YUAN Jinhong, BAI Baoming, FAN Pingzhi, AI Bo

Editorial: Special Topic on OTFS Modulation for 6G and Future High Mobility Communications

Guest Editor

YUAN Jinhong received the B.E. and Ph.D. degrees in electronics engineering from the Beijing Institute of Technology, China in 1991 and 1997, respectively. From 1997 to 1999, he was a research fellow with the School of Electrical Engineering, University of Sydney, Australia. In 2000, he joined the School of Electrical Engineering and Telecommunications, University of New South Wales, Australia, where he is currently a professor and the Head of Telecommunication Group with the school. He has published two books, five book chapters, over 300 papers in telecommunications journals and conference proceedings, and 50 industrial reports. He is a co-inventor of one patent on MIMO systems and four patents on low-density-parity-check codes. He has co-authored four Best Paper Awards and one Best Poster Award, including the Best Paper Award from the IEEE International Conference on Communications, USA in 2018, the Best Paper Award from IEEE Wireless Communications and Networking Conference in 2011, and the Best Paper Award from the IEEE International Symposium on Wireless Communications Systems in 2007. He is an IEEE Fellow and currently serving as an Associate Editor for the IEEE Transactions on Wireless Communications and IEEE Transactions on Communications. His current research interests include error control coding and information theory, communication theory, and wireless communications.

Guest Editor

BAI Baoming received the B. S. degree from the Northwest Telecommunications Engineering Institute, China in 1987, and the M.S. and Ph.D. degrees in communication engineering from Xidian University, China in 1990 and 2000, respectively. From 2000 to 2003, he was a senior research assistant at the Department of Electronic Engineering, City University of Hong Kong, China. Since April 2003, he has been with the State Key Laboratory of Integrated Services Networks (ISN), School of Telecommunication Engineering, Xidian University, China, where he is currently a professor. In 2005, he was with the University of California, USA, as a visiting scholar. In 2018, he spent one month as a Senior Visiting Fellow at McMaster University, Canada. Dr. BAI co-authored the book *Channel Coding for 5G* (in Chinese, 2020). His research interests include information theory and channel coding, wireless communication, and quantum communication. He received the Best Paper Award from the CIC/IEEE *China Communications*, in 2018. He is a senior member of IEEE.

Guest Editor

FAN Pingzhi received the M.Sc. degree in computer science from Southwest Jiaotong University, China in 1987, and the Ph.D. degree in electronic engineering from Hull University, U.K. in 1994. He is currently the director and distinguished professor of the Institute of Mobile Communications, Southwest Jiaotong University, China, and a visiting professor of Leeds University, UK (1997-), a guest professor of Shanghai Jiaotong University (1999-). He served as an EXCOM member for the IEEE Region 10, IET (IEE) Council and the IET Asia Pacific Region. He was a recipient of the UK ORS Award (1992), the National Science Fund for Distinguished Young Scholars (1998, NSFC), IEEE VT Society Jack Neubauer Memorial Award (2018), IEEE SP Society SPL Best Paper Award (2018), IEEE WCSP 10-Year Anniversary Excellent Paper Award (2009-2019), and IEEE/CIC ICCC Best Paper Award (2020). He served as a chief scientist of the National 973 Plan Project between 2012.1 – 2016.12. His research interests include high mobility wireless communications, massive random-access techniques, signal design & coding, etc. He is an IEEE VTS Distinguished Speaker (2019-2022), a fellow of IEEE, IET, CIE and CIC.

Guest Editor

AI Bo is a professor and doctoral supervisor of Beijing Jiaotong University. He is also the deputy director of the State Key Laboratory of Rail Traffic Control and Safety. Prof. AI has been awarded the National Science Fund for Distinguished Young Scholars, the Outstanding Youth Science Fund, the Newton Advanced Fellowship, the National Central Organization Department's 10 000-Person Plan Leading Talents, the Chinese Academy of Engineering Distinguished Young Investigator of China Frontiers of Engineering. Prof. AI has published 6 Chinese academic books, 3 English books, 150 IEEE journal articles. He has obtained 13 international paper awards include IEEE VTS Neil Shepherd Memorial Best Propagation Award and IEEE GLOBECOM 2018 Best Paper Award, 32 invention patents; 21 proposals adopted by the ITU, 3GPP, etc., and 9 provincial and ministerial-level science and technology awards. His research results have been involved in 4 national standards. He is mainly engaged in the research and application of the theory and core technology of broadband mobile communication and rail transit dedicated mobile communication systems (GSM-R, LTE-R, 5G-R, LTE-M). He is the president of IEEE BTS Xi'an Branch, vice president of IEEE VTS Beijing Branch, and IEEE VTS distinguished lecturer. He is a fellow of IEEE.

Future wireless networks are expected to provide high speed and ultra-reliable communications for a wide range of emerging mobile applications, including real-time online gaming, vehicle-to-everything (V2X), unmanned aerial vehicle (UAV) communications, and high-speed railway systems. Communications in high mobility scenarios suffer from severe channel Doppler spreads as well as delay spread, which deteriorates the performance of the widely adopted orthogonal frequency division multiplexing (OFDM) modulation in the current 4G and 5G networks.

