SCFDE for STBC Transmission over Frequency Selective Fading Channel

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Abstract – *In wireless communication, multipath propagation results in several fading effect. To equalize such long fading channel traditional single carrier time domain equalization becomes infeasible due to its large computational complexity. Single-carrier frequency-domain equalization (SCFDE) offers low complexity, minimum peak to average power ratio as well as less sensitive to carrier frequency offset compared with orthogonal frequency division multiplexing (OFDM). This paper we proposed Alamouti like scheme by combining space time block coding with single carrier frequency domain equalization. The Alamouti scheme is shown to achieve significant diversity gain at low complexity over frequency selective fading channels with the help of two transmit antenna and one receive antenna.*

***Key Words* - STBC, Alamouti Signaling, SCFDE, cyclic prefix, diversity etc.**

1. INTRODUCTION

Single-carrier minimum mean square error frequency domain equalization (SC-MMSE FDE) is an attractive equalization scheme for broadband wireless channels which is characterized by their long impulse response memory [1],[2]. SC-MMSE FDE uses computationally efficient Fast Fourier Transform (FFT). For this reason, SC-MMSE FDE has lower complexity than time domain equalization whose complexity grows exponentially with channel memory and spectral efficiency (trellis based schemes) or require very long FIR filters to achieve acceptable performance (e.g. decision feedback equalizers). It has been shown that SC-MMSE FDE have two main advantages over Orthogonal Frequency Domain Multiplexing (OFDM) that are lower peak to average power ratio (PAPR) and it reduced sensitivity to carrier frequency offset (CFO) [1].

A mobile radio channel is characterized by a multipath fading environment. The signal is occurred at the receiver contains not only line of sight of radio wave, but also a large number of reflected radio waves which arrive at the receiver at different times. Delayed signals are offered by reflections from terrain features such as trees, hills, mountains, vehicles or buildings. These reflected delayed waves interfere with original waves and cause Inter Symbol Interference (ISI) which causes significant degradation of network performance. The MIMO stands for multiple input multiple output. A MIMO wireless communication system has multiple antennas at the transmitter as well as receiver. The very important goal of MIMO wireless technology is to improve quality of communication to improve the bit error rate of signal also data rate of communication. Increase in number of antennas in MIMO system leads to increase in capacity of communication. MIMO achieves better network performance by higher spectral efficiency and link reliability or diversity. Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution and WiMAX [3, 4]. Here we used MISO which stands for multiple input single output. The performance of the two transmit one receive antenna case resulting in a 2×1 MISO channel have been studied.

Diversity transmission using Alamouti's space time block coding (STBC) scheme [3] has been proposed in several standards due to its many attractive features. First, for 2 transmit antennas and any signal constellation it achieves full diversity at full transmission rate. Second, at transmitter it does not require channel state information. Third, ML (maximum likelihood) decoding of STBC requires only simple linear processing.

Alamouti published his technique on transmit diversity. The Alamouti STBC scheme uses two transmit antennas and Nr receives antennas and can accomplish a maximum diversity order of 2Nr. Moreover, the Alamouti scheme has full rate (i.e. a rate of 1) since it transmits 2 symbols every 2 time intervals.

It has been seen that SC MMSE FDE was first combined with receive diversity in [4]. Alamouti scheme was combined with OFDM [5] and with time domain equalization [6]. The rest of this paper is organized as follows. In section II, our model and assumption is described. In section III, Alamouti like scheme for combining STBC and SC-MMSE FDE is proposed. And last, simulation result is given and paper is concluded.

2. BACKGROUND

2.1 Channel Model and Assumptions

Here we consider SC (single carrier) block transmission over an additive noise frequency selective channel with memory length of *v*. In this, IBI (Inter Block Interference) is removed by each block of length *N* is appended with a length *v cyclic prefix*. And this is achieved by discarding the first *v* received symbols corresponding to the cyclic prefix. Hence, *N* symbols are received out of every (*N*+*V*) received symbols. Therefore, the input-output relationship can be expressed in matrix form which is as follows

$$y = Hx + n \quad (1)$$

where, y – received *signal*
x – input signal
n – noise signal
H – *N* x *N* channel matrix

The input and noise signal are assume to be complex, zero mean and uncorrelated with variances σ^2_x and σ^2_n respectively. The matrix H is circulant with first column equal to the channel impulse response (CIR) appended by (*N*-*v*-1) zeros. It has eigen decomposition because of H circulant matrix.

$$H = Q^*\Lambda Q \quad (2)$$

Where Q is the Orthonormal Discrete Fourier Transform (DFT) matrix.

