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Low Delay General Complex Orthogonal Space-Time Block Code for Seven and Eight Transmit Antenna

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Abstract

Space time block codes using orthogonal designs have full code rate, maximum diversity at the receiver simple decoding algorithm. Complex orthogonal designs of maximum possible rate of full, 3/4, and 3/4 have been presented for two, three, and four transmit antennas respectively. For five, six, seven and eight transmit antennas, four generalized complex orthogonal space-time block codes of rates 2/3, 2/3,5/8, and 5/8 were proposed recently. Complex orthogonal designs STBCs for other numbers of transmits antennas exhibit rates of 1, 1for four, eight antennas respectively. In this paper we achieved low delay generalized complex orthogonal space time block code for 7& 8 transmit antenna.

Index Terms – Diversity, (generalized) complex orthogonal designs, space –time block codes.

1.INTRODUCTION

For two transmit antennas full-rate OSTBC is Alamouti's transmit diversity scheme [1] for given a complex-valued modulation scheme. For half-rate OSTBC the complex-valued modulation scheme was constituted for any number of transmit antennas which is shown in[6]. The generalized Space-time block codes exist with symbol transmission rate 3/4 for 3 and 4 transmit antennas with linear processing [6] or from GCODs without linear processing

Let k , n k, n, and p be positive integers. A complex orthogonal space-time block code (STBC) for any number of transmit antennas n may be described by a $p \times n$ matrix O , the nonzero entries of which are the k complex variables $Z_1, Z_2, \ldots.., Z_k$ or their conjugates $Z_1^*, Z_2^*, \ldots\ldots.., Z_k^*$ or the negative of these complex variables and their conjugates, satisfying the following complex orthonormality condition.

$$O^H O = \left(|Z_1|^2 + |Z_2|^2 + \ldots\ldots. + |Z_k|^2\right) I_{n\times n}$$

Where O^H represents the Hermitian transpose of O and In×n the $n \times n$ identity matrix. The matrix O is said to be a $[p,n,k]$ complex orthogonal STBC. For example, Altamonte's code [1] for 2 transmit antennas is a $[p,n,k]$ = [2, 2, 2] complex orthogonal STBC given by

$$\begin{pmatrix} z_1 & z_2 \\ -z_2^* & z_1^* \end{pmatrix}$$

The rate of complex orthogonal STBC O is defined as $R = k/p$. For example, Alamouti's code in (2) for 2 transmit antennas has the rate $R = k/p = 2/2 = 1$. Clearly, a complex orthogonal STBC O with high rate can improve the bandwidth efficiency.. In the recent work [5], we have demonstrated that, for any number of transmit antennas $n = 2m - 1$ and 2m with any given positive integer m, the maximum achievable rate $R = k/p$ for a [p, n, k] complex orthogonal STBC is the same value $\frac{m+1}{2m}$. For example, two complex orthogonal STBCs of [p, n, k] = [4, 3, 3] and [p, n, k] = [4, 4, 3] with the same maximal rate 3/4 for 3 and 4 transmit antennas, respectively, were constructed in [6]. A specific complex orthogonal STBC of [p, n, k] = [15, 5, 10] with maximal rate 2/3 for 5 transmit antennas was successfully handcrafted in [4]

For any given number of transmit antennas, we have presented in [5] a simple construction procedure with initial diagonal arrangement for complex orthogonal STBCs with various rates and decoding delays In particular, the construction procedure can generate complex orthogonal STBCs with the maximal rate $\frac{m+1}{2m}$ for any number of transmit antennas n = 2m − 1 and 2m. For example, for 6, 7, and 8 transmit antennas, we have constructed the complex orthogonal STBCs of [p, n, k] = [30, 6, 20], [p, n, k] = [56, 7, 35], and [p, n, k] = [112, 8, 70] with the maximal rates 2/3, 5/8, and 5/8, respectively. Note that the decoding delay of the above complex orthogonal STBC for 8 transmit antennas is twice of that of the complex orthogonal STBC for 7 transmit antennas, i.e., 112 = 56 × 2. From practical point of view, it is significant for a [p, n, k] complex orthogonal STBC O with the maximal rate to have the memory length or decoding delay p as small as possible

