DETECTION AND CORRECTION OF REPEATED RESTRICTED BURST ERRORS IN SUB-BLOCKS

***Subodh Kumar*[1], *Tarun Lata*[2], *Subodh Rana*[3], *Megh Pal*[1]**

[1]*Mathematics Dept., Shyam Lal College, University of Delhi, India*
2Mathematics Dept., Dr. A. K. Gupta Institute of Technology and Management, Delhi, India
[3]*Mathematics Dept., Multanimal Modi College, Modinagar, Uttar Pradesh, India*

skumarmath@shyamlal.du.ac.in; tarunlata1983@gmail.com; subodhrana@mmcmodinagar.ac.in; meghdu@gmail.com

ОТКРИВАНЕ И КОРИГИРАНЕ НА ПОВТАРЯЩИ СЕ ОГРАНИЧЕНИ ПАКЕТНИ ГРЕШКИ В ПОДБЛОКОВЕ

Abstract: *In this paper, we present bounds on check symbols required for the codes capable to detect as well as correct the restricted bursts errors that are repeating themselves in a single sub-block. For these codes the whole code length is considered to be subdivided into a certain number of mutually exclusive sub-blocks of equal length.*

Keywords: *Repeated Restricted Burst Errors; Detection and Correction; Sub-Blocks; Parity Check Matrix, Error Patterns, Syndromes*

Subject Classification [2010]: *94B05, 94B65.*

1. Introduction

The correction of the different types of errors such as random error [7], burst [6], CT burst [2], repeated burst errors (RB errors) [1], [5] and key errors [3] is the main goal of the coding theory. These errors occur during the transmission through a channel. Different communication channels work with different frequencies of transmission. It came in observation that in very busy communication channels the errors that are in clusters repeat themselves frequently. Berardy et all [1] studied the burst errors that repeat themselves two times and they named such type errors as 2-RB errors. Dass and Verma [5] did the further study of these errors and gave the bounds for the existence of the codes that can correct the m-RB errors. In the article [4], the authors derived the bounds on the check symbols of the codes that can correct RB errors over $GF(q)$ occurring in any sub-block.

The transmission rate of a communication channel is inversely proportional to the number $n-k$ for an (n, k) code. Fulfilling this condition, Tyagi and Lata [10], [11] obtained some optimal codes by introducing a new type of burst errors and they named these errors as *restricted burst*. By [11] *A restricted burst of length t or less is a vector whose all the non-zero components are confined to some t consecutive positions, the first and the last of which is nonzero with a restriction that all the non-zero consecutive positions contain same field element*. For q=4, t=3, and n=5, all the following 5-tuples: 00101, 22200, 01100, 00202, 10000, 01110, 33300, are examples of restricted bursts over $GF(4)$ with length upto 3. Carrying forward the study of the restricted burst errors the authors of the research paper [8] gave the definition RRB errors over $GF(q)$ (Note: we will denote these errors as RRB errors). They also derived the bounds on the check symbols of a code that can correct m-RRB errors spread over the whole code length. They gave the following definition:

Definition 1.1. *An m-repeated restricted burst of length t is a vector whose only non-zero components are confined to m-distinct sets of t consecutive components, the first and last component of each set being same non-zero field element*.

The vector 00222200202200, 1101000100100, 04044000404400 are the example of 2-RRB erros over $GF(5)$.

In this communication, we consider that the length of a code is sub divided into a certain number of sub-blocks of equal length. We obtained the codes that have the capability to detect and correct the m-RRB errors occurred in one the sub-blocks.

We organize this paper into three sections. First section contains the introduction including some basic definitions. In the second section we establish the bounds on the number $(n-k)$ needed for the existence of (n, k) codes that detects the m-RRB errors. The third and the last section of of this paper contains the derivations of the bounds on the number $(n-k)$ needed for the existence of (n, k) codes that corrects m-RRB errors.

2. Detection of RRB errors

We assume that the code length is divided into certain number (say, f) of sub-blocks that are mutually exclusive and of equal length t. The codes

Theorem 2.1. *The number $(n-k)$ for a $(n=fl, k)$ code over $GF(q)$ with no m-RRB errors occurring in any one of the f sub-blocks satisfies the following inequality*

$$n-k \geq log_q[1+f(q-1)(2^{mt}-1)].$$

Proof. If we are able to show that in all sub-blocks any detectable m-RRB errors is not a code word, then the code will detect these errors.

