INTEGRATED CIRCUITS FOR COMMUNICATIONS

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In this issue of Topics in Integrated Circuits for Communications, we have selected three papers that mark recent progress in the communications semiconductor industry which is enabling emerging short-range millimeter-wave (mmWave) communications and power-efficient transmissions.

With the proliferation of wireless communications in recent years, frequency spectrum has become extremely congested, especially for frequencies below 6 GHz. The spectral congestion is aggravated by a steep rise in demand for higher data rates in excess of 1 Gb/s. To support the rise in the number of users as well as data rates, wider available bandwidth or more complex signal processing is required to increase spectral efficiency. For mid-range to long-range systems, such as IEEE 802.11n/ac and LTE-A, the communications industry is leveraging high-order modulation and multiple-antenna technology to implement diversity, and multiple-input multiple-output (MIMO) to boost channel capacity while supporting high-bit-rate services. In addition, carrier aggregation is employed to group channels in existing allocated bands to provide effectively wider transmission spectrum.

In contrast, millimeter-wave and terahertz frequencies offer alternative means to achieve high data rate because of the availability of abundant spectrum, as well as high propagation loss and short wavelengths. Given large available bandwidths (e.g., 7 GHz), less spectrally efficient modulations could be used to achieve data rates > 10 Gb/s at short distances. The high propagation loss facilitates frequency reuse at short distances, while short wavelengths lead to small antenna aperture, making it possible to integrate large numbers of antennas in a phased array radio. The ability to achieve short-range focused radio beams enables high-resolution medical imaging and radar ranging. Thus, mmWave devices are poised to usher in portable devices for medical imaging and onboard radar systems for self-driving cars of the future.

Advanced silicon technologies have played a key role in materializing integrated mmWave radios due to their high density for digital integration and high effective cutoff frequency. In particular, SiGe BiCMOS technologies deliver better power handling capability than silicon CMOS, and may bring unique advantages in implementing integrated mmWave and terahertz transceivers. However, the manufacturability and cost of large phased arrays becomes challenging due to low yield. In the article "W-Band Scalable Phased Arrays for Imaging and Communications," the authors propose a modular approach to address the conflicting requirements between high directivity and manufacturing cost for a phased array. After a brief overview, the authors discuss both circuit and architecture trade-offs leading to a 64-element phased array that contains four 16 dual-polarized RF phase-shifting front-ends together with 64 dual-polarized antennas housed in a single package, occupying 16.2 mm × 16.2 mm × 0.7 mm. Their work has demonstrated the feasibility of achieving large arrays by tiling smaller array modules using low-cost silicon-based technology.

Over the past two decades, we have come to embrace the notion of the "last mile," portraying the reach of communication infrastructure to every home. Now with the realization of mmWave communications, we can talk about perhaps an even more challenging problem — the "last centimeter," the ability to connect large numbers of high-speed integrated circuits or backplanes. With the abundant bandwidths available in the terahertz range (i.e., 50–300 GHz), terahertz interconnect can potentially meet the bandwidth density (Gb/s/mm^2) and energy efficiency (Joules per bit) required for future high-speed computing devices and network backplanes. In the article "THz Interconnect: the Last Centimeter Communication," the author gives a detailed overview of the trade-offs that exist for designing THz circuits to meet the bandwidth density and energy efficiency required for high-speed inter-chip communications. To overcome the bandwidth limitations in process technology, the article describes an interesting circuit technique to introduce negative resistance into the signal path such that resistive losses can be reduced, effectively lifting the bandwidth limitation imposed by process technology. Moreover, to achieve data rates in excess

of 100 Gb/s, the author proposes a micro-machined dielectric waveguide in a silicon process to address the significant line loss exhibited at such high frequency. This article highlights the potential of realizing mmWave circuits to address the increasing demand for IO bandwidth using low-cost silicon-based technologies.

The last article in this issue of our Series addresses the age-old problem of low power efficiency in wireless transmissions. In a mobile device, more than half of the power is being dissipated by the power amplifier, which makes it the dominant factor in determining battery lifetime. Likewise, in a base station, the power amplifier is the dominant source of heat leading to high air-conditioning cost. Making the power amplifier more efficient will greatly enhance the user experience with longer battery lifetime, as well as reduce the maintenance cost of base stations by reducing heat generation. Several articles from past issues of this Series have described digital enhancement techniques to improve the efficiency of power amplifiers based on RF digital-to-analog (DAC) architecture. In the last article, "Outphasing Transmitters, Enabling Digital-Like Amplifier Operation with High-Efficiency and Spectral Purity," the authors give an in-depth overview of another widely known PA architecture based on outphasing. They have shown its potential to provide greater than 80 percent power efficiency in contrast to the 40–50 percent typically achieved in conventional PAs. Moreover, a 70 W power amplifier has been demonstrated using a CMOS-driven GaN outphasing amplifier. Their work shows that outphasing is a strong contender in solving this age-old problem in transmission systems, although reaching toward 100 percent efficiency remains a challenging goal for future circuit designers.

We would like to take this opportunity to thank all the authors and reviewers for their contributions to this Series. Future issues will continue to cover circuit technologies that are enabling new emerging communication systems. If readers are interested in submitting a paper to this Series, please send your paper title and an abstract to either of the Series Editors for consideration.

BIOGRAPHIES

CHARLES CHIEN (charles.chien@creonexsystems.com) is the president and CTO of CreoNex Systems, which focuses on technology development for next generation communication systems. Previously he held various key roles at Conexant Systems, SST Communications, and Rockwell. In his career, he has architected several key products including a CMOS/SiGe chip-set for multimedia over coax (MoCA), an IEEE 802.11abg WLAN RF CMOS transceiver and GaAs PA/RF switches, a wireless audio CMOS chip-set for home theatre in a box, digitally-assisted cellular transceivers, and low-power wireless networked sensors. He was also an assistant adjunct professor at the University of California, Los Angeles (UCLA) from 1998 to 2009. His interests focus mainly on the design of system-on-chip solutions for wireless multimedia and networking applications. He has published in various journals and conferences, and has authored a book. Digital Radio Systems on a Chip. He received his B.S.E.E. from UC Berkeley, and his M.S. and Ph.D. from UCLA. He served as a member of the Technical Program Committee of ISSCC from 1998 to 2006.

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