Measurement and modeling of wireless propagation channels for MIMO and UWB

Andreas F. Molisch

Lund University, Sweden and Mitsubishi Electric Research Lab, USA

Fredrik Tufvesson

Lund University, Sweden

Ernst Bonek

Technische Universität Wien, and Forschungszentrum Telekommunikation Wien (ftw), Vienna, Austria

Abstract

The last decade has seen several exciting developments in wireless communications. Two of the most notable ones are the emergence of (i) MIMO (multiple-input multiple-output) systems, which utilize multiple antennas link ends, thus exploiting the spatial domain, and (ii) ultrawideband systems, which spread the signal over extremely large bandwidths, and can operate simultaneously with narrowband (legacy) systems, thus exploiting the frequency domain in a new way.

The ultimate performance limits, as well as the performance of practical systems, of any wireless system is limited by the wireless propagation channels that the system is operating in. It is thus critical that we understand the channel properties that are relevant for the systems under consideration: directional properties of the multipath components in the MIMO case, and variations of the channel frequency response over a large frequency range for UWB systems. Any such understanding must be based both on the understanding of the physical propagation processes and actual measurements; furthermore, it is very helpful to have good channel models that can be used to test the performance of algorithms and systems. All of these aspects will be treated in our tutorial.

We start out with an introduction of channel sounding techniques, emphasizing the spatial sounding techniques that form the basis for spatial channel measurements and spatial channel characterization. We will present new 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. Both indoor and outdoor scenarios will be treated. We will 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.

Then, the various methods to model the directional radio channel will be discussed. The relative merits and shortcomings of measurement-based stochastic models, relying on parameter estimation techniques; of geometry-based parametric models, approximating a

radio environment by geometry, but adding stochastic processes; and of deterministic models (ray-tracing or measured) will be highlighted. The accuracy of prediction of the channels as well as the need for tuning of these various approaches will be compared. Finally, a comprehensive report on standardized MIMO channel modeling will be given. It includes the models of 3GPP/3GPP2 for outdoor environments, the IEEE 802.11n models for indoor environments, and the COST 273 model, which is valid for all environments.

We then turn our attention to UWB channel measurements. We first discuss the generic differences between UWB propagation and narrowband propagation. We then discuss the results of several existing measurement campaigns, and how the results reflect those differences. Finally, we describe the standardized UWB channel models of IEEE, namely the 802.15.3 and 802.15.4a models, and how the propagation characteristics reflected in those models influence UWB system design.

Biographies

Andreas F. Molisch received the Dipl. Ing., Dr. techn., and habilitation degrees 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 a Senior Principal Member of Technical Staff with Mitsubishi Electric Research Labs, Cambridge, MA. He is also professor and chairholder for radio systems at Lund University, Sweden. He is also deputy director of the SSF Inter-University Center of Excellence for High-Speed Wireless Communications.

Dr. Molisch's current research interests are measurement and modeling of mobile radio channels, MIMO systems, sensor networks, and UWB. He has authored, co-authored or edited four books (among them the recent textbook "Wireless Communications, Wiley-IEEE Press), eleven book chapters, some 85 journal papers, and numerous conference contributions. 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 has been editor and guest editor for several journals, and chairman, vice-chairman, of TPC member for a number of conferences. He is a Fellow of the IEEE and recipient of several awards

Fredrik Tufvesson was born in Lund, Sweden 1970. He received the M.Sc. degree in Electrical Engineering from Lund University, Sweden, in 1994, the Licentiate Degree in 1998 and got his Ph.D. in 2000. After one and a half year at a startup company, Fiberless Society, working on fixed wireless systems Fredrik is now an associate professor in radio systems at the Department of Electroscience, Lund University. His main research area is channel measurements and modeling for both MIMO and UWB systems. Beside this, his research interests include channel estimation and synchronization problems in wireless OFDM systems and tranceiver structures for wireless communication.

Ernst Bonek was born in Vienna, Austria, 1942. He received the Dipl. Ing. and Dr. techn. degrees (with highest honors) from the Technische Universität (TU) Wien. In 1984, he was appointed Full Professor of Radio Frequency Engineering at the TU Wien. Since then, his field of interest has been mobile communications at large. Recent contributions concern the characterization of mobile radio channels and advanced antennas designs, mostly smart antennas. Altogether, he authored or co-authored some 180 journal publications, and contributed to two books, “Wireless Internet Access over GSM and UMTS” and “Advances in UMTS Technology”. He holds several patents on mobile radio technology. He is a former Chairman of Commission C “Signals and Systems “ within URSI (Union of Radio Scientists). Currently he is Chairman of the "Antennas and Propagation" working group in the European research initiative COST 273 "Toward Mobile Multimedia Networks”. Recently, he enjoyed the privilege of a two months visit to NTTDoCoMo´s Research Lab in Yokosuka, Japan, as a Guest Professor on “Adaptive Antenna Technology”.