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LTE-Advanced 8×8 MIMO Measurements in an Indoor Scenario

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Abstract

The potential link performance gains obtained with up to 8×8 MIMO transmissions as standardized in 3GPP LTE Release 10 have been evaluated in an indoor measurement campaign using a testbed implementation. For well-separated antennas, the results show increasing downlink throughput when increasing the number of transmit and receive antennas, up to a median throughput of 335 Mbps for an 8×8 MIMO configuration on a 20 MHz carrier. A similar and only slightly smaller throughput is achieved when using a compact UE array of a size that is more reasonable for a consumer device implementation.

1. Introduction

Multiple input multiple output (MIMO) systems have attracted much attention as a key enabler for an increased spectral efficiency. The 3GPP Long Term Evolution (LTE) standard for mobile broadband in its release 10 [1], also known as LTE-Advanced, includes multi-antenna transmission modes that permit the design of algorithms to improve performance in a wide range of scenarios. A new transmission mode introduced in LTE Rel. 10 is the transmission mode 9 (TM9) which supports non-codebook based precoding for MIMO transmissions up to eight layers.

Previous work, covering field measurements of antenna configurations up to 4×4 MIMO (number of transmit antennas × number of receive antennas) for HSPA and LTE Rel. 8, has been presented in [2,3]. This paper presents the results of a measurement campaign carried out with the aim of better understanding the practical gains with 3GPP LTE Rel. 10 with support for 8×8 MIMO.

2. Testbed Description

The results and measurements presented in this paper have been obtained with an LTE-Advanced testbed developed by Ericsson. The main components of the testbed are the same as the ones incorporated in the latest Ericsson radio base-station hardware product line for LTE. The system is aligned with the LTE FDD mode of 3GPP LTE Rel. 10. Hence, the measurement results are expected to be representative of the relative performance gains of setups utilizing up to 8x8 MIMO on LTE systems. However, the higher layers and the control features of the testbed are not aligned with the commercial requirements and therefore absolute performance can not be extrapolated to be representative of the products.

The testbed consists of one base station (eNB) and a single user equipment (UE) which is scheduled over the entire bandwidth (20 MHz) for downlink transmission with full buffers at a carrier frequency of 2.7 GHz. The impact of interference is not covered in this study.

The eNB system supports up to eight antennas for downlink transmission and the UE system supports up to eight receive antennas with a linear MMSE receiver. Since, in TM9, the reference symbols intended for demodulation (DM-RS) are precoded together with the data, the choice of the codebook is transparent to the UE. An open-loop spatial diversity scheme for MIMO precoding has been implemented, in which the precoders, designed to select different antennas, are cycled in frequency.

In order to extract performance figures per rank, a fixed transmission rank choice pattern is used where each subframe is assigned a specific rank. The rank pattern is repeated with a cycle of 10 ms and link adaptation is performed per rank. This allows the logging of throughput, block error rate, and channel estimates at a rate of 10 ms.

3. Measurement setup

The measurements were conducted indoors in a 15×70 m section of an office building.. This building consists of a long corridor with offices on both sides. The inner walls are made of plaster and glass, while the outer walls are reinforced concrete and brick.. The eNB was located in the centre of the corridor, thereby providing good coverage throughout the whole area. This deployment is similar to one antenna installation in a distributed antenna systems (DAS), where one cell serves an entire building using multiple, geographically separated, antennas that are passively or actively combined. Further, it is also representative of a single, small cell, deployment. Four dual-polarized (vertical and horizontal polarization) omni directional Kathrein 80010709, antennas were connected to the eight ports of the eNB. The antennas were mounted in the ceiling, in a square configuration with two different antenna spacings: a closely spaced, 26 cm spacing (2.3λ), and a widely spaced, 1 m spacing (9λ). The total transmit power was restricted to 10 mW which is representative of e.g. one radio head in a DAS. The transmit power is normalized over the number of layers and the number of transmit antennas.

