Title: Spatial Modulation for MIMO Wireless Communications Systems

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Motivation and Objectives:

The key challenge for future wireless communications is to make these networks energy-efficient and spectrum efficient *at the same time*. This results in a paradigm-shifting requirement which necessitates a *clean-slate approach* of wireless system design. Clearly, such approach will have to embrace the rich body of knowledge that has been created especially on Multiple-Input-Multiple-Output (MIMO) technology during the last 25 years.

This motivates us to give a talk on an emerging wireless communications concept for "massive" MIMO systems, which is today known under the name of Spatial Modulation (SM). SM has recently established itself as a beneficial transmission paradigm, potentially subsuming all members of the MIMO wireless system family, which exploits multiple antennas in a novel fashion. The research on SM has reached sufficient maturity to substantiate its claimed advantages compared with state-of-the-art standardized MIMO concepts, as well as its applications to other emerging wireless systems such as relay-aided, cooperative, small cell, optical wireless, and green communications. Furthermore, it has received sufficient attention to be implemented in testbeds, and holds the promise of stimulating further vigorous inter-disciplinary research in the next years. We believe that this is a timely topic and we anticipate that this talk will be of interest to many researchers/students/practitioners with different backgrounds.

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 talk 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.

Detailed Outline

1. SM-MIMO: Operating Principle and Generalized Transceiver Design
    a. Short overview of MIMO wireless systems
    b. Advantages and disadvantages of MIMO, and motivation behind SM-MIMO
    c. Generalized MIMO transceiver based on SM (transmitter, receiver, spatial- and signal-constellation diagrams)
    d. Advantages and disadvantages of SM-MIMO (single-RF, single-stream decoding, low-complexity "massive" implementation, etc.)
2. SM-MIMO: A Comprehensive Survey
    a. Historical perspective
    b. State-of-the-art on transmitter design
    c. State-of-the-art on receiver design
    d. State-of-the-art on transmit-diversity and space-time-coded SM-MIMO
    e. State-of-the-art on performance and capacity analysis over fading channels
    f. State-of-the-art on performance and design in the presence of multiple-access interference

    g. State-of-the-art on robustness to channel state information at the receiver
    h. etc.

3. SM-MIMO: Application Domains Beyond the PHY-Layer
    a. Distributed/network implementation of SM-MIMO
    b. Application to relaying-aided and cooperative wireless networks
    c. Application to green networks: “Massive” SM-MIMO design and the GreenTouch initiative
    d. Application to visible light communications: From MIMO-WiFi to SM-MIMO-LiFi

4. SM-MIMO: Research Challenges and Opportunities
    a. Space-time coded SM-MIMO with single-RF transmitter and single-stream decoding
    b. Channel-aware receiver design for distributed SM-MIMO design
    c. Channel-aware robust pre-coding for network SM-MIMO design
    d. Interference-aware transmitter and receiver design for heterogeneous small cell cellular systems
    e. Implementation challenges of SM-MIMO design

5. SM-MIMO: From Theory to Practice - Initial Experimental Results and Channel Measurements from a Testbed Platform
    a. Description of the hardware testbed
    b. Description of the measurements campaign
    c. Real-world performance results and comparison with state-of-the-art MIMO

Bios of the Presenter

Marco Di Renzo (SM’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 Academic Researcher (“Chargé de Recherche Titulaire”) with the French National Center for Scientific Research (CNRS), as well as a faculty 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; the 2012 IEEE CAMAD Best Paper Award; and the 2013 Reviewer Appreciation Award from the IEEE Wireless Communications Letters. He has been a Technical Program Committee (TPC) member of many IEEE conferences and a reviewer in major IEEE journals. He is an author of more than 130 IEEE journal and conference papers. Currently, he serves as an Editor of the IEEE COMMUNICATIONS LETTERS.