Unit II :- Baseband Digital Transmission

4.1 Digital Multiplexing / Multiplexers :

→ Multiplexing is the process of combining multiple signals into one signal over a shares or common medium.

→ If the analog signals are multiplexed then it is called as analog multiplexing.

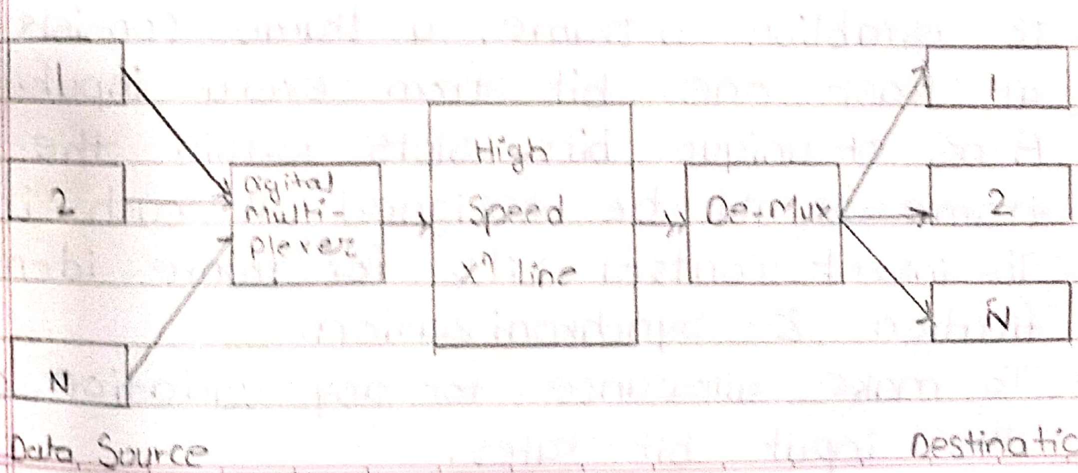
→ Similarly if the digital signals are multiplexing then it is called as digital multiplexing

→ Multiplexing is a key feacture of all commencial long distance communication system.

→ Digital multiplexing is based on the principle or interleaving symbols from two or more digital signals.

→ The digital multiplexing will enable us to combine many digital signals such as computer outputs, digital voice, digital facimile & TV signals.

★ Block Diagram :



→ Digital Multiplexing is based on the principle of interleaving Samples from two or more digital Signals. It is Similar to the Time Division multiplexing but it does not require periodic Sampleing or waveform preservation. ie. the Signals which are to be multiplexed these Signals may come from digital data Sources or analog Sources that have been digitally coded.

→ Digital Multiplexer is used to merge the input bits from diff. Source.

→ The digital data can be multiplexed by using a bit-by-bit interleaving procedure.

→ It is done by selector Switch which sequentially selects a bit from each input & places it over high Speed x^n line.

→ At receiving end, the bits received on the Common line are separated out & delivered to their respective destination.

* Some of the important functions performed by multiplexers are:

1) To establish a frame, a frame consists of at least one bit from every input.
2) A no. of unique bits slots within the frame should be assigned to each i/p
3) To insert control bits for frame identification & Synchronization.
4) To make allowance for any variation of the input bit rates.

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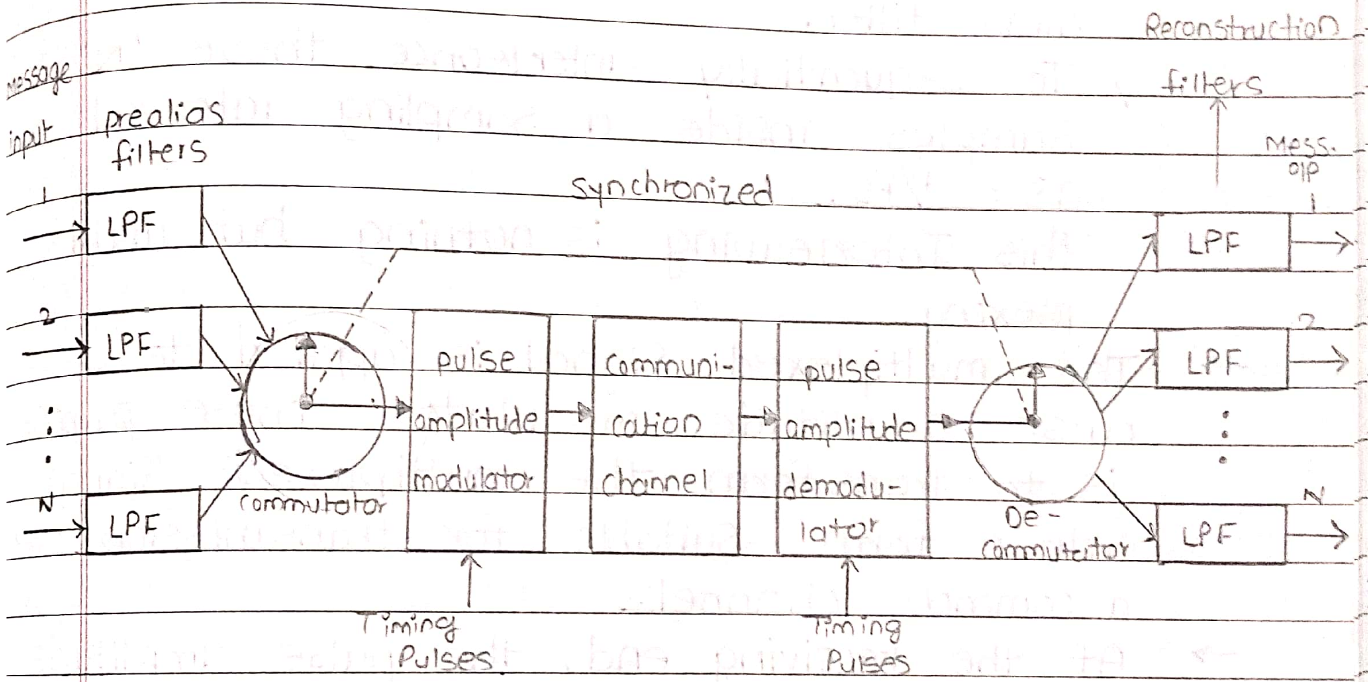
* Time Division Multiplexing (TDM):

July-05, 5M	Jan-07, 5M	Jan-08	July-09, 5M

→ An Important feature of TDM is Conservation of time i.e. different time Intervals (periods) are allocated for different message Signals, so that a common channel is utilized for transmission of these Signals without any Interference



fig①: Block Diagram of TDM system.

The Concept of TDM is illustrated in the block diagram.

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→ The Low pass pre-alias filters are used to remove high-frequency components which may be present in the message signal.

→ The O/P of the pre-alias filters are then fed to a commutator, which is usually implemented using electronic switching circuitry.

→ The function of commutator is 2 fold:

1) To take a Narrow Sample of each of the 'N' I/P Signals at a rate $fs \geq 2W$, where 'w' is the cut-off frequency of pre-alias filter.

2) To Sequentially interleance these 'N' Samples inside a Sampling interval $Ts = 1/fs$.

This Interleaving is nothing but multiplexing.

→ The multiplexed Signal is applied to a pulse amplitude modulator whose purpose is to transform the multiplexed Signal into a form Suitable for transmission over a common channel.

→ At the receiving end, the pulse amplitude demodulator performs the ~~Increase~~ reverse operation of PAM & the decommutator distributes the Signals to the appropriate low pass reconstruction filters.

→ The decommutator operates in Synchronization with the commutator.

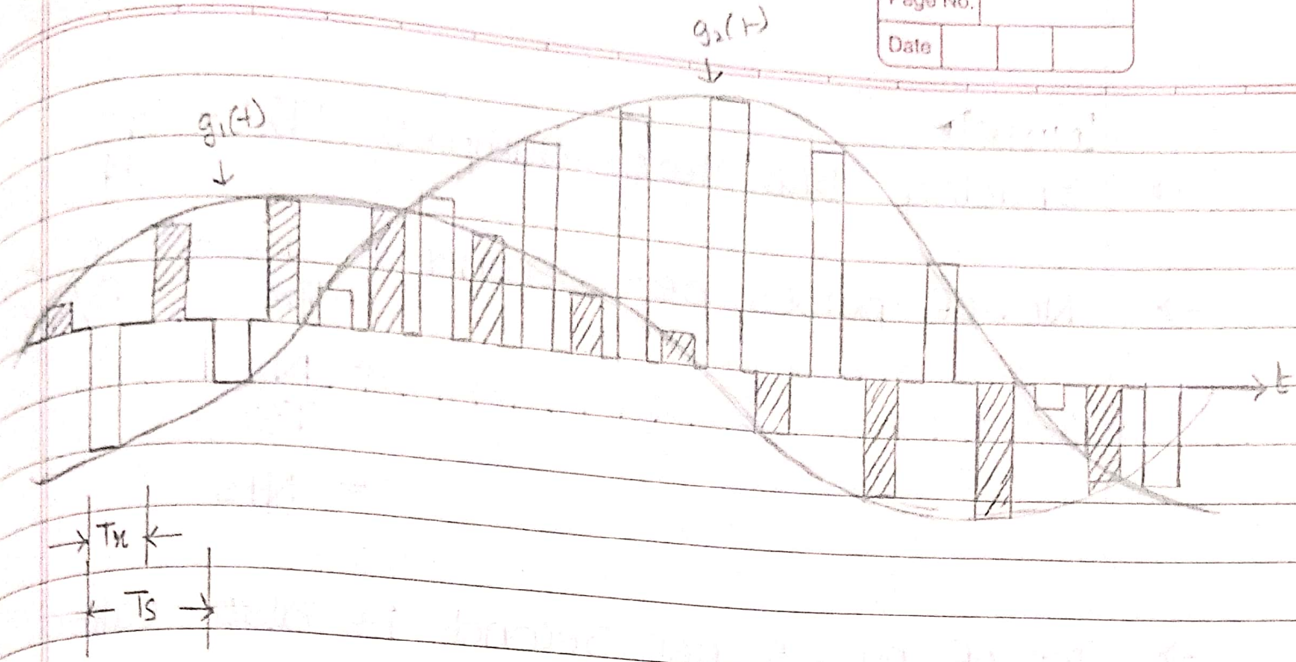

fig ②: Waveforms Illustrating TDM for two message signals.

→ Suppose that the 'N' message signals to be multiplexed (Txed) have the Same Spectral properties (BW). Then the Sampling rate rate for the each message signal is determined in accordance with the Sampling theorem.

→ Let 'T_s' denotes the Sampling period.
Let 'T_x' denote the time spacing between adjecent Samples in the TDM Signal.
i.e.

$$\boxed{T_x = \frac{T_s}{N}}$$ as shown in fig ②

NOTE

→ Spacing b/w two Samples 'T_x' = $\frac{T_S}{N}$

→ No. of pulses per Second $= \frac{1}{T_x} = \frac{1}{T_S/N}$

$= \frac{N}{T_S}$

$= Nf_s$

→ No. of pulses per Second is also Called as Signalling rate 'r'

i.e.

$$\boxed{r = Nf_s}$$

Since $f_s \geq 2f_m$

$$\boxed{r \geq N2f_m}$$

→ Transmission Band width = $\frac{\text{Signalling Rate}}{2}$

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1

TDM (formulae)

1) Speed of the commutator in revolution per Second (rps) = $2W$
where 'W' is the minimum BW of message Signal.