One measurement route consists of a walk through the full corridor and several offices, thus covering varying channel conditions such as line of sight and non line of sight. During each measurement run, the UE locations were manually recorded in a map. Figure 1 shows the two UE antenna setups used in the measurements. To explore the potential with low correlated antennas, a reference configuration consisting of four electric and four magnetic dipole antennas arranged in a well-separated rectangle with 20 cm spacing (1.8λ) was used. A second antenna setup consisting of four dual-polarized patch elements in a uniform linear array configuration with 0.5λ spacing (5.5 cm) was also employed. This configuration is indicative of the array size that would be possible to install in a consumer device. In this case the size of the array is comparable to the width of an iPad as shown in Figure 1.

The UE was configured to operate with two, four, or eight antennas. When using less than eight antennas, the selection of the UE antennas to connect to differed for each of the two setups described above. For the well-spaced setup sub-arrays were chosen with maximum spatial or polarization separation, while for the compact array the 2- or 4-element sub-arrays were selected from the minimal spatial separation, i.e. one or two patches were used.

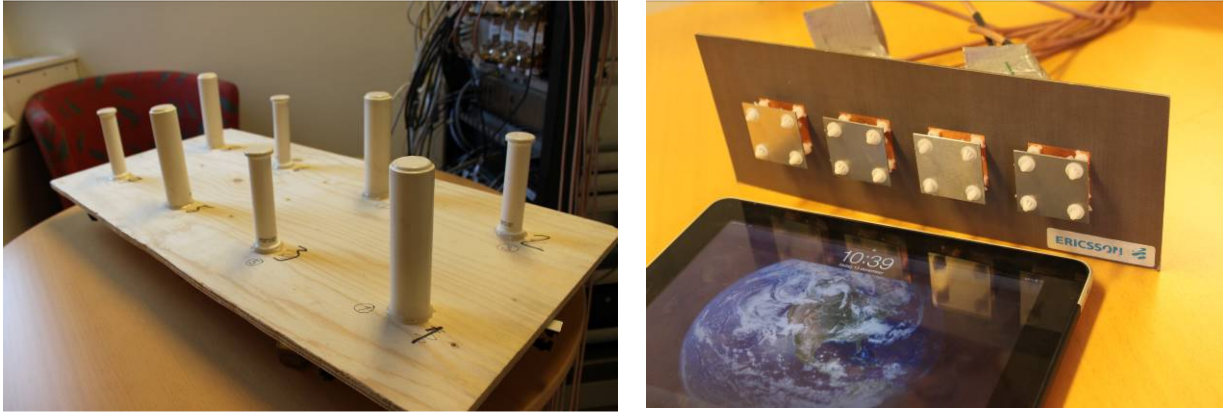

Figure 1 Reference UE antenna array (left) and compact array (right).

4. Field measurements and analysis

A set of measurements were conducted during which the number of transmit and/or receive antennas and their spacing were varied. Each measurement run consisted of an entire walk route through the 15×70 m section of the building with duration of 5-7 minutes, thereby providing good statistics for the comparison. The repeatability of the measurements was determined through comparing the results of repeated test cases. For a measure such as the median downlink throughput over the entire route the difference was within 2%.

4.1 Well-spaced reference antennas

An example of the downlink throughput achieved in the covered area with 8×8 MIMO with well separated antennas both at the eNB and the UE is shown in Figure 2. With this antenna configuration a very high throughput is achievable throughout most of the area. In fact, only at the farthest ends of the building some degradation can be observed, primarily due to SNR-limitations.

