V.J.T.I

T.Y.B.Tech (ExTc)

Sub: Digital communication system

Sem-V

Course Instructor

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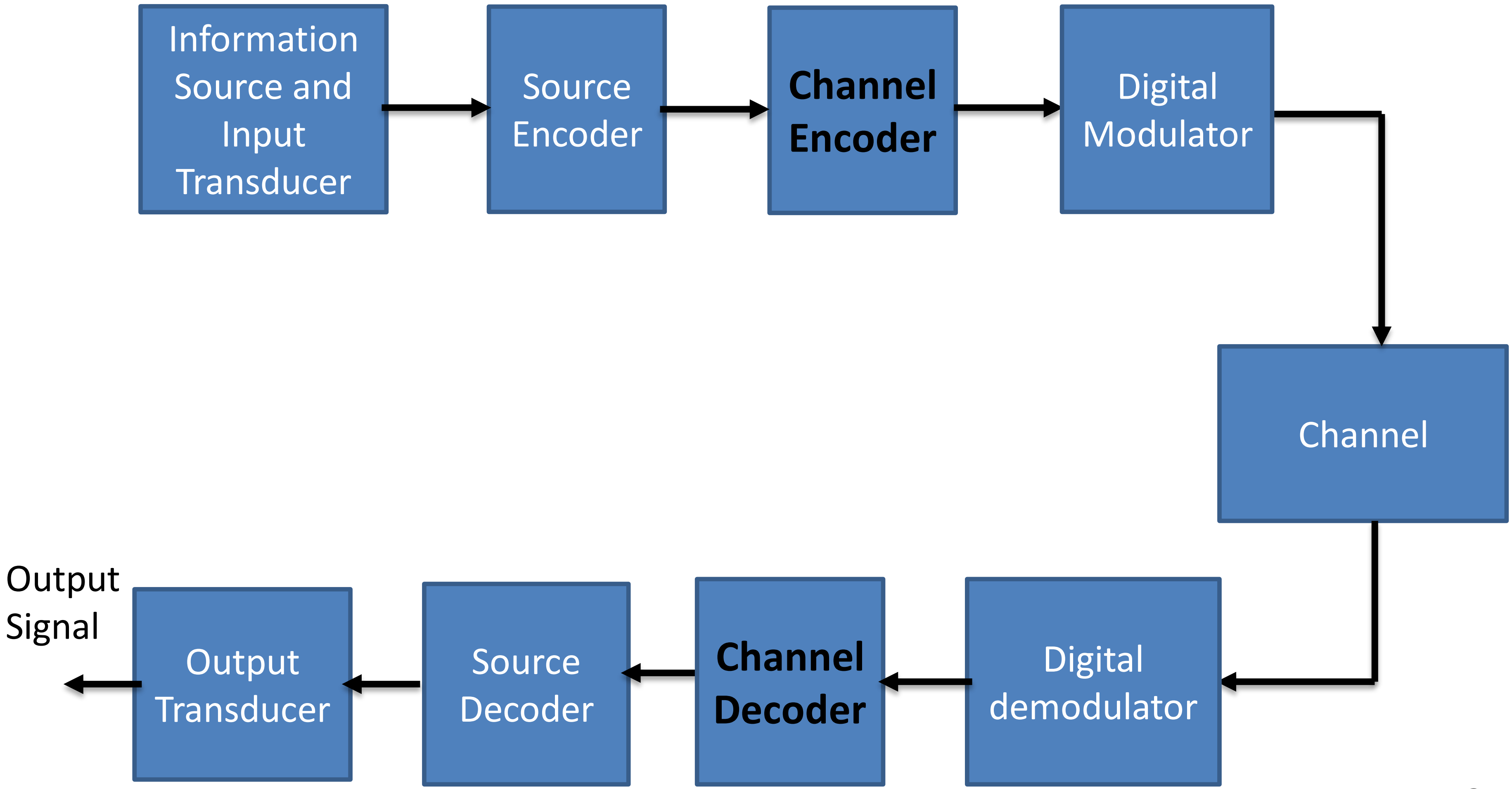
Modern Digital Communication System

