

Research on the optimal synchronization parameter of Turbo code

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Abstract. When a new monitoring and control system downstream data transmission frame using CCSDS data transmission frame structure, downlink data transmission rate information is less than 8Mbit/s, using Turbo coding, the best studied different synchronous code block lengths, different coding efficiency Turbo Codes parameters, to the best time to lock and data efficiently. According to the theoretical derivation of analytical formulas to calculate the error rate lock time and under different synchronization parameters to arrive at the best Turbo synchronization parameters, and summed up the characteristics of the synchronization parameters set for the actual project to provide practical reference.

1. Introduction

In order to improve emission efficiency, saving resources satellite, Beidou II test project using satellite orbit directly above the emission level manner, its upper-level monitoring and control system and some satellites using the latest measurement and control system, tracking ship baseband device through special projects, and Compass after three lunar renovation project monitoring and control system monitoring and control with the ability to complete the downlink data reception demodulation, distance and speed measurement, with Turbo and LDPC channel coding designed to address the problem of a shortage link level. When downlink data transmission rate information is less than 8Mbit/s, using Turbo coding, considering the carrier lock time and bit error rate testing synchronous demodulation performance under different code lengths and different encoding block Efficiency studied Turbo coding scheme to obtain the best synchronization parameter.

2. Fundamental

2.1 Turbo technology

The basic principle of Turbo codes are constructed by ingenious encoder, two simple component codes by a pseudo-random interleaver parallel concatenated to construct a long code having a pseudo-random characteristics, and by the two soft-in / soft-out (SISO) conduct multiple iterations between decoder implements pseudo-random decoding, repeated use of the mechanism of internal combustion engine exhaust similar iterative decoding, thereby obtaining near Shannon limit error correction performance. Turbo Coding block diagram shown in Figure 1, Theoretical Studies show that: the pattern of $(64 \times 57)^2$ of TPC, bit error rate of 1×10^{-7} , to occupy 125% channel system Bandwidth can be obtained about 7dB channel gain.

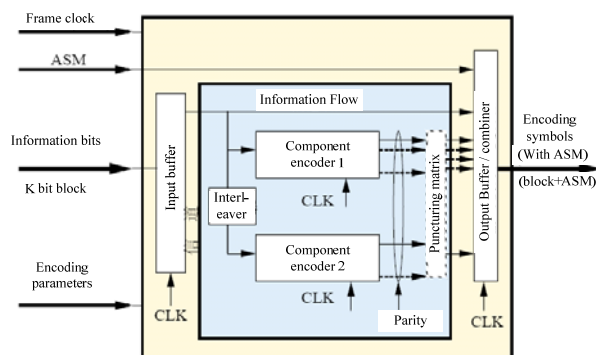


Figure 1. Turbo Coding block diagram

The new monitoring and control system downstream data transmission frame using CCSDS data transmission frame structure, frame after frame group downlink Turbo coding, plus ancillary sync tip identification. Turbo decoder synchronous code block by code block located in each Turbo subsidiary before synchronization identification (ASM) implementation. Increase at the end of Turbo code block cycle synchronization subsidiary identifies its length depends on Turbo coding rate. Turbo code block structure see Figure 2 identifies the synchronization with the subsidiary.

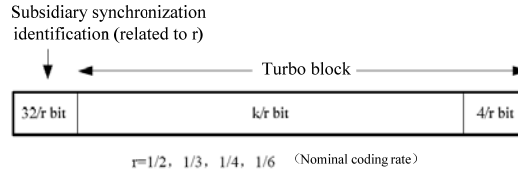


Figure 2. Turbo code block synchronization affiliated with logo

With Turbo coding, Turbo coding may be set to the nominal encoding rate $r = 1/2, 1/3, 1/4$ or $1/6$, Turbo code block length of the output of $N = (k + 4)/r$, in the code block Turbo before adding ASM synchronous identification and a length of $32/r$, the decoder searches ASM code blocks in order to achieve synchronization.

CCSDS recommendations given Turbo decoding performance simulation shows that the error rate at different rates and different coding efficiency information 10^{-4} after decoding Turbo corresponding SNR as shown in Table 1, Turbo decoding error rate as before the ASM table 2.

