AN INTERPOLATION OF MIMO COEFFICIENTS IN FAST VARYING CHANNELS WITH NON-ORTHOGONAL SPACE-TIME BLOCK CODING

Ing. Martin ŠVIRÁK, Doctoral Degree Programme (2)
Dept. of Radio Electronics, FEEC, BUT
E-mail: svirak@feec.vutbr.cz

Supervised by: Prof. Vladimír Šebesta

ABSTRACT

Transmission over Multiple Input Multiple Output (MIMO) radio channels is considered. This paper investigates the impact of imperfect CSI (Channel State Information) on non-orthogonal space-time block coded system. Recent works describe impact of phase or amplitude error on the space-time block coded systems. In this paper it is shown how temporary imperfect knowledge of CSI can degrade bit error rate performance of the non-orthogonal space-time block codes in fast varying channels and how it can be improved by linear or cubic spline interpolation of the MIMO coefficients.

1 INTRODUCTION

The space-time coding is a technique that exploits the combination of spatial and temporal diversity. There are two main types of space-time codes, namely space-time block codes (STBC) and space-time trellis codes (STTC). STBC operates on a block of input symbols, rows of the coding matrix represent time and columns represent antennas. Main feature of STBC is very simple decoding scheme. STTC operates on one input symbol at a time, the result of STTC is vector whose length represents transmit antennas. Disadvantage of STTCs is that they are difficult to design and require high complexity decoders.

One of the first space-time codes is due to Alamouti [3], who suggested to simultaneously transmit two complex symbols c_1 and c_2 from two transmitting antennas during two symbol periods by the following matrix:

$$\mathbf{G} = \begin{pmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{pmatrix}. \tag{1}$$

Symbols c_1 and c_2 are transmitted by two antennas at time t and then symbols $-c_2^*$ and c_1^* are transmitted at time $(t + T_s)$, where T_s denotes symbol interval. Columns of the matrix correspond to the antennas and rows correspond to the time slots. The rate of the Alamouti code is equal to $R = 2/2 = 1$. This code is orthogonal, it guarantees that the (coherent) ML detection of different symbols c_n is decoupled and diversity order is equal to $n_r n_t$, where n_r and n_t is number of receiving and transmitting antennas respectively. Orthogonal linear space-time block code has the following property:

$$\mathbf{G}\mathbf{G}^H = \sum_{n=1}^{n_s} |c_n|^2 . \mathbf{I}, \tag{2}$$

where **I** is unit matrix 2 x 2. The space-time decoder combines the received signals as follows:

$$\begin{pmatrix} \tilde{c}_1 \\ \tilde{c}_2 \end{pmatrix} = \begin{pmatrix} h_1^* & h_2 \\ h_2^* & -h_1 \end{pmatrix} \begin{pmatrix} r_1 \\ r_2^* \end{pmatrix}, \tag{3}$$

where $\tilde{c}_1$, $\tilde{c}_2$ are estimates of symbols c_1, c_2 and h_1, h_2 are complex path gains from transmit antennas to the receive antenna and r_1, r_2 are received symbols at time t and $(t + T_s)$.

2 NON-ORTHOGONAL SPACE-TIME BLOCK CODE

The two essential features of space-time block codes on orthogonal design are linearity and orthogonality [5]. These two properties do not fit well together with achievable symbol rate of the STBC. The orthogonality has to be sacrificed to increase the rate of the STBC [4]. The non-orthogonal space-time block code from [4] was adopted. This code has symbol-rate 2, employing 2 transmitting and 2 receiving antennas. Coding matrix 2 x 2 contains 4 comlex symbols encoded by the following formula:

$$\mathbf{C}(c_1, c_2, c_3, c_4) = \begin{pmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{pmatrix} + \mathbf{U} \begin{pmatrix} c_3 & c_4 \\ -c_4^* & c_3^* \end{pmatrix} \tag{4}$$

where **U** is 2 x 2 unitary matrix, which satisfy:

$$\det(\mathbf{U}) = -1 .$$

In [4], the non-orthogonal space time block code with

$$\mathbf{U} = \begin{pmatrix} e^{j\frac{\pi}{4}} & 0 \\ 0 & e^{-j\frac{\pi}{4}} \end{pmatrix} \tag{5}$$

was proposed.

3 SYSTEM MODEL

We investigate a communication system over Multiple Input, Multiple Output (MIMO) Rayleigh fading channels with two transmitting and two receiving antennas. No multipath is assumed. The channel realizations between the antennas are denoted by the matrix:

$$\boldsymbol{\alpha} = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix}, \tag{6}$$

where the α_{ij} are assumed uncorrelated fading path gains. Channels are simulated as time selective with Doppler power spectrum. It means, that channels path gains α_{ij} varying continuously in time domain with specific characteristics, which is denoted by maximum Doppler shift [2]. We assume that α_{ij} is constant for the duration of two symbol periods, block of four symbols z_i, $i = 1...4$ are transmitted. The symbols are in a 2 x 2 matrix **C.** The rows of **C** are transmitted during one symbol period from the two transmitting antennas, the columns are transmitted from one antenna during two symbol periods. The received signal from the two receiving antennas during the two symbol periods can be written as:

$$\mathbf{r} = \mathbf{C}\boldsymbol{\alpha} + noise\,. \tag{7}$$

We assume no channel state information at the transmitter and partial CSI at the receiver side. The time variant environment with fast varying impulse responses of MIMO channels severely impacts on the performance of the space-time block coded systems. Consequnce of this may be difficult identification of complex path gains of the MIMO channels. It means, that the channel estimator may be temporarily unable to update α_{ij} coefficients, necessary for space-time block decoding. We assume, that the system can store certain number of received symbols. Then received symbols can be decoded with estimated α_{ij} coefficients. Estimations are obtained from previous α_{ij} coefficients by its interpolation. This evidently introduces some delay to signal processing.

