**Lab 4: MIMO Transmission System**

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| **Introduction**  **Theoretical analysis**   1. **MIMO system application and deployment**   MIMO system is the system with multiple inputs and multiple outputs, which means using multiple antennas at the transmitter and receiver. MIMO is sometimes called spatially diverse because it uses multiple spatial channels to transmit and receive data. MIMO can be deployed only when a site (mobile device) or access point (AP) supports MIMO. It use multiple antennas to supress channel fading. According to the number of antennas at tansmitter and receiver, MIMO systems can also include SIMO(Single-Input Multiple-Outputs) system and MISO(Multiple-inputs Single-Outputs) system compared to SISO(Single-Input Single-Output) system.    MIMO system can increase the channel capacity and spectrum utilization of communication system doubly without increasing bandwidth. For SISO system, the channel capacity  is the the channel capacity in bits per second, is the bandwidth of the channel in hertz and is the signal-to-noise ratio.  For MIMO system, the channel capacity is  Both the transmitter and the receiver have antennas, and is orthogonal channel matrix.  According to the formula, the spectrum utilization of MIMO system is higher than that of SISO system.   1. **MIMO transmission model** 2. **Methods for implementing MIMO** 3. **Pre-coding**   In multi-user MIMO system, one of the main problem is to eliminate the interference between each user signal. In the downlink, the mobile stations can’t cooperate with each other because thay are geographically dispersed. Therefore, the receiving algorithm used in the uplink can’t be used to detect the transmitted signal jointly. At this time, the channel state information can be utilized at the transmitter, and the pre-coding technology of multi-user MIMO system can be adopted to preprocess the transmitted signal, so that each user can receive the pure signal that is not interfered by other users.  Take MIMO pre-coding as example. The steps for pre-coding are as below：  **Step1:** do SVD(Singular Value Decomposition of matrices) to .  The expression of the received signal is as below  is the channel matrix. The SVD of is  And  **Step2:**replace with the SVD of it  Define , which satisfy  Because , then  So  Multiply both sides of this equation by  Further expansion expression:  According to the expression, it is obvious that the received signal contains the pre-coded transimitted signal and the noise of the channel, which means interference from other users have been eliminated.     1. **Zero-forcing(zxd)**   The essence of the zero forcing algorithm is to form the beam to separate the transmitted data stream by using the base station, so that the unit response is generated in the expected direction and the response in the non-expected direction is zero. Interference users form zero trap, completely eliminating interference between user data streams. The idea is to make use of the known channel state information, multiply the sender by the inverse (pseudo-inverse) matrix of the channel matrix, and implement linear zero forcing interference among independent signals based on the least square estimation, so as to obtain the required signals.  Assume that channels are held constant for the whole frame, the pre-coding matrix of zero forcing algorithm is  In order to ensure that the power of the transmitted signal remains unchanged after pre-coding, normalization processing is carried out. is used to represent the power normalization factor, and theexpression of final precoding matrix is:  The expression of is:  This precoding algorithm can completely eliminate the interference between users and the interference between data streams within users, that is  Therefore it is called zero forcing algorithm.  The advantage of zero forcing algorithm is low complexity, which can completely eliminate interference. The disadvantage is that it will affect the transmission power and make the additive noise amplified by weighting.     1. **Minimum Mean Squared Error (MMSE)** 2. **Alamouti coding** 3. **comm.OSTBCEncoder** 4. **comm.OSTBCCombiner**   **Lab results & Analysis**   1. **Methods for implementing MIMO** 2. **Programming procedure of Pre-coding(zxd)**   The function of pre-coding is as below:         1. **Programming procedure of Zero-forcing(zxd)**   The function of zero forcing algorithm is as below:       1. **Programming procedure of Minimum Mean Squared Error (MMSE)** 2. **BER comparison(zxd)**     From the above picture, what can be known is that when SNR is less than 8dB, the BER using zero forcing is less than those using pre-coding and MMSE. When SNR is greater than 8dB, the BER using MMSE is less than those using pre-coding and zero-forcing. That means the performance of zero-forcing algorithm is better under the condition when SNR is low and the performance of MMSE algorithm is better under the condition when SNR is high. In practice, we should choose the corresponding method of MIMO system according to the actual signal-to-noise ratio.   1. **Apply Alamouti 2×2 to the QPSK transceiver** 2. **Programming procedure** 3. **Results**  * **Text recovery** * **BER** | |
| **Experience**  **Experience**  孙逸涵:  张旭东:   1. I have a deep understanding the application and deployment of MIMO system and the advantages of it. 2. I have a deep understanding of the pre-coding algorithm and be preliminarily familiar with the process of algorithm derivation and the process of code programming. 3. I have a deep understanding of the zero forcing algorithm and be preliminarily familiar with the process of algorithm derivation and the process of code programming.   **In-class lab screenshot**  孙逸涵:  张旭东: | |
| **Score** | 100 |