TSG-RAN Working Group1 meeting #3 **TSGR1#3(99)160**

Stockholm 22-26, March 1999

Agenda Item : 9.1

Source : LG Information & Communications, Ltd.

Title : Pilot Patterns for Frame Synchronization

Document for : Proposal of Pilot Patterns for Frame Synchronization

---

Abstract :

This contribution proposes a new set of pilot patterns for the Uplink DPCCH, Downlink DPCCH, and Secondary CCPCH. The proposed pilot patterns have the lowest out-of-phase values of autocorrelation function with the two peak values equal in magnitude and opposite in polarity at zero and middle shifts. It is shown that the proposed pilot patterns are suitable for frame synchronization since by simply adding autocorrelation functions of such sequences, we can obtain double maximum correlation values equal in magnitude and opposite polarity at zero and middle shifts. This property can be used to double-check frame synchronization timing and reduce the synchronization search time. We would like the proposed pilot patterns to be added to 3GPP RAN S1.11.

1. Introduction

Matched filtering or correlation to the known frame synchronization word are optimum methods for establishing initial synchronization. A matched filter or correlator to the known pilot pattern looks for exceedence of a predetermined threshold. When this occurs, frame synchronization is established. Thus, choosing pilot patterns that have good autocorrelation property is very important.

This document proposes a set of pilot patterns that have the lowest out-of-phase values of the autocorrelation function with the two peak values equal in magnitude and opposite in polarity at zero and middle shifts [1] for frame synchronization words on Uplink DPCCH, Downlink DPCCH, and Secondary CCPCH channels [2]. We show that the proposed sequences are suitable for frame synchronization since we can obtain double maximum correlation values equal in magnitude and opposite polarity at zero and middle shifts by adding autocorrelation functions of the patterns proposed. This correlation property can be used to double-check frame synchronization timing and reduce the synchronization search time.

2. Background

Table 1 denotes 16 sequences and their autocorrelation functions with two peak values equal in magnitude and opposite in polarity at zero and middle shifts.

Table 1. 16 sequences that have the lowest out-of-phase values of the autocorrelation function with the two peak values equal in magnitude and opposite in polarity at zero and middle shifts.

Sequence	Autocorrelation
C_1 = (1 1 0 1 1 1 1 1 0 0 1 0 0 0 0 0)	16 4 0 4 0 -4 0 -4 -16 -4 0 -4 0 4 0 4
C_2 = (1 0 0 0 1 0 1 0 0 1 1 1 0 1 0 1)	16 -4 0 -4 0 4 0 4 -16 4 0 4 0 -4 0 -4
C_3 = (1 1 1 1 1 0 1 1 0 0 0 0 0 1 0 0)	16 4 0 4 0 -4 0 -4 -16 -4 0 -4 0 4 0 4
C_4 = (0 1 0 1 0 0 0 1 1 0 1 0 1 1 1 0)	16 -4 0 -4 0 4 0 4 -16 4 0 4 0 -4 0 -4
C_5 = (0 0 1 1 1 0 1 1 1 1 0 0 0 1 0 0)	16 4 0 -4 0 4 0 -4 -16 -4 0 4 0 -4 0 4
C_6 = (0 0 1 0 0 1 0 1 1 1 0 1 1 0 1 0)	16 -4 0 4 0 -4 0 4 -16 4 0 -4 0 4 0 -4
C_7 = (0 1 1 1 0 0 0 0 1 0 0 0 1 1 1 1)	16 4 0 -4 0 4 0 -4 -16 -4 0 4 0 -4 0 4
C_8 = (1 0 1 1 1 0 1 0 0 1 0 0 0 1 0 1)	16 -4 0 4 0 -4 0 4 -16 4 0 -4 0 4 0 -4
C_9 = (0 0 1 1 0 1 1 1 1 1 0 0 1 0 0 0)	16 4 0 4 0 -4 0 -4 -16 -4 0 -4 0 4 0 4
C_{10} =(0 0 1 0 1 0 0 1 1 1 0 1 0 1 1 0)	16 -4 0 -4 0 4 0 4 -16 4 0 4 0 -4 0 -4
C_{11} =(1 1 0 0 0 0 0 1 0 0 1 1 1 1 1 0)	16 4 0 4 0 -4 0 -4 -16 -4 0 -4 0 4 0 4
C_{12} =(1 0 1 1 1 0 0 1 0 1 0 0 0 1 1 0)	16 -4 0 -4 0 4 0 4 -16 4 0 4 0 -4 0 -4
C_{13} =(0 1 0 0 0 0 1 1 1 0 1 1 1 1 0 0)	16 4 0 -4 0 4 0 -4 -16 -4 0 4 0 -4 0 4
C_{14} =(1 0 0 0 1 0 0 1 0 1 1 1 0 1 1 0)	16 -4 0 4 0 -4 0 4 -16 4 0 -4 0 4 0 -4
C_{15} =(0 0 0 0 1 0 0 0 1 1 1 1 0 1 1 1)	16 4 0 -4 0 4 0 -4 -16 -4 0 4 0 -4 0 4
C_{16} =(1 0 0 1 0 0 0 1 0 1 1 0 1 1 1 0)	16 -4 0 4 0 -4 0 4 -16 4 0 -4 0 4 0 -4

