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[54] TWO STAGE CODING METHOD

[75] Inventors: Kiyoshi Matsutani; Ken Ohnishi, both of Kyoto, Japan

[73] Assignee: Mitsubishi Denki Kabushiki Kaisha, Tokyo, Japan

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[22] Filed: Sep. 6, 1990

Related U.S. Patent Documents

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Filed: Dec. 19, 1985

[30] **Foreign Application Priority Data**

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[51] Int. Cl.^{5} G06F 11/10

[52] U.S. Cl. 371/38.1; 371/40.1

[58] Field of Search 371/37.2, 38.1, 39.1, 371/40.1

[56] **References Cited**

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Primary Examiner—Charles E. Atkinson

[57] **ABSTRACT**

Errors which arise in recording and reproducing data in a recording material are corrected with the use of an error correction code such as an RS (Reed-Solomon) code, and a two stage C_2 and C_1 coding method is conducted at an interval of repetition of a combination of $[k_2/n_2]$ and $[k_2/n_2]+1$ on digital data having a two dimensional arrangement of k_1 in the first direction and k_2 in the second direction, whereby burst error correction ability is enhanced by the enhancement of error correction capacity.

27 Claims, 4 Drawing Sheets

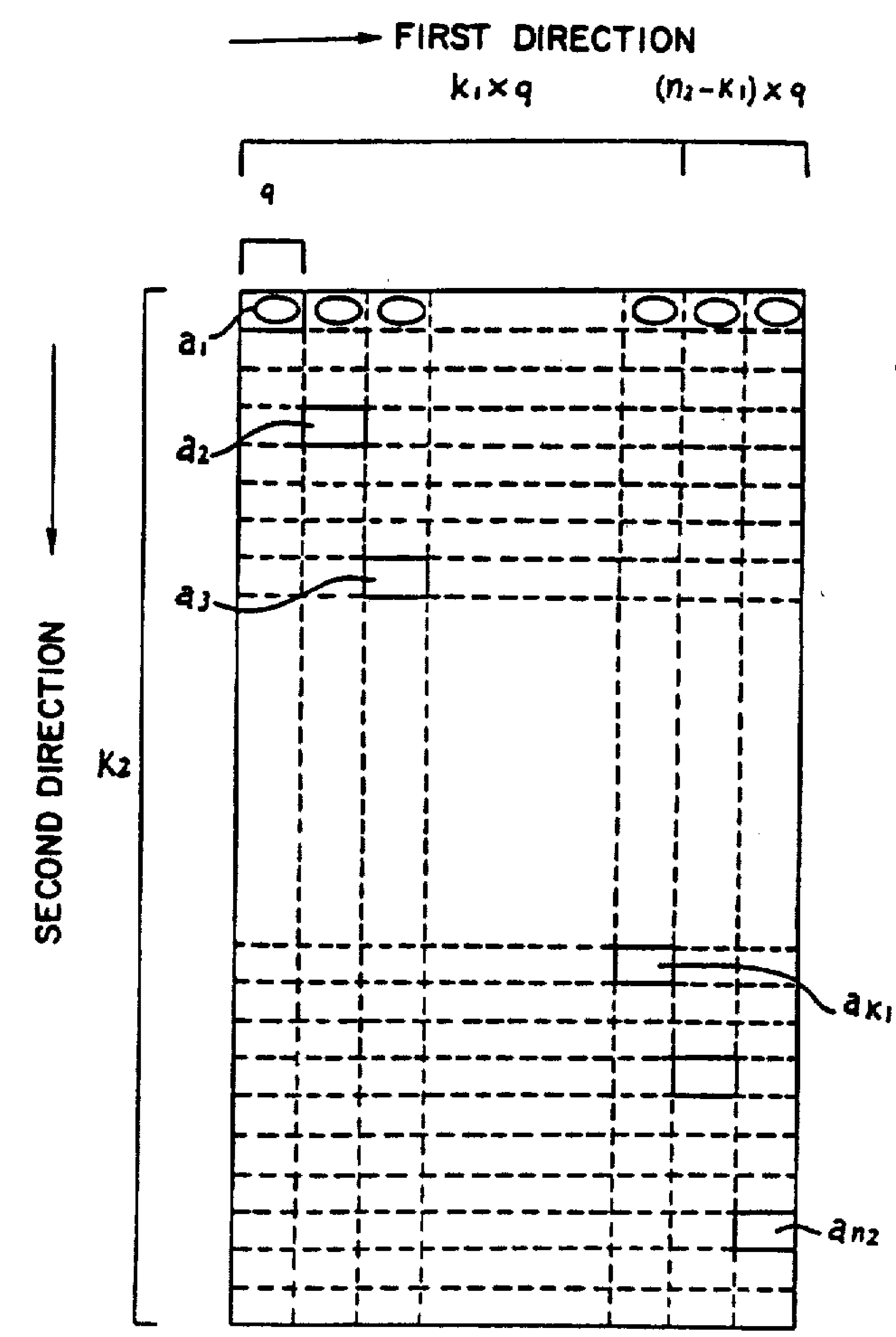


FIG. 1

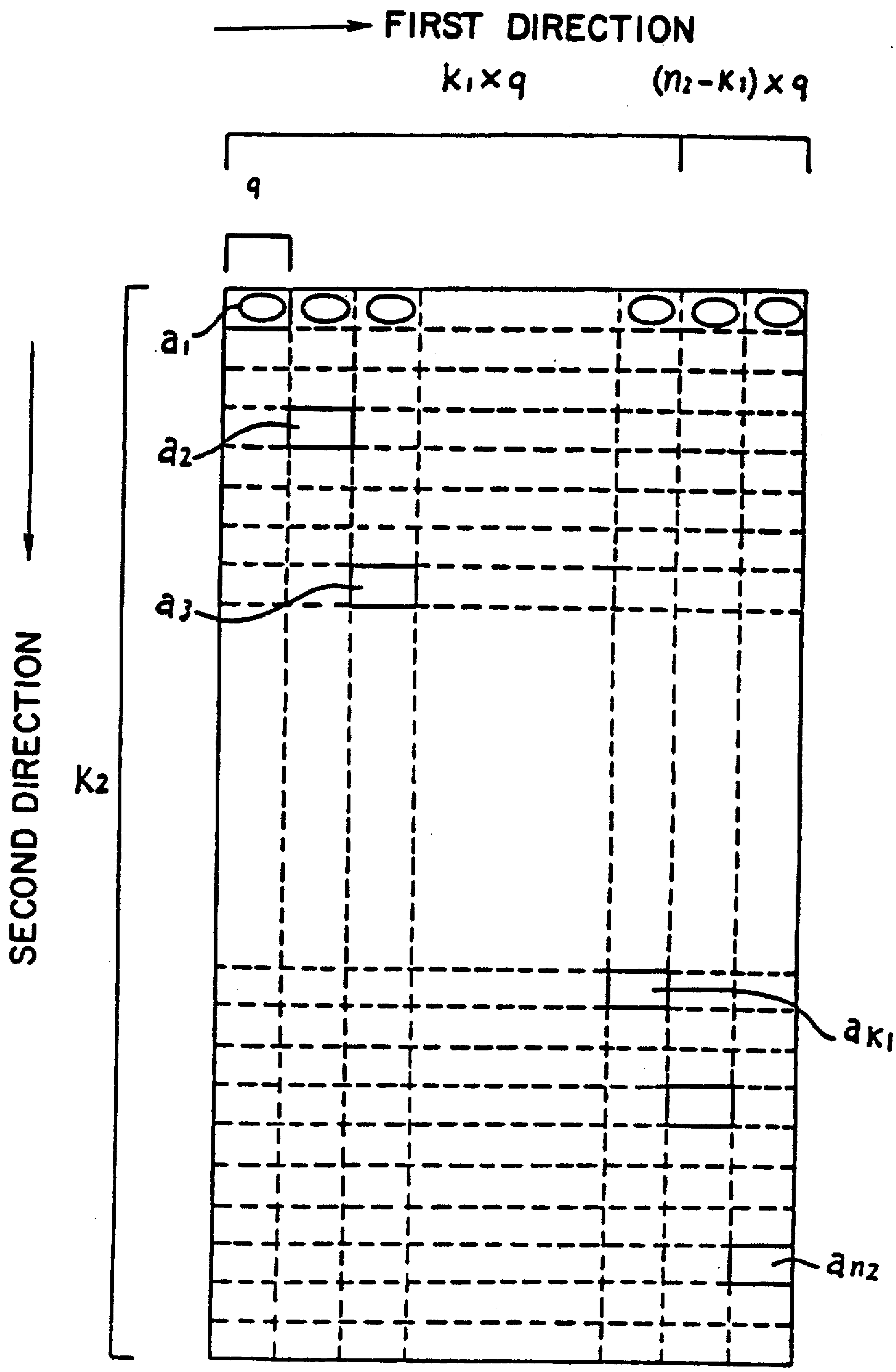

FIRST DIRECTION
$k_1 \times q$
$(n_2-k_1) \times q$
q
a_1
a_2
a_3
a_{k1}
a_{n2}
SECOND DIRECTION
K_2

