3GPP TSG RAN WG1#17 R1-00-1351

Stockholm / Sweden
November 21st - 24th, 2000

Agenda Item: **AH30**

Source: **Siemens, Mitsubishi Electric**

Title: **CEC sequences with multiple offsets for Node B sync in UTRA TDD**

Document for: **Discussion and Decision**

---

1 Summary

It has been proposed to use **C**oncatenated periodically **E**xtended **C**omplementary sequences [2] for inter-base station synchronisation in UTRA TDD. CEC-sequences provide a perfect channel estimation window, i.e. no auto-correlation side lobes at all around the main correlation peak in a window of adjustable size, whilst still exhibiting excellent auto-correlation properties for the overall aperiodic auto-correlation function. Due to the existence of low complexity matched-filter structures for Polyphase complementary pairs, a significant computational complexity reduction can also be achieved for correlation with CEC-sequences.

The option that several Node B's within one RNS transmit their cell sync bursts simultaneously, i.e. in the same PRACH timeslot has been proposed recently [1]. The introduction of this option into the current Node B sync concept could allow a more efficient usage of the allocated resources and could also allow more frequent measurement occasions. A straightforward approach for enabling simultaneous reception and detection of more than one neighbouring Node B is to assign them different code offsets by means of cyclically shifted versions of one common basic sequence.

In this contribution, the construction of CEC-sequences is extended to the multiple code offset case and it is shown that these Node B sync sequences offer the same advantages as the original ones in terms of their auto-correlation properties and low-complexity receiver implementation.

2 Introduction

The construction principle of the original CEC-sequences as proposed in [2] is shown in Figure 1. The basic sequences *s(n)* and *g(n)* make up a Golay or Polyphase complementary pair with an integer power of 2 as length. The sum of the aperiodic auto-correlation functions of a complementary pair yields a perfect Dirac-function.

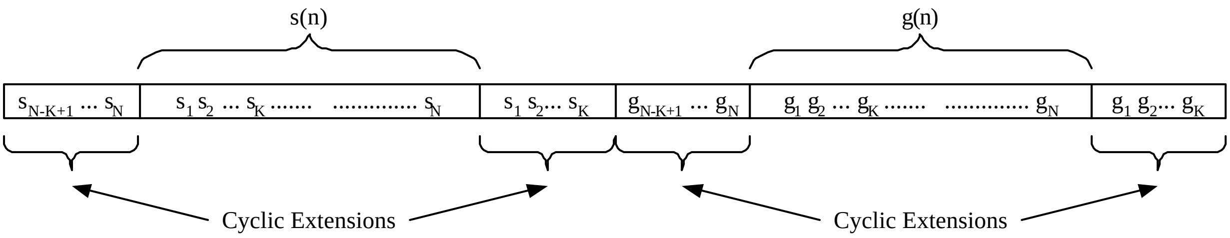

Figure 1: Construction principle of the CEC-sequences without code offset

The receiver in a first step correlates the overall received signal separately with a local replica of *s(n)*. In a second step, it correlates at a $N+2\,K$ chip offset with a local replica of *g(n)*. Finally, the auto-correlation sum is obtained after adding up corresponding matched-filter outputs.

It can be shown that following the construction principle in Figure 1, a perfect auto-correlation window of size $\pm K$ can be obtained around the main correlation peak. The size of the perfect auto-correlation window is scalable and dependent on the length of the pre- or post extensions. In addition, the overall aperiodic auto-correlation properties, i.e. outside the window are better than can be obtained by a Gold-sequence of comparable length.

In an alternative way, CEC-sequences could be constructed from a complementary pair by either leaving out the pre- or the post-extension for each of the basic sequences . Without pre-extensions, the overall CEC-sequence would look like shown in Figure 2.

