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To the study of application using MIMO (multiple-input, multiple-output) technology for wireless communications

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Abstract

A Multi-Input Multiple-Output (MIMO) system, designed and built for higher-order transmitting and receiving antennas, incorporates the space-time block coding technique (STBC) and the Maximum Ratio Combining (MRC) diversity scheme. brand-new product range A Successive Interference Cancellation (SIC) method is developed and implemented to enhance the detection capability and functionality of MIMO systems to individual branches to decrease interference.

Keywords: MRC, Maximum, portability, SIC, coding, and interference

Introduction

As the internet of things (IoT) and mobile devices continue to grow in popularity, the need for dependable, high-speed data transfer over wireless networks is only going to increase. The conventional single-antenna approach has many drawbacks, which led to the development of Multiple Input Multiple Output (MIMO) technology. This is accomplished by equipping the transmitter and receiver with an array of many antennas to simultaneously broadcast various data streams, this technique enhances system capacity and spectral efficiency. Since optimizing transmission performance and channel capacity in complex propagation environments, dealing with channel estimation errors and antenna correlation in real-world deployments, and other challenges are common in wireless communication, utilizing and optimizing MIMO technology is the focus of this article these areas.

In addition, the channel model, capacity optimization strategy, and power allocation technique of the MIMO system are studied theoretically. This study explores the design and concepts of research on methods to improve channel capacity and performance using multiple-input multiple-output (MIMO) technology and talks about how it will be used and what problems it will have in 5G and other future communication systems. This study's findings will facilitate the implementation about 5G and 6G networks' Massive MIMO and contribute to the improvement of wireless communication systems.

In order to make MIMO systems work better, Space-Time Coding (STC) is one option which entails encoding data in both the spatial and temporal dimensions. Enhancing signal dependability and interference resistance, it makes use of the spatial multiplexing capabilities of several antennas to encode and transmit data across distinct antennas. The space-time layered code and the space-time block code are two well-known STC approaches. The well-known coding approach that improves signal resilience and interference resistance without increasing bandwidth is STBC, which includes the Alamouti encoding scheme.

By sending out several copies of the signal via various antennas, this method successfully reduces the impact of multipath effects and channel fading by allowing the receiver to recreate the original data using combined spatial and temporal processing. STLC employs a multi-layer processing approach, with each layer using a distinct coding scheme, to handle the transmitted signals. System throughput and spectrum efficiency may be further enhanced by this method, which makes it possible to send many data streams at once. However, STLC implementation is more complex, especially in systems with many antennas, necessitating sophisticated signal processing and decoding skills.

Literature Review

Pundir, Pankaj. (2016) [1]. The most recent iteration of this system is the fourth generation, and mobile technology inside it is constantly improving the state of wireless communication. In an effort to solve the problem of how to make mobile devices more helpful in the future, 4G mobile is now in the works. Compared to previous generations of mobile networks, the 4G system is light years ahead of its predecessors. This article details the main challenges posed by both narrow-band and wide-band mobile wireless channels, as well as practical solutions that make use of spatial dimension. This work primarily aims to explain the advancements in spatial multiplexing, spatial-time coding, and spatial-time processing, as well as related approaches such as diversity bringing together.

Odeyemi, Kehinde & Ogunti, Erastus. (2014) [3]. Current wireless system designers have interesting issues in meeting the expectations of next-generation wireless networks. Improved wireless communications with faster data rates and enhanced quality of service (QoS) has generated a lot of interest as of late. Reason being, issues including channel multi-path fading, increased power consumption, and bandwidth constraints, meeting these demands becomes difficult for internet-based data transmission networks. Where this is concerned, the MIMO system ranks high among the potential options. In order to establish an electromagnetic network that transmits data at a rapid pace, this research contrasted the beamforming method with spatial multiplexing MIMO. A smart antenna array was included into both ends of the proposed wireless system's transmission and reception, and each component was used in its proper place. Under the identical simulated conditions, the findings demonstrate that the spatial multiplexing approach enhanced the system's comparison to beamforming in terms of bit error rate (BER) and effectiveness of the spectrum. In contrast to the standard MIMO, the suggested system performs better using these two methods.

