USE OF ORTHOGONAL SETS OF EIGHT COMPLEMENTARY SEQUENCES FOR ASYNCHRONOUS DS-CDMA

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Abstract

Golay sequences and complementary sets of sequences have been long studied for applications in asynchronous Direct Sequence CDMA systems. Procedures for the generation of two or more complementary sequences make possible to have two or more orthogonal sets of sequences. However, the feasibility of these systems depends on the design of an efficient generator and correlator for these sets in order to reduce the computational load and hardware complexity in the implementation. This work proposes a new algorithm to generate sets of eight complementary sequences with a length $L = 8^n$ what allows autocorrelation maximum values of $8 \cdot L \cdot \delta[i]$ to be obtained. Also, it is possible the generation of eight perfect orthogonal sets, with null values in cross correlations. The hardware implementation is possible with efficient generators and correlators which implies a remarkable reduction in the number of operations, compared to the classic hardware implementation.

Keywords
Sets of Complementary Sequences, Efficient Sets of Sequences Generator and Correlator, Direct Sequence CDMA.

1. INTRODUCTION

The effectiveness of the DS-CDMA technique depends on the properties of the used spreading codes, requiring ideal properties of autocorrelation (AC) and cross-correlation (CC). Many algorithms have been designed to generate codes, but not all of them meet these ideal properties simultaneously. Examples are the Pseudo-Random sequences [1], Barker codes [2], Golay sequences [3], sets of complementary sequences [4] [5], etc.

Works related to Golay sequences provide methods to generate two or more complementary sequences, called Complementary Sets (CS) of sequences [4]. This makes possible to have two or more mutually orthogonal (MO) sets of sequences in order to be used in multi-emission applications with very low SNR conditions. Nevertheless, the feasibility of these systems depends on the design of an efficient correlator and generator for these sets, so the computational load and hardware complexity can be reduced in the implementation. Budisin [5] presented a recursive method to generate pairs of Golay sequences by an efficient generator, and Popovic [6] introduced an Efficient Golay Correlator (EGC) for pairs of complementary sequences. These imply a remarkable reduction in the number of operations compared to the classical hardware implementation of the correlation. More recently, Alvarez [7] has provided a similar method for generation of sets of four complementary sequences with length $L = 4^n$ called 4-ESSG (*Efficient Set of Sequences Generator*). Also the efficient correlator of these sets (4-ESSC) was presented. The proposed generator has allowed four MO sets of four sequences to be easily found.

This work deals with an extension of this recursive method for the efficient generation of sets of eight complementary sequences (8-ESSG) and also presents the efficient implementation of the correlation of these sets (8-ESSC). The paper is organized as follows: section 2 explains the proposed algorithm for generation of sets of eight complementary sequences, section 3 describes the efficient correlator for these sets, and, finally, section 4 discusses the simulation results of this implementation.

2. ALGORTIHM PROPOSED

A CS of sequences is a set of binary sequences whose elements are either 1 or -1. They have the property that the sum of their aperiodic autocorrelation functions for a set of M complementary sequences with length $L = M^n$ is equal to zero for all non-zero time shifts and have a maximum value defined for zero time shifts of them as:

$$\sum_{k}^{M} R_{kk} = R_{aa} + R_{bb} + R_{cc} + \ldots + R_{MM} = M \cdot L \cdot \delta[i] = M.M^{n} \cdot \delta[i] = M^{n+1} \cdot \delta[i] \tag{1}$$

Where, $R_{kk} = \sum_{j=1}^{L} x[i] x[i+j]$, $i, j = [1,2,3,\ldots M^n]$ and $k = [a, b, c, d, \ldots, M]$

Complementary sets were initially studied by Tseng and Liu [4], who provided two methods for constructing sets of longer sequences, starting from shorter ones. It is possible to generate longer sequences and a larger number of sets of sequences according to the following explanation:

Let $\boldsymbol{\Delta}$ be a matrix whose columns are MO sets of even sequences; applying the computations in (2), the columns of $\boldsymbol{\Delta}'$ are also MO complementary sets.

$$\boldsymbol{\Delta}' = \begin{bmatrix} \boldsymbol{\Delta} \otimes \boldsymbol{\Delta} & (-\boldsymbol{\Delta}) \otimes \boldsymbol{\Delta} \\ (-\boldsymbol{\Delta}) \otimes \boldsymbol{\Delta} & \boldsymbol{\Delta} \otimes \boldsymbol{\Delta} \end{bmatrix} \tag{2}$$

Where $\boldsymbol{\Delta} \otimes \boldsymbol{\Delta}$ denote the interleaving of each element of matrix. If the length of the sequences in $\boldsymbol{\Delta}$ is L and this recursive procedure is repeated r times, 2^{r+1} MO sets of sequences will be obtained, each one consisting of 2^{r+1} sequences with length $2^r L$.

