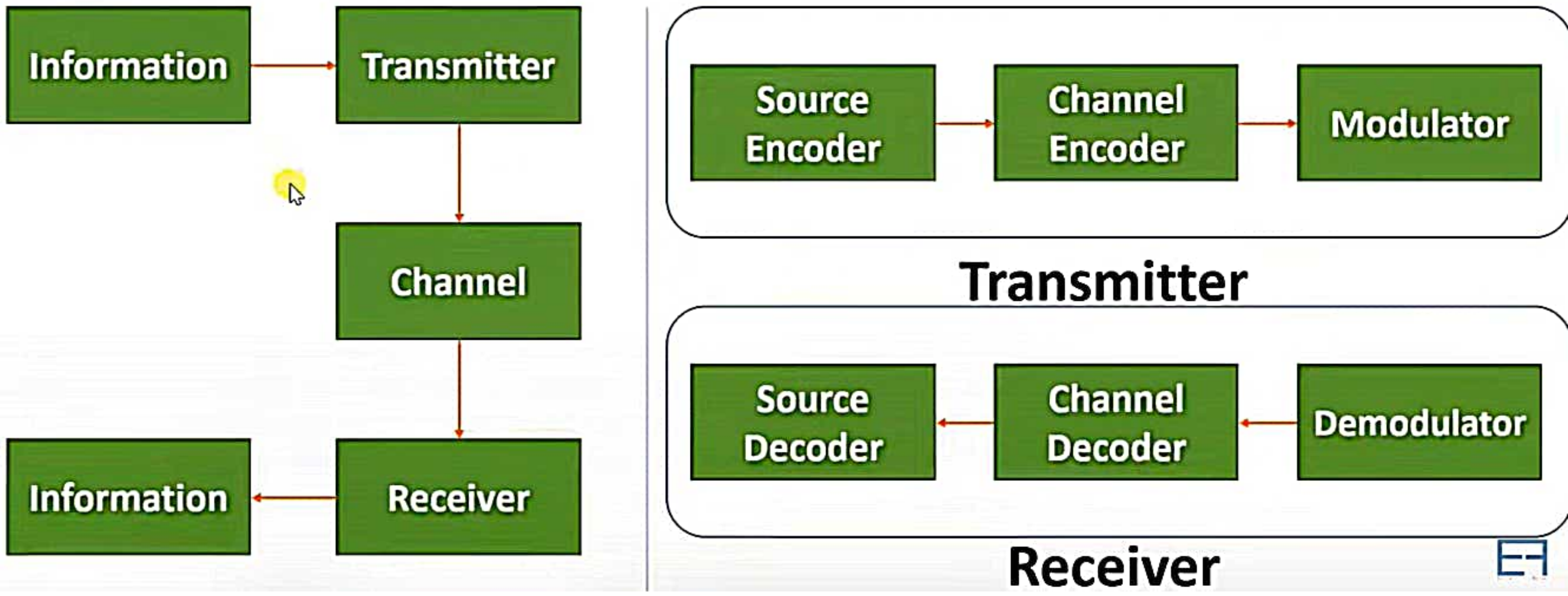
Basic structure of communication system



Basics of Block Code

- Information bits = k

$$i = [i_1, i_2, i_3, \dots \dots, i_k]$$

- Parity bits/ Redundant bits = r

$$p = [p_1, p_2, p_3, \dots \dots, p_r]$$

- Here, Total bits of code, n = k+r

$$n = [i_1, i_2, i_3, \dots \dots, i_k, p_1, p_2, p_3, \dots \dots, p_r]$$

- (n, k) is block code representation
- A code word, whose information bits are kept together is Systematic
- A code word, whose information bits are not kept together is non-systematic

Important parameters of block code (n,k)

- Total code words required as per n Block codes = 2^n
- Total code words required as per k information = 2^k
- Total redundant code words required as per r parity bits= $2^n - 2^k$
- So, Code rate, $R = \frac{k}{n}$
- And n bits bock code will be

k information bits	r Redundant bits (Parity bits)

Representation of Block Code (n,k)

