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Design of Binary Linear Block Code (BLBC) for Hadamard Rhotrix and its sub Rhotrices Constructed from Special Type of M_n-Matrix

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ABSTRACT

In this paper we present a new design for Binary Linear block Code (BLBC) for Hadamard rhotrix and its sub rhotrices constructed from special Type of M_n-Matrix, N-matrix. Hadamard rhotrix of order 9 and its sub rhotrics of order 7,5,3 is used to explained our design as well theorem is given for this design to the Binary Linear Block code (BLBC) with proofs.

Keywords: Binary Linear Block code (BLBC), M_n-Matrix, N-matrix, coupled matrix, Hadamard rhotix, Hamming distance.

1. INTRODUCTION

Hadamard matrices have wide applications in image analysis, signal processing, coding theory, cryptology and combinatorial designs. The codes generated from Hadamard matrices are of much importance due to the large distance between them. These codes can correct large number of errors and are essential components of the study in communication channels. Rhotrix is a new concept for mathematical enrichment introduced in 2003 [1] with objects that are placed in between 2×2 and 3×3 matrices. The properties of rhotrices are studied in [2-9] the construction of MDS matrices given in [10-12], Secure communication through RSA given in [13] The construction of MDS rhotrices given in [14-18]. Decompostion and factorization of vandermonde rhotices given in [19,20]. Natrural and even dimensional rhotrices define in [21,22], Sylvester rhotrices over finite field [23], Circulant rhotrices given in [24] and a Hadamarad Matrix over finite field is defined in [25]. M_n-Matrix and used it for constructing matrices with ±1 elements defined in [26]. Hadamard rhotrices were used in construct of Balanced Incomplete Block Design (BIBD) [27-28]. Rhotirces and the construction of finite field given in [25]. Hadamard code is defined in [29].Vasic and Milenkovic [30] gave a method of construction of Low-Density parity check (LDPC) codes.

1.1 Hadamard Matrix.

A Hadamard matrix is defined as square matrix with entries ±1 satisfying $HH^T = nI_n$. This Hadamard matrix has unique property called orthogonality property which means the inner product of any two rows or columns are always zero.

Example: $$H = \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & -1 & 1 \\ -1 & -1 & 1 & 1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

1.2 Rhotrix and Hadamard rhotrix.

Rhotrix is a mathematical object which is in some way between 2×2- dimensional and 3×3 -dimensional matrices. A rhotrix of dimension 3 is defined as

$$R_3 = \left\langle \begin{matrix} & a_1 & \\ a_2 & a_3 & a_4 \\ & a_5 & \end{matrix} \right\rangle \quad \text{---(1)}$$

where $a_1, a_2, a_3, a_4, a_5 \in$ R.

Hadamard rhotrix over finite field is defined in [25]. A rhotrix R_n is Hadamard rhotrix over GF(2) if and only if there exist two coupled square matrices ehose rows are orthogonal to each other. Also, it is established that a rhotrix R_n of order n>3 is Hadamard if and only if the sub rhotrices of R_n given by $R_{n-(2p+2)}$, P=1,2, 3…… are Hadamard over GF(2) [31]. Construction of Hadamard rhotix of order 9 using speciaal type of M_n-matrices given in [32].

The Hadamard rhotrix of order n is defined as

$$RH_n = \left\langle \begin{array}{ccccccccc} & & & & a_{11} & & & & \\ & & & a_{31} & a_{21} & a_{12} & & & \\ & & . & a_{41} & a_{32} & a_{22} & . & & \\ & a_{d-2,1} & . & . & . & . & . & a_{1,n-1} & \\ a_{d,1} & a_{d-1,1} & a_{d-2,2} & . & . & . & a_{3,n-1} & a_{2,n-1} & a_{1,n} \\ & a_{d,2} & a_{d-1,2} & . & . & . & a_{4,n-1} & a_{3,n} & \\ & & . & . & a_{d-2,n-1} & . & a_{d-2,n} & & \\ & & & a_{d,n-1} & a_{d-1,n-1} & a_{d-2,n} & & & \\ & & & & a_{d,n} & & & & \end{array} \right\rangle$$ ---------------------------(2)

The coupled matrices of equation (2) are:

$$M_1 = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1n} \\ a_{31} & a_{32} & . & . & . & a_{3n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{d,1} & a_{d,2} & . & . & . & a_{d,n} \end{bmatrix} \qquad (2.1)$$

$$M_2 = \begin{bmatrix} a_{21} & a_{22} & . & . & . & a_{2,n-1} \\ a_{31} & a_{32} & . & . & . & a_{4,n-1} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{d-1,1} & a_{d-1,2} & . & . & . & a_{d-1,n-1} \end{bmatrix} \qquad (2.2)$$

1.3 M_n-matrices

The Mn-matrices are constructed from the formula $M_n = (d_i \otimes d_h d_j) \bmod n$ by suitable defining and $\otimes$. There are three of Mn- matrices are introduced.

