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2012 IEEE International Symposium on Antennas and Propagation, Chicago, USA, July 8-14, 2012 (ISSN: 1522-3965)

Citation for the published paper:
Orlenius, C. ; Lötbäck Patané, C. ; Kildal, P. (2012) "Evaluation of multi element antennas in reverberation chamber". 2012 IEEE International Symposium on Antennas and Propagation, Chicago, USA, July 8-14, 2012

http://dx.doi.org/10.1109/APS.2012.6348695

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Evaluation of Multi Element Antennas in Reverberation Chamber

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***Abstract*— This paper focuses on the latest advances in the use of reverberation chambers for active device testing. Contained are description and comparison of different figure-of-merits that are applicable to multi element antennas, with a specific focus on LTE devices with MIMO capability. There are two new parameter concepts introduced: Modified Total Isotropic Sensitivity measurements to include MIMO signaling, and a Throughput Threshold Level for simplified quantification of data bit throughput measurement results.**

I. Introduction

In the wireless industry today the trend is to implement multi element antennas in handsets and other wireless units, and this trend calls for new ways of characterizing the communication performance for such units. The reverberation chamber has been shown useful in this situation, not only because the ability to measure traditional antenna parameters, but to a big extent due to the simulated isotropic scattering environment offered by a well designed chamber.

II. Figure-of-Merits for Multi Element Antennas

There are several figure-of-merits which are interesting for characterization of MEAs. All will not be covered in detail here, but a summary is given in this section.

The FOMs can be divided into *passive* and *active* parameters, where the former are antenna only parameters, and the latter including radio circuitry. This division reflects another fundamental difference between the two groups of FOMs, which is that the passive antenna parameters are component values, whereas the active parameters are composite values combining performance of several components into a single value.

Commonly used passive antenna parameters are:

a. Radiation efficiency [1]

b. Impedance mismatch [1]

c. Signal branch correlation [2]

d. Diversity gain [2]

e. MIMO capacity [2]

The first two are traditional antenna parameters also applicable to single element antennas, but not less important for MEAs. On the contrary, antenna radiation efficiency is still the most important design parameter for electrically small antennas.

The third parameter, signal branch correlation, comes into play for antennas with two or more branches, and describes how uncoupled the antenna elements are. This parameter, as well as the two preceding, is example of component parameters, i.e. parameters directly showing the performance of a certain part of the communication system.

The two latter passive parameters, diversity gain and MIMO capacity are actually composite parameters determined by the first three mentioned passive antenna parameters; efficiency, mismatch, and correlation. Note that there are a variety of definitions of both diversity gain and MIMO capacity, with applicability to different situations.

Commonly used active antenna parameters are:

f. Total Radiated Power (TRP) [1]

g. Total Isotropic Sensitivity (TIS) [1]

h. Average Fading Sensitivity (AFS) [3]

i. Data bit throughput (TPUT) [4]

The last parameter, data bit throughput, has attracted considerable interest in MIMO-OTA discussions in the antenna community over the past few years, mainly because the close link to end-user experience. How the throughput behaves in a rich scattering environment such as the reverberation chamber is quite well understood and can be accurately modeled [5].

The TIS parameter on the other hand is a well-used single antenna parameter, directly related to the radiation efficiency of the antenna element. Originally a single antenna parameter, it is possible, when measuring TIS in a multipath scattering environment as the reverberation chamber, to extend the measurement to include multi element antenna performance. That is, exactly the same measurement procedure as used for single element TIS will include the performance improvement offered by the multi element implementation, as long as the measurement is performed in a multipath scattering and with the multiple signal combination activated in the device.

III. Reverberation Chamber Measurement Setups

All of the above mentioned measurement parameters can be measured in a reverberation chamber. Many of these measurement setups have been described in the literature, see for instance [1,2,3,4]. Focus here will be on new advances in active MIMO measurements.

A generic measurement setup for active device testing in a reverberation chamber is shown in figure 1, where a multi-port base station simulator is connected to fixed measurement antennas in the chamber, and a mode stirrer is used to create fading inside the chamber. With a well-stirred chamber the field experienced by the test device will be statistically isotropic, i.e. with equal probability for incoming waves from each direction of arrival.