Let us form a set X in an arbitrary single sub-block consisting of such vectors that have all their components different from zero and confined to some m number of fixed and distinct sets of length t or less.

Now we claim that no coset has two equal elements from the set X, to prove this, let us consider that two elements x_1 and x_2 of X are lying in a same coset. As we know that the difference or sum of these two elements will be a code vector. But since the vector x_1-x_2 contains m-RRB errors of length upto t. This shows a contradiction. Therefore each element of X lies in a distinct coset.

The total number of vectors in the set X is $2^{mt}(q-1)-(q-2)$ including the vectors of all zeros. Since f is the number of total partitions of the whole code length. So the total count of the m-RRB errors occurred in the whole code length is

$$1 + f(q-1)\{2^{mt} - 1\}.$$

Since there are q^{n-k} cosets, thus

(1)

$$q^{n-k} \geq 1 + f(q-1)\{2^{mt} - 1\}.$$

The required result will be obtained by taking log on both side of (1) with base q. i.e.

$$n - k \geq log_q[1 + f(q-1)(2^{mt} - 1)].$$

Corollary 2.2. The number $(n-k)$ for a $(n=fl,\ k)$ code over $GF\ (q)$ with no 2-RRB errors occurring in any one of the f sub-blocks satisfies the following inequality

$$n - k \geq log_q[1 + f(q-1)(2^{2t} - 1)].$$

Theorem 2.3. *A sufficient bound for an* $(n=fl,\ k)$ *code,* $(l>mt)$ *over* $GF\ (q)$ *with no m-RRB errors of length t occurring in any one of the f sub-blocks is*

$$q^{n-k} > 1 + [2^{t-1}(q-1) - (q-2)] \times \left[\left[2^{(t-1)(m-1)}(q-1)\left\{\binom{l + (m-1) - mt}{m-1} + \sum_{r=0}^{m-2} 2^{m-r-2} \times \binom{l + r - mt}{r}\right\} - (q-2)\right] + (f-1)\left[(q-1)2^{m(t-1)}\left\{\binom{l - mt + m}{m} + \sum_{r=0}^{m-1} 2^{m-1-r} \times \binom{l + r - mt}{r}\right\} - (q-1)\right]\right]$$

Proof. The required bound will be proved by getting a parity check matrix (PC matrix) through suitable construction by adopting the technique used to establish the Varshamov-Gilbert-sacks bound [9]. According to this we will form a matrix H of the order $(n-k)\times n$. Let the first $t(f-1)$ columns and $\rho-1$ columns of the last sub-block of the PC matrix have been chosen suitably by taking $n-k$ tuples. Now the ρ^{th} column h_ρ of f^{th}

sub-block can be added to H only if the column h_ρ should not be equal to the linear sum of $t-1$ columns just preceding the h_ρ column plus the linear sum of any $m-1$ sets of columns lying in the vector of length $\rho-l$. i.e.,

(2)

$$h_\rho \neq \left(\alpha_1 h_{\rho-1} + \alpha_2 h_{\rho-2} + \cdots + \alpha_{t-1} h_{\rho-(t-1)}\right) + \left(\beta_{11} h_{i_1} + \beta_{12} h_{i_1+1} + \cdots + \beta_{1t} h_{i_1+(t-1)}\right) + \left(\beta_{11} h_{i_1} + \beta_{12} h_{i_1+1} + \cdots + \beta_{1t} h_{i_1+(t-1)}\right) + \cdots + \left(\beta_{(m-1)1} h_{i_{m-1}} + \beta_{(m-1)2} h_{i_{m-1}+1} + \cdots + \beta_{(m-1)t} h_{i_{m-1}+(t-1)}\right)$$

The expression (2) has 2^{t-1}(q–1)-(q–2) coefficients α_i's (see, [8]). The counting of the coefficients β_{ij}'s is equal to the count of the $m-1$ RRB errors occurring in $\rho-t$ positions of f^{th} sub-block, this is given by (see, Theorem 2.1 of [8] and Theorem 3.1 of [5])

$$2^{(t-1)(m-1)}(q-1)\left[\binom{\rho+(m-1)-mt}{m-1} + \sum_{r=0}^{m-2} 2^{m-2-r}\binom{\rho+r-mt}{r}\right] - (q-2)$$

