

## SPACE TIME CODING FOR TRELIS CODED MODULATION IN ADDITIVE WHITE GAUSSIAN CHANNELS

<sup>1</sup>Ömer ERKAN

<sup>2</sup>Onur OSMAN

<sup>3</sup>Osman Nuri UÇAN

<sup>1,3</sup> Istanbul University Engineering Faculty, Electrical and Electronics Dept.  
34850 Avcilar, Istanbul-Turkey

<sup>2</sup> Istanbul Commerce University Vocational School,  
Ragip Gumuspala cd. No:84 34378 Eminonu, Istanbul-Turkey

<sup>1</sup> E-mail: [uerkan@istanbul.edu.tr](mailto:uerkan@istanbul.edu.tr)    <sup>2</sup> E-mail: [uosman@istanbul.edu.tr](mailto:uosman@istanbul.edu.tr)

<sup>3</sup> E-mail: [uosman@iticu.edu.tr](mailto:uosman@iticu.edu.tr)

### ABSTRACT

*In this study, Trellis Coded Modulation (TCM) technique is combined with Space Time Codes (STC) and error performance is investigated in Additive White Gaussian (AWGN) channels. For this purpose a different receiver structure is proposed and mathematical model is given. Investigated system's error performance curves are given for different signal-to-noise ratios.*

**.Keywords:** *Space Time Codes, Trellis Coded Modulation, AWGN.*

### I. INTRODUCTION

Multipath fading causes severe amplitude and phase distortion in mobile communication. Thus, to overcome this fading effect both at receiver and transmitter side without using more bandwidth and power is important for the success of communication system. To remove fading effect diversity may be used. Recently, to benefit from antenna diversity, different transmission diversity techniques have been introduced. Space Time Trellis Coding is introduced in [1],[2],[3] as a joint design of

coding, modulation, transmission diversity and receiver diversity.

The outline of this paper is as follows. In section II, Trellis Coded Modulation (TCM) is introduced and error performance criteria is investigated. Space Time Codes are presented in Section III. The system under interest is explained in details and mathematical model is given in Section IV. In section V, the system's error performance is given. In last section results are interpreted.

*Received Date : 24.6.2001*

*Accepted Date: 03.03.2003*

## II. TRELIS CODED MODULATION

Trellis Coded Modulation (TCM) technique, in which coding and modulation thought together, was first proposed by Ungerboeck [4]. In TCM system design; modulated channel symbols that appointed to the binary code words on the trellis structure is placed to the trellis structure. Let  $a_i$  and  $b_i$  denote channel symbols. The squared Euclidian distance between these signals is denoted as  $d^2(a_i, b_i)$ . At the receiver, maximum likelihood error that the soft decision decoder can make is to choose the nearest Euclidian distanced symbol instead of the transmitted symbol. In trellis structure minimum distance merging in any common state all array is defined as "Free Euclidian Distance" (FED) and formulated as follows:

$$d_{SE}^2 = \min \left\{ \sum_{a_i \neq b_i} d^2(a_i, b_i) \right\} \quad (1)$$

In Additive White Gaussian Channels for high signal-to-noise ratios, error performance criteria of the TCM system is FED. To improve the error performance of TCM system, the encoder should be designed in the way that the FED of the codes to be maximised. Binary signals at the output of the encoder are mapped by set partitioning method as in [4]. In this method, twice much

more than needed signal set is divided into subsets which have less elements in such a way that the Euclidian distance between the elements in the subsets is chosen to be maximum. The partitioned subsets are placed to the chosen trellis structure's branches in the way that the FED between channel signals are chosen as maximum. During this process, all channel symbols should be used equally often, subsets appointed to the merging and emerging states should be chosen with maximum intradistances. The soft demodulator outputs are sent to the soft decision Viterbi decoder.

## III. SPACE TIME CODING

Using of Space Time Codes that provides antenna diversity is effective and largely used technique to reduce the effect of multipath fading channels [2],[3]. Space Time coding is bandwidth and power efficient communication method that profits the use of multi antenna in stead of one. By using multi antenna, even if severe fading is effective from one propagation path, from one of the other propagation paths we have the more probability to get the signal without being severe faded. In STC, in first coding step from all antennas different signals are sent. In second coding step, the conjugates of these signals are sent through antennas according to a coding rule.