2) Speed of the commutator in Samples / sec
= Total number of segments × speed of commutator in rps

3) Minimum transmission BW = $\frac{1}{2}$ [Sum of Nyquist rate]

4) Minimum bit rate = $\frac{1}{2}$ [Sum of Nyquist rate] bits/sec.

5) Angle of Separation of Corresponding Segments $= \frac{360°}{n}$
where,
'n' is the number of segments.

6) Angle of separation b/w each segment (pole) $= \frac{360°}{\text{Total No. of Segments}}$.

TDM (Problems)

Q.1. A Signal $m_1(t)$ is band-limited to 3KHz & 3 other signals $m_2(t)$, $m_3(t)$ & $m_4(t)$ are bandlimited to 1.5 KHz each. These are transmitted by means of TDM.

i) Set up a commutator Scheme to realize the multiplexing with each signal Sampled at Nyquist rate.

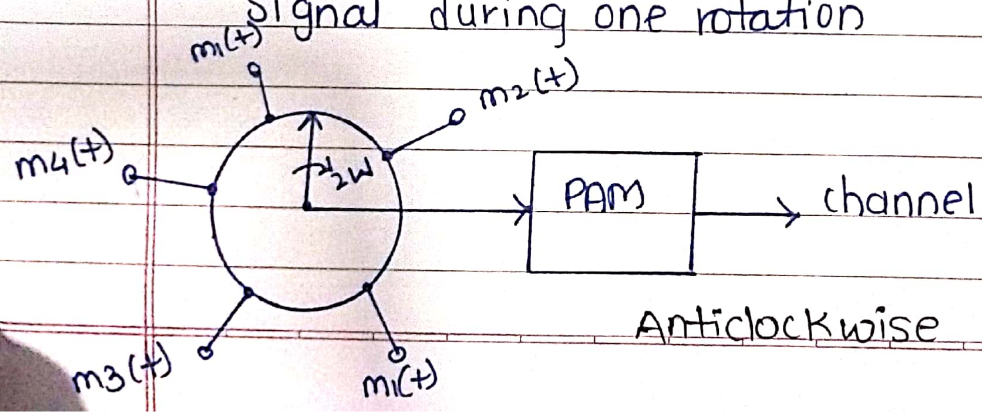
ii) find the Speed of the Commutator in Samples /sec & the minimum band width of the channel.

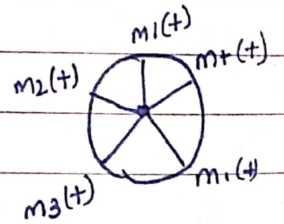
i)

Message Signal	BW	Nyquist rate	No. of Segment 'N'	Angle of Separation of Corre. Segment = $\frac{360}{N}$
$m_1(t)$	3 KHz	6 KHz	2	180°
$m_2(t)$	1.5KHz	3 KHz	1	360°
$m_3(t)$	1.5KHz	3 KHz	1	360°
$m_4(t)$	1.5KHz	3 KHz	1	360°

→ Angle of Separation b/w each Segment (pole) $= \dfrac{360°}{\text{Total No. of Segments.}}$

6KHz Nyquist rate is twice than that of other signal during one rotation $= \dfrac{360°}{5} = 72°$





— (4M)

Anticlockwise rotation

→ If the Commutator is rotated at 3000 rev/sec, then in each revolution we obtain one Sample each for $m_2(t)$, $m_3(t)$, & $m_4(t)$ & 2 Samples from $m_1(t)$.

→ commutator Speed in rps = $2W$

$= 2 \times 1.5\ KHz$

$= 3000\ rps$.

ii) Speed of the commutator in Samples/Sec

= [Total No. of Seg × Speed of Commutator in rps]

$= 5 \times 3000\ rps$

$= 15{,}000$ Samples/Sec. —— 1M

Minimum BW of channel $= \frac{1}{2}$ [Sum of Nyquist rate]

$= \frac{1}{2}[6KHz + 3KHz + 3KHz + 3KHz]$

$= \frac{15\ KHz}{2}$

$= 7.5\ KHz$ —— 1M

A signal $m_1(t)$ is band limited to 3.6 KHz & there other signals $m_2(t)$, $m_3(t)$ & $m_4(t)$ are band limited to 1.2 KHz each. These signals are to be transmitted by means of TDM. Sketch set up a Scheme for realizing this multiplexing requirements with each signal sampled at its Nyquist rate. Determine the speed of Commutator in Samples per sec.

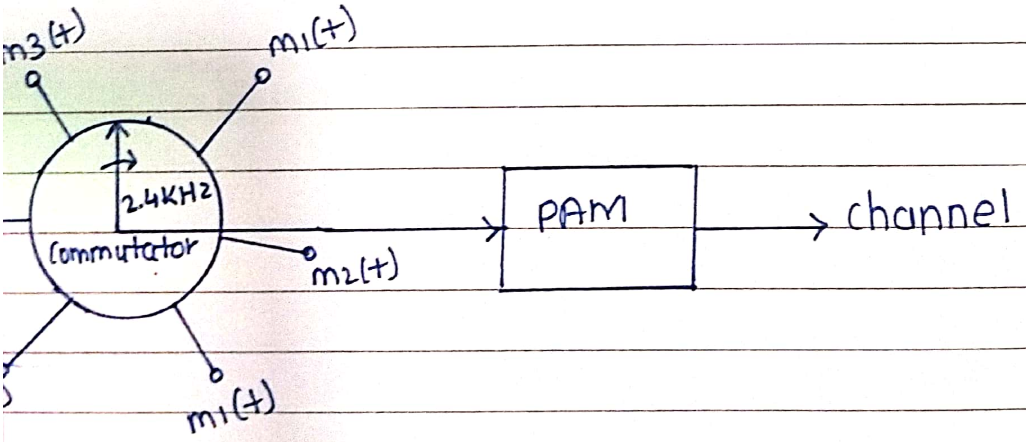
Jan-08, 8M

Mess. Signal	BW	Nyquist rate $f_s = 2W$	No. of Seg. 'N'	Angle of Separation of corr. Segment $= \frac{360°}{N}$
$m_1(t)$	3.6 KHZ	7.2 KHZ	3	120°
$m_2(t)$	1.2 KHZ	2.4 KHZ	1	360°
$m_3(t)$	1.2 KHZ	2.4 KHZ	1	360°
$m_4(t)$	1.2 KHZ	2.4 KHZ	1	360°

Angle of Separation b/w each segment $= \frac{360°}{\text{Total. No. of Segment}}$

$= \frac{360}{6}$

$= 60°$



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→ If the Commutator is rotated at 2400 rev/sec then in each revolution, we obtain one sample each for $m_2(t)$, $m_3(t)$, & $m_4(t)$ and 3 samples from $m_1(t)$

→ Commutator Speed in rps = $2W$

$= 2 \times 1.2\,KHZ$

$= 2400$ rps.

→ Speed of Commutotor in Samples / sec.

= Total. No. of Segments x speed of Commutator in rps

$= 6 \times 2400$

$= 14{,}400$ Samples / sec.

→ Minimum BW of the channel $= \frac{1}{2}\left[7.2\,KHZ + (3 \times 2.4\,KHZ)\right]$

$= 7.2\,KHZ$

Q.3. Three Independent message Sources of band-width 1KHZ, 1KHZ, 2KHZ respectively are to be transmitted using TDM Scheme.

Determine :

i) The Commutator Segment arrangement

ii) the Speed of Commutator if each Signal is Sampled at its Nyquist rate.

iii) Minimum transmission bandwidth

$\boxed{\text{July-06, 6M}}$

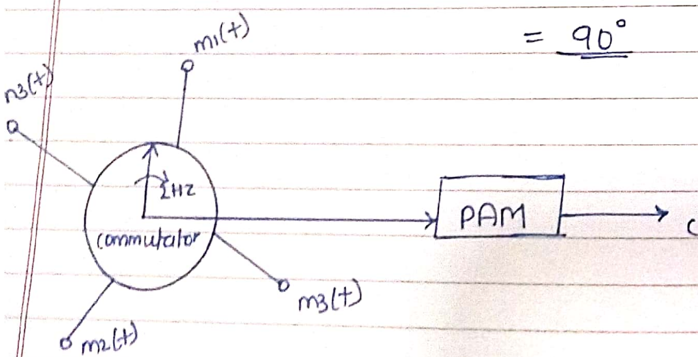
→ i)

Message Signal	BW	Nyquist rate $f_s = 2W$	No. of Segment 'N'	Angle of Separation of Corresponding Segment $= \frac{360}{N}$
$m_1(t)$	1KHZ	2KHZ	1	360°
$m_2(t)$	1KHZ	2KHZ	1	360°
$m_3(t)$	2KHZ	4KHZ	2	180°

Angle of Separation b/w each Segment $= \dfrac{360^\circ}{\text{Total. No. of Segment}}$

$= \dfrac{360}{4}$

$= \underline{\underline{90^\circ}}$



→ Commutator Speed in rps $= 2W$

$= 2 \times 1\text{ KHZ}$

$= 2000$ rps.

→ If the Commutator is rotated at 2000 rev/sec then in each revolution we obtain one Sample each from $m_1(t)$, $m_2(t)$ & 2 Samples from $m_3(t)$

ii) Speed of the commutator in Samples / sec = Total no. of segments X Speed of commutator in rps

$= 4 \times 2000$ rps

$= 8000$ Samp/sec.

iii) Minimum BW $= \frac{1}{2}\left[2\text{KHZ} + 2\text{KHZ} + 4\text{KHZ}\right]$

$= 4\text{ KHZ}$

Q.4 four message bandlimited to W, W, W, & 3W are to be TDM, with W being 2000 Hz. Set up a TDM Scheme for the Same & find speed of the Commutator in Samples per Second

$\boxed{\text{Jan - 10, 8M}}$

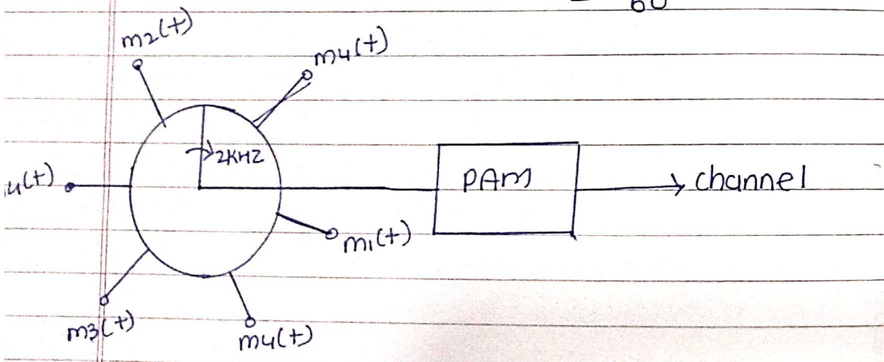
→ Given W = 2 KHZ

Message Signal	BW	Nyquist rate $f_s = 2W$	no. of segment	Angle of Separation of Correspond^n Segment $= \frac{360}{N}$
$m_1(t)$	W = 2KHZ	4KHZ	1	360
$m_2(t)$	2KHZ	4KHZ	1	360
$m_3(t)$	2KHZ	4KHZ	1	360°
$m_4(t)$	6KHZ	12KHZ	3	120°

Angle of Separation b/w each Segment $= \frac{360°}{\text{Total. No. of Segment}}$

$= \frac{360°}{6}$

$= 60°$



Commutator Speed in rps = 2W = 2x2KHZ

= 4000 rps.

