Date 11/10/2018
Place

igital signal

umber of bits $= \log_2 8 = 3$
per level

$= \log_2 M$
(M - number of levels)

umber of levels (M) $= 2^{\text{No. of bits}}$

Data Rate Limits

Noiseless Channel
Nyquist Theorem

Capacity = Bitrate $= 2 * \text{Bandwidth} * \log_2 M$
Capacity $= 2B\log_2 M$

Noisy Channel
Shannon Capacity

Capacity $= B * \log_2(1 + SNR)$

SNR = Signal to Noise Ratio

Low SNR = Low Signal
High SNR = High Signal

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Signal to Noise Ratio (dB)

$$(SNR)_{dB} = 10 \log_{10} \frac{\text{Signal power}}{\text{Noise power}}$$

Noiseless Channel
B = 3000Hz
M = 2
Using Nyquist Theorem
Bitrate $= 2 * B * \log_2 M$
$= 2 * 3000 * \log_2 2 = 2 \times 3000 = 6000\text{bps}$
B = 3000Hz, M = 4
Bitrate $= 2 * B * \log_2 4 = 2 \times 3000 \times 2 = 12000\text{bps}$

Ex:- Extremely Noisy Channel
Signal is almost zero i.e SNR = 0
Using Shannon Capacity
Capacity $= B \times \log_2(1 + SNR) = B \times \log_2(1 + 0) = B \times \log$
$= B \times 0 = 0$
This means that we cannot receive any signal

Ex- Noisy Channel B = 3000Hz, SNR = 3162
$C = B \times \log_2(1 + SNR) = 3000 \times \log(1 + 3162)$
$= 3000 \times \log_2 3163 = 3000 \times 11.62 = 34860\text{bps}$
$= 34.860$ Kbps.

exponent

$a^x = y$ $\quad 2^3 = 8 \rightarrow \log_2 8 = 3$
$\log_a y = x$

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Spectrum of channel between 3MHz and 4MHz

B = 4MHz − 3MHz = 1MHz = 10^6 Hz

SNR_{dB} = 24dB = $10\log_{10}$ SNR

SNR = 251

Capacity = $10^6 \times \log_2(1+SNR) = 10^6 \times \log_2 251 = 10^6 \times 8$
= 8Mbps

How many signal levels are required?
Nyquist Theorem

$C = 2 * B * \log_2 M$
$8\times10^6 = 2\times10^6 \times \log_2 M$

$4 = \log_2 M$
$M = 2^4 = 16$

1. $(SNR)_{dB} = 30dB$

B = 2.7KHz = 2.7×10^3 Hz

SNR = 30dB = $10\log_{10}$ SNR
$= \frac{30}{10} = \log_{10}$ SNR
$= 10^3 = 1000$

Capacity = $B \times \log_2(1+SNR)$
$= 2.7\times10^3 \times \log_2 1001$
$= 2.7\times10^3 \times 9.967$
$= 26.91 \times 10^3$
= 27kbps

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2. $(SNR)_{dB} = 10dB$

B = 200kHz = 200×10^3 Hz

SNR = 10

$C = 200\times10^3 \times \log_2(1+10) = 200\times10^3 \times 3.46 = 692\times10^3$ = 692kbps

Antennas: Directed and sectorized.
To get more energy multiple antenna is used

Parabolic Reflective Antenna

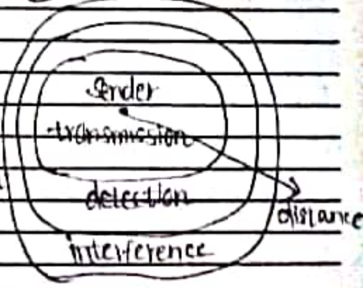
Antenna Gain is a measure of directionality of antenna
It is defined as power output in a particular direction
It does not refer to obtaining more input power

Relationship between antenna gain and effective area

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2} \quad \left[\because \lambda = \frac{c}{f}\right]$$

Signal propagation ranges
Transmission range

Ground wave
(refraction) Sky wave
Line of sight
(ionosphere)
} Propagation



Transmission Limitations

1. Attenuation

Means loss of energy → weaker signal

$$dB = 10\log_{10}\frac{P_t}{P_r}$$

P_t - Input signal - Transmission } signal
P_r - Output signal - Receiver

2 Distortion - Change in shape

3 Free space loss $= P_t / P_r$

For any type of wireless communication the signal disperses with distance

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

λ = carrier wavelength
f = carrier frequency
d = propagation distance

$$L_{dB} = 10\log_{10}\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$$L_{dB} = 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$$= -20\log(\lambda) + 20\log(d) + 21.98\,dB$$

$$= 20\log\left(\frac{4\pi f d}{c}\right) = 20\log(f) + 20\log d - 147.56\,dB$$

Ex Determine the isotropic free space loss at 4GHz for the shortest path to a synchronous satellite from earth (35,863 km) At 4GHz the wavelength is $(3\times10^8)/(4\times10^9) = 0.075m$

Then $L_{dB} = -20\log(0.075) + 20\log(35.853\times10^6) + 21.98$
$= 195.6\,dB$

Signal Propagation

Receiving power proportional to $1/d^2$ in vaccum: (d = distance between sender and receiver).