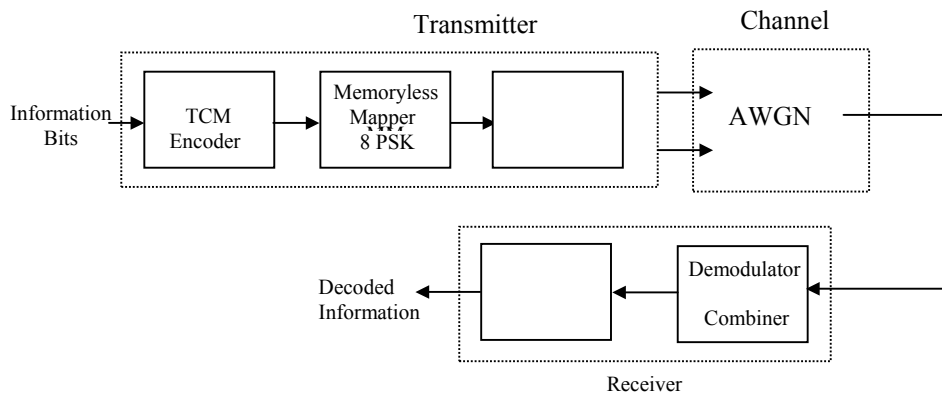


Figure 1. Block diagram of Space Time Coded TCM system

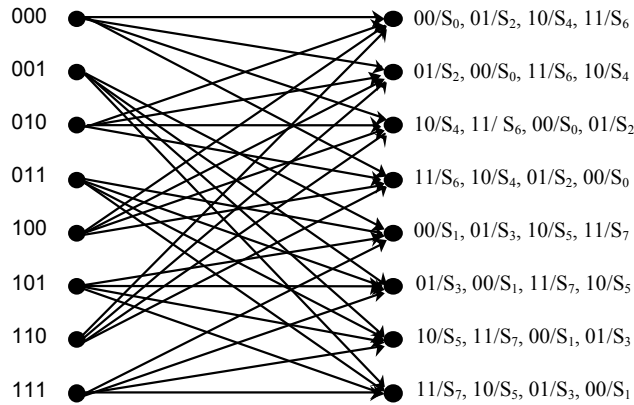


Figure 2. Trellis structure of 2/3 rate TCM encoder

Let assume a system with two transmitter antennas and one receiver antenna and  $x$  denote the output of demodulator. In first coding step  $x_0$  is sent from antenna0 and  $x_1$  is sent from antenna1. In second coding step  $-x_1^*$  is sent from antenna0 and  $x_0^*$  is sent from antenna1. Here  $*$  represents the complex conjugate of the signal. Outputs of the modulator are encoded according to this coding rule.

IV. SYSTEM MODEL

The block diagram of the proposed system is shown in Figure 1. TCM encoder is a rate 2/3 with three memories convolutional encoder. Trellis structure of this encoder is shown in Figure 2. Memoryless Mapper (MM) maps the coded binary signals according to natural mapping method

$$(s_0 \leftarrow 000 \quad s_1 \leftarrow 001 \quad s_2 \leftarrow 010 \quad s_3 \leftarrow 011, \\ s_4 \leftarrow 100 \quad s_5 \leftarrow 101 \quad s_6 \leftarrow 110 \quad s_7 \leftarrow 111)$$

and turns them into 8 PSK (Phase Shift Keying) signals. Outputs of the MM are encoded by ST encoder according to below rule. In first coding step  $x_0$  is sent from antenna0 and  $x_1$  is sent from antenna1. In second coding step  $(t+T) -x_1^*$  is sent from antenna0 and  $x_0^*$  is sent from antenna1. outputs of the ST encoder are sent to the channel. The channel in our system is Additive White Gaussian Channel. In this channel , zero mean, variance with  $N_0/2$  Additive White Gaussian Noise is added to the signal. The signals are received by the receiver antenna and pass to the receiver structure shown in Figure 3 which proposed by alamouti [1]. With this

structure, after demodulation process, simple mathematical operations are done by using combiner structure and these modified signals pass to the decoder.