→ If the Commutator is rotated at 4000 rev/sec then in each revolution, we obtain one Sample each for $m_1(t)$, $m_2(t)$, $m_3(t)$ and 3 Samples from $m_4(t)$

→ Speed of Commutator in Samples per sec

= Total No. of Segment x Speed of Commutator in rps

= 6 x 4000 rps

= 24,000 Samples/sec

→ Minimum Transmission (BW) $= \frac{1}{2}\left[\text{Total. No. of Nyquist rate}\right]$

$= \frac{1}{2}\left[4KHZ + 4 + 4 + 12\right]$

$= \frac{24 KHZ}{2}$

= 12 KHZ

Q.5 6 Independent message Sources of BW's W, W, 2W, 2W, 3W & 3W Hz are to be transmitted on a TDM basis using a Common Communication channel.

i) Set-up a Scheme for accomplishing this multiplexing requirements with each message Signal Sampled at its Nyquist rate.

ii) Determine the minimum transmission BW of the channel.

[July-08, 5M]

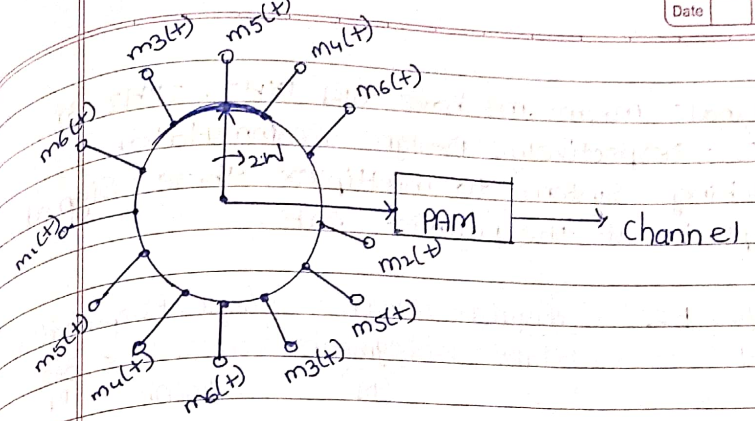
→

Message Signal	BW	Nyquist rate $f_s = 2W$	No. of Segments (N)	Angle of Separaⁿ of Corr. Segment $= \frac{360}{N}$
$m_1(t)$	W	2W	1	360°
$m_2(t)$	W	2W	1	360°
$m_3(t)$	2W	4W	2	180°
$m_4(t)$	2W	4W	2	180°
$m_5(t)$	3W	6W	3	120°
$m_6(t)$	3W	6W	3	120°

→ Angle of Separation b/w each segment $= \frac{360°}{\text{Total. No. of Segment}}$

$= \frac{360°}{12}$

$= 30°$



→ Speed of Commutator in rps = 2W

→ If the Commutator is rotated at 2W rps/sec, then in one rotation of the Commutator we get one Sample each of $m_1(t)$ & $m_2(t)$ and 2 Samples each of $m_3(t)$ & $m_4(t)$ and 3 Samples each of $m_5(t)$ & $m_6(t)$

→ Speed of the Commutator in Samples per Second

= To. No. of Segment x Speed of Commutator in rps

$= 12 \times 2W$

= 24 W Samples/sec.

→ Minimum transmission BW $= \frac{1}{2}\left[\text{Sum of Nyquist rate}\right]$

$= \frac{1}{2}\left[2W + 2W + 4W + 4W + 6W + 6W\right]$

$= 12W$

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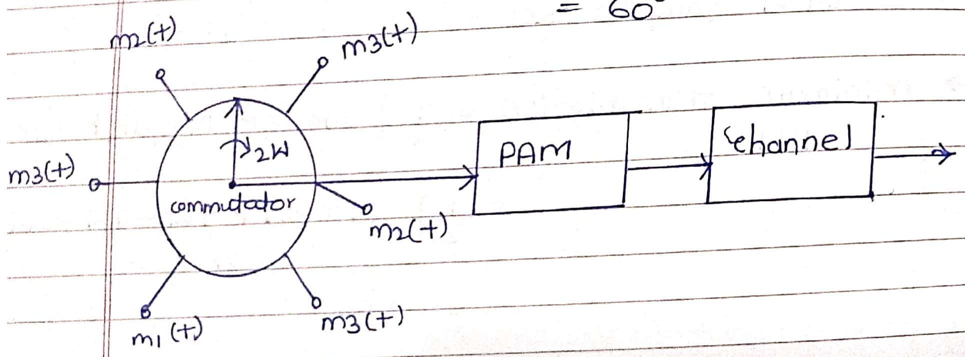
Q.6 3 Signals m_1, m_2, m_3 have BW 1KHZ, 2KHZ & 3KHZ - respectively. Design a commutator Switching System to multiplex these Signal sampled at the Nyquist rate.

Message Signal	BW	Nyquist rate	No. of Segments (N)	Angle of Separatn of Corres. Segment $= \frac{360°}{N}$
$m_1(t)$	1KHZ	2KHZ	1	360°
$m_2(t)$	2KHZ	4KHZ	2	180°
$m_3(t)$	3KHZ	6KHZ	3	120°

→ Angle of separation b/w each Segment $= \frac{360°}{\text{Total. No. of segment}}$

$= \frac{360°}{6}$

$= 60°$



→ Speed of the Commutator in rps $= 2W$

$= 2 \times 1KHZ$

$= \underline{2000 \text{ rps}}$

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→ If the commutator is rotated at 2W res./sec. then in one rotation of the commutator, we get one sample from $m_1(t)$, 2 Samples from $m_2(t)$, 3 Samples from $m_3(t)$.

→ Speed of commutator in Samples per/sec.
= Total no. of Segment X Speed of Commutator in rps

$= 6 \times 2 \text{ KHZ}$

$= 12 \text{ KHZ Samples/sec}$

→ Minimum bit rate = Minimum transmission bandwidth

$= \frac{1}{2}\left[\text{Sum of Nyquist rate}\right]$

$= \frac{1}{2}\left[2+4+6\right]$

$= 6 \text{ Kilo bits / sec.}$

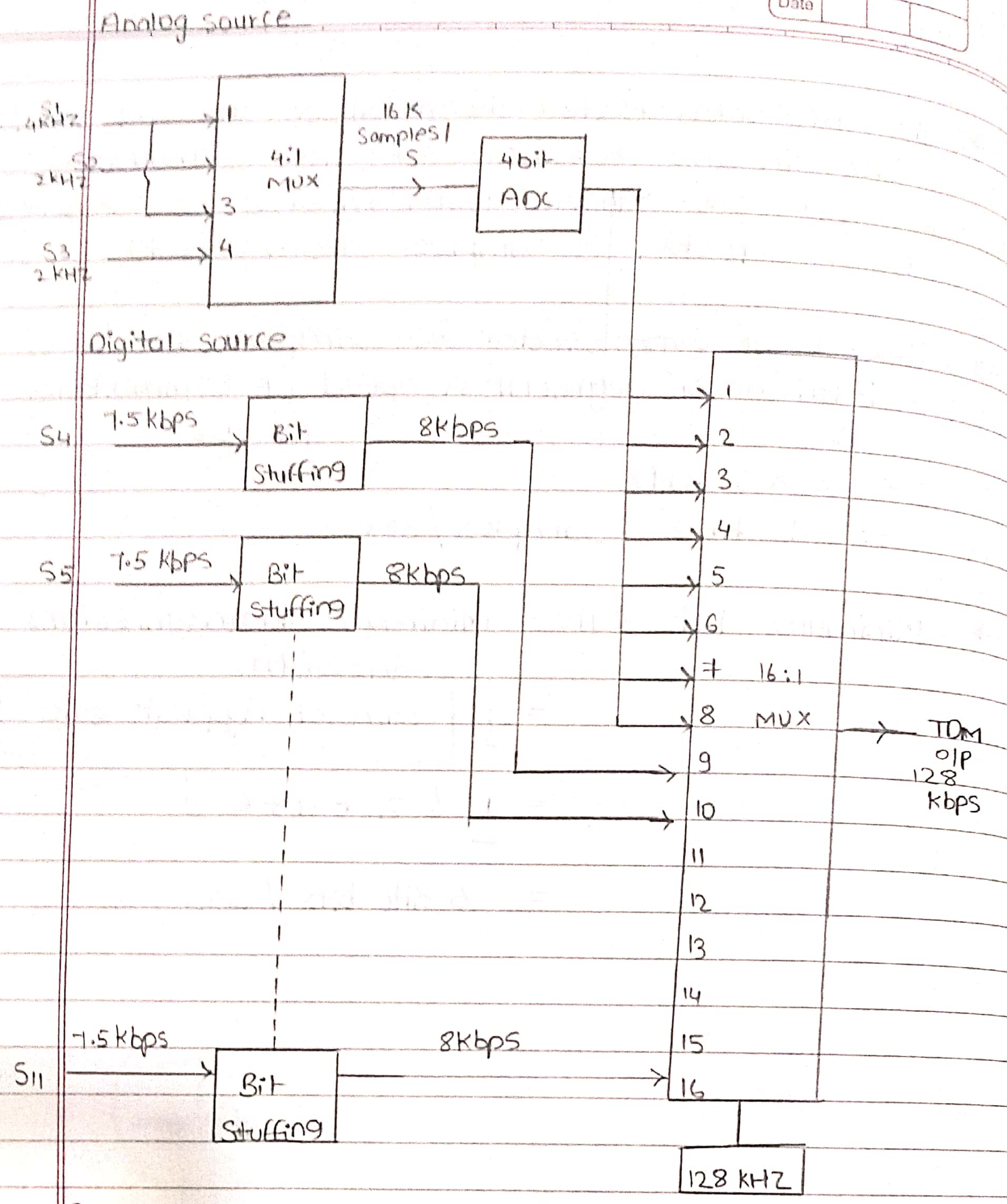

fig.4.6: Multiplexer design for Example 4.3

Signaling rate $(r) = 16 \times 8\,KHZ = 128$ KbPs

Bandwidth requirement

$$B_T = \frac{r}{2}$$

$$= 64\,KHz.$$

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2. Multiplexing Hierarchies & Data Multiplexers :

There are two types of digital Multiplexers.

I. Low Speed Multiplexers :

→ These are used with digital Computer Systems to merge digital Signals from Several Sources.

→ The output rates of these multiplexers are standardized to 1.2, 2.4, 3.6, 4.8, 7.2, 7.6 and 19.2 Kbps. The output is designated as digital Signal level 0 (DS0).

II. High Speed Multiplexers :

→ They are used in Commercial data transmission Systems.

