

Data Synthesis in PCM Telemetry System

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ABSTRACT

In the field of re-entry telemetry, data synthesis is an important research task for multi-beam and multi-receiver system. This paper presents a microcomputer-based method to synthesize PCM data in real-time. The performances of various criteria used in data synthesis systems are also analyzed here.

PREFACE

Re-entry telemetry is a technology to study transmission and processing of information within the vehicle as re-entering the atmosphere. There are many tasks in this field. For instance, the research of re-entry communication break, i.e., the plasma sheaths, began at 50's. Real-time penetrating technique is certainly an ideal way to solve the blackout, which includes such methods as raising frequency, increasing emitter power and abating the plasma sheaths—for example, by using the newly heat-proof materials. All these methods have had a good performance.[1][2] However these methods take a considerable cost. Another technique is by recording and retrying which records the data while in the plasma sheaths and reemits the data speedily while out of the plasma sheaths. Although this method can't achieve real-time transmissions it can easily solve the blackout. But there exists a consequential postulate in the use of recording and retrying technique that the time of the vehicle takes from exiting the plasma sheaths to reaching at the ground must be long enough so that the recorded data could be re-emitted completely. Hence primarily imports near-ground communication, or called the low altitude communication, plus the requirement of recording and retrying, has become another essential task in reentry telemetry.

As the vehicle near the ground, the difficulty in tracking antenna increases due to the increase of angular speed in tracking the vehicle. Meanwhile ground reflect increases sharply due to the decrease of antenna elevation angle. It has been shown in practice that the receive scheme of multireceiver, multibeam tracking antenna and distributed receive stations is effective in use, especially suitable for the low altitude telemetry of high speed target, even in the instant of touching ground. Comparing, with other systems, this scheme has obviously advantages of simplicity practicability and reliability.

The basic configuration of this scheme is that receive system consists of intercovering space defined by multichannel, and multibeam antenna and the terminal obtains several data groups simultaneously from the same source. This characteristic can be fully utilized in data processing. Hence data synthesis becomes an essential task in low altitude transmission. By simple logic addition, data synthesis has been realized for PCM reentry telemetry. In the case of PCM data, each receiver output a different pattern as the signal phases through a different path, hence the simple logic addition can not be effective. However by the use of microcomputer, the condition to solve the problem has been brought about. This paper presents some discussion about this topic

BASIC PRINCIPLE AND METHOD

If multichannel and multibeam scheme is adopted in PCM reentry telemetry, it is necessary to investigate the synthesis of multichannel, especially of the real-time synthesis. In such a situation the most desirable fashion draws support from microcomputer. A block diagram of PCM data synthesis system is shown in Figure 1.

Figure 1. shows that each receiver conveys a dissimilar PCM data to microcomputer which compares and discriminates the received data and synthesizes out a highly reliable data for output or further process.

The input process to computer of PCM data of each channel is accomplished by an interrupt service program. CPU accepts one or several data at each interruption and stores the data in proper address. This part of storage is called the frame storage. Each receiver has a corresponding frame storage whose volume is defined to store just a frame of data. The data in frame storage are arranged according to frame synchronizing signal. The flow chart of interrupt service program is shown in Figure 2.

The task of main program is to continually compare and discriminate the data in the N frame storages, to perform synthesizing and to output the result to so called output frame storage finally and then to repeat the process again and again. A subroutine could be inserted into the main program to estimate the error rate in PCM data stream and to print or display if necessary. The flow chart of main program is shown in Figure 3.

More over, the data stored in the output frame storage, that is the synthesized data, can be directly conveyed to terminal recorder or kept in computer for further process. This need not go into details here.

SIMPLE 1-OUT-OF-N CRITERION

It is necessary to define a criterion to compare and discriminate the PCM data. If only consider that the simple criterion be able to choose the best from the N data streams. such a criterion discussed here is called the 1-out-of-N criterion.

