

Tutorial: Multiple-antenna systems for communications - Smart antennas, MIMO systems, and the propagation channels they operate in

Abstract

Smart antennas and MIMO (multiple-input multiple-output) systems utilize multiple antennas at one and at both wireless link ends, respectively. These techniques can be used to increase the capacity of mobile radio systems, both for upgrading second-generation systems and for use in third- and fourth generation systems. Thus, multi-antenna systems have attracted enormous interest and a lot of effort has been spent for its system development and standardization. The tutorial will give a comprehensive overview over all relevant aspects of smart antenna and MIMO systems.

The mobile radio channel, especially its directional nature defined by the directions-of-arrival and directions-of-departure of the waves propagating from transmitter to receiver, determines the performance of multi-antenna systems. Therefore, we start out with an introduction of spatial channel sounding techniques forming the basis for spatial channel measurements and spatial channel characterization. We present measurement results of the directional channel properties as seen from the base station and from the mobile terminal only, as well as measurements of the double-directional propagation characteristics. We then explain how these measurement results can be utilized and included in spatial channel models, which are required for the design and development of adaptive antenna and MIMO systems.

Next, we describe transceiver structures and algorithms for smart antennas at one link end. After an introduction to the basic smart antenna technology, we describe different adaptation techniques for multi-antenna reception in detail. Thereby, we consider temporal reference, spatial reference as well as blind adaptation algorithms and present their performance in different propagation conditions. Moreover, the fundamental differences of reception and transmission using several antennas will be explained and transmission strategies including downlink beamforming and transmission diversity will be derived. The more practical aspects of roll-out and capacity of smart antenna base stations – especially in the context of 3G systems - will complete the considerations of multiple antennas at one link end.

Next, we present the two operation modes of MIMO systems applying multiple antennas for transmission and reception: diversity enhancement, and BLAST-like schemes. In the former case, the multiple antennas at both link ends are used to provide a high degree of diversity, resulting in a high-quality link. We explain what diversity degree and beamforming gain can be achieved in different types of wireless channels. Then, we describe BLAST schemes where independent data streams are sent from the different transmit antennas, and the multiple receive antennas are used to receive and separate those different data streams. We show how the capacity of these systems can increase linearly with the number of transmit and receive antennas. Different BLAST

implementations are explained, and their advantages and drawbacks are discussed. Finally, we demonstrate the principles of space-time codes, and show how those can be applied for diversity and capacity increase. A discussion of interference-limited MIMO systems, and of waterfilling schemes, will round off the presentation.

Speaker's bio

Andreas F. Molisch (S'89, M'95, SM'00, F'05) received the Dipl. Ing., Dr. techn., and habilitation degrees from the Technical University Vienna (Austria) in 1990, 1994, and 1999, respectively. From 1991 to 2000, he was with the TU Vienna, becoming an associate professor there in 1999. From 2000-2002, he was with the Wireless Systems Research Department at AT&T (Bell) Laboratories Research in Middletown, NJ. Since then, he has been with Mitsubishi Electric Research Labs, Cambridge, MA, where he is now a Distinguished Member of Technical Staff. He is also professor and chairholder for radio systems at Lund University, Sweden.

Dr. Molisch has done research in the areas of SAW filters, radiative transfer in atomic vapors, atomic line filters, smart antennas, and wideband systems. His current research interests are measurement and modeling of mobile radio channels, UWB, cooperative communications, and MIMO systems. Dr. Molisch has authored, co-authored or edited four books (among them the recent textbook "Wireless Communications, Wiley-IEEE Press), eleven book chapters, some 100 journal papers, and numerous conference contributions.

Dr. Molisch is an editor of the IEEE Trans. Wireless Comm., co-editor of recent or upcoming special issues in J. Wireless Comm. Mob. Comp., IEEE – JSAC, and the Proceedings of the IEEE. He has been member of numerous TPCs, vice chair of the TPC of VTC 2005 spring, general chair of ICUWB 2006, TPC co-chair of the wireless symposium of Globecom 2007, and TPC chair of Chinacom2007. He has participated in the European research initiatives "COST 231", "COST 259", and "COST273", where he was chairman of the MIMO channel working group, he was chairman of the IEEE 802.15.4a channel model standardization group, and is also chairman of Commission C (signals and systems) of URSI (International Union of Radio Scientists). Dr. Molisch is a Fellow of the IEEE, an IEEE Distinguished Lecturer, and recipient of several awards.