Frontiers of Information Technology & Electronic Engineering
www.jzus.zju.edu.cn; engineering.cae.cn; www.springerlink.com
ISSN 2095-9184 (print); ISSN 2095-9230 (online)
E-mail: jzus@zju.edu.cn

Editorial:

High-throughput millimeter-wave wireless communications

Wei HONG[‡1], Guangrong YUE[2], Xiaohu GE[3], Haiming WANG[1]

[1]*State Key Laboratory of Millimeter Waves, Southeast University, Nanjing 210096, China*
[2]*National Key Laboratory of Science and Technology on Communications,*
University of Electronic Science and Technology of China, Chengdu 611731, China
[3]*School of Electronic Information and Communications, Huazhong University of Science and Technology, Wuhan 430074, China*
E-mail: weihong@seu.edu.cn; yuegr@uestc.edu.cn; xhge@mail.hust.edu.cn; hmwang@seu.edu.cn

https://doi.org/10.1631/FITEE.2120000

Mobile communication is a fundamental element of information flow in modern society. The fifth-generation mobile communication system (5G) has recently entered commercial use. Simultaneously, the evolution of 5G and the development of sixth-generation mobile communication system (6G) are becoming hot topics of research in both academic and industrial circles. The most important resource for achieving high-throughput wireless communications is the frequency spectrum. Since the utilization of millimeter-wave (mmWave) band is one of the key technologies for high-throughput wireless communications, the band of the available frequency spectrum needs to be widely investigated and applied. Several important tendencies exist in the development of mmWave wireless communications:

1. New mmWave propagation characteristics and channel models are applied to more user scenarios.

The mmWave wireless communication technologies are expected to be employed in an increasing number of environments. Multiple frequencies, transmission scenarios, and new propagation characteristics need to be first investigated as a response to new configurations of large-scale antenna arrays to establish new channel models for link-level and system simulations.

2. High-throughput mmWave wireless communication systems using advanced technologies appear.

To meet the requirements of future high-throughput wireless communications, the persistent evolution and innovation of protocol structure and signal processing are inevitable to solve the challenges of higher frequency, wider bandwidth, higher data rates, and to develop new technical specifications by integrating communication and sensing functions.

3. Novel broadband, low-power, and high-performance mmWave components are being developed using new techniques.

Electronic components face a declining performance and elevated power consumption with the increase of the signal frequency; thus, it is mandatory that new circuit structures, materials, and manufacturing processes can meet the requirements of higher throughput and robustness.

In short, the evolution of existing 5G and the development of 6G standard put mmWave wireless communications against numerous challenges. The overall performance improvement of existing mmWave wireless communication systems will inevitably rely on the upgrade of components, signal processing methods, and system schemes. The evolution and innovation of channel models, components, and system design can also pave the way for new applications.

‡ Corresponding author
© Zhejiang University Press 2021

In this context, the journal of *Frontiers of Information Technology & Electronic Engineering* organized a special issue on high-throughput mmWave wireless communications. This special issue covers mmWave channel models, system designs, and components, and is intended to review the advances and future research directions in the field of mmWave wireless communication research. After rigorous review processes, 13 papers authored by researchers worldwide have been selected for this issue, including two review articles, 10 research articles, and one correspondence.

In the framework of the recently emerging fiber-to-the-room (FTTR) home network architecture of the fifth-generation fixed networks (F5G), mmWave technology can be cascaded well into a new optical network terminal located in the room to enable high-throughput communication. The study by Chao HE et al. provides insights into and analysis of the new FTTR+mmWave architecture to improve the customer experience in future broadband services, such as immersive audiovisual videos.

Using the highly directional transmission characteristics of mmWaves is a promising route for integrating communication and localization. Accordingly, Shi JIN and his collaborators explained the integrative process of communication and localization in mmWave systems, where these processes share the same set of hardware architecture and algorithm. They summarized the key enabling technologies and the basic knowledge on localization, and outlined the future trends on the mutual assistance and enhancement of communication and localization in integrated systems.

Radio propagation characteristics and channel models are essential for the design and deployment of new wireless communication systems at new frequency bands. Haiming WANG and his collaborators performed radio propagation measurement and cluster-based analysis for mmWave wireless communication systems at 28 and 39 GHz in dense urban environments, and demonstrated that the cluster-based analysis took full advantage of mmWave beamspace channel characteristics and had further implications for the design and deployment of mmWave wireless networks.

