Compensation of Hardware Impairments in MATE, the Chalmers mmWave MIMO Testbed

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I. Introduction

The ever-growing demand for high data rates and the global bandwidth shortage has motivated the emergence of millimeter wave (mmWave) multiple-input and multiple-output (MIMO) systems. As a capable tool for studying the limitations and requirements of future mmWave MIMO communications, we have developed the MATE testbed at the Chalmers University of Technology [1]. This setup supports up to 16 transmitters and up to 9 receivers and it operates between 28-31 GHz providing 1 GHz analog bandwidth per transmitter or receiver. In the remainder of this paper, we briefly explain a number of most important hardware impairments which limit the performance of MATE and we describe the techniques we employ in order to compensate each impairment.

II. Compensation of Hardware Impairments

Similar to any other wireless communication system, MATE is also prone to different hardware impairments. Our objective is to implement the best algorithms possible for every aspect of a communication link.

A. Carrier Frequency Offset

We have developed blind algorithms for carrier frequency offset (CFO) estimation using a model for the received spectrum. We have also proposed a blind algorithm based on the autocorrelation of the received signal, and on noise modeling. Furthermore, we have implemented a pilot-based algorithm which relies on transmitting a pilot tone, allowing for the receiver to estimate CFO and track phase noise.

B. ADC Quantization Noise

In order to minimize the quantization noise and effects of clipping in analog-to-digital converters (ADCs), we have proposed a novel approach which relies on the knowledge samples which are clipped[1]. Moreover, the correlation over the array and due to receiver oversampling further allows for performance improvement in case of clipping. The proposed algorithms allow us to have a significant percentage of the input samples to be clipped, thereby improving the dynamic range of the receiver.

C. Nonlinearity

We have developed a strategy for analysis of transmitter nonlinearities with the aid of measurements performed by the receiver. The observations at the receiver are used to extract a model for the nonlinearities which is then employed for designing digital predistorters for every transmit branch. The proposed algorithm can additionally compensate for antenna crosstalk and possesses a lower hardware complexity with respect to the state-of-the-art solutions [2].

[1]This knowledge is easily attained; we define clipping as the samples quantized to the outermost quantization regions

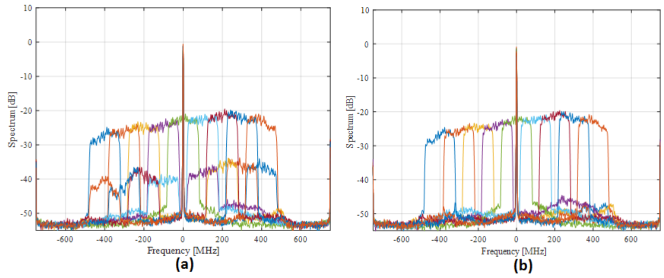

Fig. 1: (a) prior to applying the joint solution (b) after applying the joint solution.

D. I/Q Imbalance

In the MATE system, we have quite a high I/Q imbalance, which is frequency selective over the entire bandwidth of the system. To deal with this problem, we have developed a joint frequency selective I/Q imbalance, CFO, channel and frame synchronization estimator. Noting the fact that all of these issues are interleaved in a complicated fashion, it is difficult to tackle them one by one. Instead, we implement a joint solution, solving for I/Q imbalance, CFO offset and channel equalization simultaneously. Our results (as depicted in Fig. 1) reveal the efficacy of the proposed method as it successfully compensates the transmit and receive I/Q imbalance.

III. Conclusions

We have discussed the steps taken for canceling the hardware impairments in the MATE testbed. Our proposed algorithms yield improved performance with respect to the state-of-the-art solutions.

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References

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