New Eight-phase ZCD spreading sequences design for Interference-cancelled WPAN based on AS-CDMA

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Abstract

New Eight-phase Preferred Pairs (EPPs) that have Zero-Correlation Duration (ZCD) of (0.5N+1) chips are constructed for the periods of N=4x2n (n=1,2,3···). By using the chip-shift operation of the EPP, new eight-phase ZCD sequences are constructed in this paper. We certified its ZCD property by various correlation simulations. This new eight-phase spreading sequence can be used for Interference cancelled wireless personal area network(WPAN) based on approximately synchronized code-division-multiple-access(AS-CDMA) system.

Key Words : Eigh-phase, ZCD, Zero Correlation Duration, Spreading Sequences, CDMA, WPAN

1. Introduction

For any two complex sequences of period $N, C_N^{(x)} = (C_0^{(x)}, \cdots m C_{N-1}^{(x)})$ and $C_N^{(y)} = (C_0^{(y)}, \cdots, C_{N-1}^{(y)})$, the periodic correlation function with a shift τ is defined as

$$\theta_{x,y}(\tau) = \sum_{k=0}^{N-1} C_k^{(x)} C_{(k+\tau, \bmod N)}^{(y)*} \tag{1}$$

where * represents the complex conjugate.Eqn.(1) becomes the autocorrelation function (ACF) when $x = y$ and the crosscorrelation function (CCF) when $x \neq y$. In Eqn.(1), the local duration around zero τ with zero ACF sidelobe and zero CCF is

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defined as zero-correlation duration [ZCD] [1]. ZCD property is important to cancel interference such as MAI(multiple access interference) or MPI(multi-path interference) in the WPAN systems[2], spread spectrum communication applications[3] and CDMA systems. ZCD property can be mainly found in the 2-phase [1,2,4,5], 3-phase [3,6], and 4-phase [7,8] sequences. Although some poly-phase sequences for MAI / MPI cancellation of CDMA are proposed in the 18-phase or larger-phase sequences [9,10], they have no ZCD property [9] or too complex in generating sequences in the hardware implementation [10]. In the eight-phase case which can be easily implemented in the sequence generator, there is a class of eight-phase sequence [11] with low correlation, however it also has no any ZCD property. In this paper, we propose a new class of eight-phase sequences with ZCD property. At first, we present a generalized

construction method for eight-phase preferred pairs (EPPs) that have ZCD of $(0.5N+1)$ chips and periods of. Secondly, using the chip-shift operation to the EPP, we generate new eight-phase ZCDsequences that have sufficient ZCD and family sizes for Interference-cancelled CDMA systems such as WPAN using AS-CDMA.

2. Construction method of new eight-phase ZCD sequences

Step (I) Method for constructing EPP

The EPP of period $N = 4 \times 2^n (n=1,2,3\cdots)$ with ZCD of $(0.5 \times N+1)$ is denoted as $\{E_N^{(a)}, E_N^{(b)}\}$, where $E_N^{(a)} = (e_0^{(a)}, e_1^{(a)}, \cdots e_{N-1}^{(a)})$ and $E_N^{(b)} = (e_0^{(b)}, e_1^{(b)}, \cdots e_{N-1}^{(b)})$. The initial basic matrix for generating $\{E_N^{(a)}, E_N^{(b)}\}$ is defined as

$$G_E = \begin{bmatrix} W_8^0 & W_8^5 & W_8^2 & W_8^3 & W_8^0 & W_8^5 & W_8^6 & W_8^7 \\ W_8^0 & W_8^1 & W_8^2 & W_8^7 & W_8^0 & W_8^1 & W_8^6 & W_8^3 \\ W_8^0 & W_8^7 & W_8^2 & W_8^5 & W_8^0 & W_8^7 & W_8^6 & W_8^1 \\ W_8^0 & W_8^3 & W_8^2 & W_8^1 & W_8^0 & W_8^3 & W_8^6 & W_8^5 \\ W_8^4 & W_8^5 & W_8^2 & W_8^7 & W_8^0 & W_8^1 & W_8^2 & W_8^7 \\ W_8^4 & W_8^1 & W_8^2 & W_8^3 & W_8^0 & W_8^5 & W_8^2 & W_8^3 \\ W_8^4 & W_8^3 & W_8^2 & W_8^5 & W_8^0 & W_8^7 & W_8^2 & W_8^5 \\ W_8^4 & W_8^7 & W_8^2 & W_8^1 & W_8^0 & W_8^3 & W_8^2 & W_8^1 \end{bmatrix}$$