Sachdeva, Shippu & Sindhwani, Manoj & Arora, Krishan. (2022) [4]. Our focus is on improving the duration of an optical wireless connection between spacecraft (IsOWC) systems by utilising various modulation formats, including RZ, NRZ, and Manchester coding are ways to go back to zero. We take into account hybrid systems that use radiofrequency (RF) to offer many inputs and multiple outputs and work towards a system based on IsOWC in medium earth orbit (MEO). A 40 Gbps system with 16 × 8 MIMO is suggested about an IsOWC channel that extends over 22,000 kilometers that can provide a 40 GHz RF transmission utilising modes of odd linear polarization (O-LP) and even linear polarization (E-LP). Additionally, we evaluate NRZ, RZ, and Manchester coding performance on the Q-factor at different IsOWC distances. The findings show that the proposed system, which uses O-LP mode and Manchester coding, can cover the 22,000 km IsOWC link length with a Q factor value of 6.35.

This research modelled and analysed the efficacy of optical communication networks deployed underwater using and without coding for various input/output combinations. Assuming a random lognormal distribution for mild ocean turbulence, channel coding and MIMO diversity were used to decrease the transmitter power. Additionally, the Monte-Carlo simulation was shown with a connection range of 30 m in the presence of minimal weather patterns in the ocean and on-off-keying at 500 Mbps. With the concatenated code, 2x5 achieved a gain of around 33.60 dB, which is an improvement above Uncoded SISO. Due to the extremely high demands placed on data security, bit rate, and energy consumption using next-gen communication systems enabled by the Internet of Things (IoT) in the water and cutting-edge mobile technology will also have a substantial influence on underwater wireless optical communications (UWOC). The coded MIMO-based UWOC system has great robustness and power qualification, making it a potential candidate for application in the IoUT.

Vuckovic, Katarina & Rahnavard, Nazanin. (2023) [5]. An introduction to localisation methods Information in this section is relevant to multiple-input multiple-output (MIMO) communication systems. Most of this chapter is devoted at frequencies below 6 GHz and millimeter wave range. The complexity of the signal propagation environment poses issues for localisation when using MIMO technology, which allows high-capacity wireless communication. In response to these difficulties, a number of approaches have been devised, making use of auxiliary data like the area map or methods like clustering, deep learning, compression sensing, or gaussian process regression. To determine the user's approximate position, these methods take into consideration wireless communication data as RSSI, CSI, ADP, AoD, AoA, or ToA, which stands for "Channel State Information," as well as any number of other names. This chapter is meant to serve as an extensive introduction to MIMO localisation techniques and to discuss the advantages and disadvantages of these methods. In addition, the theoretical foundations of channel models and wireless channel characteristics that are necessary for comprehending the localisation methods will be covered.

An ordered scheme to design a MIMO system

1. By determining HH, the Hermitian matrix, and I, the Identity matrix, are equal to each other. we can confirm that H matrices have the most crucial attribute, orthogonality.
2. The fact that each column is perpendicular to each of the other columns is another way to check for orthogonality.

Design Process

It is necessary to construct the MISO system, which consists of p transmitting antennas and a single receiving antenna. Channel Planning Matrix –

Step 1: Allow p columns to make up the first row.

$$\begin{bmatrix} h_1 & h_2 & h_3 & \cdots & h_{p-1} & h_p \end{bmatrix}$$

{No. of columns p gives space diversity}

Step 2: Adding rows while keeping them orthogonal

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & \cdots & h_{1xp} \\ -h_{12}^* & -h_{11}^* & 0 & 0 & \cdots & 0 \end{bmatrix}$$

Step 3: We add a third row and make the first two columns orthogonal.

$$\begin{bmatrix} h_1 & h_2 & h_3 & \cdots & h_{p-1} & h_p \end{bmatrix}$$

Step 4: Some changes are made, for example, by dividing the first three columns into four orthogonal ones and inserting a fourth row.

