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State-of-the-Art Measurements of LTE Terminal Antenna Performance Using Reverberation Chamber

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***Abstract*—This paper presents a proposed measurement method utilizing the reverberation chamber to measure MAC layer throughput for LTE enabled wireless devices. By using the reverberation chamber a statistically isotropic environment is produced, which is a suitable reference environment for terminal antenna testing.**

I. Introduction

The evolution of new communication systems with support for more advanced antenna solutions in general, and the implementation of LTE (Long Term Evolution) systems in particular, require new methods to test the full functionality of the handsets. Especially demanding to test are the multi-antenna solutions such as diversity or MIMO. This is also considered by organizations like 3GPP and CTIA which both have set out to define new characterization methods for multi-antenna devices.

The main challenge in this context is to produce measurement setups which can sort out good and bad antenna designs. The results should also reflect the performance of the devices when they are used in the intended type of real-life environments.

Previously, measurements in reverberation chamber of multi-antenna properties such as diversity gain and MIMO capacity have been presented [1]–[4], as well as some active MIMO testing with WLAN (IEEE 802.11n) [5].

In this paper measurements for LTE MIMO throughput are presented. Throughput performance is gaining more popularity and is now the most commonly used parameter for performance ranking of high speed internet devices. The throughput performance is highly correlated with the end user experience and is therefore the most critical parameter of such devices. The proposed method describes how the throughput of LTE MIMO devices can be measured in a repeatable isotropic environment. The throughput results can then be used to distinguish between good and bad devices. It is also important to relate the measured performance to the performance of devices in real use situations, and this is analyzed via comparisons with drive tests.

II. Measurement Setup

In this study we use two different measurement setups. The first setup, illustrated in Fig. 1, is used for measurements on devices with internal antennas. The MIMO enabled device under test (DUT) is located inside the reverberation chamber. The device is communicating with a base station simulator which is connected to fixed measurement antennas in the chamber. Due to the highly reflective walls in the chamber a rich multipath environment is created. This kind of environment is ideal for MIMO communication [2]. The second setup is illustrated in Fig. 2. This setup is used for measurements on devices which are connected to external antennas. The use of external antennas makes it possible to test a wide range of antenna configurations using a single LTE device.

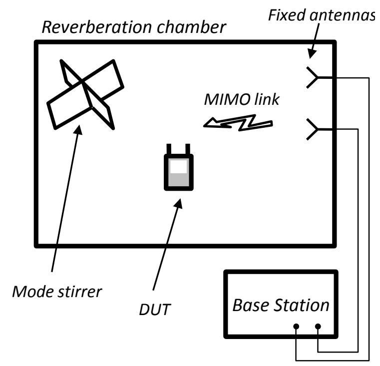

Fig. 1. Setup for active 2×2 MIMO devices with built in antennas.

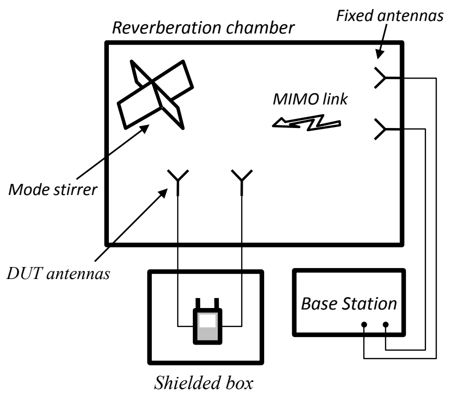

Fig. 2. Setup for active 2×2 MIMO devices connected to external antennas.

The reverberation chamber used in this setup is a Bluetest RTS60 chamber. The chamber features high electromagnetic shielding and a 2×2 MIMO switch box which make the system well suited for active MIMO measurement [1], [2]. The base station emulator is a Rohde & Schwarz CMW 500 communication tester.

Fig. 3. The Bluetest RTS60 reverberation test system.

The MAC layer throughput measurement is performed by sending data frames with a fixed data rate, FRC (Fixed Reference Channel), from the base station simulator to the DUT. The throughput value is computed based on the ACK/NACK response from the DUT. The average MAC throughout is measured during a continuous mode stirring sequence corresponding to 50000 sub frames. The measurement is then repeated for different base station power levels to find the MAC layer throughout as a function of available power.

III. Test Cases

To demonstrate the antenna performance impact on the MAC layer throughout a number of test cases are investigated. Common parameters for all measurements are the following.