The 16 sequences can be divided into 4 classes according to the autocorrelation function as follows :

E = $\{C_1, C_3, C_9, C_{11}\}$

F = $\{C_2, C_4, C_{10}, C_{12}\}$

G = $\{C_5, C_7, C_{13}, C_{15}\}$

H = $\{C_6, C_8, C_{14}, C_{16}\}$

Table 2 denotes the autocorrelation functions of sequences of the classes E, F, G, and H. From table 1 and 2, we find that each class contains four sequences, and sequences of the same class have the same autocorrelation function.

Table 2. Autocorrelation functions of sequences of the classes E, F, G, and H.

$R(\tau)$ τ	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$R_E(\tau)$	16	4	0	4	0	-4	0	-4	-16	-4	0	-4	0	4	0	4
$R_F(\tau)$	16	-4	0	-4	0	4	0	4	-16	4	0	4	0	-4	0	-4
$R_G(\tau)$	16	4	0	-4	0	4	0	-4	-16	-4	0	4	0	-4	0	4
$R_H(\tau)$	16	-4	0	4	0	-4	0	4	-16	4	0	-4	0	4	0	-4

We find the following relationships between the four autocorrelation functions:

$$R_E(t) = R_F(t) = R_G(t) = R_H(t)\ ,\ t \text{ is even} \tag{1}$$

$$R_E(t) = -R_F(t)\ ,\ t \text{ is odd} \tag{2}$$

$$R_G(t) = -R_H(t)\ ,\ t \text{ is odd} \tag{3}$$

$$R_i(\tau) + R_i(t+8) = 0\ ,\ i \in \{E,F,G,H\}, \text{ for all } t \tag{4}$$

From (1), (2), and (3), we can easily obtain the following equation.

$$R_E(t) + R_F(t) = R_G(t) + R_H(t)\ , \text{ for all } t \tag{5}$$

The addition of two autocorrelation functions $R_E(t)$ and $R_F(t)$, or $R_G(t)$ and $R_H(t)$ becomes the correlation with two peak values equal in magnitude and opposite in polarity at zero and middle shifts, which is depicted in figure 1. The other combinations such as ($R_E(t)$ + $R_G(t)$), ($R_E(t)$ + $R_H(t)$), ($R_F(t)$ + $R_G(t)$), and ($R_F(t)$ + $R_H(t)$) do not have the same correlation as in Fig. 1. Since the addition of two autocorrelation functions $R_E(t)$ and $R_F(t)$, or $R_G(t)$ and $R_H(t)$ becomes the correlation function of figure 1, sequence pair from two classes E and F, or G and H is called the PCSP (Preferred Correlation Sequence Pair).

Fig. 1. Addition of two autocorrelation functions $R_E(t)$ and $R_F(t)$, or $R_G(t)$ and $R_H(t)$.

The addition of the four autocorrelation functions becomes figure 2, which is the same as figure 1 except the fact that the maximum value is doubled since $(R_E(t) + R_F(t) + R_G(t) + R_H(t)) = 2\,(R_E(t) + R_F(t))$.

Fig. 2. Addition of four autocorrelation functions $R_E(t)$, $R_F(t)$, $R_G(t)$, and $R_H(t)$.

This correlation property is very important for frame synchronization since it allows us to double-check synchronization timing and reduce the synchronization search time.

3. Pilot patterns for Uplink DPCCH, Downlink DPCCH, and Secondary CCPCH.

3.1 Uplink DPCCH

Table 3 shows the proposed new pilot patterns which can be used for frame synchronization for Uplink DPCCH with N_{pilot2}=6 and 8. The shadowed parts of the table 3 can be used for frame synchronization words, and the value of pilot bit other than the frame synchronization word is "1". Table 4 describes the mapping relationship between the 16 sequences of table 1 and shadowed column pilot patterns of table 3. We know that the sequences C_1 and C_3 are the elements of the set E and the sequences C_2 and C_4 are the elements of F. And the two sequence pairs (C_1, C_2) and (C_3, C_4) are PCSPs.

Table 3. New pilot bit patterns for Uplink DPCCH with N_{pilot2}=6 and 8.