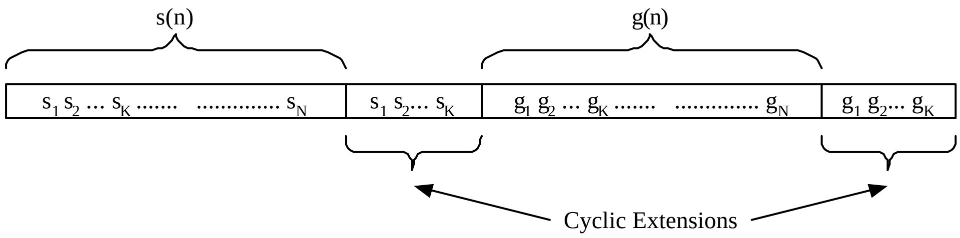

Figure 2: CEC-sequences with post-extensions only

The receiver would in a first step correlate the received signal with a cyclically rotated version of *s(n)*, here denoted as *s'(n)*. The elements of this local replica *s'(n)* are obtained from the original basic sequence *s(n)* as being,

$$s'_i = \begin{cases} s_{(K+1)/2+i} & i \le N-(K+1)/2 \\ s_{(K+1)/2+i-N} & i > N-(K+1)/2 \end{cases}$$

Here, *K* denotes the length of the post-extension and *N* the length of the complementary pair. If *K* is an odd number, the nominal code correlation position starts with s_i where $i = (K+1)/2 + 1$.

The receiver would in a second step proceed in an analogue way correlate the received signal with a cyclically rotated version of *g(n)* at the time offset *N+K* chips and finally add up corresponding correlation values from the first and second step in order to obtain the auto-correlation sum.

When removing the pre-extension and correlating with a cyclically rotated version of the basic sequences, the size of the perfect auto-correlation window around the main correlation peak is reduced to ±*K*/2. If *K* is not an odd number, the perfect auto-correlation window becomes very slightly asymmetrical.

CEC-sequences derived following either Figure 1 or Figure 2 are equivalent, both have excellent aperiodic auto-correlation properties and for both the possibility to use low-complexity receiver structures for Polyphase complementary pairs exists. However, CEC-sequences with post-extension only, such as shown in Figure 2 are conceptually closer to the multiple code offset case that is described in the next section.

3 CEC-sequences with multiple code offsets

If CEC-sequences are derived as in Section 2, a single Node B sync sequence is obtained from a single Golay or Polyphase complementary pair. When several Node B's in a RNS shall be enabled to transmit simultaneously, they can be differentiated by either

(1) using different complementary pairs or
(2) using different code offsets of the same complementary pair

for constructing different Node B sync sequences.

The second option offers the advantage that because of the perfect auto-correlation sum property of complementary pairs, orthogonality is preserved between different Node B sync sequences derived from the same complementary pair by means of a different code offset. It is therefore advantageous to generate a family of CEC-sequences from one particular Golay or Polyphase complementary pair by allowing variable cyclic shifts of the basic sequences *s(n)* and *g(n)*. The construction principle is shown in Figure 3 and Figure 4.

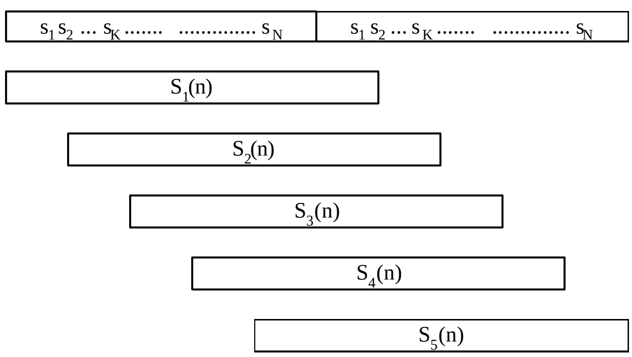

Figure 3: Deriving different code offset versions of the basic sequence s(n)

