

MIMO Antenna System Throughput Simulation

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Abstract - Throughput, being the ultimate criterion of performance of most, if not all, communication systems, is routinely tested via conducted and Over-the-Air (OTA) tests. A method is outlined to simulate OTA throughput tests, especially for Multiple Input Multiple Output (MIMO) capable wireless systems. The method is particularly useful in optimizing antenna throughput performance early in the design process and so de-risk 5G antenna design.

Index Terms — Throughput, OTA testing, MIMO, MPAC, RTS, RC.

1. Introduction

It is well understood that, in the vast majority of applications, the purpose of antenna design is to optimize the throughput in a wireless communication link. Throughput is usually tested when the product of interest is fully functional and real, modulated and encoded data are transmitted during a test. Traditionally, such tests have been performed either conducted (i.e. with cables connected directly to the RF connectors of the device, prior to the antenna), or Over the Air (OTA). However, it is increasingly more difficult to perform such conducted tests as we start using the higher and higher frequencies of 5G [1], [2], [3]. There are a few throughput measurement methods described in the literature such as the Multi Probe Anechoic Chamber (MPAC), the Radiated Two Stage (RTS) and the reverberation chamber (RC) [4], [5], [6]. Each has advantages and disadvantages. But all measure the throughput performance of a Device Under Test (DUT) in a setting that tries to emulate closely the propagation environment of interest in the intended mode of operation of the device. The OTA throughput tests use fully functional devices and, consequently, they capture everything that affects the device and are a true indicator of its performance. For the antenna designer, however, these tests are not performed early enough. If a product is found not to perform well during a throughput test, going back to redesign the antenna system and/or its occupied real estate in the product is too difficult because all the concomitant changes that have to be made by the other affected parts of the design. Therefore, a need exists to be able to reliably predict the OTA throughput performance of an antenna system early on. This paper describes such a simulation method. The method attempts to duplicate the performance of an antenna system in a realistic model of the device in which it resides. Although a simulation cannot possibly capture all the effects affecting performance in a fully functional device, its value is unquestionable in de-risking the design in the early phases of the process. And, as always, it is far easier and more reliable to compare the simulated

performance of two different designs than it is to match the simulated performance of a single device to its real performance in the field.

2. MEA Throughput Simulation Approach

For a wireless communication system outfitted with MEAs, the basis of simulating the throughput consists of calculating the baseband-to-baseband channel matrix and knowing what is the Signal to Noise plus Interference Ratio (SINR) in front of the decoder. The latter determines the probability of correct decoding based on the modulation and coding schemes used. The probability of detection is a specification that is directly driven by the desired Quality of Service (QoS) specification, i.e. the tolerated Bit Error rate (BER) for a satisfactory experience. The throughput is then the maximum possible throughput determined by the modulation scheme and the bandwidth as reduced by the BER due to the finite SINR. Bit level link simulations, therefore, need to be performed using the baseband-to-baseband channel matrix, the SINR and the specific details of the communications protocol used (e.g. LTE, WiFi, etc.).

Our approach hinges on calculating accurately the Antenna-to-Antenna (A2A) channel matrix and the associated SINR at the receiver (Rx) antenna terminals. We utilize an electromagnetics exact characterization of the MEAs at both sides of the link consisting of the active E-field gains of the individual antenna elements and their full S-parameter matrix [7]. The MEAs at each side of the link are then coupled via a plane wave decomposition of the propagation environment. This plane wave decomposition can be derived from a Ray Tracing analysis, or from various suitable propagation models such as those developed in the literature, the 3GPP and the IEEE standards organizations [8], [9]. Then, we transfer the SINR at the antenna terminations to the SINR in front of the decoder by using the Noise Figure (NF) of the entire RF branch (i.e. from the antenna terminal to the front of the decoder). With this information, link simulations provide the resultant throughput. Many researchers have used capacity in order to address the performance of MEAs in MIMO. Unlike capacity, however, throughput calculation requires knowledge of the protocol.

