element 27.9dBm Psat and 33.1dBm Peak EIRP Using Multi-Feed Antenna for Direct On-Antenna Power Combining,” accepted and to appear in *IEEE International Solid-State Circuits Conference (ISSCC)* Dig. Tech. Papers, Feb. 2017.