+ve DS ↑Fading
Fading [Due to Multipath propagation
-ve DS ↓Fading Due to Doppler Effect]

Rapid fluctuations of received signal strength over short time intervals and /or travel distances

2 most important effects:-
1. Rapid changes in signal strength
2. Changes in the frequency of signals

Doppler Shift
Change in frequency of a wave for an observer moving relative to the source of the wave
+ shift → Moving toward source
- shift → Moving away from source

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V: velocity (m/s)

λ: wavelength (m)

θ: angle between mobile direction

$\Delta l = d\cos\theta = V\Delta t \cos\theta$

Δt is the time required for the mobile to travel from X to Y

The phase change in the received signal due to the difference in path lengths is therefore,

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi V\Delta t\cos\theta}{\lambda}$$

$$f_d = \frac{1}{2\pi} \times \frac{\Delta\phi}{\Delta t} = \frac{V}{\lambda}\cdot\cos\theta$$

1. Time dispersion → Multipath delay
2. Frequency dispersion → Doppler spread

Coherence Time (T_c): Time Interval over which impulse response remains invariant → amplitude & phase of multipath signals ≈ constant

Flat Fading	B.W of signal < B.W of channel
Frequency Selective Fading	B.W of signal > B.W of channel

Transmitting

User 1 Data 00

User 2 Data 10

User 3 Data 11

User-1 code is also called as spread code 0101

User2 code is 0011, User 3 code is 0000

0 bit is represented with +1 code and

1 bit is represented with -1 code

User 1 Data 00 ~~User-2~~

0 0 0 0   0 0 0 0

0 1 0 1   0 1 0 1

0 1 0 1   0 1 0 1

User 2 Data 10

1 1 1 1   0 0 0 0

0 0 1 1   0 0 1 1

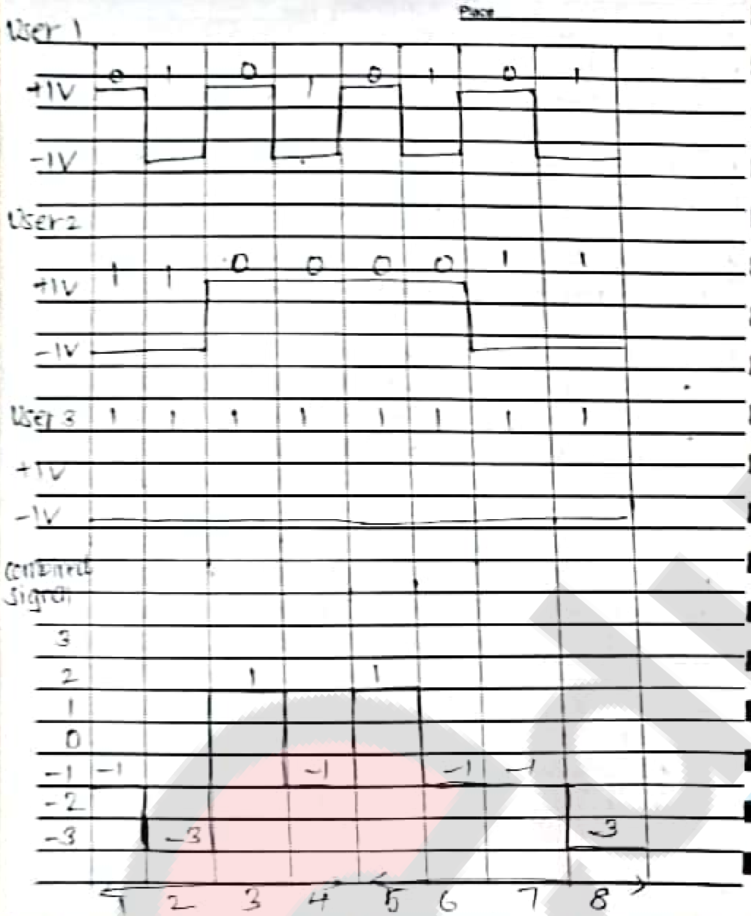
1 1 0 0   0 0 1 1

User 3 Data 11

1 1 1 1   1 1 1 1

0 0 0 0   0 0 0 0

1 1 1 1   1 1 1 1



0 1 0 1

↓ ↓ ↓ ↓

+1 -1 +1 -1

carrier frequency is a radio processor frequency with high bandwidth supporting signal

