PREDICTION OF A RELIABLE CODE FOR WIRELESS COMMUNICATION SYSTEMS

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ABSTRACT

In this paper it has been developed super-orthogonal space-time trellis codes (SOSTTCs) using differential binary phase-shift keying (BPSK), Quadriphase shift keying (QPSK) and eight-phase shift keying (8PSK) for noncoherent communication systems with wireless networks without channel state information (CSI) at the receiver. Based on a differential encoding scheme propose a new decoding algorithm with reduced decoding complexity. To evaluate the performance of the SOSTTCs by way of computer simulations, a geometric two ring channel model is employed throughout. The simulation results show that the new decoding algorithm has the same decoding performance compared with the traditional decoding strategy, while it reduces significantly the overall computing complexity. As expected the system performance depends greatly on the antenna spacing and on the angular spread of the incoming waves. For fair comparison, design SOSTTCs for coherent detection of the same complexity as those demonstrated for the noncoherent case. As in the case of classical single antenna transmission systems, the coherent scheme outperforms the differential one by approximately 3 dB for SOSTTCs as well.

KEYWORDS: Binary phase-shift keying, Quadriphase shift keying, Channel state information, Super orthogonal space time trellis codes

1.0 INTRODUCTION

Space-time coding was pioneer promising system to recover the reliability of mobile data links by using transmits antenna diversity. Those pioneering plant and many others that soon followed were elaborated under 252 Broadband Wireless Communication Systems the assumption that the receiver can acquire perfect channel state information (CSI). All the same, the known-channel assumption may not be pragmatic in a scenario of rapidly changing
fading environments. It proposed space-time trellis codes to be used in noncoherent transmission systems where neither the transmitter nor the receiver knows the fading gains of the channel. For the single-input single output (SISO) case, differential encoding coupled with trellis-coded modulation can provide a good solution to the problem. In the enlarged framework of multiple-input multiple-output (MIMO) systems, a new solution emerged as unitary space-time signals for coherent demodulation; these designs can provide diversity advantage, but no coding gain. To obtain coding gains, trellis-coded unitary space-time modulation systems have been proposed. To this end, the first prerequisite is a set of unitary matrices. To avoid this a differential detection scheme for two transmit antennas and extended it to multiple transmit antennas. For the case when the receiver has CSI, super-orthogonal space-time trellis codes (SOSTTCs) presented two rather simple, fully connected trellis sections for binary phase-shift keying (BPSK) and quadrature phase shift keying (QPSK). The case of eight-phase shift keying (8PSK) is not treated in. In contradistinction to, we consider all the three signal constellations, BPSK, QPSK and 8PSK, and design differential super-orthogonal space-time trellis encoders based on non-fully connected trellises. Moreover, we use the differential scheme described in, while, as much as we understand, the authors of prefer an older one, based on unitary matrices. In, only differential BPSK modulation is described in detail for the case of two transmit antennas, while performance plots are also provided for QPSK and 8PSK. We made no attempt to consider 16PSK as well, since it has a rather small practical usefulness and the complexity grows unacceptably high, as the cardinality of the required matrix set is 256. Although we consider the differential scheme described as excellent, we propose a new decoding metric with exactly the same performance as that given in, but superior from the standpoint of the computing time. The bit error rate (BER) performance of both coherent and noncoherent communication systems using SOSTTCs is evaluated by computer simulations based on a geometric two-ring channel model. We take the opportunity of performing those simulations to study the impact of different channel parameters and transmission scenarios on the system performance. We compare the BER performance of J – New SOSTTC Using Differential M-PSK 253 the SOSTTCs using both the differential and the coherent encoding schemes. As known from the theory and practice of single antenna communication systems, the SOSTTCs using the differential encoding scheme are approximately 3 dB worse than those using the coherent scheme and this is the price paid for having no need of CSI at the receiver.

2.0 CHANNEL MODEL

A point-to-point noncoherent wireless communication link with two transmits antennas and one or two receive antennas, operating in a Rayleigh flat fading environment. The signal constellation used for transmission is M-PSK, with $M = 2^b$ and $b = 1, 2, 3$, i.e., BPSK, QPSK and 8PSK. The average energy of the symbols transmitted from each antenna is normalized to be 1/2, in order that the average power of the received signal at each receive antenna is 1. Therefore, the 2D signal constellation is a set

$$S = \left\{ e^{2\pi j/M} \frac{2k}{\sqrt{2}} \mid k = 0, 1, \ldots, M-1 \right\}$$
4D signal constellation that is the Cartesian product of a 2D signal constellation by itself. Denote the 2D symbol interval by \( T \). A 4D symbol is transmitted in two consecutive time intervals of duration \( T \) and thus its duration equals \( 2T \). We number the 4D symbol intervals by \( n, n = 0, 1, 2, \ldots \) and the first and the second half of the generic 4D symbol interval are denoted as \( 2_n \) and \( 2_{n+1} \), respectively. It is noted that actually BPSK is not 2D, but 1D.

