DESIGN OF STBC ENCODER AND DECODER FOR 2X1 AND 2X2 MIMO SYSTEM

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ABSTRACT

This paper describes a method to design, evaluate and simulate adaptive algorithm for system with multiple transmit and receive antennas. The idea is to transmit multiple streams of data on multiple antennas at the same frequency, to increase reliability and throughput. Typically, multiple receiver antennas are used as well, since this configuration achieves high data rates and reliability, multiplied by the number of channels between either ends. This principle is called Multiple Input Multiple Output (MIMO). They are particularly attractive because they do not require any additional transmission Bandwidth, and unlike traditional systems use multi-path interference to their benefit.

The present work focuses on design of encoder and decoder for multi-antenna scheme such as 2x1, 2x2 MIMO System, employing Space Time Block coding to get higher reliability. The BER performance charts for a MIMO 2X1, MIMO 2X2 got by simulation of code using MATLAB and the comparison of these BER plots are included in the result.

KEYWORDS: OFDM, MIMO, STBC

Data rates for wireless cellular and local area networks have been steadily increasing in recent years, with an approximate five-fold increase in throughput every four years. With new applications such as wireless multimedia and the replacement of cables for communication purposes in home, office and public access scenarios, we can anticipate this trend to continue. Three challenging requirements arise from the call for higher data rates and reliability in next generation wireless systems: we have to increase spectral efficiency, design systems for larger bandwidths, and we shall reduce the costs per bit as well.

Exploiting the rich scattering typical for indoor and urban environments [R. S. Blum, 2001], multiple-input multiple output (MIMO) systems allow for sound gains in the spectral efficiency, thus facilitating the transmission at higher reliability in a spectrum which is usually limited by regulation and other factors.

Multiple antennas can be used at the transmitter and receiver, an arrangement called a multiple-input multiple-output (MIMO) system. A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain. Generally, there are three categories of MIMO techniques. The first aims to improve the power efficiency by maximizing spatial diversity. Such techniques include delay diversity, space–time block codes (STBC) [S. Alamouti, 1998], [V. Tarokh, 1999], [V. Tarokh, 1998] and space–time trellis codes (STTC) [V. Tarokh, H, 1999]. The second class uses a layered approach to increase capacity. One popular example of such a system is V-BLAST suggested by Foschini et al. where full spatial diversity is usually not achieved. Finally, the third type exploits the knowledge of channel at the transmitter. It decomposes the channel coefficient matrix using singular value decomposition (SVD) and uses these decomposed unitary matrices as pre- and post-filters at the transmitter and the receiver to achieve near capacity.

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Multi Antenna Systems

One possible way to improve the reliability of wireless communications is to employ diversity. Diversity is the technique of transmitting the same information across multiple Channels to achieve higher reliability. It operates on the principle that it is unlikely that all of the channels used to transmit the redundant information will be experiencing deep fading at the same time. Even if one particular channel is unusable, the information may still be recovered from the redundant transmission over the other channels. Therefore the overall reliability of the communications system is improved, at the cost of
transmitting redundant information. If multiple antennas are used at the transmitter or receiver there are potentially multiple transmission channels between the transmitter and receiver. See Figure 1 for an example of the potential channels in a 2×2 MIMO system. These multiple channels can be used to exploit diversity.

![Figure 1: Multi Antenna System](image1)

In the 2×2 system in Figure 1, there is the potential for both transmit and receive diversity. Receive diversity is when the same information is received by different antennas. For instance the information sent from Tx1 is transmitted across channels $h_{11}$ and $h_{21}$ and received by both Rx1 and Rx2. Transmit diversity is when the same information is sent from multiple transmit antennas. One possible way to achieve this is to code across multiple symbols periods.

**STBC Encoder and Decoder for 2X1 Antenna Configuration**

Let $S$ be the code matrix transmitted by antennas Tx1 and Tx2 at time interval $t$ and $t+1$, given by

\begin{equation}
S = \begin{bmatrix}
s_1 & -s_2^* \\
s_2 & s_1^*
\end{bmatrix}
\end{equation}

\[multiplied by\]

The Channel matrix for 2×1 is

\begin{equation}
H = \begin{bmatrix}
h_{11} & h_{12} \\
h_{21} & h_{22}
\end{bmatrix}
\end{equation}

where $h_{11}$ is the channel between Tx1 & Rx1 and $h_{12}$ is the channel between Tx2 & Rx1 as shown in fig 2.

