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RESEARCH OF FRAME SYNCHRONIZATION TECHNOLOGY BASED ON PERFECT PUNCTURED BINARY SEQUENCE PAIRS

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Abstract. Synchronization technology is crucial in wireless communication. The Communication proceeds effectively depending on the availability of good synchronization system. The probability of missing synchronization and false synchron1zation, and frame synchronization time are the main factors to influence the performance of synchronization. In the paper, the properties and combinatorial admissibility conditions about the almost perfect punctured binary sequence pairs are studied. In order to compare with the length of Barker code in synchronization performance, the application model is established. The simulation results show that the perfect punctured binary sequence pairs' performance of synchronization is better than Barker codes.

1. INTRODUCTION

In digital communication system, frame synchronization is necessary in order to guarantee the consistency of receiving terminal and sending terminal [1,2]. The basic method to realize frame synchronization is to insert a set of specific synchronization codes in digital frame of sending terminal and then to capture, test and decode synchronization codes of the input code sequences using setting synchronization method at receiving terminal. The frame synchronization system is established in a short time and has a great anti-interference property. Due to noise and interference, some mistakes of code element in frame synchronization may be induced, thus causing missing synchronization phenomenon, that is, the identifier misses the sent frame synchronization codes [3]. The code elements in information code element may be the same with ones in identified frame synchronization codes, and then the identifier will treat them as the same elements mistakenly, thus causing false synchronization phenomenon. The probability of missing synchronization and false synchron1zation, and frame synchronization time are the main factors to influence the performance of the synchronization.

In wireless communication, it is very easy for frame synchronization codes in attenuation channel to be destroyed, bringing about missing synchronization phenomenon. In order to solve the above problems, a new frame synchronization method has been put forward. This method is named by perfect punctured binary sequence pairs [4,5]. The concrete procedures are as follows: 1) from punctured binary signal pairs in the sending terminal of communication system a signal is selected at random as the transmitting signal; 2) another signal in punctured binary signal pairs is chosen as local signal of the receiving terminal; 3) by calculating autocorrelation function of punctured binary signal pairs, the information extraction has been realized.

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In additive Gauss channel, the simulation experiment for the same length of Barker codes and perfect binary sequence pairs have been made. The simulation results show that the perfect punctured binary sequence pairs' performance of synchronization was better than Barker codes'.

2. DEFINITIONS AND PROPERTIES OF PERFECT PUNCTURED BINARY SEQUENCE PAIRS [6,7]

The p–numbered punctured sequence $y = (y_0, y_1,\ldots, y_{N-1})$ of the sequence $x = (x_0, x_1, \ldots, x_{N-1})$ is

$$y_j = \begin{cases} 0 & j \in p \text{ punctured number(s)} \\ x_j & j \in N - p \text{ non-punctured number} \end{cases}, \quad (1)$$

in which P is the punctured number of the x sequence. If $x_j = \{-1,+1\}$, then the element of the punctured sequence $y_j = \{-1,0,+1\}$, with (x, y) called the punctured binary sequence pairs.

Definition 1: The periodic autocorrelation function of punctured sequence pairs (x, y), $R_{xy}(m)$ is

$$R_{xy}(m) = \sum_{j=0}^{N-1} x_j y_{j+m}, \ \ 0 \le m \le N-1. \quad (2)$$

If the following conditions can be satisfied in $R_{xy}(m)$

$$R_{xy}(m) = \begin{cases} E & m \equiv 0 \bmod N \\ 0 & other \end{cases}. \quad (3)$$

It can be obtained that binary sequence pairs (x,y) have p periodic perfect punctured binary sequence pairs, shortened as the perfect punctured binary sequence pairs.

Definition 2: The balance degree of sequence x can be defined as follows,

$$I = \sum_{j=0}^{N-1} x_j = n_p - n_n, \quad (4)$$

in which np and nn are the number of "+1" and "–1" in the sequence x.

If sequence (x,y) is the perfect punctured binary sequence pairs, it has the following properties.

1) If the mapping property $x_1(i)$ is equal to $x(-i)$ and $y_1(i)$ is equal to $y(-i)$, the punctured binary sequence pairs (x_1,y_1) is the perfect punctured binary sequence pairs.

2) If $x_1(i)$ is equal to $-x(i)$ and $y_1(i)$ is equal to $-y(i)$, the punctured binary sequence pairs (x_1, y_1) is the perfect punctured binary sequence pairs.