As an example, we here apply the approach outlined above to the conditions described in the CTIA OTA test plan for 2x2 LTE MIMO and transmit diversity for a Frequency Domain Duplex (FDD) case [10]. In this test the objective is to assess the throughput performance as a function of the

Signal to Interference Ratio (SIR). Figure 1 shows the quiet zone center, a signal and an interference transmitting radio at some distance from it. The signal radio uses a $\pm 45^\circ$ dipole antennas, as prescribed by the CTIA plan [10]. The propagation model connecting Tx and Rx is a 3GPP Urban Macrocell (UMa) SCME with 120 plane waves and 9dB cross-polarization [8]. In the CTIA test this environ is recreated via a complex arrangement of at least eight uniformly distributed dual polarization antennas surrounding the quiet zone and driven by sophisticated channel emulators [10]. Here, the environ is created via a software routine. Figure 1 also shows a V-pol and an H-pol omnidirectional calibration probes that are used to convert the SIR perceived by the DUT to the SIR illuminating the quiet zone [10].

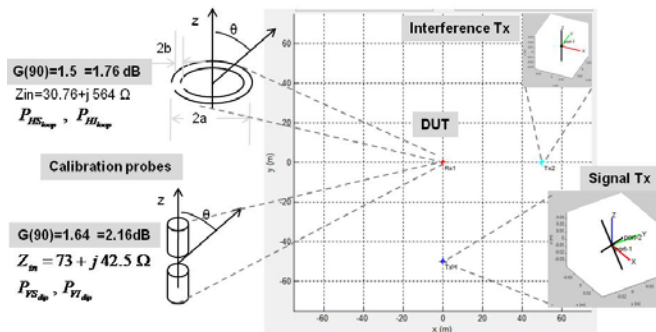


Fig. 1. Tx and Rx arrangement of the throughput test.

After the calibration simulations, the DUT (a certain cell phone model is used here), is placed at the center and throughput simulations are performed for several values of the interference power. The results are repeated for different orientations of the DUT and different random instantiations of the propagation model. The mean values of the throughput are plotted in Fig. 2. The Euler angle index indicates rotation angles every 30 degrees and the SIR index 1 to 5 indicates illuminating SIR=20 to 30 dB in 2.5 dB steps.

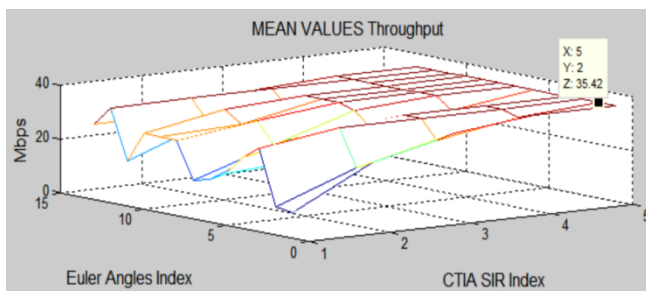


Fig. 2. Mean throughput vs. DUT orientation and SIR.

It is seen that the throughput reaches the theoretical maximum of 35.424 Mbps for certain values of SIR and orientation angles [10]. This is because the FDD link simulations were performed for 64-QAM modulation and 1/2 coding rate in a 10MHz bandwidth of which only 9MHz carried signal data (LTE transmission mode TM3). The lower SIR value at which the DUT reaches its maximum, the better the MEA system design.

3. Discussion

The aforementioned approach tacitly assumed that one knows the NF of the RF. However, that is a limiting

assumption only in noise limited scenarios. The CTIA OTA test is an interference limited scenario and the NF of the Rx plays no role by comparison (i.e. the interference power is significantly higher than the noise power and, thus, $SINR \approx SIR$). Additionally, the calculation of the S-parameters and the active E-field gains of the MEA are as accurate as the simulation models. Although significant progress has been made in the electromagnetic (EM) simulation tools in the last 20 years, capturing in detail the complex interactions of different parts of a device remains an art in which the experience of the practicing engineer cannot be overestimated. For example, it is not easy to create an EM model that can capture the interaction between the display of a cell phone and the RF circuitry between the antenna(s) and the encoder/decoder. This interaction is desensing the receiver and, if the designer is not careful, can be of the order of the order of a couple to a few dBs. Despite such weaknesses, the simulation of the throughput is very useful for comparing the relative performance of MEA designs under considerations. If the simulations models are built expertly enough, some of the errors due to the aforementioned limitations could be almost systematic errors and thus do not alter the results of the relative performance between two MEA designs.

4. Conclusion

A throughput simulation approach of MEA systems which duplicates the OTA throughput test plans is presented. Such approaches are useful in designing and optimizing antennas for 4G and 5G MIMO capable systems.

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