

# Simulation of MIMO Antenna Systems in Simulink and Embedded Matlab

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**Abstract**—Multi-Input Multi-Output (MIMO) has emerged as a hot topic in wireless communications during the last decade. This is due to possible dramatic increases in reliability and capacity as compared to single-antenna solutions. However, much of the existing theoretical results are based on very simplistic models of the antennas and transceiver circuitry. Within the Strategic Research Center on Antenna Systems Chalmers at Chalmers, we are developing a systems simulator for making more realistic studies of MIMO systems. Models of different complexity can be used for the different components. For the linear components, S-parameters are used as the interface. These can come from theoretical models, electromagnetic field simulations, or directly from measurements. For the non-linear components, simple memoryless models can be used, as existing in the RF Toolbox. However, wideband applications demand more elaborate models. We have implemented a so-called memory polynomial model, which has been found to match measurements of non-linear wideband power amplifiers well. Since RF Toolbox cannot handle multi-port scattering matrices (yet), the MIMO part is here computed in a Matlab function, and then implemented as a MIMO transfer function. The paper describes an implementation of a transceiver chain including mixers, filters, PA/LNA, matching network, MIMO antennas and channel models. The simulator can be used for a wide range of wireless communication applications.

## I. INTRODUCTION

Today, hardly any hardware of some complexity is built without first performing extensive computer simulations. Communication and radar systems involving antennas is no exception. However, in almost all cases a communication (or radar) system is simulated with very crude models of the hardware and underlying physics. In contrast, the hardware (e.g. antennas) design is based on detailed electromagnetic simulation, but not taking the system aspects into account. The purpose of this paper is to describe some steps in bridging the gaps between system and hardware level simulation, based on Matlab and Simulink. The goal is to be able to directly see the effect of component design, or architecture, on system-level performance measures. The focus in this presentation is on a wireless communication system, and the performance measures are usually given in the form of bit-error rate (BER) or some other Quality-of-Service (QoS) measure. The ultimate goal of such a system-level simulator is to enable system-level optimization of components, such as material properties or

physical dimensions of antennas etc. However, in this presentation the focus is on simulation of the hardware models at radio frequency (RF). Some details regarding implementation of the signal processing part of a MIMO (Multiple Input Multiple Output) Wideband Code-Division Multiple Access (WCDMA) system, which is the 3G standard for mobile telephony, is given in the companion paper [1].

This paper is organized as follows: The next subsection gives a short introduction to MIMO communication systems, after which an overview of the architecture is given. Section II presents our implementation of the MIMO channel, whereas the antenna frontend is presented in III. This block consists of all parts of the transmitter (receiver) that are represented with physical scattering (S-parameter) models. This includes the antenna, matching network, receiver filters, and also the front-end of the amplifier. In IV, the implementation of amplifier non-linearities is discussed. Section V presents some preliminary simulation results, whereas Section VI concludes the paper.

### A. MIMO in Wireless Communication

During the last 20 years or so there has been a tremendous growth in the wireless communication industry. In the beginning, the focus was only on speech, and the challenge was to allocate as many users as possible within a given bandwidth. Today, there is also an increasing demand in bitrate, to allow more advanced services such as video streaming and TV. Traditionally, the growing demand of capacity has been met by increasing the bandwidth and/or by inventing more spectrally efficient communication protocols. However, since the introduction at Bell Labs about 10 years ago (see e.g. [2]), the concept of MIMO (Multiple Input Multiple Output) has received an increasing attention. The main observation is that if both the transmitter and the receiver are equipped with  $n$  antennas, the capacity (bitrate) can be increased by up to a factor of  $n$ , depending on the richness of the wireless channel. In principle, one can form  $n$  parallel channels, which can transmit independently of one another. In general, this is not possible for line-of-sight (LOS) channels, since the multiple channels cannot be independent and will therefore interfere. However, in a rich scattering environment, the capacity can increase by a factor up to  $n$  [3]. The transmission of data in parallel streams is usually referred to as *spatial multiplexing*.

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