On the other hand, a recursive method for generation of sets of four complementary sequences is shown in [7] and described in (3). These equations permit a construction of an efficient generator and fast compressor that implies a high reduction on the implementation hardware. The coefficients $w_{2,n}, w_{1,n}$ have values $+1$ or -1 and permit the generation of four MO sets of four sequences.

$$\begin{aligned}
&a_0[i] = b_0[i] = c_0[i] = d_0[i] = \delta[i] \\
&a_n[i] = a_{n-1}[i] - b_{n-1}[i - S_n] + w_{1,n} \cdot c_{n-1}[i - 2 \cdot S_n] + w_{1,n} \cdot d_{n-1}[i - 3 \cdot S_n] \\
&b_n[i] = a_{n-1}[i] + b_{n-1}[i - S_n] + w_{1,n} \cdot c_{n-1}[i - 2 \cdot S_n] - w_{1,n} \cdot d_{n-1}[i - 3 \cdot S_n] \\
&c_n[i] = w_{2,n} \cdot a_{n-1}[i] - w_{2,n} \cdot b_{n-1}[i - S_n] - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 2 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 3 \cdot S_n] \\
&d_n[i] = w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot b_{n-1}[i - S_n] - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 2 \cdot S_n] + w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 3 \cdot S_n]
\end{aligned} \tag{3}$$

Defining a matrix $\boldsymbol{\Delta}_{S4}$ in (5) according to (2) , where each column is a set of four CS generated with the equations (4) combining the coefficients $w_{2,n}$ and $w_{1,n}$:

$$\Delta_{S4} = \begin{bmatrix}
1 & -1 & -1 & -1 & 1 & -1 & -1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 & 1 & 1 \\
1 & 1 & -1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & -1 \\
-1 & 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 \\
-1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 & 1
\end{bmatrix} \tag{4}$$

Applying $\boldsymbol{\Delta} \otimes \boldsymbol{\Delta}$ over matrix $\boldsymbol{\Delta}_{S4}$ it is possible the generation of four sequences with length $L = 8^n$. This operation over equations (4) can be observed in (5) for generate a_n, b_n, c_n, d_n in the set of eight CS. The operation $-\Delta \otimes \Delta$ generates the rest of the sequences in the new set, e_n, f_n, g_n, h_n. With these equations, four sets of eight sequences can be obtained, whereas the other four sets are generated using the same procedure but in inverse order: first applying the operation $-\Delta \otimes \Delta$ to generate a_n, b_n, c_n, d_n and then obtaining the sequences e_n, f_n, g_n, h_n from the matrix $\Delta \otimes \Delta$.

$$
\begin{aligned}
a_n[i] &= a_{n-1}[i] + a_{n-1}[i - S_n] - b_{n-1}[i - 2 \cdot S_n] - b_{n-1}[i - 3 \cdot S_n] + w_{1,n} \cdot c_{n-1}[i - 4 \cdot S_n] + w_{1,n} \cdot c_{n-1}[i - 5 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot d_{n-1}[i - 6 \cdot S_n] + w_{1,n} \cdot d_{n-1}[i - 7 \cdot S_n] \\
b_n[i] &= a_{n-1}[i] + a_{n-1}[i - S_n] + b_{n-1}[i - 2 \cdot S_n] + b_{n-1}[i - 3 \cdot S_n] + w_{1,n} \cdot c_{n-1}[i - 4 \cdot S_n] + w_{1,n} \cdot c_{n-1}[i - 5 \cdot S_n] - \ldots \\
&\ldots - w_{1,n} \cdot d_{n-1}[i - 6 \cdot S_n] - w_{1,n} \cdot d_{n-1}[i - 7 \cdot S_n] \\
c_n[i] &= w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot a_{n-1}[i - S_n] - w_{2,n} \cdot b_{n-1}[i - 2 \cdot S_n] - w_{2,n} \cdot b_{n-1}[i - 3 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 4 \cdot S_n] - \ldots \\
&\ldots - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 5 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 6 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 7 \cdot S_n] \\
d_n[i] &= w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot a_{n-1}[i - S_n] + w_{2,n} \cdot b_{n-1}[i - 2 \cdot S_n] + w_{2,n} \cdot b_{n-1}[i - 3 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 4 \cdot S_n] - \ldots \\
&\ldots - w_{2,n} \cdot w_{1,n} \cdot c_{n-1}[i - 5 \cdot S_n] + w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 6 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot d_{n-1}[i - 7 \cdot S_n]
\end{aligned}
\tag{5}
$$