The angle of arrival (AoA) is vital for analyzing channel characteristics and estimating link performance. An empirical study of the uplink and downlink azimuth AoA was conducted by Jianhua ZHANG et al. in an urban micro (UMi) scenario at 28 GHz. They successfully verified that the AoA of clusters follows a Gaussian distribution in the uplink and downlink by comparing measurement results with those of standard channel models. Besides, a two-dimensional Gaussian distribution for ray AoA and power was established therein to reflect their correlation.

The existing communication channel tests select mostly low-speed and small-range vehicle communication scenarios for testing. A large number of channel measurements were carried out by Lin YANG and his collaborators in mmWave vehicle-to-infrastructure long-distance communication scenarios at the 41 GHz band. By studying the received signal strength (RSS) in detail, they established that the vibration features of RSS can be best modeled by the modified two-path model considering road roughness. In addition, they proved the efficacy of the modified two-path model, the close-in transmitter-receiver heights model, and the two-section exponential power delay profile model.

Satellite-to-ground communications have recently received much attention as a typical high-mobility scenario, while they face great challenges due to the high Doppler shift. Orthogonal time-frequency space (OTFS) modulation has thus been widely considered for high-mobility scenarios. The results of Ruisi HE, Haoxiang ZHANG, and others showed that, compared with a conventional minimum mean square error (MMSE) equalizer, MMSE with successive detection can improve the performance of OTFS modulation. These authors evaluated OTFS modulation performance for geostationary Earth orbit and low Earth orbit satellite-to-ground channels at sub-6-GHz and mmWave bands for both line-of-sight and non-line-of-sight cases.

Orbital angular momentum (OAM), which provides a new degree of freedom for mmWave wireless communication systems, is recognized as one of the possible enabling techniques for future mobile communication networks. A new OAM-GSM mmWave wireless communication system was presented by Qiang LI and his collaborators by combining OAM beams that have theoretically infinite and mutually orthogonal states with the generalized spatial modulation (GSM) strategy. They demonstrated that, compared with traditional GSM systems, the OAM-GSM system has a more complex transmission and reception mechanism, while the channel capacity and maximum achievable energy efficiency of the combined system can be increased by 80% and 54%, respectively.

Performance evaluation is a mandatory step to ensure the success of 5G mmWave deployment; therefore, over-the-air (OTA) radiated methods of testing 5G mmWave in laboratory conditions are highly attractive for research. Wei FAN and his collaborators summarized the need for, as well as the challenges of, OTA measurement of 5G mmWave under fading channel conditions. Their work also includes the preliminary experimental validation results in an anechoic chamber for the wireless cable and multi-probe anechoic chamber methods at 28 GHz.

Transmission distance can be increased by deploying a broadband ultra-massive phased array in high-throughput mmWave communication systems. The beam squint effect on high-throughput mmWave communication systems with the single-carrier frequency-domain equalization transmission scheme was investigated by Guanrong YUE and his research team. Their results showed that the proposed Zadoff-Chu-based analog beamforming method can effectively mitigate the performance loss by the beam squint.

A multi-cell mmWave MIMO system that features a mixed analog-to-digital converter and hybrid beamforming architecture has been highly recommended. Jiayi ZHANG and his collaborators proposed an efficient power allocation scheme by solving a complementary geometric programming problem, and investigated the energy efficiency and an optimal tradeoff between the achievable rate and power consumption.

An amplifier with low noise figure (NF) (i.e., low-noise amplifier, LNA), which is often the first active component after the antenna or duplexer/diplexer, determines the performance of one receiver. With the aim to construct such an LNA, Quan XUE et al. presented a 9.8–30.1 GHz CMOS LNA with 3.2-dB minimum NF and 15.6-mW power consumption using a 1.2-V supply. In their work, a topology at the architecture level based on common-gate (CG) cascading with a common-source (CS) amplifier was proposed for simultaneous wideband input matching and relatively high gain. At the circuit level, multiple techniques are presented to improve the LNA performance.

Antennas with low-cost and high-gain characteristics are always a highly preferred option in the wireless communication industry to compensate for the propagation loss at mmWaves frequencies. Qingyi GUO and Hang WONG introduced a dual-polarized Fabry-Pérot cavity mmWave antenna with high-gain and wideband characteristics with peak gains of vertical- and horizontal-polarization of 18.4 and 17.6 dBi, respectively, and impedance matching bandwidth for the two polarizations of 14%.

Due to their advantages of low cost and high integration compared with a metal-made waveguide, substrate integrated waveguide (SIW) based mmWave antennas are popular research subjects. A low-cost slot array antenna for 5G mmWave applications was featured in the study by Xiuping LI et al., who found that the simplified feeding network can be implemented using high-order-mode cavities, which results in high radiation efficiency.