4 NUMERICAL RESUTS

Performace of system is evaluated in BER, without any concatenated coding. The symbols were taken from BPSK, the channels are Rayleigh fading with block length 2. Due to the low number of bits, maximal likelihood detection was used. The fading with maximal Doppler shift 200 Hz is considered for all simulations. In the first plot (fig. 1), MIMO fading coefficients are not known for every N blocks of the length 2. The latest known coefficients were used for decoding until they were updated after N blocks of two symbols. Figure 2 shows BER perfomance for N = 50 with linear and cubic spline interpolation of the MIMO coefficients. Similarly figure 3 is for N = 100 and figure 4 for N = 200.

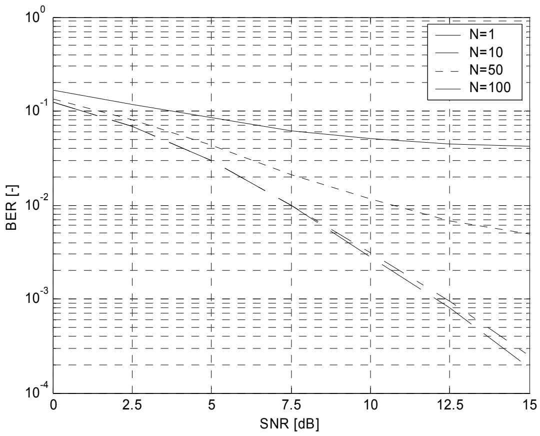

Fig. 1: *Uncoded BER performance for N = 100 with none, linear and cubic spline interpolation.*

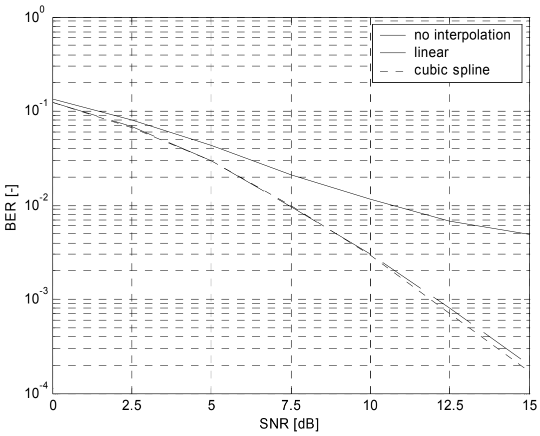

Fig. 2: *Uncoded BER performance for N = 50 with none, linear and cubic spline interpolation*

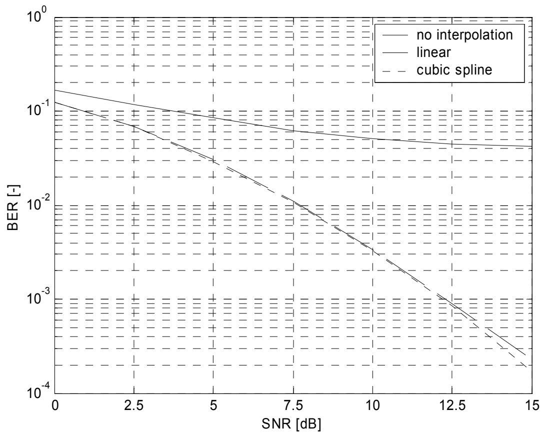

Fig. 3: *Uncoded BER performance for N = 100 with none, linear and cubic spline interpolation.*

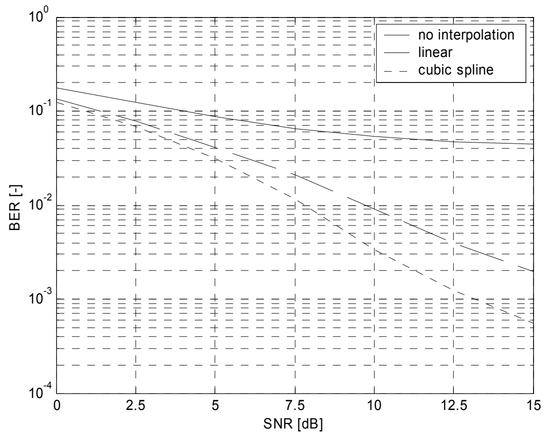

Fig. 4: *Uncoded BER performance for N = 200 with none, linear and cubic spline interpolation*

5 CONCLUSION

We have considered a MIMO 2 x 2 scheme with non-orthogonal space-block coding. Numerical results show how temporal imperfect channel state information degrade BER performance and how it can be improved by linear and cubic spline interpolation. It is shown that for low value of parameter N (50,100), the linear and cubic spline interpolation gives the similar results, but for $N = 200$, BER performance can be improved considerably, especially for better SNR conditions.

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