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Agenda Item: Adhoc 12

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Title: Text Proposal for Generalised Hierarchical Golay Sequence for PSC with low complexity correlation using pruned efficient Golay correlators

Document for: **Discussion**

Abstract

In the accompanying contribution "Generalised Hierarchical Golay Sequence for PSC with low complexity correlation using pruned efficient Golay correlators" R1-99567 we presented an improved PSC code, combing the advantages of the hierarchical and the Golay codes in a harmonised proposal. This proposal has a lower complexity than each of the above mentioned PSC schemes while maintaining the synchronisation properties even under high frequency errors.

We therefore suggest to use this harmonised approach for the PSC, as shown in the text proposal below.

Text proposal for 25.213 and 25.223 (Spreading and modulation)

The following changes are proposed in 25.213 and 25.223, the former S1.13 and S1.23.

Note that previously the sequence was first defined binary with elements {0, 1} and then mapped to the bipolar representation {1, -1}. Because the Golay sequences can better be described with the final bipolar representation, only the later is used. Consequently the definition of the hadamard matrix is changed to bipolar representation as well.

5.2.3.1 Code Generation

The Primary and Secondary code words, C_p and $\{C_1,\ldots,C_{17}\}$ are constructed as the position wise addition modulo 2 of a Hadamard sequence and a fixed so called generalised hierarchical Golay sequence *y*. The Primary SCH is furthermore chosen to have good aperiodic auto correlation properties.

The hierarchical sequence y is constructed from two constituent sequences x_1 and x_2 of length n_1 and n_2 respectively using the following formula:

$$y(i) = x_2(i \bmod n_2)\ \cancel{+}\ *\ x_1(i \operatorname{div} n_2)\ \cancel{\text{modulo } 2},\ i = 0 \ldots (n_1 * n_2) - 1$$

The constituent sequences x_1 and x_2 are chosen to be the following length 16 (i.e. $n_1 = n_2 = 16$) sequences:

~~x1 = < 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 1 >~~

~~and~~

~~x_2 = < 0, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0 >~~

- x_1 is defined to be the length 16 ($N^{(1)}=4$) Golay sequence obtained by the delay matrix $D^{(1)} = [8, 4, 1, 2]$ and weight matrix $W^{(1)} = [1, -1, 1, 1]$.

- x_2 is a generalised hierarchical sequence using the following formula, selecting s=2 and using the two Golay sequences x_3 and x_4 as constituent sequences. The length of the sequence x_3 and x_4 is called n_3 respectively n_4.

  $x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$

  x_3 and x_4 are defined to be identical and the length 4 ($N^{(3)} = N^{(4)} = 2$) Golay sequence obtained by the delay matrix $D^{(3)} = D^{(4)} = [1, 2]$ and weight matrix $W^{(3)} = W^{(4)} = [1, 1]$.

The Golay sequences x_1, x_3 and x_4 are defined using the following recursive relation:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k) \quad \text{-----(1)}$$

$$a_n(k) = a_{n-1}(k) + W^{(j)}_n \cdot b_{n-1}(k-D^{(j)}_n)\,, \quad \text{-----(2)}$$

$$b_n(k) = a_{n-1}(k) - W^{(j)}_n \cdot b_{n-1}(k-D^{(j)}_n)\,, \quad \text{-----(3)}$$

$$k = 0, 1, 2, \ldots, 2^{**}N^{(j)} - 1,$$

$$n = 1, 2, \ldots, N^{(j)}.$$

a_n *assuming* $n=N^{(j)}$ then defines the wanted Golay sequence x_j. The Kronecker delta function is described by δ, k and n are integers.

Alternatively, the sequence y can be viewed as a pruned Golay code and generated using the following parameters in equations (1-3):

(a) Let $j = 0$, $N^{(0)} = 8$

(b) $[D_1^0, D_2^0, D_3^0, D_4^0, D_5^0, D_6^0, D_7^0, D_8^0] = [128, 64, 16, 32, 8, \cancel{4}1, \cancel{1}4, 2]$

(c) $[W_1^0, W_2^0, W_3^0, W_4^0, W_5^0, W_6^0, W_7^0, W_8^0] = [1, -1, 1, 1, 1, 1, 1, 1]$

(d) For $n = 4, 6$, set $b_4(k) = a_4(k)$, $b_6(k) = a_6(k)$, where $a_4(k)$, $a_6(k)$ are given by equation (2).

The Hadamard sequences are obtained as the rows in a matrix H_8 constructed recursively by:

$$H_0 = (1)$$

$$H_k = \begin{pmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & -H_{k-1} \end{pmatrix}, \quad k \geq 1$$

$$H_0 = (0)$$

$$\cancel{H_k = \begin{pmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & \overline{H_{k-1}} \end{pmatrix}, \quad k \geq 1}$$

The rows are numbered from the top starting with row *0* (the all ~~zeros~~ones sequence).

The Hadamard sequence *h* depends on the chosen code number *n* and is denoted h_n in the sequel.

This code word is chosen from every 8^{th} row of the matrix H_8. Therefore, there are 32 possible code words out of which 18 are used.

Furthermore, let $h_n(i)$ and $y(i)$ denote the *i*:th symbol of the sequence h_n and *y*, respectively.

Then h_n is equal to the row of H_8 numbered by the bit reverse of the 8 bit binary representation of *n*.

The definition of the *n*:th SCH code word follows (the left most index correspond to the chip transmitted first in each slot):

$C_{SCH,n} = < h_n(0)\cancel{+}*y(0), h_n(1)\cancel{+}*y(1), h_n(2)\cancel{+}*y(2), \ldots, h_n(255)\cancel{+}*y(255) >$,

~~All sums of symbols are taken modulo 2.~~

~~These binary code words are converted to real valued sequences by the transformation ‘0’ -> ‘+1’, ‘1’ -> ‘-1’.~~

The Primary SCH and Secondary SCH code words are defined in terms of $C_{SCH,n}$ and the definition of C_p and $\{C_1,\ldots,C_{17}\}$ now follows as:

$C_p = C_{SCH,0}$

and

$C_i = C_{SCH,i}$, i=1,…,17

The definitions of C_p and $\{C_1,\ldots,C_{17}\}$ are such that a 32 point fast Hadamard transform can be utilised for detection.