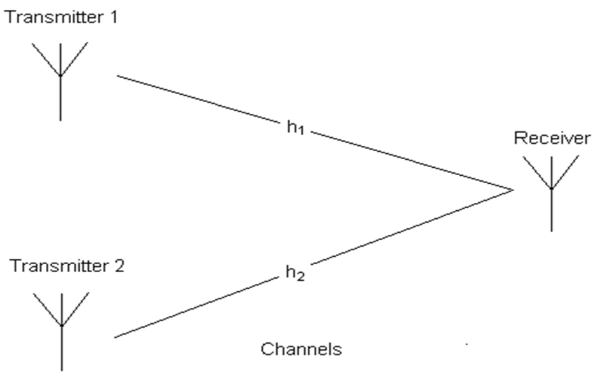

Fig-1 Transmit and receive antennas with channel

Table -1: Encoding is done in the following manner:

	Transmitter 1	Transmitter 2
Time t	x_1	x_2
Time t+T	$-x_2^*$	x_1^*

Where x_1 and x_2 are modulated signals. The received vectors are given as,

$y_1 = h_1(x_1) + h_2(x_2) + n_1$ (First time slot)

$y_2 = h_1(-x_2^*) + h_2(x_1^*) + n_2$ (Second time slot) (3)

where n_1, n_2 are AWGN noise and y_1, y_2 are received vectors. These equations can be written in matrix form as,

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^1 \end{bmatrix} \quad (4)$$

$$H = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}$$

Above matrix H is 2 x 2 channel matrix where * represents the complex conjugate. It is readily apparent that this is a rate-1 code. It takes two time-slots to transmit two symbols. The bit error rate (BER) of this STBC is equivalent to $2n_R$-branch maximal ratio combining (MRC). This is a result of the perfect orthogonality between the symbols after receive processing — there are two copies of each symbol transmitted and n_R copies received.

2.2 Single Carrier MMSE FDE

The zero-forcing equalizer, although removes ISI, may not give the best error performance for the communication system because it does not take into account noises in the system. A different equalizer that takes noises into account is the minimum mean square error (MMSE) equalizer. It is based on the mean square error (MSE) criterion.

Single-carrier minimum mean square error frequency domain equalization (SC-MMSE FDE) is an attractive equalization scheme for broadband wireless channels which is characterized by their long impulse response memory [7],[8]. SC-MMSE FDE uses computationally efficient Fast Fourier Transform (FFT). For this reason, SC-MMSE FDE has lower complexity than time domain equalization whose complexity grows exponentially with channel memory and spectral efficiency (trellis based schemes) or require very long FIR filters to achieve acceptable performance (e.g. decision feedback equalizers). It has been shown that SC-MMSE FDE have two main advantages over Orthogonal Frequency Domain Multiplexing (OFDM) that are lower peak to average power ratio (PAPR) and it reduced sensitivity to carrier frequency offset (CFO) [7].

2.3 Space-Time Coding

Space-time coding (STC), introduced first by Tarokh at el. [12], [13] gives method where the number of the transmitted code symbols per time slot is equal to the number of transmit antennas. Space -time encoder generates the code symbol in manner that the diversity gain, coding gain, as well as high spectral efficiency are achieved. Space-time coding finds its application in cellular communications as well as in wireless local area networks because its property to improve the reliability of data transmission. There are various coding methods as space-time trellis codes (STTC), space-time block codes (STBC), space-time turbo trellis codes and layered space-time (LST) codes. A main issue in all these schemes is the exploitation of redundancy to achieve high reliability, high spectral efficiency and high performance gain [11]. To design STC first find code matrix which satisfy certain

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optimality criteria. Also it allows achieving goals of maintaining a simple decoding algorithm, low error probability and maximizing information rate.

2.4 Space-Time Block Coding

The simplest spatial temporal code is Space-Time Block Codes (STBCs which exploit the diversity for several transmit antennas. [10] Shows Alamouti scheme for simple diversity technique with two transmit antennas which gives full diversity. This scheme requires simple linear operation for transmission and reception of data. On block of transmission symbol the encoding decoding process are performed. [11] The transmit diversity technique proposed by Alamouti was space time block code (STBC). By using set of two modulated symbol the encoding decoding operation is performed. Hence, the information data bits are first modulated and mapped into their corresponding constellation points. Therefore let us assume s_0 and s_1 are two modulated symbols that enter the space-time encoder. Usually for the system with only one transmit antennas; these two modulated symbols are transmitted at two consecutive time instances t_1 and t_2. The constant time duration T is the time separation between the t_1 and t_2. For Alamouti scheme for first time instance the symbol s_0 and s_1 are transmitted by first and second antenna element respectively. Now for second time instance t_2, the negative of the conjugate of the second symbol, i.e., $-s_1^*$ is sent by first antenna at that time conjugate of first constellation point, i.e., s_0^* is transmitted by second antenna. The space–time encoding mapping of Alamouti's two-branch -transmit diversity technique can be represented by the coding matrix:

$$S = \begin{bmatrix} s_0 & -s_1^* \\ s_1 & s_0^* \end{bmatrix} \quad (5)$$

3. PROPOSED TRANSMIT DIVERSITY SCHEME

Diversity transmission using Alamouti's space time block coding (STBC) scheme has been proposed in several standards due to its many attractive features. Below figure shows proposed transmission and receiver block diagram.

