

System Simulations for MIMO Antenna Designs

Mehrbod Mohajer, Seyed Yahya Mortazavi, Essam Elkhoully, Chen Chen

Amazon Lab126, 1100 Enterprise Way

Sunnyvale, CA, USA 94089

mehrbodj@amazon.com, smmortaz@amazon.com, essae@amazon.com, cchc@amazon.com

Abstract—this paper proposes a simulation methodology to optimize MIMO antenna designs for the system performance parameters. The proposed design flow provides a co-simulation bench to evaluate MIMO antenna designs with system-level criteria. In one example, two MIMO antenna designs are considered, where both of them meet conventional antenna design parameters. The proposed methodology identifies the antenna design which statistically results in higher system throughput.

Keywords—*co-simulation, MIMO antenna design, system capacity, system throughput, wireless communication system.*

I. INTRODUCTION

Conventionally, MIMO antennas are modeled and optimized for antenna design parameters such as return loss, isolation, radiation efficiency, and correlation coefficients. These parameters are not sufficient to represent the wireless system performance and do not necessarily correlate with system performance parameters. Hence, a new design methodology is proposed to link MIMO antenna designs to the wireless system performance matrix. This way, the antenna design efforts will be focused on the final target specifications such as the system throughput rather than intermediate parameters. Additionally, rather than using a deterministic design parameter, the statistical analysis is employed to analyze the MIMO antenna designs.

II. WIRELESS SYSTEM MODELING

To include system parameters in antenna design process, a wireless communication system modeling has been developed to analyze and optimize the MIMO antennas. This model utilizes a co-simulation platform which integrates various simulation tools into a single design flow. In this platform, MATLAB [1] is used as the central node which communicates to CST Studio Suite [2] for antenna designs (3D Electromagnetic simulations), Wireless InSite [3] for wave propagation simulations (3D Ray-Tracing models), and Keysight SystemVue [4] for RF system modeling (circuits and wireless communication systems). The detailed simulation steps are as follows:

- 1) CST Studio Suite is used to design antennas for the given electronic device model and generate 3D gain radiation patterns to be imported into MATLAB.
- 2) Wireless InSite modeling is utilized to simulate the wireless channel for various communication environments.
- 3) Using the simulated propagation paths and 3D gain radiation patterns, the wireless channel matrix of the MIMO system is calculated in MATLAB for transmitter and receiver

locations. The theoretical system capacity can be calculated for the given channel matrix H .

- 4) MATLAB further calls SystemVue engine to simulate wireless communication system along with the calculated MIMO channel matrix.
- 5) For each channel matrix realization, system performance parameters such as packet error rates (PER), bit error rates (BER), and the maximum achievable NSS and MCS rates (or equivalently throughput) are calculated in SystemVue.

This approach provides the statistical data on how a certain MIMO antenna design can affect the wireless system performance parameters such as the system throughput in various wireless communication scenarios.

III. 2×2 MIMO ANTENNA EXAMPLE

For a given electronic device, two different 2×2 MIMO antenna designs have been simulated in CST Studio Suite. Both designs meet return loss, antenna efficiency, isolation between MIMO antenna elements, and gain requirements for 2.4GHz WiFi communications. The only difference is in their radiation patterns, and the main goal of this study is to investigate which MIMO antenna design provides better wireless system performance. For a given indoor environment, Wireless InSite is used as a Ray-Tracing tool to model propagation paths between one transmitter and 100 receiver points. These 100 Rx points have been selected in the spots where weak wireless communication is expected. Propagation paths, complex impulse responses, and direction of arrivals/departures are exported from Wireless InSite to model the indoor wireless environment. Having the complex impulse response between Tx and Rx points and 3D gain radiation patterns, the channel transfer matrix of H is calculated for 2X2 MIMO systems. From the theoretical capacity equation [5], the system capacity can be calculated from H -matrix for 100 channel realizations. Fig. 1-a shows the CDF of the calculated system capacity for two different MIMO antenna designs. As can be seen, antenna design#2 CDF plot is towards the right side, indicating higher probability of higher system capacity. To evaluate the statistical behavior of system throughput, the calculated H matrices are used in SystemVue WiFi 11ac simulations to find optimal NSS and MCS for each channel realization. The CDF of the system throughput is plotted in Fig. 1 –b. Since the optimal throughput is obtained from corresponding MCS and NSS in the WiFi data rate lookup table, the CDF plot is a stepwise function. Statistical behavior of both system capacity and throughput suggest that the MIMO antenna design#2 provides higher wireless system performance.

IV. SYSTEM CAPACITY VERSUS THROUGHPUT

Although it was shown that the statistical behaviors of both system capacity and throughput are in agreement for the given particular example, one may wonder if the system capacity analysis is sufficient for MIMO antenna design or it should be taken further to throughput analysis. In order to investigate that, the system capacity has been ascendingly sorted in Fig. 2-a for MIMO antenna design#1 at 20 first Rx points. Simulated system throughputs are also plotted in Fig 2-b for corresponding 20 Rx points. As can be seen, the system throughput trend does not correlate with the theoretical system capacity. For instance, Rx point#16, which gives higher system capacity than 15 previous Rx points, does not necessarily maintain higher throughput. The same behavior is observed for antenna design#2. This comparison highlights the importance of full wireless communication simulations, and shows that the proposed methodology can capture certain aspects of wireless communication systems that cannot be covered in conventional antenna design.

