

**Beyond Diagonal Reconfigurable Intelligent Surfaces:
The Next Frontier for Smart Radio Environment**

Bruno Clerckx, Prof., Imperial College London, UK

Abstract

Reconfigurable intelligent surface (RIS) is expected to be a key technology in 6G to enhance wireless systems by efficiently and cost-effectively manipulating the propagation environment. In conventional RIS, each RIS element is independently controlled by a tunable load disconnected from the other elements. Thus, conventional RIS results in a diagonal scattering matrix, also known as a phase shift matrix, which has limited passive beamforming capabilities. To enhance the flexibility of RIS, beyond diagonal RIS (BD-RIS) has been introduced as a generalization of conventional RIS, in which the scattering matrix is not restricted to being diagonal. In this lecture, we review the emerging concept of BD-RIS, showing its promising benefits in terms of performance, coverage, deployment, and flexibility in wave manipulation over conventional RIS. We discuss the modelling and architectures of BD-RIS and compare the performance and circuit complexity of BD-RIS architectures with conventional RIS. We discuss potential applications of BD-RIS in various wireless systems and outline the future research directions for BD-RIS.

Bio



Bruno Clerckx is a (Full) Professor, the Head of the Wireless Communications and Signal Processing Lab, and the Deputy Head of the Communications and Signal Processing Group, within the Electrical and Electronic Engineering Department, Imperial College London, London, U.K. He is also the Chief Technology Officer (CTO) of Silicon Austria Labs (SAL). He received the MSc and Ph.D. degrees in Electrical Engineering from Université Catholique de Louvain, Belgium, and the Doctor of Science (DSc) degree from Imperial College London, U.K. Prior to joining Imperial College in 2011, he was with Samsung Electronics, Suwon, South Korea, where he actively contributed to 4G (3GPP LTE/LTE-A and IEEE 802.16m). He has authored two books on “MIMO Wireless Communications” and “MIMO Wireless Networks”, 300 peer-reviewed international research papers, and 150 standards contributions, and is the inventor of 80 issued or pending patents among which several have been adopted in the specifications of 4G standards and are used by billions of devices worldwide. His research spans the general area of wireless communications and signal processing for wireless networks. He received the prestigious Blondel Medal 2021 from France for exceptional work contributing to the progress of Science and Electrical and Electronic Industries, the 2021 Adolphe Wetrems Prize in mathematical and physical sciences from Royal Academy of Belgium, multiple awards from Samsung, IEEE best student paper award, and the EURASIP (European Association for Signal Processing) best paper award 2022. He is a Fellow of the IEEE and the IET, and an IEEE Communications Society Distinguished Lecturer.

**Artificial Intelligence and Machine Learning:
Past, Present, and Future**

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Abstract

Machine learning (ML) and artificial intelligence (AI) have progressed from niche research topics to pivotal tools in science, technology, and business, profoundly influencing various societal aspects, including social media and decision-making processes. Their transformative role is evident in fields such as medicine, autonomous vehicles, and computational biology, with Alphafold's protein structure predictions being a notable example. ML and AI enhance traditional scientific methods, facilitating novel solutions to complex challenges. This advancement is epitomized by physics-informed machine learning, which combines data with mathematical models to solve problems that were intractable with conventional numerical methods. In my talk, I will review the history of AI and ML, underscore the economic and technological shifts that have fueled their rapid expansion, and discuss their significant impact on scientific research, as well as technological development and innovation.

Bio



Mário Figueiredo received his MSc (1990), PhD (1994), and Habilitation (*Agregação*, 2004) degrees in Electrical and Computer Engineering, all from Instituto Superior Técnico, University of Lisbon, where he is an IST Distinguished Professor and holder of the Feedzai endowed Chair on Machine Learning. He is also a senior researcher, group leader, and thematic line coordinator at Instituto de Telecomunicações. His research areas include machine learning, signal processing, and optimization. He has received several distinctions and awards, namely: Fellow of the Institute of Electrical and Electronics Engineers (IEEE), Fellow of the International Association for Pattern Recognition (IAPR), Fellow of the European Association for Signal Processing (EURASIP), Fellow of the European Laboratory for Learning and Intelligent Systems (ELLIS), W. R. G. Baker Award (IEEE), EURASIP Technical Achievement Award, member of the Portuguese Academy of Engineering, and member of the Lisbon Academy of Science.