NAG 5-407

SEMIANNUAL REPORT

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland

CODING FOR RELIABLE SATELLITE COMMUNICATIONS

(NASA-CR-174315) CODING FOR RELIABLE SATELLITE COMMUNICATIONS Semiannual Report (Hawaii Univ., Manoa.) 11 p HC A02/MF A01 CSCL 17B N85-17257
Unclas
G3/32 14006

Grant Number NAG 5-407

Shu Lin
Principal Investigator
Department of Electrical Engineering
University of Hawaii at Manoa
Honolulu, Hawaii 96822

CODING FOR RELIABLE SATELLITE COMMUNICATIONS

ABSTRACT

This research project is set up to investigate several error control coding techniques for reliable satellite communications. The main objective of the research is to find algorithms for fast decoding of Reed-Solomon codes in terms of dual basis. Particularly, we are concerned with the decoding of the (255,223) Reed-Solomon code which is used as the outer code in the concatenated TDRSS decoder.

Research effort will also be expended in the following problems: (1) to investigate the performance (error probability and throughput) of a concatenated coding scheme using a Reed-Solomon code as the outer code for error detection only; (2) to investigate the synchronization recovery properties of Reed-Solomon and extended Reed-Solomon codes; (3) using hybrid coding schemes (error correction and detection incorporated with retransmission) to improve system reliability and throughput in satellite communications; and (4) using coding techniques to resolve collisions in packet satellite communications.

I. INTRODUCTION

This research project is set up to investigate several coding techniques for controlling transmission errors in satellite communications. The main task of this research is to find algorithms for fast decoding of Reed-Solomon codes [1-6]. Reed-Solomon codes have been applied by NASA for controlling transmission errors in satellite communications. For example, the (255,223) Reed-Solomon code with symbols from $GF(2^8)$ has been adopted as the outer code of a concatenated coding scheme used in NASA's TDRSS System. Recently Berlekamp [7] devised a new method for encoding Reed-Solomon codes which greatly reduces the encoding complexity. Berlekamp's encoder is implemented in terms of dual basis using bit-serial multiplication. In this research, we will investigate decoding of Reed-Solomon codes in terms of dual basis. Particularly, we are concerned with the decoding of the (255,223) Reed-Solomon code used in NASA's TDRSS System. We also intend to suggest possible decoder architectures which are capable of achieving high speed decoding.

Another task of the proposed research is to investigate the performance (error probability) of a concatenated coding scheme in which the inner code is used for both error correction and detection but the outer code is used for error detection only. A retransmission is requested if the outer code detects the presence of errors after the inner code decoding. Such a scheme is being considered for NASA telecommand operation. In this research we will consider using a Reed-Solomon code as the outer code for error detection.

In random-access packet satellite packet communications, a major cause of congestion is the channel wastage due to packet collisions. In this research, we will investigate using coding techniques to resolve packet collisions and improve the system throughout.

II. SUMMARY OF RESEARCH PROGRESS

During the first six months of the project period, our research effort has been divided in the first two areas of the research project, namely decoding of Reed-Solomon codes in terms of dual basis and performance study of a concatenated coding scheme for NASA Telecommond System. We will summarize our research results in this section.

1. Decoding of Reed-Solomon Codes in Dual Basis

Reed-Solomon codes form a class of very powerful cyclic block codes. They are widely used for controlling transmission errors in data communication systems as well as data storage systems. Recently Berlekamp [7] devised a new method for encoding these codes which greatly reduces the encoding complexity. Berlekamp's encoder is implemented in terms of dual basis using bit-serial multipliers.

