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INCORPORATING DIVERSITY IN WIRELESS SYSTEM TO COMBAT FADING EFFECTS: A REVIEW

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Abstract- ***Wireless communication system today requires high voice quality and high bit rate data services. The systems are supposed to have better quality and coverage, be more power and bandwidth efficient, and be deployed in diverse environments. Fading is the dominating factor which not only affects the transmission of data but also made the data erroneous. This means that severe attenuation in a multipath wireless environment makes it extremely difficult for the receiver to determine the transmitted signal unless the receiver is provided with some form of diversity, i.e., some less-attenuated replica of the transmitted signal is provided to the receiver. The receiver diversity plays a crucial role in wireless communication. This paper provides the brief review of all the diversity technique.***

Index Terms - Almouti, STBC, Diversity, MIMO.

I. INTRODUCTION

The transfer of information through wireless communication includes: radio frequency communication, microwave communication, for example long-range line-of-sight via highly directional antennas, short-range communication, for example from remote controls. Today wireless system requires high voice quality and high bit rate data services. Also the communication units are remote and light weighted, and they have to be operating in various environments reliably. However the wireless channel suffers from attenuation due to destructive and constructive addition of multipath in the propagation media and to interference from other users. The transmitting information riding on radio (electromagnetic) waves and hence the information undergoes attenuation effects (fading) of radio waves. These attenuation effects could also vary with time due to user mobility, making wireless a challenging communication medium [1]. Multipath Fading is known to arise due to the non-coherent combination of signals arriving at the receiver antenna. Typically, this phenomenon is described as the constructive/destructive interference between signals arriving at the same antenna via different paths, and hence, with different delays and phases, resulting in random fluctuations of the signal level at the receiver. Deep-fades that may occur at a particular point in space, or at a particular time or frequency, result in severe degradation of the quality of signals at the receiver making it impossible to detect and decode.

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Diversity is a powerful communication receiver technique that provides wireless link improvement at a relatively low cost. Diversity techniques are used in wireless communications to mitigate the effect of fading over a radio channel. The wireless communication channel suffers from much impairment such as Additive White Gaussian Noise (AWGN), the path loss, the shadowing and the fading. Fading is a major problem and in order to reduce it, diversity is being used. Thus in diversity technique, multiple copies of the same data is transmitted to the receiver via multiple paths or channels and the final decision is made by the receiver without knowing to the transmitter [2].

II. TYPES OF DIVERSITY

There are basically three kinds of Diversities namely: Time Diversity, Frequency Diversity and Space Diversity

Time Diversity

Multiple versions of the same signal are transmitted at different time instants. Alternatively, a redundant forward error correction code is added and the message is spread in time by means of bit-interleaving before it is transmitted. Thus, error bursts are avoided, which simplifies the error correction.

Frequency Diversity

Frequency diversity is the simultaneous use of multiple frequencies to transmit information. This is a technique used to overcome the effects of multipath fading since the wavelength for different frequencies result in different and uncorrelated fading characteristics.

Space Diversity

The signal is transmitted over several different propagation paths. In the case of wired transmission, this can be achieved by transmitting via multiple wires. In the case of wireless transmission, it can be achieved by antenna diversity using multiple transmitter antennas (transmit diversity) and/or multiple receiving antennas (reception diversity). Space diversity is one of several wireless diversity schemes that use two or more antennas to improve the quality and reliability of a wireless link. Often, especially in urban and indoor environments, there is no clear line-of-sight (LOS) between transmitter and receiver. Instead the signal is reflected along multiple paths before finally being received. Each of these bounces can introduce phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna. Antenna diversity is especially effective at mitigating these multipath situations. This is because multiple antennas offer a receiver several observations of the same signal. Each antenna will experience a different interference environment. Thus, if one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Collectively such a system can provide a robust link. While this is primarily seen in receiving systems (diversity reception), the analog has also proven valuable for transmitting systems (transmit diversity) as well. So as to achieve this diversity we use MIMO (Multiple Input and Multiple Output) system.

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III. SPACE TIME BLOCK CODE

STBC is designed to achieve transmit diversity and power gain without scarifying any more bandwidth. STBC is performed over two axis spatial (space) and temporal (time) axis for multiple antennas at different time. It is assumed that there are N transmit antennas and M receive antennas. The input source data bits are firstly modulated, and then carried into a space-time block encoder. Mapping from the modulated symbols to a transmission matrix, which is completed by the STBC encoder, is a key step in STBC systems. The input symbols of the encoder are divided into groups of several symbols. The number of symbols in a group is according to the number of transmit antennas. Different symbol columns are transmitted through different antennas separately and different symbol rows in different time slots. For example, the encoded symbol of column i and row f should be transmitted through the ith antenna in the fth time slot.

