Reconstruction of Optimal Correlation Property for Frame Synchronization

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Abstract. Compressed mode is needed when making measurements from another frequency in a CDMA (Code Division Multiple Access) system without a full dual receiver terminal. In 3GPP (3^{rd} Generation Partnership Project) W-CDMA (Wideband Code Division Multiple Access) system, the FSW (Frame Synchronization Word) of time multiplexed pilot bit patterns are used for frame synchronization. Among the pilot bit patterns there are special relationships, and using this we can reconstruct the optimal frame synchronization property in compressed mode. Using this principle, we can improve the synchronization performance in a lossy channel environment since compressed mode means that transmission and reception are halted for a certain period of time.

Keywords: Compressed mode, CDMA, frame synchronization, lossy channel

1 Introduction

The pilot bit patterns in W-CDMA (Wideband Code Division Multiple Access) system are time multiplexed. The pilot bits are also used for frame synchronization, and thus the patterns are also called FSW (Frame Synchronization Word) [1]-[2]. If the autocorrelation function of a sequence has double maximum values equal in magnitude and opposite polarity at zero and middle shifts, and further if the function has the lowest out-of-phase values except for at middle shift, then such a sequence is said to have “optimal frame synchronization property”. The pilot bit patterns in W-CDMA system are designed to have “optimal frame synchronization property” [2]. Since Wolfmann’s “almost perfect autocorrelation sequences” exists only for the length of multiple of 4 [3], these are not suitable for frame synchronization in W-CDMA system.

The compressed mode where up to 7 slots per one 10msec frame are not transmitted to make measurements from another frequency in a CDMA system without a full dual receiver terminal [1]. In this paper, we show a method to maintain optimal frame synhronization property in the compressed mode. This principle can be applied to a lossy channel environment where one or more slots can be erased.

2 Compressed Mode

W-CDMA System employs a compressed mode when making measurement from another frequency without a full dual receiver terminal. In this case, maximum 7 slots per frame can be punctured to measure communication systems (e.g. GSM: Global System for Mobile Communications) with different frequency. The compressed mode means that transmission and reception are halted for a short time, in the order of a few milliseconds, in order to perform measurements on the other frequencies [1]. In compressed frames, TGL (Transmission Gap Length) slots from N_{first} to N_{last} are not used for transmission of data. As illustrated in figure 1, the instantaneous transmit power is increased in the compressed frame in order to keep the quality (bit error rate, frame error rate, etc.) unaffected by the reduced processing gain. The maximum idle length is defined to be 7 slots per one 10 msec frame.

3 Reconstruction of Correlation Property

Table 1 shows 8 different pilot bit patterns whose length is equal to the number of slots per frame of W-CDMA system [2]. The pilot bit patterns are also called FSW (Frame Synchronization Words) as they can be used for frame synchronization. They all have the same two-valued ideal auto-correlation property. $\mathbf{S}_i = (s_{i,0}, s_{i,1}, \cdots, s_{i,14})$, $i = 1, \cdots, 8$, can be divided into 4 classes

$$E = \{\boldsymbol{S}_1, \boldsymbol{S}_2\}$$
$$F = \{\boldsymbol{S}_3, \boldsymbol{S}_4\}$$
$$G = \{\boldsymbol{S}_5, \boldsymbol{S}_6\}$$
$$H = \{\boldsymbol{S}_7, \boldsymbol{S}_8\}$$

and have the following relationships:

$$\chi(s_{i,z(\mathrm{mod}15)}) = -\chi(s_{i+1,(z+7)\,\mathrm{mod}15}) \tag{5}$$

$$\chi(s_{i+1,z(\mathrm{mod}15)}) = -\chi(s_{i,(z+8)\,\mathrm{mod}15}) \tag{6}$$

where $i = 1,3,5,7$ and z is an integer [2]. Table 2 is the relationship between pilot bit patterns in W-CDMA system when the number of pilot bits per slot is N_{pilot} = 6. From this we confirm the relationship between pilot bit patterns. To maintain the desired property in compressed mode, we will use the relationship between FSWs in the same class E, F, G, and H. We can properly reconstruct frame synchronization words in compressed mode using the relationships of (5) and (6) as illustrated in figure 1. When using single frame method, the transmission gap is located within the compressed frame depending on the TGL (Transmission Gap Length). When using double frame method, the transmission gap is located on the center of two connected frames as sown in Fig. 1. In the case of double frame method, N_{first} and TGL must be chosen so that at least 8 slots in each radio frame are transmitted [1]. For example, in compressed mode assume pilot bit patterns from slot #5 to 11 are not transmitted. Then the erased pilot bits $s_{1,5}$ ~ $s_{1,11}$ are easily recovered from the second pilot bits $s_{2,12}$ ~ $s_{2,14}$. Similarly, the erased part of pilot bits $s_{2,5}$ ~ $s_{2,11}$ are recovered from the pilot bits $s_{1,13}$ ~ $s_{1,14}$ and $s_{1,0}$ ~ $s_{1,4}$.

This principle can be applied to a lossy channel environment where one or more slots can be erased.

Table 1. Pilot Bit Patterns in W-CDMA system

Class	Pilot Bit Patterns
E	$\boldsymbol{S}_1$ = (100011110101100) $\boldsymbol{S}_2$ = (101001101110000)
F	$\boldsymbol{S}_3$ = (110001001101011) $\boldsymbol{S}_4$ = (001010000111011)
G	$\boldsymbol{S}_5$ = (111010110010001) $\boldsymbol{S}_6$ = (110111000010100)
H	$\boldsymbol{S}_7$ = (100110101111000) $\boldsymbol{S}_8$ = (000011101100101)

Table 2. Relationship between pilot bit patterns in W-CDMA system

		$N_{pilot} = 6$					
Bit #		0	1	2	3	4	5
Frame #K	Slot #0	1	$s_{1,0}=\bar{s}_{2,7}$	$s_{2,0}=\bar{s}_{1,8}$	1	$s_{3,0}=\bar{s}_{4,7}$	$s_{4,0}=\bar{s}_{3,8}$
	1	1	$s_{1,1}=\bar{s}_{2,8}$	$s_{2,1}=\bar{s}_{1,9}$	1	$s_{3,1}=\bar{s}_{4,8}$	$s_{4,1}=\bar{s}_{3,9}$
	2	1	$s_{1,2}=\bar{s}_{2,9}$	$s_{2,2}=\bar{s}_{1,10}$	1	$s_{3,2}=\bar{s}_{4,9}$	$s_{4,2}=\bar{s}_{3,10}$
	3	1	$s_{1,3}=\bar{s}_{2,10}$	$s_{2,3}=\bar{s}_{1,11}$	1	$s_{3,3}=\bar{s}_{4,10}$	$s_{4,3}=\bar{s}_{3,11}$
	4	1	$s_{1,4}=\bar{s}_{2,11}$	$s_{2,4}=\bar{s}_{1,12}$	1	$s_{3,4}=\bar{s}_{4,11}$	$s_{4,4}=\bar{s}_{3,12}$
	5	1	$s_{1,5}=\bar{s}_{2,12}$	$s_{2,5}=\bar{s}_{1,13}$	1	$s_{3,5}=\bar{s}_{4,12}$	$s_{4,5}=\bar{s}_{3,13}$
	6	1	$s_{1,6}=\bar{s}_{2,13}$	$s_{2,6}=\bar{s}_{1,14}$	1	$s_{3,6}=\bar{s}_{4,13}$	$s_{4,6}=\bar{s}_{3,14}$
	7	1	$s_{1,7}=\bar{s}_{2,14}$	$s_{2,7}=\bar{s}_{1,0}$	1	$s_{3,7}=\bar{s}_{4,14}$	$s_{4,7}=\bar{s}_{3,0}$
	8	1	$s_{1,8}=\bar{s}_{2,0}$	$s_{2,8}=\bar{s}_{1,1}$	1	$s_{3,8}=\bar{s}_{4,0}$	$s_{4,8}=\bar{s}_{3,1}$
	9	1	$s_{1,9}=\bar{s}_{2,1}$	$s_{2,9}=\bar{s}_{1,2}$	1	$s_{3,9}=\bar{s}_{4,1}$	$s_{4,9}=\bar{s}_{3,2}$
	10	1	$s_{1,10}=\bar{s}_{2,2}$	$s_{2,10}=\bar{s}_{1,3}$	1	$s_{3,10}=\bar{s}_{4,2}$	$s_{4,10}=\bar{s}_{3,3}$
	11	1	$s_{1,11}=\bar{s}_{2,3}$	$s_{2,11}=\bar{s}_{1,4}$	1	$s_{3,11}=\bar{s}_{4,3}$	$s_{4,11}=\bar{s}_{3,4}$
	12	1	$s_{1,12}=\bar{s}_{2,4}$	$s_{2,12}=\bar{s}_{1,5}$	1	$s_{3,12}=\bar{s}_{4,4}$	$s_{4,12}=\bar{s}_{3,5}$
	13	1	$s_{1,13}=\bar{s}_{2,5}$	$s_{2,13}=\bar{s}_{1,6}$	1	$s_{3,13}=\bar{s}_{4,5}$	$s_{4,13}=\bar{s}_{3,6}$
	14	1	$s_{1,14}=\bar{s}_{2,6}$	$s_{2,14}=\bar{s}_{1,7}$	1	$s_{3,14}=\bar{s}_{4,6}$	$s_{4,14}=\bar{s}_{3,7}$