- Fig1.1 Block diagram of a digital communication system



Digital communication System

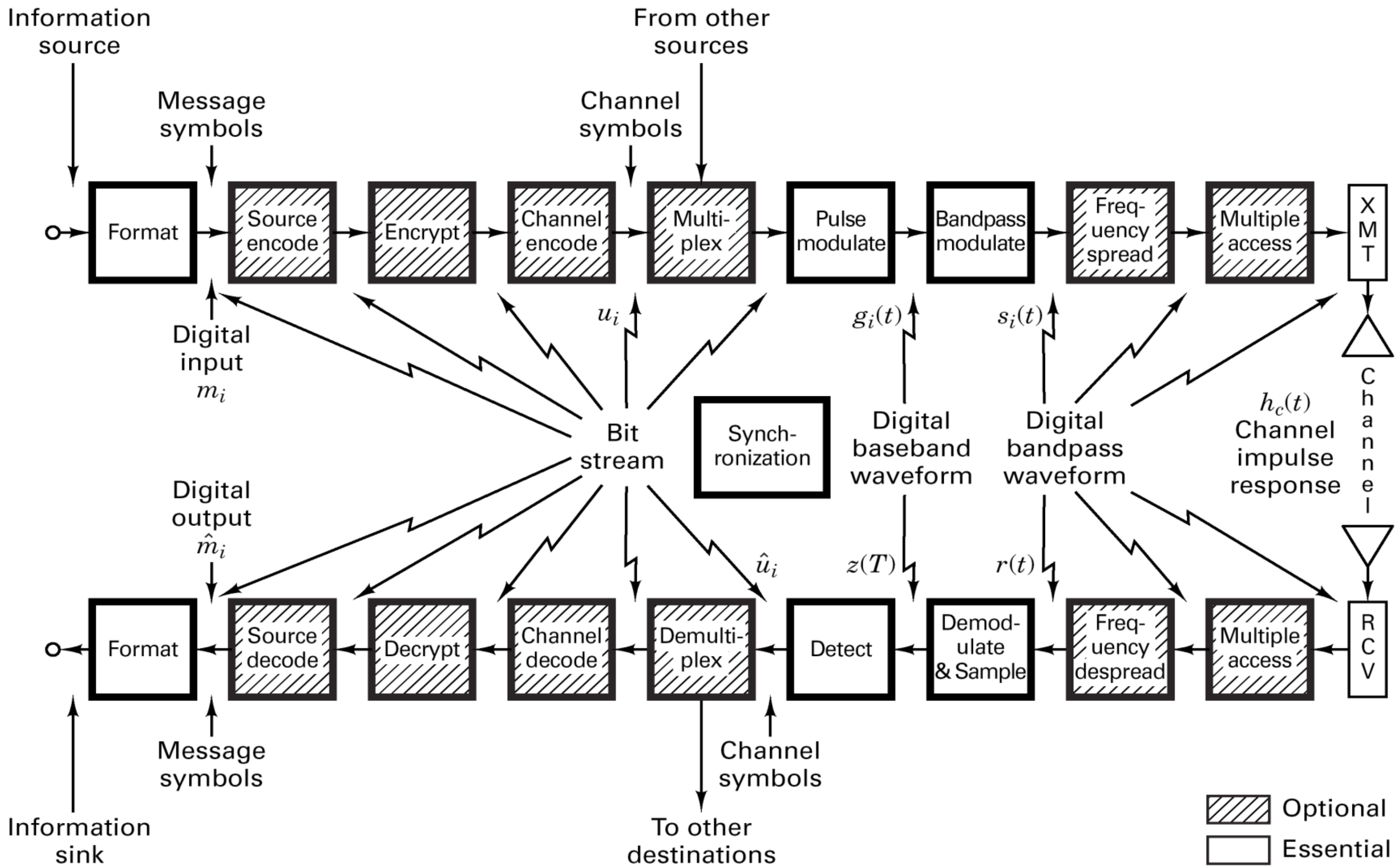


Figure 1.2 Block diagram of a typical digital communication system.

Digital modulation/demodulation Techniques

- Basic digital modulation and demodulation techniques includes
- BASK(Binary amplitude shift keying)
- BPSK(Binary phase shift keying)
- BFSK(Binary Frequency Shift keying)
- M-ary digital modulation techniques

Error Correcting Codes/Coding Theory

- **Clude Shannon** is called as Father of coding Theory
- He published a landmark seminal paper on “Mathematical theory for communication” in 1948
- According to Shannon, there exists error correcting coding techniques to achieve reliable communication over a noisy transmission channel
- Shannon’s central theme was that , if the signaling rate of the system is less than the channel capacity, reliable communication can be achieved if one chooses proper encoding and decoding technique.
- There has been increasing demand for efficient and reliable digital data transmission and storage system.

Error Correcting Codes/Coding Theory

- High speed digital systems and use of error correcting codes has become an integral part of modern communication system and data storage system.
- Error correcting codes are broadly classified as

  Forward Error Correcting Codes **(FEC)** and Backward Error Correcting Codes **(BEC)**
- Further, FEC are classified as-

  Linear block codes **(n, k)** &convolution codes**(n, k, L)**
- Linear block codes can be cyclic code **(n, k)**
- **n** is code word length and **k** bit is the message length

Error Correcting Codes/Coding Theory

- The design of good codes and efficient decoding method, initiated by Hamming, Slepian and other in the early 1950’s,

- BCH code, R-S code, LDPC code in late 1960’s

- Turbo codes and other burst error correcting codes in late 1980’s

Error Correcting Codes/Coding Theory

- Concatenated codes
- Interleaved codes
- Fire codes
- Product Codes
- Burton Code
- R. M. Code
- Golay code
- Convolutional codes etc..

