Outdoor Channel Characterization of MIMO-LTE Antenna Configurations through Measurements

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***Abstract*—In this paper different MIMO-antenna configurations are tested in a real outdoor MIMO-LTE environment. The outdoor investigations took place in Stuttgart-Zuffenhausen, Germany, where Alcatel-Lucent (ALU) provided an LTE base station for the measurements. The various MIMO-antennas were mounted in different positions on a BMW 525d station wagon. The measurements were performed in the upper LTE frequency band at 2.6 GHz. Here, the results of the yielded data throughput as well as an analysis of the variations of the modulation technique depending on the received SNR will be presented and some preliminary conclusions will be discussed.**

Keywords-component; MIMO-LTE; MIMO-antennas; data-throughput

I. INTRODUCTION

The number of radio transmission standards which are needed in order to provide the user with information and entertainment services, is steadily growing. Todays and future radio standards (3GPP LTE, WiMax, UWB, UMTS-HSPA and DSRC) are and will be used also by high-speed end users, for example, on board of a car. The automotive industry has a great interest in integrating these standards into their products. It is essential that a robust, wideband data transfer is guaranteed for such user applications. This is the reason why Multiple-Input-Multiple-Input (MIMO) antenna systems should be considered. In the past years, the use of MIMO-antenna systems has proven to be a very reliable solution in order to achieve these goals [1] [2].

To investigate whether MIMO antenna systems could also contribute to an increase in data rates for on-board communications, not only radio channel simulations were investigated but also several measurements were performed. Different antenna configurations on a car and related measurements were performed during a test drive in an LTE cell. The outcome of these measurements allows some first conclusions on the performance of the MIMO-antenna configurations, as will be discussed in this paper.

II. MIMO-LTE CELL ALCATEL-LUCENT

Fig. 1 shows the test route for all MIMO-LTE measurements. The measurements have been performed in Stuttgart (Germany), where Alcatel-Lucent (ALU) has its premises. There, an ALU LTE-cell was used for test purposes. Different wave propagation areas, e.g. with rich multipath or obstructed line-of-sight environments, could be observed in the scenario.

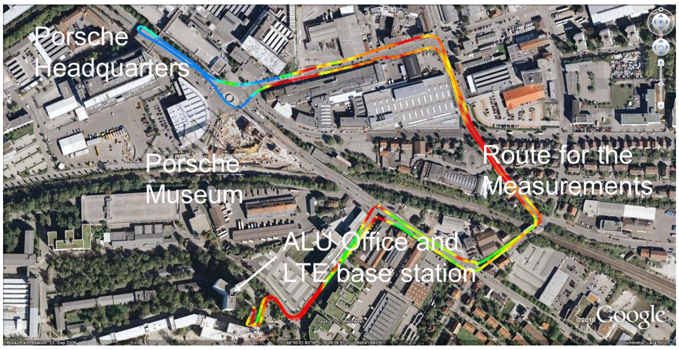

Figure 1: Inner-city scenario in Stuttgart for the MIMO-LTE measurement campaign

The MIMO-LTE base station is placed on ALU's highest building. The area which is covered by such a base station is approximately 120° in azimuth, thus three base stations are needed for full area coverage. During the measurement campaign, only two transmit MIMO-antenna configurations were active. This was enough for covering the measurement area. Each base station consists of two cross-dipoles rotated by 45°, and operating in the upper LTE-band, around 2.6 GHz. According to the ALU measurement setup, one of the antennas is described as "main antenna" and the other as "diversity antenna". The main antenna is always active; while the diversity antenna is used to implement either transmit diversity or MIMO. The transmit power of each antenna is set to 40W.

III. PREPARE YOUR PAPER BEFORE STYLING

In order to characterize the performance of the automotive MIMO-antennas, several configurations were mounted on a shark fin on the rooftop and in the side rearview-mirrors of a BMW 525d station wagon, as depicted in Fig. 2. This car was provided by the Department for Research and Technology (Forschung und Technik) of BMW (Munich, Germany).