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & \cdots & h_{1Xp} \\ -h^{*}_{12} & -h^{*}_{11} & 0 & 0 & \cdots & 0 \\ h^{*}_{13} & 0 & -h^{*}_{11} & 0 & \cdots & 0 \\ h^{*}_{14} & 0 & 0 & -h^{*}_{11} & \cdots & 0 \end{bmatrix}$$

Step 5: Afterwards, we continue by adding rows in a manner that makes the third and second columns are perpendicular to one another.

This procedure is repeated until the whole matrix achieves orthogonality.

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & \cdots & h_{1Xp} \\ -h^{*}_{12} & -h^{*}_{11} & 0 & 0 & \cdots & 0 \\ h^{*}_{13} & 0 & -h^{*}_{11} & 0 & \cdots & 0 \\ h^{*}_{14} & 0 & 0 & -h^{*}_{11} & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 \\ 0 & 0 & 0 & 0 & \cdots & -h^{*}_{1Xp-1} \end{bmatrix}$$

How many rows are needed to convey t symbols is equal to the number of time intervals.

Orthogonal Requirement and Satisfaction

The orthogonality criteria for the H matrix (channel matrix) are met by this procedure. In order to transmit p symbols in other words, there can't be less than or equal to two timestamps for each row. We need to add (k-1) rows to the first column before we can make it orthogonal to column 2. After that, set up the second column such that it is perpendicular to the third, we must add (k-2) rows, and so on. Hence, the row count of the MIMO channel matrix

$$1 + \sum_{k=1}^{p-1} k = 1 + \frac{p(p-1)}{2} = \frac{p^2-p+2}{2}$$

Step 1: A relationship between input and output, as determined by the H-matrix, may be expressed as

$$Y = \mathrm{H}x + \eta$$

$$\begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^{*}_{(\frac{p^2-p+2}{2})} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} & \dots & h_{1Xp-1} & h_{1Xp} \\ -h^{*}_{12} & h^{*}_{11} & 0 & 0 & \dots & 0 & 0 \\ -h^{*}_{13} & 0 & h^{*}_{11} & 0 & \dots & 0 & 0 \\ -h^{*}_{14} & 0 & 0 & h^{*}_{11} & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & -h^{*}_{1Xp} & h^{*}_{1Xp-1} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ \vdots \\ x_p \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \\ n_3^* \\ n_4^* \\ n_5^* \\ \vdots \\ \vdots \\ n^{*}_{(\frac{p^2-p+2}{2})} \end{bmatrix}$$

Step 2: The equation may be used to find the received signal *b*.

$$\tilde{x} = \mathrm{H}^{\mathrm{H}}\mathrm{y} = \mathrm{H}^{\mathrm{H}}[\mathrm{H}x + \eta]$$

$$\begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \\ \tilde{x}_3 \\ \vdots \\ \tilde{x}_p \end{bmatrix} = \mathrm{H}^{\mathrm{H}} \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^{*}_{(\frac{p^2-p+2}{2})} \end{bmatrix} = \begin{bmatrix} h^{*}_{11} & -h_{12} & h_{13} & h_{14} & \dots & 0 & 0 \\ h^{*}_{12} & h_{11} & 0 & 0 & \dots & 0 & 0 \\ h^{*}_{13} & 0 & h_{11} & 0 & \dots & 0 & 0 \\ h^{*}_{14} & 0 & 0 & h_{11} & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & 0 & 0 \\ h^{*}_{1p-1} & \vdots & \vdots & \vdots & \vdots & \vdots & -h_{1Xp} \\ h^{*}_{1p} & 0 & 0 & 0 & \dots & 0 & h_{1Xp-1} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2^* \\ y_3^* \\ y_4^* \\ y_5^* \\ \vdots \\ \vdots \\ y^{*}_{(\frac{p^2-p+2}{2})} \end{bmatrix} + \eta$$

The formula for noise is $\eta = \mathrm{H}^{\mathrm{H}}\mathrm{n}$

Step 3: Therefore, each indicative sign will be provided by

$$\tilde{x}_1 = \left(\sum_{l=1}^{p} \left|h_l\right|^2\right) x_1 + \eta_1$$

$$\tilde{x}_2 = \left(\sum_{l=1}^{p} \left|h_l\right|^2\right) x_2 + \eta_2$$

$$\vdots$$

$$\vdots$$

$$\tilde{x}_p = \left(\sum_{l=1}^{p} \left|h_l\right|^2\right) x_p + \eta_p$$

We may deduce from the preceding equation that BER can be enhanced by increasing spatial diversity, which in turn increases the receiving signal's loudness.