Type I matrix- When 'n' is a prime as M_n- matrix (a_{ij}) is defined as a matrix obtained from 1+[(i-1)(j-1)]mod n, i,j=1,2,3……n. In the resulting matrix retain 1 as it is, substitute +1 for even numbers and -1 for odd numbers. This is n×n symmetric matrix with entries ±1.

Type II matrix- M_n matrix (a_{ij}) is obtained by equation a_{ij}=(i,j)mod(n+1), where (n+1) is prime and i,j=1,2,3……n. In the resulting matrix substitute +1 for even numbers and -1 for odd numbers. Also change all +1's and -1's. Each row (column) consists of an equal number of +1's and -1's This is also n×n symmetric matrix with entries ±1.

Type III matrix- M_n- matrix (a_{ij}) is obtained by equation a_{ij}=(i+j) mod n, wheren is any integer and i,j=1,2,3……n. In this matrix each row (column) has 'n' elements. In the resulting matrix substitute +1 for even numbers and -1 for odd numbers and change +1 to -1 or substitute -1 for even numbers, 1 for odd numbers and retain +1 as itself.

Type IV matrix or N_1-matrix- A matrix obtained by the equation (a_{ij})=(i+j) mod $\frac{n+1}{2}$,where 'n' is odd number. Each row (column) of the matrix so obtained has 'n'elements and every row (column) has elements 1,2...... $\frac{n+1}{2}$. The off-diagonal elements are always $\frac{n+1}{2}$ and the matrix obtained is a symmetric matrix. If $\frac{n+1}{2}$ is odd then the resulting matrix, substitute +1 for odd numbers, -1 for even numbers and change +1 to -1. Then change all the -1's to zeros so that the resultant matrix is Hadamard over (GF(2).

Remark- If any matrix obtained by the equation (a_{ij})=(i+j)mod $\frac{n+1}{2}$,where 'n' is odd number and $\frac{n+1}{2}$ is even then we fail to define N_1-matrix.

Type V matrix or N_2-matrix-A matrix obtained by equation (a_{ij})=(i+j)mod $\frac{n-1}{2}$ where 'n' is odd number. If $\frac{n-1}{2}$ is even and 'n' is non-prime then the resulting matrix, substitute +1 for odd numbers, -1 for even numbers and change +1 to -1. If $\frac{n-1}{2}$ is odd or n is prime, then the resulting matrix, substitute +1 for odd numbers, -1 for even numbers and retain 1 as 1 itself. Finally change all the -1's to zeros. In both the cases the resultant matrix so obtained will be a Hadamard matrix over (GF(2).

Remark-To construct a Hadamard matrix H_m of order m=2p where p=2,3,4,...... we use the N_2-matrix for n=m+1 then from the resultant matrix delete (n-m) rows and columns. Similarly if H_m is of order m=2p+1, use the N_2-matrix for odd p and N_1-matrix for even values of p. If N_2-matrix is used, then let n=m+2 and from the resultant matrix delete (n-m) rows and columns. For example to construct H_6, we taken n=7 and use N_2-matrix. From the resultant delete 1 row and 1 column (n-m=7-6=1). To construct H_7, take n=9 and after constructing N_2-matrix, delete (n-m=9-7=2) rows and columns.

1.4 Binary Linear Block Code

An (r,s) binary linear block code is a s-dimensional subspace of the r-dimensional vector space $P_r = \{c = (c_0, c_1, ..., c_{r-1} / \forall c_j, c_i \in \{0,1\} = GF(2)\}; r$ is called the length of the code, *s* th dimension.

A binary block code C(r,s) of length r and r=2^s codewords is called *linear block code if its* 2^s codeword's form a s-dimensional subspace of vector space P_r of r-tuples over the field GF(2)= {0,1} .

1.5 Generator for Binary Linear Block Code

An (r,s) BLBC can be specified by any set of s linear independent codeword $(c_0, c_1, ..., c_{s-1})$. If we arrange the *s* code words in to *S*r* matrix G, G is called a generator matrix for code *C*.
If $l=(u_0, u_1\ u_2 \ ......u_{s-1})$ where $l_j \in GF(2)$, then $c= (c_0, c_1\ c_2 \ ......c_{r-1})=lG$.

1.6 Parity Check Matrix

Let $G=[I_s:A]$. Since $cP^t=lGP^t=0$, GP^t must be 0. If $P=[A^t:I_{r-s}]$. Then $GP^t=0_{s*(r-s)}$, thus the above P is called the parity check matrix.