During the first six months of the project period, we have investigated decoding of Reed-Solomon codes using the dual basis. The decoding algorithm being used is the Peterson-Berlekamp-Chien algorithm. The algorithm consists of four steps:

1. Compute the syndrome $\bar{S} = (S_1, S_2, \ldots S_{2t})$ from the received polynomial $\bar{r}(X)$.
2. Determine the error-location polynomial $\sigma(X)$ from the syndrome $\bar{S}$.
3. Determine the error-value evaluator $Z(X)$ from the syndrome.
4. Evaluate the error-location numbers and error values, and perform error correction

All the four decoding steps can be carried out in dual basis using bit-serial multiplications or combination of bit-serial multiplications and parallel multiplications. The circuits for the four decoding steps are shown in

Figures 1 to 3. An organization for a Reed-Solomon code decoder is shown in Figure 4.

A technical report on the decoding of Reed-Solomon codes in the dual form has been completed and sent to NASA Goddard Space Flight Center.

2. Performance Study of a Concatenated Coding Scheme for NASA Telecommand System

During the first half of the project period, we have also investigated a concatenated coding scheme for error control in data communications. In this scheme, the inner code is used for both error correction and error detection, however the outer code is used only for error detection. A retransmission is requested if the outer code detects the presence of errors after the inner code decoding. Probability of undetected error is derived and bounded. A particular scheme proposed for NASA Telecommand system is analyzed.

In the scheme proposed for NASA Telecommand system, both inner code and outer code are shortened Hamming codes. The inner code is a distance-4 shortened Hamming code with generator polynomial,

$$\bar{g}(X) = (X+1)(X^6+X+1) = X^7+X^6+X^2+1 .$$

This code is capable of correcting any single error and detecting any double errors. The outer code is also a distance-4 shortened Hamming code with generator polynomial,

$$\bar{g}(X) = X^{16} + X^{12} + X^5 + 1 .$$

This code is the X.25 standard for packet-switched data network [8]. The 16 parity bits of this code is used for error detection only. The reliability performance of the above scheme is analyzed. We have shown that, for bit-error-rate less than 10^{-5}, the scheme provides extremely high reliability.

A technical report on the performance study of the concatenated coding scheme described above has been completed and sent to NASA Goddard Space Flight Center.

We have also analyzed the NASA scheme using a shortened Reed-Solomon code as the outer code. The Reed-Solomon code used has the generator polynomial $\bar{g}(X)=(X+1)(X+\alpha)$ with symbols from the Galois field $GF(2^8)$. Our analysis shows that the scheme with this Reed-Solomon code also gives extremely good reliability. A report on this analysis is in progress and will be completed soon.

III. RESEARCH ACTIVITIES

Publications

1. "On the Probability of Undetected Error for the Maximum Distance Separable Codes," IEEE Transactions on Communications, Vol. COM-32, No. 9, September, 1984.

2. "On the Undetected Error Probability for Shortened Hamming Codes," accepted for publication in IEEE Transactions on Communications, 1985.

3. "Encoding and Decoding of Reed-Solomon Codes in Dual Basis," Technical Report, NASA Grant NAG 5-407, October, 1984.

4. "Probability of Undetected Error After Decoding for a Concatenated Coding Scheme for Error Control," Technical Report NASA Grant 5-407, July, 1984.

Presentations

1. "Encoding and Decoding of Reed-Solomon Codes in Dual Basis," Seminar, Osaka University, October 31, 1984.

2. "Probability of Undetected Error after Decoding for a Concatenated Coding Scheme," 7th Conference on Information Theory and Its Applications, Kinaugawa, Japan, November 4-7, 1984.

3. "Future Problems in Coding" (guest speaker), 7th Conference on Information Theory and Its Applications, Kinaugawa, Japan, November 4-7, 1984.

4. "Performance Analysis of a Concatenated Coding Scheme for Error Control," 1984 Globecom, Atlanta, Georgia, November 26-29, 1984.

Consultation

On November 29, 1984, Dr. Lin visited NASA Goddard Space Flight Center and discussed with Dr. James Morakis and Mr. Warner H. Miller on a number of future research problems.

REFERENCES

1. I.S. Reed and G. Solomon, "Polyno ial Codes over Certain Finite Fields," J. Soc. Ind. Appl. Math., 8, pp. 300-304, June, 1960.

