Blind Estimation of Frame Synchronization Patterns in Telemetry Signal

Byunghoon Oh, Jinwoo Jeong, Yeonsoo Jang, and Dongweon Yoon
Department of Electronic Engineering
Hanyang University
Seoul, Korea
elfinston5@hanyang.ac.kr, jhjeong@hanyang.ac.kr, ysjang83@hanyang.ac.kr and dwyoon@hanyang.ac.kr

***Abstract*— Telemetry signals are widely used in order to control electric equipment, collect information for launching satellites and for testing aircraft and guided weapons. In non-cooperative contexts, a blind estimation algorithm is essential to acquire data from telemetry signals. Generally, telemetry signals have a frame structure which consists of data words and a unique frame synchronization pattern. To obtain the telemetry signals blindly, we have to estimate the synchronization patterns in the frame structure first. In this paper, we propose a new algorithm for the estimation of frame synchronization patterns for the blind detection of telemetry signals and verify the proposed algorithm through computer simulations. By exploiting this algorithm, structures of unknown telemetry signals can be reconstructed.**

Keywords- detection and estimation; telemetry signal; frame synchronization.

I. INTRODUCTION

Telemetry signals containing data measurements made at distance [1] are commonly used in vehicles such as aircraft, missiles, automobiles, and satellites, and applied in various fields including space exploration, flight control, and traffic control systems [2]. For example, National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and other space agencies have used telemetry systems for the collection of data from spacecraft and satellites since telemetry signals can contain various measurements such as temperature, pressure and a radian level. Telemetry signals have a frame structure for transmitting each measurement as a single stream. Generally, the frame structure consists of data words and a unique synchronization pattern. Data words are composed of measurements, counters, commands, or other information. The synchronization pattern is a unique sequence for identifying each minor frame. To acquire the telemetry signals blindly, we first have to estimate the frame synchronization patterns in the frame structure.

In this paper, we propose an algorithm for the estimation of frame synchronization patterns for the blind detection of telemetry signals, and verify the proposed algorithm through computer simulations. With this algorithm, unknown telemetry signals can be reconstructed.

II. FRAME STRUCTURE OF THE TELEMETRY SYSTEM

There are various telemetry standards, such as IRIG 106, CCSDS 102.0-B-4, and PSS-04-106 [3-5]. Among these the standards, IRIG 106 is widely used in both military and commercial fields because it is made to ensure the interoperability in aeronautical telemetry application from Range Commanders Council [6]. In this paper we consider IRIG 106 as a telemetry standard in this paper.

Telemetry signals can be classified by the method of modulation: Pulse Code Modulation (PCM), Frequency Modulation (FM), and Pulse Amplitude Modulation (PAM). Among these schemes, PCM is widely used in telemetry systems because it has the advantages of better accuracy, greater dynamic range, and less noise than other schemes. In Chapter 4 of IRIG 106 standard [3], the PCM formats are divided into two classes, Class 1 and Class 2. Table 1 shows the specifications of the two classes, and Figure 1 depicts the frame structure of Class 1 [3].

TABLE I. SPECIFICATION OF CLASS 1 AND CLASS 2 IN IRIG 106

	Class 1	Class 2
Format change	X	O
Word length	4~32 bits	4~64 bits
Max. minor frame length	8192bits & 1024 words	16384 bits & 1024 words
Max. major frame length	256 minor frames	
Min. frame synchronization	16~33 consecutive bits	

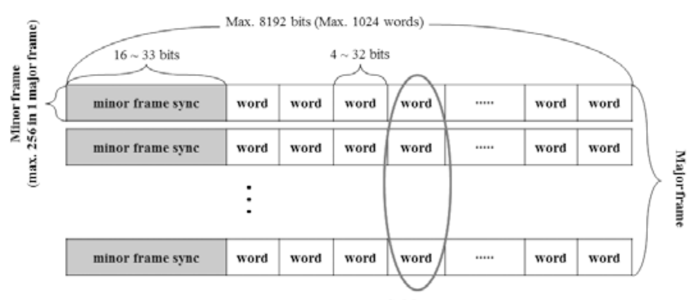

Figure 1. Frame structure of IRIG Class 1

 ISBN: 978-1-61208-245-5

As shown in Figure 1, the major frame structure of IRIG 106 Class 1 consists of up to 256 minor frames. Each minor frame has the maximum length of 8192 bits and 1024 words, and each word consists of 4 to 32 bits. Note that there is a minor frame synchronization(sync) pattern having 16 to 33 bits at the head or tail of each minor frame, and each minor frame sync pattern is also treated as a word in a minor frame. Table 2 shows the minor frame sync patterns of IRIG 106 Class 1. In a major frame, each minor frame has the same sync pattern.

