자켓행렬에 의한 OVSF 부호 설계의 새로운 방법

A New Method to Construct OVSF Codes Based on Jacket Matrices

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Abstract - Orthogonal Variable Spreading Factor codes are used as channelization codes in WCDMA. In this particular paper, we present a new OVSF codes which is generated from the Jacket Matrices for DS-CDMA systems. The simulations result shows that the purposed OVSF can efficiently reduce the peak values of the correlations than the conventional HOVSF without orthogonality loss. It will be useful to detect the multi-user system under the asynchronous system and save the power of transmission.

Key Words : WCDMA, OVSF, HOVSF, SF

1. introduction

The next generation wireless system used as channelization codes for data spreading in both uplink and downlink. Orthogonal variable spreading factor (OVSF) codes are used as channelization codes in WCDMA to achieve the capacity under multi user system requesting different data rates. It allows that the orthogonal multi code assignment is efficiently applied for different users. The higher rate services such as file tranfer and QOS guaranteed multimdedia applications are expected to be supported by next generation systems with variable date rate The demand for multimedia communications including not only voice but also high speed video transmissions is ever increasing. Multirate communications can be realized with orthogonal variable spreading factor (OVSF) codes [1 2] that have orthogonality among codes with different spreading factors. For a direct sequence CDMA (DS CDMA), orthogonal variable spreading factor (OVSF) codes preserve the orthogonality among various channels used. OVSF has the ability to support higher and variable data rates with a single code using one transceiver, making its hardware less complex than other adaptive transmission schemes.

The objective of this paper is to construct the new OVSF codes based on the Jacket matrix which has the lower correlations and autocorrelation values than the conventional binary OVSF codes based on Hadamard, which is entitled as HOVSF[2].

2.Proposed OVSF Code and Analysis

The tree generation of the complex valued OVSF codes is the same as that of the conventional binary OVSF codes based on Hadamard and we may call it as HOVSF which includes only {±1}, and seeds of those codes are different. The purposed OVSF codes which includes four phase symbols {±1,±i}, are based on Jacket Matrices.

2.1 Definition of Jacket Matrices

Jacket Matrices [4] which are motivated by the center weight Hadamard matrices are a class of matrices with their inverse being determined by the element wise of the matrix.

The inverse of Jacket matrices can be calculated very easily, it is helpful to employ this kind of matrices in the signal processing, encoding, mobile communication, image compression, cryptography, etc. Especially, the interesting orthogonal matrices, such as Hadamard ,Haar, DCT, DFT, slant matrices, belong to the Jacket matrix family. In addition, the Jacket matrices are associated with the many kind of matrices, such as unitary matrices and Hermition matrices which are very important in signal processing, communication (e.g. encoding), mathematics and physics.

Mathematically, if a square matrix of size $m\times m$ has nonzero elements and an inverse form this is only from the entrywise inverse and transpose, such as

$$[J]_m = \begin{bmatrix} j_{0,0} & j_{0,1} & \cdots & j_{0,m-1} \\ j_{1,0} & j_{1,1} & \cdots & j_{1,m-1} \\ \vdots & \vdots & & \vdots \\ j_{m-1,0} & j_{m-1,1} & \cdots & j_{m-1,m-1} \end{bmatrix} \quad (1)$$

and its inverse is

$$[J]_m^{-1} = \frac{1}{C}\begin{bmatrix} 1/j_{0,0} & 1/j_{0,1} & \cdots & 1/j_{0,m-1} \\ 1/j_{1,0} & 1/j_{1,1} & \cdots & 1/j_{1,m-1} \\ \vdots & \vdots & & \vdots \\ 1/j_{m-1,0} & 1/j_{m-1,1} & \cdots & 1/j_{m-1,m-1} \end{bmatrix}^T, \quad (2)$$

where C is the normalized value for this matrix, and T is the transpose of this matrix. The form of the Jacket matrix could be obtained by using a recursive function as

$$J_N = [J]_{N/2} \otimes H_2, N > 4, \quad (3)$$

where

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$$J_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -i & i & -1 \\ 1 & i & -i & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \tag{4}$$

It is clear that the Jacket matrix from (3) is orthogonal matrix.