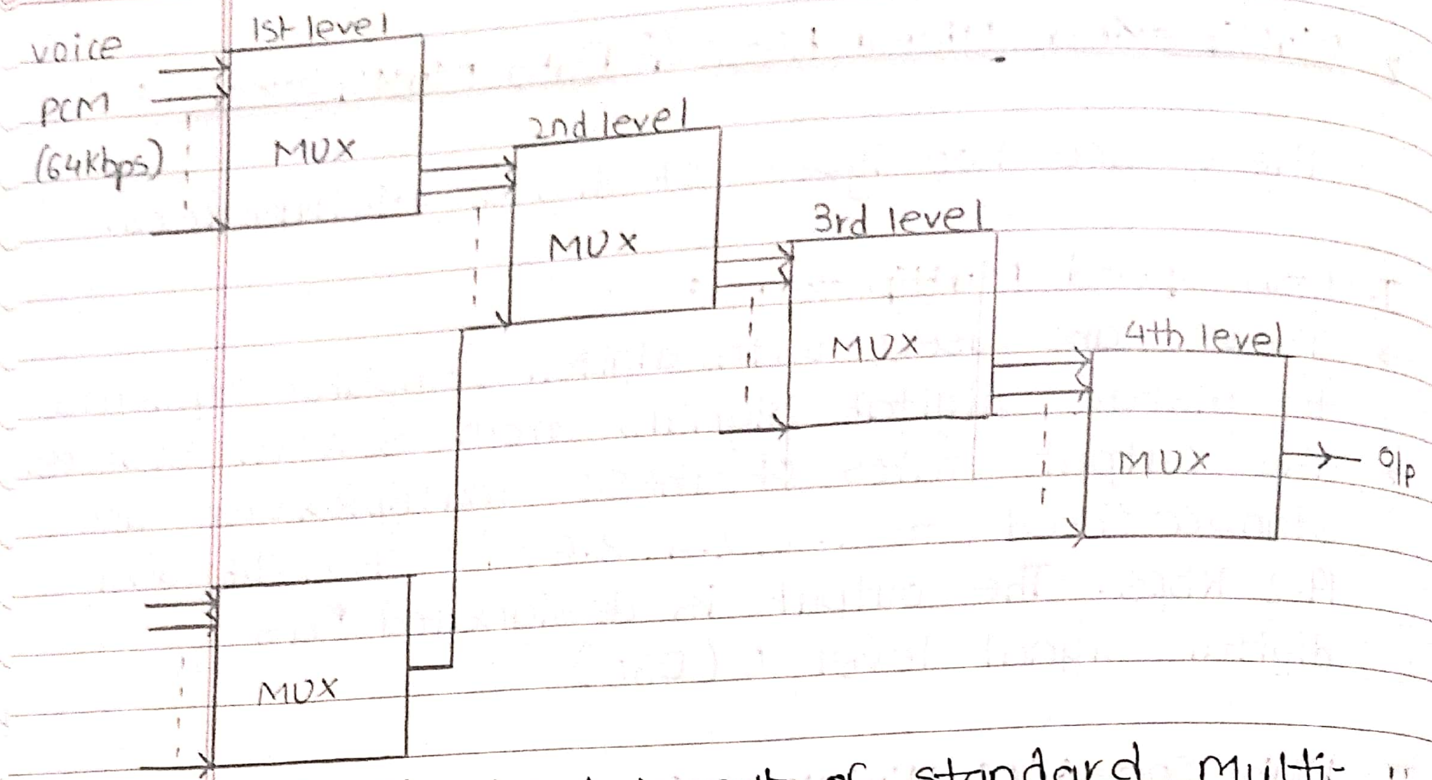
→ Two different multiplexing Standards have been adopted for digital Communication.

→ The AT & T hierarchy in North America & Japan and CCITT hierarchy in Europe and rest of world. Both hierarchy are Based on 64 Kbps voice PCM unit.

→ Their Structural layout is shown in fig 4.7.

→ The telephone industry has standardized the bit rates to 1.544 Mbps, 6.312 Mbps, etc. and designed them as DS-1 (Digital Signal type 1) DS-2, etc.

→ Thus, higher the DS level, higher will be data rate. Different transmission medium is used for different DS levels.



4.7 : Structural layout of standard Multi-plexing Schemes

- → for Example for higher DS - levels, fibre optic cables, microwave links are used.
- → A single DS-1 Signal is usually transmitted over a pair of twisted pair cables.
- → This type of DS-1 transmission over a twisted pair medium is called T_1 - Carrier systems.
- → Similarly, the higher DS-levels transmission are known as T_2, T_3, T_4 Carrier Systems

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2.17 T_1 Carrier System :

(Nov-15, Aug-16)

→ fig. 4.8 shows basic T_1 carrier System which is used to transmit 24 voice Signals over a Single DS-1 line

→ Two lines, one for transmission and another for reception are used in the System.

→ Repeaters will be required if the T_1 line is connecting telephone equipments over a large distance after every 2 km.

→ Sampling rate used, for each voice Signal is 8 KHZ. $\left(f_s = 8\,KHZ \right) = \cancel{800}$
$= 8000$

→ Hence, frame length will be $\frac{1}{8000} = 125\,\mu\text{-Sec}$

$= \frac{1}{F_S} = T_S.$

→ 8-bit PCM is used, hence frame length will be $24 \times 8 = 192$ bits.

→ 1-bit is added at the beginning of each frame for frame Synchronisation. Hence, total bits in one frame = 193 bits

→ Hence, the T_1 data rate (r_b)
$= (193 \text{ bits/ frame}) \times 8000 \text{ frames/Sec}$
$= 1.544$ Mbps

Hence, bit duration will be 0.6488 usec $(1/r_b)$

→ A telephone System must transmit Speech as well as other Signals related to call Setup, terminator etc. This is called Signalling. After every 6 frames the 8^{th} bit in every 24 channel is used for Signalling purpose. Hence the Signalling data rate for each of 24 input channel is = (1 bit / 6 frames) × 8000 f...

= 1.333 kbps

a total equivalent Signaling rate for 24 channe...

$= 1.33 \times 24 = 32$ Kbps.

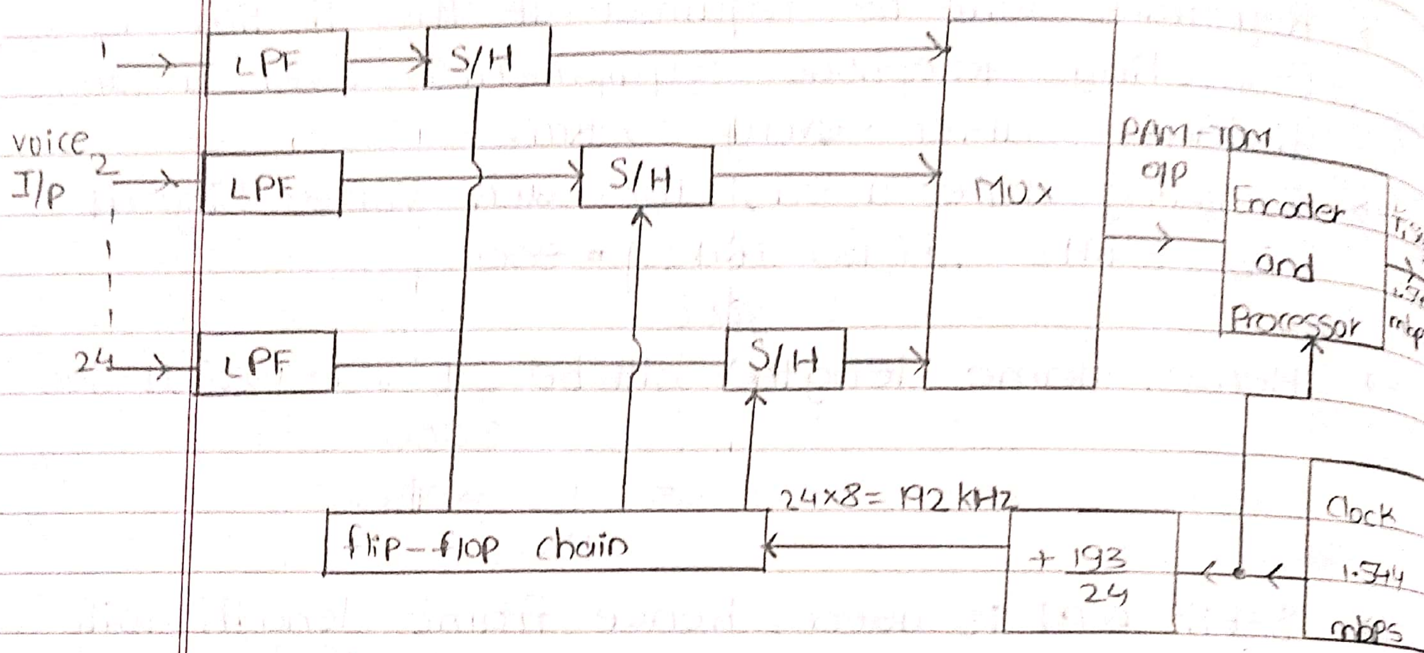


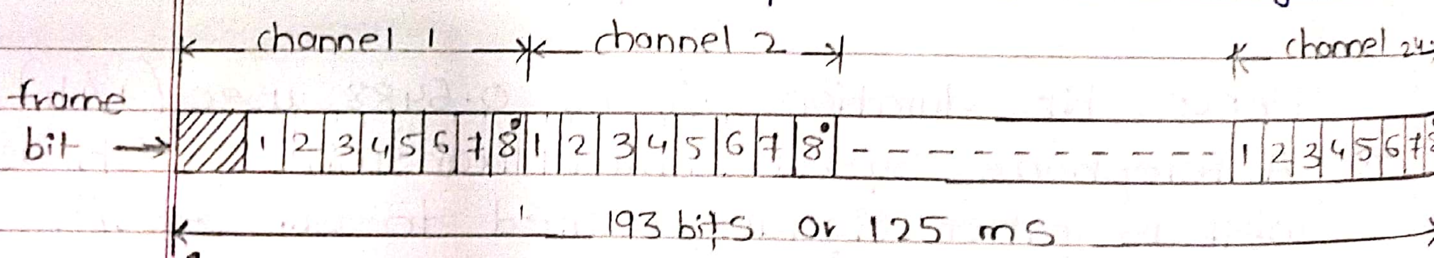
fig. 4.8 : T1 Carrier system.

→ T1 Signals Can be combined at an higher level multiplexer or transmitted directly over Short distance links (upto 80 km)

→ It uses bipolar Signal format.

→ The T1 transmission line is twisted pair Cable

→ frame format for T1 System is shown in fig. 4.9.



8 → used for Signalling after every Sixth frame.

fig. 4.9: frame format for T1 System.

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2.2) AT&T Hierarchy :

(Aug.15 , May-17)

→ fig. 4.10 Shows the AT&T multiplex hierarchy used in North America and Japan.