Simple methods of synthesis rely on discriminating the quality of known message in each frame data—for example the frame synchronizing code—to choose the best out as the synthesized output in unit of frame. For the multibeam and multireceiver system, this type synthesis method is relatively practical with the view to inter-covering of beams in space. The bit rate of synthesized data in a certain instant equals the minimum one of all data streams at the same instant.

By the use of single board computer of 8-bits word length, an 1-out-of-2 synthesis test was performed. In this test, the frame configurations of data were 128 words in frame length, 8 bits in word length and 24 bits in frame synchronizing code length. This test has also obtained an expectant result. Because the detection for each frame had only one time and the discrimination was only for frame synchronizing code, thus same method could bring out its advantage only when the bit error rate was high and it couldn't work out which data was the best while the bit error rate was relatively low, for instance, less than 10^{-3} . Thus, the one-out-of-N synthesis method can merely play the role of a "editor" in data processing. It is for frame genuine data synthesis.

PARITY-CHECK CODE CRITERION

To counter the disadvantage of 1-out-of-N criterion it brings in a criterion fairly easy in realization and better in performance of PCM data synthesizing—the parity-check code criterion.

Parity-check code have been used in elementary for a long time. The method of checking is to add a checking bit to each word to show its parity character. Hence the error words caused by transmission or other reasons could be eliminated by the indication of parity checking in latter processing.

In multi-receiver system of re-entry telemetry, parity-check codes not only play the role discussed above but also aid the synthesis. since parity checking performs word by word and the parity check bit is relative to every bit of the word, the discrimination could be done for each word when the parity-check code is used as the criterion of data quality but not for each frame as in the case of 1-out-of-N criterion, even could it be considered as for each bit in a certain sense.

If the number of error bits in each word does not exceed one, in other words the checking, of each word is in effective, the synthesis with purity-check code criterion will achieve the optimal result. The bit error rate is equal to the multiplication of that of every channel:

$$P = P_1 \cdot P_2 \cdot \dots \cdot P_n \quad (1)$$

However, parity-check codes have a fatal defect that if the number of error bits in a word exceeds one and is just an even number, the checking will be useless and the discriminating will be wrong in case of parity-check codes being criterion. This is a situation not to be ignored which is the main error source in data synthesis. For the case of N PCM data streams, bit error rate after synthesizing is defined by the following formula:

$$P_q = P_1 \cdot P_2 \cdot \dots \cdot P_n + C_b^2 \sum P_i^2 + C_b^4 \sum P_i^4 + \dots + C_b^b \sum P_i^b \quad (2)$$

Where:

- P_a —bit error rate of synthesized data
- P_i —bit error rate in channel No. 1
- b —word length
- N —number of channels

When the bit error rates of every channel are identical or comparable, equation (2) is simplified to:

$$P_a = C_b^2 \cdot N \cdot P^{2*} \quad (3)$$

Where: P —bit error rate of every channel

When the bit error rates of every channel are different, Equation (2) becomes:

$$P_a = C_b^2 \cdot P_{\max}^2 \quad (4)$$

Where: P_{\max} —maximum bit error of each channel

Obviously, from Equation (3) and (4) it can be shown that the error rate of synthesized data has much to do with the worst one of the data streams with parity-check codes being the criterion. If a bit error rate is higher than 10^{-2} in the N data streams, the bit error rate, of synthesized data may be higher than 10^{-2} also. The relations of bit error, rate between

* When $N=2$, this equation should be $P_a = C_b^2 \cdot (N+1) \cdot P^2$

the synthesized data and worst data stream versus different word length are represented by a group of curves as shown in Figure 4.

In order to prevent data streams with large error rate from joining in the synthesized data, we may pre-process data streams before using parity-check method. For example, if simple, 1-out-of-N criterion is used as the pre-processing method to reject data streams with higher error rate (10^{-3}) and pick out data streams with less error rate (10^{-3}) for reprocessing on parity-check code criterion, more desirable synthesized data can be obtained.