Thus the expression (2) consists of the linear sums as

(3)

$$[2^{t-1}(q-1)-(q-2)] \times \left[2^{(t-1)(m-1)}(q-1)\left\{\binom{\rho+(m-1)-mt}{m-1} + \sum_{r=0}^{m-2} 2^{m-2-r}\binom{\rho+r-mt}{r}\right\} - (q-2)\right]$$

we consider the second condition, according to which, the column h_ρ should not be equal to the linear sum of $t-1$ columns just preceding the h_ρ column plus the linear sum of any m sets of columns from any one of the first $f-1$ partitions (sub-blocks) of length l. i.e.,

(4)

$$h_\rho \neq \left(\alpha_1 h_{\rho-1} + \alpha_2 h_{\rho-2} + \cdots + \alpha_{t-1} h_{\rho-(t-1)}\right) + \left(\gamma_{11} h_{i_1} + \gamma_{12} h_{i_1+1} + \cdots + \gamma_{1t} h_{i_1+(t-1)}\right) + \left(\gamma_{11} h_{i_1} + \gamma_{12} h_{i_1+1} + \cdots + \gamma_{1t} h_{i_1+(t-1)}\right) + \cdots + \left(\gamma_{m1} h_{i_m} + \gamma_{m2} h_{i_m+1} + \cdots + \gamma_{mt} h_{i_m+(t-1)}\right).$$

In expression (4), the number of α_i's is same as in the expression (2).The number of γ_{ij}'s is equal to the count of m-RRB errors contained in a l-tuple. Thus, the expression (4) consists of total linear sums (including the all zeros tuple) is

$$[2^{t-1}(q-1)-(q-2)] \times \left[2^{m(t-1)}(q-1)\left\{\binom{1+m-mt}{m} + \sum_{r=0}^{m-1} 2^{m-r-1}\binom{t+r-mt}{r}\right\} - (q-2)\right]$$

As $f-1$ is the number of such sub-blocks, thus, the second condition provides the linear sums in total (excluding the all zeros tuple) as

(5)

$$(f-1)[2^{t-1}(q-1)-(q-2)] \times \left[2^{m(t-1)}(q-1)\left\{\binom{l+m-mt}{m} + \sum_{r=0}^{m-1} 2^{m-r-1} \times \binom{l+r-mt}{r}\right\} - (q-1)\right]$$

Now, The count of the all linear sums such that h_ρ is not equal to is

$$Exp.(3) + Exp.(5)$$

Since there are q^{n-k} cosets, Thus we have,

$$q^{n-k} > Exp.(3) + Exp.(5)$$

i.e.

$$q^{n-k} > \times \left[\begin{array}{c} \left[2^{(t-1)(m-1)}(q-1)\left\{ \binom{\rho + (m-1) - mt}{m-1} + \sum_{r=0}^{m-2} 2^{m-r-2} \times \binom{\rho + r - mt}{r} \right\} - (q-2) \right] + \\ (f-1)\left[(q-1)2^{m(t-1)}\left\{ \binom{l - mt + m}{m} + \sum_{r=0}^{m-1} 2^{m-1-r} \times \binom{l + r - mt}{r} \right\} - (q-2) \right] \end{array} \right]$$

We get the required result by putting ρ as l.

Corollary 2.4. A sufficient bound for an (n=fl, k) code, (l>2t) over $GF(q)$ with no 2-RRB errors of length t occurring in any one of the f sub-blocks is

$$\begin{aligned} q^{n-k} > {} & [2^{t-1}(q-1) - (q-2)] \\ & \times \left[\left[2^{(t-1)}(q-1)\left\{ \binom{l-2t+1}{1} + 1 \right\} - (q-2) \right] \right. \\ & \left. + (f-1)\left[(q-1)2^{2(t-1)}\left\{ \binom{l-2t+2}{2} + \binom{l+1-2t}{1} + 2 \right\} - (q-2) \right] \right] \end{aligned}$$

Now we verify Theorem 2.3 by giving an example of a code, which is capable detect 2-RRB errors occurring in a single sub-block.

Example 2.5. For the parameters q=3, l=9, f=2, m=2, t=2, the Theorem 2.3 predicts the existence of an (18, 11) linear code. Below, H is a PC-matrix of this code.