FIG. 2

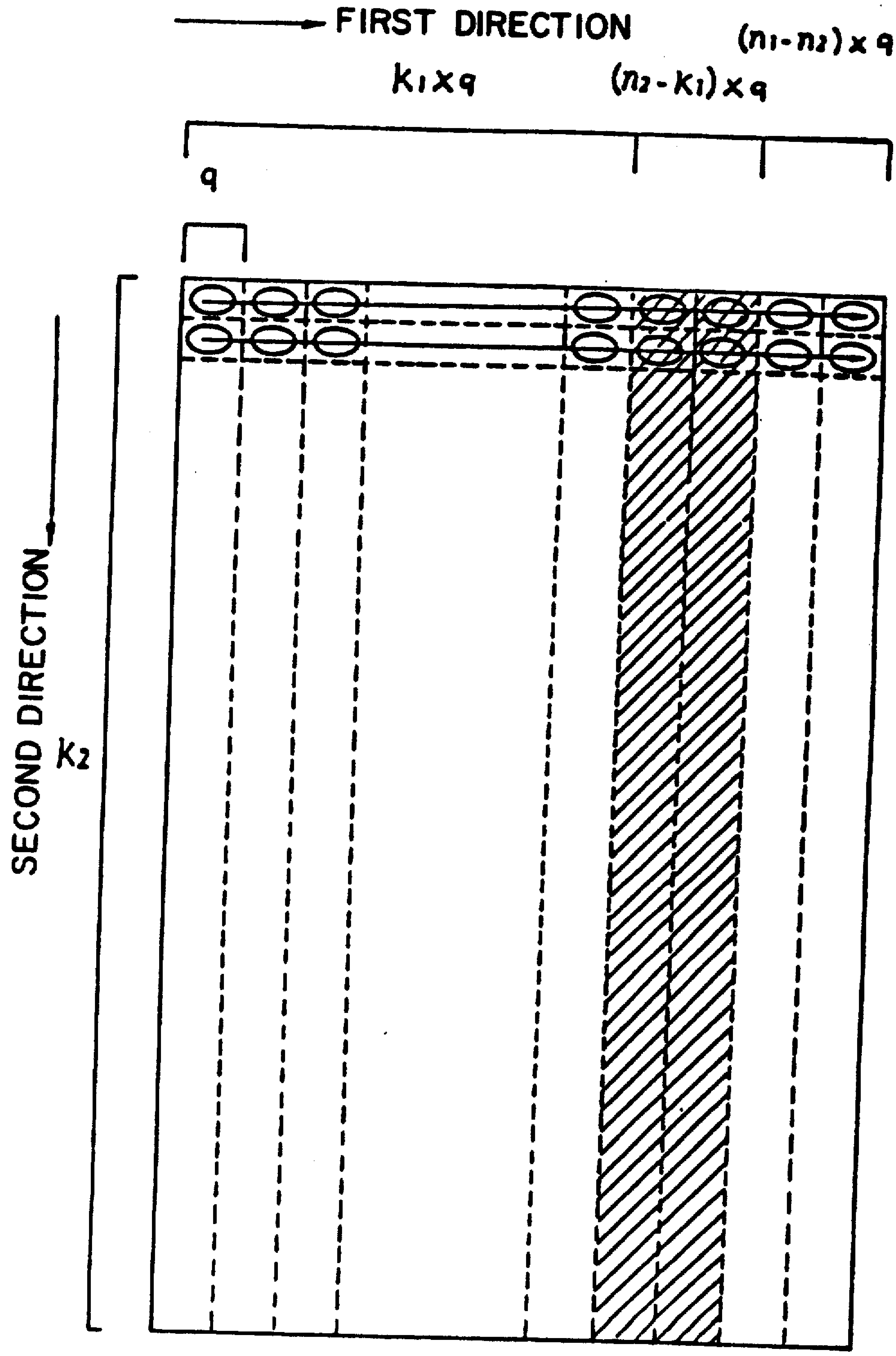


FIG. 3

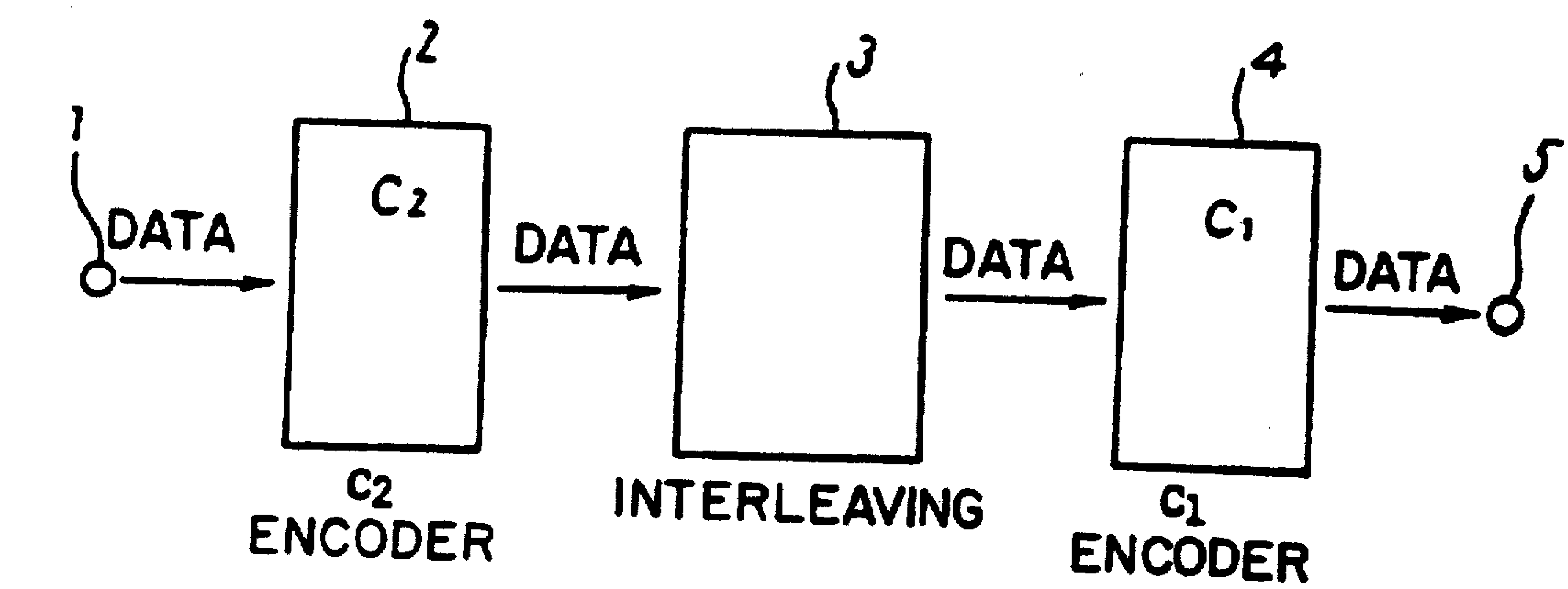

1
DATA
2
C2
DATA
3
DATA
4
C1
DATA
5
C2
ENCODER
INTERLEAVING
C1
ENCODER

FIG. 4

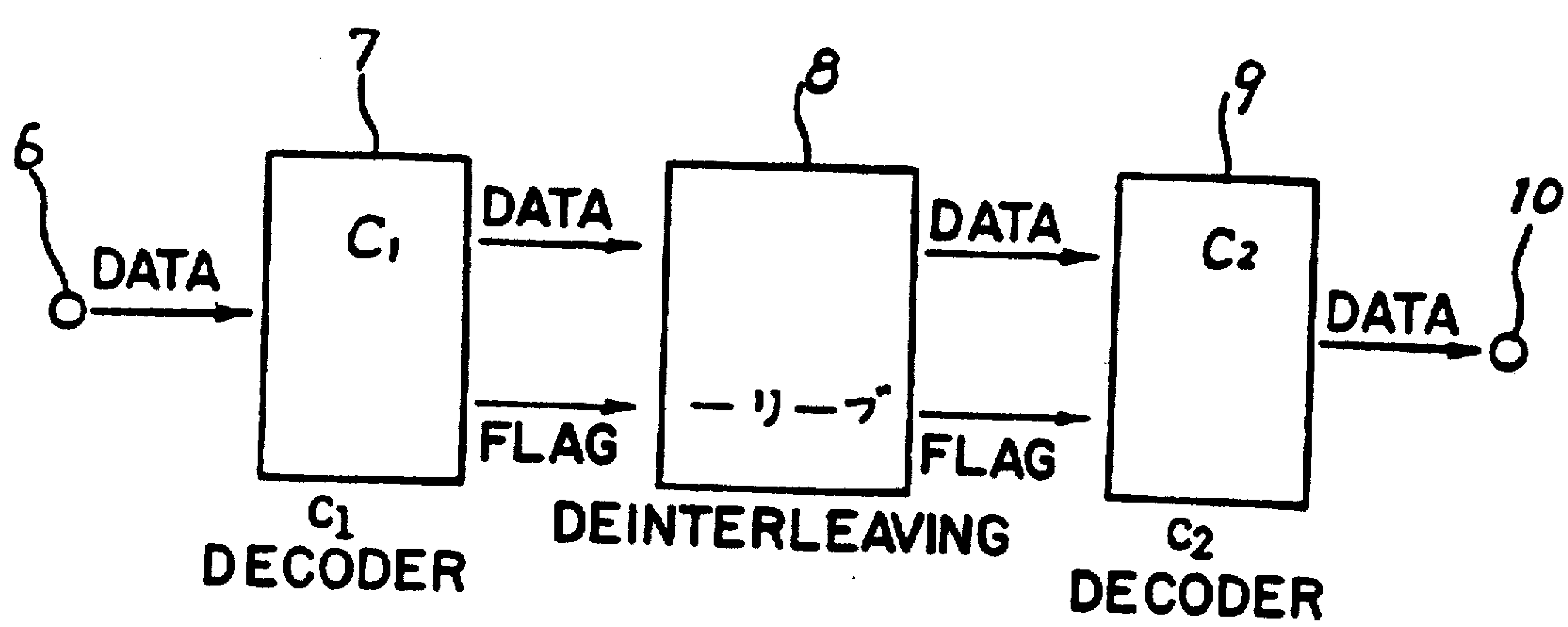
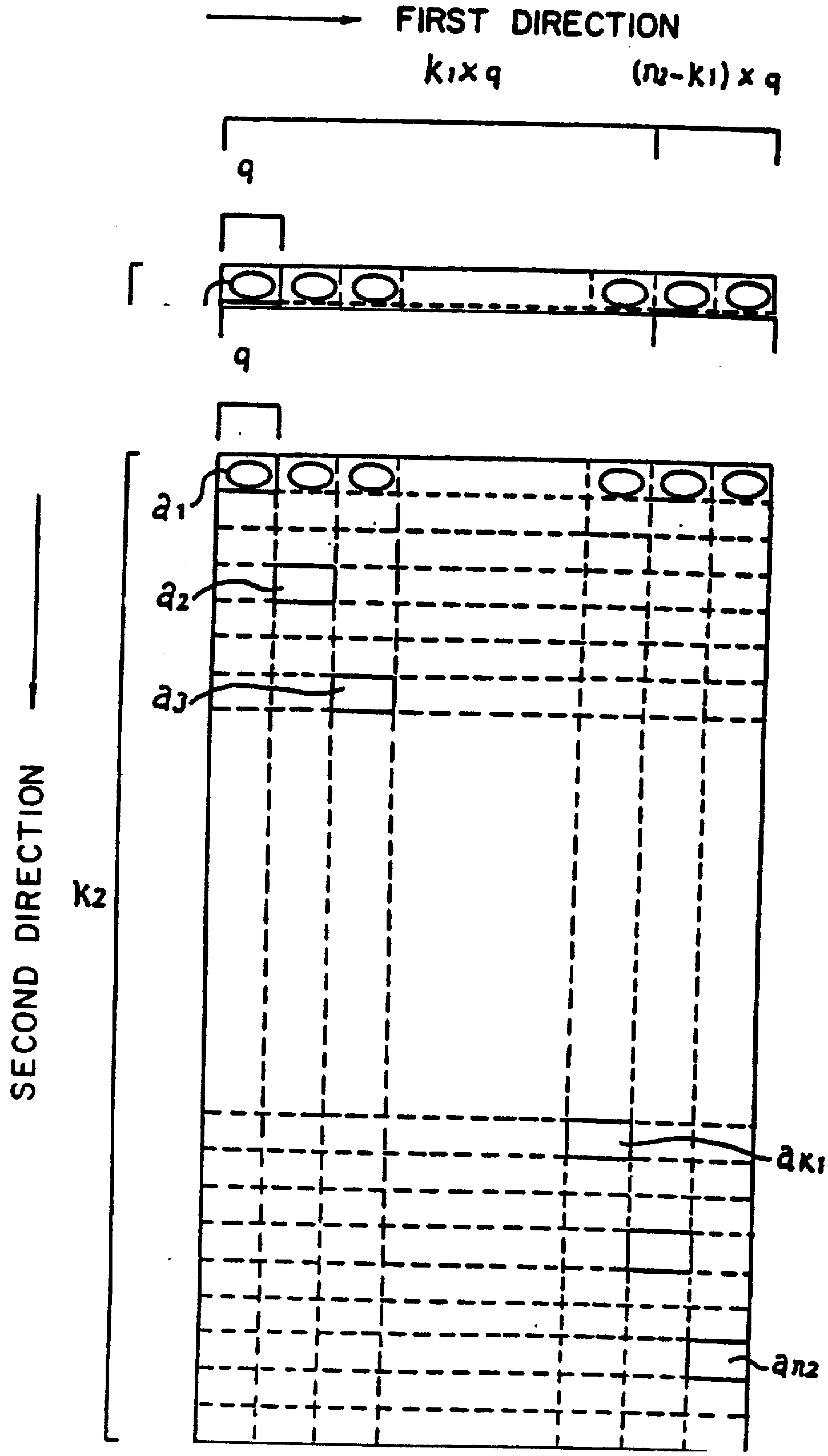

6
DATA
7
C1
DATA
FLAG
8
ーリーブ
DATA
FLAG
9
C2
10
DATA
C1
DECODER
DEINTERLEAVING
C2
DECODER

FIG. 5



FIRST DIRECTION
$k_1 \times q$
$(n_2-k_1) \times q$
q
q
a_1
a_2
a_3
SECOND DIRECTION
K_2
a_{K1}
a_{n2}

TWO STAGE CODING METHOD

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

TECHNICAL FIELD

The present invention relates to a two stage coding method having a high burst error correction ability and also a random error correction ability equivalent to that of the prior art when an error correction code such as a Reed Solomon code (hereinafter referred to as "RS code") is used in order to correct data errors which arise in reproducing data recorded in a recording material such as a magnetic disk.