The implemented antenna configurations consist of simple dipoles or monopoles. The aim is, on one hand to investigate the MIMO performance for car applications in an LTE cell and,

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on the other hand, to analyze how the position of the antennas on the car affects s the achieved data rate.

Figure 2: MIMO-antennas on the rooftop and in the side mirror of a BMW

For this purpose, the following configurations were realized:

- two λ/4 monopoles spatially separated by λ/2 on the roof;
- two λ/4 monopoles spatially separated by λ/4 on the roof;
- a single antenna with two ports, to include the case of a fully correlated antenna configuration;
- two cross dipoles in the side rearview mirror to investigate the impact of orthogonal polarization [3] on the outdoor MIMO-system;

For the first two cases, a power divider with a phase shifter was added to set a different phase (90° or 180°) between the antenna ports. The following table gives an overview of all antenna configurations that were examined during the measurement campaign.

TABLE I. MEASURED ANTENNA CONFIGURATIONS

Config. Index	***Description of MIMO Antenna Configuration***
1	Two spatial separated monopoles at λ/2 distance on the vehicle roof
2	A monopole array excited with same phase on the vehicle roof
3	A monopole array exited with 90° phase shift on the vehicle roof
4	Fully correlated antenna on the vehicle roof
5	Two conventional dipoles provided by ALU on the vehicle roof
6	Two spatial separated monopoles at λ/4 distance on the vehicle roof
7	A monopole array excited with same phase on the vehicle roof
8	Cross dipoles mounted in the right side mirror
9	Cross dipoles mounted in the left side mirror
10	A roof monopole and a horizontal positioned dipole in the left side mirror
11	A horizontal positioned dipole in each of the side mirrors
12	A vertical positioned dipole in each of the side mirrors
13	The two dipoles of config. 5 turned by 45°

IV. MEASUREMENT RESULTS

Different kinds of data were recorded during the test drives using ALU's mobile measurement equipment which was installed in the car. The data included the current position of the car (provided by a GPS receiver), the received Signal-to-Noise-Ratio (SNR), the correlation of the received signals and the data throughput, which is considered the most important parameter.

Additionally, the data throughput for the two receiving antennas for each codeword sent could also be monitored. As an example, in Figure 3 is displayed the graphical representation of the data throughput in dependence of the received SNR for the two code words as well as the sum of them for the antenna configurations 6 resp. 8 of Table I.

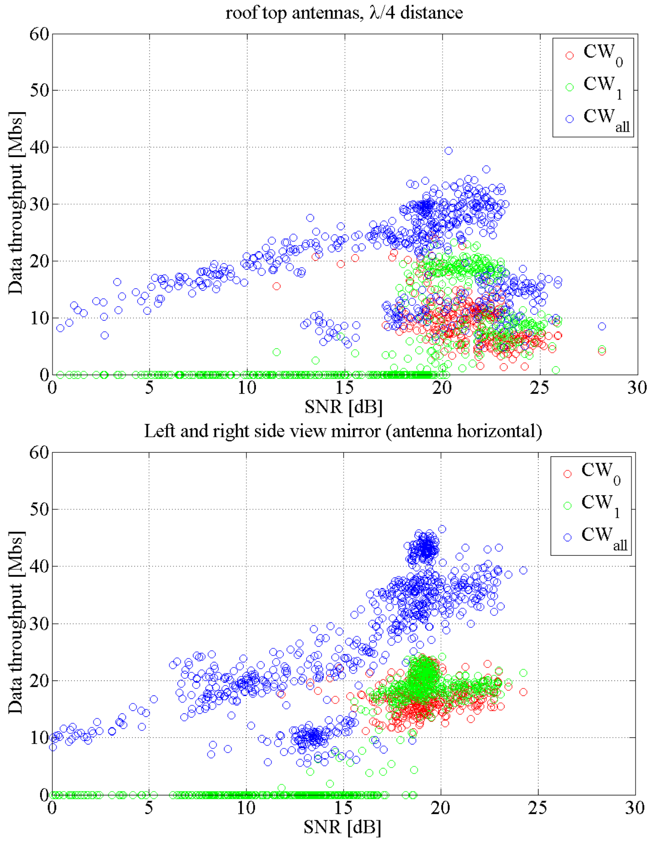

Figure 3: Data throughput for the antenna configuration 6(top) and 8(bottom)