Of course other preprocessing methods can be used to reject wrong data streams. However it's one defect of parity-check code criterion. A more criterion is error-correcting codes and its application in data synthesis is discussed tentatively as follows.

THE APPLICATION OF ERROR-CORRECTING CODE'S IN DATA SYNTHESIS

Error-correcting codes are the major, research field of channel coding technology. Coding is to insert certain redundancy bits into the sectioned data stream so that the receiver can correct errors caused by transmission with the redundancy bits to improve error rate.

For a re-entry telemetry system of multi-receiver, data synthesis technique discussed in the preceding sections is essentially an error correcting. The difference is of course obvious. For example, 1-out-of-N method can only check the data frame by frame. No other than "editor" could be the most proper description of the method. With the parity-check code as another example, although the processing unit is declined to a word, the basic principle still consider that there always exists a "good" data at any time in the several data streams to be synthesized. If for some reasons, all channels are seriously interfered and the errors are brought about at the same time, a "good" data won't be chosen out in spite of the errors in each channel being different. This very problem can be readily solved once the error-correcting codes are introduced. There is no error not to be corrected theoretically so long as a proper code is chosen.

There are many types of error-correcting codes. A class of codes called the modulo-M check code is very worth studying from the view of data synthesis. [3] For a modulo-M code the data word is considered as the code is configured by data blocks which consists of several words. This code is often applied in data exchange between or in computers. If a word has 8 bits, then $M=2$.

The modulo-M checking is to carry out modulo-M addition for all words one by one in data blocks and to take its complement:

$$A_M = \sum_{i=1}^n A_i \pmod{M} \quad (5)$$

Where: A_M —checking result
 A_i —values of the word No. i
 n —length of block

Checking result A_M add to the end of data block to result in a new block with the ability of modulo-M check. A_M is also called the modulo-M check word. But such a modulo-M code can merely indicate whether the block is in error and cannot correct any errors. However, if the data block is arranged in an array form and each row and column is coded with modulo-M coding, then the error locations can be determined and errors can be corrected with not too complicated calculations by the use of the two modulo-M check codes in row and columns of the data block.

It will obviously be more ideal to take an error-correcting code as the criterion of data synthesis. A similar work has been performed with computer simulation. Certain results has been achieved also. Of course there will be much to do to apply to engineering, especially in more difficult real-time synthesis. In brief, now with the combination of telemetry technology and computer technology, data synthesis tend to make full use of inferior data, but not to choose merely an excellent data in the data streams, so that every data can contribute to data synthesis and an indeed optimal synthesized data will come out.

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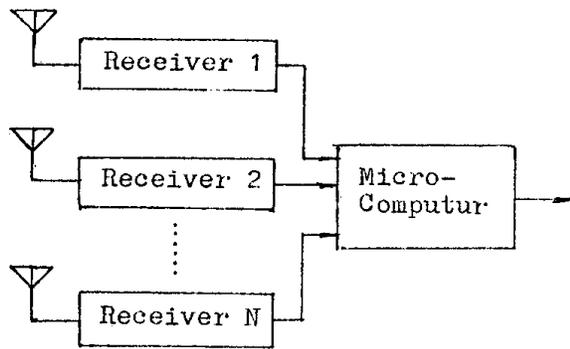


