Capacity of MIMO Systems: Impact of polarization, mobility and environment

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This work presents results concerning the MIMO channel capacity of a real wireless channel. For the analysis, we developed a real time UMTS MIMO Sounder platform at Eurecom Institute. The platform, also called EMOS (Eurecom MIMO Openair Sounder), is able to give actual information of the channel environment, offering a possibility to estimate the MIMO channels and the instantaneous capacity. With the available results, the impact of polarization, terminal mobility and propagation environment (small versus large delay spread) are analyzed with the purpose of characterizing the system capacity.

Keywords: MIMO, Capacity, channel propagation, mobile terminal

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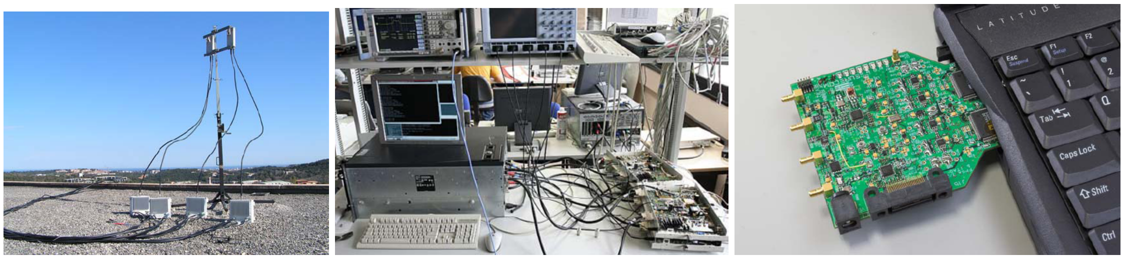
1 Introduction

During the last years, many studies were developed to investigate the capacity offered by Multiple-Input Multiple- Output (MIMO) systems [FG98, Tel99, CS01]. By exploiting the multipath propagation channel, multiple antenna systems were shown to significantly increase the performance of single antenna systems. As a consequence, single user MIMO systems have gained more and more attention.

Eurecom has a long tradition working on mobile communications hardware and has built up two hardware platforms. Both platforms are able to cope with multiple antennas which is the key request for MIMO communications. The goal of this work is to explore the impact of the channel environment in more detail using Eurecom's hardware platform.

2 Eurecom MIMO Openair Sounder (EMOS)



(a) Antennas and power amplifiers. (b) Transmit server. (c) Eurecom dual-RF CardBus/PCMCIA Card.

Figure 1: EMOS equipment.

2.0.1 General features

The EMOS equipment operates in the 1.9GHz UMTS-TDD band using a bandwidth of 5MHz. The output power of the transmitter is 34 dBm. For the measurements, different sets of transmit- and receive-antenna combinations have been used: 2x1, 2x2, 4x2. Since the first two antenna combinations can be seen as a subset of the third one, in this work we measured the channel using the full antenna combination (4x2). In our system, we use 2 dual polarized transmit-antennas (patch-elements) at the Eurecom's building roof top (see figures 1(a) and 1(b)) and use two omni-directional receive antennas for each receiver. A set of 3 receivers are possible to perform multi-user measurement.

For the transmit part of the channel sounder the PLATON Cards [BCE+00,BGH+02,BCG+03,BCG+05] were used. In this case, it is possible to stack up to 4 cards to get the 4 required transmit channels. The PLATON cards were originally built as a UMTS-TDD testbed and include much more functionality than required for the measurements.

For the receiver part, we use Eurecom's dual-RF CardBus/PCMCIA card (see figure 1(c)) which allow for two-way real-time experimentation (physical layer, MAC and networking layer) with reconfigurable broadband air interfaces. In addition, it allows for experimenting with system on-chip architectures for wireless communications.

2.1 Transmit signal

At the transmitter four pilot sequences are transmitted in parallel. The receiver antennas synchronize to that signal. With the designed hardware, one is able to transmit arbitrary sequences. To be able to track back the timing information of the system, the transmit sequences are time-coded. This allows further correlation analisis of several receivers.

The hardware was originally built to fulfill the UMTS standard and therefore the UMTS data structure has been used for the measurements as well. Since channel estimation is the crucial task, the pilot sequence uses the first 2048 chips of the UMTS time slot. The timing information is inserted after the transmission of the pilot sequence. The guard interval between the slots is larger than in the UMTS standard since spectral efficiency is less critical for channel measurements. Note that the silent guard interval is used for noise estimation.

To allow easy channel estimation, the sequences for different antennas are generated as cyclic shifted sequences. Again this approach is not optimal from a spectral efficiency point of view, but requires only one FFT to obtain all the impulse responses of one receive antenna at the receiver.

2.2 Graphical User Interface (GUI)

To allow for an easy operation of the measurement hardware without specific training, a graphical user interface was designed. The GUI allows for adjusting the most important measurement parameters like the sample rate of impulse responses and the number of measured snapshots. In addition it provides fields for documentation parameters like the receive and transmit position of a single measurement run.