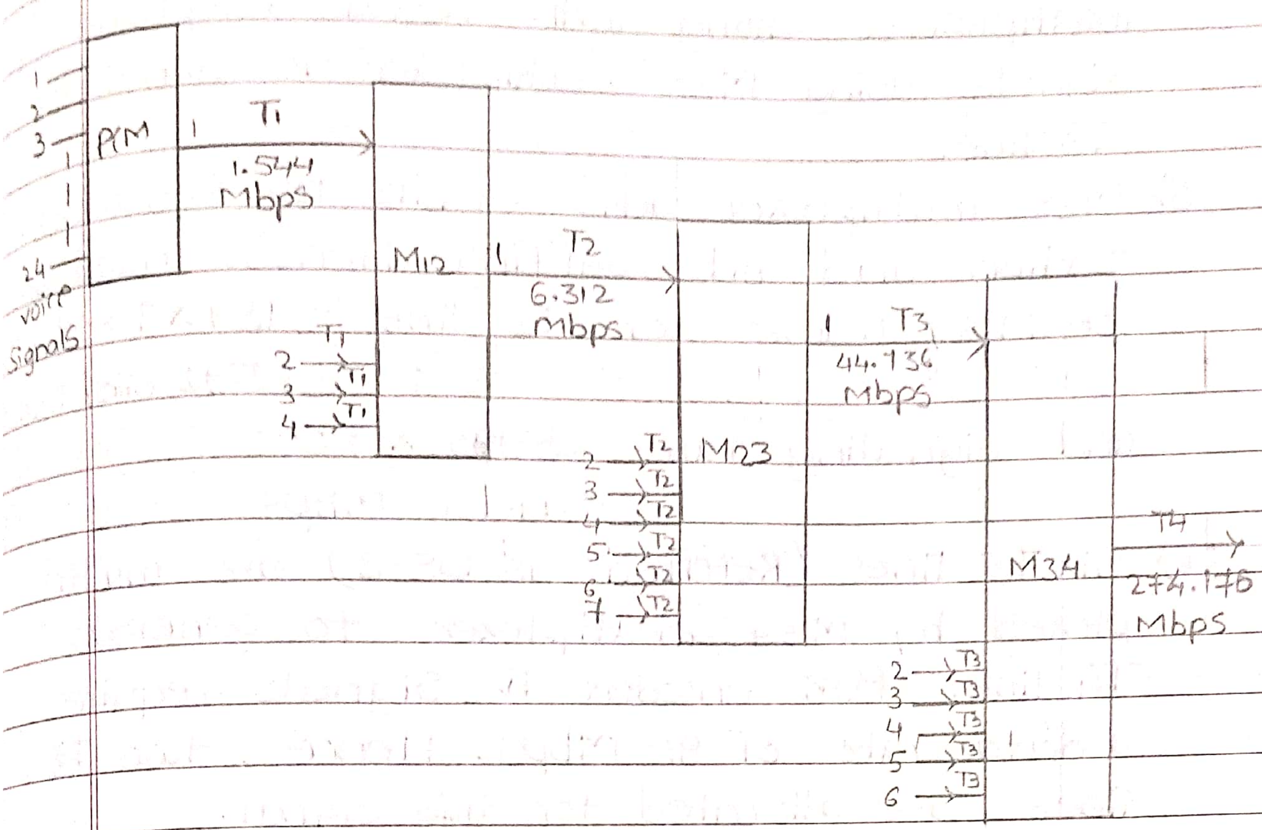

fig.4.10 : AT&T hierarchy

→ It shows transmission of voice, data from Computer visual telephone and colour TV Signals on a Signgle T_4 line.

→ 1) T_1 Carrier line Carries PCM voice or multiplexed digital data at a Speed of 1.544 Mbps.

2) Four Such T_1 lines (referred as DS_1) are multiplexed by an M_{12} multiplexed generating T_2 line.

3) M_{12} multiplexer adds 17 bits / frame Synchronization and bits Suffing. Hence, numbers of bits / frame = $193 \times 4 + 17$

= 789 bits / frame

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Hence, bit rate of T_2 line = 789 bits/frame × 8000 frames/sec
→ 6.312 Mbps.

4) Seven T_2 Signals (Referred as DS-2) are multiplexed along with visual telephone signals using M23 multiplexer to generate T3 line.

5) M_{23} multiplexer adds 69 bits for synchronization and bits Suffing. Hence, number of bits / frame for T3 line = 789 × 7 + 69
= 5592 bits/frame

and Signaling rate = 5592 × 8000
= 44.736 Mbps

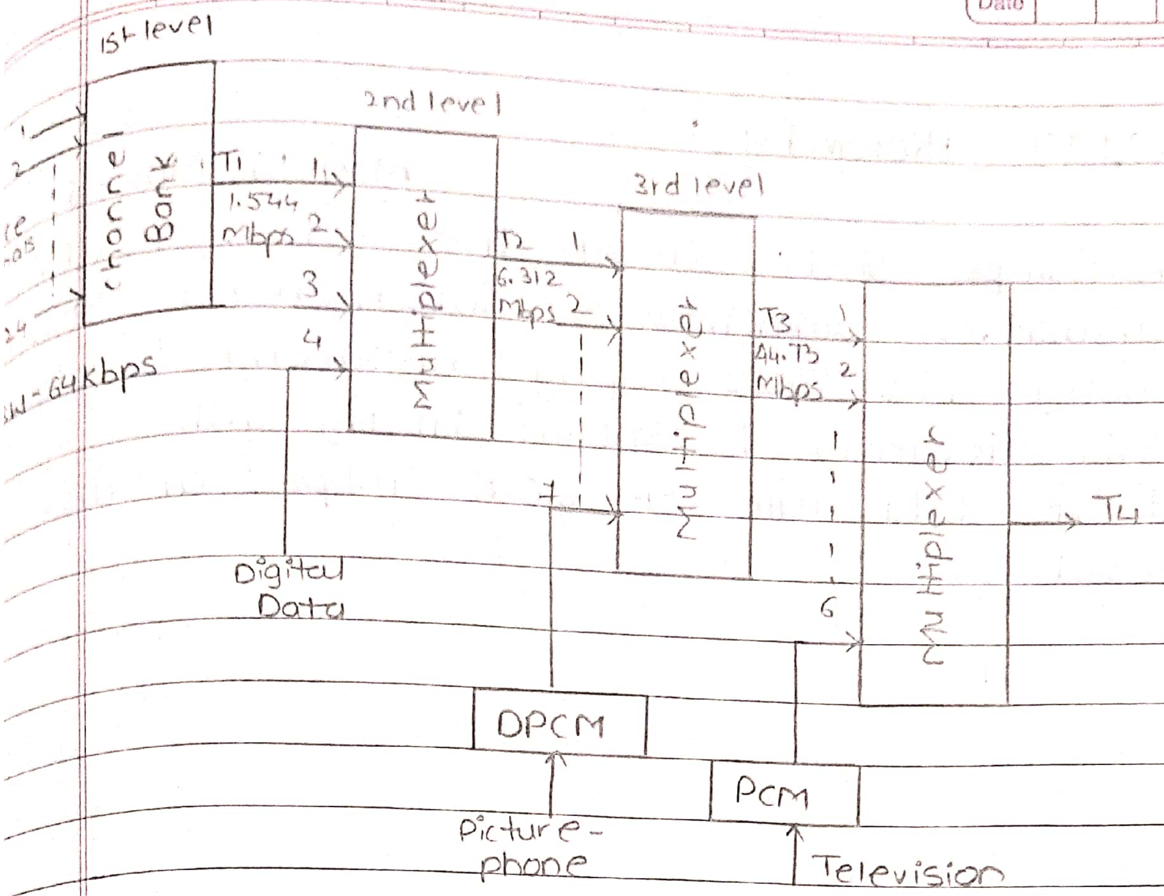
6) Six T3 lines (Referred as DS-3) are multiplexed by M34 multiplexer to generate T4 line. PCM encoded TV Signals require a data rate of 90 Mbps. Hence, two T3 lines are allocated for this Signal.

7) M34 multiplexer adds 720 bits for Synchronization of bits Suffing. Hence, number of bits/frame for T4 line = 5992 × 6 + 720
= 34,272 bits/frame.

And bit rate = 34,272 × 8000
= 274.176 Mbps.

8) The higher level multiplexors (M12, M23; M34) are quasi-synchronous.

$\boxed{\text{or}}$



1) T_1 – Uses PCM Signal with TDM, originally used copper wire but now optical wires are used, for longer duration. It is common for Internet access provider.

2) T_2 is Combination of 4 T_1 channels.
∴ 96 Telephone channels Can be Connected.
∴ BW of T_2 Channel is 6.312 Mbps.

3) T3 is Combination of 7 T2 Channels. ∴ 672 telephone Channels Can be Connected. BW of T3 Channel 4's 44.73 Mbps.

4) T4 is Combination of 6 T3 Channels. ∴ 4032 channels Can be Connected.
BW = 274.176 Mbps.

2.3 CCITT Hierarchy :

(May-16, Nov-15)

→ In Europe and rest of the world, CCITT (consutative Committee on International Telephony and Telegraphy) hierarchy is adopted.

→ This hierarchy is shown in fig 4.11.

→ It has data rate of 2.048 mbps / at first level.

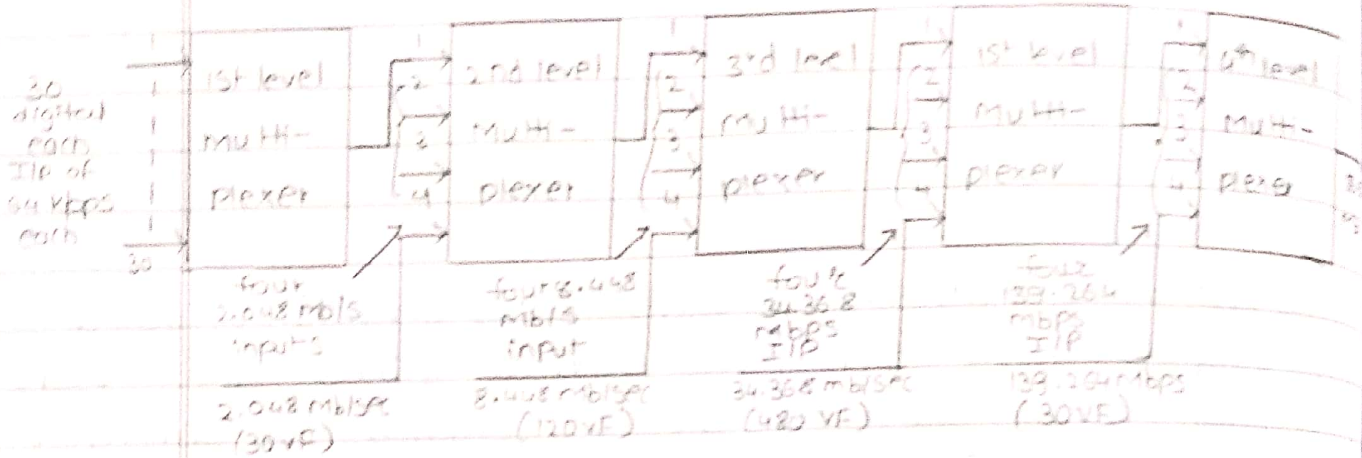


fig. 4.11: CCITT Digital TDM Hierarchy

→ Rest of the Specifications are as below:

→ 30 voice freq. channels of 64 Kbps are multiplexed at first level to generate 2.048 Mbps line.

→ Four 2.048 Mbps lines are multiplexed to generate 8.448 Mbps output rate at Second level.

→ four 8.448 Mbps line are multiplexed to generated 34.368 Mbps output line 3rd level.

→ four 34.368 lines are multiplexed to generate 139.264 Mbps o/p line at 4th level.

→ four 139.264 Mbps lines are multiplexed to generate 565.148 Mbps output line at 5^{th} level.

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3. DATA FORMATS:

→ Till Now, we have seen different methods of converting analog Signals in digital format and how to multiplex these digital Signals.

→ Now is the time to transmit these Signals over Channels.

→ We have a stream of 1s and 0s which can be transmitted using electrical pulses or wave-forms which are called line codes or data formats or Signaling formats.

→ A number of wave-form representation exist.

→ Each representation has its own applications.

→ These are two major categories:

1) Return - to - Zero (RZ)
2) Non - Return - to - Zero (NRZ)

→ In RZ coding only half width pulse is used whereas in NRZ coding full width pulses is used.

