

## **T9. Spatial Modulation for MIMO Wireless Systems**

### **Abstract:**

Future wireless communication systems deployment, including fourth generation (4G) cellular systems, will be based on the MIMO transmission technology. Conventional MIMO schemes usually take advantage of the many antennas available at the transmitter by simultaneously transmitting multiple data streams from all of them. Furthermore, common open-loop MIMO schemes usually assume that all transmit-antennas are simultaneously active at any time instance. By properly choosing the transmission matrices, both multiplexing and transmit-diversity gains can be obtained via space-time coding. As a consequence, higher data rates and smaller error performance are obtained at the cost of: i) increasing the signal processing complexity at the receiver, which is caused by the need to counteract the interference created by simultaneously transmitting many data streams; and ii) making more stringent the synchronization requirements among the transmit-antennas.

Furthermore, more recently, with the advent of the green and sustainable information and communication era, state-of-the-art MIMO schemes are facing two additional major challenges: i) the need of multiple RF chains at the transmitter to be able to simultaneously transmit many data streams, which do not scale with Moore's law and make the transmitter very bulky; and ii) the need of independent power amplifiers for each RF chain, each one being responsible of the vast majority of the power consumed at the transmitter as well as being extremely power inefficient due to the stringent linearity requirements of state-of-the-art phase/amplitude modulations. For example, recent studies have shown that, for a fixed RF output power, the total power consumption of base stations linearly increases with the number of active RF chains.

These considerations imply that a major challenge of next-generation MIMO-enabled wireless networks is the design of multi-antenna transmission schemes with a limited number of active RF chains aiming at reducing circuitry complexity, inter-antenna synchronization requirements, inter-channel interference, signal processing complexity at the receiver, as well as at improving the energy efficiency. Fueled by these considerations, SM has recently established itself as an emerging and promising transmission concept belonging to the "massive" MIMO wireless systems family but exploiting the multiple antennas in a novel way compared with state-of-the-art high-complexity and power-hungry classic MIMOs. This tutorial is intended to offer a comprehensive state-of-the-art survey on SM-MIMO, the critical appraisal of its beneficial application domains and their research challenges, the analysis of the related technological issues associated with the implementation of SM-MIMO, and, finally, the description of the world's first experimental activities in this research field.

### **Speaker's Biography:**

**Marco Di Renzo, French National Center for Scientific Research, France**

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**Marco Di Renzo** (S'05-AM'07-M'09) received the Laurea (cum laude) and the Ph.D. degrees in Electrical and Information Engineering from the Department of Electrical and Information Engineering, University of L'Aquila, Italy, in April 2003 and in January 2007, respectively. From August 2002 to January 2008, he was with the Center of Excellence for Research DEWS, University of L'Aquila, Italy. From February 2008 to April 2009, he was a Research Associate with the Telecommunications Technological Center of Catalonia (CTTC), Barcelona, Spain. From May 2009 to December 2009, he was an EPSRC Research Fellow with the Institute for Digital Communications (IDCOM), The University of Edinburgh, Edinburgh, United Kingdom (UK). Since January 2010, he has been a Tenured Researcher ("Chargé de Recherche Titulaire") with the French National Center for Scientific Research (CNRS), as well as an academic staff member of the Laboratory of Signals and Systems (L2S), a joint research laboratory of the CNRS, the Ecole Supérieure d'Electricité (SUPELEC), and the University of Paris-Sud XI, Paris, France. His main research interests are in the area of wireless communications theory, signal processing, and information theory. Dr. Di Renzo is the recipient of the special mention for the outstanding five-year (1997-2003) academic career, University of L'Aquila, Italy; the THALES Communications fellowship for doctoral studies (2003-2006), University of L'Aquila, Italy; and the Torres Quevedo award for his research on ultra wide band systems and cooperative localization for wireless networks (2008-2009), Ministry of Science and Innovation, Spain. He has been a Technical Program Committee (TPC) member of many IEEE conferences and a reviewer in major IEEE journals. Currently, he serves as an Editor of the IEEE COMMUNICATIONS LETTERS. He is an author of more than 130 IEEE journal and conference papers, and he is a co-recipient of the IEEE CAMAD 2012 Best Paper Award.

**Ali Ghrayeb** (S'97-M'00-SM'06) received the Ph.D. degree in electrical engineering from the University of Arizona, Tucson, USA in 2000. He is currently a Professor with the Department of Electrical and Computer Engineering, Concordia University, Montreal, QC, Canada. He is a co-recipient of the IEEE Globecom 2010 Best Paper Award. He holds a Concordia University Research Chair in Wireless Communications. He is the co-author of the book "Coding for MIMO Communication Systems" (Wiley, 2008). His research interests include wireless and mobile communications, error correcting coding, MIMO systems, wireless cooperative networks, and cognitive radio systems. Dr. Ghrayeb has instructed/co-instructed technical tutorials related to MIMO systems at several major IEEE conferences, including ICC, Globecom, WCNC and PIMRC. He served as a co-chair of the Communications Theory Symposium of IEEE Globecom 2011, Houston, Texas. He serves as an Editor of the IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, the IEEE TRANSACTIONS ON COMMUNICATIONS, and the Physical Communications Journal. He served as an Editor of the IEEE TRANSACTIONS ON SIGNAL PROCESSING, an Associate Editor of the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY.

**Harald Haas** (S'98-AM'00-M'03) holds the Chair of Mobile Communications in the Institute for Digital Communications (IDCOM) at the University of Edinburgh. He is co-founder and part-time CTO of a university spin-out company pureVLC Ltd. His main research interests are in the areas of wireless system design and analysis as well as digital signal processing, with a particular focus on

interference coordination in wireless networks, spatial modulation, and optical wireless communication. Professor Haas holds more than 23 patents. He has published more than 55 journal papers including a Science Article and more than 160 peer-reviewed conference papers. Nine of his papers are invited papers. He has co-authored a book entitled "Next Generation Mobile Access Technologies: Implementing TDD" with Cambridge University Press. Since 2007, he has been a Regular High Level Visiting Scientist supported by the Chinese "111 program" at Beijing University of Posts and Telecommunications (BUPT). He was an invited speaker at the TED Global conference 2011. He has been shortlisted for the World Technology Award for communications technology (individual) 2011. He is Associate Editor of IEEE TRANSACTIONS ON COMMUNICATIONS. He has been chair and co-chair of the Optical Wireless Communications (OWC) workshop at Globecom 2011 and 2012 respectively. He recently has been awarded the EPSRC Established Career Fellowship.