BACKGROUND ART

Generally, in recording and reproducing data into and from a recording material such as a magnetic disk a data error may arise dependent on the state of the recording material. A data error may be a burst error caused by a signal drop out [on] *or* a random error caused by a deterioration in SN ratio. In order to correct these errors a two stage coded error correction code is used. As an example, a two stage code using RS codes on a GF [(2^8)] *(2^q)* where $q=8$ will be considered. A two stage encoder is shown in FIG. 3. In FIG. 3, reference numeral **1** designates an input terminal, reference numeral **2** designates a C_2 encoder, reference numeral **3** designates an interleaving circuit, reference numeral **4** designates a C_1 encoder, the reference numeral **5** designates an output terminal. First of all, C_2 encoding is performed on the original data, interleaving is executed thereto, and thereafter C_1 encoding is conducted, and the resulting code signal is output to the output terminal. A two stage decoder is shown in FIG. 4. In FIG. 4, reference numeral **6** designates an input terminal, reference numeral **7** designates a C_1 decoder, reference numeral **8** designates a deinterleaving circuit, reference numeral **9** designates a C_2 decoder, and reference numeral **10** designates an output terminal. In this decoder deinterleaving is executed after the C_1 decoding, and thereafter C_2 decoding is conducted. There is a prior art two stage coding method which, assuming that data obtained by arranging [$k_1 \times 9$] *$k_1 \times q$* digits in a first direction and k_2 digits ($k_1 < k_2$) in a second direction as shown in FIG. 5 is arranged into 8 [data] *digit* words in the first direction, consists of adding a first check code of $n_2 - k_1$ digits, and thereafter adding a second check code of $n_1 - n_2$ digits as shown in FIG. 2, (n_2, k_1) RS code is used as the C_2 code, and (n_1, n_2) RS code is used as the C_1 code.

A specific coding example will be described with reference to FIGS. 5 and 2. When it is established that $k_1=32$, $k_2=128$, $n_1=40$, $n_2=36$, and $h_1=h_2=\ldots=h_{35}=h=3$, the data region comprising the data and the first check code becomes data of $n_2 \times k_2 = 4608$ digits as shown in FIG. 5, and when a_1 is set to 1, a_2 to a_{36} become as follows:

$$a_2 = a_1 + n_2 \times h + 1 = 110$$
$$a_3 = a_2 + n_2 \times h + 1 = 219$$
$$\vdots$$
$$a_{32} = a_{31} + n_2 \times h + 1 = 3380$$

-continued

$$\vdots$$
$$a_{36} = a_{35} + n_2 \times h + 1 = 3816$$

and C_2 encoding is conducted on the data corresponding to the a_1-th, a_2-th, . . . , a_{32}-th data *selected* with use of the following generation polynomial of C_2 code

$$G_2(x) = \prod_{i=0}^{n_2-K_1-1} (x - \alpha^i).$$

where α is a root of a primary polynomial (for example, such as $x^8+x^4+x^3+x^2+1$ on GF (2^8)). The generated check codes are arranged at the positions corresponding to the a_{33}-th, a_{34}-th, . . . , a_{36}-th data. Next, a_1 is set as follows:

$$a_1 = a_1 + n_2 = a_1 + 36,$$

and similarly check codes are added to the data successively. Herein, if the calculated result of a_2 to a_{36} exceeds $n_2 \times k_2 = 4608$, a number obtained by subtracting 4608 therefrom is made the result. The encoding is repeated k_2 times thereby to conclude the C_2 encoding.

Next, C_1 encoding is conducted on the data of n_2 digits in each column arranged in the first direction as shown in FIG. 2 with the use of the following generation polynomial of C_1 code

$$G_1(x) = \prod_{i=0}^{n_1-n_2-1} (x - \alpha^i).$$

The generated check code is added to the end portion of the data and the encoding is repeated k_2 times. In the recording of the data onto the recording material data of $n_1=40$ digits arranged in the first direction is sent out k_2 times successively. In the reproduction of the same the sent out data are arranged in a column in the first direction by 40 digits successively.

In the prior art two stage coding method with such a construction, the C_2 code is concerned with burst error correction ability, and the C_1 and C_2 codes are concerned with random error correction ability. In the stage of conducting C_2 encoding the h must be made large in order to enhance the burst error correction ability, and h is set as follows:

$$h = [k_2/n_2] = [128/36] = 3$$

where [A] denotes an integer which does not exceed A The C_2 codes are gathered at the right end portion of the data region in FIG. 5, and the C_2 and the C_1 code are arranged adjacent to each other in the first direction subsequent to the data of $k_1=32$ digits when the C_1 encoding is completed.

The prior art two stage coding method is constructed in such a manner, and the error correction ability by one code amounts to $n_2 - k_1$ digits when forfeiture correction is conducted by the C_2 decoding. Accordingly, the burst error correction ability becomes as follows for data of $n_2 \times k_2 = 4608$ digits comprising all the data and the C_2 code

$$(n_2 - k_1) \times n_2 \times h = 432,$$

but h becomes as follows:

$$h=[k_2/n_2]=[128/36]=3<128/36,$$

and k_2/n_2 does not equal an integer, thereby resulting in deterioration of error correction capability.

DISCLOSURE OF THE INVENTION

The present invention is directed to solve the problems pointed out above and an object is to provide a two stage coding method in which the above-described deterioration in a burst error correction ability is improved and a higher burst error correction ability than that of the prior art device is obtained.