2. COMPLEX ORTHOGONAL DESIGNS

Definition 1: A generalized complex orthogonal design (GCOD) in variables $x_1, x_2, \ldots, x_k$ is a p × n matrix G such that:

- the entries of G are complex linear combinations of $x_1, x_2, \ldots, x_k$ and their complex conjugates $x_1^*, x_2^*, \ldots, x_k^*$
- $G^H G = D$, where G^H is the complex conjugate and transpose of G, and D is an n×n diagonal matrix with the (i, i) th diagonal element of the form $l_{i,1}|x_1|^2 + l_{i,2}|x_2|^2 + l_{i,3}|x_3|^2 + \ldots\ldots + l_{i,k}|x_k|^2$ where all the coefficients $l_{i,1}, l_{i,2}, l_{i,3}, \ldots\ldots, l_{i,k}$ are strictly positive numbers.

The rate of G is defined as R = k/p. If $G^H G = \left(|x_1|^2 + |x_2|^2 + \ldots\ldots + |x_k|^2\right) I_{nxn}$ Then G is called a complex orthogonal design (COD).

Tarokh, Jafarkhani, and Calderbank [6] first mentioned that the rate of space-time block codes from generalized complex orthogonal designs cannot be greater than 1, i.e., R = k/p ≤ 1. Later, it was proved in [9] that this rate must be less than 1 for more than two transmit antennas. For a fixed number of transmit antennas n and rate R, it is desired to have the block length p as small as possible.

The first space–time block code from complex orthogonal design was proposed in Alamouti [1] for two transmit antennas. It is the following 2 × 2 COD in variables x_1 and x_2

$$G_2 = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix}$$

Clearly, the rate of G2 achieves the maximum rate 1. For space–time block codes from (generalized) complex orthogonal designs, rate 1 is achievable only for two transmit antennas.

For n = 3 and n = 4 transmit antennas, there are complex orthogonal designs of rate R = 3/4 for example,

$$G_3 = \begin{pmatrix} x_1 & x_2 & x_3 \\ -x_2^* & x_1^* & 0 \\ x_3^* & 0 & -x_1^* \\ 0 & x_3^* & -x_2^* \end{pmatrix}$$

$$G_4 = \begin{pmatrix} x_1 & x_2 & x_3 & 0 \\ -x_2^* & x_1^* & 0 & x_3 \\ x_3^* & 0 & -x_1^* & x_2 \\ 0 & x_3^* & -x_2^* & -x_1 \end{pmatrix}$$

The theory of space-time block codes was further developed by Weifen Su and Xian-Gen Xia [7]. They defined space time block codes in terms of orthogonal code matrices. The properties of these matrices ensure rate 7/11 and 3/5 for 5 and 6 transmit antenna.

$$G_5 = \begin{pmatrix} x_1 & x_2 & x_3 & 0 & x_4 \\ -x_2^* & x_1^* & 0 & x_3 & x_5 \\ x_3^* & 0 & -x_1^* & x_2 & x_6 \\ 0 & x_3^* & -x_2^* & -x_1 & x_7 \\ x_4^* & 0 & 0 & -x_7^* & -x_1^* \\ 0 & x_4^* & 0 & x_6^* & -x_2^* \\ 0 & 0 & x_4^* & x_5^* & -x_3^* \\ 0 & -x_5^* & x_6^* & 0 & x_1 \\ x_5^* & 0 & x_7^* & 0 & x_2 \\ -x_6^* & -x_7^* & 0 & 0 & x_3 \\ x_7 & -x_6 & -x_5 & x_4 & 0 \end{pmatrix}$$

3. EXISTED COMPLEX ORTHOGONAL STBC FOR 7 TRANSMIT ANTENNAS

A complex orthogonal STBC of [p, n, k] = [56, 7, 35] with rate 1/2 and decoding delay 56 for 7 transmit antennas is given as shown in Tabe.1.

4 . A NEW COMPLEX ORTHOGONAL STBC FOR 7 TRANSMIT ANTENNAS

A complex orthogonal STBC of [p, n, k] = [42, 7, 21] with rate 1/2 and decoding delay 42 for 7 transmit antennas is given as shown in Tabe.2.

