SIMULATION OF SPACE-TIME BLOCK CODING IN BROADBAND INDOOR FADING CHANNEL USING MATLAB

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Abstract

In this paper, the author's experience with simulation of space-time block coding system in the indoor fading channel model is presented. Space-time coding is new technique using joint of transmit diversity and coding. Space-time codes provide both diversity and coding gain when using multiple transmit antennas to increase spectral efficiency over wireless communications systems. Alamouti's simple two-branch transmit diversity scheme is adopted [1]. Alamouti's scheme was originally designed for flat (frequency non-selective) fading channels, but the condition for frequency selectivity is not defined exactly. The efficiency of space-time block coding in frequency selective and non-selective fading channels is compared. Quasi-static Rayleigh fading channels in indoor environment are assumed. This paper presents a large effect of frequency selectivity on the space-time communication system. These results are useful for FER vs. bit rate performance evaluation of the indoor radio communication systems.

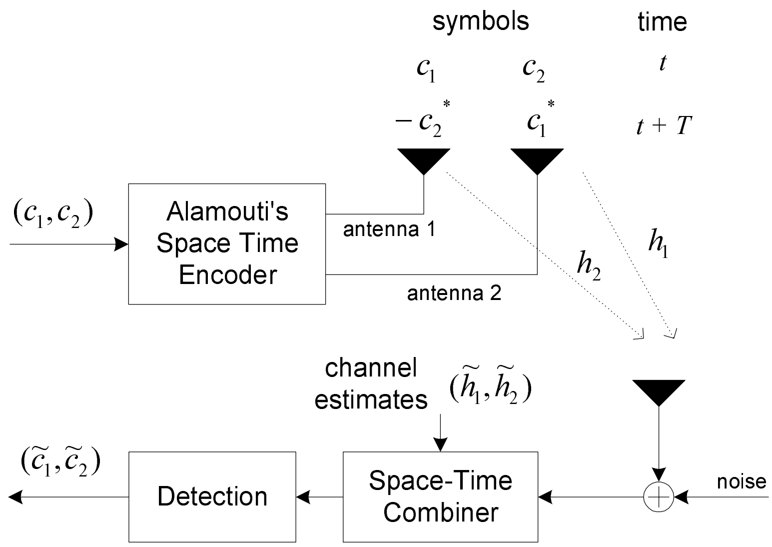

Fig. 1: Alamouti's two antenna transmit diversity scheme.

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, columns of the coding matrix represent time and rows 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 encoders and decoders. In 1998, Alamouti [1] proposed a simple STBC transmit diversity scheme (Fig. 1), which improves the signal quality at the receiver on one side of the radio link by simple processing across two transmit antennas.

Alamouti code encodes two complex baseband symbols c_1, c_2 by this coding matrix:

$$G = \begin{pmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{pmatrix} \qquad (1)$$

where * denotes complex conjugation.

At a given symbol period, two signals are simultaneously transmitted from the two antennas, namely c_1 from the first antenna and c_2 from the second antenna. In the next symbol period ($t + T_s$), signal $-c_2^*$ and c_1^* are transmitted from the first and the second antenna, where T_s denotes symbol period. Columns of the matrix correspond to the antennas and rows corresponds to the time slots. This code matrix is orthogonal.

At the receiver site, the space-time combiner combines the received signals as follows:

$$\begin{aligned} \tilde{c}_1 &= h_1^* r_1 + h_2 r_2^* \\ \tilde{c}_2 &= h_2 r_1 - h_1 r_2^* \end{aligned} \qquad (2)$$

where $\tilde{c}_1$ and $\tilde{c}_2$ 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 the received signals at the time t and $t + T_s$. Channel estimator estimates path gains h_1, h_2 from the received signal using the training or pilot signals.

Implementation of Alamouti's encoder and decoder in MATLAB:

```
% Alamouti's encoder

% first antenna symbols
TX1(1:2:length(input)) = input(1:2:length(input));
TX1(2:2:length(input)) = - conj(input(2:2:length(input)));

% second antenna symbols
TX2(1:2:length(input)) = input(2:2:length(input));
TX2(2:2:length(input)) =  conj(input(1:2:length(input)));


% Alamouti's combiner

for i = 1:chan_num            % fading channel index

 % first time slot
 output(i,1:2:s(2)) = RX(i,1:2:s(2)).*conj(h1(i)) +
                      conj(RX(i,2:2:s(2))).*h2(i);
 % second time slot
 output(i,2:2:s(2)) = RX(i,1:2:s(2)).*conj(h2(i)) -
                      conj(RX(i,2:2:s(2))).*h1(i);

end
```

Indoor fading channel model

Fading channels are commonly used in wireless communications. New applications such as wireless local area networks (LANs) require very high data rate transmissions. This applications are usually used in indoor environments. The result of radio signal multipath propagation in real environment is signal spread in time and it leads to the frequency selectivity of the channel. Indoor fading channels are ursually frequency selective for data rates over roughly several Mbps.