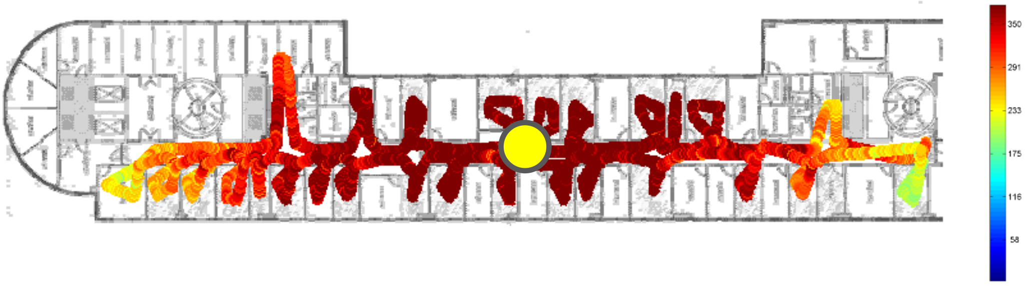

Figure 2 Downlink throughput map for 8×8 MIMO on a 20 MHz carrier with well-separated eNB and UE antennas. The yellow circle denotes the location of the eNB antennas.

The optimal rank (giving the highest throughput) at each given instant was found to be quite high, around six or seven, although the gains from adding streams diminishes above rank 4 (Figure 3). Increasing the number of streams, from one to two, in a setup with eight transmit and eight receive antennas essentially doubles the throughput over the whole route. However, this trend is not observed for higher layers. In fact, the gain of using seven instead of six streams is very small and from seven to eight is non-existent (overlapping curves in Figure 3). This is a well-understood and fundamental behaviour for MIMO and is a result of the spread of the eigenvalues of a MIMO channel.

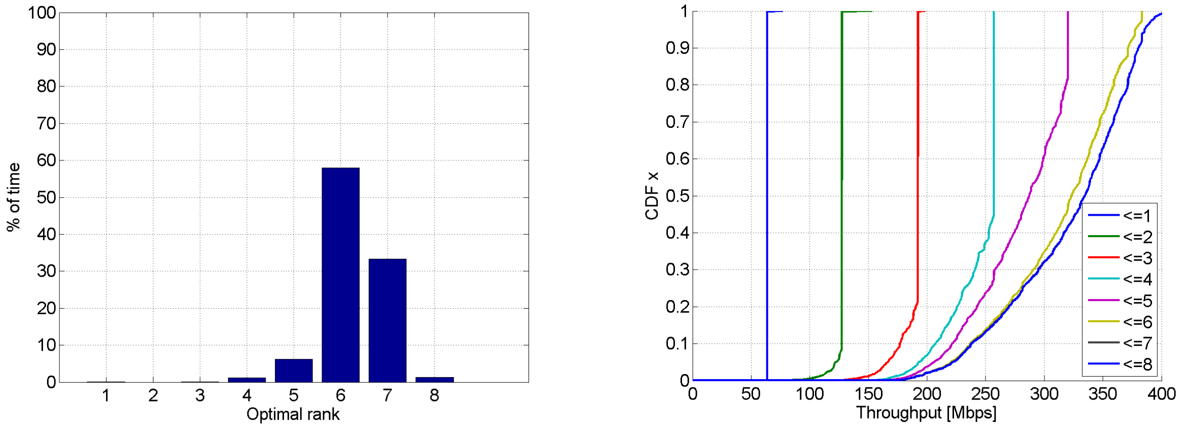

Figure 3 Histogram of the optimal rank (left) and cumulative distribution functions of the downlink throughput for different choices of rank cap (right). Results are for 8×8 MIMO with well-separated antennas at eNB and UE.

The results when varying the number of transmit and receive antennas are summarized in the left diagram in Figure 4. It is apparent that there are significant throughput gains for each increase in the number of transmit or receive antennas. It is only when the throughput is almost saturated, as in the 90th percentile for 2×2 MIMO, that there is a non significant gain from adding further receive antennas.

4.2 Compact MIMO antennas

The tests were repeated with the closely spaced eNB antennas in combination with the compact antenna array at the UE. These results are summarized in the right diagram in Figure 4. There appears to be large gains from higher order MIMO also with these more compact antenna arrays. In fact, the throughput degradation compared to the well-separated case is in most cases less than 10% and there is almost no degradation at the 90th percentile. This means that the indoor channel is rich enough to support MIMO even with 0.5λ spacing, and that the limit to the useable MIMO order is essentially determined by the number of antennas that can be fitted into a UE with this spacing (allowing for dual-polarized implementations for further compactness). The directivity of the compact array does not seem to be of any decisive significance which further hints that an equal number of antennas could have been utilized on the back of the ground plane in this particular implementation.