- **Alamouti Scheme (2 Transmitter & 1 Receiver)**

M. Alamouti in his landmark paper offers simple methods to achieve spatial diversity with two transmit antennas and one receive antenna. The encoding of signal is done in space and time (space–time coding). The encoding, however, may also be done in space and frequency. Instead of two adjacent symbol periods, two adjacent carriers may be used (space–frequency coding). Consider we have a transmission sequence e.g. x_1, x_2, x_3.....x_n. In normal transmission, we send x_1 in first time slot, x_2 in second time slot and so on. However, Alamouti suggested that group the symbols into the group of two. In the first time slot send x_1 and x_2 from first and second antenna and $-x_2^*$ and x_1^* from first and second antenna at second time slot. In third time slot x_3 and x_4 from first and second antenna and there conjugates in fourth time slot and so on. Now the signal is transmitted through various channels. The channel experience by each transmit antenna is independent from the channel experienced by another antennas. For i^{th} transmitted antenna, the transmitted symbol is multiplied by h_i i.e. Rayleigh channel coefficient. The channel experienced between each transmit to receive antenna is randomly varying in time. However the channel is assumed to remain constant over two time slots. G2 represents a code which utilizes two transmit antennas and is defined by:

$$G2=\begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix}$$

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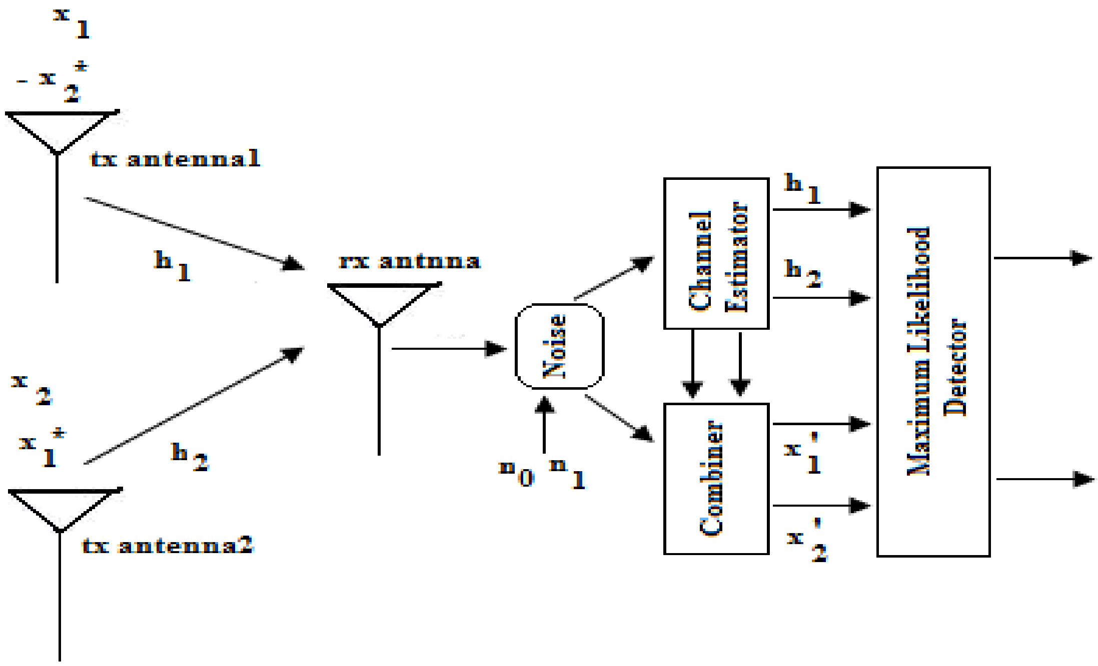

Figure 1: Two Transmitter Diversity scheme with 1Receiver

Receiver with Alamouti STBC

In the first time slot, the received signal is

$$y_1=h_1x_1 + h_2 x_2 + n_0$$

In second time slot the received signal is

$$y_2=-h_1x_2^* + h_2 x_1^*+n_1$$

Combining scheme

$$X_1'=h_1^* y_1 + h_2^*y_2$$

$$X_2'=h_2^*y_1 + h_1^*y_2$$

These combined signals are then sent to maximum likelihood detector. There are many applications where higher order of diversity is needed and multiple receive antennas at the remote unit is feasible.

In such cases, it is possible to provide a diversity order of 2M with two transmit and M receive antenna.

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Higher Order Alamouti scheme (Orthogonal Space-Time Block Coding)

If the transmission of data is through multiple transmit and receive antennas then the encoding method is said to be Orthogonal Space Time Block coding. Depending upon the selection of transmission antennas and the transmission rate, the encoder can be implemented on one of the algorithms in the following table.