According to the coding method of the present invention, assuming that data of $k_1\times 8\times k_2$ digits are arranged in a matrix of $k_1\times 8$ digits in a first direction and k_2 digits(s) in a second direction and the data is divided into words of 8 digit(s) in the first direction, in conducting C_2 encoding by taking out n_2 data words from the data of **[**n_2**]** *n_2-k_1* words in the first direction and k_2 words in the second direction with no duplication of data in either of the first and second directions, a C_2 code of **[**code**]** length **[**n_2**]** *n_2-k_1* is produced by establishing a_1 at an arbitrary data number word, and establishing $h_1, h_2, \ldots, h_{n2-1}$ such that they become a repetition of a combination satisfying the condition that $[k_2/n_2]$ and $[k_2/n_2]+1$ may be

$$[k_2/n_2]\times l_1+([k_2/n_2]+1)\times l_2\leqq k_2$$

(herein, $l_1+l_2=n_2$(l_1, l_2: integer) and a_2 to a_{n2} exceeding $n_2\times k_2$ are obtained by subtracting $n_2\times k_2$ therefrom) for a_2 to a_{n2} as in the following:

$$a_2 = a_1 + n_2 \times h1 + 1$$
$$a_3 = a_2 + n_2 \times h_2 + 1$$
$$\vdots$$
$$a_{k1} = a_{k-1} + n_2 \times h_{k1-1} + 1$$
$$\vdots$$
$$a_{n2} = a_{n-1} + n_2 \times h_{n2-1} + 1$$

when numbering is conducted successively in the first direction on the data of n_2 words in the first direction and k_2 words in the second direction, and this is repeated k_2 words in the second direction, and thereafter C_1 encoding of each $n_2\times q$ digits in the first direction **[**into a**]**, *forming an C_1C_2 encoded data matrix having a total* code length n_1 is conducted.

In the two stage coding method of the present invention, C_2 codes are constructed to be effective for error correction at the portion of n_2-k_1 in the first direction and at the portion of k_2 in the second direction against the data obtained by arranging k_1 digits in the first direction and k_2 digits in the second direction, as shown in FIG. 1. According to the present invention, the burst error correction ability against the data of $n_2\times k_2=4608$ digits comprising all the data, and the C_2 codes becomes

$$(n_2-k_1)\times n_2\times(h_4+h_B)/2=504.$$

and this exceeds 432 which is the burst error correction ability of the prior art device against the same number of data and the same number of check codes.

In this way, it is possible to conduct a two stage coding having a higher burst error correction ability than that of the prior art, and having a random error correction ability equivalent to that of the prior art due to the C_1 and C_2 codes.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing a data arrangement for conducting a C_2 encoding method as one embodiment of the present invention;

FIG. 2 is a diagram showing a data arrangement for conducting a prior art two stage coding method and a C_1 encoding method as an embodiment of the present invention;

FIG. 3 is a block diagram showing a two stage encoding circuit;

FIG. 4 is a block diagram showing a two stage decoding circuit; and

FIG. 5 is a diagram showing a data arrangement for conducting the C_2 encoding method of the prior art two stage coding method.

BEST MODES OF EMBODYING THE INVENTION

Embodiments of the present invention will be described with reference to the drawings. In FIGS. 1 and 2, the constants are established that $q=8$, $k_1=32$, $k_2=128$, $n_1=40$, $n_2=36$, and data are divided into words of 8 digits in the first direction. FIG. 1 shows a C_2 encoding method. Data of $k_1\times k_2=4096$ data words are arranged sequentially in the first direction and in a matrix of $k_1=32$ words in the first direction and $k_2=128$ words in the second direction, and when h_{2i-1} and h_{2i} are set as follows

$$h_{2i-1}=h_A=]k_2/n_2]=3$$

$$h_{2i}=h_B=[k_2/n_2]+1=4,$$

(i: integer, $1\leqq i\leqq(n_2-1)/2$)
and a_1 is set 1, a_2 to a_{36} become

$$a_2 = a_1 + n_2 \times h_A + 1 = 110$$
$$a_3 = a_2 + n_2 \times h_B + 1 = 255$$
$$\vdots$$
$$a_{32} = a_{31} + n_2 \times h_A + 1 = 3920$$
$$a_{36} = a_{35} + n_2 \times h_A + 1 = 4428$$

and, C_2 encoding is performed on the data corresponding to the a_1-th, a_2-th, $\ldots$, and a_{32}-th data with the use of the generation polynomial of the C_2 code

$$G_2(x) = \prod_{i=0}^{n_2-k_1-1} (x - \alpha^i).$$

Herein, α is a root of a primary polynomial. The generated check codes are arranged at the positions corresponding to the a_{33}-th, a_{34}-th, $\ldots$, a_{36}-th data. Next, a_1 is set as follows

$$a_1=a_1+n_2=a_1+36$$

and similarly inspection codes are added to the data successively. a_2 to a_{36} exceeding $n_2\times k_2=4608$ are made by subtracting 4608 therefrom. When this encoding operation is repeated k_2 times the C_2 encoding is completed.

Next, C_1 encoding is performed on the data of n_2 words in each column arranged in the first direction as shown in FIG. 2 with the use of the generation polynomial of C_1 code

$$G_1(x) = \prod_{i=0}^{n_1-n_2-1} (x - \alpha^i).$$

The generated check codes are added to the data, and the encoding is repeated k_2 times. The recording of the data on a recording material is conducted by sending out data of $n_1=40$ words arranged in the first direction successively k_2 times. The data format reproduction is conducted by arranging the sent out data by 40 words successively in a column in the first direction.

In the two stage coding method of the present invention, the C_2 code is concerned with burst error correction ability and both C_1 and C_2 codes are concerned with random error correction ability. In conducting the C_2 encoding, C_2 codes of n_2-k_1 in the first direction and k_2 in the second direction can be used effectively for the error correction of the data arranged in a matrix of k_1 in the first direction and k_2 in the second direction.