So, there are two different sets of equations in order to generate eight MO sets of sequences. Trying to generalize the algorithm, it is necessary to add a new coefficient $-w_{3,n}$ and to rename the assignment of the sequences as shown in (6).

$$
\begin{aligned}
& a_0[i] = b_0[i] = c_0[i] = d_0[i] = e_0[i] = f_0[i] = g_0[i] = h_0[i] = \delta[i] \\
a_n[i] &= -w_{3,n} \cdot a_{n-1}[i] + b_{n-1}[i - S_n] + w_{3,n} \cdot c_{n-1}[i - 2 \cdot S_n] - d_{n-1}[i - 3 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] + w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
b_n[i] &= -w_{3,n} \cdot a_{n-1}[i] + b_{n-1}[i - S_n] - w_{3,n} \cdot c_{n-1}[i - 2 \cdot S_n] + d_{n-1}[i - 3 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] + w_{3,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] - w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
c_n[i] &= -w_{3,n} \cdot w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot b_{n-1}[i - S_n] + w_{3,n} \cdot w_{2,n} \cdot c_{n-1}[i - 2 \cdot S_n] - w_{2,n} \cdot d_{n-1}[i - 3 \cdot S_n] + \ldots \\
&\ldots + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
d_n[i] &= -w_{3,n} \cdot w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot b_{n-1}[i - S_n] - w_{3,n} \cdot w_{2,n} \cdot c_{n-1}[i - 2 \cdot S_n] + w_{2,n} \cdot d_{n-1}[i - 3 \cdot S_n] + \ldots \\
&\ldots + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] - w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] + w_{2,n} \cdot w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
e_n[i] &= w_{3,n} \cdot a_{n-1}[i] + b_{n-1}[i - S_n] - w_{3,n} \cdot c_{n-1}[i - 2 \cdot S_n] - d_{n-1}[i - 3 \cdot S_n] + w_{3,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] + w_{3,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] + w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
f_n[i] &= w_{3,n} \cdot a_{n-1}[i] + b_{n-1}[i - S_n] + w_{3,n} \cdot c_{n-1}[i - 2 \cdot S_n] + d_{n-1}[i - 3 \cdot S_n] + w_{3,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] - w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
g_n[i] &= w_{3,n} \cdot w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot b_{n-1}[i - S_n] - w_{3,n} \cdot w_{2,n} \cdot c_{n-1}[i - 2 \cdot S_n] - w_{2,n} \cdot d_{n-1}[i - 3 \cdot S_n] - \ldots \\
&\ldots - w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] - w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n] \\
h_n[i] &= w_{3,n} \cdot w_{2,n} \cdot a_{n-1}[i] + w_{2,n} \cdot b_{n-1}[i - S_n] + w_{3,n} \cdot w_{2,n} \cdot c_{n-1}[i - 2 \cdot S_n] + w_{2,n} \cdot d_{n-1}[i - 3 \cdot S_n] - \ldots \\
&\ldots - w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot e_{n-1}[i - 4 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot f_{n-1}[i - 5 \cdot S_n] + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot g_{n-1}[i - 6 \cdot S_n] + w_{2,n} \cdot w_{1,n} \cdot h_{n-1}[i - 7 \cdot S_n]
\end{aligned}
\tag{6}
$$

The way $w_{3,n}, w_{2,n}, w_{1,n}$ appear in (6) always allows to generate eight orthogonal sets of sequences with any length $L = 8^n$, just using the eight possible combinations.