2. E.R. Berlekamp, Algebraic Coding Theory, McGraw-Hill, 1968.

3. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, MIT Press, 1972.

4. F.J. MacWilliams and N.J.A. Sloane, The Theory of Error-Correcting Codes, North-Holland, 1977.

5. R.E. Blahut, Theory and Practice of Error Control Coding, Addison Wesley, 1983.

6. S. Lin and D.J. Costello, Jr., Error Control Coding: Fundamentals and Applications, Prentice-Hall, 1982.

7. E.R. Berlekamp, "Bit-Serial Reed-Solomon Encoders," IEEE Transactions on Information Theory, Vol. IT-28, No. 6, pp. 869-874, November, 1982.

8. CCITT: Recommendation X.25, "Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment for Terminals Operating in Packet Mode on Public Data Networks," with Plenary Assembly, Doc. No. 7, Geneva, 1980.

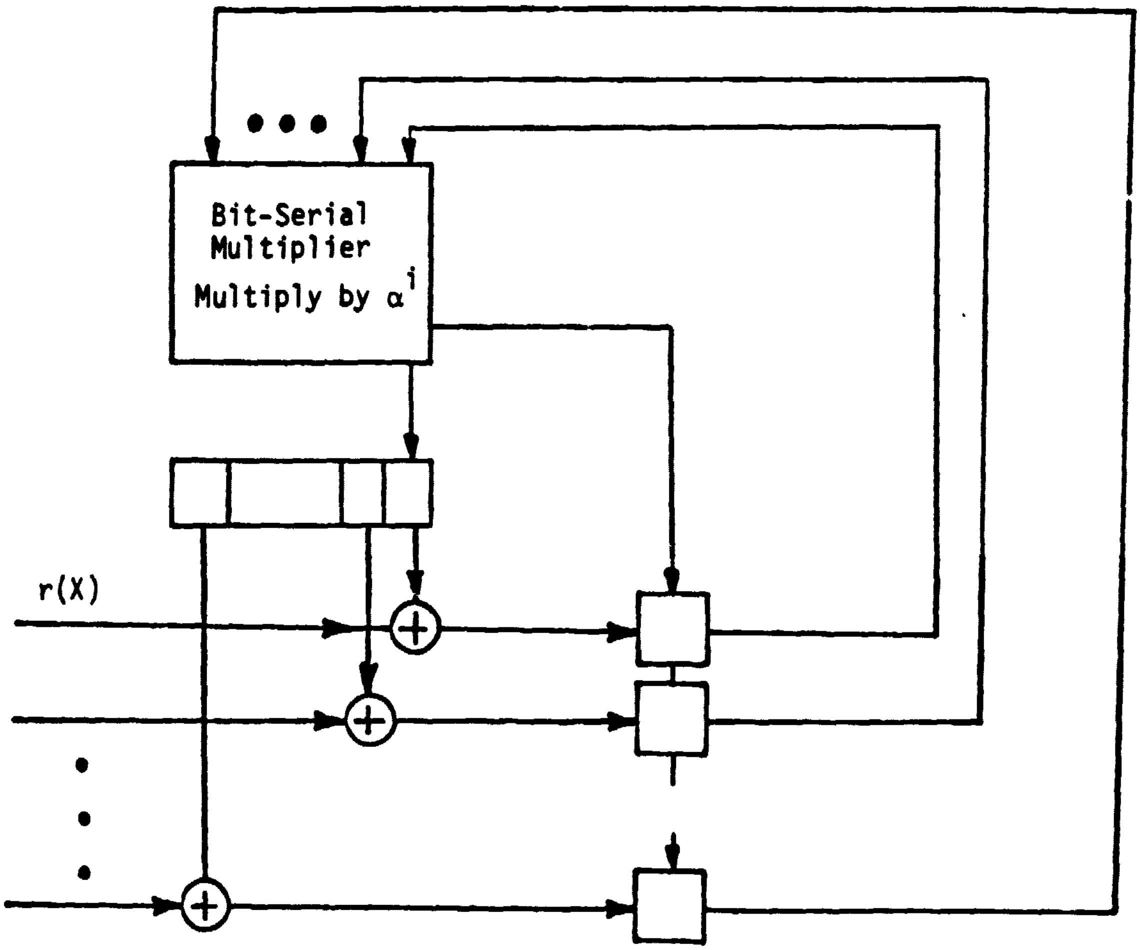

Figure 1 A circuit for computing the syndrome component S_i with a bit-serial multiplier