Code Rate

Where k is the number of symbols sent from the transmit antennas, the coding rate is denoted as k/t. The symbol t represents the number of symbols in the channel matrix, and it stands for the number of columns durations required for transmission. Row count in the channel matrix. Code rate may also be expressed as the ratio of the channel matrix's column to row counts. Looking at the rate from the orthogonality perspective is a simple approach to do it. During the design phase, we made sure that every pair of columns was orthogonal by inserting certain values into the rows beginning in the second row and continuing all the way to the conclusion. Adding one to the total number of rows may be calculated by adding up all the column pairs, which takes the first row into consideration.

We take p and choose a pair to obtain the total rows from it to get the number of column pairs.

$$c_2^p = \frac{p(p-1)}{!2} = \frac{p(p-1)}{2}$$

How many rows

$$1 + c_2^p = 1 + \frac{p(p-1)}{!2} = \frac{p^2 - p + 2}{2}$$

Consequently, the p-antenna system's rate is

$$rate(r_p) = \frac{p}{1 + c_2^p} = \frac{2p}{p^2 - p + 2}$$

It is evident from the rate calculation that the rate falls below ½ when p > 4, meaning when we send more than four symbols in a block.

MIMO-OFDM

A MISO-OFDM system may use an indefinite number of transmit antennas and one receiving antenna with STBC. However, according to the IEEE 802.16a standard, OFDM signals can only be sent by a single antenna. In a MISO-OFDM configuration with two transmit antennas, a total of 384 information symbols are sent from the two antennas at the same time, using two distinct OFDM signals. Encoding is carried out via the STBC encoder across two successive blocks of symbols. Here is how the four blocks of encoded symbols for transmission are built:

$$x_1 = \left[x[1]x[2]......x[192]\right]$$

$$x_2 = \left[x[193]x[194].....x[384]\right]$$

$$x_3 = \left[-^{*}x[193] - x^{*}[194]... - x^{*}[384]\right]$$

$$x_4 = \left[x^{*}[1]x^{*}[2]......x^{*}[192]\right].$$

Since this block structure is similar to the STBC method discussed above, STBC-OFDM is a term that appears in various publications from time to time. Following the guidelines laid forth in the IEEE 802.16a OFDM standard, the subcarriers are distributed. A 2x1 the picture shows a schematic of a MISO-OFDM system that makes use of STBC.