Table: 1 Algorithm for STBC encoder

Transmit Antenna	Rate	OSTBC Codeword Matrix
2	1	$\begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix}$
3	½	$\begin{pmatrix} s_1 & s_2 & 0 \\ -s_2^* & s_1^* & 0 \\ 0 & 0 & s_1 \\ 0 & 0 & -s_2^* \end{pmatrix}$
3	¾	$\begin{pmatrix} s_1 & s_2 & s_3 \\ -s_2^* & s_1^* & 0 \\ s_3^* & 0 & -s_1^* \\ 0 & s_3^* & -s_2^* \end{pmatrix}$
4	½	$\begin{pmatrix} s_1 & s_2 & 0 & 0 \\ -s_2^* & s_1^* & 0 & 0 \\ 0 & 0 & s_1 & s_2 \\ 0 & 0 & -s_2^* & s_1^* \end{pmatrix}$
4	¾	$\begin{pmatrix} s_1 & s_2 & s_3 & 0 \\ -s_2^* & s_1^* & 0 & s_3 \\ s_3^* & 0 & -s_1^* & s_2 \\ 0 & s_3^* & -s_2^* & -s_1 \end{pmatrix}$

Combining Scheme

The OSTBC Combiner block combines the input signal (from all of the receive antennas) and the channel estimate signal to extract the soft information of the symbols encoded by an OSTBC. The input channel estimate may not be constant during each codeword block transmission and the combining algorithm uses only the estimate for the first symbol period per codeword block.

A symbol demodulator or decoder would follow the Combiner block in a MIMO communications

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system. The block conducts the combining operation for each symbol independently. The combining algorithm depends on the structure of the OSTBC.

Table 2: Algorithm for STBC Combiner

Transmit Antenna	Rate	Computational algorithms per codeword block length
2	1	$\begin{bmatrix}\hat{s}_1\\ \hat{s}_2\end{bmatrix} = \frac{1}{\lvert H\rvert^2}\sum_{j=1}^{M}\begin{bmatrix}h_{1j}^* r_{1j} + h_{2j} r_{2j}^*\\ h_{2j}^* r_{1j} - h_{1j} r_{2j}^*\end{bmatrix}$
3	½	$\begin{bmatrix}\hat{s}_1\\ \hat{s}_2\end{bmatrix} = \frac{1}{\lvert H\rvert^2}\sum_{j=1}^{M}\begin{bmatrix}h_{1j}^* r_{1j} + h_{2j} r_{2j}^* + h_{3j} r_{3j}^*\\ h_{2j}^* r_{1j} - h_{1j} r_{2j}^* - h_{3j} r_{4j}^*\end{bmatrix}$
3	¾	$\begin{bmatrix}\hat{s}_1\\ \hat{s}_2\\ \hat{s}_3\end{bmatrix} = \frac{1}{\lvert H\rvert^2}\sum_{j=1}^{M}\begin{bmatrix}h_{1j}^* r_{1j} + h_{2j} r_{2j}^* - h_{3j} r_{3j}^*\\ h_{2j}^* r_{1j} - h_{1j} r_{2j}^* - h_{3j} r_{4j}^*\\ h_{3j}^* r_{1j} + h_{1j} r_{3j}^* + h_{2j} r_{4j}^*\end{bmatrix}$
4	½	$\begin{bmatrix}\hat{s}_1\\ \hat{s}_2\end{bmatrix} = \frac{1}{\lvert H\rvert^2}\sum_{j=1}^{M}\begin{bmatrix}h_{1j}^* r_{1j} + h_{2j} r_{2j}^* + h_{3j}^* r_{3j} + h_{4j} r_{4j}^*\\ h_{2j}^* r_{1j} - h_{1j} r_{2j}^* + h_{4j}^* r_{3j} - h_{3j} r_{4j}^*\end{bmatrix}$
4	¾	$\begin{bmatrix}\hat{s}_1\\ \hat{s}_2\end{bmatrix} = \frac{1}{\lvert H\rvert^2}\sum_{j=1}^{M}\begin{bmatrix}h_{1j}^* r_{1j} + h_{2j} r_{2j}^* - h_{3j} r_{3j}^* - h_{4j}^* r_{4j}\\ h_{2j}^* r_{1j} - h_{1j} r_{2j}^* + h_{4j} r_{3j}^* - h_{3j} r_{4j}^*\\ h_{3j}^* r_{1j} + h_{4j} r_{2j}^* + h_{1j} r_{3j}^* + h_{2j} r_{4j}^*\end{bmatrix}$

IV. CONCLUSION

In this paper, we give the brief overview and design equation of diversity schemes. Incorporating diversity in wireless system, it is possible to effectively mitigate the effects of multipath fading. The scattering of signal severely affects single input and single output (SISO) systems hence require some way to neglect its effect. The performance of the system is improved by providing the receiver with multiple copies of the data and hence incorporate the diversity improves the performance of the system.

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