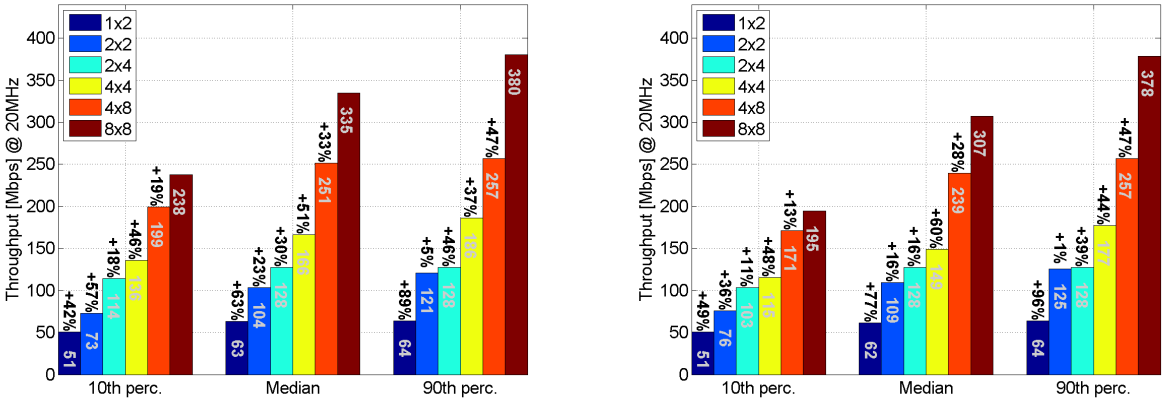

Figure 4 Downlink throughput as a function of the number of transmit and receive antennas for the well-separated configurations (left) and the compact configurations (right). The numbers on top of the bars denote the relative gain with the next higher configuration size.

5. Conclusions

The potential link performance gains with up to 8x8 MIMO according LTE Rel. 10, also known as LTE-Advanced, have been evaluated by an indoor field measurement campaign using a testbed implementation. The results showed that adding transmit and receive antennas from 1×2 (number of transmit antennas × number of receive antennas) MIMO up to 8×8 MIMO gave significant throughput gains in every step. For the 8×8 MIMO configuration, a median throughput of 335 Mbps on a 20 MHz carrier was observed in the indoor scenario. Although these results have been obtained without consideration for the impact of interference, they conclusively show that the MIMO concept in LTE Rel. 10 can have a profound impact on the user experience. In scenarios where good cell isolation can be achieved, such as in an indoor cell, much of the potential showed in these measurements should be realizable.

The rich scattering nature of the indoor channel supported similar performance gains also for quite compact antenna solutions, such as the λ/2-spaced dual polarized patch array used at the UE. At the studied frequency of 2.7 GHz, UE antenna implementations of up to eight antennas are definitely feasible in a reasonably sized consumer device, which is further encouraging. These results are very encouraging for the outlook of going beyond 2×2 MIMO support in consumer devices as is now possible with 3GPP LTE Rel. 10.

References

[1] E. Dahlman, S. Parkvall, J. Sköld, *4G LTE/LTE-Advanced for Mobile Broadband*, Elsevier Ltd., 2011.

[2] M. Riback, S. Grant, G. Jöngren, T. Tynderfeldt, D. Cairns, T. Fulghum, “MIMO-HSPA testbed performance measurements,” in proc. of IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 2007), Athens, Greece, pp.1-5, Sept. 2007.

[3] K. Werner, J. Furuskog, M. Riback, B. Hagerman, “Antenna configurations for 4x4 MIMO in LTE - field measurements,” in proc. of IEEE 71st Vehicular Technology Conference (VTC 2010-Spring), Taipei, Taiwan, pp.1-5, May 2010.