Real Time Telemetry Data Synthesis With The TMS320C25

Yao Jun, and Liu Shi-yan
Xinan Electronic Engineering Institute
P. 0. Box : 517 - 17, Chengdu 610003
Sichuan, China

Abstract

This paper presents the method of real time telemetry data systhesis for multi-beams and multi-receivers system in theory. For the practical implementation, we introduce a TMS320C25-based data synthesis board. Through a large number of simulating experiments, the satisfactroy results are obtained, which obviously improve the performance of telemetry system. Therefore, all those technigues and results have the value of practical applications.

Key Words: telemetry, real time data synthesis, channel coding, TMS320C25

Introduction

In some special telemetry system, ground receive system employs multi-beams and multi-receivers which forms multi-channel wait receive station to accomplish the task of low altitude testing. In process of the vehicle approaching to the ground, however, the received telemetry signals in each receive channel will have different signal intensity due to sharply change in the altitude of the vehicle, and have different interference intensity due to electro-magnetic interference in space and internal noise in receivers. All those will cause telemetry data from each receive channel to have various error probability. For acquiring optimal tememetry data, it is very necessary to synthesize such real time data by sufficiently ultilizing the characteristic of multi-channels, and to generate a group of high quality data for telemetry data processing system so that the whole telemetry system obtains relatively accurate results of the testing.

As for multi-beams and multi-receivers wait receive station, actually, it is a compound receive system with intercovering space antenna beams. Since transmission signals come from the same source (the vehicle), all signls from every receive channel can simultaneously be obtained, which are of better synchroniziation. Hence, it is possible to synthesize those multi-channel data groups in real time.

The structure of the system

The principle block diagram of the multi-beams and multi-receivers wait receive station is shown in Fig 1.

From the theory of channel coding, we have known: For the capacity C of the noise memoryless discrete channel, on condition that the arbitrary information transmission rate Rt is less than the channel capacity C, there exists such kind of coding whose length is n, its error probability of transmission information can be expressed as follow[1]

$$p_e < 2^{(-n\,Eb(Rt))} \qquad (1)$$

where, n is the length of the code.

Eb(Rt) is a positive function only determined by the characteristic of the channel under the condition of Rt<C.

Equation (1) means that the error probability p_e can arbitrarily be decreased by increasing the length n of the code, on condition that the transmission rate is less than channel capacity C and the bit rate keeps constant. However, lowering the error probability is at the cost of increasing the code length. increasing the code length means not only that redundant information will be added to the system and the quantity of useful information will be decreased but also that the coding and the decoding devices will comparatively become more complicated. In order to solve the contradiction, we fully ultilize the characteristic of multi-channels to raise efficency of channel coding and add reduntant code as less as possible in the transmission system. For this reason, it is quite necessary to synthesize the received telemetry data in real time in the receive system. During the later disscussion. we will know that the good results can be obtained with this method.

Data synthesis with the cyclic code

Cyclic code is a important subset of linear code, and have many special algebra structure. Its coding, decoding, and computation of accompany matrix can easily be implemented with shift register containing feed-back linker. Therefore, by making use of cyclic code for telemetry data synthesis, we need only compile simple program and spend less time to implement the coding and the decoding of the cyclic code. In the vehicle, hence, using softwere to implement coding can simplify the circuits and contract the volume of the system. Meanwhile, because cyclic code is capable of error-correcting, the error probability of synthesized data will obviously be decreased by means of combining multi-channel data synthesis with decoding of the cyclic code. In consideration of the requirement of real tune data synthesis, we select short code, (7,4) cyclic code, which almost corresponds to the word length of the telemetry system and has the capability of correcting one bit error and detecting one bit error. The transmission rate of (7,4) cyclic code is Rt=4/7.