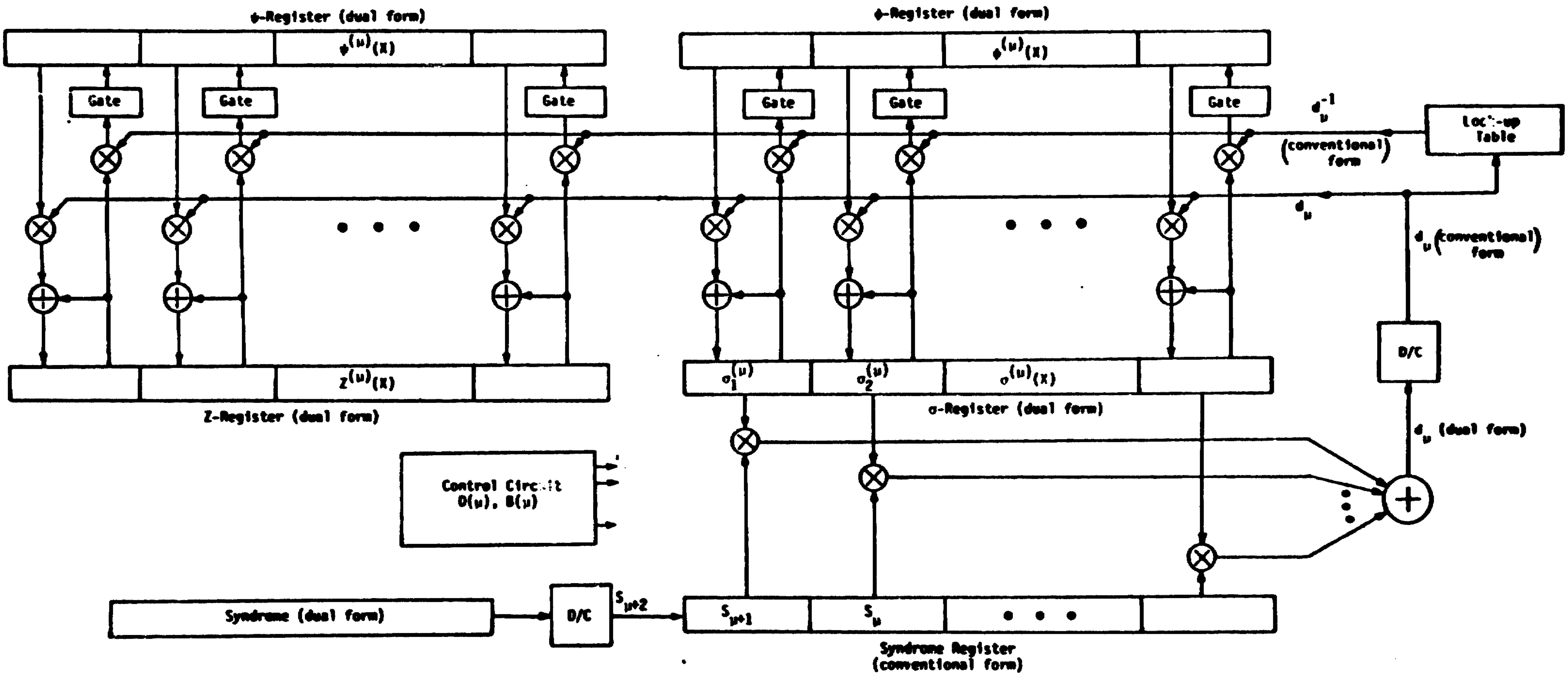

Figure 2 Circuit for finding σ(X) and Z(X)