TABLE II. MINOR FRAME SYNC PATTERNS OF IRIG 106 CLASS 1

Length	Sync Patterns
16	111 010 111 001 000 0
17	111 100 110 101 000 00
18	111 100 110 101 000 000
19	111 110 011 001 010 000 0
20	111 011 011 110 001 000 00
21	111 011 101 001 011 000 000
22	111 100 110 110 101 000 000 0
23	111 101 011 100 110 100 000 00
24	111 110 101 111 001 100 100 000
25	111 110 010 110 111 000 100 000 0
26	111 110 100 110 101 100 110 000 00
27	111 110 101 101 001 100 110 000 000
28	111 101 011 110 010 110 011 000 000 0
29	111 101 011 110 011 001 101 000 000 00
30	111 110 101 111 001 100 110 100 000 000
31	111 111 100 110 111 110 101 000 010 000 0
32	111 111 100 110 101 100 101 000 010 000 00
33	111 110 111 010 011 101 001 010 010 011 000

III. BLIND ESTIMATION OF FRAME SYNCHRONIZATION PATTERNS IN TELEMETRY SIGNALS

The length of minor frame in IRIG 106 Class 1 is up to 8192 bits, and one minor frame can have up to 1024 words with the same sync pattern at the same position. If we divide the unknown telemetry data sequence into data blocks having the estimated minor frame length of N_e and load the data blocks to a matrix $H(M,N_e)$ row by row, then we can make the matrix for the analysis of minor frame sync pattern as shown in Figure 2, where N_e is an arbitrarily chosen minor frame length, N_p is the original minor frame length, M is the numbers of rows in the matrix $H(M,N_e)$, and s is an integer.

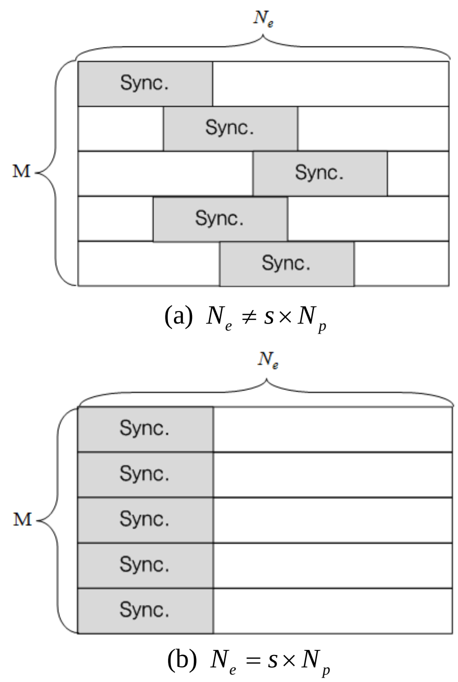

Figure 2. Matrix $H(M,N_e)$ for the estimation of minor frame sync pattern

In Figure 2, each matrix consists of sync patterns and words, where shaded areas represent sync patterns, and plain areas represent words. As shown in Figure 2 (a), when the arbitrarily chosen minor frame length N_e is not an integer multiple of the original minor frame length N_p, the sync patterns are not aligned in the same column in the matrix $H(M,N_e)$. On the other hand, if N_e is an integer multiple of N_p, as shown in Figure 2 (b), the sync patterns are aligned in the same column and the correlation between the rows can be seen in the matrix $H(M,N_e)$. If there is an equal bit sequence of the length over 16 bits in every row, we can find a sync pattern in the unknown telemetry data sequence.

Figure 3 depicts the matrix $H(M,N_e)$ constructed from an unknown telemetry data sequence with 16 bits minor frame sync pattern. As shown in Figure 3, if N_e is estimated to be the original minor frame length N_p, the 16 bits sync pattern is aligned in the same position in the matrix.