A broad spectrum of current research topics relevant to high-throughput mmWave wireless communications is covered in this special issue, from propagation measurement and channel modeling to antennas, amplifiers, baseband signal processing, system design, OTA measurement, etc. We hope that this collection of diverse but interconnected topics will be beneficial to persons with interest in mmWave wireless communication or related areas.

Finally, we would like to express our special gratitude to the authors, reviewers, etc. for their support and valuable contributions to this issue, the editorial staff, and the Editors-in-Chief Profs. Yunhe PAN and Xicheng LU.

Prof. Wei HONG received his BS degree from the University of Information Engineering, Zhengzhou, China, in 1982, and his MS and PhD degrees from Southeast University, Nanjing, China, in 1985 and 1988, respectively. All degrees are in radio engineering.

Since 1988, Dr. HONG has been with the State Key Laboratory of Millimeter Waves, Southeast University; he has been the director of the laboratory since 2003. He is currently a professor at the School of Information Science and Engineering of the same university. In 1993 and from 1995 to 1998, he was a short-term visiting scholar at the University of California, Berkeley, and the University of California, Santa Cruz, CA, US, respectively. He has authored or co-authored over 300 technical publications, and published two books. He was an elected IEEE MTT-S AdCom member from 2014 to 2016, and is currently a fellow of the Chinese Institute of Electronics. He was awarded the National Natural Prizes twice and the First-Class Science and Technology Progress Prizes four times by the Ministry of Education of China and Jiangsu Province, China, the IEEE Microwave Prize, and the IEEE certificate of outstanding contributions to 802.11aj, among other honors. He was supported by the National Natural Science Foundation of China for Distinguished Young Scholars and Innovation Groups. He is a vice president of the CIE Microwave Society and the Antenna Society, and chair of the IEEE MTTS/APS/EMCS Joint Nanjing Chapter. He served as an associate editor for *IEEE Trans Microw Theory Techn* from 2007 to 2010, and was one of the guest editors of the 5G special issue of *IEEE Trans Antenn Propag* in 2017. His current research interests include numerical methods for electromagnetic problems, millimeter-wave theory and technology, antennas, electromagnetic scattering, and RF technology for mobile communications.

Prof. Guangrong YUE received his BS degree from the University of Information Engineering, Zhengzhou, China, in 1996, and his PhD degree from the University of Electronic Science and Technology of China, Chengdu, China, in 2006.

He was a postdoctoral fellow at the Department of Electrical Engineering and Computer Science at the University of California, Berkeley, during 2007–2008. He has been a faculty member at the University of Electronic Science and Technology of China since 2008. He has authored or co-authored over 50 technical publications, and published two books. His current research interests include wireless communication theory and millimeter wave communications system design, channel measurement, and modeling.

Prof. Xiaohu GE received his PhD degree in Communication and Information Engineering from the Huazhong University of Science and Technology (HUST), China, in 2003.

He has worked with HUST since November 2005. Prior to that, he worked as a researcher with Ajou University, South Korea, and the Politecnico Di Torino, Italy, from January 2004 to October 2005. He is currently a full professor at the School of Electronic Information and Communications, HUST. He is an adjunct professor with the Faculty of Engineering and Information Technology, University of Technology Sydney, Australia. He has published about 200 articles in refereed journals and conference proceedings. He has been granted 25 patents in China. He serves as an IEEE distinguished lecturer and an associate editor for *IEEE Access*, *IEEE Wirel Commun*, and *IEEE Trans Veh Technol*, among other roles. His research interests are in the areas of mobile communications, traffic modeling in wireless networks, green communications, and interference modeling in wireless communications.

Prof. Haiming WANG received his BS, MS, and PhD degrees in Electrical Engineering from Southeast University, Nanjing, China, in 1999, 2002, and 2009, respectively.

He joined the State Key Laboratory of Millimeter Waves and the School of Information Science and Engineering, Southeast University, Nanjing, China, in 2002. He is currently a distinguished professor there. He is also a part-time professor at the Purple Mountain Laboratories, Nanjing, China. He has authored and co-authored over 50 technical publications in *IEEE Trans Antenn Propag* and other peer-reviewed academic journals. He holds over 70 patents, and has been granted 52 patents. He was awarded for contributing to the development of IEEE 802.11aj by the IEEE Standards Association in July 2018. He serves as a corresponding expert of *Front Inform Technol Electron Eng*. His current research interests include AI-powered antenna and radiofrequency technologies, AI-powered channel measurement and modeling technologies, and millimeter-wave and THz wireless communications.