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Space – Time Block Coding for Wireless Communications

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Abstract – Wireless communication is one of the most resonant areas in the communication field today. Wireless communication domain is very interesting on account of the phenomenon of fading (the time variation of the channel) and wireless users communicate over the air and there is significant interference between them.

In this article, I will analyze the performance of space-time code block used in wireless communication. This analysis is making for a system with two antennas for transmission and two antennas for receptions.

Keywords: multiantenna systems, MIMO communications, Alamouti coding.

I. INTRODUCTION

Wireless communications is based on radio signals. Traditionally, the conventional radio transmissions use one antenna for transmission and one antenna for reception. This system is called Single Input Single Output (SISO). For improving the performances, it is used a multiantenna technique which improve the Signal to Noise Ratio (SNR). It is distinguish thus Multiple Input Single Output (MISO) system, Single Input Multiple Output (SIMO) system or Multiple Input Multiple Output (MIMO) system. A MIMO system with identical number of antennas for transmission and reception is able to multiply the bit rate with each additional antenna [1].

Multiantenna system represent any multiport antenna (MPA) system in which each port can be associated with distinct and physically separated antennas, with different polarization, with different radiation patterns, or with any combination of the above possibilities [2]. The MIMO system schema is presented in Fig.1:

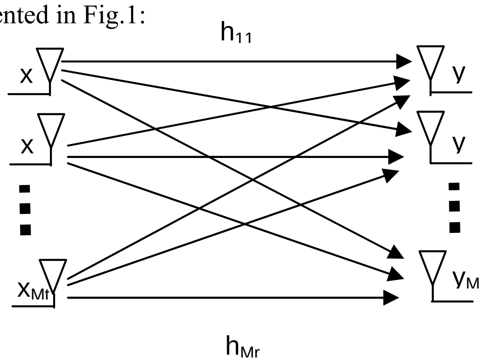

Fig. 1. MIMO system

This system can be described in the discrete temporal domain with the following function [3]:

$$y = Hx + n \tag{1}$$

where y is the received symbols vector at the M_r receiver antennas side, $y = [y_1, y_2, ..., y_{M_r}]^T$, H is the channel matrix,

$$H = \begin{pmatrix} h_{11} \cdots h_{M_t} \\ \vdots \quad \ddots \quad \vdots \\ h_{M_r 1} \cdots h_{M_r M_t} \end{pmatrix}$$

and $h_{i,j}$ is the gain from the transmission antenna j to the receiver antenna i; x represents the transmitted symbols vector by the M_t transmission antennas, $x = \left[x_1, x_2, ..., x_{M_t} \right]^T$, whereas n represents the noise vector, $n = [n_1, n_2, ..., n_{M_r}]^T$.

II. SPACE-TIME CODING

The wireless communication technology is more and more important. The development of this technology is achieved by improving efficient coding, modulation and signal processing. Space-time coding is used in wireless communications. There are several kinds of space-time coding techniques, including space-time trellis coding, space-time block coding, layered space-time coding, unitary space-time modulation and differential space-time modulation. The latter two kinds are using noncoherent detection methods.

The concept of diversity is referred to some replicas of transmitted signal which is less-attenuated is provided to the receiver. In most wireless communication systems, a number of diversity methods are used in order to get the required performance. According to the domain where diversity is introduced, diversity techniques are

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classified into temporal, frequency and space diversity.

The Alamouti schema is the first space-time code block which presents maximum transmission diversity for a system which uses two antennas for emission. The Alamouti coder schema is presented in Fig.2:

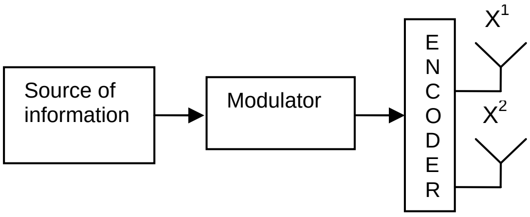

Fig. 2. The Alamouti coder schema

It is supposed a modulator which has the length of modulation sequence *M*. In Alamouti coder, each group by *m* information bits is modulated before, where $m = \log_2 M$ [4]. Then, during each coding operation, the coder takes a block with two modulated symbols x_1 and x_2 and it transfers of transmission antennas in conformity with a code matrices:

$$X = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix} \qquad (2)$$

The coder outputs are transferred by two transmission antennas in two periods of transmission consecutives. In the first period of transmission, the antennas number one and number two transfer simultaneously two signals x_1 and x_2. In the second period of transmission, the antenna number one transfer the signal $-x_2^*$ and the antenna number two transfer the signal x_1^* [4].