1.7 Hamming Distance

The Hamming distance between two codeword's c and z is defined as d(c,z)= the number of components in which c and z are differ.

1.8 Minimum Distance

The minimum distance d_{min} of a binary code C, is the smallest distance between two distinct code word: $d_{min} = \min\{ d_H(c,z)/ c,z \in C, c \neq z\}$.

Error Detection- A binary linear block code with minimum distance d_{min} can detect all error patterns of weight less than or equal to $d_{min} \geq s+1$, where s is called the error detection capability of a code C.

Error Correction- A binary linear block code with minimum distance d_{min} can correct all error patterns of weight less than or equal to $d_{min} \geq 2t+1$, where t is called the error correction capability of a code C.

2. MAIN RESULTS

Theorem 2.1 A binary code c can detect up to s- error in any code word iff $d_{(H)} \geq s+1$.
Theorem 2.2 A binary code c can correct up to t- error in any code word iff $d_{(H)} \geq 2t+1$.
Theorem 2.3 All the binary block code which generating by coupled matrices of Hadamard rhotrix of order 3,5,7 respectively are linear having one bit error detection and zero error correction.
Proof:
Consider the binary code C which generating by coupled matrices of Hadamard rhotrix of order .We need to show that : $\forall$ code words x,y $\in$ C and every scalar $\beta \in \{0,1\}$, it holds that : $x + y \in C$,and $\beta^* x \in C$. However, this follows immediately from $x + y = z \in C, z$ is linear combination of x and y and $\beta^* x$ belongs to C, Since :

Case(1): $\beta = 0$, then, $\beta * x = 0 * x = 0 \in C$.

Case(2). $\beta = 1$, then, $1 * x = 1 * x = x \in C$.

Theorem 2. 4. The binary block code which generating by coupled matrices of Hadamard rhotrix of order 9 are linear having two bit error detection, one bit error correction for first matrix and one bit error detection and zero error correction for second matrix.
***Lemma (1)*:** For all binary block code C which generated by coupled matrices of Hadamard rhotrices generated from M_n- Matrices of order 3,5,7,9 respectively, are contains the zero code word 0 .
Proof:
The proof of this lemma based upon general case Let x be a code word in C. Since C is a Linear block code then by using theorem 3 then x+x=0.
Lemma (2) : The minimum Hamming distance of code C in our design is 3 and 4.
***Proof*:**
The parity check matrices H_1 and H_2 for the code C have columns which are all non zero and no two of which are the same. Hence C code can correct single error. By theorem (1) can correct 1-errror, as well as, we conclude that the minimum Hamming distance of C code is at least 3 or 4.

3. DESCRIPTION OF DESIGN FOR HADAMARD RHOTRICES CONSTRUCTED FROM M_N - MATRICES

Consider the Hadamard rhotrix RH_n of order n with their coupled matrices M_1 and M_2, then, we will have two generating matrices of the form; $G_1=[I_1: M_1]$ and $G_2=[I_2: M_2]$, where I_1 and I_2 are identity matrices their orders dependent on the order of M_1 and M_2 respectively with their parity check matrices of the form : $P_1=[\ M_1^t: I_1]$ and $P_2=[\ M_2^t: I_2]$,. Also the code words can be represented by $c_1=lG_1$ and $c_2=mG_2$, where l and $m \in$ GF(2) and their length dependent on the orders of P_1 and P_2 respectively.

Example (1): Binary linear Block code C based on RH_9 For the code C in $c_1=lG_1$, we have r=32,s=5, and ($c_2=mG_2$), we have r=16,s=4.
Let RH_9 be a Hadamard rhotrix of order 9 defined as using special type of M_n matrix defined as

$$RH_9 = \left\langle \begin{array}{c} 1 \\ 0\ \ 1\ \ 0 \\ 0\ \ 0\ \ 0\ \ 0\ \ 0 \\ 1\ \ 1\ \ 1\ \ 1\ \ 1\ \ 1\ \ 1 \\ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0 \\ 1\ \ 1\ \ 0\ \ 1\ \ 0\ \ 1\ \ 0 \\ 0\ \ 0\ \ 1\ \ 0\ \ 1 \\ 0\ \ 1\ \ 0 \\ 1 \end{array} \right\rangle \quad \text{-- (3)}$$

The coupled matrices in RH_9 are :

$$M_1 = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix} \quad \text{--(3.1)}$$

$$M_2 = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix} \quad \text{--(3.2)}$$

Having order 5 and 4 respectively.

Table (1) Binary linear Block code C based on RH_9 For the code C in $c_1=lG_1$, we have r=32,s=5, and ($c_2=mG_2$), we have r=16,s=4.