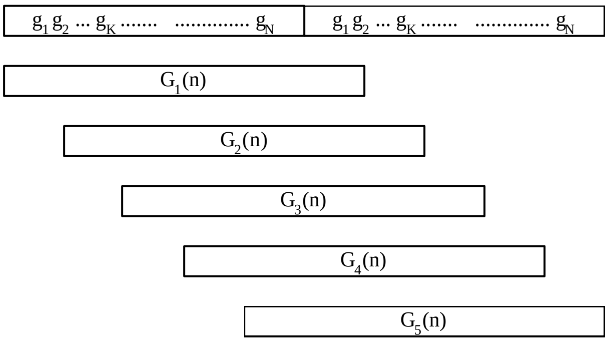

Figure 4: Deriving different code offset versions of the basic sequence g(n)

The cyclically shifted versions of *s(n)* and *g(n)*, referred to as S_m(n) and G_m(n) for code offset *m* are derived by selecting appropriate elements from the repetitions of *s(n)* and *g(n)* respectively. The periodically repeated version of *s(n)* is denoted by $s_e(n)$, with its elements given as $s_{e,i} = \begin{cases} s_i & i \le N \\ s_{i-N} & i > N \end{cases}$.

Then the elements of S_m(n), denoted as $S_{m,i}$ are given by $S_{m,i} = s_{e,i+(m-1)w}$, where *w* is the offset in terms of the number of code elements. Typically *w* is chosen to equal *K* and the total available number of offsets *M* is then given by *M=N/K* although other relationships are not excluded. The corresponding cyclically shifted versions of G_m(n) are constructed in identical fashion.

The overall Node B sync sequence derived from a particular Golay or Polyphase complementary pair *s(n)* and *g(n)* and corresponding to a particular code offset *m* is finally given by the concatenation of S_m(n) and G_m(n) as illustrated in Figure 5. Node B sync sequences build from CEC-sequences with multiple code offsets have an overall length of *2(N+K)* chips.

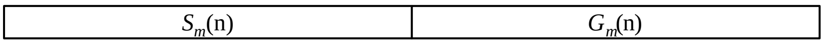

Figure 5: Node B sync sequence derived from a complementary pair s(n) and g(n) for code offset m

The receiver in a first step cyclically correlates the first half of the overall received signal with a local replica *s'(n)* whose elements are derived from *s(n)* as in Section 2. The first *K* chips of the *N+K* chip long segment corresponding to *s(n)* are discarded. This is equivalent to the computation of the periodic auto-correlation with the local replica *s'(n)* by means of a cyclic shift register.

The correlation with *g'(n)* is done in a second step in an analogue manner on the second half of the overall received signal. By discarding the first *K* chips, any undesired cross-correlation between the parts corresponding to *s(n)* and *g(n)* due to a multi-path channel with channel impulse response length smaller than *K* can be avoided. Finally, the auto-correlation sum is obtained after adding up corresponding matched-filter outputs from the first and second step.

A typical auto-correlation obtained for the case of *N=1024* and *M=16* possible code offsets with a resolution of *K=64* chips between different simultaneously transmitting Node B's is shown in the Appendix for the case of code offsets *1, 3* and *7* being present.

4 Conclusion

CEC-sequences with multiple code offsets have all the benefits of the original proposed CEC-sequences in terms of ease of implementation of the decoder [2] and ideal auto-correlation properties. In addition, multiple code offsets are available for a particular Golay or Polyphase complementary pair. Due to the complementary property of the CEC-sequences their offset versions also remain orthogonal, i.e. without any undesired cross-correlation.

Golay complementary pairs of length *N=1024* seem to be a good choice for building the CEC-sequences, as the EGC-receiver structure simplifies the most for this special binary case of Polyphase complementary pairs. Providing *M=16* possible code offsets for one RNS leaves *K=64* chips of resolution between different Node B's which should be more than sufficient. The overall length of a Node B sync sequence would then be *2176* chips which yields a maximum usage of the available time in the cell sync timeslots. Also, we propose that at least *8* Golay complementary pairs are chosen for deriving the CEC-sequences with multiple code offsets. These basic Golay complementary pairs could be chosen based on their aperiodic auto-correlation properties which are important in the initial Node B sync scenario.