Table 1

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

The coding is made in space and time domain. The sequences transferred from antennas number one and two are noted by X^1 and X^2:

$$X^1 = [x_1 \quad -x_2^*]$$
$$X^2 = [x_2 \quad x_1^*] \qquad (3)$$

The fundamental element of Alamouti system is the orthogonality of the sequences transferred from two antennas:

$$X^1 X^2 = x_1 x_2^* - x_2^* x_1 = 0 \qquad (4)$$

The coding matrix has the next property:

$$XX^H = \begin{bmatrix} |x_1|^2 + |x_2|^2 & 0 \\ 0 & |x_1|^2 + |x_2|^2 \end{bmatrix} \qquad (5)$$

Supposing a single antenna used for reception, the receiver block schema is presented in Fig.3:

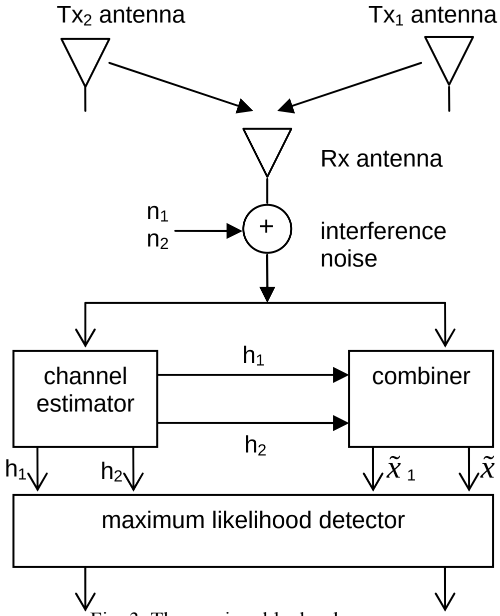

Fig. 3. The receiver block schema

The fading coefficients transferred from two antennas of transmission to reception antenna at *t* moment, are noted $h_1(t)$ and $h_2(t)$ [4]. Supposing the fading coefficients value being constants during of two consecutively periods of transmission, these can be writing as follows:

$$h_1(t) = h_1(t+T) = h_1 = |h_1| e^{j\theta_1}$$
$$h_2(t) = h_2(t+T) = h_2 = |h_2| e^{j\theta_2} \qquad (6)$$

At reception antenna, the signals r_1 and r_2 received during of two consecutively periods at *t* and *t* + *T* moments can be writing as follows:

$$r_1 = h_1 x_1 + h_2 x_2 + n_1$$
$$r_2 = -h_1 x_2^* + h_2 x_1^* + n_2 \qquad (7)$$

where n_1 and n_2 are the independent complex variables with zero average and power spectral density $N_0/2$, representing sample of Gaussian white noise at the time moments *t* and *t* + *T*.

Alamouti coding can be used for the systems with multiple receiver antennas. In this case, the signals received from *j* antenna at time moments *t* and *t* + *T* are noted with r_1^j and r_2^j.:

$$r_1^j = h_{j,1}x_1 + h_{j,2}x_2 + n_1^j$$
$$r_2^j = -h_{j,1}x_2^* + h_{j,2}x_1^* + n_2^j \quad (8)$$

The receiver made two approximations of the received signal having of basis a combination of these:

$$\tilde{x}_1^j = h_{j,1}^* r_1^j + h_{j,2}(r_2^j)^*$$
$$\tilde{x}_2^j = h_{j,2}^* r_1^j - h_{j,1}(r_2^j)^* \quad (9)$$

These combined signals are then sent to the maximum likelihood detector, which make the most possible decision to recover the original transmission signals.