In the above-illustrated embodiment a repetition pattern of (h_A, h_B) is adopted for $h_1, h_2, \ldots, h_{n2-1}$, but other combinations using h_A and h_B such as (h_B, h_A) or (h_A, h_B, h_B) can be used if they comply with the following conditions

$$h_A \times l_1 + h_B \times l_2 \leqq k_2$$

$$l_1 + l_2 = n_2$$

Furthermore, an RS code on GF (2^q) is used as an error correction code, but another code such as a BCH code can be used as an error correction code. Furthermore, the number of data, the construction of information lengths in the first and second directions, and the C_2 and C_1 code lengths can be arbitrarily established. Furthermore, in the illustrated embodiment the region occupied by the check codes of the C_2 code and the C_1 code is shown in FIG. 2, but this occupied region can be arbitrarily established by establishing a_1 at an arbitrary number.

Furthermore, it is possible to add the additional information of $k_3 \times q$ digits in the second direction k_2 times precedent to the C_1 encoding, and thereafter to conduct C_1 encoding on GF (2^q) having the $(n_1+k_3) \times q$ digits in the first direction, and to conduct a coding k_2 times repeatedly in the second direction.

APPLICABILITY TO THE INDUSTRY

The present invention is applicable not only to a magnetic disk apparatus but also to an optical recording and reproducing apparatus, and an optical magnetic recording and reproducing apparatus.

We claim:

1. A two stage coding system for encoding digital information arranged in a matrix of $k_1 \times q$ digits in a first direction, and k_2 digits in a second direction orthogonal to the first direction, wherein

K_1, q, and k_2 are integers,

$K_1 < k_2$; q = the number of digits per data word, and

K_1, K_2 = the number of data words in said first and second directions respectively, comprising:

C_2 encoder means for encoding said digital information with a C_2 code on a Galois Field GF (2^q),

including means for [numbering] *selecting* data words in said matrix diagonally from an arbitrary data word a_1 and establishing a_2 to a_{n2}, wherein n_2 is the length of [code] *the C_2 encoded data*, such that

$$a_2 = a_1 + n_2 \times h_1 + 1$$
$$a_3 = a_2 + n_2 \times h_2 + 1$$
$$\vdots$$
$$a_{k1} = a_{k1-1} + n_2 \times h_{k1-1} + 1$$
$$\vdots$$
$$a_{n2} = a_{n2-1} + n_2 \times h_{n2-1} + 1$$

wherein h_1 to h_{n2-1} satisfy the following

$$h_{2i-1} = [K_2/n_2]$$

$$h_{2i} = [k_2/n_2] + 1 \quad 1 \leqq i \leqq (n_2-1)/2$$

said C_2 encode means including means for C_2 encoding said [numbered] *selected* data words, and means for adding the obtained C_2 code to an end of said matrix in said first direction; and

C_1 encoder means for encoding said C_2 encoded matrix with a C_1 code having a *predetermined* length [of n_1] on a GF (2^q) for each row of data words in said first direction, and adding the obtained C_1 code to an end of said matrix in said first direction.

2. The two stage coding system of claim 1 wherein said means for C_2 encoding further encodes said selected data words in each said diagonal;

said means for adding a C_2 code to the end of each said diagonal to form a C_2 code field at the end of said matrix in said first direction.

3. The two stage coding system of claim 2 wherein said C_2 encoder means subtracts $n_2 \times k_2$ from any initially calculated value of a_2 to a_{n2} that exceed $n_2 \times k_2$ to select data words in said matrix diagonally.

4. The two stage coding system of claim 1 wherein said C_2 encoder means subtracts $n_2 \times k_2$ from any initially calculated value of a_2 to a_{n2} that exceed $n_2 \times k_2$ to select data words in said matrix diagonally.

5. The two stage coding system of claim 1 wherein additional data added to said rows of data words in said first direction prior to encoding of said C_2 encoded matrix with a C_1 code is also encoded with this C_1 code by said C_1 encoder means.

6. A two stage coding system for encoding digital information arranged in an information matrix of $k_1 \times q$ digits in a first direction, and k_2 digits in a second direction orthogonal to the first direction, wherein

k_1, q, and k_2 are integers,

$k_1 < k_2$; q = the number of digits per data word, and

k_1, k_2 = the number of data words in said first and second directions respectively, comprising:

C_2 encoder means for encoding said digital information with a C_2 code on a Galois field GF(2^2), said C_2 encoder means selecting data words in said information matrix diagonally from an arbitrary data word a_1 and including a_2 to a_{n2}, wherein n_2 is the length of the C_2 encoded data, such that

$$a_2 = a_1 + n_2 \times h_1 + 1$$

$$a_3 = a_2 + n_2 \times h_2 + 1$$

:

$$a_{k1}=a_{k1-1}+n_2\times h_{k1-1}+1$$

:

$$a_{n2}=a_{n2-1}+n_2\times h_{n2-1}+1,$$

h_1 to h_{2n-1} each being selected from one of h_A and h_B, wherein,

$$h_A=[k_2/n_2],$$

$$h_B=[k_2/n_2]+1, \text{ and}$$

$$h_A\times l_1+h_B\times l_2\leq k_2, \text{ where}$$

$$l_1+l_2=n_2$$

said C_2 encoder means forming said C_2 code from said selected data words and adding the obtained C_2 code to an end of said information matrix in said first direction thereby forming a C_2 encoded matrix; and

C_1 encoder means for encoding each line in said first direction of said C_2 encoded matrix with a C_1 code having a predetermined length on a GF(2^q), and adding the obtained C_1 code to an end of each said line of said matrix in said first direction to form a C_2C_1 encoded matrix.

7. The two stage coding system of claim 6 wherein a group of two or more adjacent lines h_1, h_2, . . . utilize a repetition pattern having at least one of each of h_A and h_B contained therein, said selection of data words a_1 to a_n by said C_2 encoder means utilizing said repetition pattern for selection of all said data words (a) in said information matrix.

8. The two stage coding system of claim 7 wherein said repetition pattern is selected from the group consisting of h_A, h_B; h_B, h_A; and h_A, h_B, h_B.

9. The two stage coding system of claim 6 wherein:

$$h_{2i-1}=h_A,$$

$$h_{2i}=h_B,$$

where $1<i<(n_2-1)/2$.

