بسم الله الرحمن الرحيم

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics Engineering and Electrical Communications

Performance Evaluation of MU-Massive MIMO Based FDD Systems

A Thesis Submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Electrical Engineering
(Electronics Engineering and Electrical Communications)

by
Abdallah Fathy Mohamed Badawy
Master of Science in Electrical Engineering
(Electronics Engineering and Electrical Communications)
Faculty of Engineering, Ain Shams University, 2013

Supervised by
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Cairo – (2021)

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STATEMENT

This dissertation is submitted as a partial fulfillment for the degree of Doctor of Philosophy in Electrical Engineering (Electronics Engineering and Electrical Communications), Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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ABSTRACT

Massive multiple-input multiple-output (MIMO) is a breakthrough technology advancing huge network capacities in multiuser (MU) scenarios in which a base station, with a large number of antennas, simultaneously serves multiple users in the same time-frequency resources. The presented study gives an overall view of the massive MIMO channel behavior for different situations through the channel matrix singular value spread (SVS) and users' channels correlation. As the inter-user spacing or the number of base station antennas increase, the SVS and inter-user correlation enhance and the users' channels can be easily separated. In addition, and based on dirty-paper coding (DPC), the behavior of these situations is discussed by computing the sum-rate capacity versus the number of antennas at the base station in the massive MIMO downlink channel. Moreover, the proposed model applies the reciprocity theorem to account for the transmission channel by using the antennas transfer functions to compute the magnitude and phase of the voltage induced at the receiving antennas terminals for a given input excitation. Through channel matrix normalization and singular value decomposition (SVD), the obtained results are close to those obtained experimentally where as the number of base station antennas increases, the SVS decreases and the monotonic sum-rate capacity improves. The ray tracing recipe for an ultra-wideband (UWB) channel is analytically validated with the experimental results in the literature and the magnitude and phase of the received voltage are estimated as a function of frequency in a given environment through the antenna transfer function and reciprocity theorem. The model is then extended to a massive MIMO channel to validate its performance metrics, i.e., the SVS and sum-rate…etc., with the experimental results in the literature and demonstrate the favorable features of massive MIMO systems. The setting is a suitable case study for a 100 m ×100 m indoor environment typically found in a harsh RF industrial environment. The results also show that using more antennas at the base station improves the capability of focusing power to a certain user. Besides, via the water-filling

algorithm to demonstrate the optimal transmit power distribution among users' channels to achieve maximum mutual information, the results show that as the number of antennas at the base station side grows up, the disparity of the power values among users' channels significantly reduces. Concerning the duplexing transmission schemes, in time division duplexing (TDD) mode, the entire bandwidth for both uplink and downlink is utilized and the propagation channel reciprocity can be used where the amount of resources needed for pilots only depends on the number of simultaneously served terminals. However, in frequency division duplexing (FDD) systems, which are widely deployed because of their existing spectrum assignments, the uplink and downlink channels are at different frequencies and thus are not reciprocal where a considerable amount of feedback overhead is required. One of the main objectives of the thesis is to exploit the directional spatial correlation for the uplink and downlink channels, based on the structure of their multipath clusters, to estimate the downlink channel for an FDD system. The proposed method uses the spatial correlation between the uplink and downlink where the clusters are deduced from the uplink channel. Then, the phase of the signal arriving at the base station is modified to construct the signal departing from the base station and hence the downlink channel can be estimated.

SUMMARY

Massive multiple-input multiple-output (MIMO) is a scalable form of multiuser MIMO (MU-MIMO) in that the application of linear processing is possible and that only the base station is required to know the channel state information (CSI). In the downlink, the base station needs to make sure that each terminal only receives the signal intended for it. Increasing the number of base station antennas enhances the performance, in terms of both the number of terminals that can be concurrently served and in terms of the reduced radiated power. In addition, using a large number of base station antennas is influential not only to achieve high spectral efficiencies, but also to provide uniformly good quality of service (QoS) for as many terminals at the same time. Moreover, increasing the number of base station antennas simplifies the resource allocation and the signal processing required due to channel hardening where the frequency dependency and small-scale fading effects vanish as the number of base station antennas increases without bound. By using the ray tracing technique, the downlink ultra-wideband (UWB) massive MIMO channel, including the transmitting and the receiving antennas, is deterministically characterized to determine its performance in a typical indoor environment, corresponding to the CM 7 and CM 8 identified statistically by the IEEE 802.15.4a work group. The evaluation of the electromagnetic fields is performed ray by ray so that each ray is affected by the antenna transfer function corresponding to its direction-of-arrival (DoA) at the receiving antenna and direction-of-departure (DoD) from the transmitting antenna where the utilization of each ray separately is proposed by Tchoffo Talom and Uguen. While considering single-antenna users, the UWB massive MIMO channel behavior is investigated under three characteristic propagation scenarios where the users are 1) closely-located with line-of-sight (LoS) to the base station, 2) located at intermediate distances from each other with non-line-of-sight (NLoS) to the base station, and 3) well-separated with LoS to the base station. The singular value spread (SVS) cumulative distribution functions (CDFs) of these situations are compared while allowing the number of base station antennas to change. Since a given cluster includes a set of rays for a given transceiver according to the surrounding scaterers, using clusters in an extensive category of environments is very beneficial since they provide systematic, regardless of the scene, and more comprehensive facilities to characterize a given radio channel. The clustering process offers a compromise between the computational complexity and accuracy and facilitates system integration without sacrificing the required QoS for the end-user. Concerning the duplexing transmission schemes, in time division duplexing (TDD) mode, the entire bandwidth for both uplink and downlink is utilized and the propagation channel reciprocity can be used where the amount of resources needed for pilots only depends on the number of simultaneously served terminals. However, in frequency division duplexing (FDD) systems, which are widely deployed because of their existing spectrum assignments, the uplink and downlink channels are at different frequencies and thus are not reciprocal where a considerable amount of feedback overhead is required. Extensive research has been carried out till now on the possibility of using the channel reciprocity between the downlink and uplink channels in FDD systems to improve the system efficiency. In the presented study, the channel correlation between the downlink and uplink clusters is utilized to relate the downlink and uplink channels for a massive MIMO system employing FDD scheme. This is achieved by relating the channels observed at the base station array to the signal paths. This simplified the estimation process since the transformation from the uplink frequency to the downlink in the angular domain is simpler than that in the wireless domain.

Key words: Antenna transfer function, channel capacity, channel clusters, channel reciprocity, frequency division duplexing (FDD), massive multiple-input multiple-output (MIMO), ray tracing, singular value decomposition (SVD), and wave propagation characterization.