From this Jacket matrix we can construct the complex OVSF codes. Let C_N denote the set of N quadric phase spreading codes of N chip length, $\{C_N(n)\}_{n=1}^{N}$, where $C_N(n)$ is the row vector of N elements and $N = 2^k$ (K is a positive integer), it is generated from $C_{N/2}$ as

$$\begin{bmatrix} C_N(2l-1) \\ C_N(2l) \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \otimes C_{N/2(l)}, \quad N \ge 8 \tag{5}$$

where $l = \{1, 2, \ldots, N/2\}$, and $\otimes$ is the Kronecker product.

Let us take $\begin{bmatrix} 1 & -i \\ 1 & i \end{bmatrix}$ from equation (4) and Kronecker product with H_2, so get,

$$\begin{bmatrix} 1 & -i \\ 1 & i \end{bmatrix} \otimes \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$= \begin{bmatrix} 1 & 1 & -i & -i \\ 1 & -1 & -i & i \\ 1 & 1 & i & i \\ 1 & -1 & i & -i \end{bmatrix}, \tag{6}$$

After rows and columns permutation of equation (6), we can get following matrix,

$$C_4 = \begin{bmatrix} 1 & 1 & i & i \\ 1 & 1 & -i & -i \\ 1 & -1 & i & -i \\ 1 & -1 & -i & i \end{bmatrix}, \tag{7}$$

Thus, we can write orthogonal spreading sequences as

$$C_4(1) = \begin{bmatrix} 1 & 1 & i & i \end{bmatrix}$$

$$C_4(2) = \begin{bmatrix} 1 & 1 & -i & -i \end{bmatrix}$$

$$C_4(3) = \begin{bmatrix} 1 & -1 & i & -i \end{bmatrix}$$

$$C_4(4) = \begin{bmatrix} 1 & -1 & -i & i \end{bmatrix}$$

The tree structured spreading codes are generated recursively, as shown in Fig.1.

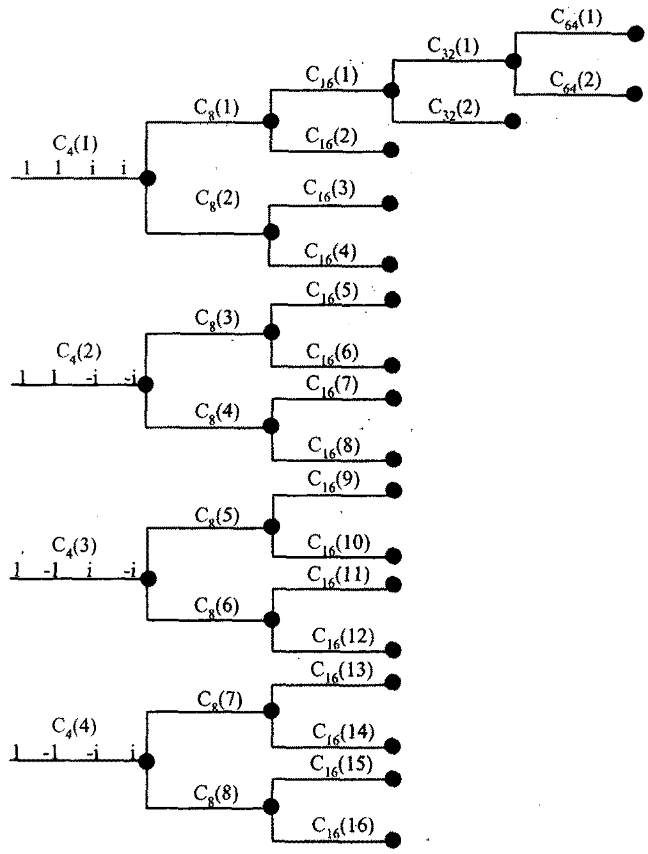

Fig.1. Generated code tree of Proposed OVSF

Starting from C_4, a set of 2^k spreading codes are generated at the kth layer $(k = 1, 2, \ldots, K)$ from the top. The code length of the kth layer is 2^k chips and can be used for the code channels transmitting data at $2^{(K-k)}$ times the lowest rate. It can be understood from equation (5) that generated codes of the same layer constitute a set of Hadamard functions and they are orthogonal. Furthermore, any tow codes of different layers are also orthogonal except for the case that one of the two codes is a mother code of the other, which is the same as the restriction proposed in [3]. The codes from different parts are also orthogonal and satisfy the variable rate (length) spreading properties. The data rate supported by an OVSF code depends on its spreading factor (FA). An OVSF code with smaller SF can support higher date rate services than that with lager SFs. Randomly assigning the OVSF code with a larger SF to a user may preclude a larger number of OVSF codes with small SFs, which may cause lots of high date rate call request to be blocked. Therefore the OVSF code assignment affects the performance of the WCDMA system significantly.