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 2 & 2 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 2 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 2 & 1 & 1 & 0 & 1 & 2 & 0 & 2 & 2 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 2 & 1 & 0 & 2 & 2 & 2 & 1 & 0 & 1 \\ 0 & 0 & 0 & 2 & 0 & 0 & 0 & 2 & 2 & 0 & 2 & 2 & 1 & 2 & 0 & 2 & 2 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 2 & 1 \\ 0 & 0 & 0 & 0 & 0 & 2 & 0 & 2 & 0 & 2 & 1 & 1 & 1 & 2 & 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 2 & 2 & 1 & 1 & 2 & 1 \end{bmatrix}$$

By using the MS-Excel, we can get the error patterns and syndromes table. We can see all the syndromes corresponding to the all possible 2-RRB errors are different from zero, which verifies that this code detects all the 2-RRB errors occurring in one of the two sub-blocks each of length 9.

3. Correction of RRB Errors

The codes that correct the RRB errors occurring in one of the sub-blocks are considered in this section.

Theorem 3.1. *A lower bound for an* (n=ft, k) *code over* $GF(q)$ *that can correct m-RRB errors occurring in one of the* f *sub-blocks is*

$$q^{n-k} > 1 + f(q-1)\left[2^{m(t-1)}\left\{\binom{l+m-mt}{m} + \sum_{r=0}^{m-1} 2^{m-r-1} \times \binom{l+r-mt}{r}\right\} - 1\right]$$

Proof. We establish this theorem in the similar manner as we prove the Theorem 2.1 will be used to establish this theorem. In a single sub-block of length t, the count of m-RRB errors that are to be corrected is

$$(q-1)2^{m(t-1)}\left\{\binom{l+m-mt}{m} + \sum_{r=0}^{m-1} 2^{m-r-1} \times \binom{l+r-1}{r}\right\} - (q-2)$$

Since code length is partitioned into f sub-blocks, thus total count of m-RRB errors (excluding the zero vector) is

$$f(q-1)\left[2^{m(t-1)}\left\{\binom{l+m-mt}{m} + \sum_{r=0}^{m-1} 2^{m-r-1} \times \binom{n+r-mt}{r}\right\} - 1\right]$$

As q^{n-k} is the number of total cosets, Thus

$$f(q-1)\left[2^{m(t-1)}\left\{\begin{matrix} l+m-mt \\ m \end{matrix}\right\} + \sum_{r=0}^{m-1} 2^{m-r-1} \times \binom{l+r-mt}{l} - 1\right]$$

Corollary 3.2. A lower bound for an (n=fl, k) code over $GF(q)$ that can correct 2-RRB errors occurring in one of the f sub-blocks is

$$f(q-1)\left[2^{2(t-1)}\left\{\binom{l+2-2t}{2} + \binom{l+r-2t}{l} + 2\right\} - 1\right]$$

Theorem 3.3. *An upper bound bound for an* (n=fl, k) *code,* (l>$2mt$) *over* $GF(q)$ *that corrects m-RRB errors of length t occurring in any one of the f sub-blocks is*

$$\begin{aligned} &1^{n-k} \\ &> [2^{t-1}(q-1) - (q-2)] \\ &\times \left[\begin{matrix} \left[2^{(t-1)(2m-1)}(q-1)\left\{\binom{l+(2m-1)-2mt}{2m-1} + \sum\limits_{r=0}^{2m-2} 2^{2m+r+2} \times \binom{l+r-2mt}{r}\right\} - (q-2)\right] + \\ (f-1)\left[(q-1)2^{2m(t-1)}\left\{\binom{l-2mt+2m}{2m} + \sum\limits_{r=0}^{2m-1} 2^{m-1-r} \times \binom{l+r-2mt}{r}\right\} - (q-1)\right] \end{matrix}\right] \end{aligned}$$

Proof. We will prove this theorem by adopting the procedure used to Theorem 2.3. According to this we construct a PC matrix of the dimension $(n-k)\times n$ for the code. Let the construction of the first $l(f-1)$ columns and $\tau-1$ columns of the last sub-block can be added to the PC matrix H only if the column h_τ should not be equal to the linear sum of $t-1$ columns just preceding the $h\tau$ column plus the linear sum of any $2m-1$ sets of columns lying in the vector of length $\tau-t$. In other words,