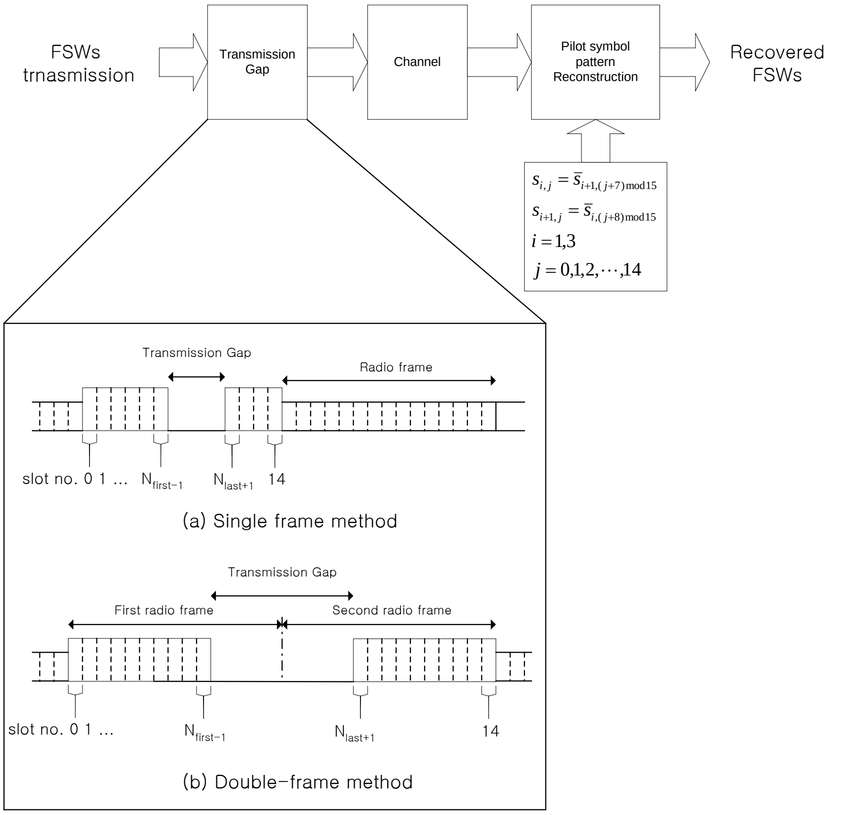

Fig. 1. Reconstruction process of frame synchronization words in pilot bit patterns.

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