3) If circular shift $x_1(i)$ is equal to $x(i+u)$ and $y_1(i)$ is equal to $y(i+u)$, the punctured binary sequence pairs (x_1,y_1) is the perfect punctured binary sequence pairs.

3. SCANNING METHOD OF PERFECT PUNCTURED BINARY SEQUENCE PAIRS

For the punctured binary sequence, whose length is N and the punctured digital capacity is p, the sequence number will be $2^N C^P_N$. In order to improve computer's scanning efficiency and reduce scanning scope of sequence pairs, the following theorems are given firstly.

Theorem 1: If the punctured binary sequence pairs (x,y), whose length is N, is perfect punctured binary sequence pairs, the following formula can be obtained,

$$N - p = I^2 + \left(p_n - p_p\right) I, \quad (5)$$

in which p is the number of punctured location, I is the balance degree, pp and pn are the punctured number at +1 and –1 location, respectively. Therefore, formula (6) can be gotten.

$$p = p_p + p_n. \quad (6)$$

Theorem 2: If N, the length of binary sequence x, is even number, the balance degree I will be even number. And if N is odd number, I will be odd number.

Theorem 3: If the punctured binary sequence pairs (x,y), whose length is N, is perfect punctured binary sequence pairs and N is even number, the punctured number p will be even number. And if N is odd number, p will be odd number.

Theorem 4: If the punctured binary sequence pairs (x,y) is perfect punctured binary sequence pairs, the equations can be obtained as follows,

$$R_x(m) = \sum_{i=0}^{p-1} x_{j_i - m} x_{j_i}, \ \ m \ne 0 \bmod N, \quad (7)$$

$$R_x(m) \bmod 2 \equiv p \bmod 2, \quad (8)$$

in which j_i is the i-th punctured location,

Based on the above combinatorial conditions and properties of perfect binary sequence pairs, the scanning program of perfect binary sequence pairs has been developed [8]. The perfect binary sequence pairs, whose length is not greater than 31, have been found. The search results are showed in Table 1.

Note: the sequence is signified by octal method, in which the number "1" and "0" are signified as "+1"

Table 1. Perfect punctured binary sequence pairs.

Length	Sequence (octal)	Punctured location	Energy efficiency %
3	6	3	66.67
5	32	3 4 5	40.00
	34	2 4 5	
7	142	4 5 7	57.14
	164	4 6 7	
9	652	1 2 3 4 5 6 7	22.22
	760	1 2 3 4 6 7 8	
11	3426	4 5 6 8 11	54.54
	3550	4 7 9 10 11	
12	7426	1 6 7 12	66.67
	7550	4 5 10 11	
	7624	3 6 9 12	
13	16606	2 4 7 8 9 10 13	46.15
	17124	5 6 8 9 10 12 13	
15	74232	5 6 7 9 10 13 15	53.33
	75310	6 7 10 11 13 14 15	
17	351134	4 6 7 8 9 10 12 16 17	47.06
	372142	3 6 8 9 10 13 14 15 17	
19	1715412	5 6 9 12 13 14 15 17 19	52.63
20	3433330	2 5 6 7 8 9 12 15 16 17 18 19	40.00
	3610556	1 6 7 8 9 10 11 16 17 18 19 20	
21	7405316	2 5 6 7 8 9 11 13 14 16 17 20 21	38.10
	7563240	3 5 6 9 10 12 13 15 17 18 19 20 21	
23	37024632	6 7 8 9 11 13 14 17 18 21 23	52.17
	37263120	6 8 11 12 15 16 18 20 21 22 23	
28	1702164566	4 5 6 7 10 11 18 19 20 21 24 25	57.14
	1734164226	4 5 8 9 10 11 18 19 22 23 24 25	
	1740465534	4 6 7 9 10 13 18 20 21 23 24 27	
29	3556415302	4 7 11 13 14 15 16 19 20 21 24 25 26 27 29	48.28
	3642213634	5 7 8 9 11 12 14 15 16 18 23 24 26 28 29	
31	17053411166	5 6 7 9 11 15 16 17 18 20 21 23 24 28 31	51.61
	17464412730	6 7 10 12 13 15 16 17 18 20 22 26 29 30 31	

and “-1”, respectively and the punctured location is calculated from the left to the right.