Codeword 0 (CW0: red marker) is representing the data throughput of the main antenna and codeword 1 (CW1: green marker) the diversity antenna. The sum of these results gives the total data throughput (CWall: blue marker) obtained during the measurement. From these two examples, one observes that for both antenna configurations the data throughput of the main antenna is lower than the one when the diversity antenna is active.

Furthermore, according to the ALU measurement set-up, if the reference signal SNR at the main antenna is lower than 15 dB, the diversity antenna is inactive and the system operates in a transmit diversity scheme. Some artifacts can be observed for SNR values greater than 15 dB but their contribution is negligible.

Another measurement evaluation method to investigate the switch between the modulation types for the different MIMO antenna configurations is depicted in Figure 4. This is similar to Fig.3; the data throughput for each codeword - but this time depending on the used modulation technique - for the case which the antennas are on the vehicle's rooftop (config. 1) and for the case where the antennas are mounted in the side rear view mirror (config. 12), is presented.

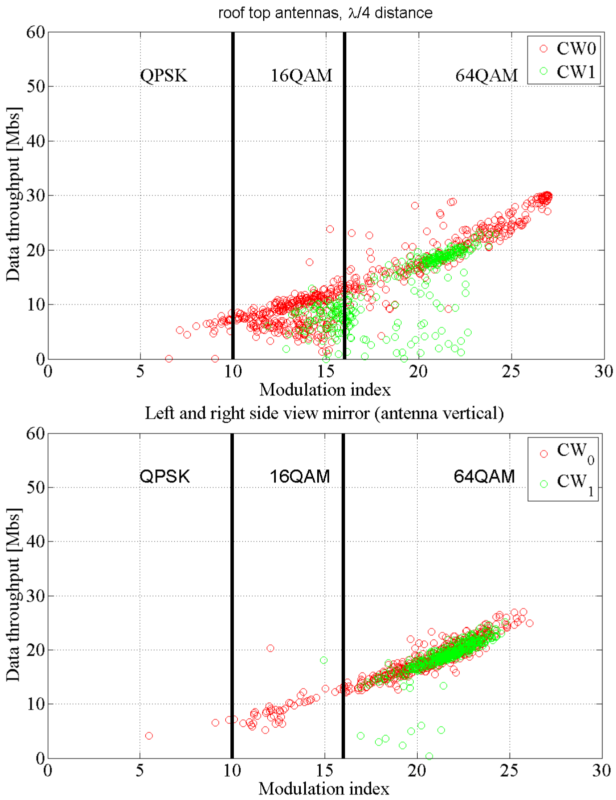

Figure 4: Data throughput depending on the modulation art for the antenna configuration 1(top) and 12 (bottom)

From these two figures, it is clear that the variance of the codeword throughput is larger when rooftop antennas are used. This makes the antennas on the side rear view mirrors perform in a more stable way. This effect holds for every MIMO antenna configuration which was investigated. Another outcome of these measurements is that the higher the reference signal SNR is, the higher can be the used modulation technique used in the system.

Next, some general results of the measurement campaign in the MIMO-LTE cell of Alcatel-Lucent are presented.

In Fig. 5, the empirical complementary cumulative distribution function of the measured data throughput is depicted.