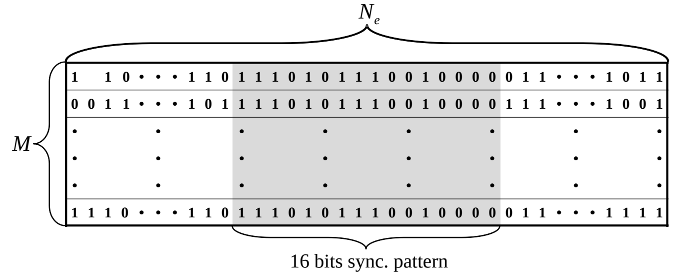

Figure 3. Matrix $H(M,N_e)$ including 16 bits sync Pattern

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To verify the equality of column bits in the 16 bits sync pattern, we change the data bit representations: zeros to -1 and one to 1 in Figure 3, and show the results in Figure 4.

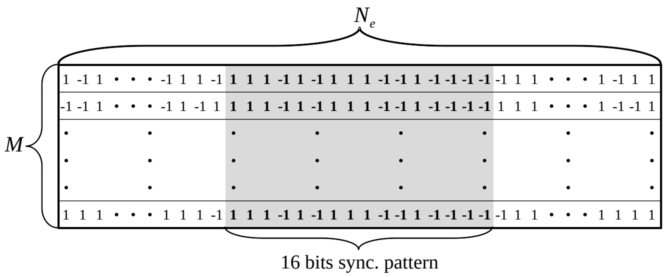


Figure 4. Matrix $H(M, N_e)$ after bit mapping

In Figure 4, if we estimate the sync pattern correctly, the column-wise sum of all data bits in the 16 bits sync pattern will be M or –M. In this case, if we take an absolute value for the sum, there are continuous 16 values equal to minor frame number M when the estimated frame length N_e is equal to the original frame length N_p as shown in Figure 5.

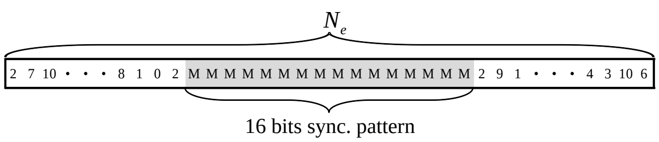


Figure 5. Absolute value of summation result when $N_e = N_p$

We summarize the overall process of blind estimation of minor frame length and sync pattern in Figure 6.

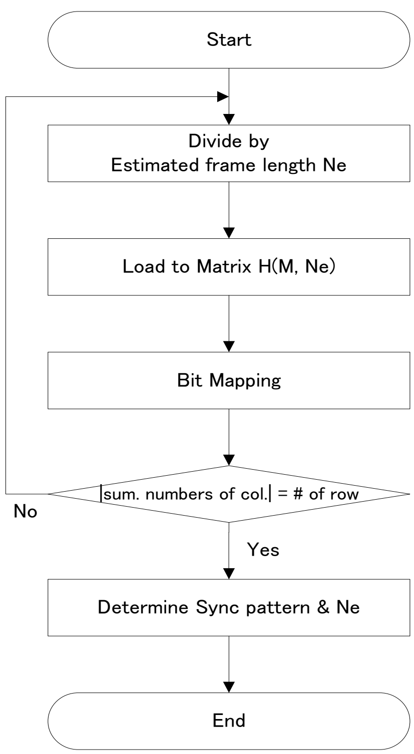


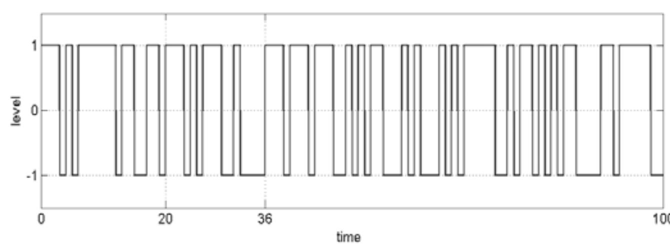
Figure 6. Blind estimation process of the minor frame length and sync pattern

As shown in Figure 6, we first divide the unknown telemetry data sequence into data blocks of the estimated minor frame length N_e and load the data blocks to the matrix $H(M, N_e)$ row by row. Then we map the data bits onto 1 or -1. If the absolute values of the column-wise sum of the matrix are equal to the number of divided data blocks through 16 consecutive columns, we can determine that the sequential bits in every row as a minor frame sync pattern and the estimated minor frame length N_e as the original minor frame length.

