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# Best Implementation of Alamouti Scheme to Improve Bit Error Rate in 2x2 MIMO OFDM System

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**Abstract:**To increase the data rates in mimo system we have implemented a new technology called Alamouti which was first introduced by S.Alamouti in his paper in 1998 to improve data rates in wireless communication .In this paper we are discussing transmit diversity and relay selection algorithm on the basis of Alamouti scheme .We discuss how the data rates can be doubled by transmitting more symbols in one time slot.
**Keywords –** Alamouti, MIMO, TD, RS, TD-DF, TD-AF,TD-DF-AF

**1. INTRODUCTION**

We are trying to introduce a much better system which is more practical and undergoing implementation .In this paper we have analyzed a system which improves the data rate to a great extent in wireless communication. This system has overcome the drawbacks of wireless communication that reduces the data rates. We have combined the OFDM with MIMO system that contribute to reduction in data rates. We have further modified the system with Alamouti STBC code that contributes to doubling of data rates. Again we have modified the system with OFDM –MIMO combined with Transmit Diversity and relay Selection Algorithm that include decode forward and Amplify Forward Protocol for relay selection. Thus the combined effects are the reduction in bit error rates and increase in data rates of the system.

**2. Hurdles of Wireless Communication**

In conventional technology, single antenna use at both source and destination. But due to the multipath effect, electromagnetic field bounces off hills, canyons, buildings. Hence, signal reaching at the receiving antenna multiple times having different angle and cause problem such as fading, cut-off, intermittent reception. It causes a reduction in data rate and increased in number of error. This is as shown in figure below. Along with multipath there are other problems such as delay spread,cochannel interference, Rayleigh fading etc .that causes reduction in data rates.

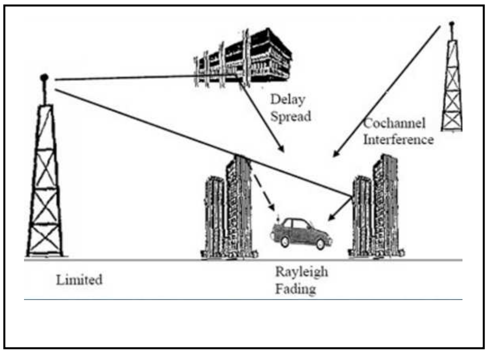


Fig. 1: Hurdles of Wireless Communication

Wireless fundamentals says that signal should be decoded successfully and signal strength should be greater than combination of noise and interference. Higher data rates means higher signal to noise ratio. Signal strength decrease with increase in range of system. Also data rates decreases with increase in number of antennas..Efforts have made to increase data rates .Hence a new technology is introduced to increase the data rates called as Orthogonal frequency division Multiplexing instead of frequency division multiplexing.

**3. OFDM Vs. FDM**

An effective technique for high data rate wireless mobile communication. In OFDM a wideband is divided unto number of parallel narrow bands as shown in figure below. This result into long symbol time and more bands to transfer data at higher rates

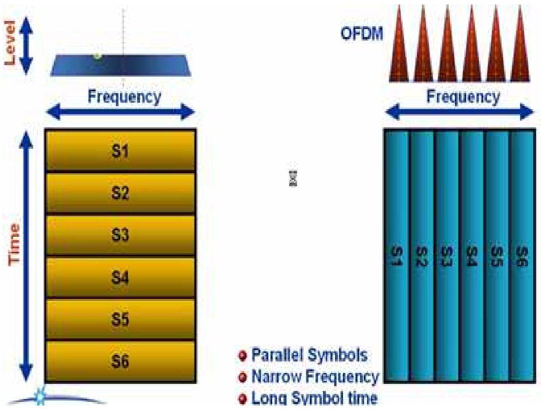


Fig. 2: FDM Vs.OFDM

**4.Advantages of OFDM**

- Makes efficient use of the spectrum by allowing overlap.
- By dividing the channel into narrowband channels, OFDM is more resistant to frequency selective fading than single carrier systems are.
- OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions.
- Provides good protection against cochannel interference