At the first, we analyze the results of two-channel data synthesis. Asumming that the bit error rates of each channel are p_1 and p_2, respectively, the probability of right synthesis is P_G. According to the criteria of the paper[4], we can obtain

$$P_G = \sum_{i=0,\neq 3,\neq 6}^{7} C_7^i p_1^i (1-p_1)^{7-i} \sum_{j=0}^{1} C_7^j p_2^j (1-p_2)^{7-j} \qquad (2)$$

Asumming that the equivalent hit error rate of synthesized data is $\tilde{p}_{ec}$ because wrong synthesis is mainly caused by two bit errors in a code, and because (7,4) cyclic code is able to correct only one bit error, decoder will changes the code with two bit errors to another code. In this case, the criterion of two channel data synthesis does not identify such error code. Therefore, the equivalent bit error rate of synthesized data should approximately be 3/7 times wrong synthesis. The $\tilde{p}_{ec}$ can be obtained

$$\begin{aligned}\tilde{p}_{ec} &= (3/7)(1-P_G)\\ &= (3/7)\Big[1-\sum_{i=0,\neq 3,\neq 6}^{7} C_7^i p_1^i (1-p_1)^{7-i} \sum_{j=0}^{1} C_7^j p_2^j (1-p_2)^{7-j}\Big]\end{aligned} \qquad (3)$$

By the same way, the equivalent bit error rate $\tilde{p}_{ec}$ of synthesized data from three channels is

$$\tilde{p}_{ec} = (3/7)\Big[1-\sum_{i=0,\neq 3,\neq 6}^{7} C_7^i p_1^i (1-p_1)^{7-i} \sum_{j=0,\neq 3,\neq 6}^{7} C_7^j p_2^j (1-p_2)^{7-j} \sum_{r=0}^{1} C_7^r p_3^r (1-p_3)^{7-r}\Big] \qquad (4)$$

While the number of the channels $M\to\infty$, the lowest limit of the $\tilde{p}_{ec}$ is

$$\tilde{p}_{maxec} = (3/7)\Big[1-\sum_{i=0,\neq 3,\neq 6}^{7} C_7^i p_1^i (1-p_1)^{7-i}\Big] \qquad (5)$$

From the results above, we have known that the bit error rate p_1 of the first channel mostly affects the synthesis results. In order to improve the performance of data synthesis, it is demand to determine which channel is better as the first channel for data synthesis with the method of dynamical statistic in practical application.

Asumming that the bit error rates of every channel are equal, namely $p_1=p_2=p_3=\cdots$. we may acquire the comparative curves of data synthesis with various numbers of channels from the equation (3), (4), (5). As shown in Fig 2.

We have seen that the bit error rate of two-channel synethsized data is obviously lower than that of one-channel data with direct decoding of the (7,4) cyclic code. Further improvement, however, is not easy to get by increasing the number of channels for data synthesis. Because the minimal distance of the (7,4) cyclic code is three, decoder will consider it as a right code but actually a wrong code when a received code has 3 bit error or 6 bit error. consequently, such bit error could not be identified and would cause a wrong sysnthesis.

Data sysnthsis with modulo-M check code

In the preceding section, we introduce the cyclic code into data systhesis. Because the transmission rate Rt of cyclic code is relatively lower, strictly speaking, there are more redundent information in the telemetry system, it will obviously decrease the useful quantity of information, and it couldn't be tolerated if the whole information system of telemetry system employs such cyclic code as channel coding. Hence, we, here, discuss the useful modulo-M check code for data synthesis. Since its transmission rate (Rt=n-1/n) is comparatively high, it is of certain advantages for the system requiring large amount of information. In addition that modulo-M check code possesses the characteristic of simple coding and easy implementation.

Every element of modulo-M check code contains K bit information which forms a information word. Each word X has 2^k posible state. The relations between n-1 information words and a check word should be content with following equation

$$\left[\ \sum_{i=1}^{n} X_i\ \right] \text{MOD } M = 0 \qquad (6)$$

In the receive system, if check sum of the received word group has the relation that

$$\left[\ \sum_{i=1}^{n} X_i\ \right] \text{MOD } M \neq 0$$

It represents that there are some word errors in the received word group. Although modulo-M check code only has the capability of error-detecting and no error-correcting, we may ultilize the characteristic of the multi-channels to draw up some synthesis criteria and make data synthesis have the capability of error-correcting.

Because the received data of each receive channel come from the same trnasmission source (the vehicle) and have correlativity, we can synthesize those data with correlative process on condition that word error rate of each channel is not too high. The concrete method refers to the paper[4].

