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The Effect of the Eigenvalues of the Zero-Forcing Detector on Its Performance in the Space-Division Multiplexing System

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Abstract: Zero-Forcing (ZF) detector is used in Space-Division Multiplexing (SDM) receiver to remove interference among the received symbols. Previous works showed that the power of channel noise is enhanced in the output of the ZF detector. They recommend using the ZF detector when the received Signal-to-Noise Ratio (SNR) is high. This work proves that the performance of the ZF detector depends on the eigenvalues of the channel correlation matrix. The paper shows that if the sum of the eigenvalues of this correlation matrix is equal to the rank of the channel matrix, the ZF detector will not enhance noise power at its outputs. Moreover, if the sum of the eigenvalues is smaller than the rank of the channel matrix, the ZF detector will reduce noise power at its outputs. In this work, a theorem, which demonstrates the performance of the ZF detector in SDM receiver, is introduced and proved. The proposed work uses smart antennas in the transmitter and receiver to control the elements and eigenvalues of the channel matrix. The introduced theorem and a complete SDM receiver with ZF detector are simulated and evaluated at different conditions with different criteria. A real-time SDM receiver with ZF detector is also implemented and evaluated. The simulation and implementation results are shown at the end of this study. The results of the proposed systems show that a ZF detector can be used to remove interference in the SDM system without enhancing the channel noise.

Keywords: Space division multiplexing, Zero-forcing detector, Interference cancellation, Noise reduction, Eigenvalues, Correlation matrix

1. Introduction

The multiplexing of symbols is used to increase the data transmission rate in communication systems. Multiplexing systems transmit N modulated symbols through N parallel channels in one symbol period. Frequency Division Multiplexing (FDM), Orthogonal Frequency Division Multiplexing (OFDM), Code Division Multiplexing (CDM), and Space Division Multiplexing (SDM) are the known multiplexing methods, which are used in communication systems to increase the data transmission rate. SDM is used to increase the bandwidth efficiency of the communication system as well as increasing the data transmission rate [1, 2]. The bandwidth efficiency is defined as the ratio between the total transmission rate and the total transmission bandwidth. In FDM systems, the maximum achievable bandwidth efficiency is half [3]. On the other hand, the bandwidth efficiency of OFDM systems is close to one but it never reaches it [4]. In SDM systems, the bandwidth efficiency is greater than one. The SDM transmitter sends N different modulated symbols parallel through the same frequency channel at the same time slot (symbol period) using N transmitting antennas [5, 6]. The transmitted symbols in the SDM system occupy the same bandwidth, which is used by the non-multiplexing system. Since the transmission rates from the N transmitting antennas are always equal, the total transmission rate in the SDM system is equal to the symbol rate of the non-multiplexed system multiplied by the number of the transmitting antennas. The bandwidth efficiency of the SDM system is also equal to the bandwidth efficiency of the non-multiplexed system multiplied by the number of the transmitting antennas. The SDM system has bandwidth efficiency greater than the bandwidth