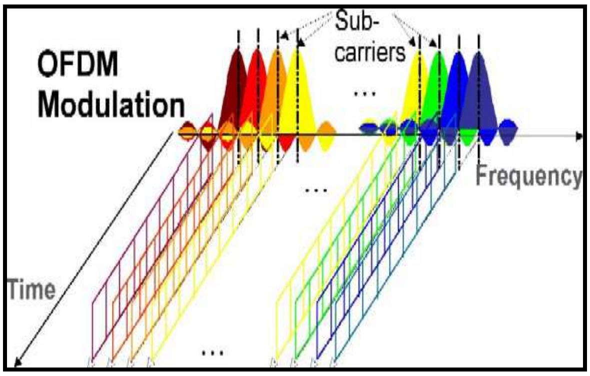


Fig. 3: Diagram of OFDM

**5.MIMO (Multiple input Multiple Output)**

MIMO is an antenna technology in which multiple antennas at Transmitter & Receiver. MIMO systems provide a significant capacity gain .Multiple antenna at each end minimizes the errors and optimizes speed and data integrity MIMO system enables to increased spectral efficiency for a given total transmit power. MIMO and OFDM techniques, significantly increases data rate, justified by reducing the bit error rate (BER) performance.[1]


Fig. 4: Diagram of OFDM-MIMO

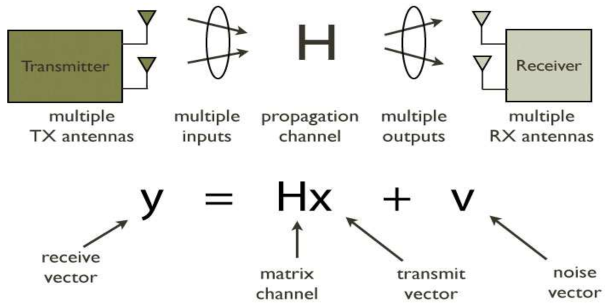


Fig 5: MIMO System

**6. Alamouti Scheme**

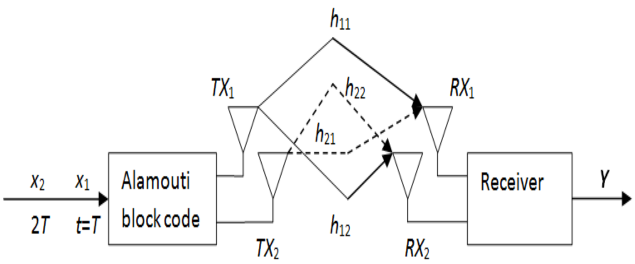


Fig. 6: Alamouti Scheme

A simple Space Time Code, suggested by Mr. Siavash M Alamouti in his landmark October 1998 paper – A Simple Transmit Diversity Technique for Wireless Communication, offers a simple method for achieving spatial diversity with two transmit antennas. The scheme is as follows:[4]

1. Consider that we have a transmission sequence, for example $\{x_1, x_2, x_3, \ldots, x_n\}$

2. In normal transmission, we will be sending $x_1$ in the first time slot, $x_2$ in the second time slot, $x_3$ and so on.

3. However, Alamouti suggested that we group the symbols into groups of two. In the first time slot, send $x_1$ and $x_2$ from the first and second antenna. In second time slot send $-x_2^*$ and $x_1^*$ from the first and second antenna. In the third time slot send $x_3$ and $x_4$ from the first and second antenna.In fourth time slot, send $-x_4^*$ and $x_3^*$ from the first and second antenna and so on.

4. Notice that though we are grouping two symbols, we still need two time slots to send two symbols. Hence, there is no change in the data rate.

5. This forms the simple explanation of the transmission scheme with Alamouti Space Time Block coding.

Thus it is the only block code that has a data rate of 1,while achieving maximum diversity gain.Breifly two antennas are used to send two OFDM symbols and their conjugate in two time slots which brings a diversity gain without having to compromise on the data rates .Thus over the air , transmitted symbol will suffer from channel fading and at the receiver their sum will be received.