As an example of data synthesis with modulo-M check code for two channels, we asumme that the word error rate of each channel is P_1, P_2, respectively. when different word errors between the two channels in a check group do not exceed four, the equivalent word error rate $\tilde{P}_{ew}$ of synthesized data can be obtained

$$\tilde{P}_{ew} = (2/n)\{1-[\sum_{i=0}^{1} C_n^i C_n^i P_1^i (1-P_1)^{n-i} P_2^i (1-P_2)^{n-i} + \sum_{j=1}^{2}\sum_{i=1}^{2} nP_j(1-P_j)^{n-1} C_{n-1}^i P_{3-j}^{i+1} (1-P_{3-j})^{n-i}$$
$$+ C_n^2 P_1^2 (1-P_1)^{n-2} C_{n-2}^2 P_2^2 (1-P_2)^{n-2} - (1-P_1)^n (1-P_2)^n]\} \qquad (7)$$

Asumming P_1=P2. For different code length n of the modulo-M check code, the comparative curves for data synthesis from the equation (7) can be obtained. as shown in Fig 3. From the curves, we have seen, the shorter the code length n of the modulo-M check code, the less the word error rate $\tilde{P}_{ew}$ of synthesized data. As for data synthesis for more channels with the modulo-M check code, we can draw up more suitable criteria to further improve the performance of data synthesis according to the characteristic of easy error-detecting. Because analyzing data synthesis for more channels with the modulo-M check code is much complicated, it will not be discussed here.

Data synthesis board with the TMS320C25

For the purpose of practical application, now we concentrate on putting into effect for real time data synthesis on the background of the telemetry system of pulse code modulation (PCM). The parameters of PCM system are

bit rate: 102.4kb/s   each word: 8 bit   frame period: 20ms

The principle block diagram of data synthesis board is shown in Fig 4. The board can synthesize real time telemetry data of 2 to 4 channels which come from demodulators, and then transfer the synthesized data to telemetry data processing system for further processing.

The board mainly consists of the TMS320C25, the program and the data memory, the mode selection switch, the complex identification circuit of the frame sync and the word sync, output circuit of the synthesized data, external port decode and control circuit, input ports of the received data, and display units.

The TMS320C25: master frequency is 40MHZ, that is to say, with a 100-ns instruction cycle time. its function is to simultaneously receive real time telemetry data of 4 channels from the demodulators, and synthesize such data at high speed in accordance with the selected mode which corresponds to the method of channel coding, and then transfer the synthesized data to the telemetry data processing system.

The program and the data memory: the external progrom memory are selected with two high speed EPROM 27HC64-45 to form the 8K*16 bits program memory space. the external data memory is constructed of two static high speed chips 6164C45 to arrange the 8k*16 bits data memory space.

Since the access time of both kinds of chips is only 45ns, the TMS320C25 can run at full-speed with no wait cycle when the CPU accesses the external memory.

The mode selection switch : it is used for selecting different sorts of synthesizing softwere to fit the the requirement of channel coding.

The complex identification circuit of the frame sync and the word sync : the circuit is used for identifying which channel's frame sync from the demodulators is the most qualification and then marking the best channel as the first channel for data synthesis so that the effect of data synthesis is better.

Output circuit of the synthesized data: it is comprised of a 8 bit output port, and output circuit of sync signal. it sends the synthesized data and corresponding sync signal to telemetry data processing system in regulation fashion.

The external port decode and control circuit: it coordinates operation between the TMS320C25 and external port circuit, and also implements the function of port decode and control for each part of external circuit.

Input ports of the received data: this part consists of four 8 bit ports, and is used for receiving data of 4 channels which correspond to the frame sync and the word sync sign1s.

Display units : the units are of two 8-segment light-emitting diodes. its function is to indicate whether the data synthesis board is normal or not and the results of synthesized data are dynamically displayed.