Table 1. After the Turbo decoding BER 10^{-4} corresponding SNR

k/bit	1/2	1/3	1/4	1/6
1784	1.3	0.66	0.44	0.15
3568	1.11	0.47	0.24	-0.03
7136	0.97	0.34	0.13	-0.15
8920	0.9	0.3	0.11	-0.22
16384	0.87	0.25	0.02	-0.23

Table 2. Turbo synchronization error rate identified

k/bit	1/2	1/3	1/4	1/6
1784	0.12	0.19	0.23	0.28
3568	0.13	0.19	0.23	0.28
7136	0.13	0.20	0.23	0.29
8920	0.13	0.20	0.23	0.29
16384	0.13	0.20	0.24	0.29

2.2 Code block synchronization process

Currently the channel code block packet synchronizer synchronize code blocks. The method is usually draws telemetry data frame synchronization, block synchronization operates in the following three states: search state, checking state, lock state.

When searching for state-by-bit synchronizer block search, find the block synchronization code group by correlation calculation. When the error data set block synchronization code group is less than the value of the fault-tolerant search to retrieve, find that the required standards of the block synchronization code group in the data stream, that is, into block sync checked state otherwise maintain state continues to search in the search block preamble set.

In the state checking, testing to identify states in the search for the location of the position is indeed block synchronization code group. In a code block for the cycle, the searched location data and the setting block group do preamble correlation calculation, the error is less than the value that the block check fault-tolerant synchronization code group by checking the code block, the error is greater than the value of the fault-tolerant check when checking that the failure, in order to verify that the number of successive code blocks appear periodically block synchronization code group. If you examine the code block to the next block is not in the same position preamble set, block synchronization search state returns. Check if the specified number of successive code blocks are all correct position, then transferred to the synchronizer block lock state.

When the block synchronizer into the locked state, begins to block synchronization status

indication is given, and the synchronous clock and data directly, Turbo decoding module decodes the received data processing. When in this state, according to the code block length test results related to the same position as the block synchronization code group and block synchronization code group set, error is less than the value that the fault-tolerant code lock block lock properly, the lock fault-tolerant error is greater than the value of the loss that the code block lock. When a predetermined number of consecutive checks failed to find the code block synchronization code group, decision block synchronization loss of lock, re-block synchronization search.

3. Synchronization parameter test

3.1 The average lock time

A synchronizer according to code-block 3 state synchronization logic, the establishment of a code block synchronization state transition diagrams. Suppose code block length of N , the probability of the word in the symbol error rate of P_e 's condition is detected the synchronization of

$P_a = \sum_{i=0}^a C_n^i (1-P_e)^{n-i} P_e^i$, the probability of false sync word detection for virtual $P_b = \sum_{i=0}^a C_n^i (\frac{1}{2})^n$, in the locked and protected stage due to the wrong lock and makes the synchronization word inconsistent probability $P_d = 1 - \sum_{i=0}^k C_n^i (\frac{1}{2})^n$.

When an error is detected synchronizer sync word, there may be two cases: one is the error that is found in the search and check state; the other is synchronized by checking into the locked state, then after synchronization protection stage, finally exit locked. After that, the synchronizer shift 1bit, synchronizer re-enter the search mode. Translation of a waste code number block:

$$N_f = (1-P_b) \frac{1}{S} + P_b(1-P_b) \left(\frac{1}{S} + 1 \right) + P_b^2(1-P_b) \left(\frac{1}{S} + 2 \right) + \dots + P_b^{G-1}(1-P_b) \left[\frac{1}{S} + (G-1) \right] + P_b^G \left(\frac{1}{S} + G + N_{\text{unlock}} \right)$$

Wherein $N_{\text{unlock}} = \frac{1-P_d^L}{(1-P_d)P_d^L}$ is the average time to unlock.

When the error-free transmission, the first synchronization code found the average time for the $N_1 = \frac{1}{2} (NN_f + \frac{n}{S})$, if undetected during a sync word is found next preamble time $N_2 = NN_f + \frac{n}{S}$; when there is error, discovered the first synchronization word time:

$$\tilde{N}_f = P_a N_1 + (1-P_a) P_a [N_1 + (S-1)N_1] + (1-P_a)^2 P_a [N_1 + 2(S-1)N_1] + \dots = N_1 + \frac{1-P_a}{P_a} (S-1)N_f$$

Preamble missed found next preamble time $N_l = N_2 + \frac{1-P_a}{P_a} (S-1)N_f$, the process of checking if you find the first exit after the preamble, to return to the search condition in the search condition and check the state of continuous x synchronized code blocks are found the average time code is:

$$N_x = P_a (N_{x-1} + 1) + (1-P_a) P_a \cdot 2(N_{x-1} + 1) + (1-P_a)^2 P_a \cdot 3(N_{x-1} + 1) + \dots = \frac{1}{P_a^{x-1}} (N_1 + \frac{1}{1-P_a}) - \frac{1}{1-P_a}$$