Encoding (Channel encoding)

- **Encoding** is the process in which **k-bit message** (information) is augmented with **‘n-k’ parity- check bits** to form an n-bit **codeword**

- **Encoding , C=m.G**

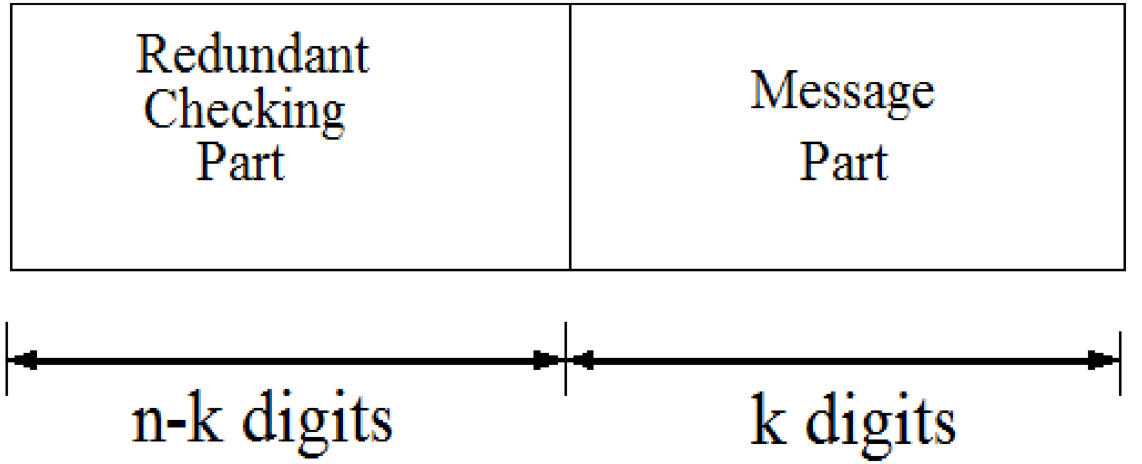
Where, **G** is a **(k x n)** generator matrix required to generate the codeword and

Encoding

m is message of **k** bit length

n is code word length obtained after encoding operation

Codeword = k bit message + (n-k) parity bits



Encoding

- Consider (7,4) block code
- code word length is n=7 bits
- Message length k = 4 bits
- Parity check bits=(n-k)=3 (redundant bits) appended to k=4 bit message to form a n=7 bit code word C

Decoding(Channel Decoder)

- For every code there exists a corresponding **(n-k x n)** parity check matrix **H**,
- which is required to decode the message (**$r.H^T$ =0** mod-2 operation (**channel decoder)**
- Where **r** is received message bits at decoder
- **If $r.H^T$ =0 mod-2,** then the received codeword is same as transmitted
- **Otherwise it is erroneous**

Systematic Codes & cyclic Codes

- If **k x n** generator matrix, $\mathbf{G = [I_k : P]}$ and
- Parity check matrix, $\mathbf{H = [P^T : I_{n-k}]}$ **,** are in this form
- Then the (n, k) codes constructed are systematic codes

- **Cyclic linear block codes (n , k)**
- If the codes having cyclic property then the (n, k) codes constructed are called cyclic code

Cyclic Codes

- Cyclic codes are constructed using polynomial form hence easy to implement using simple shift registers and logic gates, switches etc.

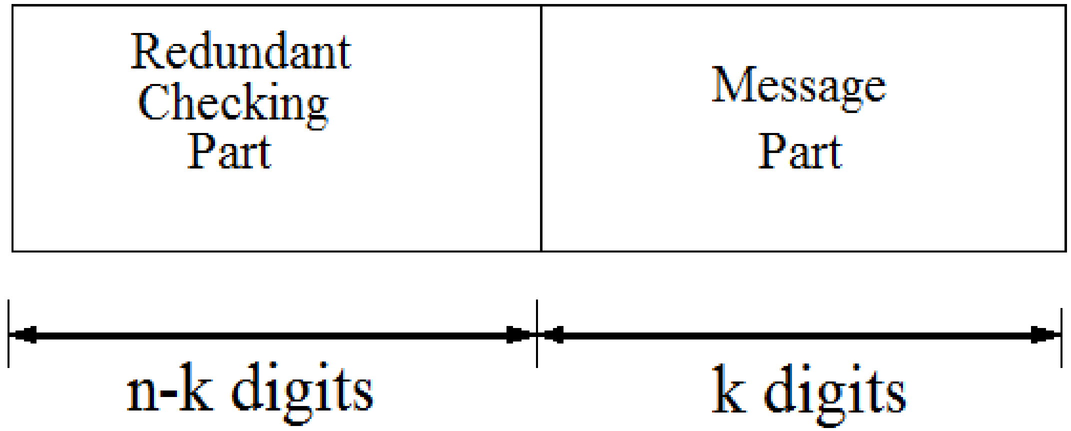
- In cyclic codes generator polynomial of degree (n-k) is required to construct a code (channel Encoding)