- Information bits = k

$$i = [i_1, i_2, i_3, \ldots \ldots, i_k]$$

- Parity bits/ Redundant bits = r

$$p = [p_1, p_2, p_3, \ldots \ldots, p_r]$$

- Code word, c = [I, p]

$$c = [i_1, i_2, i_3, \ldots \ldots, i_k, p_1, p_2, p_3, \ldots \ldots, p_r]$$

- Error code word

$$e = [e_1, e_2, e_3, \ldots \ldots, e_n]$$

- Where, $e_j = 1$ means error and $e_j = 0$ means no error
- So valid data = received codeword + error code word

Definition and Basics for Block codes for parity check

- These are a class of error detecting codes that provides the simplest form of error control.
- In this, the codes uses a single parity bit to generate codewords with EVEN or ODD parity.
- In (n, k) block codes, information bits are k.

$$\boldsymbol{i} = [\boldsymbol{i}_1, \boldsymbol{i}_2, \boldsymbol{i}_3, \ldots \ldots, \boldsymbol{i}_k]$$

- For EVEN parity bit $P = \boldsymbol{i}_1 \oplus \boldsymbol{i}_2 \oplus \boldsymbol{i}_3 \oplus \ \ldots \ldots \oplus \boldsymbol{i}_k$
- For ODD parity bit $P = \boldsymbol{i}_1 \oplus \boldsymbol{i}_2 \oplus \boldsymbol{i}_3 \oplus \ \ldots \ldots \oplus \boldsymbol{i}_k \oplus \mathbf{1}$
- Codeword is

$$\boldsymbol{C} = [\boldsymbol{i}_1, \boldsymbol{i}_2, \boldsymbol{i}_3, \ldots \ldots, \boldsymbol{i}_k, \boldsymbol{P}]$$

Example of Block Code for parity check with Encoding

Example 1 : Given the (5, 4) even parity block code, find codewords corresponding to I = (1011) and (1010)

- (5, 4) = (n, k)
- Information bits k = 4
- Parity bits r = n – k = 5 – 4 = 1
- For Information I = 1 0 1 1 = $I_1\ I_2\ I_3\ I_4$
- For Even Parity

  P = $I_1 \oplus I_2 \oplus I_3 \oplus I_4$

  P = $1 \oplus 0 \oplus 1 \oplus 1$

  P = 1
- So Codeword is = [Information, Parity]

  $\boldsymbol{C} = [\boldsymbol{i_1}, \boldsymbol{i_2}, \boldsymbol{i_3}, \boldsymbol{i_4}, \boldsymbol{P}]$

  $\boldsymbol{C} = [\mathbf{1}, \mathbf{0}, \mathbf{1}, \mathbf{1}, \mathbf{1}]$

- For Information I = 1 0 1 0 = $I_1\ I_2\ I_3\ I_4$
- For Even Parity

  P = $I_1 \oplus I_2 \oplus I_3 \oplus I_4$

  P = $1 \oplus 0 \oplus 1 \oplus 0$

  P = 0
- So Codeword is = [Information, Parity]

  $\boldsymbol{C} = [\boldsymbol{i_1}, \boldsymbol{i_2}, \boldsymbol{i_3}, \boldsymbol{i_4}, \boldsymbol{P}]$

  $\boldsymbol{C} = [\mathbf{1}, \mathbf{0}, \mathbf{1}, \mathbf{0}, \mathbf{0}]$

Decoding Stage of Parity check

- At the decoding stage, received Codeword is

$$V = [V_1, V_2, V_3, \dots\dots, V_n]$$

- To determine/check whether V is the correct codeword, we do check sum of received codeword.

$$S = V_1 \oplus V_2 \oplus V_3 \oplus \dots\dots \oplus V_n$$

- If S = 0 , (Even Parity Codeword with correct received data)
- If S = 1 , (Odd Parity Codeword with correct received data)

Example of Block Code for parity check with Decoding

Example 2 : Given the (8, 7), even parity block code, Determine whether $V_1 = (10110110)$ and $V_2 = (01101001)$ gives parity failures.