The recursive algorithm explained in (6) can be considered as a digital filter in figure 1, consisting of n similar stages with twenty-four adders/subtractors and seven delay elements. It is necessary to be careful with the order of outputs when connecting the stage $n-1$ to the next stage n. Generally, the order of outputs is not the same as the inputs in the following stage.

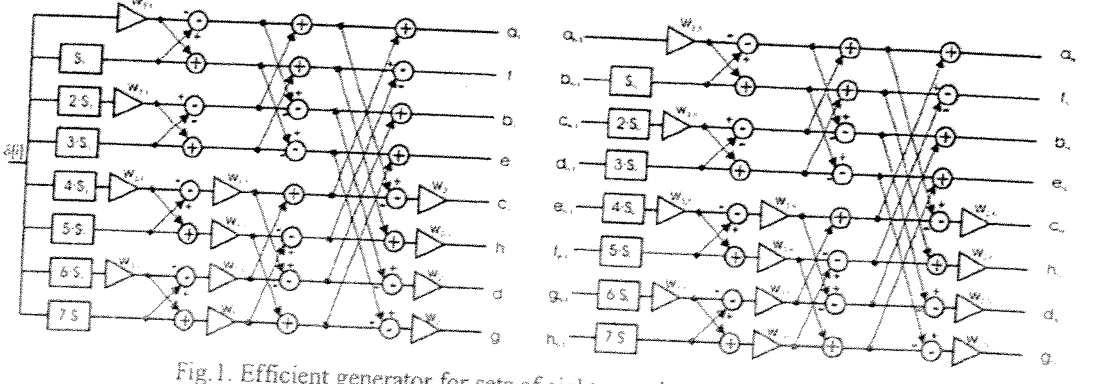

Fig. 1. Efficient generator for sets of eight complementary sequences.

If the AC function is computed for every sequence in the set and added all of them, the obtained AC maximum value is shown in (7).

$$R_{aa} + R_{bb} + R_{cc} + \ldots + R_{hh} + R_{gg} = 8 \cdot L \cdot \delta[i] = 8.8^{n} \cdot \delta[i] = 8^{n+1} \cdot \delta[i] \qquad (7)$$

3. EFFICIENT CORRELATOR

If the order of the delays in (6) is interchanged as has been explained in [6] and [7] and as is shown in (8) for sequences a'_n, b'_n and c'_n (the rest would be treated in the same way), what is equivalent to concatenate the sequences in the reverse order, a correlation-matching filter for the direct sequences is obtained. The filter shown in figure 2 performs simultaneously the correlation of the input signal $r[i]$ with the eight complementary sequences of the set.

$$\begin{aligned}
&a'_0[i] = b'_0[i] = c'_0[i] = d'_0[i] = e'_0[i] = f'_0[i] = g'_0[i] = h'_0[i] = \delta[i] \\
&a'_n[i] = -w_{3,n} \cdot a'_{n-1}[i - 7 \cdot S_n] + b'_{n-1}[i - 6 \cdot S_n] + w_{3,n} \cdot c'_{n-1}[i - 5 \cdot S_n] - d'_{n-1}[i - 4 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot e'_{n-1}[i - 3 \cdot S_n] + \ldots \\
&\ldots + w_{1,n} \cdot f'_{n-1}[i - 2 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot g'_{n-1}[i - S_n] + w_{1,n} \cdot h'_{n-1}[i] \\
&b_n[i] = -w_{3,n} \cdot a'_{n-1}[i - 7 \cdot S_n] + b'_{n-1}[i - 6 \cdot S_n] - w_{3,n} \cdot c'_{n-1}[i - 5 \cdot S_n] + d'_{n-1}[i - 4 \cdot S_n] - w_{3,n} \cdot w_{1,n} \cdot e'_{n-1}[i - 3 \cdot S_n] + \ldots \qquad (8) \\
&\ldots + w_{1,n} \cdot f'_{n-1}[i - 2 \cdot S_n] + w_{3,n} \cdot w_{1,n} \cdot g'_{n-1}[i - S_n] - w_{1,n} \cdot h'_{n-1}[i] \\
&c_n[i] = -w_{3,n} \cdot w_{2,n} \cdot a'_{n-1}[i - 7 \cdot S_n] + w_{2,n} \cdot b'_{n-1}[i - 6 \cdot S_n] + w_{3,n} \cdot w_{2,n} \cdot c'_{n-1}[i - 5 \cdot S_n] - w_{2,n} \cdot d'_{n-1}[i - 4 \cdot S_n] + \ldots \\
&\ldots + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot e'_{n-1}[i - 3 \cdot S_n] - w_{2,n} \cdot w_{1,n} \cdot f'_{n-1}[i - 2 \cdot S_n] + w_{3,n} \cdot w_{2,n} \cdot w_{1,n} \cdot g'_{n-1}[i - S_n] - w_{2,n} \cdot w_{1,n} \cdot h'_{n-1}[i]
\end{aligned}$$