3 Measurement Environment

The area of Sophia Antipolis, where Eurecom Institute is situated, covers rural to suburban environments. The usual building height is about 4 stories. Measurements were performed inside street canyons and at open places. For some of the measurements, small delay spread is considered while most of the measurements are performed under large delay spread conditions. For the study conducted within this work, two measurement campaigns that mostly characterize these two environments were selected. The aerial view of the environments are given in Figure 2 showing the measurement routes. The base station is positioned on top of the Eurecom building for all the measurements. The TX antennas are mounted on a mast of 3m height.

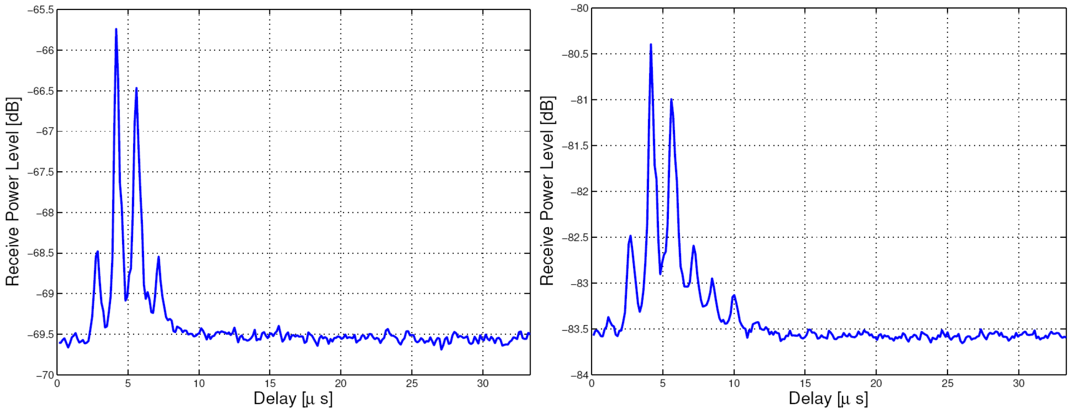
(a) Small delay spread.

(b) Large delay spread.

Figure 2: Small and large delay spread measurement routes.

4 Results

The results obtained consider two different environments as described in the previous section. A slow power control is applied in an offline manner over the results. In Figures 3(a) and 3(b), an example sample from the impulse responses is shown for both environments. From these figures it is possible to see a reduction of the overall signal power for the large delay profile case in comparisson to the small one. This is caused by the attenuation of the signal power due to the shadowing from the surrounding buildings. One can also notice, as expected, that the large delay profile case is indeed caracterized by a greater dispersion of the delay spread, denoting the presence of nore multipaths than the low delay profile case.

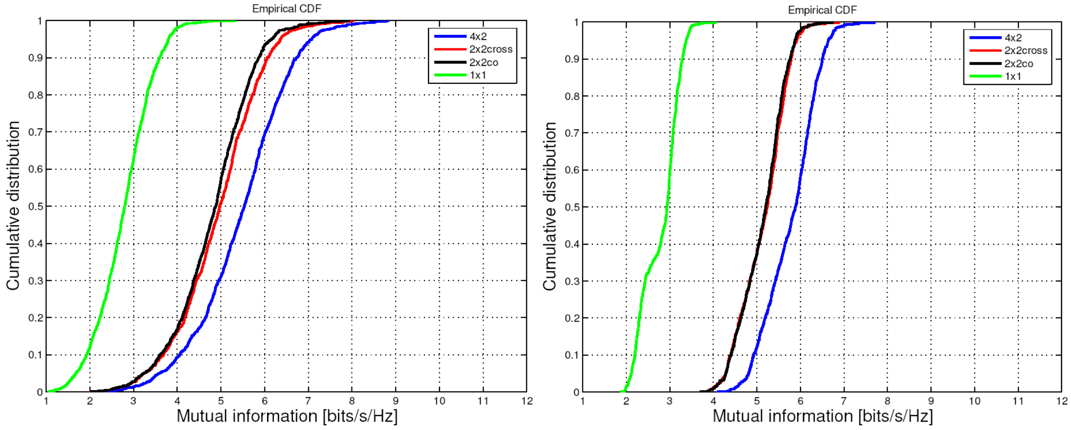


(a) Small delay spread.

(b) Large delay spread.

Figure 3: Measured impulse responses for the EMOS platform.

In figures 4(a) and 4(b), the Cumulative Distribution Function (CDF) of the mutual information is given for both the small and large delay profile cases, comparing the 4x2, 2x2 co-polarized, 2x2 cross-polarized and 1x1 (TX x RX) setups. From these figures it is possible to see that, as expected, the largest capacity is obtained from the 4x2 case, followed by both 2x2 combinations and finally by the SISO case. It is also noticeable that the large delay profile case has a gain over the small one. The large delay spread case profits from a greater number of multipaths enabling a better exploitation of the available diversity.



(a) Small delay spread.

(b) Large delay spread.

Figure 4: CDF of the mutual information for the EMOS platform for 4 TX-RX antenna combinations.

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