The received signal $R$ is given by

\[multiplied by\]

\[multiplied by\]

\[multiplied by\]
\[ R = \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} \]

At time instant \( t \), the receiver Rx1 receives the signal
\[ r_{11} = h_{11} \times s_1 + h_{12} \times s_2 \]

At time instant \( t+1 \), the receiver Rx1 receives the signal
\[ r_{12} = h_{11} \times (-s_2^*) + h_{12} \times s_1^* \]

At the decoder, calculate \( s_1 \) and \( s_2 \) estimate from \( r_{11} \) and \( r_{12} \) as follows
\[ s_1 - est = h_{11}^* \times r_{11} + h_{12} \times r_{12}^* \]
\[ h_{11}^* \times h_{11} \times s_1 + (h_{11}^* \times h_{12} \times s_2) + (h_{12} \times h_{11}^* \times -s_2) + h_{12} \times h_{12} \times s_1 \]
\[ = h_{11}^* \times h_{11} \times s_1 + h_{12} \times h_{12} \times s_1 \]
\[ = s_1 \times (h_{11}^* \times h_{11}^* + h_{12} \times h_{12}^*) \]

Normalize the \( s_1 - est \) to get the recovered data symbol as follows:
\[ s_1 = s_1 - est + \left( h_{11}^* \times h_{11}^* + h_{12} \times h_{12}^* \right) \]  
\[ .................(3) \]

\[ s_2 - est = h_{12}^* \times r_{11} - h_{11} \times r_{12}^* \]
\[ s_2 = s_2 - est \div \left( h_{11}^* \times h_{11}^* + h_{12} \times h_{12}^* \right) \]
\[ .................(4) \]

From equation (3) and (4) the symbol \( s_1 \) and \( s_2 \) are recovered back at decoder which is transmitted by Tx1 and Tx2.

**STBC Encoder and Decoder for 2X2 Antenna Configuration**

The received signal \( R \) is
\[ R = H \times S \]
\[ \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \times \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \]

At time instant \( t \), the receiver Rx1 and Rx2 receives the signals
\[ r_{11} = h_{11} \times s_1 + h_{12} \times s_2 \]
\[ r_{12} = h_{11} \times (-s_2^*) + h_{12} \times s_1^* \]

At time instant \( t+1 \), the receiver Rx1 and Rx2 receives the signals
\[ r_{21} = h_{21} \times s_1 + h_{22} \times s_2 \]
\[ r_{22} = h_{21} \times (-s_2^*) + h_{22} \times s_1^* \]
At the decoder, calculate $s_1$ and $s_2$ estimates from $r_{11}, r_{12}, r_{21}$ and $r_{22}$ as follows:

$$s_{1\_est} = h_{11}^* \times r_{11} + h_{12}^* \times r_{12} + h_{21}^* \times r_{21} + h_{22}^* \times r_{22}$$

$$= s_1 \times \left(h_{11}^* \times h_{11} + h_{12}^* \times h_{12} + h_{21}^* \times h_{21} + h_{22}^* \times h_{22}\right)$$

Normalize the $s_{1\_est}$ to get the recovered data symbol as follows:

$$s_1 = \frac{s_{1\_est}}{\left(h_{11}^* \times h_{11} + h_{12}^* \times h_{12} + h_{21}^* \times h_{21} + h_{22}^* \times h_{22}\right)}$$

From equation (5) and (6) the symbol $s_1$ and $s_2$ are recovered back at the decoder which is transmitted by Tx1 and Tx2.

Since there are four channels between the encoder and decoder in 2x2 antenna configuration, there are more chances of decoding the transmitted symbol correctly than 2x1 antenna configuration.

**SIMULATION RESULTS**

The current testing/simulation/validation is carried out by entering the values of various system parameters in code files. By the current invention the tester/user/valuator is provided a convenient way to enter the values. From simulation graphs as shown in fig 6 and 7 we can observe that, MIMO 4x2 gives better performance than MIMO 2x2, since 4x2 antenna configurations have more channels than 2x2 antenna configurations. Hence reliability is directly proportional to the number of channels between STBC encoder and decoder.

![MIMO OFDM BER Plot](image)

**Figure 6: MIMO 2x1 BER plot with BPSK modulation**

CONCLUSION

With the simulation results, we can conclude that, MIMO 2x2 gives better performance than MIMO 2x1, since MIMO 2x2 antenna configurations have more channels than MIMO 2x1 antenna configurations. Hence reliability is directly proportional to the number of channels between STBC encoder and decoder.

REFERENCES