The operation principle of the data synthesis board are described as follow: When power is on, the board will do self-check to ensure that it is in the good condition at the first, and send the results of self check to the display units. Then the data synthesis board is initiated. After that, the main prograin enters into sub procedure according to the mode selection switch have been set, and then wait for receiving and synthesizing data. As long as frame sync signals come, the complex identification circuit distinguishes these frame sync signals to form a single frame sync signal as frame sync's interrupt reqest INT0 to the TMS320C25. Meanwhile, it sends the superior and inferior state codes corresponding to each channel's frame sync signal to the TMS320C25. While the TMS320C25 responds the INT0 interrupt request, the interrupt service program sets the symbol of new frame's data so that the data synthesis program process those data according to certain sequency, and reads the superior and inferior state codes into buffer memory. the control gate corresponding to the superior frame sync signal will be opened on the basis of the state codes, and the other control gates corresponding to the inferior's will be closed. Thus, the superior word sync signal through the complex circuit of word sync as a INT1 causes the TMS320C25 to respond the interrupt reqest. In the interrupt service, the program synchronously reads 4 channel's data from input ports and store them to assigned buffer memory for data synthesis. Now, the received data are firstly pre-synthesized by making use of the state codes. According to the synthesis mode that user have previously selected, data synthesis program calls relative sub program (such as data synthesis with cyclic code, modulo-M check code, ie.) to synthesis those real time data, then sends a group of the optimal synthesis data to telemetry data processing system. This is a basical operation procedure of the data synthesis board.

In this section, we have described the function of each part and the operation principle on the data synthesis board. We have used it to actual telemetry system and done a large number of simulating experiments. The satisfactory results have been obtained, which are close to the theory results.

Conclusions

In the context, we have introduced only two kinds of channel coding for real time data synthesis, which are a few aspects of a variety of channel codings. Since the vehicle within low altitude segement collects a large number of useful telemetry data, and the bit rate of signal is also very high, it presents many difficult tasks before us. It demands not only to completely receive high speed data streams of multi-channels but also to rapidly synthesize such data in real time and to simultaneously transfer to the telemetry data processing system. Consequently, it is very necessary for us to do further approach about a variety of channel codings to find out more suitable method of data synthesis for this type of the receive system so that the much better results of the telemetry can be obtained.

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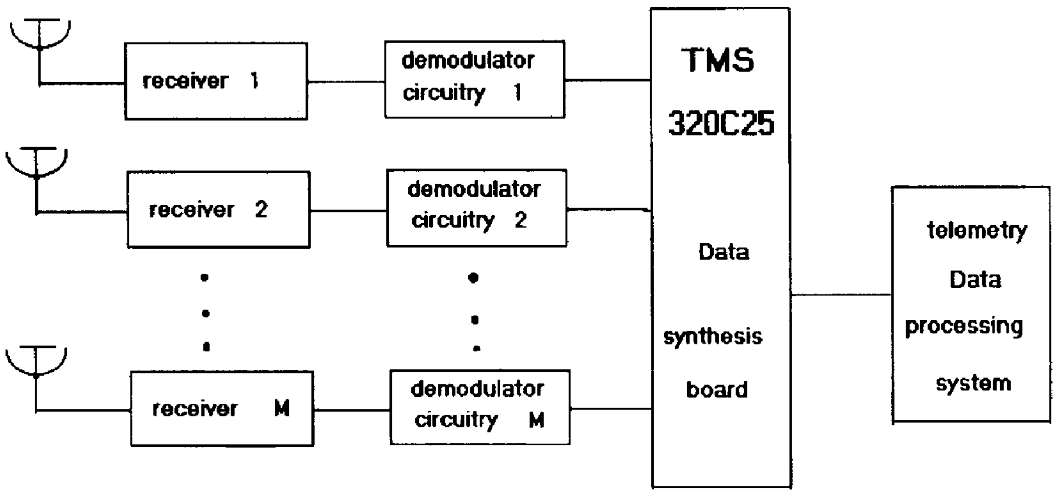