- (8, 7) = (n, k)
- Information bits k = 7
- Parity bits r = n – k = 8 - 7 = 1
- For $V_1 = (10110110)$
- Checksum S will be

$S = D_1 \oplus D_2 \oplus D_3 \oplus D_4 \oplus D_5 \oplus D_6 \oplus D_7 \oplus D_8$

$S = 1 \oplus 0 \oplus 1 \oplus 1 \oplus 0 \oplus 1 \oplus 1 \oplus 0$

$S = 1$

- For Even received codeword, it is parity failure
- Means there is error in received data

- For $V_2 = (01101001)$
- Checksum S will be

$S = D_1 \oplus D_2 \oplus D_3 \oplus D_4 \oplus D_5 \oplus D_6 \oplus D_7 \oplus D_8$

$S = 0 \oplus 1 \oplus 1 \oplus 0 \oplus 1 \oplus 0 \oplus 0 \oplus 1$

$S = 0$

- For Even received codeword, it is parity success
- Means there is no error in received data

Example of Block Code for Product code

	Data Bits				Row Parity check	
	1	1	0	1	1	
	0	1	1	0	0	
	1	0	0	0	1	
	0	0	0	0	0	
	1	1	1	0	1	
	1	0	0	1	0	
Colom Parity Check	0	1	0	0	1	Over All Parity

- ❖ Here, total 7 rows and 5 Colom's, So total 35 bits.
- ❖ Out of 35 bits 24 bits are information bits.
- ❖ So given block code is (35, 24)

- ❖ It is happening as per $(5, 4) \times (7, 6)$.
- ❖ It is used to detect and correct one bit error.

Definition and Basics for Block codes for Repetition Code

- These are the codes that repeat information bits two or more times.
- They are block codes in which the parity bits are set equal to a single information bit and if the no of parity bits is ‘n - 1’ then the code is referred to as (n, 1).

Example of Block Code for Repetition code

- Let's have example of (3, 1) Repetition code
- (3, 1) = (n, k)
- Information bits k = 1
- Parity bits r = n – k = 3 – 1 = 2
- Encoding process

Information bits	Parity Bits		Codeword		
0	0	0	0	0	0
1	1	1	1	1	1

- Decoding process
- It is done based on Majority vote Decoding

Received Data			Decoding Decision	Output Data			Infor. *i*
0	0	0	No Error	0	0	0	0
0	0	1	One Bit Error	0	0	0	0
0	1	0		0	0	0	0
1	0	0		0	0	0	0
1	1	1	No Error	1	1	1	1
1	1	0	One Bit Error	1	1	1	1
1	0	1		1	1	1	1
0	1	1		1	1	1	1

✓ Majority of vote for (V_1, V_2, V_3) is taken as per $i = V_1.V_2 + V_1V_3 + V_2V_3$

Hamming Code Basics

→ It is given by RW Hamming.

→ It is used to detect and correct error.

→ In Hamming code, we send data along with parity bits or Redandent bits.

→ It is represented by $(\underbrace{n}_{\text{total bits}}, \underbrace{k}_{\text{Message bits}})$ code.

→ Parity bits $p = n - k$

→ To Identify parity bits, It should satisfy given Cond.^{n}

$$\Rightarrow 2^{p} \geq p + k + 1$$

→ So for $k = 4$ message bits.

Linear codes basics & property with example

Defination - A Block code is said to be linear code If its codewords satisfy the condition that the sum of any two codewords gives another codeword.

i.e. $C_p = c_i + c_k$

property

i) The all-zero words [0, 0, 0, ... 0] is always a codeword.

ii) Given any three codewords c_i, c_j and c_k such that

$$c_p = c_i + c_k \text{ , then } d(c_i, c_j) = W(c_p)$$

iii) Minimum distance of the code

$$d_{min} = W_{min}$$

- Cyclic Codes are subpart of linear block codes
- It follows following properties.

① Linearity Property

- If we have two code words c_i & c_j then

$$c_p = c_i + c_j$$

where, c_p should be a codeword.