Recently, a new two-dimensional (2D) modulation scheme referred to as orthogonal time frequency space (OTFS) modulation was proposed, where the information symbols are multiplexed in the delay-Doppler (DD) domain rather than the

DOI: 10.12142/ZTECOM.202104001
Citation (IEEE format): J. H. Yuan, P. Z. Fan, B. M. Bai, et al., "Editorial: special topic on OTFS modulation for 6G and future high mobility communications," *ZTE Communications*, vol. 19, no. 4, pp. 1–2, Dec. 2021. doi: 10.12142/ZTECOM. 202104001

time-frequency (TF) domain as in the traditional modulation techniques. The DD domain multiplexing provides the possibility to embrace the channel impairments and to provide the benefits of delay- and Doppler-resilience. OTFS enjoys the full time-frequency diversity of the channel, a key to provide reliable communications. Since it was introduced in 2017, OTFS has been recognized globally for its great potential to achieve high-speed and high-reliable communications in a high-mobility environment. While some initial works on the concepts and the implementations of OTFS have been investigated, there are still several challenges and open problems to be addressed.

In this special issue, we have invited seven active and leading research groups who have been working on this topic in the last few years to provide tutorials, surveys or technical papers on various important issues facing OTFS system designs, including efficient DD domain channel estimation, low complexity OTFS signal detection, coded OTFS systems performance evaluations, iterative receiver designs, multiple-antenna OTFS systems designs, OTFS based multiple access for satellite communications, etc. These papers provide an overview of the latest OTFS research and innovations as well as their applications. Thereby, it is expected that these papers will motivate and inspire further work amongst researchers, engineers, and Ph.D students working on OTFS and related areas.

One of the challenges facing OTFS system design is how to detect the transmitted symbols with a low complexity receiver. In this special issue, three papers investigate OTFS receiver designs, particularly on the signal detection and channel estimations for OTFS systems. ZHANG Zhengquan et al. in the paper entitled "A Survey on Low Complexity Detectors for OTFS Systems" provide a survey on low complexity OTFS detectors and their related insights on future researches. OTFS detector structures and classifications are compared and discussed. Motivated by the principles of OTFS detection algorithms, the authors propose the design of hybrid OTFS and OFDM detector in single user and multi-user systems.

The paper entitled "Signal Detection and Channel Estimation in OTFS" by CHOCKALINGAM et al. presents an overview of the state-of-the-art approaches in the OTFS signal detection and DD domain channel estimation. Three signal detection methods (linear detection, approximate maximum a posteriori detection, and deep neural network based detection) and three DD channel estimations (separate pilot, embedded pilot, and superimposed pilot) are discussed. The main challenges and future research directions are identified.

Considering that an efficient detector is paramount to harvesting the time and frequency diversities promised by OTFS, GUO Qinghua et al. in their paper "Message Passing Based Detection for Orthogonal Time Frequency Space Modulation" offer an overview of some recent message passing based OTFS detectors, which can exploit the features of the OTFS channel matrices, compare their performance, and shed some light on potential research on the design of OTFS receivers.

While most of the existing OTFS work deals with uncoded systems, this special issue has two papers contributing to the design of coded OTFS systems. In the paper entitled "Performance of LDPC Coded OTFS Systems over High Mobility Channels" by ZHANG Chong et al., the performance of coded OTFS systems with 5G LDPC codes and 5G OFDM frame structure over high mobility channels is evaluated. Various iterative detection and decoding algorithms are proposed. The effect of channel estimation error on the LDPC coded OTFS system performance is discussed.

The work "Coded Orthogonal Time Frequency Space Modulation" by LIU Mengmeng et al. analyses the performance of the uncoded/coded OTFS system and compare them with OFDM systems with different relative speeds, modulation schemes and iterations. They show that the OTFS system has the potential of full diversity gain and better robustness under high mobility scenarios.

The paper "OTFS Enabled NOMA for MMTC Systems over LEO Satellite" by MA Yiyan et al. suggests one potential application of OTFS for the massive machine type communications (mMTC) in low earth orbit (LEO) satellite networks with notable Doppler shifts. OTFS-NOMA schemes are described for the systems. The challenges of applying OTFS and NOMA into the LEO satellite mMTC systems and the potential technologies for the system are investigated.

Finally, in the work "Orthogonal Time Frequency Space Modulation in Multiple-Antenna Systems" by WANG Dong et al., the application of OTFS modulation in multiple-antenna systems is investigated. Two classes of OTFS-based multiple-antenna approaches for both the open-loop and the closed-loop (with Tomlinson-Harashima precoding) systems are proposed. Key challenges and opportunities for applying OTFS to multiple-antenna systems are presented.

In summary, this special issue covers the state-of-the-art OTFS technologies for channel estimation, detection, code design, iterative receiver development, and its applications for LEO satellite and multiple-antenna systems. We thank all authors, reviewers, editorial staff who have contributed to this issue. It is our expectation that these papers will inspire further research and development for future 6G and emerging wireless communications.