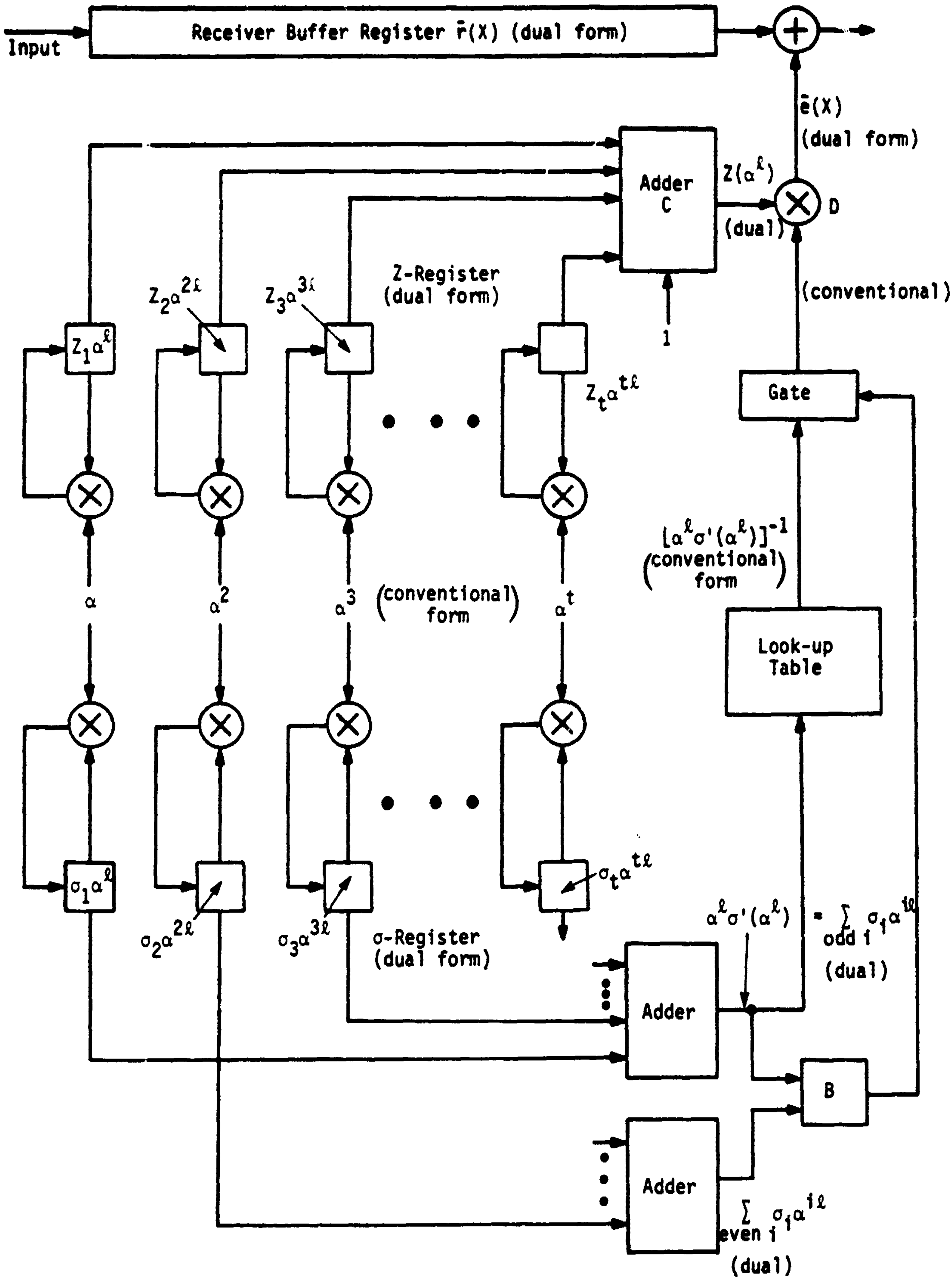

Figure 3 Error-correction circuit