TABLE I
Common measurement parameters

Parameter	Value
Operating mode	MIMO
Band	7
DL Channel	2850
DL Frequency	2630 MHz
Connection type	FRC

A. Device comparison

Two different DUTs, A and B, are tested under the same conditions. The data rate is chosen in such a way that both devices could establish a connection. Since the DUTs are data cards, the measurements are performed with a host laptop in the chamber. The same laptop is used for both DUTs.

B. Efficiency comparison

Two equal devices are tested, but DUT C has high efficiency antennas, -3.0 dB, and DUT D has low efficiency antennas, -7.0 dB. There is no gain imbalance and no difference in correlation between the devices.

C. Correlation comparison

One device is tested with high and low correlated external antennas. The low correlated antenna configuration, DUT E, is based on two miniature ceramic WLAN/BT antennas. The high correlated antenna configuration, DUT F, is a dual feed PIFA antenna. Both antenna configurations are mounted inside cell phone shells. The antennas are intentionally designed for correlation tests, however the normal operating frequency for the antennas are 2.45 GHz, which make the branch efficiencies relatively low at the specified frequency.

TABLE II
External antenna properties

Device	Power Corr	Efficiency Ant 1	Efficiency Ant 2
DUT E	0.2	-4.9 dB	-5.7 dB
DUT F	0.6	-3.2 dB	-4.6 dB

The high correlated antenna has approximately 1.5 dB better mean efficiency.

D. Gain imbalance

One of the branches of the external antennas is connected through an attenuator. Different attenuations are used to show the impact of gain imbalance. DUT E is used for these measurements.

IV. Results

The measurement results are divide into two parts, lab tests and drive tests.

A. Lab Tests

In Fig. 4 throughput results for two different commercial LTE devices are presented. Both devices are tested under exactly the same conditions. The devices are connected to the very same laptop and USB port, and the measurements are conducted using two different data rates. The results clearly show that there is a 3 dB difference between the devices, and this difference does not seem to be related to the data rate.

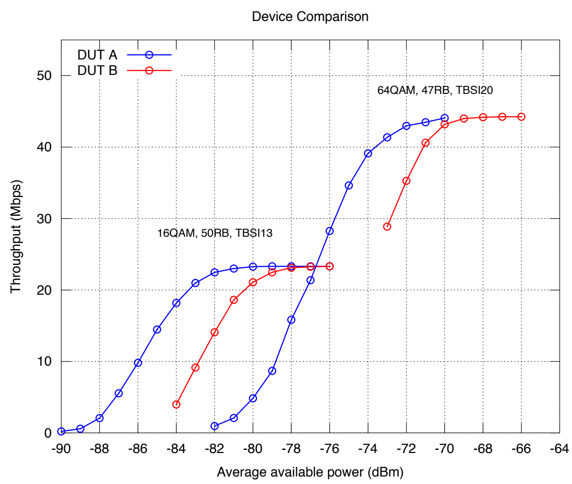

Fig. 4. LTE MIMO throughput for two different commercial LTE devices. Bandwidth is 10 MHz and RMS delay spread is 90 ns.

Higher data rates and wider bandwidths were also tested, but the measurements could not be completed due to connection stability issues with at least one of the devices.

Antenna efficiency is one of the most critical parameters of an antenna design. The throughput impact of different antenna efficiencies is presented in Fig. 5.

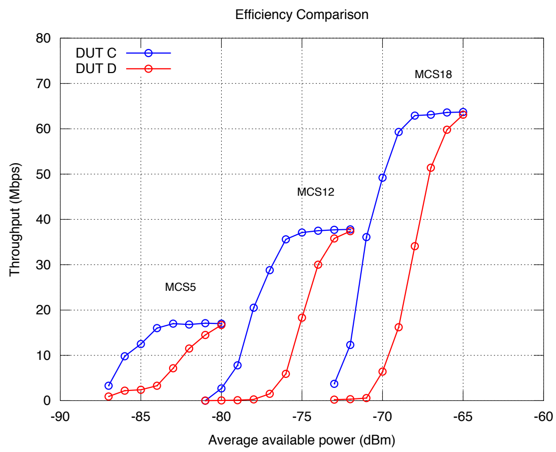

Fig. 5. LTE MIMO throughput for two equal devices with different antenna efficiencies. Bandwidth is 20 MHz.

The results in Fig. 6 are measured with one device connected to two different antenna configurations. The weakly correlated antenna configuration provide more than 3 dB better throughput performance. Note that the strongly correlated antenna configuration has higher antenna efficiency, which makes the actual performance difference (i.e due to the correlation) seem smaller, see Table II. Fig. 6 also demonstrates the excellent repeatability of the measurements.