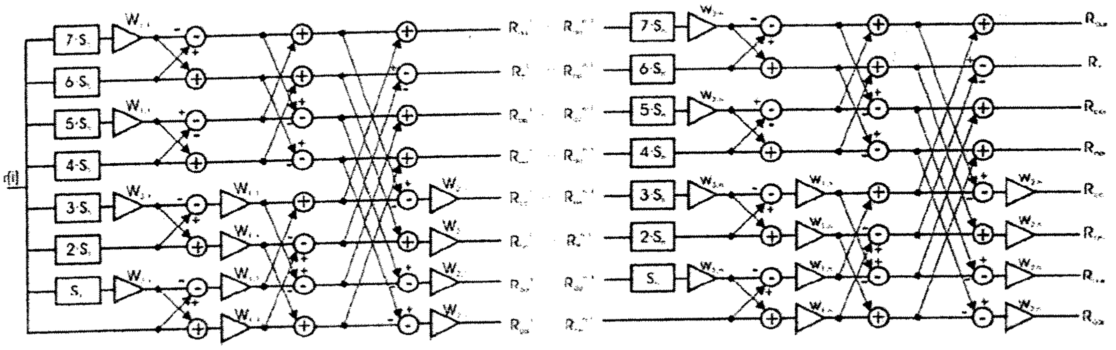

Fig.2. Efficient Correlator for sets of eight complementary sequences.

This architecture implies a remarkable reduction in the number of calculations compared to the classical hardware implementation of the correlation. If the length of the sequences is $L = 8^n$, the computations (additions, subtractions and multiplications) required for the classical implementation are $8 \cdot (2 \cdot 8^n - 1)$, whereas in the implementation based on efficient correlators this amount is $36 \cdot n$.

4. SIMULATIONS

In order to verify the properties of the sequences generated by the proposed algorithm, simulations about the generator and the correlator have been carried out. Table 1 shows two sets of eight complementary sequences with length $L = 8$ ($n = 1$) generated with different coefficients (w).

Set 1. Coefficients $w_{3,n} = -1$ $w_{2,n} = -1$ $w_{1,n} = -1$									Set 2. Coefficients $w_{3,n} = -1$ $w_{2,n} = -1$ $w_{1,n} = 1$								
a_0	1	1	-1	-1	-1	-1	-1	-1	a_1	1	1	-1	-1	1	1	1	1
b_0	1	1	1	1	-1	-1	1	1	b_1	1	1	1	1	1	1	-1	-1
c_0	-1	-1	1	1	-1	-1	-1	-1	c_1	-1	-1	1	1	1	1	1	1
d_0	-1	-1	-1	-1	-1	-1	1	1	d_1	-1	-1	-1	-1	1	1	-1	-1
e_0	-1	1	1	-1	1	-1	1	-1	e_1	-1	1	1	-1	-1	1	-1	1
f_0	-1	1	-1	1	1	-1	-1	1	f_1	-1	1	-1	1	-1	1	1	-1
g_0	1	-1	-1	1	1	-1	1	-1	g_1	1	-1	-1	1	-1	1	-1	1
h_0	1	-1	1	-1	1	-1	-1	1	h_1	1	-1	1	-1	-1	1	1	-1

Table 1. Sets of sequences generated by an efficient generator and different coefficients (w).