A complex orthogonal STBC of [p, n, k] = [15, 8, 9] with rate 3/5 and decoding delay 15 for 8 transmit antennas is given as shown in Tabe.3.

5. Conclusion

Here in this Paper the Complex orthogonal space-time block codes (COSTBC) satisfy full diversity as well as fast ML decoding conditions. In the previous work the designs of rate greater than ½ and less than 1 were give only for three or four transmit antennas with rate of ¾ and only the code rate 1 was for two transmit antenna and 4 transmit antennas. In this work we Propose the new complex orthogonal design with low delay code rate ½ using 7 transmit antennas. By increasing number of transmit antennas the bit error rate decreases and hence the Performance of the Wireless Communication system increases

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$$
\varsigma = \begin{pmatrix}
x_1 & x_2 & x_3 & 0 & x_7 & 0 & x_{21} \\
-x_2^* & x_1^* & 0 & x_4^* & 0 & x_{11}^* & 0 \\
-x_3^* & 0 & x_1^* & x_5^* & 0 & x_{12}^* & 0 \\
0 & -x_3^* & x_2^* & x_6^* & 0 & x_{13}^* & 0 \\
0 & -x_4 & -x_5 & x_1 & x_8 & 0 & x_{22} \\
x_4 & & -x_6 & x_2 & x_9 & & x_{23} \\
x_5 & x_6 & 0 & x_3 & x_{10} & 0 & x_{24} \\
-x_6^* & x_5^* & -x_4^* & 0 & 0 & x_{14}^* & 0 \\
-x_7^* & 0 & 0 & -x_8^* & x_1^* & x_{15}^* & 0 \\
0 & -x_7^* & 0 & -x_9^* & x_2^* & x_{16}^* & 0 \\
0 & 0 & -x_7^* & -x_{10}^* & x_3^* & x_{17}^* & 0 \\
-x_9^* & x_8^* & 0 & 0 & x_4^* & x_{18}^* & 0 \\
-x_{10}^* & 0 & x_8^* & 0 & x_5^* & x_{19}^* & 0 \\
0 & -x_{10}^* & x_9^* & 0 & x_6^* & x_{20}^* & 0 \\
x_8 & x_9 & x_{10} & -x_7 & 0 & 0 & x_{25} \\
0 & -x_{11} & -x_{12} & 0 & -x_{15} & x_1 & x_{26} \\
x_{11} & 0 & -x_{13} & 0 & -x_{16} & x_2 & x_{27} \\
x_{12} & x_{13} & 0 & 0 & -x_{17} & x_3 & x_{28} \\
0 & 0 & x_{14} & -x_{11} & -x_{18} & x_4 & x_{29} \\
0 & -x_{14} & 0 & -x_{12} & -x_{19} & x_5 & x_{30} \\
x_{14} & 0 & 0 & -x_{13} & -x_{20} & x_6 & x_{31} \\
x_{15} & x_{16} & x_{17} & 0 & 0 & x_7 & x_{32} \\