(6)

$$h_r \neq \left(\alpha_1 h_{\tau-1} + \alpha_2 h_{\tau-2} + \cdots + \alpha_{\tau-1} h_{\tau-(\tau-1)}\right) + \left(\lambda_{11} h_{i_1} + \lambda_{12} h_{i_1+1} + \cdots + \lambda_{1t} h_{i_1+(t-1)}\right) + \cdots + \left(\lambda_{(2m-1)1} h_{i_{2m-1}} + \lambda_{(2m-1)2} h_{i_{(2m-1)}+1} + \cdots + \lambda_{(2m-1)t} h_{i_{(2m-1)}+(t-1)}\right)$$

The number $(q-1)2^{t-1}-(q-2)$ i.e. the total count of of α_i's coefficients possibly present in expression (6), (see, Theorem 2.1 and Theorem 2.3 of [8]). The counting of coefficients λ_{ij}'s is equal to the number of $2m-1$ RRB errors possibly present in a $(\tau-b)$-tuple, that is (see, Theorem 2.1 of [8] and Theorem 3.2 of [5])

$$2^{(t-1)(2m-1)}(q-1)\left[\binom{\tau+(2m-1)-2mt}{2m-1} + \sum_{r=0}^{2m-2} 2^{2m-2-r}\binom{\tau+r-2mt}{r}\right] - (q-2)$$

Thus, the expression (6) consists of the total linear sum as

(7)

$$[2^{t-1}(q-1)-(q-2)] \times \left[2^{(2m-1)(t-1)}(q-)\left\{\binom{\tau+(2m-1)-2mt}{2m-1} + \sum_{r=0}^{2m-2} 2^{2m-2-r}\binom{\tau+r-2mt}{r}\right\} - (q-2)\right]$$

The second condition says that the τ^{th} column can be added to H only if the column h_τ should not be equal to the linear sum of $t-1$ columns just preceding the h_τ column plus the linear sum of any $2m$ sets of columns lying in any one sub-block out of the initial $f-1$ sub-blocks. i.e,

(8)

$$h_\rho \neq \left(\alpha_1 h_{\tau-1} + \alpha_2 h_{\tau-2} + \cdots + \alpha_{t-1} h_{\tau-(\tau-1)}\right) + \left(\delta_{11} h_{i_1} + \delta h_{i_1+1} + \cdots + \delta h_{i_1+(t-1)}\right) + \cdots + \left(\delta_{2m1} h_{2m} + \delta_{m2} h_{i_{(2m)}+1} + \cdots + \delta_{(2m)t} h_{i_{(2m)}+(t-1)}\right)$$

In expression (8),the number of α_i's is same as in the expression (6).The number of δ_{ij}'s is same as there are $2m$-RRBs in a t-tuple. thus total count of linear sums due to the expr. (8) including the linear sum corresponding to all zero coefficients is

$$[2^{t-1}(q-1)-(q-2)] \times \left[2^{2m(t-1)}(q-1)\left\{\binom{l+2m-2mt}{2m} + \sum_{r=0}^{2m-1} 2^{2m-1-r}\binom{l+r-2mt}{r}\right\} - (q-2)\right]$$

As $f-1$ is the count of such sub-blocks, thus the total count of linear sums due second condition excluding the linear sum corresponding to all zero coefficients is

(9)

$$(f-1)[2^{t-1}(q-1)-(q-2)] \times \left[2^{2m(t-1)}(q-1)\left\{\binom{l+2m-2mt}{2m} + \sum_{r=0}^{2m-1} 2^{2m-1-r}\binom{l+r-2mb}{r}\right\} - (q-1)\right]$$

Now, The total count of linear sums such that h_τ differs is given by

$$Exp.(7) + Exp.(9)$$

As there are q^{n-k} cosets, thus we have,

$$q^{n-k} > Exp.(7) + Exp.(9)$$

i.e.

$$q^{n-k} > [2^{t-1}(q-) - (q-2)] \times \left[\begin{array}{l}\left[2^{(t-1)(2m-1)}(q-1)\left\{\binom{\tau+(2m-1)-2mt}{2m-1} + \sum_{r=0}^{2m-2} 2^{2m-r-2} \times \binom{\tau+r-2mt}{r}\right\} - (q-2)\right] + \\ (f-1)\left[(q-)2^{2m(t-1)}\left\{\binom{l-2mt+2m}{2m} + \sum_{r=0}^{2m-1} 2^{2m-1-r} \times \binom{l+r-2mt}{r}\right\} - (q-1)\right]\end{array}\right]$$

To get the required result we replace τ by l in this expression.

