Chapter XXII

Field Programmable Gate Array Based Testbed for Investigating Multiple Input Multiple Output Signal Transmission in Indoor Environments

Konstanty Bialkowski
University of Queensland, Australia

Adam Postula
University of Queensland, Australia

Amin Abbosh
University of Queensland, Australia

Marek Bialkowski
University of Queensland, Australia

ABSTRACT

This chapter introduces the concept of Multiple Input Multiple Output (MIMO) wireless communication system and the necessity to use a testbed to evaluate its performance. A comprehensive review of different types of testbeds available in the literature is presented. Next, the design and development of a 2×2 MIMO testbed which uses in-house built antennas, commercially available RF chips for an RF front end and a Field Programmable Gate Array (FPGA) for based signal processing is described. The operation of the developed testbed is verified using a Channel Emulator. The testing is done for the case of a simple Alamouti QPSK based encoding and decoding scheme of baseband signals.

EVOLUTION OF SMART ANTENNAS AND MIMO

In the past two decades, wireless communication systems have grown with an unprecedented speed from radio paging, cordless telephone, and cellular telephony to multimedia platforms offering voice and video streaming, interactive services, and even a global positioning information of the user. One undesired outcome of this expansion is a heavy utilization of...
Field Programmable Gate Array Based Testbed

As the conventional coding and modulation techniques are unable to overcome the problem associated with the limited frequency spectrum, the designers turn to the space/angle domain to improve capacity and reliability of wireless systems. This approach is already in use in many currently available terrestrial and satellite communication systems. The best known example is the cellular telephony. By creating physically separated cells, the same frequency spectrum is re-used only at an expense of small interference between adjacent cells. A further extension of the cellular concept is via the introduction of sectored cells. This task is realized by antennas at base stations having sectoral radiation patterns instead of omnidirectional ones. More advanced versions of this concept are antennas serving a variable width sector. This is required, to overcome a bottleneck caused by an excessive number of users in a particular time of the day in this sector (Rosol, 1995). Such an intelligent antenna system is an example of the simplest type of smart antenna (Liberti and Rappaport, 1999). A more advanced form, known as an adaptive antenna, can follow individual mobile users by forming narrow beams towards them. At the same time, they can produce nulls or low side lobes towards undesired users. In all of these cases, multiple element antennas (MEAs) are instrumental to divide space into angular slots and adapt their width in time so that the wireless system can serve an increased number of users. It is apparent that such intelligent systems are capable to fight co-channel interference and thus, they are able to improve the quality of a communication link.

All of these benefits are possible if an MEA systems are capable to distinguish between signals coming from desired and undesired directions. Such a task is relatively easy to accomplish under Line of Sight (LOS) signal propagation conditions. As a result, adaptive antennas rely on LOS conditions for their proper operation. In order to achieve this condition in practice, base station antennas are located on elevated platforms so their operation is unaffected by the presence of surrounding objects. Such conditions are usually difficult to fulfill for mobile units. This is because they operate at low heights and therefore their operation is affected by the presence of various scattering, refracting or reflecting objects that surround them.

Meeting LOS conditions becomes more challenging for indoor scenarios, as the signal’s propagation is affected by walls, indoor furniture, equipment and humans. Under such conditions, signals of similar strength arrive from many directions at antennas. As a result, there is not much benefit from forming narrow beams. This is because there are too many directions at which these beams need to be formed.

It has been pointed out in (Foschini, 1996; Telatar, 1999; Gesbert et al., 2003; Paulraj et al., 2004) that this unfavorable situation for an adaptive antenna employing a beamforming strategy can be resolved in a positive manner when both the transmitter (TX) and the receiver (RX) employ multiple element antennas. The reason is that the rich-in-scattering Non-Line of Sight (NLOS) signal propagation conditions offer multiple virtual channels between the transmitter and receiver, which fade independently. If the propagation conditions change sufficiently slowly the receiver is capable to learn about the virtual channels from training sequences (the data known both to the transmitter and receiver) and utilize them in an advantageous manner. Telatar (1999) has shown that if such channels are independent and identically distributed (have identical statistical properties), the capacity is M-fold greater than of a conventional system equipped with single antennas at the TX and RX sides, where M is the minimum number of TX/RX antennas. Such a system is named a multiple input multiple output (MIMO) system. Following this new designation, smart antennas, depending on whether they are use at the transmitter or receiver, are designated as MISO or SIMO, while the conventional fixed beam antenna systems are named as SISO systems.

From the above it is apparent that multiple element antennas accompanied by suitable signal processing algorithms at one or two sides of a communication link can lead to substantial gains in capacity of wireless systems without additional frequency spectrum. These antenna systems are also capable of offering a better quality communication link via diversity when the signals in virtual channels are uncorrelated (Jakes, 1974; Rappaport, 2002). The benefits occur when the amplitude of a correlation coefficient is in the order of 0.7 or smaller. The signals appearing in virtual channels (branches) are of a similar strength.

It is apparent that MEA used at one or two sides of communication link can offer various modes of operation of wireless system. These include beamforming, multiplexing and diversity. The choice of a particular mode depends needs on the actual properties of a communication channel.
Related Content

Application of Cognitive Radio in VANET
www.igi-global.com/chapter/application-cognitive-radio-vanet/78242?camid=4v1a

Mobile WiMAX Bandwidth Reservation Thresholds: A Heuristic Approach
www.igi-global.com/article/mobile-wimax-bandwidth-reservation-thresholds/55882?camid=4v1a

Nanocomputing in Cognitive Radio Networks to Improve the Performance
www.igi-global.com/chapter/nanocomputing-cognitive-radio-networks-improve/78237?camid=4v1a

Broadband Developments in the United States Subsequent to the Federal Communications Commission's 2010 National Broadband Plan
www.igi-global.com/article/broadband-developments-in-the-united-states-subsequent-to-the-federal-communications-commissions-2010-national-broadband-plan/104630?camid=4v1a