3. Simulation Results and Analysis

The simulations of the proposed OVSF code are according to the periodic autocorrelation of the sequence can be defined by

$$R_i(\tau) = \sum_{i=0}^{L-1} a_i a^{*}_{(i+\tau) \bmod L}, \tag{8}$$

and a periodic crosscorrelation is defined by

$$C_i(\tau)=\sum_{i=0}^{L-1} a_i b^*_{(i+\tau)\bmod L}, \quad (9)$$

Where a_i, b_i are the ith element in the sequence a and b respectively, the length of the sequence a and b is L, τ is the shift coefficient, which normally has $0 \le \tau \le L$. Now we consider the correlations of the OVSF code, we may find that

$$R_i(0)=\sum_{i=0}^{L-1} a_i a^* = L \quad (10)$$

and

$$C_i(0)=\sum_{i=0}^{L-1} a_i b^*_i = 0 \quad (11)$$

It shows that the proposed OVSF code has the same orthogonality as that of the HOVSF. By comparing the periodic autocorrelations of the HOVSF and that of the proposed OVSF, we find that the proposed OVSF has better performance. For example, the length 8 proposed OVSF can reduce $(32-24)/32=1/4$ peak values of the autocorrelations and $1/2$ peak values of the crosscorrelations, as shown in Table 1.

Table 1.The numerical results for length-8 OVSF

	Autocorrelation		Crosscorrelation	
	HOVSF	Proposed OVSF	HOVSF	Proposed OVSF
Peak Value	8	8	8	8
Number of Peaks	32	24	8	4

Moreover, the length 16 proposed OVSF code can decrease $1/5$ peak values of the autocorrelations, and $1/3$ peak values of the crosscorrelations, as shown in Table 2.

Table 2.The numerical results for length-8 OVSF

	Autocorrelation		Crosscorrelation	
	HOVSF	Proposed OVSF	HOVSF	Proposed OVSF
Peak Value	16	16	16	16
Number of Peaks	80	64	24	16

Especially, the numerical results shows that the conventional HOVSF always have some worst cases in crosscorrelations between two sequences such as, the $C_8(3), C_8(7)$ for length 8 and $C_{16}(5), C_{16}(13)$ for length 8. But these cases can be easily avoided by using the proposed OVSF, where the peak values 8 and 16 are expressed by using 4 and 8, respectively. It is clearly shown that the propose OVSF code has good autocorrelations, as shown in fig.2 and crosscorrelations, as shown in fig.3.

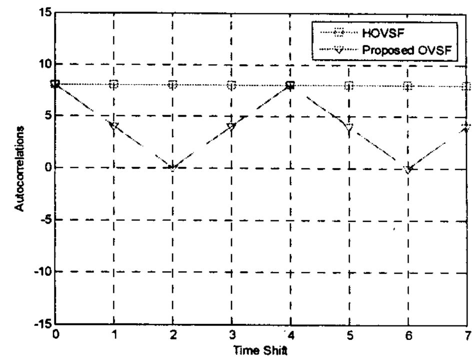

Fig.2. Autocorrelations of HOVSF and Proposed OVSF for length 8

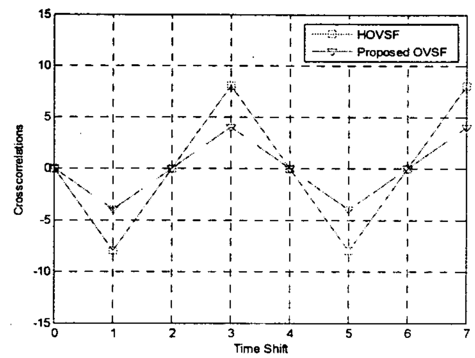

Fig.3.Crosscorrelations of HOVSF and Proposed OVSF for length 8

4. Conclusion

In this paper, we have constructed the complex valued orthogonal variable spreading factor (OVSF) from the Jacket matrix where as the conventional OVSF is constructed from the Hadamard matrix. The simulations result shows that the purposed OVSF can efficiently reduce the peak values of the correlations than the conventional HOVSF without orthogonality loss. It will be useful to detect the multi user system under the asynchronous system and save the power of transmission.

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참 고 문 헌

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