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Analytical Investigations on Optimum Antenna Selection Technique by Using Channel State Information

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Abstract - Multiple Input Multiple Output systems has better performance which can be achieved without using additional transmit power or bandwidth extension. However, it requires additional high-cost RF modules are required as multiple antennas are employed. To reduce the cost associated with the multiple RF modules, antenna selection techniques can be used to employ a smaller number of RF modules than the number of transmit antennas. This paper presents analytical and simulative investigations on an optimum antenna selection technique using channel state information.

***Keywords* - Antenna Selection, Channel State Information, Multiple Input Multiple Output, Radio Frequency, Signal to Noise Ratio.**

1. Introduction

Multiple Input Multiple Output (MIMO) systems takes advantage of multipath propagation signals by sending and receiving more than one data signal in the same frequency band at the same time by using multiple transmit and receive antennas. Orthogonal frequency division multiplexing (OFDM) is also has capability to handle the effect of ISI and Inter carrier interference (ICI). OFDM converts the frequency selective wide band signal into frequency flat multiple orthogonally spaced narrow band signals also resulting in high bandwidth efficiency [1].Figure 1 shows block diagram of a typical digital communication system.

The information source is assumed to be digital, the task of the source encoder is to represent the digital information by bits in an efficient way. The bits are then fed into the channel encoder, which adds bits in a structured way to enable detection and correction of transmission errors.

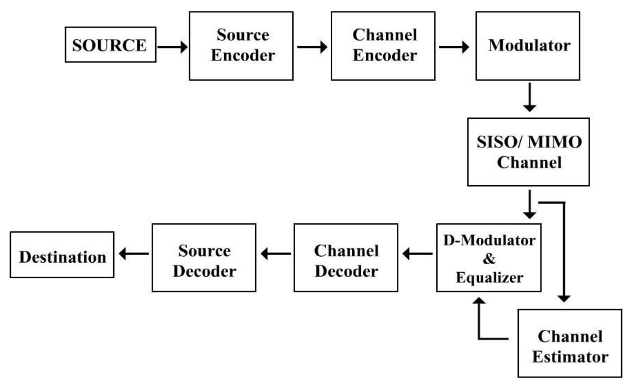

Figure1: Digital Communication System [1]

Channel encoder introduces redundancy in the information sequence, this redundancy can be used by the channel decoder to reduce the impact of channel effects as noise and interference and the result is increased reliability of the received data [2]. The bits from the encoder are grouped and transformed to certain symbols, or waveforms by the modulator and waveforms are mixed with a carrier to get a signal suitable to be transmitted through the channel. Channel represents the physical medium which connects the transmitter and receiver. This medium can be wired line or a wireless connection. All received waveforms will be more or less corrupted due to different factors that are thermal noise from electronic devices, non-linear distortion, interference from other transmissions, atmospheric noise, fading, etc. At the receiver side of the digital communication system, there are one or more receiving antennas. Each antenna

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receives a weighted and possibly filtered sum of the different transmitted waveforms. The digital demodulator processes these signals and produces a binary stream again. In MIMO systems, the equalizer module reconstructs the transmitted signals from the weighted sums of signals transmitted by different antennas, using the estimate provided by the channel estimator and received signal.

2. Antenna Selection Techniques

MIMO systems have better performance which can be achieved without using additional transmit power or bandwidth extension. However, it requires additional high-cost RF modules are required as multiple antennas are employed. To reduce the cost associated with the multiple RF modules, antenna selection techniques can be used to employ a smaller number of RF modules than the number of transmit antennas. Figure 2 illustrates the end-to-end configuration of the antenna selection in which only Q RF modules are used to support N_T transmit antennas $(Q < N_T)$. Note that Q RF modules are selectively mapped to Q of N_T transmit antennas.

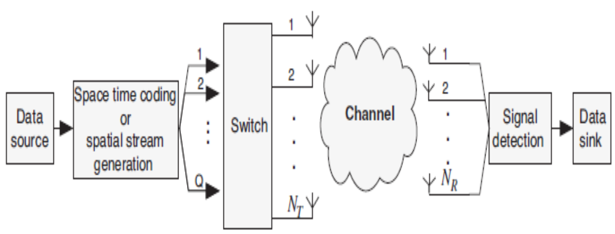

Figure 2: Antenna selections with Q RF modules and N_T transmit antennas $(Q < N_T)$ [10]

