TSG-RAN Working Group meeting #6 **_TSGR1#6(99)866_**

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**Source : Samsung Electronics Co., Ltd.**

**Title : A Simple Pilot Pattern for new frame structure with 15 slots**

**Document for : Discussion**

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# 1. Introduction

In Tdoc R1-99829[1], Tdoc R1-99830[2], LGIC proposed new pilot patterns for the frame structure with 15 slots reflecting the harmonization effect. In those proposals, they proposed a set of 8 new frame synchronization words obtained based on a single M-sequence. In order to make a set of 8 frame synchronization words, they first shifted the basic M-sequence with three different amount of offset and read forward or reverse direction. After then, they further performed a shift-and-complement operation on the original M-sequence and three offset sequences to obtain two-valued auto correlation and cross correlation properties. As a possible method to confirm the frame synchronization, they also presented single and double check method and have shown the performance of these methods. It is quite reasonable to use two kinds of correlation values at the receiver when the receiver confirms the frame synchronization.

In this document, we propose frame synchronization words based on a straightforward and natural rule. The proposed rule is simple repetition of M-sequence for each frame synchronization words. The performance and computational complexity of the proposed pattern are equivalent to those with LGIC proposal. But we can achieve such an equivalent performance by proper design of the receiver structure. In addition, the receiver can have various ways to confirm the frame synchronization. The advantage of the proposed frame synchronization words is that the transmitter does not have to neither store the whole 8 frame synchronization words, nor generate the additional 7 frame synchronization words from the basic sequence because the only one sequence is used.

## 2. New frame synchronization words

$M_0$ = (1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0) be the M-sequence with length 15, and $M_i, i = 0,1,\cdots,14$ be the $i$-bit right shifted version of the sequence $M_0$.

Then the sequence $M_i$ has the well-known two-valued auto-correlation property as follows.

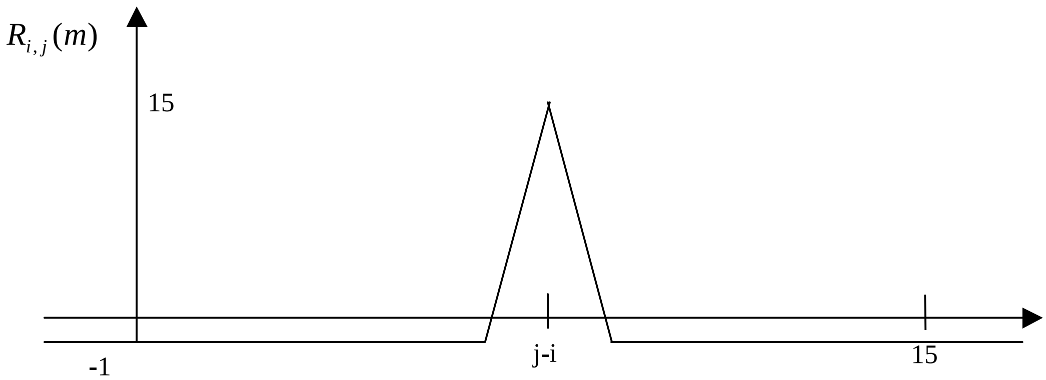
$$R_i\ \ m) = \begin{cases} 15 & m = 0 \\ - \ , & m \neq \end{cases}, \quad i = \ ,1 \cdots,14 \tag{1}$$

The cross correlation between the sequence $M_i$ and $\ _j$ is given by

$$R_{i,j}(m \ = \begin{cases} 15, & j - i \\ -1, & j - i \end{cases} \tag{2}$$

Figure 1 shows the auto correlation and cross correlation properties of the sequence $M_i$.


(a) Auto-correlation property $R_i(m)$ of the sequence $M_i$




(b) Cross-correlation property $R_{i,j}(m)$ of the sequences $M_i$ and $M_j$

**Figure 1: Auto correlation $R_i(m)$ and cross correlation properties $R_{i,j}(m)$.**

Based on the above auto correlation and cross correlation properties, we propose a simple frame synchronization words for the new frame structure with 15 slots. The proposed frame synchronization words $C_i \; i = 0,1,\cdots,7$ are simply all $M_0$, and Table 1 shows the proposed synchronization words.

**Table 1 . Proposed Frame Synchronization Words**

| | **Frame Synchronization Words** |
|---|---|
| $C_0 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_1 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_2 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_3 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_4 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_5 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_6 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |
| $C_7 = M_0$ | 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0 |

The auto correlation function of the combined frame synchronization words $C_0, C_1, \cdots, C_{N-1}$, where $N = 2,4,8$ denotes the number of frame synchronization bits per each slot, is given by