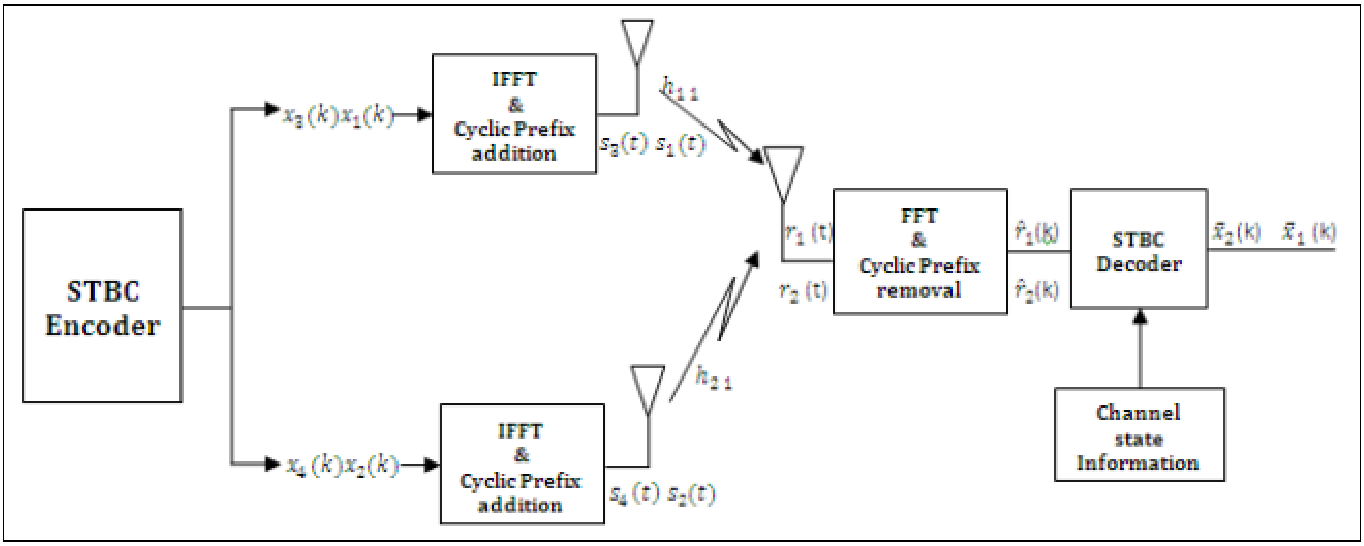

Fig 1: Block diagram of 2x1 MISO-OFDM System

Coded transmission sequence using space-time blocks $x_1(l),_2 x(l), x_3(l), x_4(l)$ in the manner shown below

$$x_3(l) = -x_2^*(l) = \begin{bmatrix} -x^*{}_2[0] \\ -\tilde{x}_2^*[1] \\ \vdots \\ -\tilde{x}_2^*[N-1] \end{bmatrix} \qquad x_1(l) = \begin{bmatrix} -x_1[0] \\ -x_1[1] \\ \vdots \\ -x_1[N-1] \end{bmatrix}$$

$$x_3(l) = -x_2^*(l) = \begin{bmatrix} -x^*{}_2[0] \\ -\tilde{x}_2^*[1] \\ \vdots \\ -\tilde{x}_2^*[N-1] \end{bmatrix} \qquad x_2(l) = \begin{bmatrix} x_2[0] \\ x_2[1] \\ \vdots \\ x_2[N-1] \end{bmatrix}$$

Assumed order at the receiving end is

$$\tilde{x}_1(l) = \begin{bmatrix} \tilde{x}_1[0] \\ \tilde{x}_1[1] \\ \vdots \\ \tilde{x}_1[N-1] \end{bmatrix} \qquad \tilde{x}_2(l) = \begin{bmatrix} \tilde{x}_2[0] \\ \tilde{x}_2[1] \\ \vdots \\ \tilde{x}_2[N-1] \end{bmatrix}$$

For every OFDM symbol $s_i(t), i = 1, 2, 3, 4,$ includes a 192-symbol block, $x_i, i = 1, 2, 3, 4,$ shown in the list above in that order. Assuming the channel parameters do not change between two OFDM symbols, the resulting signals are represented by

$$r_1(t) = h_{11}(t)s_1(t) + h_{21}(t)s_2(t)$$

$$r_2(t) = h_{11}(t)s_3(t) + h_{21}(t)s_4(t)$$

Where $h_{11}(t)$ and $h_{21}(t)$ depict the two MISO channels' time-response channel parameters. Receiving the signal, the STBC decoder uses the decoding equations provided by to approximate the signal sent at the frequency of the l-th subcarrier.

$$\tilde{x}(l) = H^H(l)\hat{r}(l)$$

$$\tilde{x}_1(l) = H_{11}^*(l)\hat{r}_1(l) + H_{21}(l)\hat{r}_2^*(l)$$

$$\tilde{x}_2(l) = H_{21}^*(l)\hat{r}_1(l) - H_{11}(l)\hat{r}_2^*(l)$$

Where, $H_{11}^*(l)$ and $H_{21}^*(l)$ represented here via the complex conjugates of the k-th subcarrier frequency(s), and $r_1^*(l)$ and $r_2^*(l)$ to the k-th FFT block output

System Model of STBC-OFDM

Using the OFDM technique, the graphic depicts a simple model of a system with numerous transmit antennas. In this approach, the total system BW is comprised of N sub-carriers that are orthogonal and equally likely. For each given number of transmit antennas, our workspace employs time block coded orthogonal frequency division multiplexing (Yun et al., 2007).