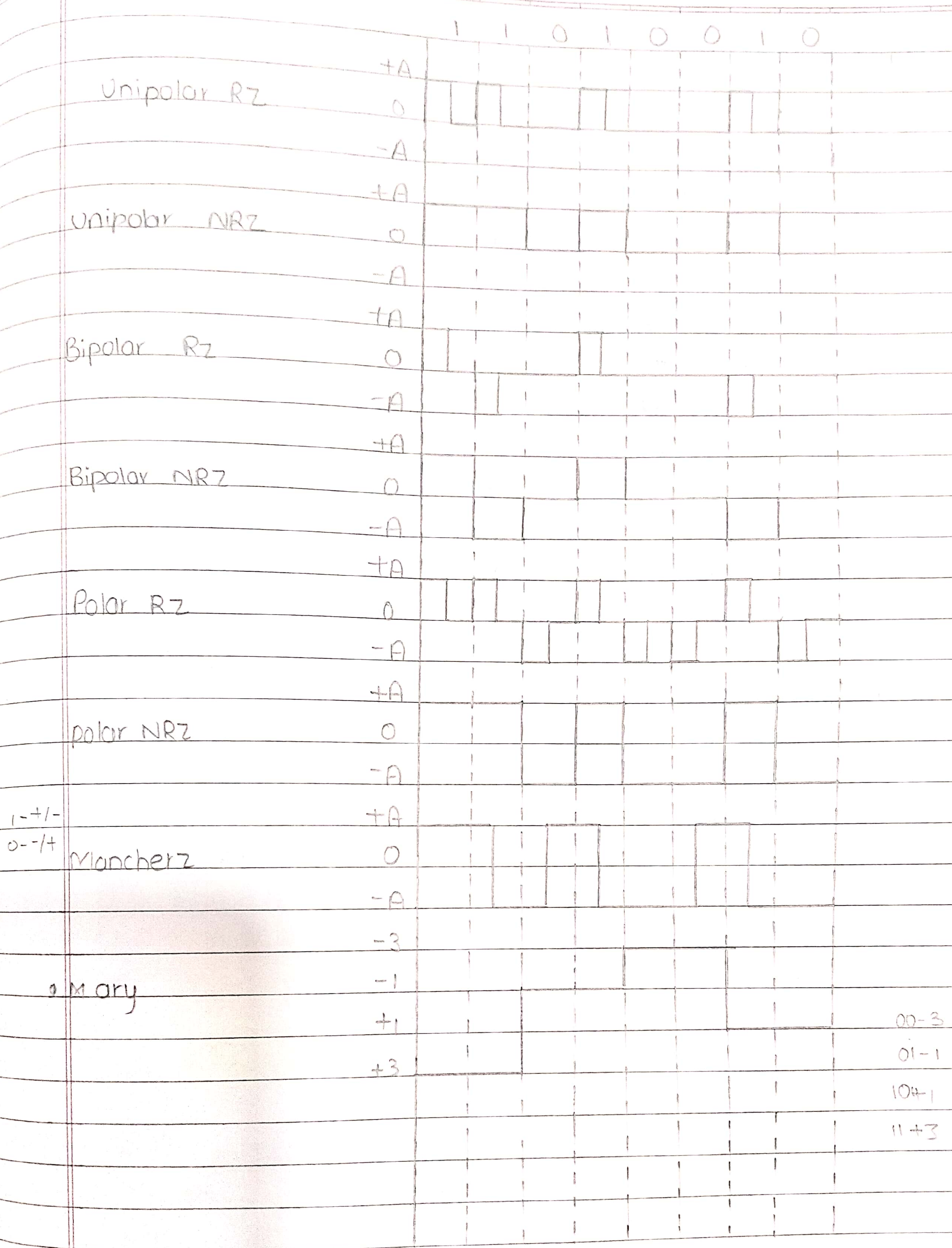
→ The waveforms for the line code may be further classified depending on the voltage levels used for representing 1's and 0's.

→ They are

i) On-off (unipolar) ii) Polar
iii) Bipolar (AMI) iv) Manchester
v) Multilevel

→ fig. 4.12 shows the various Signalling formats for the data stream.

Tb - bit duration.


1 1 0 1 0 0 1 0
Unipolar RZ
+A
0
-A
Unipolar NRZ
+A
0
-A
Bipolar RZ
+A
0
-A
Bipolar NRZ
+A
0
-A
Polar RZ
+A
0
-A
polar NRZ
+A
0
-A
1 - +/-
0 - -/+
Mancherz
+A
0
-A
M ary
-3
-1
+1
+3
00-3
01-1
10+1
11+3

i. Unipolar / on - off Signalling :

→ 1 is represented by high level (+A volt)
→ 0 is represented by zero level (0 volt)
→ When pulses occupies full duration, it is unipolar NRZ.
→ When pulse occupies half duration, it is unipolar RZ.
→ It has DC component which is undesirable.

ii Bipolar Signalling (AMI | Psuedoternary):

→ 1 is represented by alternate positive and negative values (+A / -A).
→ 0 is represented by zero level.
→ This is also called Alternate mark. Inversion (AMI)
→ The name Psuedoternary is because of three levels of representation (+1, 0, -1)
→ It can be RZ or NRZ type.
→ It has no DC component.
→ It eliminates ambiguity that may arise because of polarity inversion.

iii Polar Signalling :

→ 1 is represented by positive level (+A volt)
→ 0 is represented by negative level (-A volt)
→ It has no DC component provided there are equal 1's and 0's.
→ It is used in commercial PCM telephony.

iv. Manchester Signaling :

→ 1 is represented by positive half bit period followed by negative half bit period.

→ 0 is represented by negative half bit period followed by positive half bit period.

→ It has no DC Component.

→ It has built in Synchronization Capability

v. Multilevel Signalling (M-ary):

→ More than one bits are Combined to represent them as multiple positive & negative levels. For Example, if we Combine 2 bits,
00 represented as $-3A$ volt
01 represented as $-A$ volt
10 represented as $+A$ volt
11 represented as $+3A$ volt.

→ This is Called with M-ary Signalling with $M = 4$.

While selecting particular line Code for transmission in digital Communication we have to analyse them on the following basis.

1100110011111

1) Unipolar RZ & NRZ
- 1 → +A / +1V
- 0 → 0

2) 3) Bipolar RZ & NRZ (4)
- 1 → +A / −A V
- 0 → 0 / −1V

5) polar RZ & NRZ (6)
- 1 → +A
- 0 → −A

7) Manchester
- 1 → +ve to −ve
- 0 → −ve to +ve

8) M-ary
- 00 → −3A V
- 01 → −1A V
- 10 → +1A V
- 11 → +3A V

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Spectral Attributes of Data formats :

→ The data formats are selected on the basis of their spectral characteristics.

→ It is one of the main Criteria discussed above.

→ The power spectral density of these wave-forms can be obtained. Appendix A gives the detailed derivated of PSD's of various data formats.

→ The PSD's and their plots are as below:

→ We know (Refer Appendix A) the PSD of discrete amplitude waveform.

$$d_T(t) = \sum_{n=-N}^{+N} a_n g(t - nT_s)$$

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SYNCHRONIZATION :

→ The timing operation at the receiver should closely follow the corresponding operation at the receiver.

→ This is called synchronization between transmitter and receiver.

→ For synchronization we require a clock signal at the receiver that should have a precise frequency and phase relationship with the received signal.

→ of course, some allowance has to be made to take into account propagation delay b/w transmitter and receiver.

→ Digital Communication needs three types of synchronizing signals.

1) Bit Synchronization
2) frame Synchronization
3) carrier Synchronization.

→ Bit synchronization is required to identify the bit interval.

→ frame Synchronization identifies a group of bits belonging to a time slot.

→ Carrier Synchronization extracts carrier signal timing with coherent detection

→ fig. 4.16 shows Synchronization in binary receiver

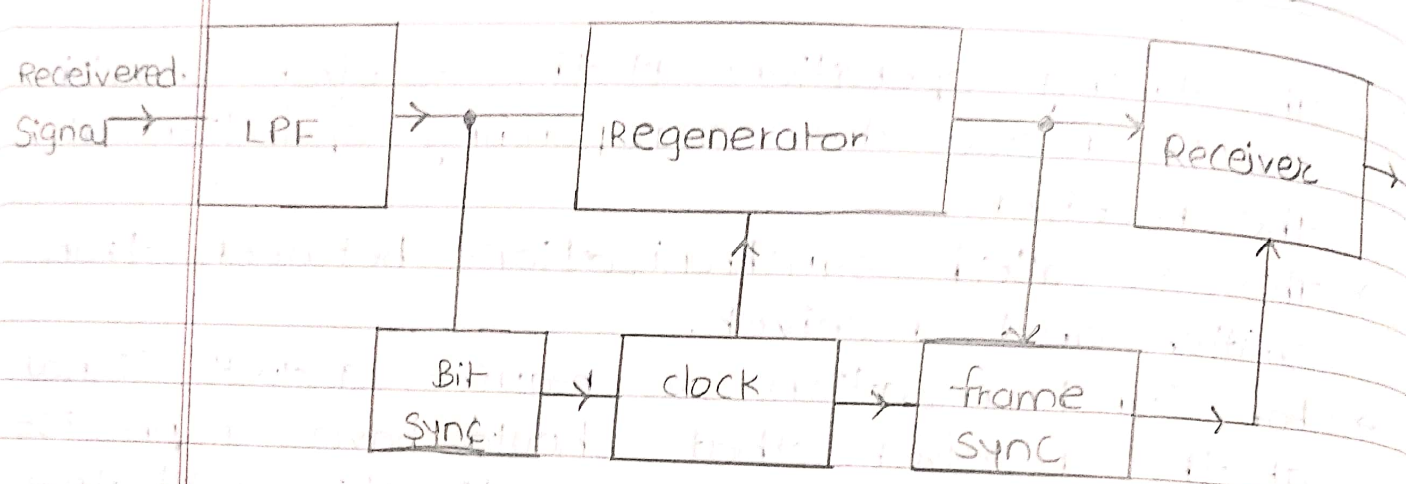


fig. 4.16: frame and bit Synchronization

i) Bit Synchronization :

→ In order to detect a binary signal at the receiver, we have to sample received signal at a precise instant.

→ This will require clock signal at the receiver in synchronisation with receiver.

→ The method of extracting bit duration is called bit synchronization.

→ There are three methods of bit synchronisation

i) Derivation of clock signal from master timing source both at transmitter and Receiver.

ii) Transmitting the clock from transmitter to receiver

iii) Extracting clock signal from the signal itself called self - synchronisation.

→ The first method is used for large volume of data and high speed communication. Its cost is high.

→ The second method uses channel capacity for transmission of clock. Hence, there should be spare capacity available.

→ The third method is more efficient and used very often

→ Let us look into the method of self-synchronisation.

→ If we have unipolar or on-off signaling format, it contains a discrete component of clock frequency we apply this received signal to a

resonant circuit (BPF) tuned to clock frequency. The output of resonant circuit will be a sinusoid $\cos(2\pi f_b t + \phi)$,
where, f_b is clock frequency.
Hence, the output is required clock signal.

→ for polar format, the signal is passed through a square law device. The resulting signal will be unipolar waveforms.
It is shown in fig. 4.17.