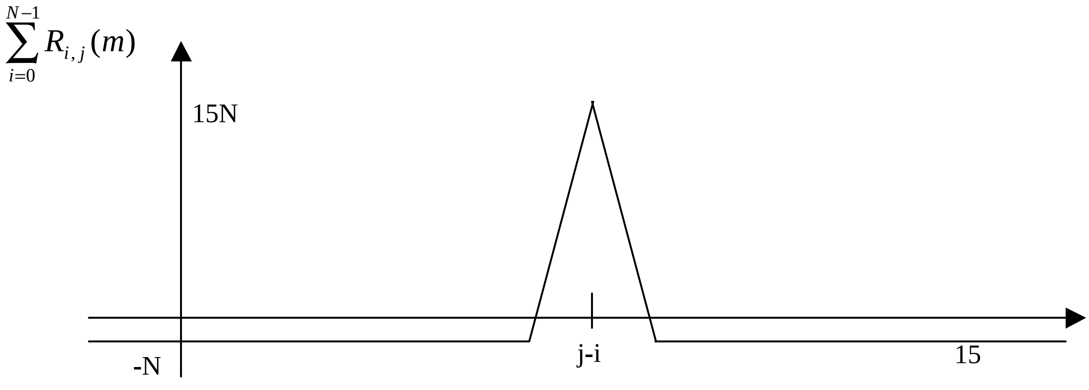
$$\sum_{i=0}^{N-1} R_0(m) = \begin{cases} 15N, & m = 0 \\ -N, & m \neq 0 \end{cases}. \qquad (3)$$

In addition, the cross correlation property between the combined frame synchronization words and the sequence with offset 7, $M_7$, is given by

$$\sum_{i=0}^{N-1} R_{0,7}(m) = \begin{cases} 15N, & m = 7 \\ -N, & m \neq 7 \end{cases}. \qquad (4)$$

Figure 2 shows the auto correlation and cross correlation properties of the combined frame synchronization words. The receiver can confirm the frame synchronization based on the auto correlation and cross correlation outputs simultaneously. If the receiver has a room for additional correlators, then additional cross correlation values can be obtained with phase offset other than 7 and used for frame synchronization confirmation. The performance and computational complexity should be equivalent to the LGIC proposal because the basic auto correlation and cross correlation properties given in Eq. (3) and (4) are exactly the same as those proposed by LGIC.


(a) Auto correlation property $\sum_{i=0}^{N-1} R_0(m)$ of the combined frame synchronization words




(b) Cross correlation property $\sum_{i=0}^{N-1} R_{i,j}(m)$ of the combined frame synchronization words

**Figure 2: Auto correlation and cross correlation properties of the combined frame synchronization words.**

## 3. Proposed Pilot Symbol Patterns

Table 2~7 show the proposed pilot patterns for uplink/downlink channels.

**Table 2. Pilot patterns for uplink DPCCH: Npilot = 5 and 6**

| | $N_{pilot} = 5$ | | | | | $N_{pilot} = 6$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit # | 0 | 1 | 2 | 3 | 4 | 0 | 1 | 2 | 3 | 4 | 5 |
| Slot #1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 3 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 14 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 15 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |

**Table 3. Pilot patterns for uplink DPCCH: Npilot = 7 and 8**

| | $N_{pilot} = 7$ | | | | | | | $N_{pilot} = 8$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bit # | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slot #1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 3 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 13 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 14 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 15 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |

**Table 4. Pilot patterns for downlink DPCH: Npilot = 4, 8, and 16**

| | $N_{pilot}$ = 4 | | $N_{pilot}$ = 8 | | | | $N_{pilot}$ = 16 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol # | 0 | 1 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slot #1 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 2 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 3 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 4 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 5 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 6 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 7 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 8 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 9 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 12 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 13 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 14 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 15 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |

**Table 5. Pilot patterns of downlink DPCH (STTD)**

| | $N_{pilot}$ = 4 | | $N_{pilot}$ = 8 | | | | $N_{pilot}$ = 16 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol # | 0 | 1 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slot #1 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 2 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 3 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 4 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 5 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 6 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 7 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 8 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 9 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 10 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 11 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 12 | 01 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 13 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 14 | 10 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 15 | 00 | 10 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |

**Table 6. Pilot patterns for downlink SCCPCH**

| | $N_{pilot}$ = 8 | | | | $N_{pilot}$ = 16 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol # | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slot #1 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 2 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 3 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 4 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 5 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 6 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 7 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 8 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 9 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 10 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 12 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 |
| 13 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 14 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |
| 15 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 | 11 | 00 |

**Table 7. Pilot patterns for downlink SCCPCH (STTD)**

| | $N_{pilot}$ = 8 | | | | $N_{pilot}$ = 16 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Symbol # | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slot #1 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 2 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 3 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 4 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 5 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 6 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 7 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 8 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 9 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 11 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 12 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 | 11 | 01 | 00 | 10 |
| 13 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 14 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |
| 15 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 | 11 | 10 | 00 | 01 |

# 4. Conclusion

In this document, we proposed frame synchronization words based on a straightforward and natural rule. The performance and computational complexity of the proposed pattern are equivalent to those with LGIC proposal. But such an equivalent performance can be achieved by proper design of the receiver structure. The advantage of the proposed frame synchronization words is that the transmitter does not have to neither store the whole 8 frame synchronization words, nor generate the additional 7 frame synchronization words from the basic sequence because the only one sequence is used.

# References

[1] LGIC, "New Pilot Patterns for 15 Slots Considering harmonization"", 3GPP TSG-RAN1#6(99)829.

[2] LGIC, "New Pilot Patterns for 15 Slots Considering harmonization"", 3GPP TSG-RAN1#6(99)830.