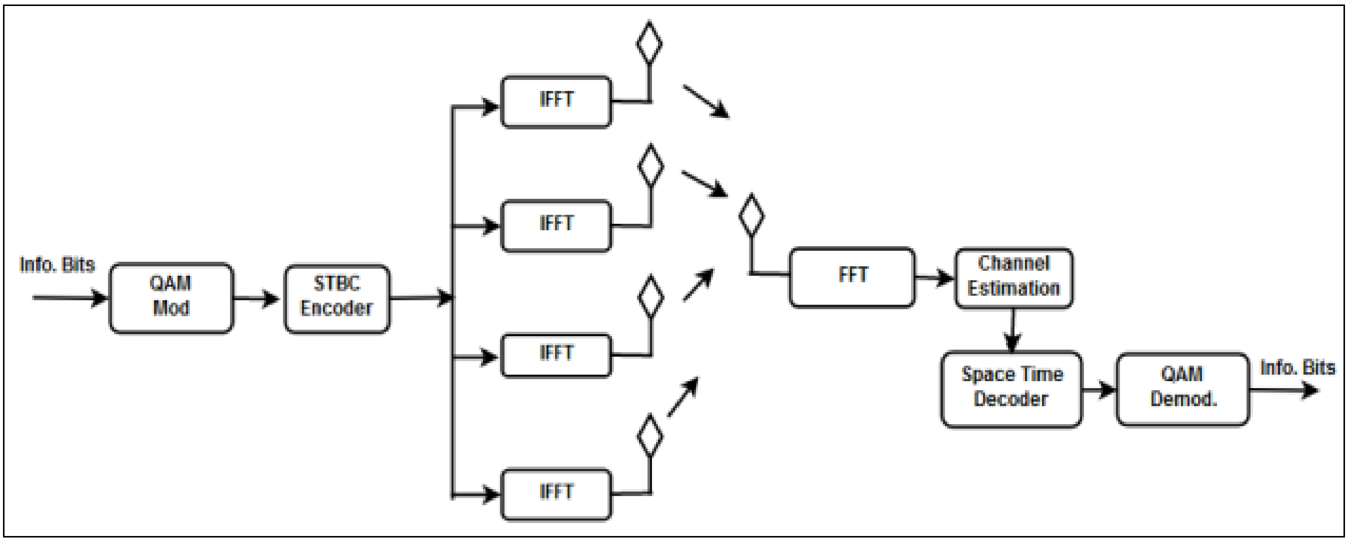

Fig 2: Simple Model of STBC-OFDM

At the beginning of the first time slot, four antennas send out the following symbols: [S0 S1 S2 S3]. The next three time slots are [-S2* -S3* S0* S1*], [-S1S0] and [-S1* -S2], respectively, during which the transmissions take place. The transmitting antennas send forth these sequences of encoded symbols. The encoding matrix equation is represented by the matrix.

$$\begin{bmatrix} h_0 & h_1 & h_2 & h_3 \\ -h_1^* & h_0^* & -h_3^* & h_2^* \\ -h_2^* & -h_3^* & h_0^* & h_2^* \\ h_3 & -h_2 & -h_1 & h_0 \end{bmatrix}.$$

The transmitted data symbols {S(k)} are converted into a set of parallel data before being inputted into the Orthogonal frequency division multiplexing (OFDM) modulator, which is made up of an inverse Fast Fourier transform (IFFT) block. Data symbols are grouped from k=0 to N-1 and passed through a serial to parallel converter. The IFFT's converted signal is subsequently sent to each transmitter as a set of complex modulated symbols. The discrete time domain (DTD) orthogonal frequency modulated sign is defined by the following equation:

$$s(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} S(k) e^{j\frac{2\pi}{N}nk} \;; 0 \le n \le N-1$$