When the G code blocks are found continuous synchronization code, the synchronizer into the locked state, the average lock time:

$$N_{\text{lock}} = \tilde{N}_1 + P_a^{G-1} (G-1) + \left(\frac{1}{P_a^{G-1}} - 1 \right) (N_1 + \frac{1}{1-P_a})$$

3.2 Efficient data

Lock state probability fault tolerant than state $P_k = 1 - \sum_{i=0}^k C_n^i (1-P_e)^{n-i} P_e^i$, there is no probability of bit errors to the error of the preamble $P_f = \frac{P_k}{c P_a^G}$, in the search mode and normal probability check is

$P_f = \frac{P_k}{c} \sum_{i=0}^{G-1} \frac{1}{P_a^i} C_n^i$, the probability of a valid code block is $P_r = \frac{1}{c} \sum_{i=0}^{L-1} \frac{1}{P_k^i} - \frac{P_k}{c}$, the received demodulated

code block a total of N_{all} , the effective rate of data $r_b = \frac{N_{all} - N_{lock}}{N_{all}} \cdot \frac{P_r}{P_r + P_g + P_f(S-1)N_f}$.

3.3 Turbo demodulation optimum parameters

From Table 1, Table 2 results, under conditions of very high threshold before Turbo decoding error rate, how to search for identity synchronization ASM under conditions of high bit error rate, and as far as possible to shorten the lockup time, so Turbo synchronous demodulation parameter setting is particularly critical.

In this paper, combining synchronization parameter settings, statistics efficient and lock time. Tables 3 and 4 are given a variety of ASM block length preamble, under optimum coding efficiency Turbo code synchronization parameter corresponding to the synchronization parameter and the corresponding data efficiently and lockup time. Best preamble length article with the CCSDS recommendations 32/r consistent. Under the conditions set optimal parameters, the error rate is less than 10^{-5} , the average lock time of less than 0.7 code block length.

Table 3. Lock Time synchronization parameters under

Coding efficiency k/bit	1/2	1/3	1/4	1/6
1784	0.61	0.59	0.60	0.68
3568	0.53	0.57	0.52	0.67
7136	0.56	0.59	0.60	0.68
8920	0.56	0.64	0.61	0.69

Table 4. BER synchronization parameter under

Coding efficiency k/bit	1/2	1/3	1/4	1/6
1784	3.9×10^{-6}	5.4×10^{-6}	7.4×10^{-5}	1.24×10^{-5}
3568	6.4×10^{-6}	1.02×10^{-5}	1.87×10^{-5}	2.42×10^{-5}
7136	1.33×10^{-5}	1.44×10^{-5}	2.84×10^{-5}	4.86×10^{-5}
8920	1.71×10^{-5}	3.3×10^{-5}	3.63×10^{-5}	6.11×10^{-5}

4. Conclusion

a. Synchronization logo ASM length n and the bit error rate related to the longer code block size, the higher the bit error rate, the greater the ASM synchronous identification n. For Turbo codes, the higher the coding efficiency, the error rate is smaller, ASM synchronization identification n is greater. Through this theoretical analysis, the synchronization word is identified 32/n is not optimal length, but the number of bits affected by computer processing, the synchronization word 32/n is the best in engineering applications.

b. The fault-tolerant synchronization identification length n bits and bit error rate P_e relevant, fault-tolerant search and check the fault-tolerant bit should be set to 1.1 to 1.6 times the length of the $n \times P_e$.

c. Fault-tolerant state and the check digit value search state should be relatively small, allowing a short time into a locked state; locking and fault-tolerant digit lock code block should be set relatively large, so as not to be easily lost due to errors lock.

5. Summary

This paper analyzes the high error rate under Turbo coding system to study the threshold conditions ASM synchronization performance, according to the information code length coding efficiency and decoding performance of Turbo codes provisions derived data efficient and lock time analytical formula and calculate best summed up synchronization parameters, and set the synchronization parameters summarized the law, with clear guidance for engineering applications.

Reference

- [1] Glavieux B C.A Near Optimum Error Correcting Coding and Decoding:Turbo Codes[J].IEEE Transaction on Communication.2012,44(10)
- [2] CCSDS 131.0-B-1-2013.TM Synchronization and ChannelCoding[S].Washington D C:CCSDS Secretariat,2013
- [3] Cousineau,Denis,Fitting the three-parameter weibull distribution: Review and evaluation of existing and new methods. Optik, 2009, 120(3):127-13.