III. SIMULATION RESULTS AND DISCUSIONSS

In these simulations, it is use a MIMO system formed by two transmission antennas and two received antennas. In the beginning, the two transmission antennas transmit the same carrier signal having the frequency of 200 kHz and the unitary amplitude like in Fig. 4:

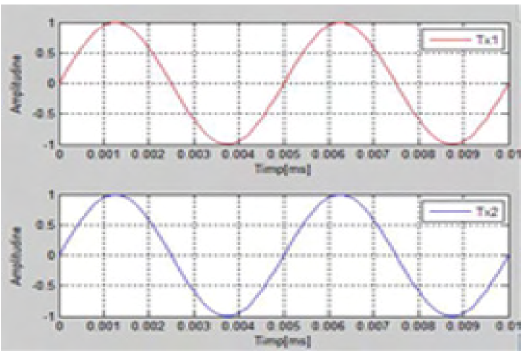

Fig. 4. Carrier signal of two transmission antennas (200 KHz)

The channel matrix is:

$$H = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

The signals received in the case of a transmission without and with Alamouti coding are presented in Fig. 5.

If the channel matrix is:

$$H = \begin{bmatrix} 0.6 & 0.2 \\ 0.2 & 0.6 \end{bmatrix}$$

the received signals are presented in Fig. 6.

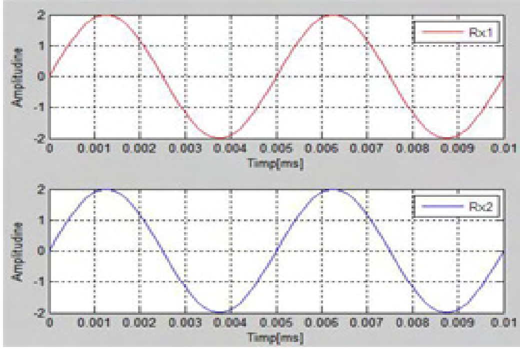

Fig. 5.a) The signal received without coding

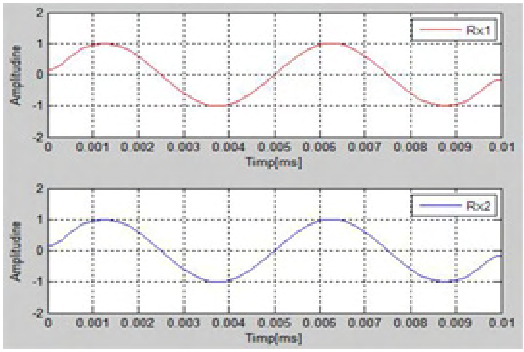

Fig. 5.b) The signal received with Alamouti coding

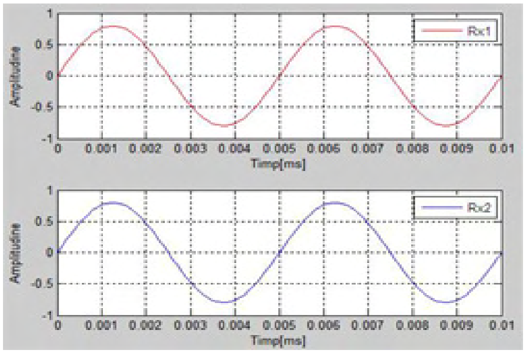

Fig. 6.a) The signal received without coding

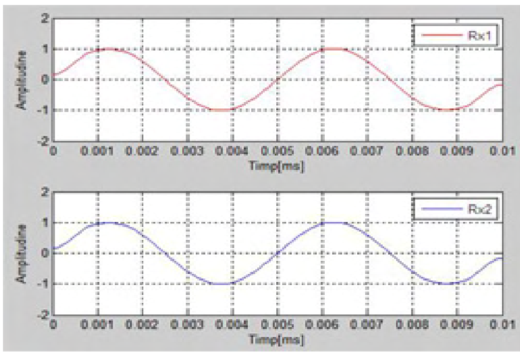

Fig. 6.b) The signal received with Alamouti coding

In the second case, it is considered that the transmitted signals from the two transmission antennas have the same level, but different frequencies (200 kHz, respectively 500 kHz), like in Fig. 7:

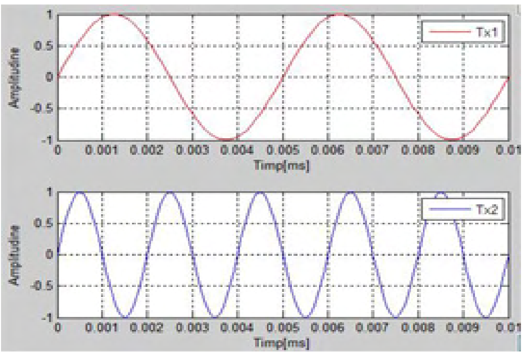

Fig. 7. Carrier signal of two transmission antennas (200 KHz; 500 KHz)

The channel matrix is:

$$H = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$$

The signals received in the case of a transmission without and with Alamouti coding are presented in Fig. 8:

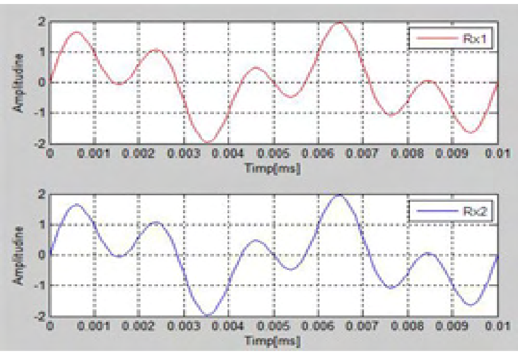

Fig. 8.a) The signal received without coding

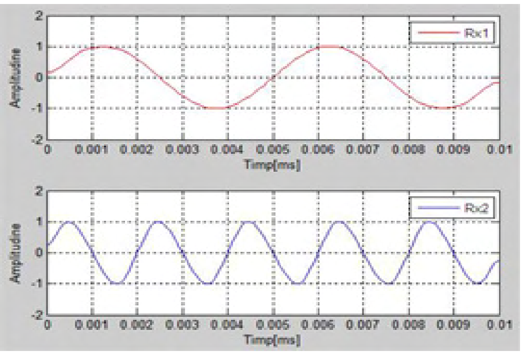

Fig. 8.b) The signal received with Alamouti coding

If the channel matrix is:

$$H = \begin{bmatrix} 0.6 & 0.2 \\ 0.2 & 0.6 \end{bmatrix}$$

the received signals are presented in Fig. 9:

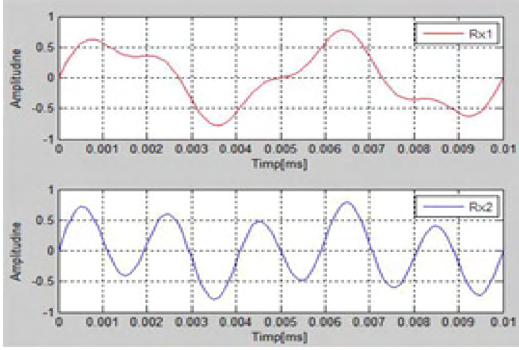

Fig. 9.a) The signal received without coding

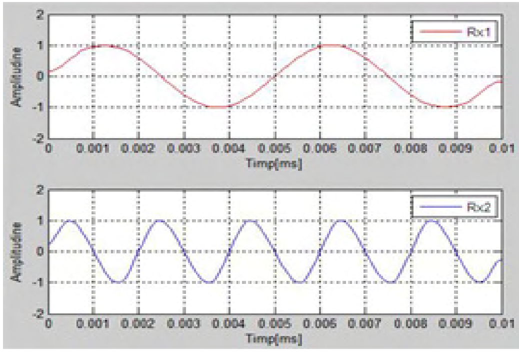

Fig. 9.b) The signal received with Alamouti coding

IV. CONCLUSIONS

The space-time coding improves significantly the transmission of dates with MIMO channels from the point of view of reduction of the interference between the transferred signals. The Alamouti coding is the first space-time code technique which presents maximum transmission diversity for transmission and receiving system which uses two antennas for emission. The performances of the space-time code are improved by introduction of the space-time turbo codes, of the differentials codes and of the stratified codes. In the present, MIMO technique is one of most used in wireless network.

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