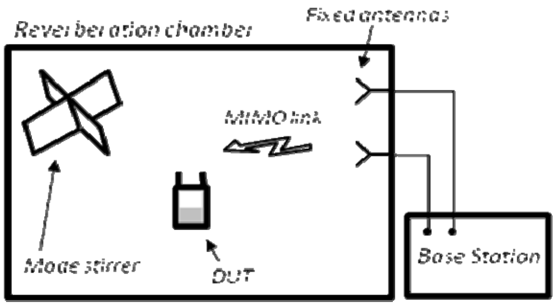

Figure 1. Setup for active MIMO measurements in reverberation chamber.

IV. FOMs for Active Device MIMO Testing

Following the trend in the community today of sampling data bit throughput as a function of average available power over a fading sequence, figure 2 shows such throughput sampling, where each point is the average throughput experienced during a measurement sequence. The data in figure 2 is taken for three different LTE data modems, with 2x2 MIMO transmission mode and two different fixed modulations (16QAM and 64QAM). Even though the tested units are commercial units taken off the shelf, there is a significant variation in performance, where DUT C always need a higher power to reach the same throughput as the other devices.

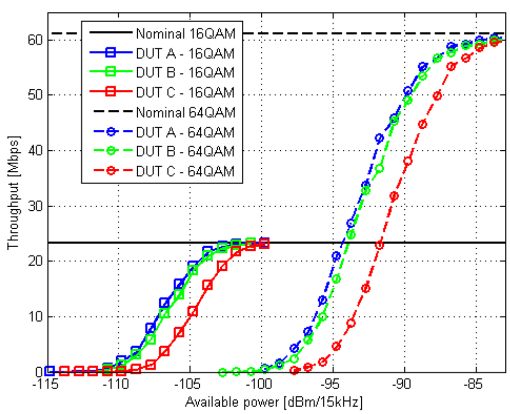

Figure 2. Example of data bit throughput as a function of average available power for three LTE enabled data modems.

Although there is some interesting information in the shape of the throughput curve as function of power, all of it is not relevant for a realistic use case since the system will choose a lower modulation or coding as soon as the achievable throughput drops below a certain level. Equivalently the system will choose a higher modulation or coding when the conditions are improved. Therefore we suggest using what we call the Throughput Threshold Level as a figure-of-merit. The **Throughput Threshold Level (TTL)** is defined as *the lowest average available power offered to the device under test which results in a data bit throughput equal to or higher than a specified percentage of the nominal data rate for a given fixed modulation and coding scheme*.

In the example given here we have chosen a 90% throughput level for 16-QAM modulation. The TTL for the three devices presented in figure 2 is then found to be 104.1, 103.7, and 102.1 dBm, respectively for DUTs A, B, and C. It is interesting to compare these TTL values to TIS values measured for the same devices. This is shown in figure 3 where the TIS values are measured with the same modulation settings as in the throughput measurements, and with a BLER threshold of 1.2%. It is interesting to note the very similar relation between the devices, whether TIS or TTL is used as parameter. There is an offset between the TIS and TTL values, which is expected from previous experience of comparison between TIS and AFS [3].

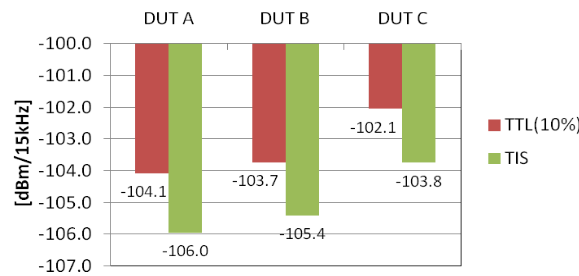

Figure 3. Comparison of TIS and TTL for the same three devices as shown in figure 2.

V. Conclusion

The implementation of multi element antennas in wireless devices calls for new types of measurements and figure-of-merits in order to fully characterize the performance of these units. This paper have discussed the applicability of reverberation chamber to these new demands, and shown examples of how such a chamber can be utilized to fully characterize MIMO devices. The key point is that the reverberation chamber physically emulates a rich scattering environment, which is essential for direct MIMO measurements.

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