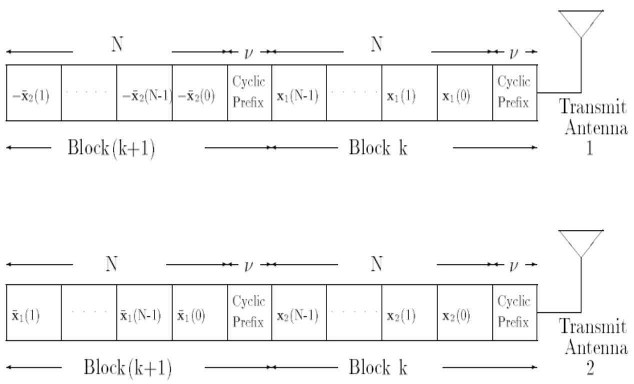

Fig-2 Block format for proposed transmission scheme

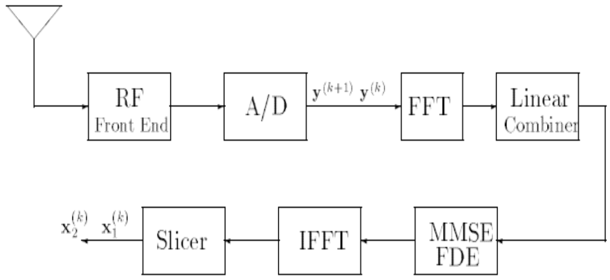

Fig-3 Receiver block diagram

Each data-block of length N is appended with a CP of length ν to eliminate Inter Block interference (IBI). $x_i^{(k)}(n)$ denotes the symbol n of the transmitted block k from antenna i. At even time slots, pairs of length-N blocks $x_1^{(k)}(n)$ and $x_2^{(k)}(n)$ are generated. The transmission scheme proposed by [9] is,

$$\begin{aligned} x_1^{(k+1)}(n) &= -x^{*(k)}_2((-n)_N) \\ x_2^{(k+1)}(n) &= -x^{*(k)}_1((-n)_N) \end{aligned} \quad (6)$$

For n=0,1,.....,N-1 and k=0,2,4,.....

A cyclic prefix length v is added to each transmitted block to eliminate IBI and make all channel matrix circulant. Finally transmitted power from each antenna is half its value in the single transmit case so that total transmitted power is fixed.

The Alamouti method of space-time signaling can also be characterized as a transmit diversity scheme. Unlike the CDD system, our analysis shows that Alamouti signaling preserves the transmit diversity and thus provides a larger diversity gain compared with the CDD scheme above a rate threshold R_{th}. We consider single-carrier block transmission over an additive-noise frequency-selective channel with memory v, similar to [9]. The model supports a 2 × 1 system and can be extended to 2 × N system.

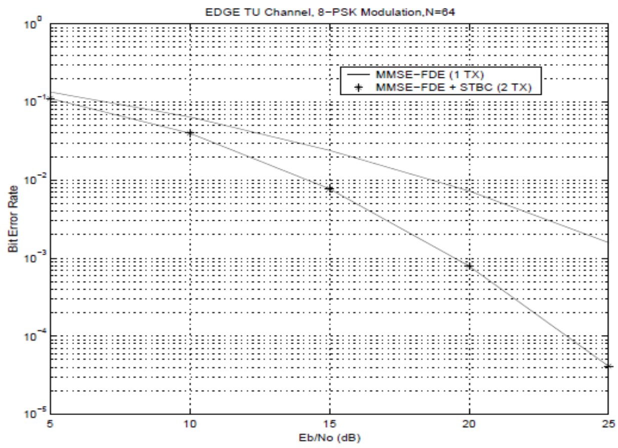

Fig-4 BER of SC MMSE-FDE with or without STBC for EDGE TU channel with 8-PSK Modulation and N=64

Above figure shows the significant improvement achieved in SC MMSE-FDE performance when combining it with the proposed STBC scheme, especially at high SNR where effect of diversity are more pronounced.

4. CONCLUSIONS

For frequency selective channels, we presented a low complexity transmit diversity scheme. This scheme combines the advantages of Alamouti like STBC (Space Time Block Coding) scheme and FFT based SCFDE (single carrier frequency domain equalization) Over single antenna transmission significant performance gains were demonstrated for EDGE TU channel.

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BIOGRAPHIES

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