Note also that when applying a continuously increasing phase offset to the elements of a Node B sync sequence derived from CEC-sequences, the order of applying the phase offset and deriving the code offset versions are inter-changeable as all code parameters are multiple's of *4*. The same holds for the receiving side.

References:

[1] R1-00-1349, "Node B synchronisation for TDD – some refinements", Siemens

[2] R1-00-1181, "Sequences for the Node B synchronisation burst", Mitsubishi Electric

[3] R1-00-0946, "Sequences for the Cell Sync burst", Siemens

[4] R1-00-0074, "Node B Synchronisation for TDD", Siemens

[5] R1-99-g42, "Synchronisation of Node B's in TDD via Selected PRACH timeslots", Siemens

[6] M.J.E. Golay, "Complementary Series", IRE Trans. on Information Theory, Vol.IT-7,pp.82-87, April 1961

Appendix

The following figures show a typical auto-correlation sum for CEC-sequences with multiple code offsets. The code offset versions of the CEC-sequence are derived from a Golay complementary pair with weight vector **W**=[W_1 W_2 … W_{10}]=[1 -1 1 1 -1 -1 -1 -1 -1 -1] and permutation vector **P**=[P_1 P_2 … P_{10}] =[9 0 8 1 7 2 6 3 5 4]. Code offsets *1*, *3* and *7* were selected.