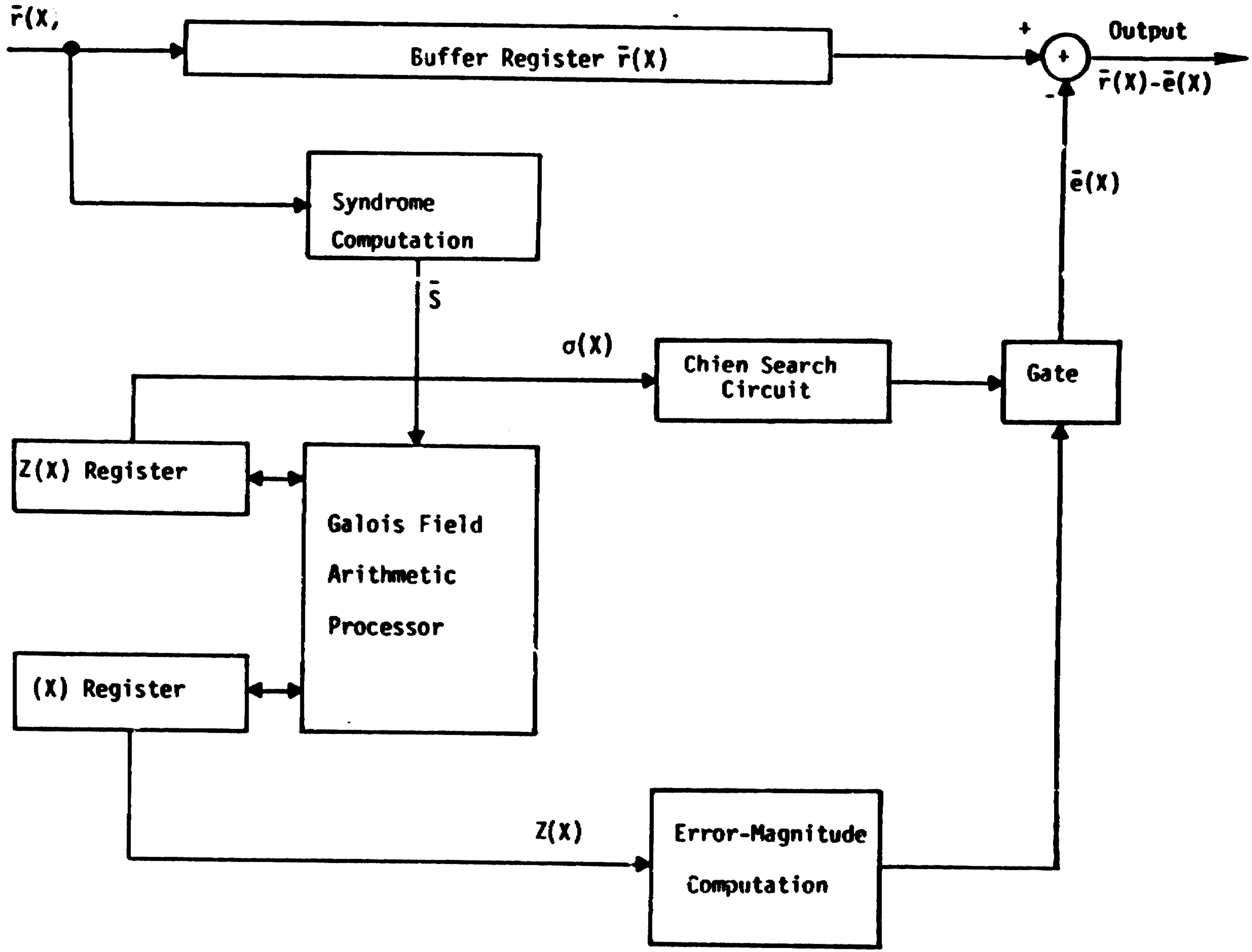

Figure 4 An organization of a RS decoder