	Code words (C)	d_{min}	$d_{min} \geq 2t+1$	$d_{min} \geq s+1$
$c_1=lG_1$	{0000000000, 0000101001, 0001111001, 0011110010, 0111110110, 1000010010, 1100010110, 1110010110, 1111001101, 1011100000, 1001101001, 1101101101, 1100111111, 1010110010, 1000111011, 1001000000, 0010001001, 0110001101, 0111011111, 0111011111, 1010011011, 0010100000, 0101010110, 0001010010, 0010001001, 0100000100, 0001010010, 0110100100, 0011011011, 0100101101, 0101111111, 11111001000}	2	0	1
$c_2=mG_2$	{00000000.00010101,00101010,01000101,10001010,0011111,01111010,01010000,101000000,01100000,100111111,11100101,11001111,10110101,11011010,11110000}	2	0	1

Example (2): Binary linear Block code C based on RH_7 For the code C in ($c_1=lG_1$, we have r=16,s=4, and ($c_2=mG_2$), we have r=8,s=3.
Let RH_7 be a Hadamard rhotrix of order 7 defined as using special type of M_n matrix defined as

$$RH_7 = \left\langle \begin{array}{c} 1 \\ 0\ \ 0\ \ 0 \\ 0\ \ 0\ \ 0\ \ 1\ \ 0 \\ 1\ \ 1\ \ 1\ \ 0\ \ 1\ \ 0\ \ 0 \\ 0\ \ 0\ \ 0\ \ 1\ \ 0 \\ 0\ \ 0\ \ 0 \\ 1 \end{array} \right\rangle \quad (4)$$

$$M_1 = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix} \quad (4.1)$$

$$M_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \quad (4.2)$$

Having order 4 and 3 respectively.

Table (2) Binary linear Block code C based on RH_7 For the code C in ($c_1=lG_1$, we have r=16,s=4, and ($c_2=mG_2$), we have r=8,s=3.

	Code words (C)	d_{min}	$d_{min} \geq 2t+1$	$d_{min} \geq s+1$
$c_1=lG_1$	{0000000,00011001,00100100,01100110,10010000,11101111,10001001,11001010,01111111,00111101,01000010,01011011,10101101,11010010,10110100,11110110}	2	0	1
$c_2=mG_2$	|{01000010,01011011,10101101,11010010,10110100,11110110}	2	0	1

Example (3): Binary linear Block code C based on RH_5 for the code C in ($c_1=lG_1$), we have r=8,s=3, and ($c_2=mG_2$), we have r=4,s=2.
Let RH_5 be a hadamard rhotrix of order 5 defined as using special type of M_n matrix defined as

$$RH_5 = \left\langle \begin{array}{ccccc} & & 0 & & \\ & 1 & 0 & 1 & \\ 0 & 1 & 0 & 1 & 0 \\ & 0 & 0 & 0 & \\ & & 1 & & \end{array} \right\rangle \tag{5}$$

$$M_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{5.1}$$

$$M_2 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{5.2}$$

Having order 3 and 2 respectively.

Table (3) Binary linear Block code C based on RH_5 for the code C in ($c_1=lG_1$), we have r=8,s=3, and ($c_2=mG_2$), we have r=4,s=2.

	Code words (C)	d_{min}	$d_{min} \geq 2t+1$	$d_{min} \geq s+1$
$c_1=lG_1$	{000000,001001,010100,011101,100010,101011,110110,111111}	2	0	1
$c_2=mG_2$	{0000,0110,1001|,1111}	2	0	1

Example (4): Binary linear Block code C based on RH_3 for the code C in $c_1=lG_1$), we have r=4,s=2.
Let RH_3 be a hadamard rhotrix of order 3 defined as using special type of M_n matrix defined as

$$RH_3 = \left\langle \begin{array}{ccc} & 0 & \\ 1 & 0 & 1 \\ & 0 & \end{array} \right\rangle \tag{6}$$

$$M_1 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \tag{6.1}$$

$$M_2 = \begin{bmatrix} 0 \end{bmatrix} \tag{6.2}$$

Having order 2 and 1 respectively.

Table (4) Binary linear Block code C based on RH_3 For the code C in $c_1=lG_1$), we have r=4,s=2.

	Code words (C)	d_{min}	$d_{min} \geq 2t+1$	$d_{min} \geq s+1$
$c_1=lG_1$	{0000,0110,1001,1111}	2	0	1
$c_2=mG_2$	{0}	0	0	0

4. CONCLUSION

In the present paper, we have introduced design of binary linear block code for Hadamard rhotrix and its sub rhotrices constructed from special type of M_n-Matrix. Since this code can correct single error, then the binary linear block code is belonging to error-correcting code which has useful application in communication system.

5. DISCLOSURE

The authors declare no conflict of interest. The findings included in this manuscript are our own and are neither published nor under consideration for publication elsewhere.

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