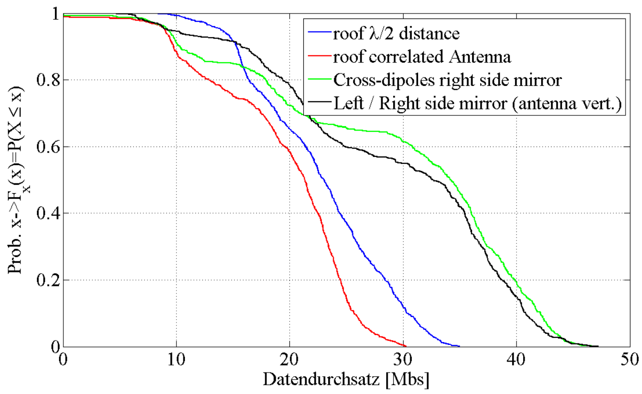

Figure 5: Empirical CCDF of the data throughput for all antenna configurations

It is obvious that there are differences in the data throughput statistic for each different MIMO antenna configuration. There are some antenna configurations which provide less data throughput but with a very high reliability (e.g. the red (config. 1) and black (config. 4) curves). Some others provide less reliability but higher throughput values (e.g. blue (config. 8) or magenta (config. 12) curves). In any case, it is clear that for this specific outdoor scenario, the use of the orthogonal polarized dipoles in the side rearview mirror could be more appropriate than the monopoles mounted on the rooftop's shark fin.

So far some general results regarding the system performance using MIMO antennas in vehicles have been presented. The question though, which MIMO antenna configuration is more appropriate for deployment, still remains unanswered. Therefore, in Figure 6 some characteristic values of the statistical evaluation of Fig.5 have been put together.

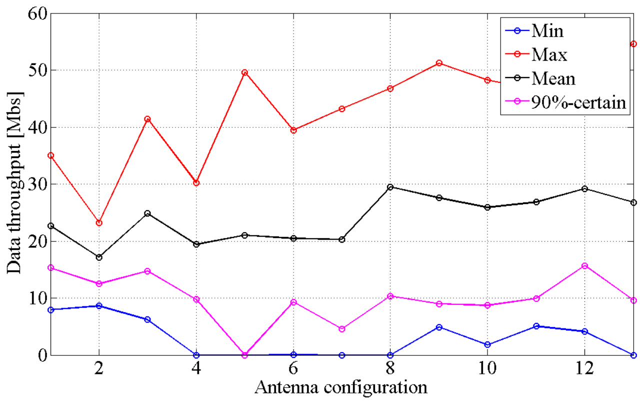

Figure 6: Characteristic statistical values for the data throughput

For each measured antenna configuration, the following data throughput values have been considered: minimum, maximum, mean and 90% certainty. The latter refers to these points of the CCDF of figure 5 where the ordinate equals 0.9.

From figure 6, it is clear that one cannot draw any conclusion on which configuration is best for MIMO-LTE vehicular applications. Yet, there are still some open questions concerning the requirements on the automotive antennas. The preliminary conclusion of this measurement campaign was that, beside the antenna configuration, also the physical layer properties should be taken under consideration to evaluate the overall performance of the LTE cell.

V. CONCLUSIONS

In this paper the results of a measurement campaign in a real Alcatel-Lucent MIMO-LTE environment in Stuttgart-Zuffenhausen in Germany, have been presented. Different MIMO antenna configurations were mounted in a BMW station wagon and the performance in means of data throughput was evaluated. Spatially separated equal polarized antennas as well as orthogonal polarized elements were investigated.

First of all it was shown that the use of a secondary (diversity) antenna increases the data throughput of the system. Furthermore, it was shown that the data transmission becomes more stable if the antennas are mounted on the side rear view mirrors instead on the vehicle's rooftop. Additionally, for the specific scenario, which is characterized by a rich multipath propagation environment, it was shown that the use of polarization diversity results in higher performance than the rooftop equally polarized elements. On the other hand the rooftop antennas result in lower data throughput values combined with higher reliability.

Due to the fact that there is no definition on the optimal performance of the system, it is also not possible to decide on the optimal antenna configuration.

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