$B_1 = (-1 \times 1) + (-3 \times -1) + (1 \times 1) + (-1 \times -1)$

$= -1 + 3 + 1 + 1 = 4$

$B_2 = (1 \times 1) + (-1 \times -1) + (-1 \times 1) + (-3 \times -1)$

$= 1 + 1 - 1 + 3 = 4$

Combined Signal = 8

Modulation:

Digital Data to Analog Signal	ASK (Amplitude Shift keying)
	FSK (Frequency Shift keying)
	PSK (Phase Shift keying)
	BFSK (Binary Frequency Shift key)

Advanced frequency shift keying

Minimum shift keying (MSK)

Analog - AM, FM, PM

Spread Spectrum

Explain its techniques

DSSS - Direct sequence

FHSS - Frequency Hopping

} Spread Spectrum

Slow Hopping

Fast Hopping

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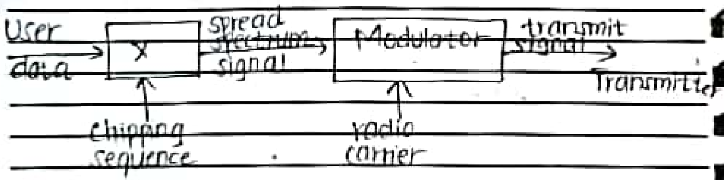

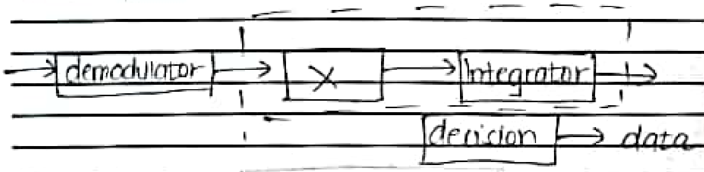

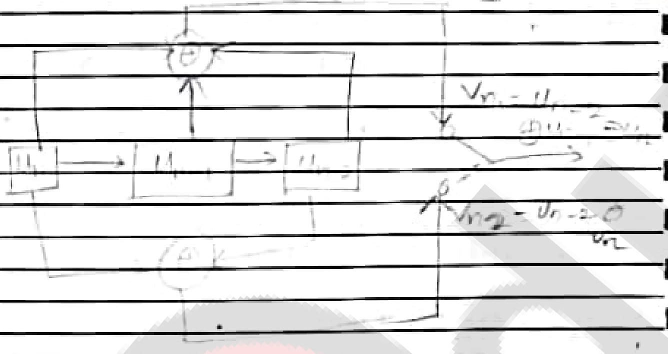

$V_{n_1} = U_{n-2} \oplus U_{n-1} \oplus U_n$

$V_{n_2} = U_{n-2} \oplus U_n$

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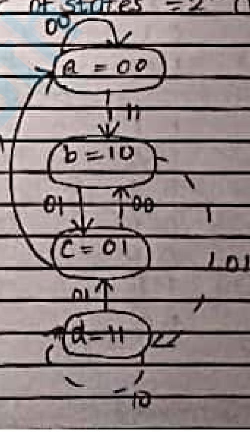
2/3 encoder

I/P	Previous		Next		O/P	
U_n	U_{n-1}	U_{n-2}	U_{n-1}	U_{n-2}	V_{n_1}	V_{n_2}
0	0	0	0	0	0	0
1	0	0	1	0	1	1
0	0	1	0	0	1	1
1	0	1	1	0	0	0
0	1	0	0	1	1	0
1	1	0	1	1	0	1
0	1	1	0	1	0	1
1	1	1	1	1	1	0

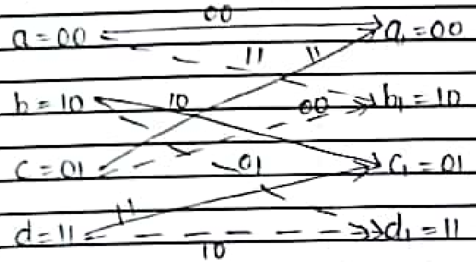
K=1
K=2

Total number of states $= 2^{K(K-1)}$

Solid line – 0
dash line – 1



Trellis diagram for 2|3 encoder.