Frequency selectivity of the fading radio channel depends on the multipath delay spread. It can be described by average root-mean-square (rms) delay spread $\overline{\tau}_{\mathrm{rms}}$ [5]. Fading channel is frequency selective if approximately:

$$\overline{\tau}_{rms} > \frac{T_{\mathrm{s}}}{10}, \tag{3}$$

when T_{s} denotes symbol interval.

The indoor channel is usually quasi-static, or very slowly time varying and it is identified by its impulse response. We consider that fading channels from transmit antennas to receive antenna are independent in time.The channel is modeled as a transversal filter with tap spacing equal to symbol interval T_{s}. Transversal filter taps are generated as independent complex-valued zero-mean Gaussian random variables with variance given by exponential power-delay profile [2]. The impulse response from the k-th antenna at transmitter to the receiver:

$$c_k(n) = \sum_i h_k(i).\delta(n-i), \tag{4}$$

where $h_k(n)$ is given by:

$$h_k(n) = \sqrt{\frac{1-e^{-2\gamma}}{2}} e^{-\gamma n}(x + jy), \tag{5}$$

when constant γ is: $\gamma = \dfrac{T_{\mathrm{sample}}}{2\overline{\tau}_{\mathrm{rms}}}$ and $\{x, y\} \approx N(0,1)$.

The variable T_{sample} is inverse value of the channel sampling frequency and $\overline{\tau}_{\mathrm{rms}}$ is average root-mean-square (rms) delay spread of the fading channel.

The time variability of the channel is modeled as a set of 200 statistically generated impulse responses. Transmitted signal passes through the each of this channels and then average FER is estimated. Necessary number of the taps of the transversal filter changes with $\overline{\tau}_{\mathrm{rms}}$ to decrease a computational complexity of the channel model because coefficients of impulse response are after time $10\,\overline{\tau}_{\mathrm{rms}}$ insignificant. For simulations with different SNR conditions are used the same set of the statistically generated impulse responses. It enables to compare the results.

Implementation of indoor fading channel in MATLAB:

```
for ch = 1:200   % set of statistically generated channels

% random matrixes of channels
h1_init = randn(chan_num,multipath_num) + j*randn(chan_num,multipath_num);
h2_init = randn(chan_num,multipath_num) + j*randn(chan_num,multipath_num);
```

```
gama = Ts/(2*tauRMS);
A = sqrt(0.5*(1-exp(-2*gama)));

for i=1:chan_num                    % channel index
     for n=1: multipath_num         % impulse response index
         h_out(i,n)=A*exp(-gama*n)*h_in(i,n);
     end
end

for i = 1:chan_num                  % channel index
 chan_out1(i,:) = filter(h_out(i,:),1,input1);
end
for i = 1:chan_num                  % channel index
 chan_out2(i,:) = filter(h_out(i,:),1,input2);
end

chan_out = chan_out1 + chan_out2;% receive antenna
```

Communication system model

The input bit stream is mapped to baseband complex values of MPSK constellation diagram. The 4-PSK modulation scheme is used in this system. The symbols of 4-PSK are encoded according coding matrix (4). Two output baseband signals of the Alamouti's encoder are oversampled and filtered with square-root raised cosine filter (SRRC). Received baseband signal is decoded with space-time combiner according equations (2). The combiner requires the Channel State Information (CSI) for its function. CSI is estimate of complex path gains h_1, h_2 in this case. We assume that CSI is known at the receiver [1]. Time resolution of the indoor channel model is set to T_{sample} = 10 ns.

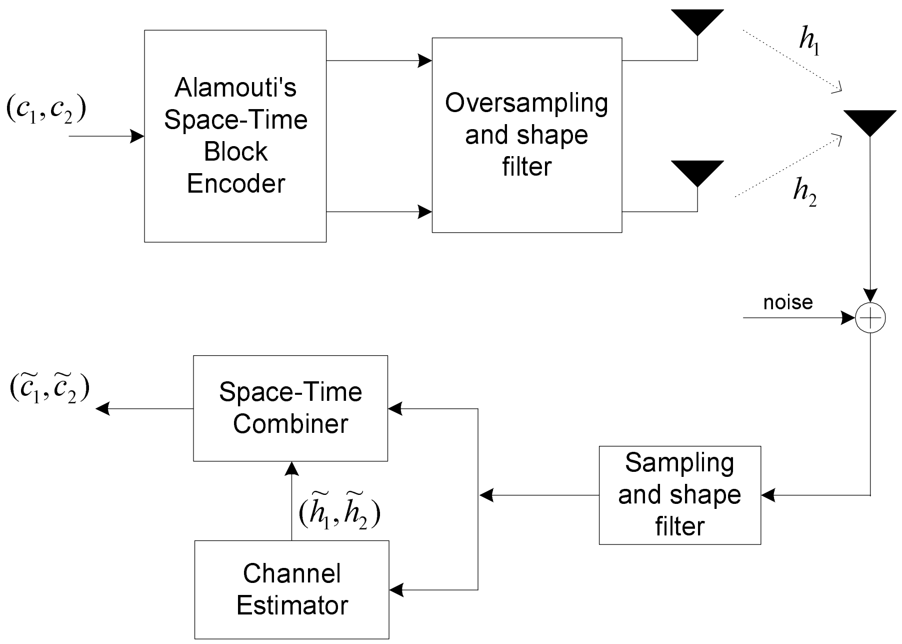

Fig. 2: Discrete-time baseband diagram of the space-time system.