② Cyclic shifting

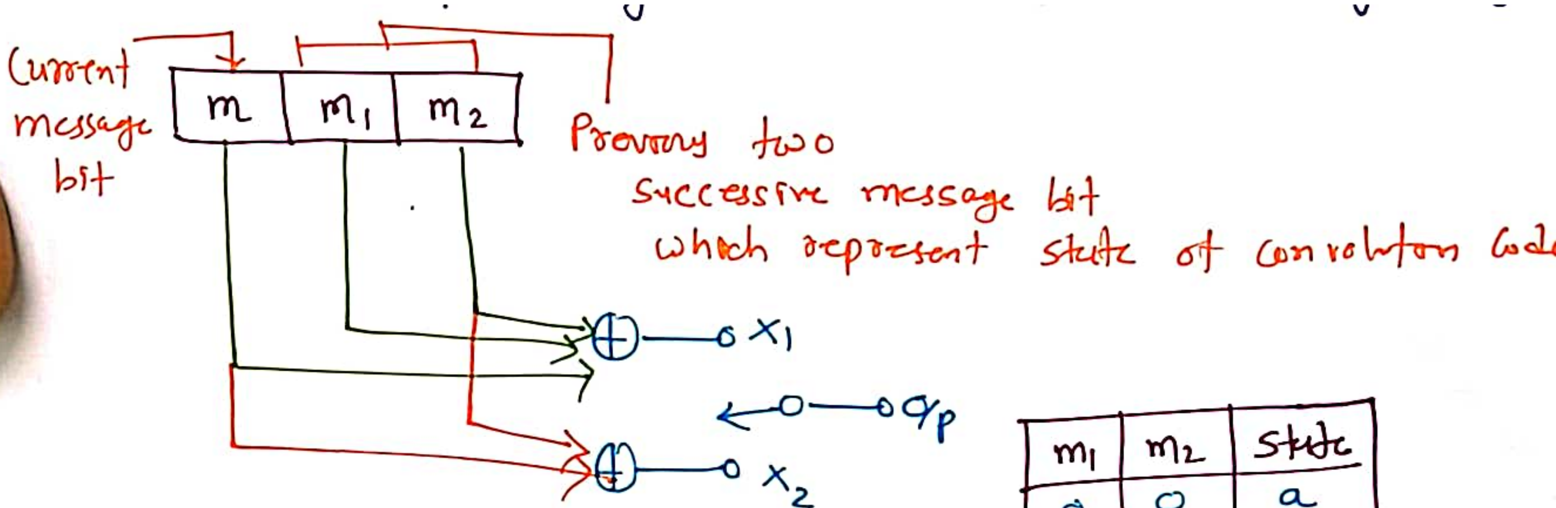
code word $= C(c_1, c_2, c_3, \ldots, c_n)$

- After shifting left or right by any no of bits, resultant code should be a codeword.

- If Codewords follow above two property then only that

Convolutional codes basics, parameters & designing

- In Convolutional codes, block of 'n' code digits generated by the encoder in time unit depends on not only block of 'k' message digits with in that time unit but also on the preceding (m-1) blocks of message digits.



$$x_1 = m \oplus m_1 \oplus m_2$$

$$x_2 = m \oplus m_2$$

m_1	m_2	State
0	0	a
0	1	b
1	0	c
1	1	d

- $\underline{k}$ = no of message bits = 1

  n = no of encoded o/p bits = 2

  K = Constrain Length = 3

- Here o/p will switch in bet.^{n} x_1 & x_2 so o/p will be

$$X = x_1 x_2 x_1 x_2 \ldots\ldots$$

- Code rate $r = \frac{k}{n} = \frac{1}{2}$

- Constraint Length (K)

  - single message bit influences encoder o/p for different successive shift.

- Code dimensions $(n, k) = (2, 1)$

Block Codes	Convolutional Codes
→ Block size is Large (k) in Block codes	→ Block size is small (k) in convolutional codes.
→ No Memory is required for encoding	→ Convolutional codes encoder requires Memory
→ Block codes are preferred in Systematic form	→ Convolutional codes are preffered in Non-Systematic form.
→ Block codes are suitable for random errors.	→ Convolutional codes are suitable for burst errors.

→ Block code decoding is done using Syndrome decoding	→ Viterbi decoding is used for convolutional codes.
→ Complex hardware	→ Simple hardware.
→ The research for block codes is Saturated	→ Research is going on & turbo codes are invented for communication applications.

Source Coding :

- The number of parity bits is reduced
- Bandwidth requirement is reduced
- Variable length coding techniques like Huffman and Shannon Fano are used.
- Symbols with lower probability contains more information
- symbols with lower probability have higher codeword length

Channel Coding

- Parity bits are added
- It protects information from error by adding parity bits
- Bandwidth requirement is higher
- It is also known as Forward Error Control Coding
- It is the process of detecting and correcting bit error
- eg. Linear Block Code, cyclic code, convolution code

NEED FOR MODULATION

Since, the baseband signals are incompatible for direct transmission over the medium and therefore we have to use modulation technique for the communication of baseband signal.

The advantage of Using modulation technique are given below.

* 1) Reduce the height of antenna.
2) Avoid mixing of signals.
3) Increase the range of communication.
4) Improves quality of reception.