0 & -x_{18} & -x_{19} & x_{15} & 0 & x_8 & x_{33} \\
x_{18} & 0 & -x_{20} & x_{16} & 0 & x_9 & x_{34} \\
x_{19} & x_{20} & 0 & x_{17} & 0 & x_{10} & x_{35} \\
-x_{13}^* & x_{12}^* & -x_{11}^* & -x_{14}^* & 0 & 0 & 0 \\
-x_{16}^* & x_{15}^* & 0 & x_{18}^* & x_{11}^* & 0 & 0 \\
-x_{17}^* & 0 & x_{15}^* & x_{19}^* & x_{12}^* & 0 & 0 \\
0 & -x_{17}^* & x_{16}^* & x_{20}^* & x_{13}^* & 0 & 0 \\
x_{20}^* & -x_{19}^* & x_{18}^* & 0 & x_{14}^* & 0 & 0 \\
-x_{21}^* & 0 & 0 & -x_{22}^* & 0 & -x_{26}^* & x_1^* \\
0 & -x_{21}^* & 0 & -x_{23}^* & 0 & -x_{27}^* & x_2^* \\
0 & 0 & -x_{21}^* & -x_{24}^* & 0 & -x_{28}^* & x_3^* \\
-x_{23}^* & x_{22}^* & 0 & 0 & 0 & -x_{29}^* & x_4^* \\
-x_{24}^* & 0 & x_{22}^* & 0 & 0 & -x_{30}^* & x_5^* \\
0 & -x_{24}^* & x_{23}^* & 0 & 0 & -x_{31}^* & x_6^* \\
0 & 0 & 0 & x_{25}^* & -x_{21}^* & -x_{32}^* & x_7^* \\
-x_{25}^* & 0 & 0 & 0 & -x_{22}^* & -x_{33}^* & x_8^* \\
0 & -x_{25}^* & 0 & 0 & -x_{23}^* & -x_{34}^* & x_9^* \\
0 & 0 & -x_{25}^* & 0 & -x_{24}^* & -x_{35}^* & x_{10}^* \\
-x_{27}^* & x_{26}^* & 0 & x_{29}^* & 0 & 0 & x_{11}^* \\
-x_{28}^* & 0 & x_{26}^* & x_{30}^* & 0 & 0 & x_{12}^* \\
0 & -x_{28}^* & x_{27}^* & x_{31}^* & 0 & 0 & x_{13}^* \\
-x_{31}^* & x_{30}^* & -x_{29}^* & 0 & 0 & 0 & x_{14}^* \\
-x_{32}^* & 0 & 0 & -x_{33}^* & x_{26}^* & 0 & x_{15}^* \\
0 & -x_{32}^* & 0 & -x_{34}^* & x_{27}^* & 0 & x_{16}^* \\
0 & 0 & -x_{32}^* & -x_{35}^* & x_{28}^* & 0 & x_{17}^* \\
-x_{34}^* & x_{33}^* & 0 & 0 & x_{29}^* & 0 & x_{18}^* \\
-x_{35}^* & 0 & x_{33}^* & 0 & x_{30}^* & 0 & x_{19}^* \\
0 & -x_{35}^* & x_{34}^* & 0 & x_{31}^* & 0 & x_{20}^* \\
x_{22} & x_{23} & x_{24} & -x_{21} & -x_{25} & 0 & 0 \\
x_{26} & x_{27} & x_{28} & 0 & x_{32} & -x_{21} & 0 \\
0 & -x_{29} & -x_{30} & x_{26} & x_{33} & -x_{22} & 0 \\
x_{29} & 0 & -x_{31} & x_{27} & x_{34} & -x_{23} & 0 \\
x_{30} & x_{31} & 0 & x_{28} & x_{35} & -x_{24} & 0 \\
-x_{33} & -x_{34} & -x_{35} & x_{32} & 0 & x_{25} & 0
\end{pmatrix}
$$

