EXPERIMENT NO. 9

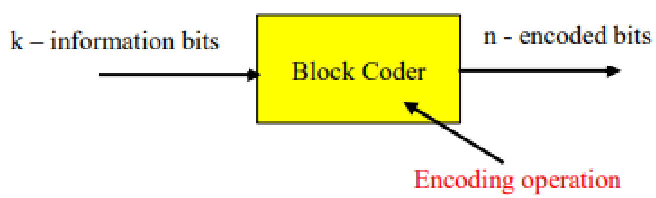
Aim: To understand linear block coding and decoding techniques.
Objective: Study of Linear Block Code Encoder and Decoder.
Software Used: MATLAB 7.6 software

Theory:

Errors are introduced in the data through the channel. The channel noise interferes the signal. The number of errors introduced due to channel noise are minimized by the encoder by adding redundant bits. This increases the overall data rate. Hence channel has to accommodate this increased data rate, and the system becomes slightly complex due to coding techniques. The codes are classified as block or convolution codes.
For a linear code, if two code words are added by modulo 2 arithmetic then, it produces a third code word in the case.

LINEAR BLOCK CODES:

(n, k) Block codes



n-digit codeword made up of k-information digits and (n-k) redundant parity check digits. The rate or efficiency for this code is k/n.

$$Code\ efficiency\ r = \frac{k}{n} = \frac{Number\ of\ information\ bits}{Total\ number\ of\ bits\ in\ codeword}$$

Note: unlike source coding, in which data is compressed, here redundancy is deliberately added, to achieve error detection.

SYSTEMATIC BLOCK CODES

A systematic block code consists of vectors whose 1st k elements (or last k-elements) are identical to the message bits, the remaining (n-k) elements being check bits. A code vector then takes the form:

$X = (m_0, m_1, m_2, \ldots\ldots m_{k-1}, c_0, c_1, c_2, \ldots\ldots c_{n-k})$

Or

$X = (c_0, c_1, c_2, \ldots\ldots c_{n-k}, m_0, m_1, m_2, \ldots\ldots m_{k-1})$

Systematic code: information digits are explicitly transmitted together with the parity check bits. For the code to be systematic, the k-information bits must be transmitted contiguously as a block, with the parity check bits making up the code word as another contiguous block.

Information bits	Parity bits

A systematic linear block code will have a generator matrix of the form:

$$G = [P \mid I_k]$$

Systematic codewords are sometimes written so that the message bits occupy the left-hand portion of the codeword and the parity bits occupy the right-hand portion.

Parity check matrix (H)

Will enable us to decode the received vectors. For each (kxn) generator matrix G, there exists an (n-k)xn matrix H, such that rows of G are orthogonal to rows of H i.e., $GH^T = 0$, where H^T is the transpose of H. to fulfil the orthogonal requirements for a systematic code, the components of H matrix are written as:

$$\mathbf{H = [I_{n-k} \mid P^T]}$$

In a systematic code, the 1st k-digits of a code word are the data message bits and last (n-k) digits are the parity check bits, formed by linear combinations of message bits $m_0, m_1, m_2, \ldots\ldots m_{k-1}$

It can be shown that performance of systematic block codes is identical to that of non-systematic block codes.

A codeword (X) consists of n digits $x_0, x_1, x_2, \ldots\ldots x_{n-1}$ and a data word (message word) consists of k digits $m_0, m_1, m_2, \ldots\ldots m_{k-1}$

For the general case of linear block codes, all the n digits of X are formed by linear combinations (modulo-2 additions) of k message bits. A special case, where $x_0 = m_0$, $x_1 = m_1$, $x_2 = m_2 \ldots x_{k-1} = mk-1$ and the remaining digits from x_{k+1} to x_n are linear combinations of $m_0, m_1, m_2, \ldots\ldots m_{k-1}$ is known as a systematic code.

The codes described in this chapter are binary codes, for which the alphabet consists of symbols 0 and 1 only. The encoding and decoding functions involve the binary arithmetic operations of modulo-2 addition and multiplication.