Transmission is done over two periods of time .At receiver, received vector Y can be represented by the following equation.

For 1st time period, received symbol is

$$Y = \begin{bmatrix} y_1^1 \\ y_2^1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \end{bmatrix}$$

For 2nd time period, received symbol is

$$Y = \begin{bmatrix} y_1^2 \\ y_2^2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} -x_2^* \\ x_1^* \end{bmatrix} + \begin{bmatrix} n_1^2 \\ n_2^2 \end{bmatrix}$$

Received symbol at 1st and 2nd time period is the combined effect of two symbols to produce result.

$$Y = \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \\ n_1^{2*} \\ n_2^{2*} \end{bmatrix}$$

Y H X noise

The next step is to find a way to isolate the transmitted symbols x1 and x2 .One way to reduce the number of unknowns is by using a channel estimator to estimate the channel coefficients. In OFDM reference design, channel estimation OFDM symbols are sent with each transmitted packets to enable estimating those channel coefficients at the receiver .Hence the following H matrix is the received matrix at the receiver. We can isolate the x1 and x2 by multiplying th matrix Y by inverse of H .Since this matrix is not squared we use moore-penrose pseudo inverse $H^+$ to solve our equations

$$H^+ = \left(H^H H\right)^{-1} H^H$$

Using inverse matrix expression ,noisy estimated transmitted symbols can be found using

$$\widehat{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}} = \left(H^H H\right)^{-1} H^H \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix}$$

The last step is to make a final decision using Minimum Square Euclidian distance Criterion. Thus Alamouti STBC is simple MIMO technique that reduces BER of system at specific SNR without loss of data rates. This is hard decision based zero forcing and simplest to implement in hardware. Linear decoding technique has low complexity. Notice that we are grouping two symbols and sending them in one time slot we need only (n/2) time slots to complete the transmission. Thus data rates are doubled.

### 7.MIMO with Transmit Diversity and Relay Selection

Diversity intends to receive the same information bearing signal in multiple antennas or to transmit them from multiple antennas improving transmission reliability.

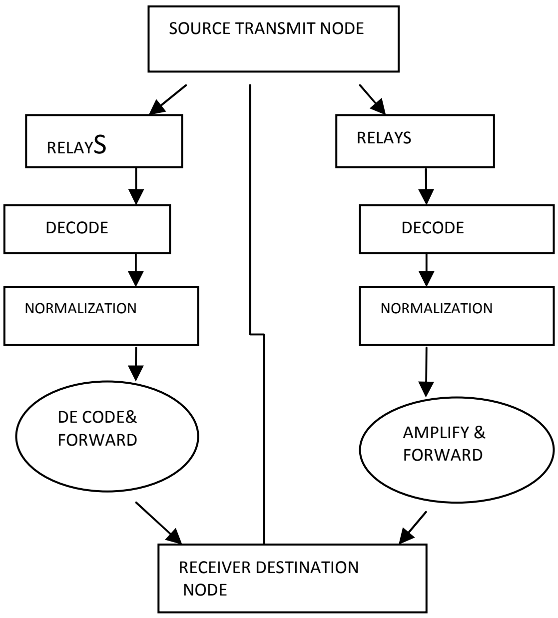


Fig. 5: Transmit Diversity and Relay Selection Algorithm

- MIMO system was designed for improving the bit error rate as compared to SISO system.
- It provided a good reduction in BER ratio.
- Further techniques were designed to improve bit error rate .
- Resulted in new technique called Transmit Diversity & Relay Selection Of MIMO System .
- Source transmitter transmits multiple signals.
- At relay node these signals are analysed using DF and AF protocol.DF happens to be first to the Af and forwarded to Receiver.

