Spectral Efficiency of MU-Massive MIMO System for Perfect and Imperfect CSI Condition

1st Ika Rohmatul Aini   
*Electrical Engineering Department*  
*Institut Teknologi Sepuluh Nopember*Surabaya, Indonesia  
ikaaini.17071@mhs.its.ac.id

2nd Puji Handayani  
*Electrical Engineering Department*  
*Institut Teknologi Sepuluh Nopember*Surabaya, Indonesia  
puji@ee.its.ac.id

*Abstract*— Multi User Massive MIMO (MU-Massive MIMO) is a form of multi-user large-scale antennas technology, in which hundreds numbers of antennas serve a significantly smaller number of users. We focus to analyze the downlink system of MU-Massive MIMO which works on Rayleigh and Uniformly Random Line of Sight (UR-LOS) channels. This system is assumed operates over a frequency-selective and uses Orthogonal Frequency Division Multiplexing (OFDM). The system performance is observed under perfect CSI and imperfect CSI conditions. Channel estimation for imperfect CSI can be obtained from uplink pilots training. ZF and MMSE linear precoding are used to overcome Multi User Interference (MUI) at receiver. From the simulation results, it can be seen that imperfect CSI has an impact on system performance due to channel estimation errors. In imperfect CSI condition, Bit error rate (BER) of the system is little bit higher and the spectral efficiency is slightly decreased. Furthermore, the use of a large number of array antennas can significantly increase the spectral efficiency without bound, both in perfect and imperfect CSI condition. In addition, spectral efficiency of the downlink scheme really depends on the use of precoding techniques. ZF and MMSE work equally well in suppressing the MUI at large number of antenna elements.

Keywords— MU-Massive MIMO, Rayleigh, UR-LOS, Perfect CSI, Imperfect CSI, Spectral Efficiency, ZF, MMSE, MUI.

# Introduction

In recent years, Multiple Input Multiple Output (MIMO) technology has been developed to support the development of high-speed wireless communication system. This technology has better performance than Single Input Single Output (SISO). This concept becomes the background for the development of Massive MIMO system. Massive MIMO system is a system that uses a very large number of antennas on the BS, the antennas can be hundreds or even more [1]. By using massive antenna elements, the spectral efficiency and energy efficiency will be significantly increased, compared to the small-scale MIMO system.

In order to serve multiple users simultaneously, Multi User Massive MIMO (MU-Massive MIMO) system is used. Hundreds of antennas on a BS can serve tens of users at same time and frequency resources, where each user uses single antenna. The advantages of single antenna user are that it is inexpensive, simple and uses more efficient power, but each user still get a high throughput [1]. The design and analysis of the Massive MIMO system is an interesting topic to study [2]-[5]. Some advantages of Massive MIMO system compared to conventional MIMO are, only BS that needs to estimate the channel, the number of BS antennas is much larger than the number of users, and simple linear processing techniques can be applied both on the uplink and downlink side [6]. In order to implement MU-Massive MIMO system which represents the real conditions, Channel State Information (CSI) on the BS or user side is required. CSI is not only useful for obtaining high SNR on the user side, but also reducing interference generated by other users in a cell. However, channel estimation will be very complex because it is proportional to the large number of BS antennas, hence some previous research on Massive MIMO system assumed perfect CSI condition on both the BS and the user side [7]-[9]. In actual condition, the channel response can change at any time according to the propagation environment, hence the channel estimation is needed. Imperfection of the channel estimation process due to channel estimation error is known as imperfect CSI condition, because BS only know the noisy version of the channel.

We assume that the system works on TDD operation, so that the uplink and downlink channel are reciprocal. BS can obtain CSI from the uplink pilots training sent by users. The number of transmitted pilots is proportional to the number of users which is much smaller than the number of BS antennas. Then BS use CSI to precode the transmitted signal in order to reduce Multi User Interference (MUI). In addition, the downlink SE for the k-th user in a cell really depends on the precoding capability to reduce interference between users [10]. Form [1,12], it is shown that the use of large-scale antennas on the BS will increase spectral efficiency without bound. Hence, the use of a massive number of antenna elements with constant number of users will significantly increase the spectral efficiency.

This paper analyses single cell MU-Massive MIMO communication system with a downlink scheme on the Rayleigh and the Uniformly Random Line of Sight (UR-LOS) channel. This system is assumed to be operated over a frequency-selective channel and uses Orthogonal Frequency Division Multiplexing (OFDM). We investigated the performance in specific conditions. First, we assume that the BS knows the channel information state (perfect CSI condition). And second, BS estimates the channel at a certain coherence interval (Imperfect CSI condition) using Least-Square (LS) estimation. The parameters that will be observed are Bit Error Rate (BER) and Spectral Efficiency (SE) using Zero Forcing (ZF) and Minimum Mean Square Error (MMSE) linear precoding technique .

*Notations:* Uppercase and lowercase bold letters denote matrices and vectors. **𝔼**{.} denotes expectation operator. For a matrix **H**, we denote the superscripts (.)*T,* (.)*H* as transpose, and Hermitian matrix operation, respectively. While tr(**H**) is trace of matrix **H** and is identity matrix. The entries of *k-*th row and *m-*th column of matrix **H** is denoted by . represents complex number, while represents complex normal random variable. The accent denote magnitude of a complex number.

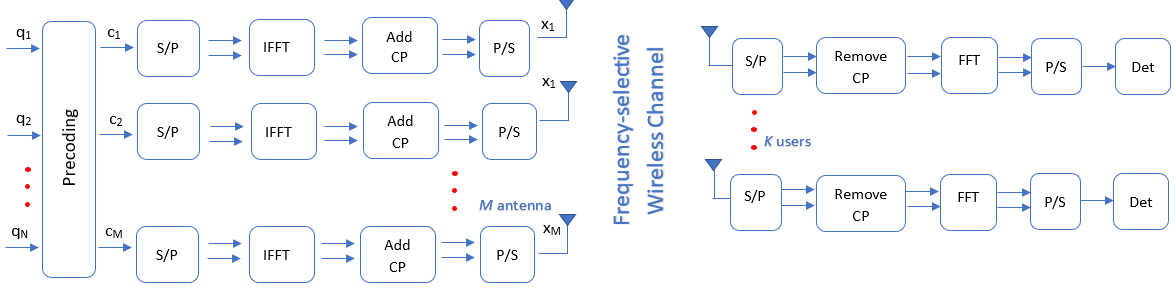


Fig. 1 System model of MU-Massive MIMO downlink scheme.

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1. G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
3. I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
4. K. Elissa, “Title of paper if known,” unpublished.
5. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

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