Matrix representation of Block codes

- An (n, k) block code consists of n-bit vectors
- Each vector corresponding to a unique block of k-message bits
- There are 2^k different k-bit message blocks & 2^n possible n-bit vectors
- The fundamental strategy of block coding is to choose the 2^k code vectors such that the minimum distance is as large as possible. In error correction, distance of two words (of same length) plays a fundamental role.

Block codes in which the message bits are transmitted in unaltered form are called systematic code.

For the block of 'K' message bits (n-k) parity bits or check bits are added. Hence the total number of bits at the output of channel encoder are 'n'. Such codes are called (n,k) block codes.

The check bits play the role of error detection and correction. The job of linear block code is to generate those check bits.

The code word can be represented as

X=mG

Where

X= Code vector of 2^k *n size
m = message vector of 2^k *k size
G= generator matrix of k *n size

[X] 2^k *n = [m] 2^k * k [G] k*n

The generator matrix depends upon the linear block code used. Generally it is represented as

$$G = [I_k : P_k * (n-k)]\ k*n$$

Where

I_k = k*k identity matrix.
P_k = k(n-k) parity matrix.

The rows of parity matrix should not be same in any case.

Example :

Find the code matrix for a (7,4) code.

Total number of bits, n = 7
Message bits, k = 4
n-k = 3
Total number of message = $2^k = 2^4 = 16$
ie. From 0000 to1111
The parity matrix can be taken as

— [P] k* (n=k) = [P] $_{4X3}$

$$P = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

I_k = [I] $_{4X4}$

$$I = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$G = \begin{bmatrix} 1 & 1 & 1 & : & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & : & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & : & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & : & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$C = mG \quad \begin{bmatrix} 0&0&0&0\\ 0&0&0&1\\ 0&0&1&0\\ 0&0&1&1\\ 0&1&0&0\\ 0&1&0&1\\ 0&1&1&0\\ 0&1&1&1\\ 1&0&0&0\\ 1&0&0&1\\ 1&0&1&0\\ 1&0&1&1\\ 1&1&0&0\\ 1&1&0&1\\ 1&1&1&0\\ 1&1&1&1 \end{bmatrix} \begin{bmatrix} 1&1&1&:&1&0&0&0\\ 0&1&1&:&0&1&0&0\\ 1&0&1&:&0&0&1&0\\ 1&1&0&:&0&0&0&1 \end{bmatrix}$$

$$C = \begin{bmatrix} 0&0&0&0&0&0&0\\ 1&1&0&0&0&0&1\\ 1&0&1&0&0&1&0\\ 0&1&1&0&0&1&1\\ 0&1&1&0&1&0&0\\ 1&0&1&0&1&0&1\\ 1&1&0&0&1&1&0\\ 0&0&0&0&1&1&1\\ 1&1&1&1&0&0&0\\ 0&0&1&1&0&0&1\\ 0&1&0&1&0&1&0\\ 1&0&0&1&0&1&1\\ 1&0&0&1&1&0&0\\ 0&1&0&1&1&0&1\\ 0&0&1&1&1&1&0\\ 1&1&1&1&1&1&1 \end{bmatrix}$$

Each row of the code matrix represents the transmitted code for the respective message.

Flowchart:

Algorithm:

Program:

Input,

Output,

Result:

Conclusion:

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ORAL QUESTIONS

1) What is Hamming weight of a code word?
2) What is Hamming distance, Code rate, Word Length,
3) Define Minimum Hamming Distance, Block length, Constraint Length
4) What is block code, Hamming Code.
5) What are the properties of a linear block code?
6) What is a systematic code, Block code?
7) What is singleton bound, Burst Error?
8) What is parity check matrix?
9) How to generate generator matrix.
10) Types of Error control methods
11) What do you mean by (n, k) code?

Timely Submission(10)	Journal Presenattaion(10)	Performance (10)	Understanding(10)	Oral(10)	Total (50)
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