Fig.1. Block Diagram of PCM Data Synthesis System

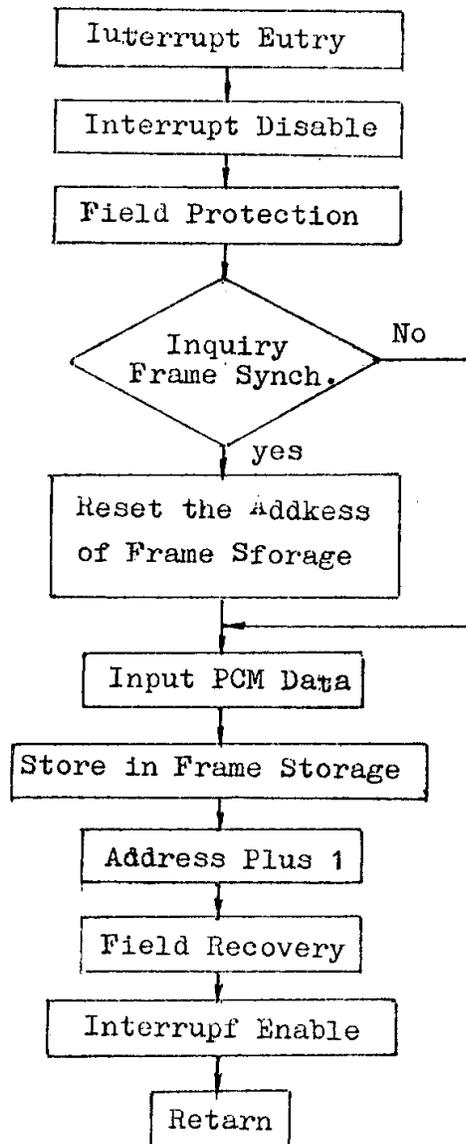


Fig.2. Flow Chart of Interrupt Service Program

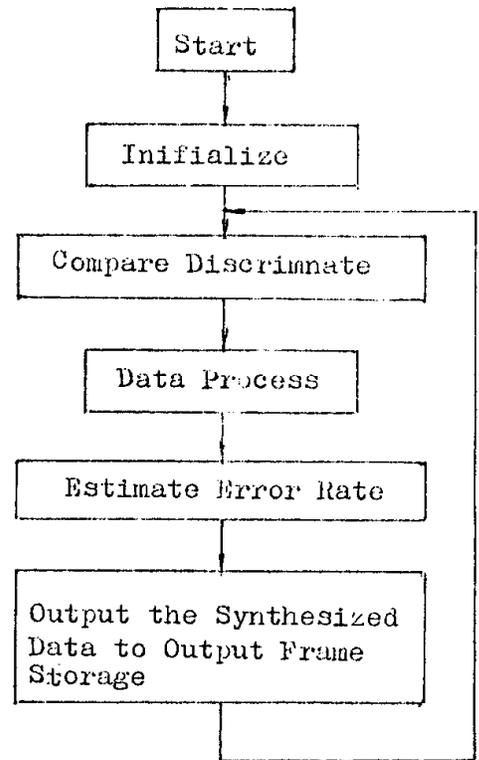


Fig.3. Flow Chart of Main Program

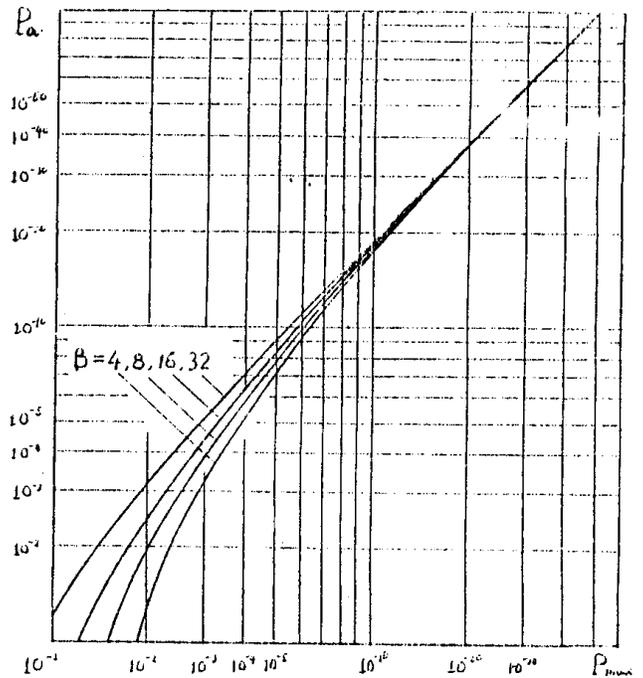


Fig.4. Bit Error Rate Curves of P_a Versus P_{max}