4. ESTABLISHMENT OF SIMULATION MODEL

The routine frame synchronization method is Barker code [9], which is finite sequence of non-periodic sequence. Barker code’s local autocorrelation property is great and similar to false random sequence [10,11]. However, at present it has been found that Barker codes are less than 13 in odd number location [12]. Thus, it has brought about many limitations in practical application. The perfect punctured sequence pairs make up with Barker codes. So they have several advantages. On the one hand, synchronization sequence inserted at sending terminal and matching sequence at receiving terminal constitute even sequences. On the other hand, the number of the perfect punctured binary sequence pairs is more than Barker codes’. Consequently, the encryption function of the frame synchronization is obtained and synchronization scheme can be chosen in a larger range. Thus, the performance of synchronization can be realized ultimately. In this paper, QPSK modulation is taken

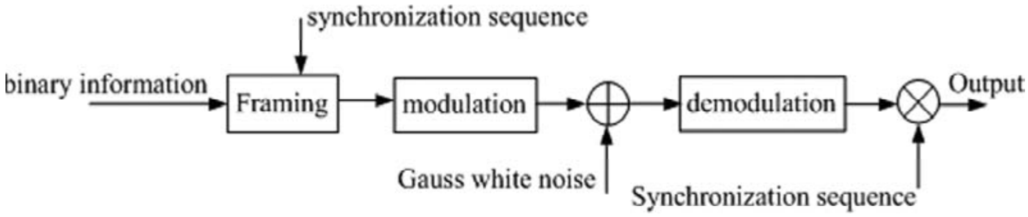

Fig. 1. Simulation model in additive channel.

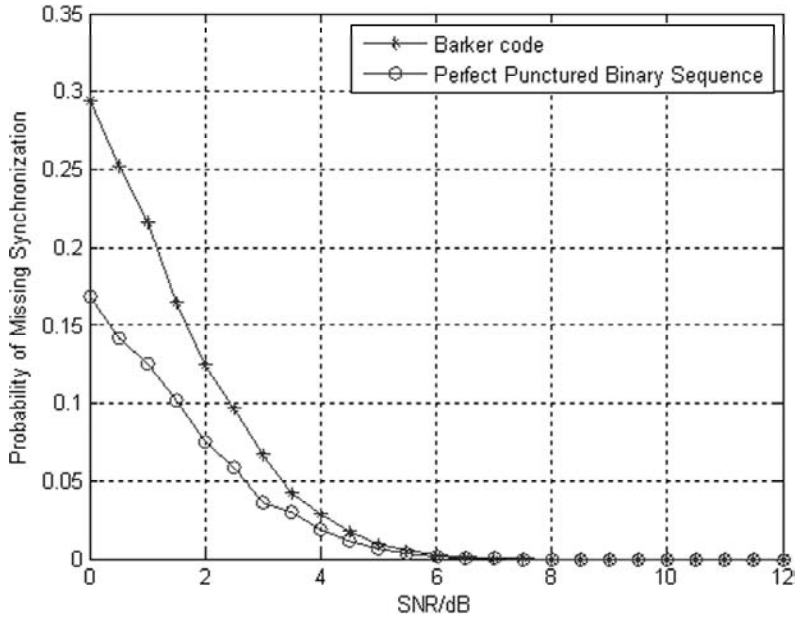

Fig. 2. Property comparison between Barker Code with the length 7 and the almost perfect punctured binary sequence pairs.

