

A Set of Spreading Sequences for a Spread Spectrum Communication System

The invention relates to a set of spreading sequences for a spread spectrum
5 communication system.

Code Division Multiple Access (CDMA) is one type of spread spectrum
communication system. In CDMA each user is assigned a distinct signature
sequence (or waveform), which the user employs to modulate and spread the
10 information-bearing signal. The signature sequences also allow the receiver to
demodulate the message transmitted by multiple users of the channel, who
transmit simultaneously and generally, asynchronously. This is possible since
the cross-correlation between the code of one user and the codes of the other
users is small. Therefore, the characteristics of the codes provide a crucial
15 determination on the performance of the whole communications systems. The
signature sequences in general will determine how much the interference is
received at a receiver from other users and the property of the sequences will
influence the extraction capacity of the desired signal from the noise-like
spectrum.

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In the forward link of the IS-95 CDMA system, orthogonal Walsh-Hadamard
Transform (WHT) sequences are used as the spreading sequences. But it is
well known that WHT sequences are not suitable for asynchronous use due to
their large auto-correlation values. Thus, the reverse link of the IS-95 CDMA
25 system, in which it is hard to achieve synchronization between the receiver and

the transmitter and between different users, employs long PN sequences to spread the information signal. However, the cross-correlation function of PN sequences is not as good as that of orthogonal sequences.

- 5 There is a need for orthogonal sequences which have better auto-correlation properties than WHT sequences.

In accordance with a first aspect of the present invention, a set of spreading sequences for a spread spectrum multiple access (SSMA) communication
10 system comprises a set of unified complex Hadamard transform sequences with half-spectrum properties (HSP-UCHT).

In accordance with a second aspect of the present invention, a spread spectrum multiple access (SSMA) communication system comprises a set of spreading
15 sequences comprising unified complex Hadamard transform sequences with half-spectrum properties (HSP-UCHT).

An advantage of the invention is that a unified complex Hadamard transform with half-spectrum properties exhibits better auto-correlation than the
20 conventional Walsh-Hadamard transform. Therefore, HSP-UCHT are advantageous for use as spreading sequences in CDMA systems, especially where asynchronous reception may occur.

Preferably, the SSMA communication system is a direct sequence - spread spectrum multiple access (DS-SSMA) system. For example, the international standard, IS-95 CDMA.

- 5 An example of a set of spreading sequences in accordance with the invention will now be described with reference to the accompanying drawing, in which:

Figure 1 is a schematic block diagram of a DS-CDMA transmitter-receiver.

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A unified complex Hadamard transform (UCHT) is defined [1] by the transformation core matrix:

$$H_1 = [W_1 \diamond \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix}] \diamond [1 \quad \tau_3]$$

- 15 where W_1 is the WHT matrix of order 2,

$$W_1 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}, \quad \tau_1, \tau_2, \tau_3 \in \{1, -1, j, -j\} \text{ and } \diamond \text{ denotes the direct matrix operation [1].}$$

The generation of the higher dimension UCHT matrices has been introduced in [1] and [2]. It has been shown in [1] that all UCHT matrices can be divided into two groups of 32 basic matrices dependently on the value of τ_3 . If H_n is a $2^n \times$

- 20 2^n UCHT matrix with half-spectrum properties, H_n is defined as follows:

$$H_n = H_1 \otimes^n = [W_1 \diamond \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix}] \diamond [1 \quad \tau_3] \otimes^n$$

where $\tau_1, \tau_2 \in \{1, -1, j, -j\}$, $\tau_3 \in \{j, -j\}$, $\otimes$ denotes the Kronecker product and $\otimes^n$ represents the n -time multiple Kronecker products and n is an integer.