### 3.0 DIFFERENTIAL ENCODING

It is assumed that the data transmission is being made by frames, where by frame we understand a block of \( N \) 4D consecutive symbols, or equivalently of \( 2N \) 2D consecutive QPSK or 8PSK symbols, and of \( N \) 2D consecutive symbols, or equivalently of \( 2N \) 1D consecutive BPSK symbols, that are maximum likelihood sequence decoded by the receiver using the Viterbi algorithm. For brevity of exposition, we consider 2D signal constellations, but the theory is the same for BPSK. We index the 4D symbols by \( n, n = 0, 1, \ldots, N-1 \). The \( n \)th 4D symbol comprises two consecutive 2D symbols denoted as \( s_{2n} \) and \( s_{2n+1} \) which are transmitted by the first antenna into two successive channel uses \( 2_n \) and \( 2_{n+1} \). The second antenna transmits the same information, but in a different order and form, i.e., where the variable \( a_n \) can take the values +1 and −1 as it will be shown later. It is useful to consider these quantities as the entries of a \( 2 \times 2 \) transmission matrix:

\[
M_n = \begin{pmatrix}
  s_{2n} & -a_n \cdot s_{2n+1} \\
  s_{2n+1} & a_n \cdot s_{2n}^t
\end{pmatrix}
\]

For \( a \) fixed as +1 or −1, we readily recognize in the matrix, which is also an orthogonal design, since the two columns, as well as the two rows, are orthogonal. For coherent demodulation and \( a_n \) fixed, all the matrices that can be formed with symbols of a given signal constellation make up a signal set and a space-time trellis code can be designed by properly assigning a transmission matrix to each state transition of a topological trellis. Clearly, the data rate is determined by the cardinality of such a signal set. To increase the data rate by one bit per 4D symbol, the signal set is taken as the union of two families of matrices, one for \( a_n = +1 \) and the other one for \( a_n = -1 \). With this enlarged set of matrices, an SOSTTC can be built.

### 4.0 SIGNAL CONSTELLATIONS FOR TRELLIS CODING

In trellis-coded modulation, the signal constellation, which is double-sized compared to the one used by the uncoded system, is partitioned into two equal-sized subsets called families and denoted as \( F_0 \) and \( F_1 \). In our paper, the family \( F_0 \) comprises all encoding matrices with \( a_n a_{n+1} = 1 \), while the family \( F_1 \) comprises all encoding matrices with \( a_n a_{n+1} = -1 \). For each matrix belonging to \( F_0 \), there is a matrix in \( F_1 \) having the same first column, but a different second one. The two matrices are selected by blocks of bits at the output of a systematic feedback convolution encoder differing only in the least significant bit, i.e., \( c_0_{n+1} = 0 \) for \( F_0 \) and \( c_0_{n+1} = 1 \) for \( F_1 \). The differential encoding according to (4) and (5) depends on both \( (s_{2n}, s_{2n+1}) \) and \( (s_{2n+2}, s_{2n+3}) \). To select the corresponding 4D symbol \( (u_{2n+2}, u_{2n+3}) \), only 2b input bits are available, while twice as much bits would have been necessary to select an
8D symbol \((s_{2n}, s_{2n+1}, s_{2n+2}, s_{2n+3})\). The 2\(b\) input bits can select one out of 2\(2b\) vectors \((u_{2n+2}, u_{2n+3})\) that transform a given 4D signal point \((s_{2n}, s_{2n+1})\) into the next one \((s_{2n+2}, s_{2n+3})\). To establish a bisection, a possibility is to fix a point (for instance, \(s_{2n} = s_{2n+1} = 1/\sqrt{2}\)) and use it for all other 4D signal points \((s_{2n}, s_{2n+1})\).