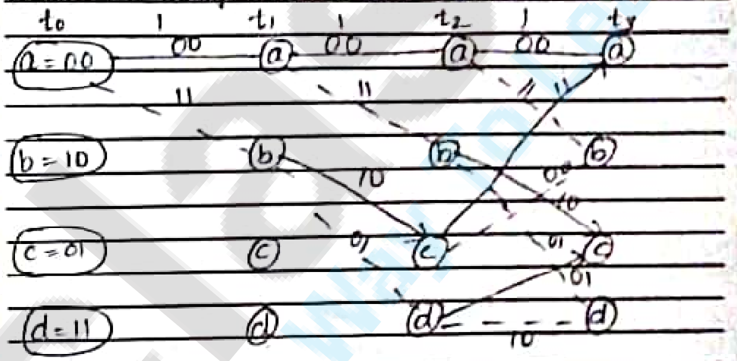


Encode 111 using 2|3 Encoder

I/P	Previous	O/P
1	0 0	1 1
1	1 0	0 1
1	1 1	1 0

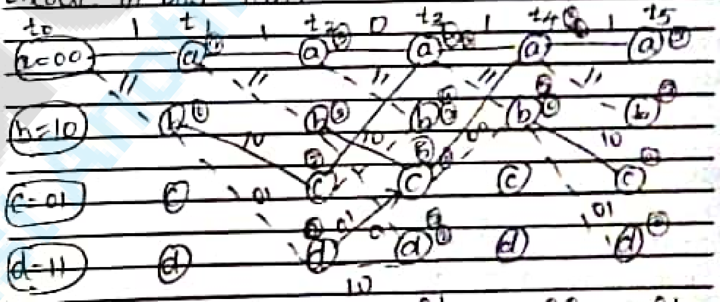
I/P	1	0 0	1 1
	0	1 0	1 0
	1	0 1	0 0
	1	1 0	0 1
	0	1 1	0 1
	0	0 1	1 1
	0	0 0	0 0

Encode 111 using Convolutional Encoder

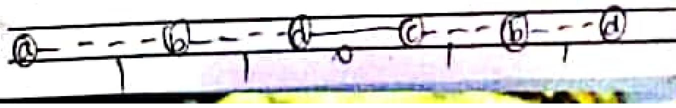


$\boxed{11 \quad 01 \quad 10}$

Encode I/P bits 11011



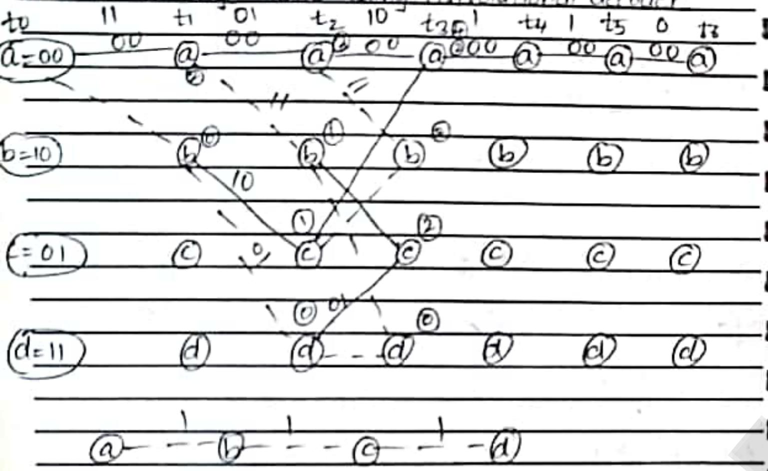
11 01 01 00 01



Date 25/07/2018

Place

Decode the message 110110 using convolutional decoder



Hamming Codes

Hamming codes are family of (n,k) block error correcting codes.

Block length $n = 2^m - 1$

Number of data bits $K = 2^m - m - 1$

Number of check bits $n - K = m$

Minimum distance $d_{min} = 3$

That is $m \geq 3$

$2^m \geq k + m + 1$

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Ex:- Calculate Hamming code for 8 bit data m=4,K=

00111001

0	0	1	1	C_4	1	0	0	C_3	1	C_2	C_1

10 1010

9 1001

7 0111

3 0011

0111 = 7

0000

1011

1011 = 11

10 1010

9 1001

7 0111

4 0100

3 0011

2 0010

1 0001

0000

Input = 1 00 11 01

1	0	0	C_4	1	1	0	C_3	1	C_2	C_1	

11 = 1 0 1 1

7 = 0 1 1 1

6 = 0 1 1 0

3 = 0 0 1 1

1 0 0 1 = 9

1 0 0 1 1 1 0 0 1 0 1

11 1 0 1 1

6 0 1 1 0

3 0 0 1 1

1 0 0 1

0 1 1 1 = 7