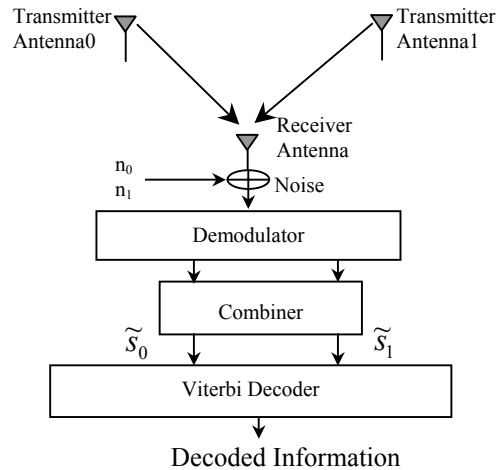


Figure 3. Receiver structure of STTCM system

The received signals may be expressed as follows.

$$r_0 = r(t) = s_0 + s_1 + n_0 \tag{3.a}$$

$$r_1 = r(t+T) = -s_1^* + s_0^* + n_1 \tag{3.b}$$

The combiner in Figure 3 does the simple mathematical operations given in equations (4.a) and (4.b).

$$\tilde{s}_0 = r_0 + r_1^* \quad (4.a)$$

$$\tilde{s}_1 = r_0 - r_1^* \quad (4.b)$$

When all quantities written to the equations and after all needed simplifications are done we get the expressions in (5.a) and (5.b).

$$\tilde{s}_0 = 2s_0 + n_0 + n_1^* \quad (5.a)$$

$$\tilde{s}_1 = 2s_1 - n_1^* + n_0 \quad (5.b)$$

From above equations it is seen that sent signals are multiplied by constant two which improves error performance of the system. The signals  $\tilde{s}_0$ ,  $\tilde{s}_1$  at the output of the combiner are decoded by the Viterbi decoder.

## V. ERROR PERFORMANCE OF STTCM SYSTEM

To obtain error performance of the system, we used computer simulations. The encoder we used has two inputs, three outputs and three memories thus having eight states. Modulation process is done using 8 PSK. There are two transmit antennas and one receive antenna in the system. Simulation results show the bit error probability for different signal-to-noise ratios.

## VI. CONCLUSION

The error performance of the system is shown in Figure 4. The channel is AWGN channel. As shown before, sent signal is multiplied by constant two and this improves the systems error performance. Only AWGN is added to the signal and for high signal-to-noise ratios the systems error performance is very well.

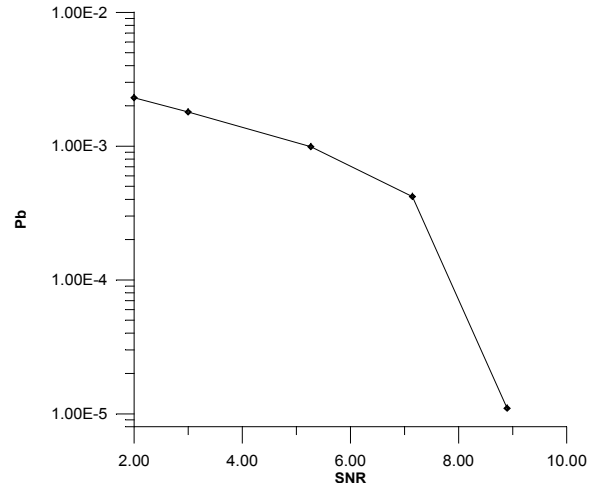


Figure 4. Error performance of the STTCM system

## REFERENCES

- [1] S.M.Alamouti, "A Simple Transmit Diversity Technique for Wireless Communication" *IEEE Journal of Selected Areas in Communications*, Vol. 16, No.8, September 1998.
- [2] V.Tarokh, N.Seshadri, A.Calderbank, "Space-time codes for high data rate wireless communication: Performance criterion and code construction", *IEEE Transaction on Information Theory*, Vol. 44, pages 744-765, March 1998.
- [3] V.Tarokh, H.Jafarkhani, A.Calderbank, "Space-time codes from orthogonal design", *IEEE Transaction on Information Theory*, June 1999.
- [4] Ungerboeck G., "Channel coding with multi-level/phase signals" *IEEE Transaction on Information Theory*, Vol. IT-28, pages 55-67, January 1982.
- [5] O.N.Ucan, O.Osman, S.Paker, "Turbo Coded Signals over Wireless Local Loop Environment", *International Journal of Electronics and Communications, AEU*, Vol. 56, No.3, pages 163-168, July 2002.



**Ömer ERKAN** was born in Konya, Turkey in 1979. He received the B.Sc. degree in 1999 from University of Istanbul, Turkey in Electrical & Electronics Engineering. He served as a Research Assistant at the Department of Electrical and Electronics Engineering, University of Istanbul from 1999 to 2002 where he continues to work on his M.Sc. dissertation. Currently he is a Researcher at the Impedance Laboratory in National Metrology Institute of Turkey (UME), TUBITAK. His research interests are digital coding and modulation techniques in wireless communication systems.

**Onur Osman** : See Vol.2, Number 1, page 375.

**Osman N. Uçan** : See Vol.2, Number 1, page 343.