	N_{pilot2} = 6						N_{pilot2} = 8							
Bit #	0	1	2	3	4	5	0	1	2	3	4	5	6	7
Slot #1	1	1	1	1	1	0	1	1	1	1	1	1	1	0
2	1	1	0	1	1	1	1	1	1	0	1	1	1	1
3	1	0	0	1	1	0	1	0	1	0	1	1	1	0
4	1	1	0	1	1	1	1	1	1	0	1	1	1	1
5	1	1	1	1	1	0	1	1	1	1	1	1	1	0
6	1	1	0	1	0	0	1	1	1	0	1	0	1	0
7	1	1	1	1	1	0	1	1	1	1	1	1	1	0
8	1	1	0	1	1	1	1	1	1	0	1	1	1	1
9	1	0	0	1	0	1	1	0	1	0	1	0	1	1
10	1	0	1	1	0	0	1	0	1	1	1	0	1	0
11	1	1	1	1	0	1	1	1	1	1	1	0	1	1
12	1	0	1	1	0	0	1	0	1	1	1	0	1	0
13	1	0	0	1	0	1	1	0	1	0	1	0	1	1
14	1	0	1	1	1	1	1	0	1	1	1	1	1	1
15	1	0	0	1	0	1	1	0	1	0	1	0	1	1
16	1	0	1	1	0	0	1	0	1	1	1	0	1	0

Table 4. Mapping relationship between the 16 sequences of table 1 and shadowed column pilot patterns of table 3 for Uplink DPCCH

N_{pilots}	Pilot bit position #	Corresponding column sequence of length 16
6	1	C_1
	2	C_2
	4	C_3
	5	C_4
8	1	C_1
	3	C_2
	5	C_3
	7	C_4

By using the derived properties of the proposed pilot patterns from the previous section, we find that

$$\sum_{i=1}^{2a} R_i(t) = a \cdot (R_E(t) + R_F(t)), 1 \leq a \leq 8 \qquad (6)$$

where $R_i(t)$ is the autocorrelation function of sequence C_i , $1 \leq i \leq 16$. We obtain Fig. 1 and Fig. 2 by letting α = 1 and 2 of (6), respectively. This enables us to double-check frame synchronization timing and reduce the synchronization time.

3.2 Downlink DPCCH

Table 5 shows the proposed new pilot patterns which can be used for frame synchronization for Uplink DPCCH with 8, 16, 32, 64, 128, 256, 512, and 1024ksps. And table 6 shows the proposed new pilot patterns which can be used for frame synchronization for Uplink DPCCH with 2048 and 4096ksps. The shadowed parts of the tables can be used for frame synchronization words, and the value of pilot bit other than the frame synchronization word is "1". Table 7 describes the mapping relationship between the 16 sequences of table 1 and shadowed column pilot patterns of table 5 and 6. Similarly, by using the autocorrelation property of proposed pilot patterns and equation (6), we can double-check frame synchronization timing and reduce the frame synchronization search time.

Table 5. New pilot symbol patterns for Downlink DPCCH with 8, 16, 32, 64, 128, 256, 512, and 1024ksps

Symbol rate	8ksps		16,32,64,128ksps				256,512,1024ksps							
Symbol #	0	1	0	1	2	3	0	1	2	3	4	5	6	7
Slot # 1	11	11	11	11	11	10	11	11	11	10	11	00	11	01
2	11	10	11	10	11	11	11	10	11	11	11	00	11	10
3	11	00	11	00	11	10	11	00	11	10	11	11	11	11
4	11	10	11	10	11	11	11	10	11	11	11	10	11	11
5	11	11	11	11	11	10	11	11	11	10	11	10	11	01
6	11	10	11	10	11	00	11	10	11	00	11	01	11	00
7	11	11	11	11	11	10	11	11	11	10	11	10	11	01
8	11	10	11	10	11	11	11	10	11	11	11	11	11	00
9	11	00	11	00	11	01	11	00	11	01	11	11	11	10
10	11	01	11	01	11	00	11	01	11	00	11	11	11	01
11	11	11	11	11	11	01	11	11	11	01	11	00	11	00
12	11	01	11	01	11	00	11	01	11	00	11	01	11	00
13	11	00	11	00	11	01	11	00	11	01	11	01	11	10
14	11	01	11	01	11	11	11	01	11	11	11	10	11	11
15	11	00	11	00	11	01	11	00	11	01	11	01	11	10
16	11	01	11	01	11	00	11	01	11	00	11	00	11	11