$$(2)$$

where $W_8^k = \exp((2\pi \cdot K \cdot \sqrt{-1})/8), (K=0,1,2,\cdots 7)$ Any row of $(\pm G_E$ or $\pm j \times G_E$ or $\pm W_8^l \times G_E$ $(l=1,2,3))$ is denoted as $E_8^{(a)} = (e_0^{(a)}, e_1^{(a)}, e_2^{(a)}, \cdots, e_7^{(a)})$. $E_8^{(b)} = (e_0^{(b)}, e_1^{(b)}, e_2^{(b)}, \cdots, e_7^{(b)})$ is generated from $E_8^{(a)}$, where $e_\rho^{(b)} = (-1)^\rho e_\rho^{(a)}$ $(\rho = 0,1,2,\cdots,7)$. A pair of $\{E_8^{(a)}, E_8^{(b)}\}$ has ZCD of $(0.5 \times 8+1)$ chips and is defined as the initial EPP. By using $\{E_8^{(a)}, E_8^{(b)}\}$, EPPs with longer period are constructed recursively as the following extension method. Using any given pair of $\{E_m^{(a)}, E_m^{(b)}\}$ with period

$m = 4 \times 2^i (i=1,2,3\cdots)$, the period-extension matrix with period $2m$ is generated as Eqn.(3).

$$PE = \begin{bmatrix} X & Y & X & -Y \\ X & Y & -X & Y \\ X & -Y & X & Y \\ -X & Y & X & Y \end{bmatrix} \quad (3)$$

where $X = (e_0^{(a)}, \cdots, e_{0.5m-1}^{(a)})$, $Y = (e_{0.5m}^{(a)}, \cdots, e_{m-1}^{(a)})$ and $m = 4 \times 2^i (i=1,2,3\cdots)$. Any row of $(\pm PE$ or $\pm j \times PE$ or $\pm W_8^l \times PE (l=1,2,3))$ is $E_{2m}^a = (e_0^{(a)}, \cdots, e_{2m-1}^{(a)})$ with the period of $2[m]$. $E_{2m}^{(b)} = (e_0^{(b)}, \cdots, e_{2m-1}^{(b)})$ is generated from , where $e_\rho^{(b)} = (-1)^\rho e_\rho^{(a)}$ $(\rho = 0,1,\cdots,2m-1)$. $\{E_{2m}^{(a)}, E_{(2m)}^{(b)}\}$ is a EPP with ZCD of $(0.5 \times 2m+1)$ chips. Thus, for the period of $N = 4 \times 2^n$ $(n=1,2,3\cdots)$, $\{E_N^{(a)}, E_N^{(b)}\}$ that have ZCD of $(0.5N+1)$ chips can be constructed.

Example

In this example, we can show a EPP with a ZCD of 33chips and its correlaton property by correlation simulations.

$\{E_{64}^{(a)}, E_{64}^{(b)}\}$ with a ZCD of 33chips is expressed as

$$\begin{cases} E_{64}^{(a)} = (4167056705230567052341230523056705234123416740 \\ \qquad 1230523412305230567) \\ E_{64}^{(b)} = (4563016301270163012745270127016301274527457634 \\ \qquad 5270127452701270163) \end{cases}$$

or

$$\begin{cases} E_{64}^{(a)} = (0761072543250725432543614325072543253436 \\ \qquad 1076143614325436143250725) \\ E_{64}^{(b)} = (0365032147210321472147654721032147214760 \\ \qquad 5036547654721476547210321) \end{cases}$$

where $(0,1,2,\cdots,7)$ denotes $(W_8^0, W_8^1, W_8^2, W_8^3, W_8^4, W_8^5, W_8^6, W_8^7)$ respectively. Using correlation simulation with EPP of above example, we can obtain

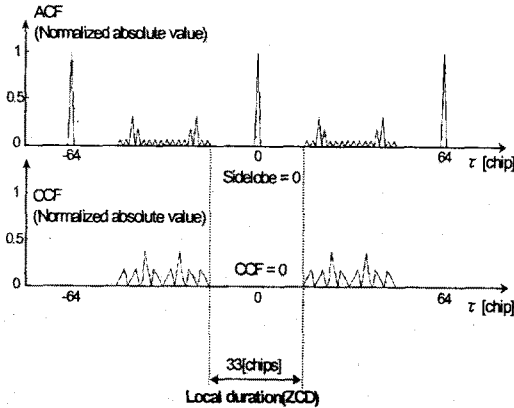distinct ZCD of 33chips The absolute values of the normalized ACF sidelobe and CCF are shown in Fig. 1.