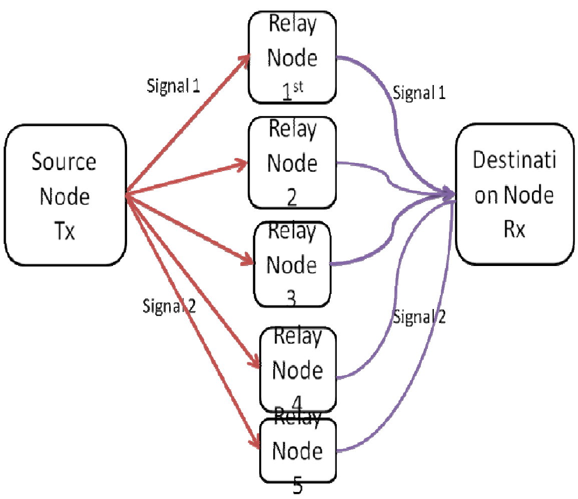


Fig. 5: Relay Selection Algorithm

**8. System And Data Model**

The cooperative network considered in this paper is a two phase system where the direct path is no negligible and no Inter symbol interference is assumed. All relays are half-duplex, and MMSE interference suppression and symbol estimation are performed at all decoding nodes. Single source and destination nodes are separated by Nr intermediate relay nodes, where the channel of each antenna pair is represented by a complex gain The direct path has a gain that is a fraction of the indirect paths to reflect the increased geographical distance and shadowing involved. The source and destination nodes each have Nas forward and Nad backward antennas, respectively, and the relay nodes have Nar forward and backward antennas. Nas data streams are transmitted in the system, and each is allocated to the correspondingly numbered antenna at the source node[2]

A. Decode-and-Forward

The received signals of the first phase at the destination and nth relay for the ith symbol are respectively given by

rsd[i] =Hsd[i]As[i]Ts[i]s[i] + ηsd[i] (1)
rsrn[i] =Hsrn[i]As[i]Ts[i]s[i] + ηsrn[i]. (2)

The structures Hsd and Hsrn are the Nas × Nad source–destination and Nas × Nar source—nth relay channel matrices, respectively. The quantities ηsd and ηsrn are the Nad × 1 and Nar × 1 vectors of zero mean additive white Gaussian noise at the destination and nth relay, respectively, whose variances are σ2 sd and σ2 srn and autocorrelation matrices σ2 sdINad and σ2 srnINsrn . The source's Nas × 1 transmit data vector is denoted by s, and As is the diagonal source transmit power allocation matrix that acts to normalize the average total transmit power of the first phase to unity assuming that the modulation scheme is also power normalized to 1. Finally,Ts is a diagonal Nas × Nas source TDS matrix ,where a 1 on each element of the main diagonal specifies whether the correspondingly numbered antenna is active. Consequently, to maintain the maximum multiplexing gain under the described protocol, all source antennas are required therefore,Ts[i] = INas throughout this paper. At the nth relay, the output of the reception and interference suppression procedure is denoted zrn[i], and the decoded symbol vector is given by[1]

ˆsrn[i] = Q(zrn[i]) (3)

where Q(·) is a general quadrature-amplitude-modulation slicer.The Nad × 1 second-phase received signal at the destination is the summation of the Nr relayed signals, yielding

$$r_{rd}[i] = \sum_{n=1}^{N_r} H_{rnd}[i]A_{rn}[i]T_{rn}[i]\hat{s}_{rn}[i] + \eta_{rd}[i] \qquad (4)$$

where $\mathbf{H}_{rnd}$ is the $n$th relay–destination channel matrix, and $\mathbf{A}_{rn}[i]$ is the $n$th relay transmit power allocation matrix that ensure the total transmit power of the second phase i s unity $\mathbf{T}_{rn}$ is the TDS matrix of the $n$th relay that specifies which of its $N_{ar}$ antennas are active. The summation of(4)can be expressed in a more compact form given by

$$\mathbf{r}_{rd}[i] = \boldsymbol{H}_{rd}[i]\boldsymbol{A}_r[i]\boldsymbol{T}_r[i]\hat{\mathbf{s}}[i] + \boldsymbol{\eta}_{rd}[i] \qquad (5)$$

