



Editorial: Special Topic on Reconfigurable Intelligent Surface (RIS)

Guest Editors >>>



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Over the past two years, reconfigurable intelligent surface (RIS), as a promising emerging technology for Beyond 5G (B5G) and 6G mobile communications systems, has attracted enormous interest from both academia and industry worldwide. In IMT-2030 (6G) Promotion Group of China, the RIS task force was created in June 2020. In IEEE, an emerging technology initiative (ETI) of RIS was formed in July 2020. In ETSI, an industry specifications group (ISG) was kicked off in September 2021. In 2022, RIS Technology Alliance (RISTA) will be established. Initial field trials of RIS have been conducted by several companies and universities.

A RIS panel is made up with many surface-laid elements, where each element can be controlled to change the phase/am-

plitude of incident electromagnetic waves. Benefiting from the rapid development of meta-material device manufacturing, RIS panels with hundreds of programable meta-surface elements now become feasible, so that RIS can significantly improve, rather than adapt to, radio environments. By properly cooperating with base station antennas, RIS can extend the network coverage and increase the system throughput. RIS is primarily a passive device requiring little or a very small amount of power. Hence its operation is more energy-efficient than deploying traditional small cell base stations or relays which usually contain active radio devices such as power amplifiers. However, RIS is a relatively new technology that still faces a lot of challenges and issues for wireless and device researchers/engineers to solve.

In this special topic, we assembled eight papers with a reasonable divide between theoretical research and practical engineering: five of them are coming from academia and three from the industry. They span over the general trends of RIS re-

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search and development, RIS devices, signal processing and control aspects of RIS systems, and prototype RIS transmitter and receiver system. In terms of research fields, certain balance is also considered to ensure diversity. Apart from the two general papers, four papers are in the field of wireless communications, e.g., signal processing and physical layer controls. Two papers are primarily about hardware and electromagnetic physics, e.g., circuit device and test systems.

The two papers “Recent Progress in Research and Development of Reconfigurable Intelligent Surface” and “Some Observations and Thoughts about Reconfigurable Intelligent Surface Application for 5G Evolution and 6G” come from wireless operators, China Mobile and NTT DOCOMO, respectively. They provide big pictures of recent R&D of RIS at both academia and the industry. The former paper has a more comprehensive coverage, including the fundamental performance bounds, channel estimation, joint optimization algorithms, propagation channel modeling, realistic issues, control mechanisms, field trials and related activities in standardization development organizations (SDOs) of RIS. The latter paper emphasizes a little bit on demo trial and system-level computer simulations carried out by NTT DOCOMO for 28 GHz millimeter wave band. For large-scale RIS panels, near field effect is analyzed and a two-step beamforming method is proposed.

The paper “Recent Developments of Transmissive Reconfigurable Intelligent Surfaces: A Review” is contributed by professors from Tsinghua University. It reviews design approaches for RIS devices: Rx-Tx structure and frequency selective surface (FSS) structure; representative designs with different phase resolutions are illustrated, such as single-polarized 1-bit, dual-polarized 1-bit, 2-bit and continuous 360° phase shifts. The operating mechanisms, schematics and transmission performances of those RIS elements are discussed in details.

Four papers in this special topic are devoted in signal processing and control aspects of RIS, reflecting the importance of control algorithms in fulfilling the performance potential of RIS. The paper “IRS-Enabled Spectrum Sharing: Interference Modeling, Channel Estimation and Robust Passive Beamforming” from Macau University pays special attention to the interference modeling in multi-user and multi-RIS panel scenarios. By decoupling the cascaded RIS channels, a novel channel estimation framework is proposed that includes off-line estimation and on-line estimation, with certain tradeoff consideration between spectral efficiency and energy efficiency of the systems. Also, in this paper, RIS beamforming is optimized in a more realistic setting, e.g., imperfect channel estimation and non-ideal or finite bits for phase shifts. The paper “Resource Allocation for Two-Tier RIS-Assisted Heterogeneous NOMA Networks” comes from Zhejiang University and considers heterogeneous networks that consist of macro base stations, small cell base stations and RIS units. In such setting, cross-tier interference becomes a limiting factor to the overall system performance. The problem is formulated as the joint optimization

of transmit power of small cell base stations and phase-shift matrix of RIS, with the aim to maximize the sum rates of all small cells. Non-orthogonal multiple access (NOMA) is employed here to further enhance the system throughput albeit with increased complexity. An efficient sub-optimal algorithm is proposed which is based on alternating iterations to convert the original non-convex problem to a convex approximation. Simulations show that the proposed scheme can reduce the transmit power of small cell base stations by 40% compared to the case without RIS. The paper “Markovian Cascaded Channel Estimation for RIS Aided Massive MIMO Using 1-Bit ADCs and Oversampling” from University of Electronic Science and Technology of China extends the technique of uplink receiver-end oversampling with low-bit width to the scenario of cascaded user-to-RIS and RIS-to-base station where both base station and RIS are equipped with a large number of antenna elements. Bussgang decomposition is applied to handle the coarse quantization, while a Markov chain model is developed for the oversampling filter. The cascaded channels are estimated by the proposed approximate message-passing (AMP) based algorithm. It is shown from the simulation that the proposed 1-bit system with oversampling can deliver the comparable mean square error performance to the 2-bit systems, while requiring significantly less processing power at the receiver. The paper “RIS: Spatial-Wideband Effect Analysis and Off-Grid Channel Estimation” comes from ZTE Corporation, with a focus on the impact of spatial wideband effect on RIS operation. Such impact can be quite significant in millimeter wave deployment whose system bandwidth is typically ~400 MHz. The paper considers sparse channel parameters such as angles and gains, which can be estimated using compressed-sensing algorithm to achieve super resolution. The effectiveness of the algorithm is verified by the simulation results. This paper also discusses several challenges of RIS, for instance, channel modeling, near-field effect, multi-user transmission, and standardization.

The paper “Dual-Polarized RIS-Based STBC Transmission with Polarization Coupling Analysis” describes the recent work by researchers from Southeast University, China. Instead of using RIS as a passive relay, RIS in this paper is employed in the transmitter to replace some of radio-frequency processing modules in traditional base stations. A dual-polarized RIS transmitter is proposed, which can achieve 4-transmit space-time block coding (STBC) with proper partitions of RIS elements with different polarizations. The polarization coupling is thoroughly analyzed by a suitable model. A prototype system of RIS-based STBC is built using the fabricated dual-polarized phase adjustable RIS unit cells. Theoretical performance analysis and experimental results match closely, indicating the effectiveness of the model in characterizing the polarization coupling in RIS.

We would like to thank all the authors for their valuable contributions and all the reviewers for their timely and constructive comments on the submitted manuscripts. We hope that this special issue would be informative and useful for readers.