Matrices with half-spectrum properties can be defined as follows:

- 5 Let $F(k)$ denote the coded data sequences where $0 \leq k \leq N-1$ and $F(k)$ may be a real or complex number which depends on a particular coding of the data, and $N=2^n$ represents the matrix order and the length of sequences. The corresponding UCHT of the data sequence may be expressed in matrix form as,

$$\vec{Z} = H_n \vec{F},$$

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where $\vec{Z} = [Z(0), Z(1), \dots, Z(p), \dots, Z(N-1)]^T$ and $\vec{F} = [F(0), F(1), \dots, F(k), \dots, F(N-1)]^T$, and the values of $Z(p)$ are complex numbers. If H_n is the HSP-UCHT matrices, then

$$Z(N-1-p) = (\tau_1 \tau_2)^\gamma \overline{Z(p)},$$

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where $\gamma = n \bmod 4$ and $\overline{Z}$ is the conjugate of Z , and the transform matrix is defined as having half-spectrum properties if there exists a $\frac{1}{2}N \times 1$ vector $\vec{Z}_{1/2}$ which completely characterizes the full transform vector $\vec{Z}$ of the orthogonal transform with the ability to recover the unique transform vector $\vec{Z}$.

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Fig. 1 is a block diagram of a basic DS-CDMA system for the x th user. The data 9 is input to an encoder and interleaver 1 and then spread 2 using a HSP-UCHT sequence which is unique to the user x . Each row of the HSP-UCHT

matrix represents an orthogonal signature sequence. If x_i is the element of any one UCHT sequence x , it follows from [1]:

$$x_i = h(x, i) = \prod_{r=0}^{n-1} h_r$$

5 where $h_r = \tau_1 + (\tau_2 - \tau_1)x_r + \tau_1(\tau_3 - 1)i_r + (\tau_1 - \tau_1\tau_3 - \tau_2 - \tau_2\tau_3)x_r i_r$,

and $n = \log_2 N$, where N is as defined above, that is the length of the UCHT sequences. After spreading, the signal is modulated 3 and transmitted via a channel 4 to a receiver 5. The receiver 5, receives the transmitted signal from the transmitter 6 and demodulates 7 the signal before despreading 8 the signal
10 using the same unique HSP-UCHT sequence for user x . That is the same HSP-UCHT sequence which was used to spread 2 the signal. The despread signal is then decoded and deinterleaved 11 to extract the data 9.

As there are 32 HSP-UCHT matrices, and within each $N \times N$ matrix there are N
15 sequences. A set of sequences is selected from the N sequences in one of the matrices, and the set of sequences is selected such that the auto-correlation and the cross-correlation are optimised.

The invention has the advantage that HSP-UCHTs have better auto-correlation
20 than the conventional Walsh-Hadamard Transform and therefore, have more reliability where the reception is asynchronous.

References

[1] S. Rahardja and B. J. Falkowski, "Family of unified Complex Hadamard Transforms", IEEE Transactions on Circuits & Systems II: Analog & Digital Signal Processing, Vol. 46, No. 8, pp. 1094-1100, Aug. 1999.

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[2] S. Rahardja, "Spectral techniques for multiple-valued logic", Ph.D thesis, Nanyang Technology University, 1997.

CLAIMS

1. A set of spreading sequences for a spread spectrum multiple access (SSMA) communication system comprises a set of unified complex Hadamard transform sequences with half-spectrum properties (HSP-UCHT).
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2. A set of spreading sequences according to claim 1, wherein the set of spreading sequences is for a direct sequence – spread spectrum multiple access (DS-SSMA) system.
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3. A set of spreading sequences according to claim 1 or claim 2, wherein the set of spreading sequences is for a direct sequence - code division multiple access (DS-CDMA) system.
- 15 4. A set of spreading sequences according to claim 3, wherein the set of spreading sequences is for IS-95 CDMA.
5. A spread spectrum multiple access (SSMA) communication system comprising a set of spreading sequences which comprise unified complex Hadamard transform sequences with half-spectrum properties.
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6. A system according to claim 5, wherein the SSMA communication system is a direct sequence – spread spectrum multiple access system (DS-SSMA) communication system.

7. A system according to claim 5 or claim 6, wherein the communication system is a direct sequence - code division multiple access (DS-CDMA) system.
- 5 8. A system according to claim 7, wherein the communication system is IS-95 CDMA.