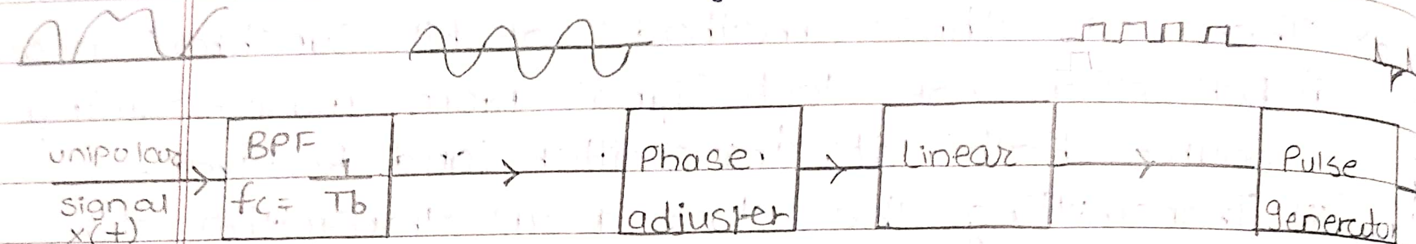


fig. 4.17. a) Bit Synchronizer for unipolar signal

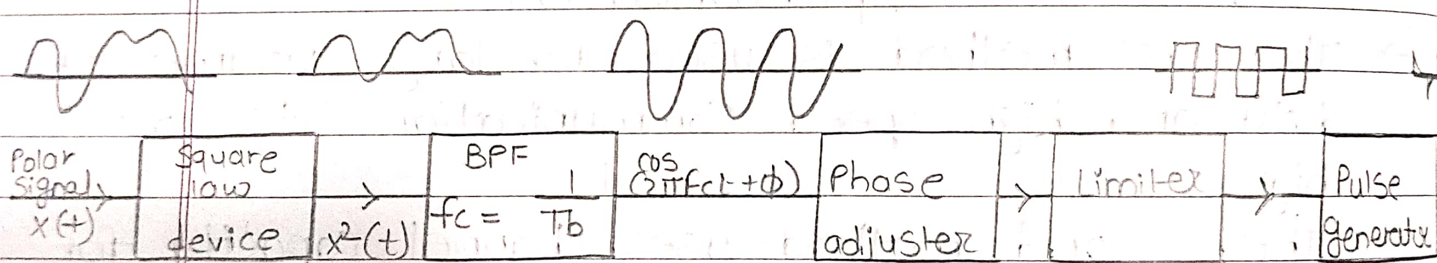
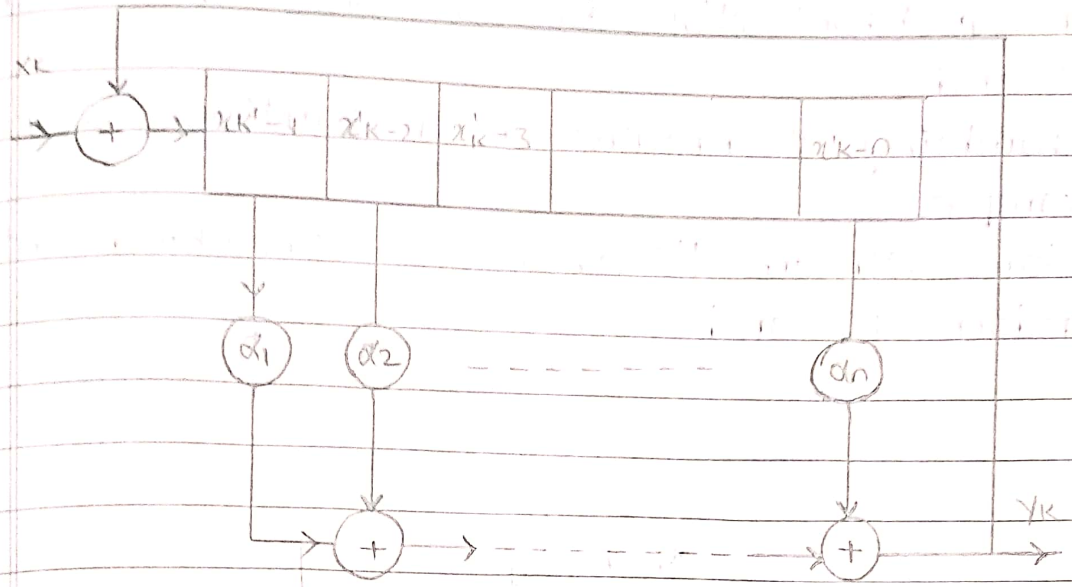


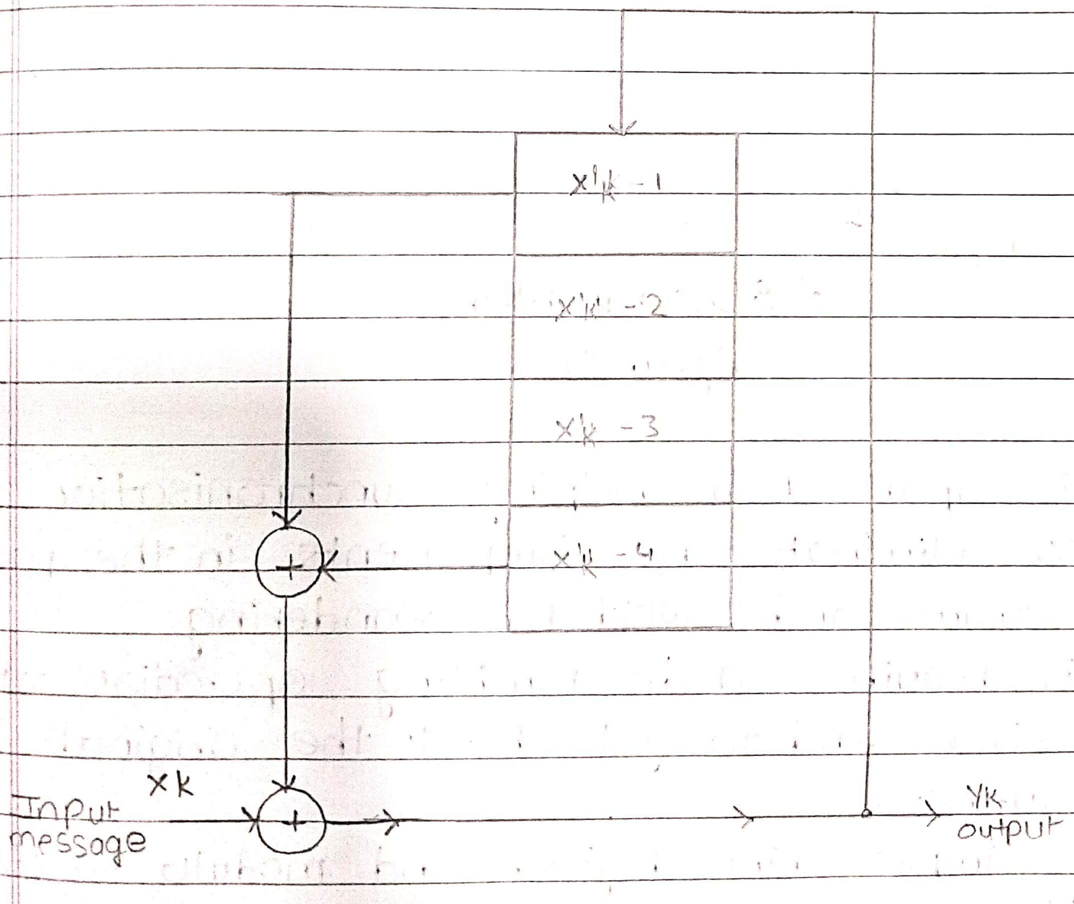
fig. 4.18 b) Bit Synchronizer for polar signal

SCRAMBLERS / Scrambling :

XOR
00 → 0
01 → 1
10 → 1
11 → 0



a) Scrambler using tapped shift register



b) Scrambler

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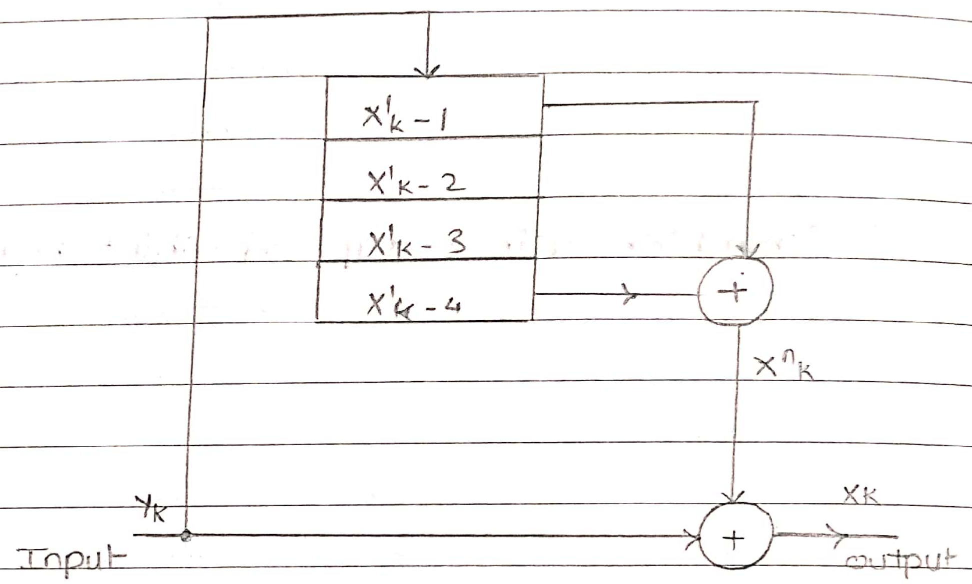
- The Synchronisation technique based on zero crossing detectors suffers from loss of synchronisation due to long stream of 1's and 0's.
- Scrambling technique is a solution to this example.
- A long stream 1's or 0's is converted into random 1's and 0's.
-



c) Unscrambler
fig. 4.20

- This apart from helping synchronisation will also eliminate DC components in the power spectrum and avoid DC wandering
- This requires a descrambling operation at the receiver end to get back the original sequence.
- A simple shift register and modulo -2 (Ex-OR) adder arrangement as shown in fig 4.20

a) Can be used for scambling and descrambling.

→ The scrambler and descrambler circuits are shown in fig 4.20 b) and c).

Input X_K	X'_{K-4}	X'_{K-3}	X'_{K-2}	X'_{K-1}	$X''_K = X'_{K-1} \oplus X'_{K-4}$	Output $Y_K = X''_K + X_K$
Initial state	0	0	0	0	—	—
1	0	0	0	0	0	1
0	0	0	0	1	1	1
1	0	0	1	1	1	0
0	0	1	1	0	0	0
1	1	1	0	0	1	0
0	1	0	0	0	1	1
1	0	0	0	1	1	0
0	0	0	1	0	0	0
0	0	1	0	0	0	0
0	1	0	0	0	1	1
0	0	0	0	1	1	1
0	0	0	1	1	1	1
1	0	1	1	1	1	0
1	1	1	1	0	1	0
1	1	1	0	0	1	0

Table 4.1: Various states of Scrambler and its output.

→ If Y is the output of the Scrambler and X is the input Sequence, then we can write,

$$y_K = a_1 X'_{K-1} + a_2 X'_{K-2} + \ldots + a_n X'_{K-n}$$

→ A Scrambler with 4 shift register is shown in fig. 4.20 (b) Hence, we can write,

$$y_K = X_K + X'_K = X_K + X'_{K-1} + X'_{K-3}$$

→ The unscramble shown in fig. 4.20 (c) has reverse structure.

→ Let us see how it reproduces original message. The unscrambled output can be written as,

$$X''_K + y_K = X''_K + (X_K + X''_K)$$

(Substituting $y_K = X_K + X''_K$)

$$= X''_K + X''_K + X_K = X_K$$

→ Thus we get back original X_K at the output.

→ Let us consider how Scrambler & descramble shown in fig 4.20 works for a input stream of 101010101000000111

→ Initially the shift register will be assumed to be in zero state.

→ Output Y_K of the Scrambler will be calculated by taking XOR of X'_{K-4}, X'_{K-1} and X_K. This Y_K will be shifted in as X'_{K-1} for next state.

→ The table 4.1 shows the various state of the Scramble and output.

→ Now take the output of Scramblers and apply it to the input of descrambler and verify whether we get the original input stream

→ Initially all shift register will be in zero table.