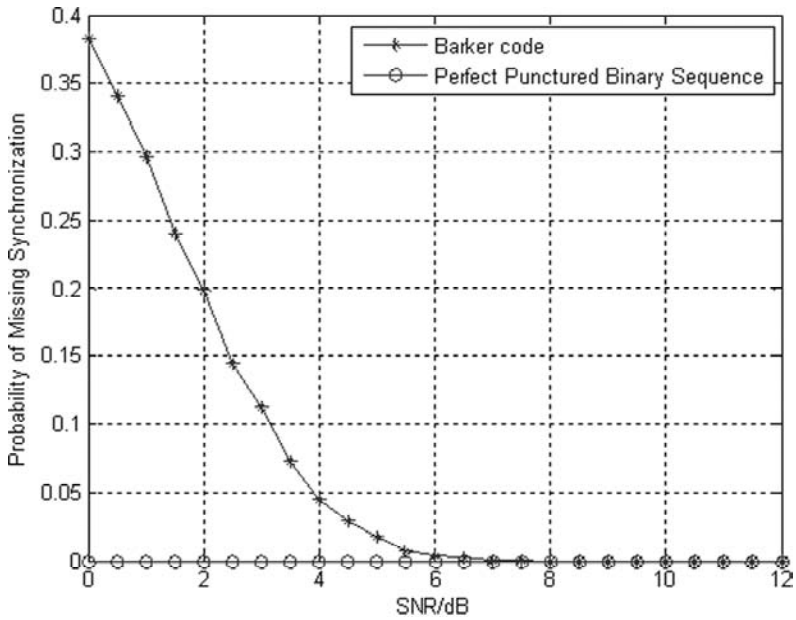

Fig. 3. Property comparison between Barker Code with the length 13 and the almost perfect punctured binary sequence pairs.

as an example [13]. The simulation model is established in Fig. 1.

The selected channel is AWGN one [14]. From the sequences with the length of 7 and 13, the sequence *x* is selected as frame synchronization codes at sending terminal and the sequence *y* is chosen as the correlative tested sequence at receiving terminal. In the sequence pairs with the length 7, the selected values *x* are +1, +1, -1, -1,-1,+1,-1 and *y* are 0, +1, 0, 0, -1, +1, and -1. That is, the punctured locations of the almost perfect binary sequence pairs are 4, 5, and 7. In the sequence with the length 13 the selected value is 16606 (octal) and the punctured locations of the almost perfect binary sequence pairs are 2, 4, 7, 8, 9, 10, and 13.

The simulation experiment for the same length of Barker codes and perfect binary sequence pairs have been made. The simulation results are as follows in Fig. 2 and Fig. 3.

5. CONCLUSION

If the ratio of signal to noise SNR is less than 4 [15], the probability of missing synchronization of perfect punctured binary sequence pairs is less than Barker codes' in the range of 0.02~0.16 and 0.03~0.31. That is to say, in the above condition the perfect punctured binary sequence pairs' performance of synchronization is better than Barker codes. However, if the ratio of signal to noise SNR is greater than 6db, the probability of missing synchronization of the perfect punctured binary sequence pairs is almost the same with Barker code's. The simulation results show that the perfect punctured binary sequence pairs' performance of synchronization was better than Barker codes'. Therefore, it will provide more choices for practical engineering application.

REFERENCES

[1] Yixian Yang, *Optimal signal theory and design* (Posts & Telecom Press, Beijing, 1996).

[2] Jinkang Zhu, *Extended frequency Spectrum Communication and Application* (Chinese Science and Technology University Press, Hefei, 1993).

[3] Zheng Xiaoyin and Li Zhengyu // *Journal of Northern Jiaotong University* **22** (1997) 13.

[4] Jian Ting and Zhao Xiaoqua // *Journal on Communications* **22** (2003) 9.

[5] Jangting, Hou Lantian, Zhao Xiaoqun and He Wenca // *Journal on Communications* **23** (2003) 117.

[6] He Wencai, Zhao Xiaoqun, Jia Shilou and Wang Zhongwen // *Chinese Journal of Electronics* **23** (1999) 52.[7] Xu Cheng Qian // *Chinese Journal of Electronics* **29** (2001) 88.

[8] K. Feng, Q. Xiang // *IEEE Transactions on Information Theory* (1999).

[9] Yang Guangzheng // *Chinese Journal of Electronics* **22** (1994) 54.

[10] Guozhen Xiao, Chuanjia Liang and Yuming Wang, *False Random Sequence and Application* (National Defense Industry Press, Beijing, 1985).

[11] Zhang Chuan-Wu, Cheng Xiang-Dong, Peng Qi-Cong // *Chinese Journal of Radio Science* **19** (2004) 18.

[12] Feng Guozhu, *The study of pseudorandom character of the primitive sequences and their highest-level* (National University of Defense Technology, Hunan, Changsha, 2001), p.50.

[13] Zhang Chongfu, *The key technologies study of Optical Code Division Multiple Access communications networks* (University of Electronic Science and Technology of China, Sichuan: Chengdu, 2004), p.80.

[14] Qiu Wanzhi, Xiao Diquan and He Janxin // *Journal of Chengdu University of Information Technology* **12** (1992) 25.

[15] Gao Liying, *On Shortest Linear Recurrence of Multi-sequences* (PLA Information Engineering University, Henan: Zhengzhou, 2001), p.50.