Figure 3 presents the AC of each sequence in the set 1 and the AC addition of all of them. Finally figure 4 shows the CC among sets 1 and 2 detailed in table 1, where the ideal orthogonality between both sets can be verified.

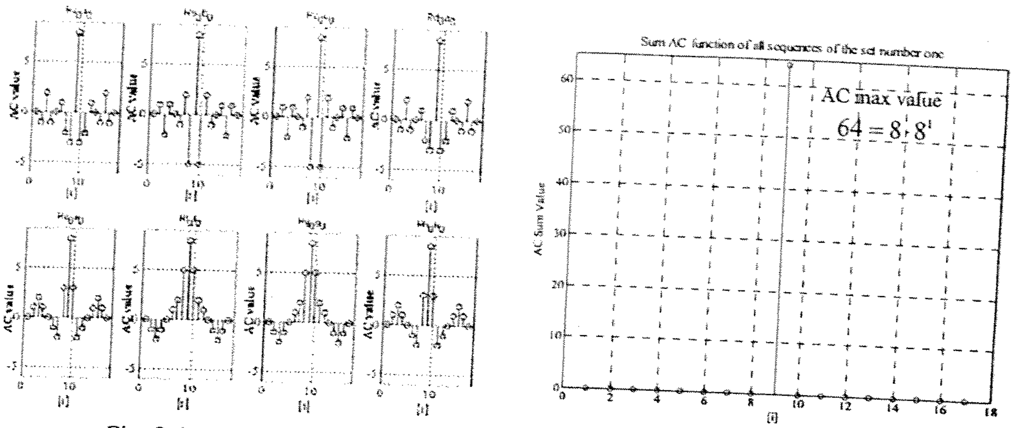

Fig. 3 Autocorrelation of each sequence in the set generated with coefficients $w_{3,n} = -1, w_{2,n} = -1, w_{1,n} = -1$ and addition of AC functions

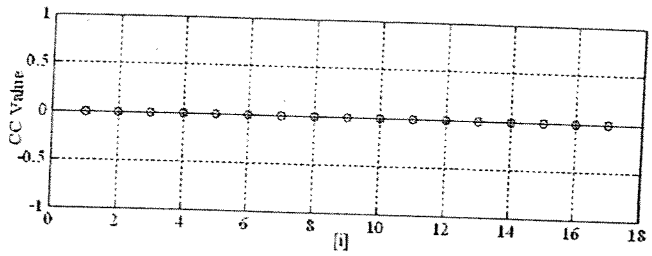

Fig. 4 Cross correlation between sets 1 and 2 generated by an efficient generator.

5. CONCLUSIONS

A new recursive algorithm for generating complementary sets of eight sequences and the correlation implementation by an efficient pulse compressor have been presented. This pulse compressor, and its feasibleness for constructing orthogonal sets, makes very attractive the usage of sets of eight complementary sequences in different sensor systems, when low signal-to-noise ratios are involved. Also, it introduces the possibility of using eight orthogonal sets for multiple simultaneous emissions. Finally, shorter lengths of sequences can be used, in order to reduce the processing times, compared to other binary codes.

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References

[1] Chow, A. "Performance of Spreading Codes for Direct Sequence Code Division Multiple Access (DS-CDMA)", Technical Report, Stanford University , 5 December 2003,.
[2] Golomb, S., "Generalized Barker Sequences", *IEEE Trans. Inf. Theory*, IT-11, (4), 1965, pp. 533-537
[3] Golay, M.J.E., "Complementary series", *IRE Trans. Inf. Theory*, IT-7, 1961, pp. 82–87.
[4] Tseng, C., "Complementary sets of sequences", IEEE Trans. Inf. Theory, IT-18, (5), 1972, pp. 644–652.
[5] Budisin, S.: "New complementary pairs of sequences", *Electron. Lett.*, 26, (13), 1990, pp. 881–883.
[6] Popovic, B.M. "Efficient Golay correlator", *Electron. Lett.*, 35,(17), 1999, pp. 1427–1428.
[7] Alvarez, F.J.; et. al.; "Efficient generator and pulse compressor for complementary sets of four sequences", *Electron. Lett.*, 40,(11), 27 May 2004, pp. 703–704.

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