The final received signal at the destination is then formed by stacking the received signals from the relay and source nodes to give

$$r_{di} = \begin{bmatrix} r_{sd}[i] \\ r_{rd}[i] \end{bmatrix} \qquad (6)$$

B. Amplify-and-Forward

For the AF protocol, the common approach of compounding the first- and second-phase signals and channels is used [10],resulting in the following expressions for the destination's second-phase received signal:

$$\mathbf{r}_{rd}[i] = \boldsymbol{H}_{rd}[i]\boldsymbol{A}_r[i]\boldsymbol{T}_r[i].\mathbf{r}_{sr}[i] + \boldsymbol{\eta}_{rd} \qquad (7)$$

where $.\mathbf{r}_{sr}[i] = [\mathbf{r}^T_{sr1}[i]\ \mathbf{r}^T_{sr2}[i] \ldots \mathbf{r}^T_{srN_r}[i]]^T$ can be interpreted as the AF equivalent of $\hat{\ }.\mathbf{s}[i]$. Expanding (7) yields

$$\mathbf{r}_{rd}[i] = \boldsymbol{H}_{rd}[i]\boldsymbol{A}_r[i]\boldsymbol{T}_r[i]\boldsymbol{H}_{sr}[i]\mathbf{A}_s[i]\mathbf{T}_s[i]\mathbf{s}[i] + \boldsymbol{H}_{rd}[i]\boldsymbol{A}_r[i]\boldsymbol{T}_r[i].\boldsymbol{\eta}_{sr} + \boldsymbol{\eta}_{rd} \qquad (8)$$

where $\boldsymbol{H}_{sr}[i] = [\mathbf{H}^T_{sr1}[i]\mathbf{H}^T_{sr2}[i] \ldots \mathbf{H}^T_{srN_r}[i]]^T$, and $\boldsymbol{A}_r[i]$ normalizes the average transmit power of the second phase based on each relay's receive power. The received signals of the first and second phases can then be stacked as in (6) to give $\mathbf{r}_d[i]$.

The Matlab script performs

- Generate random binary sequence of +1's and -1's.
- Group them into pair of two symbols.
- Code it as per the alamouti STBC, multiply the symbols with the channel and then add white Gaussian noise.
- Equalize the received symbols
- Perform hard decision decoding and count the bit errors.
- Repeat for multiple values of Eb/No and plot the simulation

.

## 9. Analysis

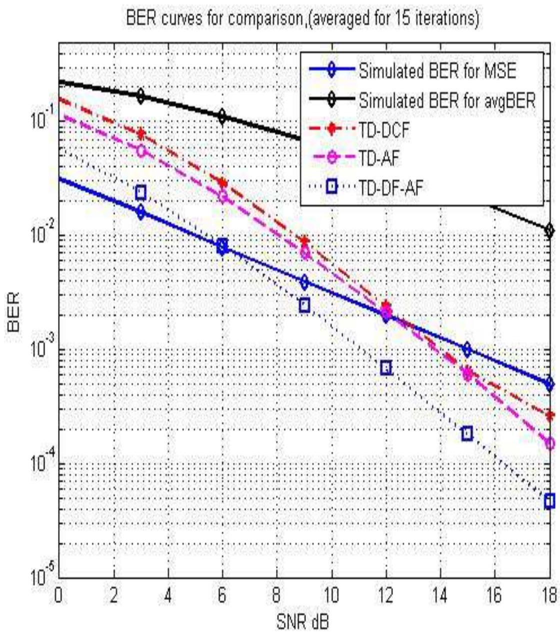


Fig. 6: Comparison Of MIMO-OFDM And MIMO-OFDM Using Transmit Diversity And Relay Selection.

Figure shows transmit diversity and relay selection for MIMO system. This shows that TD-DF-AF has more satisfactory level of bit error rate as compared to SISO, MIMO and other counterparts. Thus if bit error rate is minimum more number of users will be able to transmit at a same rate with increased accuracy .