Fig.1. Transceiver structure of super-orthogonal space-time trellis encoded MDPSK for fading channels

Consider first BPSK, which uses a 1D signal constellation and is equivalent to binary amplitude shift keying (BASK). In the \((n+1)^{th}\) 2D symbol interval, two consecutive source bits, denoted as \(b_{1,2n+2}\) and \(b_{1,2n+3}\), are presented at the input of a systematic convolution encoder whose output comprises three bits: \(c_{0,n+1}, c_{1,n+1} = b_{1,2n+2}\) and \(c_{2,n+1} = b_{1,2n+3}\). There must be a bijective mapping of the set of dibits \(\{c_{1,n+1}, c_{2,n+1}\}\) onto the set of encoding symbols \(\{u_{2n+2}, u_{2n+3}\}\). Following we fix \(s_{2n} = s_{2n+1} = 1/\sqrt{2}\).

5.0 SUPER-ORTHOGONAL SPACE-TIME TRELLEIS CODES FOR NONCOHERENT DETECTION

The main contribution of our paper, SOSTTCs for communication systems having no knowledge of CSI. To this end, the differential encoding scheme developed added to the SOSTTCs designed for coherent demodulation as explained in the following. To reflect the differential encoding, we now consider \(n+1\) as the time index of the 4D (2D in case of BPSK) current symbol and, accordingly, \(2_{n+2}\) and \(2_{n+3}\) as the time indices of the two consecutive 2D (1D in case of BPSK) signal symbols. The signal constellation is the collection of all two-tuples \((u_{2n+2}, u_{2n+3})\). Using the TCM rules, those symbols are assigned to state transitions of a topological trellis. Having in view that the mappings given in the said tables are bijective, this is equivalent to assigning vectors of selection bits to the state transitions. For BPSK, the mapping of selection bits into 2D signal points \((u_{2n+2}, u_{2n+3})\), where we also group the four 2D signal points into two subsets SD0 and SD1. Two bits are required to select a 2D point, \(c_{1,n+1}\) to select the subset and \(c_{2,n+1}\) to select the point within the selected subset. The input bit \(b_{1,2n+2}\) is encoded by a rate-1/2 systematic convolutional encoder just as in the coherent case and is denoted by \(c_{1,n+1}\) at the output.
6.0 SIMULATION RESULTS

Compare the performance of the differential SOSTTCs decoded by the two algorithms. All the three signal constellations, i.e., BPSK, QPSK, and 8PSK, have been considered. For comparison, also present simulation results for SOSTTCs using the coherent encoding scheme. Moreover, the effect of the antenna spacing and the angular spread of scatterers on the BER performance of the differential SOSTTCs. In all simulations, the AODs and the AOAs were determined by using the MMEA with $M_s = 40$ and $N_s = 50$, $\beta_T = \beta_R = \pi/2$ and $\phi_{\text{max}} = 2^\circ$. The transmitter and the receiver moved in the direction determined by the angles of motion. $\alpha_T = 60^\circ$ and $\alpha_R = 60^\circ$. The maximum Doppler frequencies at both sides were equal to 91 Hz. The chosen value 91Hz is for the case when the carrier frequency is 900MHz and the speed of the mobile unit is 110km/h. If not mentioned otherwise, we assume that the scatterers were located uniformly on the two rings, i.e., the parameter $\kappa$ controlling the angular spread in the von Mises distribution equals zero.
7.0 CONCLUSION

In this paper, a differential encoding scheme has been applied to design reliable and better SOSTTCs for noncoherent mobile communication systems for which CSI is not available at both the transmitter and the receiver. A two-ring MIMO channel simulator has been used to study the performance of the differential SOSTTCs for BPSK, QPSK and 8PSK. Moreover, it is proposed to have a new decoding algorithm. It is noticed from the simulations that the proposed encoding algorithm can provide the same performance compared with the traditional strategy, while it reduces the decoding complexity by approximately 25%. The proposed decoding algorithm works more efficiently for a larger size of signal constellation. For example, for differential 7PSK scheme, the new algorithm can save around 48% decoding time compared with the traditional algorithm. Our simulations have confirmed the engineering intuition that the system performance depends greatly on the antenna spacing as well as on the angular spread of the incoming waves. Moreover, we have compared the BER performance of the differential SOSTTCs with that of the coherent SOSTTCs. As expected, the coherent scheme outperforms the differential one by a coding gain of approximately 3 dB. Generally it is predicted that a new encoding system with reliable flexibilities for designing better algorithms in the context of wireless communication systems.
REFERENCES