Figl - The block diagram of multi-beams and multi-receivers wait receive station

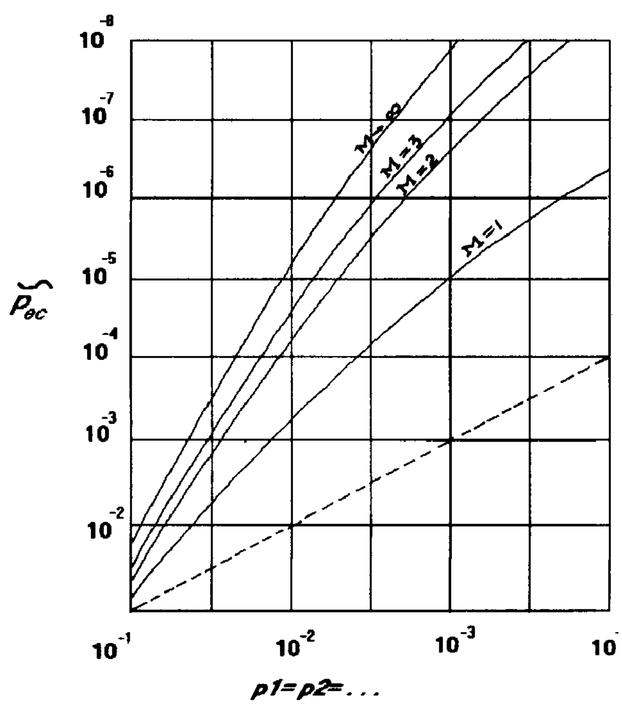

Fig2. The comparative curves of data systhesis with various numbers of channels

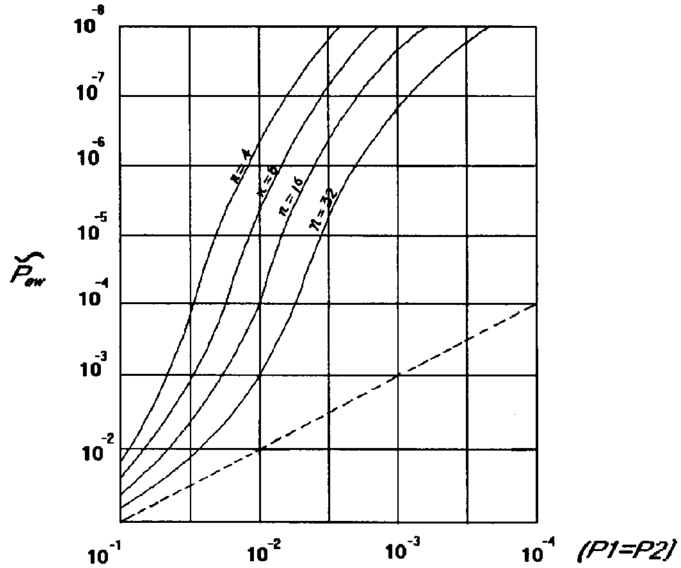

Fig3. The comparative curves of data systhesis with different code length

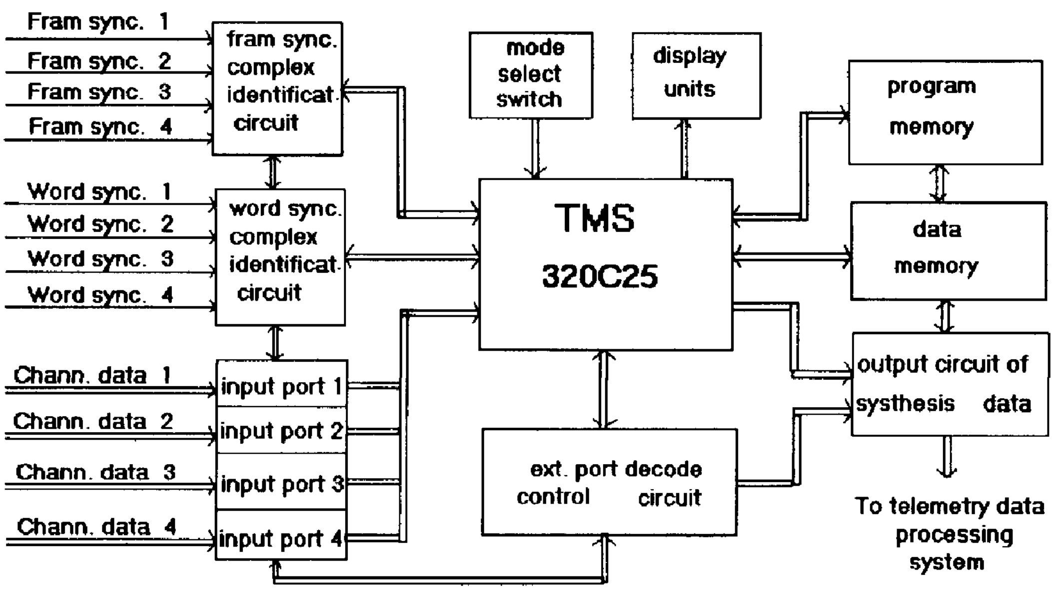

Fig4. The block diagram of data systhesis