- The generator polynomial is a factor of $X^n + 1$ over $GF(2)=\{0,1\}$

- Where, $n=2^m -1$ and m is degree of irreducible polynomial

Hamming code

- ***Linear Block Codes (n , k):*** **Hamming code(6,3)**
  - A desirable property for a linear block code to possess the *systematic structure* of the codeword.
  - A codeword is divided into two parts, the message part and the redundant checking part ((n-k)Parity bits).



Hamming code

Encoding is the process in which **k-bit message** (information) is augmented with **‘n-k’ parity- check bits** to form an n-bit **codeword**

Let

‘m’ be message;

(m =[1 1 0]=[m_1, m_2, m_3], k =03 bit)

Then

LDPC code for the message shall be

$$\mathbf{c = m\, G}$$

where,

‘G’ is Generator matrix

Hamming code

Generator matrix **'G'** is

$$G_{k \times n} = [I_k \;\; P_{k \times (n-k)}]$$

where,

G is a generator matrix of size k×n

I is a identity matrix of size k×k

P is a parity bit matrix of size k×(n-k)

The **'G' matrix** is derived from **Parity Check matrix 'H',** where ,

$$H_{(n-k) \times n} = [P^T \;\; I_{n-k}]$$

Relation between matrix G and H is such that

$$H.G^T = 0$$

Hamming code

Let us consider an example (6, 3)

Consider the 3 bit message

$$m = [\ 1\ \ 1\ \ 0] = [\ m_{1,}\ m_{2,}\ m_3]$$

Code formation required 'G' matrix which can be derived from 'H' matrix,

- Let 'H' matrix be of size 3×6

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

$$H = \begin{bmatrix} P^T & & & & I_{(n-k)} \end{bmatrix}$$

Hamming code (n , k)

Hamming (n, k) code Encoding

Generator Matrix 'G'

$$G = [\quad I_k \qquad P \quad]$$

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

$$C = mG$$

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

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

Thus the code contains 3message bit & 3 parity bits

Hamming code

Hamming Decoder

Code word is sent through Additive White Gaussian Noise (AWGN) channel with BPSK modulation.

Received code word is checked for error using 'H' matrix as;

$$H.C^T = 0$$

$$\begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} = \begin{pmatrix} 1.1 \oplus 1.1 \oplus 0.1 \oplus 1.0 \oplus 0.1 \oplus 0.0 \\ 0.1 \oplus 1.1 \oplus 1.0 \oplus 0.0 \oplus 1.1 \oplus 0.0 \\ 1.1 \oplus 1.1 \oplus 1.0 \oplus 0.0 \oplus 0.1 \oplus 1.0 \end{pmatrix}$$

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

If the result is zero then received code is correct otherwise erroneous.

Hamming code decoder

- If the error occurs in the code during transmission then correction is made at receiver.
- Error occurred during transmission in last bit, hence received code word **r** is , i.e. r= *C*

$$C = [1 \quad 1 \quad 0 \quad 0 \quad 1 \quad 1]$$

$$H.C^T = 0$$

$$\begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{bmatrix} = \begin{pmatrix} 1.1 \oplus 1.1 \oplus 0.1 \oplus 1.0 \oplus 0.1 \oplus 0.1 \\ 0.1 \oplus 1.1 \oplus 1.0 \oplus 0.0 \oplus 1.1 \oplus 0.1 \\ 1.1 \oplus 1.1 \oplus 1.0 \oplus 0.0 \oplus 0.1 \oplus 1.1 \end{pmatrix}$$

$$= [0 \quad 0 \quad 1]$$

As the resultant is non-zero the received codeword is erroneous. Decoder knows there is error in last bit, i.e. **6^{th} row of H^T matrix. The 6^{th} bit is complemented and the error is rectified.**

Home work

- Construct (7,4) Hamming Code with given
- Generator matrix G=[1 0 0 0 1 1 0; 0 1 0 0 1 0 1; 0 0 1 0 0 1 1 ; 0 0 0 1 1 1 1] and
- Message bits m=[1 0 1 1], also check validity of code word obtained
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Thank You