10. The two stage coding system of claim 6 wherein:

$$h_{2i-1}=h_B,$$

$$h_{2i}=h_A,$$

where $1<i<(n_2-1)/2$.

11. The two stage coding system of claim 6 wherein said C_2 encoder means repeatedly selects data words in said information matrix from an arbitrary data word a_1 and including a_2 to a_{n2}, said C_2 encoder means repeatedly forming said C_2 code and adding said C_2 to the end of the matrix, each repetition starting from a different arbitrary data word a_1.

12. The two stage coding system of claim 11 wherein said C_2 encoder means selects k_2 arbitrary data words from which to perform selecting, forming and adding to thereby form a complete C_2 encoded matrix.

13. The two stage coding system of claim 6 wherein said means for C_2 encoding further encodes said selected data words in each said diagonal;

said means for adding a C_2 code to the end of each said diagonal to form a C_2 code field at the end of said information matrix in said first direction.

14. The two stage coding system of claim 6 wherein additional data added to said rows of data words in said first direction prior to encoding of said C_2 encoded matrix with a C_1 code is also encoded with this C_1 code by said C_1 encoder means to thereby form said C_2C_1 encoded matrix.

15. The two stage coding system of claim 14 wherein the length of said C_2C_1 encoded data matrix in the first direction is $(n_1+k_3)\times q$ digits, where k_3 is an integer.

16. The two stage coding system of claim 6 wherein said C_2 encoder means subtracts $n_2\times k_2$ from any initially calculated value of a_2 to a_{n2} that exceed $n_2\times k_2$ to select data words in said matrix diagonally.

17. The two stage coding system of claim 6 wherein the length of said C_2C_1 encoded data matrix in the first direction is $n_1\times q$ digits.

18. A two stage coding system for encoding digital information arranged in an information matrix of $k_1\times q$ digits in a first direction, and k_2 digits in a second direction orthogonal to the first direction, wherein

k_1, q, and k_2 are integers,

$k_1<k_q$; q=the number of digits per data word, and

k_1, k_2=the number of data words in said first and second directions respectively,

said system further single stage coding additional information of $k_3\times q$ digits in the first direction, where k_3 is an integer and k_2 digits in the second direction, comprising:

C_2 encoder means for encoding said digital information with a C_2 code on a Galois field GF(2^q), said C_2 encoder means selecting data words in said information matrix diagonally from an arbitrary data word a_1 and including a_2 to a_{n2}, wherein n_2 is the length of the C_2 encoded data, such that

$$a_2=a_1+n_2\times h_1+1$$

$$a_3=a_2+n_2\times h_2+1$$

:

$$a_{k1}=a_{k1-1}+n_2\times h_{k1-1}+1$$

:

$$a_{n2}=a_{n2-1}+n_2\times h_{n2-1}+1$$

h_1 to h_{n2-1} each being selected from one of h_A and h_B, wherein,

$$h_A=[k_2/n_2],$$

$$h_B=[k_2/n_2]+1, \text{ and}$$

$$h_A\times l_1+h_B\times l_2\leq k_2, \text{ where}$$

$$l_1+l_2=n_2$$

said C_2 encoder means forming said C_2 code from said selected data words and adding the obtained C_2 code to an end of said information matrix in said first direction to form a C_2 encoded matrix; and

said additional data of k_3 words and said C_2 encoded matrix collectively forming an added data matrix having k_2 lines;

C_1 encoder means for encoding each of said k_2 lines extending in said first direction of said added data matrix with a C_1 code having a predetermined length on a GF(2^q), and adding the obtained C_1 code to an

end of each said line of said added data matrix in said first direction to form a C_2C_1 encoded matrix.

19. The two stage coding system of claim 18 wherein a group of two or more adjacent lines $h_1, h_2, \ldots$ utilize a repetition pattern having at least one of each of h_A and h_B contained therein, said selection of data words a_1 to a_n by said C_2 encoder means utilizing said repetition pattern for selection of all said data words (a) in said information matrix.

20. The two stage coding system of claim 19 wherein said repetition pattern is selected from the group consisting of h_A, h_B; h_B, h_A; and h_A, h_B, h_B.

21. The two stage coding system of claim 18 wherein:

$$h_{2i-1} = h_A,$$

$$h_{2i} = h_B,$$

where $1 < i < (n_2 - 1)/2$.

22. The two stage coding system of claim 18 wherein:

$$h_{2i-1} = h_B,$$

$$h_{2i} = h_A,$$

where $1 < i < (n_2 - 1)/2$.

23. The two stage coding system of claim 18 wherein said C_2 encoder means repeatedly selects data words in said information matrix from an arbitrary data word a_1 and including a_2 to a_{n2}, said C_2 encoder means repeatedly forming said C_2 code and adding said C_2 to the end of the matrix, each repetition starting from a different arbitrary data word a_1.

24. The two stage coding system of claim 23 wherein said C_2 encoder means selects k_2 arbitrary data words from which to perform selecting, forming and adding to thereby form a complete C_2 encoded matrix.

25. The two stage coding system of claim 18 wherein said means for C_2 encoding further encodes said selected data words in each said diagonal;

said means for adding a C_2 code to the end of each said diagonal to form a C_2 code field at the end of said information matrix in said first direction.

26. The two stage coding system of claim 18 wherein said C_2 encoder means subtracts $n_2 \times k_2$ from any initially calculated value of a_2 to a_{n2} that exceed $n_2 \times k_2$ to select data words in said information matrix diagonally.

27. The two stage coding system of claim 18 wherein the length of said C_2C_1 encoded matrix in the first direction is $(n_1 + k_3) \times q$ digits.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : Re. 34,245

DATED : May 11, 1993

INVENTOR(S) : Kiyoshi Matsutani, et. al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Fig. 5 should be deleted to be replaced with Fig. 5 as shown on attached sheet.

Signed and Sealed this

Twenty-fourth Day of May, 1994

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : Re. 34,245

DATED : May 11, 1993

INVENTOR(S) : Kiyoshi Matsutani, et. al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

FIG. 5