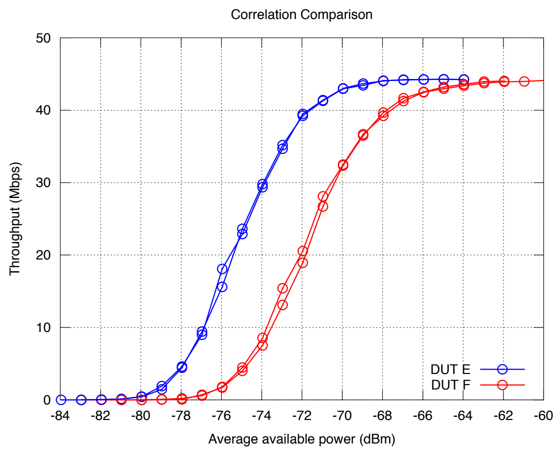

Fig. 6. LTE MIMO throughput comparison between high and low correlated antenna configurations. DUT E has power correlation 0.2 and DUT F has power correlation 0.6. Bandwidth is 10 MHz, 64-QAM, 47RB, TBSI20 and RMS delay spread 90 ns.

The impact of gain imbalance for a 2×2 MIMO antenna system is presented in Fig. 7. The low correlated cell phone antenna configuration, DUT E, is used together with attenuators to simulate different degrees of gain imbalance. The performance is degraded for increased gain imbalance.

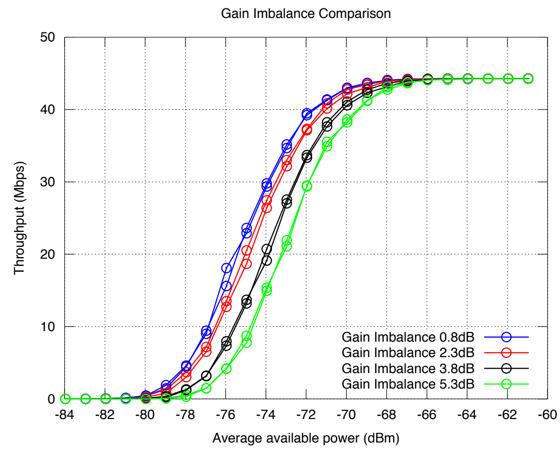

Fig. 7. LTE MIMO throughout comparison for DUT E with different gain imbalance. Each imbalance level is measured twice to show the measurement accuracy. Bandwidth is 10 MHz, 64-QAM, 47RB, TBSI20 and RMS delay spread 90 ns.

B. Drive Tests

To relate the results above to throughput performance of devices in real situations, measurements in real live networks have been made for comparison. Throughput measurement results from drive tests made in one of the first deployed LTE networks in Oslo, Norway, are presented in Fig. 8. The devices, DUT C and DUT D, are the same devices that were tested in the lab environment. The results show that DUT C outperforms DUT D in a real environment, which concurs with the lab results.

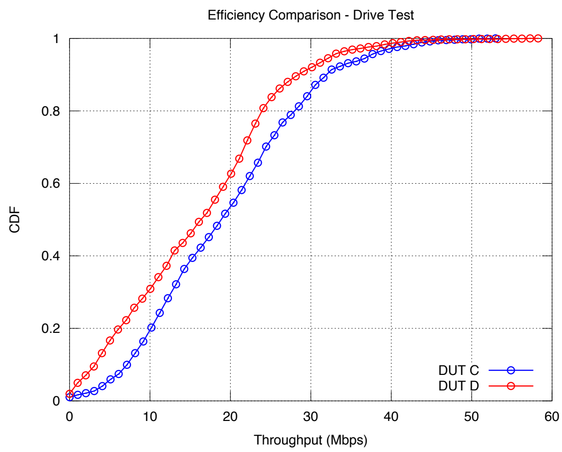

Fig. 8. CDF of throughput measured in NetCom's LTE network during drive tests in June 2010, Oslo, Norway.

The results show a typical average performance difference of 3 Mbps. The difference may look small compared to the lab testing, but it is important to note that all lab measurements were conducted using fixed data rate (FRC) while a real network utilizes adaptive modulation and coding (AMC). As shown in the lab results, the throughput difference is small, or non existing, under good channel conditions. The DUTs will occasionally be operating on low data rates with high SNR for which the devices have similar performance. The average difference in throughout performance will thus be evened out.

V. Conclusions

A method for measuring LTE MIMO throughput performance has been proposed in this paper. The method has been tested for four LTE devices and the validity of the measurements has been shown in the results. The impact of different antenna parameters such as efficiency, correlation and gain imbalance have also been demonstrated, and the results are in good agreement with the theoretical expectations as well as with results from real-life drive tests.

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