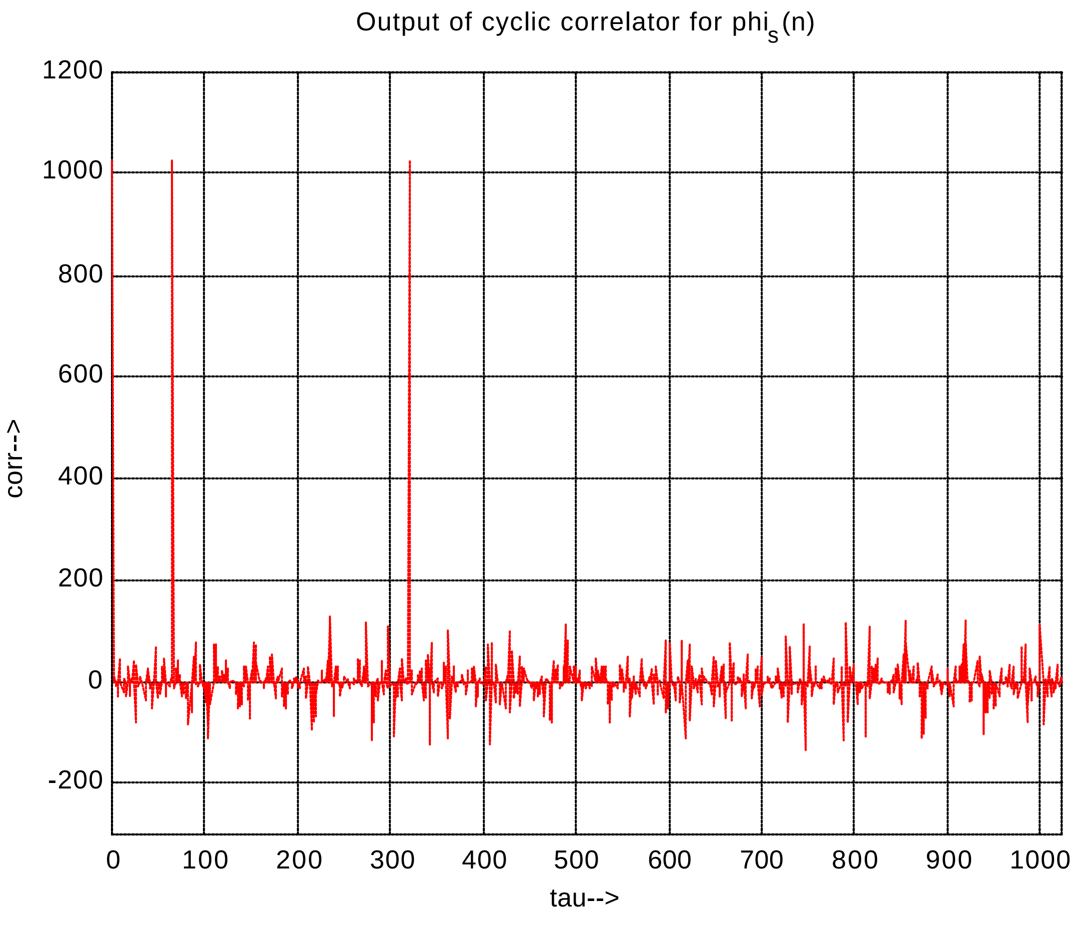

Figure 6: Cyclic correlator output for correlation with s'(n)