Table.1

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$$o_z = \begin{bmatrix}
z_1 & 0 & 0 & 0 & 0 & z_2 & z_3 \\
0 & z_1 & 0 & 0 & 0 & z_4 & z_5 \\
0 & 0 & z_1 & 0 & 0 & z_6 & z_7 \\
0 & 0 & 0 & z_1 & 0 & z_8 & z_9 \\
0 & 0 & 0 & 0 & z_1 & z_{10} & z_{11} \\
-z_2^* & -z_4^* & -z_6^* & -z_8^* & -z_{10}^* & -z_1^* & 0 \\
-z_3^* & -z_5^* & -z_7^* & -z_9^* & -z_{11}^* & 0 & z_1^* \\
-z_4 & z_2 & 0 & 0 & 0 & 0 & z_{12} \\
-z_6 & 0 & z_2 & 0 & 0 & 0 & z_{13} \\
-z_8 & 0 & 0 & z_2 & 0 & 0 & z_{14} \\
-z_{10} & 0 & 0 & 0 & z_2 & 0 & z_{15} \\
0 & -z_{12}^* & -z_{13}^* & -z_{14}^* & -z_{15}^* & -z_3^* & z_2^* \\
-z_5 & z_3 & 0 & 0 & 0 & z_{12}^* & 0 \\
-z_7 & 0 & z_3 & 0 & 0 & z_{13}^* & 0 \\
-z_9 & 0 & 0 & z_3 & 0 & z_{14}^* & 0 \\
-z_{11} & 0 & 0 & 0 & z_3 & z_{15}^* & 0 \\
0 & -z_6 & z_4 & 0 & 0 & 0 & z_{16} \\
0 & -z_8 & 0 & z_4 & 0 & 0 & z_{17} \\
0 & -z_{10} & 0 & 0 & z_4 & 0 & z_{18} \\
z_{12}^* & 0 & -z_{16}^* & -z_{17}^* & -z_{18}^* & -z_5^* & z_4^* \\
0 & -z_7 & z_5 & 0 & 0 & -z_{16} & 0 \\
0 & -z_9 & 0 & z_5 & 0 & -z_{17} & 0 \\
0 & -z_{11} & 0 & 0 & z_5 & -z_{18} & 0 \\
0 & 0 & -z_8 & z_6 & 0 & 0 & z_{19} \\
0 & 0 & -z_{10} & 0 & z_6 & 0 & z_{20} \\
z_{13}^* & z_{16}^* & 0 & -z_{19}^* & -z_{20}^* & -z_7^* & z_6^* \\
0 & 0 & -z_9 & z_7 & 0 & -z_{19} & 0 \\
0 & 0 & -z_{11} & 0 & z_7 & -z_{20} & 0 \\
0 & 0 & 0 & -z_{10} & z_8 & 0 & z_{21} \\
z_{14}^* & z_{17}^* & z_{19}^* & 0 & -z_{21}^* & -z_9^* & z_8^* \\
0 & 0 & 0 & -z_{11} & z_9 & -z_{21} & 0 \\
z_{15}^* & z_{18}^* & z_{20}^* & z_{21}^* & 0 & z_{11}^* & z_{10}^* \\
z_{16} & z_{13} & z_{12} & 0 & 0 & 0 & 0 \\
z_{17} & z_{14} & 0 & z_{12} & 0 & 0 & 0 \\
z_{18} & z_{15} & 0 & 0 & z_{12} & 0 & 0 \\
z_{19} & 0 & -z_{14} & z_{13} & 0 & 0 & 0 \\
z_{20} & 0 & -z_{15} & 0 & z_{13} & 0 & 0 \\
z_{21} & 0 & 0 & -z_{15} & z_{14} & 0 & 0 \\
0 & z_{19} & -z_{17} & z_{16} & 0 & 0 & 0 \\
0 & z_{20} & -z_{18} & 0 & z_{16} & 0 & 0 \\
0 & z_{21} & 0 & -z_{18} & z_{17} & 0 & 0 \\
0 & 0 & z_{21} & -z_{20} & z_{19} & 0 & 0
\end{bmatrix}$$

Table.2

Table.3

$$G_8 = \begin{bmatrix}
-x_2^* & -x_5^* & 0 & 0 & x_4 & x_3^* & x_9 & 0 \\
-x_5 & x_2 & 0 & x_7 & -x_9^* & 0 & x_4^* & 0 \\
x_1^* & x_6^* & 0 & x_3^* & 0 & x_7 & 0 & 0 \\
-x_8 & 0 & x_2^* & x_4 & 0 & 0 & x_6^* & x_9^* \\
0 & x_3 & x_9^* & -x_6 & x_8^* & x_5 & x_7^* & x_1^* \\
x_9 & -x_8 & x_1^* & 0 & x_3 & -x_4 & 0 & 0 \\
-x_7^* & x_9 & 0 & -x_5^* & 0 & -x_6^* & x_8 & x_2^* \\
0 & -x_4^* & x_7^* & x_9 & -x_5 & x_8^* & x_3 & x_6 \\
0 & 0 & x_3 & 0 & -x_7 & x_9^* & 0 & x_5^* \\
x_6 & -x_1 & x_8 & 0 & 0 & -x_7 & x_2^* & 0 \\
0 & x_7^* & -x_4 & -x_2^* & 0 & -x_1^* & 0 & x_8^* \\
0 & 0 & x_6^* & 0 & x_2 & 0 & x_5 & x_7^* \\
0 & 0 & -x_5^* & 0 & -x_1 & 0 & 0 & 0 \\
x_4^* & 0 & 0 & x_8^* & x_6 & 0 & x_1^* & x_3 \\
x_3 & 0 & 0 & -x_1 & 0 & x_2 & 0 & x_4^*
\end{bmatrix}$$