Fig. 1. ACF and CCF of EPP with period d of 64

Step(II) Construction of sets of eight-phase ZCD sequences

Let $E(N,M,Z_L)$ represent a set of eight-phase ZCD sequences having a sequence period of N and family size M, where any pair of $E(N,M,Z_L)$ has the common ZCD-length of . By using the chip-shift operation of $\{E_N^{(a)}, E_N^{(b)}\} = E(N,2,0.5N+1)$, a set of $E(N,M \geq 2, Z_L \leq 0.5N+1)$ can be constructed. Let be the chip-shift operator, which shifts a sequence cyclically to the left by l chips, $E(N,M \geq 2, Z_L \leq 0.5N+1)$ can be generated from $\{E_N^{(a)}, E_N^{(b)}\}$ as

$$E(N,M \geq 2, Z_L \leq 0.5N+1) = E(N,2k+1,|2\triangle -1|) \quad (4)$$

$$= \left\{ \begin{array}{l} E_N^{(a)}, E_N^{(b)}, T^{\triangle} E_N^{(a)}, T^{\triangle} E_N^{(b)}, T^{2\triangle} E_N^{(a)}, T^{2\triangle} E_N^{(b)}, \cdots \\ , T^{(k-1)\triangle} E_N^{(a)}, T^{(k-1)\triangle} E_N^{(b)}, T^{k\triangle} E_N^{(a)}, T^{k\triangle} E_N^{(b)} \end{array} \right\}$$

where $\triangle$ is a chip-shift increment and k the maximum number of chip-shifts for a sequence. $\triangle$ and k should satisfy $|(k+1)\triangle| \leq |0.25N+1|$ where $\triangle$ is a positive and a non-negative integer. The family sizes of the proposed eight-phase ZCD

sequences are listed in Table 1. As shown in Table 1, proposed eight-phase sequences have sufficient ZCD-length and family sizes for CDMA as in the case of binary ZCD sequences [1] for period N. Here, large family sizes produce a larger CDMA user capacity and large ZCDs produce longer cell radius of MAI-cancelled DS-CDMA systems, respectively.

Table 1. Family sizes of eight-phase ZCD sequences for N =32, 64,128, and 256

ZCD N	3	5	7	9	11	13	15	17	19	21	23	⋯	129
32	8	6	4	2	2	2	4	2	-	-	-	⋯	-
8	16	10	8	6	4	4	4	4	4	4	4	⋯	-
128	32	22	16	12	10	8	8	6	6	6	4	⋯	-
256	64	42	32	26	20	18	16	14	12	10	10	⋯	2

3. Conclusion

In this Paper, We have proposed new eight-phase ZCD sequences with sufficient ZCD property and family sizes for CDMA as in the case of binary ZCD sequences. Maximum ZCD length of proposed sequence is a 0.5N+1. The proposed eight-phase ZCD sequences can be usefully employed in the Interference-cancelled CDMA networks such as CDMA based WPAN system. And its sharp correlation property can be used for positioning based various spread spectrum communication applications.

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Biography

Jae-Sang Cha

Jae-Sang Cha was born in Seoul, Korea in 1968. He received B.S. and M.S. degrees in electrical engineering from Sungkyunkwan University, Korea, in 1991 and 1997, respectively, and Ph.D degree in electronics engineering from Tohoku University, Japan, in 2000. From 2000 to 2002 he was a senior researcher in Electronic and Telecommunications Research Institute (ETRI), Korea, and from 2002 to 2005 he was a assistant professor in Seokyung University. He is currently a assistant professor of the department of media engineering at Seoul National University of Technology. His research interests include spreading sequence applications, wireless home network, mobile communications and digital TV.