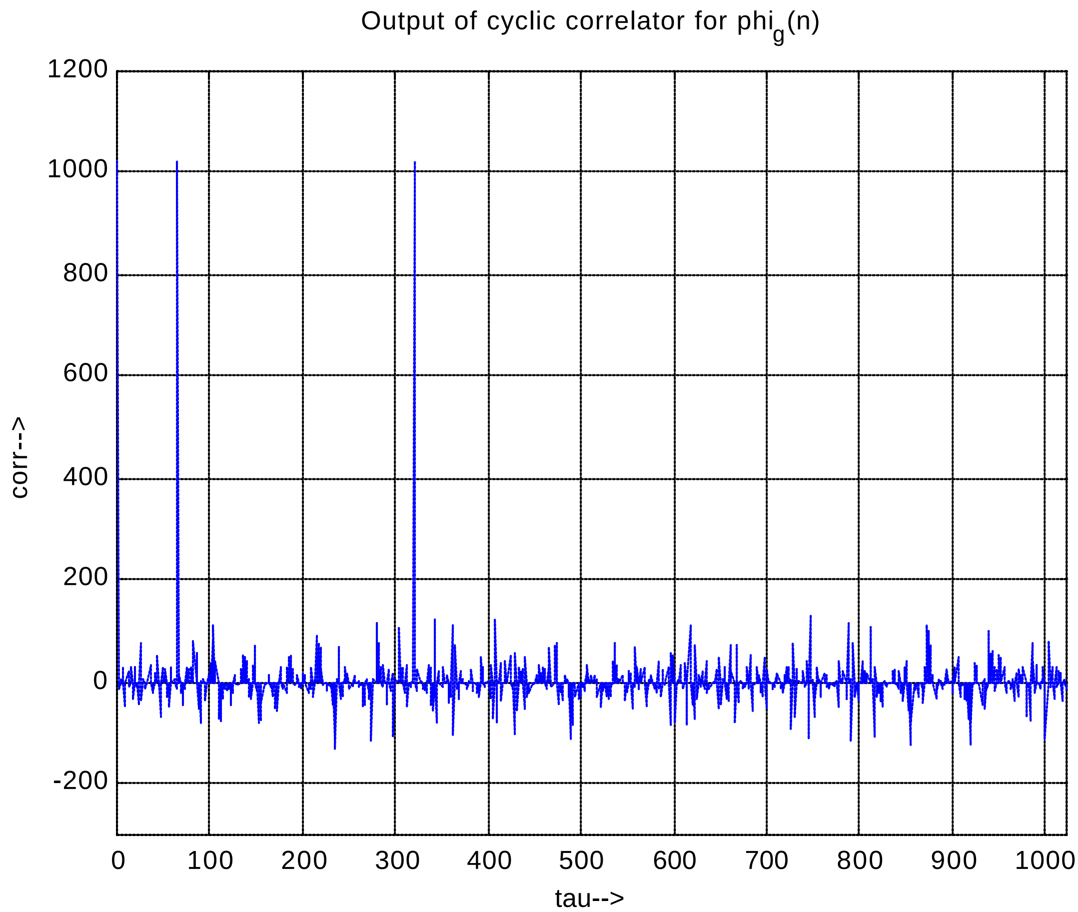

Figure 7: Cyclic correlator output for correlation with g'(n)

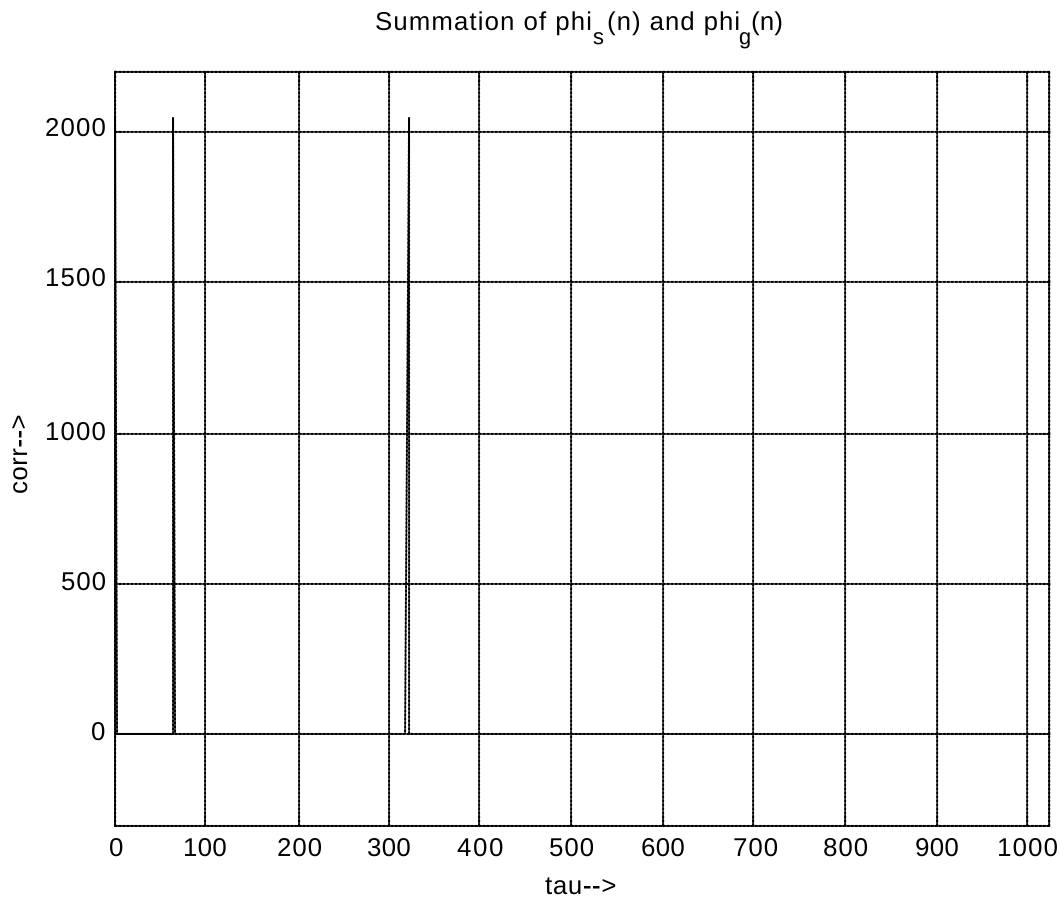

Figure 8: Sum of the correlation outputs obtained by cyclic correlation with s'(n) and g'(n)