Since Q antennas are used among N_T transmit antennas, the effective channel can now be represented by Q columns of $H \in \Re^{N_R \times N_T}$. Let p_i denote the index of the i[th] selected column, $i = 1, 2, \cdots, Q$. Then, the corresponding effective channel will be modeled by $N_R \times Q$ matrix, which is denoted by $H_{\{p_1, p_2, \cdots p_Q\}} \in \Re^{N_R \times Q}$. Let $X \in \Re^{Q \times 1}$ denote the space-time-coded or spatially-multiplexed stream that is mapped into Q selected antennas. Then, the received signal y is represented as

$$y = \sqrt{\frac{E_X}{Q}} H_{\{p_1, p_2, \cdots p_Q\}} X + Z \qquad (1)$$

where $z \in \Re^{N_R \times 1}$ is the additive noise vector. The channel capacity of the system in Equation (1) will depend on the number of transmit antennas that are chosen. In the following subsections, we will discuss how the channel capacity can be improved by the antenna selection technique.

3. Optimum Antenna Selection Technique

A set of Q transmit antennas must be selected out of N_T transmit antennas so as to maximize the channel capacity. When the total transmitted power is limited by P, the channel capacity of the system using Q selected transmit antennas is given by

$$C = \max_{R_{xx}, \{p_1, p_2, \cdots p_Q\}} \log_2 \det\left(I_{N_R} + \frac{E_X}{QN_0} H_{\{p_1, p_2, \cdots p_Q\}} R_{xx} H^H_{\{p_1, p_2, \cdots p_Q\}}\right) bps/Hz \qquad (2)$$

Where R_{xx} is $Q \times Q$ covariance matrix. If equal power is allocated to all selected transmit antennas, $R_{xx} = I_Q$, which yields the channel capacity for the given $\{p_i\}_{i=1}^{Q}$ as

$$C_{\{p_1, p_2, \cdots p_Q\}} \triangleq \log_2 \det\left(I_{N_R} + \frac{E_X}{QN_0} H_{\{p_1, p_2, \cdots p_Q\}} H^H_{\{p_1, p_2, \cdots p_Q\}}\right) bps/Hz \qquad (3)$$

The optimal selection of P antennas corresponds to computing Equation (3) for all possible antenna combinations. In order to maximize the system capacity, one must choose the antenna with the highest capacity, that is,

$$\{p_1^{opt}, p_2^{opt}, \cdots p_Q^{opt}\} = \arg\max_{\{p_1, p_2, \cdots p_Q\} \in A_Q} C_{\{p_1, p_2, \cdots p_Q\}} \qquad (4)$$

where A_Q represents a set of all possible antenna combinations with Q selected antennas. $|A_Q| = \binom{N_T}{Q}$, that is, considering all possible antenna combinations in Equation (4) may involve the enormous complexity, especially when N_T is very large. Therefore, some methods of reducing the complexity need to be developed.

Figure 3 shows the channel capacity with antenna selection for N_T =4 and N_R = 4 as the number of the selected antennas varies by Q = 1, 2, 3, 4. It is clear that the channel capacity increases in proportion to the number of the selected antennas. When the SNR is less than 10dB, the selection of three antennas is enough to warrant the channel capacity as much as the use of all four antennas.

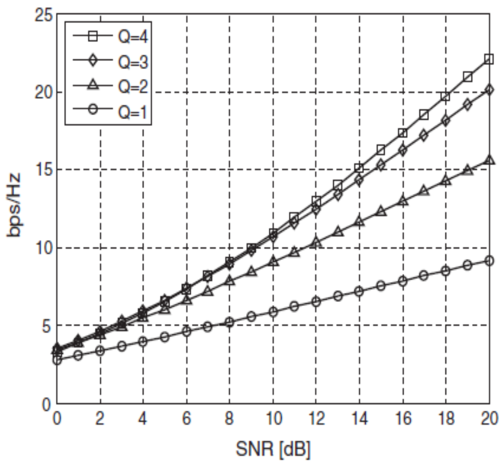

Figure 3: Channel capacity with optimal antenna selection:

$$N_T = N_R = 4 \text{ and } Q = 1, 2, 3, 4 .$$

4. Conclusion

In this paper, we have used transmission techniques that can be used to exploit the CSI on the transmitter side. The CSI can be known completely or partially. Sometimes, only statistical information of the channel state is available. We have exploited such information for optimum antenna selection and hence for achieving high the channel capacity. Simulation results show the channel capacity that the channel capacity increases in proportion to the number of the selected antennas. When the SNR is less than 10dB, the selection of three antennas is enough to warrant the channel capacity as much as the use of all four antennas. As this antenna selection method requires too much complexity depending on the total numbers of available transmit antennas.

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