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Special Focus on Millimeter Wave Communications Techniques and Devices for 5G—Editorial*

Due to the rapid development of cost-effective CMOS solutions and recent experimental validation on communications over millimeter wave (mmWave) bands, which span from 30 to 300 GHz, mmWave communications technologies are being considered for 5G mobile systems to provide ultra-high data rates for front haul, back haul, and short or middle range broadband access. Owing to the array gain of massive multiple-input multiple-output (m-MIMO) antenna arrays, the heavy path loss of mmWave propagation can potentially be compensated. In addition, the compact physical size of m-MIMO arrays over mmWave bands makes them feasible for mobile terminals as well. Much research has been reported recently on mmWave communications (including several special issues by some well referenced journals and magazines). In terms of practical implementation and standardization, however, there are still significant challenges for mmWave communications technologies and their applications-both in hardware and in signal processing algorithms.

As such, in this special section of *Science China Information Sciences*, the focus is on the latest progress in channel modelling, system and circuit design, beamforming implementation, and experimental trials over mmWave bands. Among the eight papers in this special section, seven papers have been selected from the responses to the open call while one paper is invited.

As in the case of any other frequency bands of wireless communications, channel modeling is fundamental to the proper deployment of mmWave communications networks. The paper by J. Zhang et al. provides a comprehensive overview, which summarizes the global efforts in allocating potential frequency bands and field trials from 6 to 100 GHz for 5G networks-in particular from a channel perspective (e.g. channel measurement and characterization). R. Feng et al. in their paper present their results on channel measurements at 16, 28, and 38 GHz bands using virtual large horizontal planar arrays in an indoor office environment while the data are processed by a novel 3D frequency domain SAGE algorithm. The paper by L. Zhou et al. proposes an improved 28 GHz path loss model based on multipath clustering obtained from channel measurement campaigns with rotating platforms and directional antennas in both indoor and outdoor environments.

Circuit and device solutions for mmWave bands form the most basic enabler for mmWave communications. Z. Jiang et al. in their paper discuss the design of 45 GHz and 60 GHz mmWave CMOS power amplifiers by employing a novel 8-way distributed active transformer power combiner. The letter by Z. Wang et al. addresses the challenge of fine frequency tuning in digitally controlled oscillator (DCO) design by using the digital control artificial dielectric (DiCAD) technique and avoiding direct switching in the tank.

To reduce the hardware complexity and cost of m-MIMO systems, hybrid beamforming (HBF) has recently received much attention. Given the drawbacks with practical phase shifters, the paper by J. Li et al. proposes an energy efficient Butler matrix based HBF structure for multiuser mmWave MIMO system as well as a low complexity HBF algorithm. On the other hand, a critical issue in mmWave communications is link robustness due to mmWave signals' propagation characteristics. The invited

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paper by G. Yang and M. Xiao provides a comprehensive overview on anti-blockage techniques in the existing literature, including two particular schemes for beam switching as well as the related protocols.

Last but not least, the paper by G. Yue et al. presents a 60 GHz short-range wireless communications demo system based on the IEEE 802.11ad standard and targeting high-definition video streaming transmission. The self-designed and developed hardware prototype consists of a 65-nm CMOS radio-frequency front-end and a baseband transceiver for the physical layer functions as well as all the related baseband functions.

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