Table 6. New pilot symbol patterns for Downlink DPCCH with 2048 and 4096ksps

Symbol rate	2048,4096ksps															
Symbol #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Slot # 1	11	11	11	10	11	00	11	01	11	00	11	11	11	01	11	01
2	11	10	11	11	11	00	11	10	11	00	11	10	11	10	11	00
3	11	00	11	10	11	11	11	11	11	11	11	01	11	00	11	00
4	11	10	11	11	11	10	11	11	11	10	11	01	11	00	11	01
5	11	11	11	10	11	10	11	01	11	01	11	01	11	01	11	10
6	11	10	11	00	11	01	11	00	11	10	11	00	11	00	11	00
7	11	11	11	10	11	10	11	01	11	10	11	00	11	10	11	00
8	11	10	11	11	11	11	11	00	11	11	11	11	11	11	11	01
9	11	00	11	01	11	11	11	10	11	11	11	00	11	10	11	10
10	11	01	11	00	11	11	11	01	11	11	11	01	11	01	11	11
11	11	11	11	01	11	00	11	00	11	00	11	10	11	11	11	11
12	11	01	11	00	11	01	11	00	11	01	11	10	11	11	11	10
13	11	00	11	01	11	01	11	10	11	10	11	10	11	10	11	01
14	11	01	11	11	11	10	11	11	11	01	11	11	11	11	11	11
15	11	00	11	01	11	01	11	10	11	01	11	11	11	01	11	11
16	11	01	11	00	11	00	11	11	11	00	11	00	11	00	11	10

Table 7. Mapping relationship between the 16 sequences of table 1 and shadowed column pilot patterns of table 5 for Downlink DPCCH with 8, 16, 32, 64, 128, 256, 512, 1024, 2048, and 4096ksps

Symbol rate	Symbol #	Channel	Corresponding column sequence of length 16
8ksps	1	I-CH	C_1
		Q-CH	C_2
16, 32, 64, 128ksps	1	I-CH	C_1
		Q-CH	C_2
	3	I-CH	C_3
		Q-CH	C_4
256, 512, 1024ksps	1	I-CH	C_1
		Q-CH	C_2
	3	I-CH	C_3
		Q-CH	C_4
	5	I-CH	C_5
		Q-CH	C_6
	7	I-CH	C_7
		Q-CH	C_8
2048, 4096ksps	1	I-CH	C_1
		Q-CH	C_2
	3	I-CH	C_3
		Q-CH	C_4
	5	I-CH	C_5
		Q-CH	C_6
	7	I-CH	C_7
		Q-CH	C_8
	9	I-CH	C_9
		Q-CH	C_{10}
	11	I-CH	C_{11}
		Q-CH	C_{12}
	13	I-CH	C_{13}
		Q-CH	C_{14}
	15	I-CH	C_{15}

		Q-CH	C_{16}

3.2 Secondary CCPCH

Table 8 shows the proposed new pilot patterns which can be used for frame synchronization for Secondary CCPCH. The shadowed parts of the table can be used for frame synchronization words, and the value of pilot bit other than the frame synchronization word is “1”. Table 9 shows the mapping between the 16 sequences of table 1 and shadowed column pilot patterns of table 8. Similarly, by using the derived property of PCSP, we can double-check frame synchronization timing and reduce the frame synchronization search time.

Table 8. New pilot symbol patterns for Secondary CCPCH

Symbol #	0	1	2	3
Slot #1	11	11	11	10
2	11	10	11	11
3	11	00	11	10
4	11	10	11	11
5	11	11	11	10
6	11	10	11	00
7	11	11	11	10
8	11	10	11	11
9	11	00	11	01
10	11	01	11	00
11	11	11	11	01
12	11	01	11	00
13	11	00	11	01
14	11	01	11	11
15	11	00	11	01
16	11	01	11	00

Table 9. Mapping relationship between the 16 sequences of table 1

and shadowed column pilot patterns of table 8.

Symbol #	Channel	Corresponding column sequence of length 16
1	I-CH	C_1
	Q-CH	C_2
3	I-CH	C_3
	Q-CH	C_4

4. Conclusion

This document proposed a new set of pilot patterns for the Uplink DPCCH, Downlink DPCCH, and Secondary CCPCH. We showed that the proposed sequences are especially suitable for frame synchronization word of the channels since by adding the autocorrelation functions of PCSP of proposed sequences, we can obtain double maximum correlation values equal in magnitude and opposite polarity at zero and middle shifts. This property can be used to double-check frame synchronization timing and reduce the synchronization search time.

5. Reference

[1] Y. J. Song, Y. Y. Han, and O. H. Jeong, "Synchronization Sequence Design with Double Thresholds for Digital Cellular Telephone", *ICEIC'98*, Yanbian, China, Aug. 18-20, 1998.

[2] "UTRA FDD ; Transport Channels and Physical Channels", 3GPP RAN S1.11 v0.0.1 (1999-02).