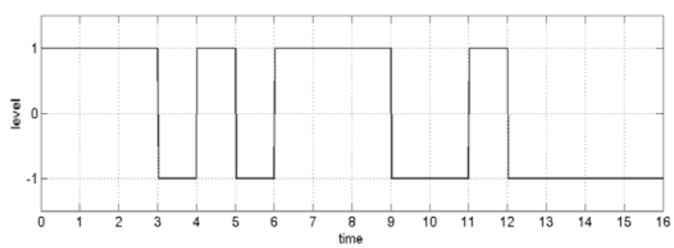
IV. SIMULATION RESULTS

For simulation of the algorithm, two telemetry data sequences depending on IRIG 106 Class1 are made. First telemetry data sequence has one major frame which consists of 128 minor frames. Each minor frame has the length of 1024 bits, and minor frame sync pattern of 16 bits. Second telemetry data sequence has one major frame which consists of 128 minor frames. Here, each minor frame has the length of 1024 bits, and minor frame sync pattern of 24 bits.

Figure 7 depicts a minor frame of the telemetry data sequence which has minor frame sync pattern of the length 16 bits and the estimated minor frame sync pattern.



(a) Data sequence of a minor frame

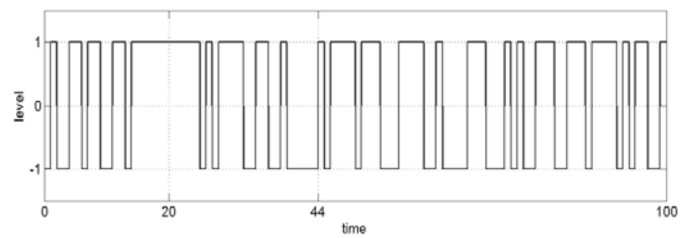


(b) Estimated minor frame sync pattern of 16 bits

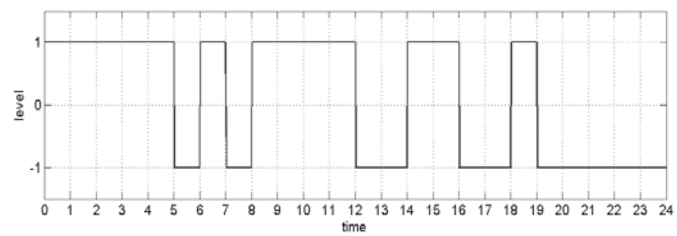
Figure 7. Determination of the minor frame sync pattern

As shown in Figure 7 (b), the estimated minor frame sync pattern is identical to 16 bits from 20^{th} bit to 36^{th} bit of Figure 7 (a). Figure 8 depicts a minor frame of the telemetry data sequence which has minor frame sync pattern of the length 24 bits and the estimated minor frame sync pattern.

 ISBN: 978-1-61208-245-5



(a) Data sequence of a minor frame



(b) Estimated minor frame sync pattern of 24 bits

Figure 8. Determination of the minor frame sync pattern

As shown in Figure 8 (b), the estimated minor frame sync pattern is identical to 24 bits from 20^{th} bit to 44^{th} bit of Figure 8 (a).

If there is an error in the minor frame sync pattern, the proposed algorithm can be modified to estimate the original frame sync pattern, by introducing the threshold coefficient that has a real value of 0 to 1.

V. CONCLUSIONS

In this paper, we have presented a new blind estimation algorithm to find frame synchronization patterns in telemetry systems based on IRIG 106, using the matrix constructed using estimated minor frame length. By computer simulations, we have confirmed performance of the proposed algorithm. Simulations are carried out for a major frame consisting of 128 minor frames with 1024 bits. By exploiting the proposed algorithm, we estimated 16 bits long and 24 bits long sync patterns. In error environments, we can estimate the frame sync pattern also by using the threshold coefficient α . Our results can be applied to an unknown telemetry signal reconstruction for various practical cases in non-cooperative contexts such as spectrum surveillance systems and guided weapon systems.

ACKNOWLEDGMENT

This research was supported by Agency for Defense Development of Korea (2011-00000002370).

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