Numerical results

In this section we study the effect of the frequency selectivity on the space-time block coding system performance. Frequency selectivity of the channel can be described by ratio s:

$$s = \frac{T_s}{\overline{\tau}_{\text{rms}}} . \tag{7}$$

The channel with constant $\overline{\tau}_{\text{rms}}$ and variable T_{s} (bit rate) is considered. According equation (3), if s >10, channel is frequency non-selective and if s < 10, channel is regarded as a frequency selective.

BER performance of the system might be improved by using some type of equalization but in this paper, the radio system with no equalization is assumed. Now we can consider, that data are transfered in frames with length l. Simply the FER (Frame Error Rate) can be defined as probability, that there is at least one error in the frame, which can be detected. Than the retransmission of the frame is needed. So that FER as a function of the parameter s can be simply calculated for specific frame length l. Results for example l = 128 are shown in fig. 3 for several SNR (Signal to Noise Ratio) conditions.

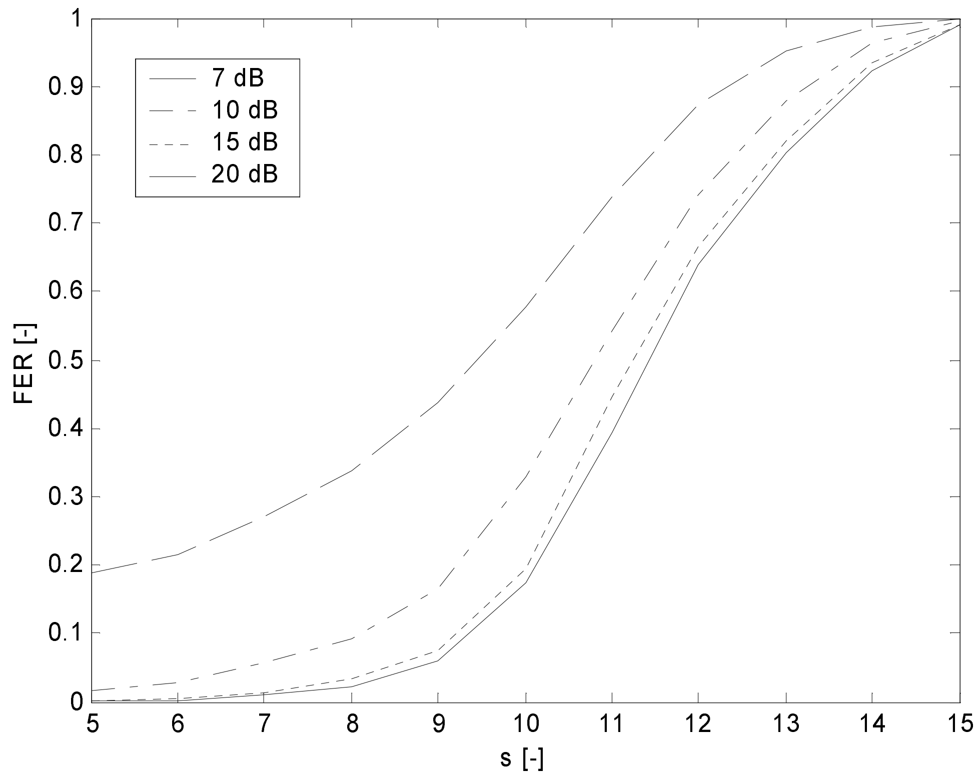

Fig. 3: FER performance vs. frequency selectivity

It is evident, that FER grows with increasing parameter s and converges to unity. It is possible, that higher bit rate with worse FER can transfer more data in the same time with suitable transfer protocol. For double bit rate (s = 10), the FER increses by 15 percent, but it is obvious that double bits are transfered at the same time. Conclusion is, that it depends on the concrete system, if it is advantageous or not to increase bit rate with increasing FER. This is applicable for better SNR conditions, because for $s = 10$, the FER is roughly 20 percent for SNR = 7 dB and this value may be unusable for some systems.

Conclusion

In this paper the effect of the frequency selectivity on the STBC performance is studied. Indoor fading channel model with exponential power-delay profile is used to evaluate the system performance. Quasi-static Rayleigh fading channel is modeled as a hundreds of statistically generated impulse responses. Frequency selectivity of the channel is expressed by ratio of the symbol interval and average RMS delay spread. Frame error rate is increasing with frequency selectivity of the channel, but at the same time, bit rate of the system is improving. Application depends on the required performance of the used radio system and transfer protocol.

Acknowledgment

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