Where N is the sum of all subcarriers and k is their index. We think of the channel coefficient as slowly changing over time since the channel model is a tapped delay line. Regarding the kth subcarrier, the frequency response of the channel is provided by

$$H(k) = \sum_{k=0}^{L-1} h(n) e^{j\frac{2\pi}{N}nk}$$

in which the n-th multipath component's channel parameter is denoted as h(n). The following equations reflect the model of the incoming signals in time at each transmission occurrence, as supplied by the input to the FFT block:

$$r^0(n) = (h_0(n) \blacklozenge s_0(n) + h_1(n) \blacklozenge s_1(n) + h_2(n) \blacklozenge s_2(n) + h_3(n) \blacklozenge s_3(n) + w(n)0) e^{j\theta(n)}$$

$$r^1(n) = (-h_0(n) \blacklozenge s_1^*(n) + h_1(n) \blacklozenge s_0^*(n) - h_2(n) \blacklozenge s_3^*(n) + h_3(n) \blacklozenge s_2^*(n) + w(n)1) e^{j\theta(n)}$$

$$r^2(n) = (-h_0(n) \blacklozenge s_2^*(n) - h_1(n) \blacklozenge s_3^*(n) + h_2(n) \blacklozenge s_0^*(n) + h_3(n) \blacklozenge s_2^*(n) + w(n)2) e^{j\theta(n)}$$

$$r^3(n) = (h_0(n) \blacklozenge s_3(n) - h_1(n) \blacklozenge s_2(n) - h_2(n) \blacklozenge s_1(n) + h_3(n) \blacklozenge s_0(n) + w(n)3) e^{j\theta(n)}$$

Gaussian Noise) and phase noise, denoted as θ(n). To determine the BER, grey code mapping is used. We have analytically developed the SNR and BER equations.

Calculation of SNR and BER: For the 16QAM scenario involving four bits (b1b2b3b4), the BER must be calculated. You may use this computation with any form of square QAM constellation. The following equation gives the Given h0, h1, h2, and h3, the conditional bit error rate (BER) for bit b1 is.

$$P_1(b_1 | h_0, h_1, h_2, h_3|) = \frac{1}{2} * \left[Q\left(\sqrt{\frac{\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) + Q\left(\sqrt{\frac{\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) \right]$$

The value of bit b3 is also determined by the equation.
P1 (b 3 | h0, h1, h2, h3|) =

$$\frac{1}{2}\left[Q\left(\sqrt{\frac{9*\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) Q\left(\sqrt{\frac{\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) Q\left(\sqrt{\frac{\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) + \left(\sqrt{\frac{25*\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}}\right) \right]$$

It is from this equation that the SNR γ is obtained.

$$\gamma = \frac{\left(2*\frac{E_g}{5}\right)(h0^2+h1^2+h2^2+h3^2)}{6\alpha^2+6\beta^2+6\omega^2}$$

Equation following provides the density of probability,

$$P(\gamma) = \frac{1}{2*6\gamma^2} exp^{-} \frac{1}{2*6\gamma^2}$$

The Bit Error Rate of the first bit is the same as the second bit and the third bit's BER is identical to the fourth bit as well. This is where their in-phase bits and quadrature bits come in names. Hence, the average BER may be calculated where γ is the PDF of the SNR and 1 b and 3 b are the conditional BERs that are averaged. Hence, the average BER may be obtained from the equation:

$$P_e = \frac{1}{2} * \int_0^{\infty} \left[\mathrm{Pe}\,(\mathrm{b}\,1\,|h_0, h_1, h_2, h_3) + \mathrm{Pe}\left(\mathrm{b}\,3\,\left|h_0, h_1, h_2, h_3\right|\right)\right]\,\mathrm{P}(\gamma)d\gamma$$

Conclusion

A MIMO system design algorithm is presented, together with a formula for determining the coding rate and an ordering method that may accommodate any sum of all antennas, including broadcast and receive. The results of the simulation show that as the number of transmit and receive antennas increases, space time block coding may enhance the performance of the bit error rate.

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