Wireless broad band will be able to increase more number of users through implementation of transmit diversity and relay selection algorithm for MIMO system.

## 10. Conclusions

We have presented TDS and RS methods based on DSA formulate relay cooperative MIMO systems, where RS improves the performance of conventional TDS. Hybrid continuous-discrete MMSE and MI optimization problems have been formed, and a framework to solve them has been developed. The resulting joint TDS with RS DSA schemes have been shown to operate well with optimal receivers, converge in parallel with low complexity linear adaptive MMSE receivers, exceed the performance of GAS, and, in the majority of scenarios, converge to the optimal solution. Increased diversity and improved interference suppression have been shown to be obtained by the proposed schemes, and full algorithmic implementations have then been given to provide designers with the tools to significantly improve the performance of cooperative MIMO systems .Thus this system leads to following results

- Extended coverage area

- Improves data-rate.
- Improves Quality of service.
- Increases speed of convergence.
- Saving considerable computational expense, thus making them ideal for mobile use.
- Low power consumption and high capacity.
- DF and AF protocols lead to significant performance.

**11. Future Scope**

The wireless broadband can become the biggest growth space among the wireless trade. The place to begin for this growth is increasing client reliance on portable computer computers. Today, a lot of laptops square measure sold-out within the us than desktop PCs. As this trend continues, thus can users' demand for constant sort of broadband service notwithstanding wherever they' reception, at the workplace, or on the road.

**High Broadband connectivity**

Wi-Fi and existing high-speed cellular networks being deployed nowadays meet a number of these wants, however OFDM-MIMO, utilized by WiMAX 802.16e or on the far side 3G, is that the technology required to permit for economic and scalable wireless broadband. The measurability volumed by these technologies becomes particularly vital once MP3 players, PDAs, transportable games devices and different hand-held devices square measure equipped to supply wireless broadband, giving users a broadband affiliation where they are going.

**Automobile Application**

If the wireless trade fast-forwards the acceptance of MIMO and OFDM technologies into the refinement of our highways, we'll be ready to place the newest, greatest automobiles--applications--on those highways and permit individuals to reach places quicker than ever before. During this approach, MIMO and OFDM square measure key technologies if sanctioned for the wireless trade we deliver on the immense potential and promises for wireless broadband.

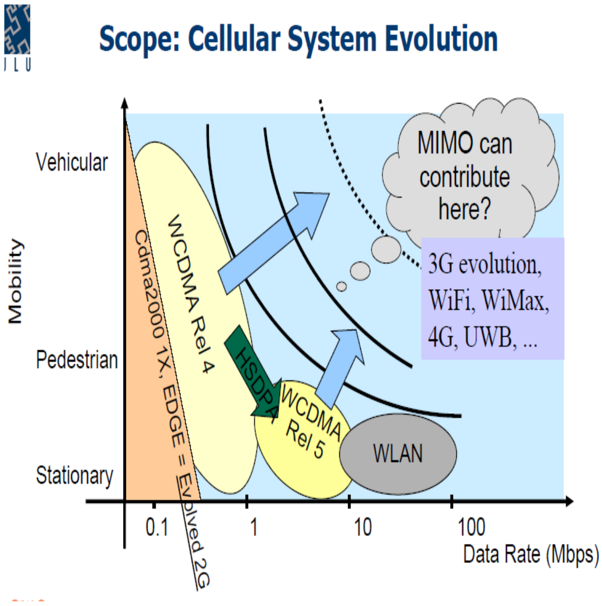


Fig. 7: Cellular System Evolution

Future implementation of MIMO OFDM is as follows

- It is the dominant air interface for 4G and 5G broadband wireless communications.
- MU-MIMO capacity appears for the first time in what have become known as "Wave 2" products. Qualcomm announced chipsets supporting MU-MIMO in April 2014.
- Trials of 5G technology have been conducted by Samsung.Japanese operator NTT DoCoMo plans to trial 5G technology in collaboration with Alcatel-Lucent, Ericsson, Fujitsu.

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