Input y_K	X'_{K-1}	X'_{K-2}	X'_{K-3}	X'_{K-4}	$X''_K = X'_{K-1} + X'_{K-4}$	Output $X_K = y_K + X''_K$
	0	0	0	0		
1	0	0	0	0	0	1
1	1	0	0	0	1	0
0	1	1	0	0	1	1
0	0	1	1	0	0	0
0	0	0	1	1	1	1
1	0	0	0	1	1	0
0	1	0	0	0	1	1
0	0	1	0	0	0	0
0	0	0	1	0	0	0
1	0	0	0	1	1	0
1	1	0	0	0	1	0
1	1	0	0	0	1	0
0	1	1	1	0	1	1
0	0	1	1	1	1	1
0	0	0	1	1	1	1

Table 4.2: various States of Descrambler and its output.

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→ Thus, the output sequence has eliminated the long streams of zero and also the initial periodic nature of the data stream.

→ The disadvantage of this method is that if there is error in the transmitted bit y_K it is going to cause several errors at the receiver end. i.e. error propagation occurs.

→ The output of descrambler will be calculated by taking XOR of X'_{K-1}, X'_{K-4} and Y_K. For the next state the input Y_K will be shifted into X'_{K-1}.

→ The table 4.2 shows various states of scramblers and output.

FRAME SYNCHRONIZATION :

→ The receiver should know when the transmission begins and when it ends.

→ otherwise when there is no transmission, noise signal will produce random bits.

→ In case of time division multiplexing, messages from various sources form a part of the frame.

→ Thus, entire message has many subdivisions.

→ These subdivisions are to be identified at the receiver end in order to distribute them at proper destinations.

→ Hence, at the beginning of each transmission or each frame a particular bit pattern is used, which can be identified at the receiver end as start of transmission or start of frame.

→ A typically frame structure is shown in fig 4.21 (a).

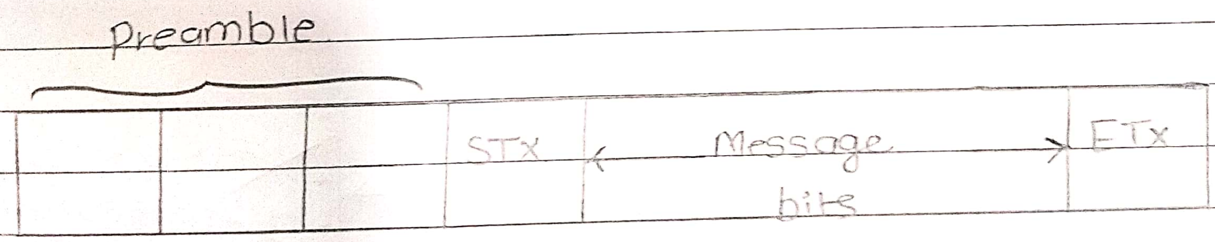

fig. 4.21 (a) : A typical frame structure.

→ At the beginning of transmission several repetitions of a synchronisation word are transmitted to acquire bit synchronisation.

- Then start of message word is transmitted which tells the receiver that the message is following.
- When the transmission is over, end of message word is sent to inform receiver that there is no more data available for transmission.
- In case of identification of frame, a synchronisation word is attached at the beginning of each frame.
- A frame synchronizer circuit is shown in fig 4.21 (b)

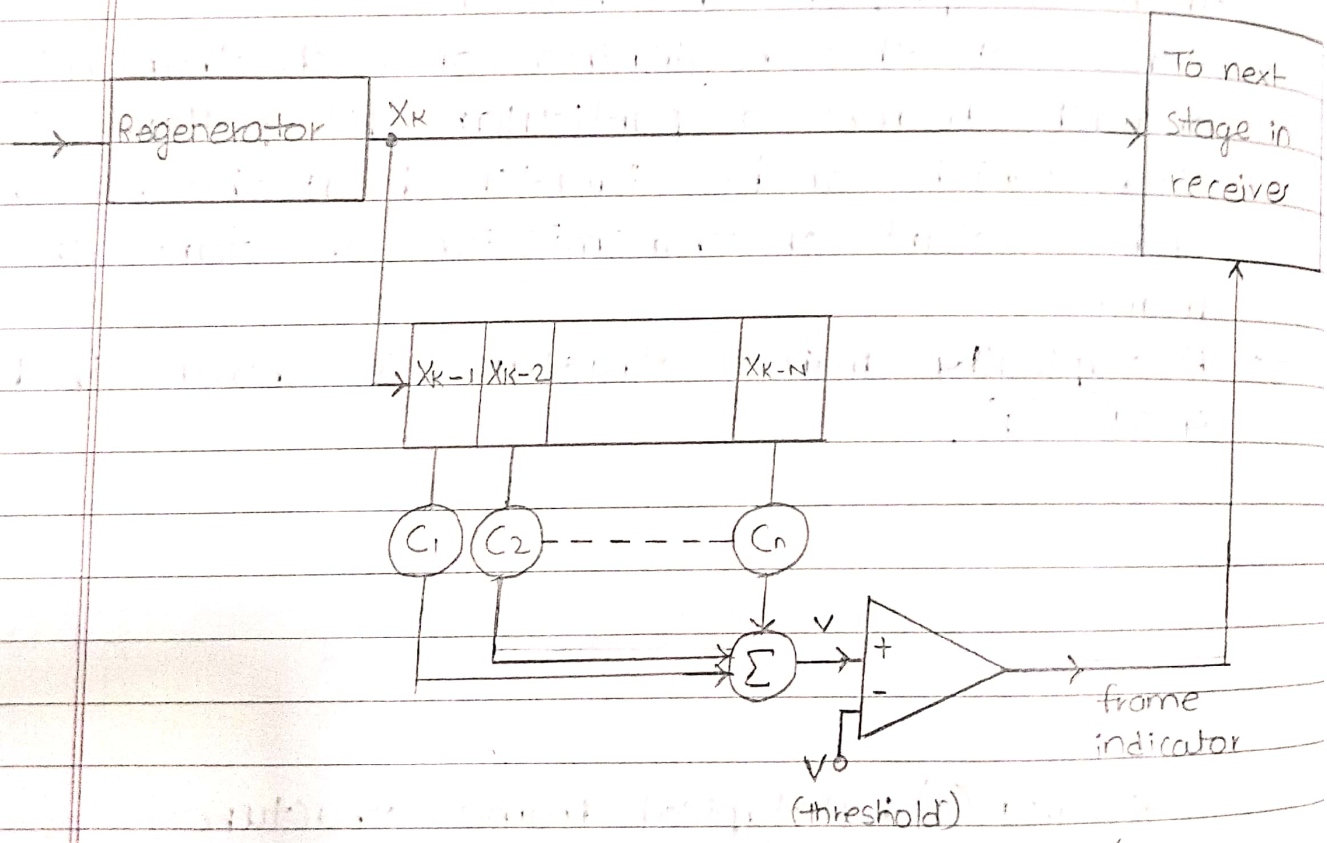

fig. 4.21 (b) : frame Synchronizer

→ The output of regenerator is reconstructed message sequence. It is stored in N-stage shift register.

→ Where, N is number of bits in synchronisation word to be identified.

→ The bits are in polar format (± 1)

→ The tap gains of shifts register are adjusted depending on the synchronisation word.

→ Let the synchronisation word be $(s_1, s_2, \ldots s_N)$ and the tap given adjusted such that,

$$c_i = 2s_{N+1-i} - 1$$

ie.

$$\left.\begin{aligned} c_1 &= 2s_N - 1 \\ c_2 &= 2s_{N-1} - 1 \\ &\vdots \\ &\vdots \\ c_N &= 2s_1 - 1 \end{aligned}\right\}$$

→ These tap gains are multiplied with received voltage collected in shift register and then added.

→ This sum is compared with a preset theshold voltage V.

→ The output of comparator will indicate whether the word in shift register is a valid synchronisation word or not.

→ This is because when valid synchronisation word is present in the register, the voltage produced by the summer will exceed the threshold voltage V.

$$V = \sum_{i=1}^{N} c_i \times x_{k-i}$$

otherwise it will remain below V.

→ When the register word is same as Synchronisation word, $x_{K-1} = C_i$.

→ Therefore, $c_i \times x_{K-1} = C_i^2 = 1$ and $V = N$

→ The threshold voltage V is set slightly below N.

→ When Synchronisation word does not match with register word let us say it differs by one bit, the output $V = N-2$

→ Hence, threshold should be between N and N-2.

→ Now what will happen if there is one bit error in the Synchronisation word.

→ It will go undetected. Hence instead of keeping the threshold between N and N-2, it can be kept slightly below N-2.

→ This will take care of single error in Synchronisation word.

→ There is Example of false frame Synchronisation in case the Synchronisation word is part of message. What is the probability of occurrence of this?

→ It will be equal to the probability that all N bits match or N-1 bits match.

→ Let the probability of 1 and 0 be equally likely, then the probability of false Synchronisation is given by,

$$p_{ff} = \underbrace{\left(\frac{1}{2}\right)^{N}}_{\text{all N bits match}} + \underbrace{\left(\frac{1}{2}\right)^{N-1}}_{\text{N-1 bits match}}$$

INTER SYMBOL INTERFERENCE (ISI):

→ The bandwidth of flat top pulses is infinity.

→ There are various filters in transmitter, channel and receiver of the Communication System.

→ If these pulses are filtered improperly as they pass through a Communication system, they will spread in time and the pulse for each symbol may be smeared into ~~adjusl~~ adjacent time slots and cause inter Symbol interference as shown in fig. 4.22

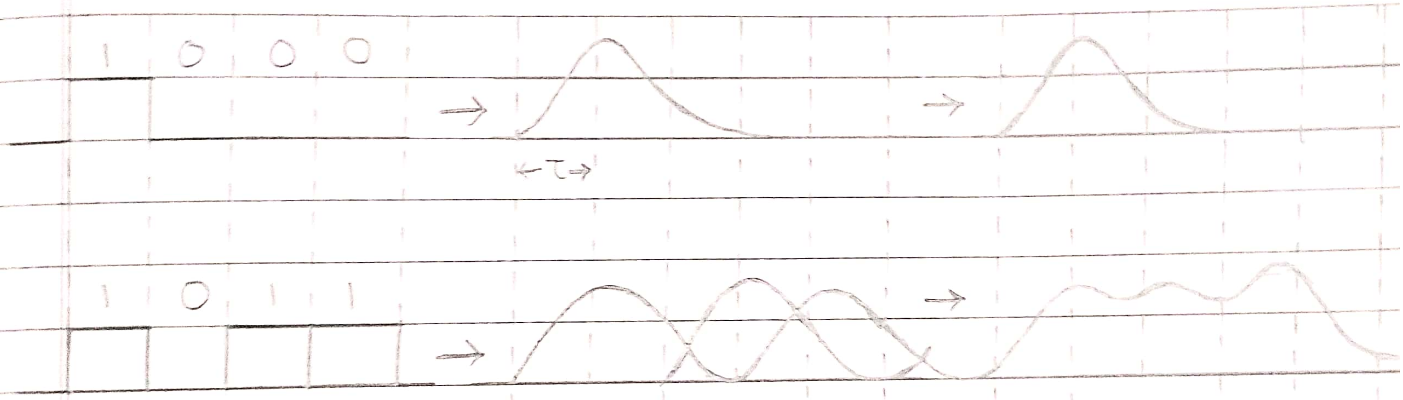

fig. 4.22: ISI Example.