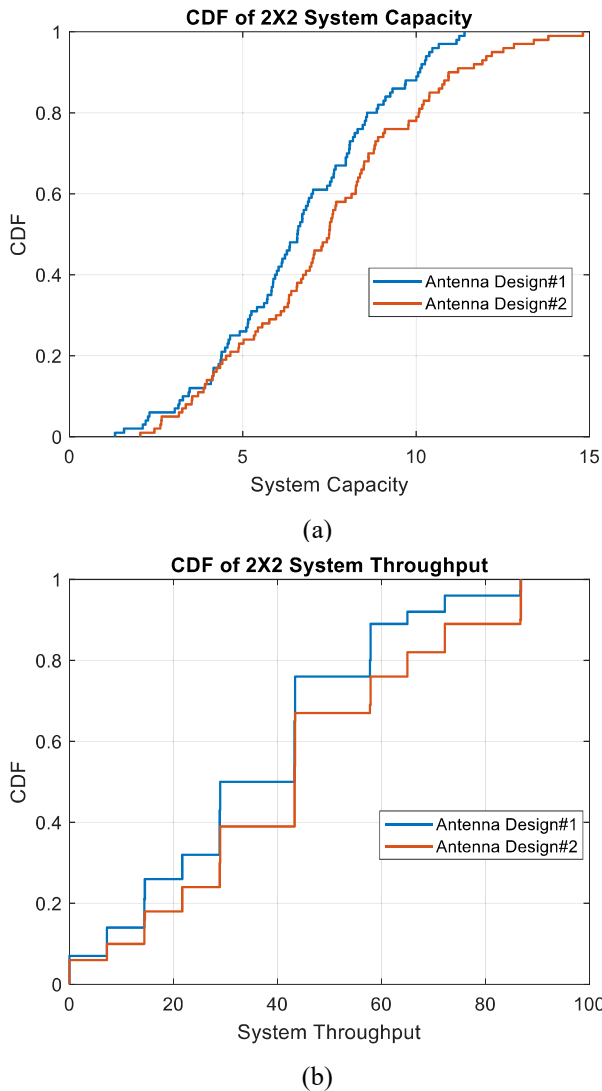


Fig. 1. CDF of 2×2 a) system capacity, b) system throughput for two different MIMO antenna designs in a given indoor environment.

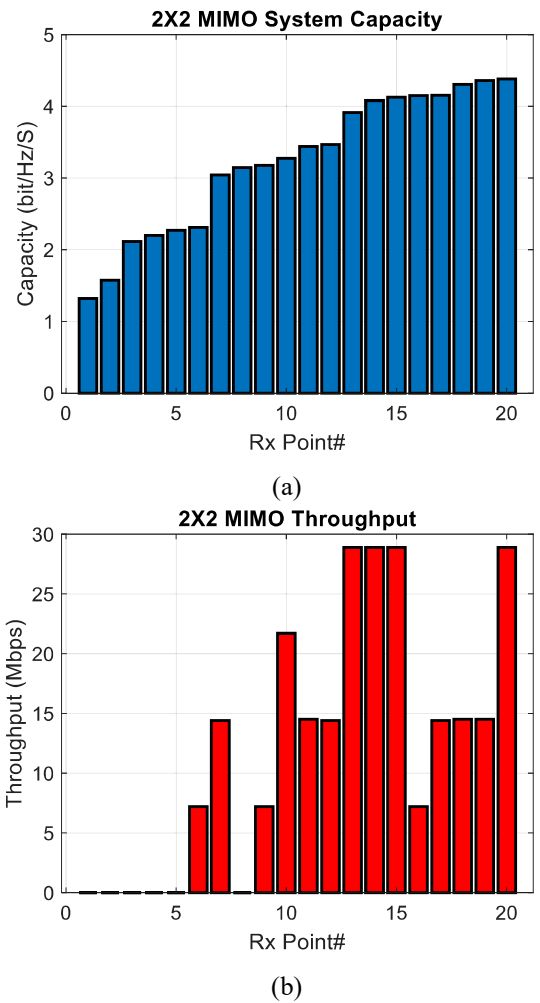


Fig. 2. a) system capacity and, b) maximum throughput for the antenna design#1 at 20 Rx points.

V. CONCLUSION

A co-simulation platform was developed to design and analyze MIMO antennas for optimal wireless system performance. Instead of deterministic design parameters, the statistical behaviors of system parameters were analyzed. Through an example, it was shown how the system performance parameters could be critical for WiFi MIMO antenna design, and how the wireless system modeling can highlight possible performance degradation, which could not be captured through conventional design criteria. Eventually, it was discussed that system-level simulations are crucial to analyze system throughputs in addition to the system capacity calculations.

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