Corollary 3.4. An upper bound bound for an ($n=fl$, k) code, ($l>4t$) over $GF(q)$ that corrects 2-RRB errors of length t occurring in any one of the f sub-blocks is

$$q^{n-k} > [2^{t-1}(q-1) - (q-2)] \times \left[\begin{array}{l}\left[2^{3(t-1)}(q-1)\left\{\binom{l-4t+3}{3} + \sum_{r=0}^{2} 2^{2-r} \times \binom{l+r-4t}{l}\right\} - (q-2)\right] + \\ (f-1)\left[(q-1)2^{4(t-1)}\left\{\binom{l-4t+4}{4} + \sum_{r=0}^{3} 2^{3-i} \times \binom{l+r-4t}{r}\right\} - (q-1)\right]\end{array}\right]$$

Through the following example we give a code that detects 2-RRB errors occurring in a single sub-block.

Example 3.5. For the parameters q=3, t=9, f=2, m=2, b=2, the Theorem 3.3 predicts the existence of an (18, 10) linear code. We obtained a PC-matrix of the code with these parameters as following:

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 2 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 1 & 2 & 0 & 0 & 2 & 2 & 2 & 0 & 0 & 2 \\ 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 & 2 & 0 & 2 & 2 & 1 & 2 & 0 & 2 & 2 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 2 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 2 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 2 & 0 & 1 & 0 & 0 & 1 & 2 & 2 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 & 2 & 0 & 2 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \end{bmatrix}$$

MS-Excel can help us to obtain all the 461 syndromes due the all 2-RRB errors. We can check that all these 8-tuples are distinct and different from zero in the same as well as in the different sub-blocks. This verifies that the code having the matrix H as its PC-matrix corrects all the 2-RRB errors occurring in one of the two sub-blocks each of length 9.

References

[1] Berardi, L.; Dass, B.K.; and Verma, R. (2009). "On 2-repeated burst error detecting linear codes". Journal of Statistical Theory and Practices, 3(2), pp. 381–391, 2009. DOI: https://doi.org/10.1080/15598608.2009.10411931

[2] Chien, R.T.; and Tang, D.T. (1965). "On definition of a burst", IBM Journal of Research and Development, vol. 9, no. 4, pp. 292-293, July 1965. DOI: https://doi.org/10.1147/rd.94.0292

[3] Das, P.K. (2015). "Codes correcting key errors". TWMS Journal of Applied Engineering Mathematics. 5(1), pp. 110–117, 2015.

[4] Dass, B.K.; and Madan, S. (2010). "Blockwise repeated burst error correcting linear codes", Ratio Mathematica-Journal of Applied Mathematics, 20, pp. 97–126, ISSN: 2282-8214, 2010.

[5] Dass, B.K.; and Verma, R. (2008). "Repeated burst error correcting linear codes", Asian-European Journal of Mathematics, 1(3), pp. 303–335, 2008. DOI: https://doi.org/10.1142/S1793557108000278

[6] Fire, P. (1959). "A class of multiple-error -correction binary codes for non independent errors", Sylvania Report RSL-E-2, Sylvania Reconnaissance Systems Laboratory, Mountain View, California. 1959.

[7] Hamming, R.W. (1950). "Error detecting and error correcting codes", The Bell System Technical Journal, 29 (2), pp. 147–160, 1950. https://doi.org/10.1002/j.1538-7305.1950.tb00463.x

[8] Kindra, B.; Kumar, M.; and Kumar, S. (2021). "Repeated restricted bursts error correcting linear codes Over GF(q); q>2". Malaya Journal of Matematik, 9(1), pp. 917–921, 2021. DOI: https://doi.org/10.26637/MJM0901/0163

[9] Peterson, W.W.; and Weldon (Jr.), E.J. (1972). "Error-correcting codes", 2nd edition, The MIT Press, Mass. ISBN: 9780262527316, 1972.

[10] Tyagi, V.; and Lata, T. (2017). "Restricted 2-burst correcting non-binary optimal codes", Journal of Combinatorics and System Sciences, 42(1-4), pp. 145-154, 2017.

[11] Tyagi, V.; and Lata, T. (2019). Restricted b_i-byte correcting non-binary optimal codes, Discrete Mathematics, Algorithms and Applications, 11(2), 1950019, 15 pages, 2019. DOI: https://doi.org/10.1142/S1793830919500198

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