DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

COURSE MATERIALS



CS 404 EMBEDED SYSTEMS

VISION OF THE INSTITUTION

To mold true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION OF THE INSTITUTION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Computer Science and Engineering

  M.Tech in Computer Science and Engineering

  M.Tech in Cyber Security
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing Highly Competent, Innovative and Ethical Computer Science and Engineering Professionals to facilitate continuous technological advancement.

DEPARTMENT MISSION

1. To Impart Quality Education by creative Teaching Learning Process
2. To Promote cutting-edge Research and Development Process to solve real world problems with emerging technologies.
3. To Inculcate Entrepreneurship Skills among Students.
4. To cultivate Moral and Ethical Values in their Profession.
5.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates will be able to Work and Contribute in the domains of Computer Science and Engineering through lifelong learning.

PEO2: Graduates will be able to Analyse, design and development of novel Software Packages, Web Services, System Tools and Components as per needs and specifications.

PEO3: Graduates will be able to demonstrate their ability to adapt to a rapidly changing environment by learning and applying new technologies.

PEO4: Graduates will be able to adopt ethical attitudes, exhibit effective communication skills, Teamwork and leadership qualities.

PROGRAM OUTCOMES (POS)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO1: Ability to Formulate and Simulate Innovative Ideas to provide software solutions for Real-time Problems and to investigate for its future scope.

PSO2: Ability to learn and apply various methodologies for facilitating development of high quality System Software Tools and Efficient Web Design Models with a focus on performance

Optimization.

PSO3: Ability to inculcate the Knowledge for developing Codes and integrating hardware/software products in the domains of Big Data Analytics, Web Applications and Mobile Apps to create innovative career path and for the socially relevant issues.

COURSE OUTCOMES

CO1	The students will be able to identify and list the various issues present in the design of a data communication system.
CO2	The students will be able to apply the time domain and frequency domain concepts of signals in data communication.
CO3	The students will be able to compare and select transmission media based on transmission impairments and channel capacity.
CO4	The students will be able to select and use appropriate signal encoding techniques and multiplexing techniques for a given scenario.
CO5	The students will be able to design suitable error detection and error correction algorithms to achieve error free data communication and explain different switching techniques.
CO6	The students will be able to gain knowledge of encoding, multiplexing and spread spectrum.

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES & PSO

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**
CO1	**3**	**2**	**1**							**3**		**3**
CO2	**3**	**2**	**1**	**2**						**3**		**3**
CO3	**3**	**2**	**1**	**2**						**3**		**3**
CO4	**3**	**2**	**1**	**2**						**3**		**3**
CO5	**3**	**3**	**2**							**3**		**3**
CO6	**3**	**3**	**2**			**2**				**3**		**3**

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

SYLLABUS

Course No.	Course Name	L-T-P-Credits	Year of Introduction
CS307	DATA COMMUNICATION	3-0-0-3	2015

Course Objectives

1. *To introduce fundamental communication models.*
2. *To discuss various time domain and frequency domain concepts of data communication.*
3. *To introduce the concepts of encoding, multiplexing and spread spectrum.*

Syllabus

Data Transmission, Transmission Impairments, Channel Capacity, Transmission media, Wireless propagation, Signal encoding Techniques, Multiplexing, Digital data transmission techniques, Sampling theorem, Error detection and correction, Spread spectrum, Basic principles of switching.

Expected Outcome

Student is able to

1. *Identify and list the various issues present in the design of a data communication system.*
2. *Apply the time domain and frequency domain concepts of signals in data communication.*
3. *Compare and select transmission media based on transmission impairments and channel capacity.*
4. *Select and use appropriate signal encoding techniques and multiplexing techniques for a given scenario.*
5. *Design suitable error detection and error correction algorithms to achieve error free data communication and explain different switching techniques.*

Text Books

1. William Stallings, Data and Computer Communication 9/e, Pearson Education, Inc. [Chapters: 4, 5, 6, 7, 8, 9].
2. Forouzan B. A., Data Communications and Networking, 5/e, Tata McGraw Hill, 2013. [Chapters:3,4, 5, 6,7,8]
3. Schiller J., Mobile Communications, 2/e, Pearson Education, 2009. [Chapters:2,3]
4. Curt M. White, Fundamentals of Networking and Communication 7/e, Cengage learning. [Chapter 3,4,9,10]

References

1. Forouzan B. A., Data Communications and Networking, 4/e, Tata McGraw Hill, 2007.
2. Tanenbaum A. S. and D. Wetherall, Computer Networks, Pearson Education, 2013.

Module	Contents	Hours	Sem. Exam Marks %
I	Data Transmission: Communication model Simplex, half duplex and full duplex transmission - Periodic Analog signals: Sine wave, phase, wavelength, time and frequency domain, bandwidth - Digital Signals; Digital data Transmission:- Analog & Digital data, Analog & Digital signals, Analog &Digital transmission – Transmission Impairments: Attenuation, Delay distortion, Noise - Channel capacity: Nyquist Bandwidth, Shannon's Capacity formula.	08	15%
II	Transmission media - Guided Transmission Media: Twisted pair, Coaxial cable, optical fiber, Wireless Transmission, Terrestrial microwave, Satellite microwave. Wireless Propagation: Ground wave propagation, Sky Wave propagation, LoS Propagation.	07	15%
FIRST INTERNAL EXAM			

KTU STUDENTS

III	Signal Encoding techniques - Digital Data Digital Signals: NRZ, Multilevel binary, Biphase - Digital Data Analog Signals : ASK, FSK, PSK - Analog Data Digital Signals: Sampling theorem, PCM, Delta Modulation - Analog Data Analog Signals: AM, FM, PM.	07	15%
IV	Multiplexing- Space Division Multiplexing- Frequency Division Multiplexing: Wave length Division Multiplexing - Time Division multiplexing: Characteristics, Digital Carrier system, SONET/SDH-Statistical time division multiplexing: Cable Modem - Code Division Multiplexing. Multiple Access– CDMA.	07	15%
	SECOND INTERNAL EXAM		
V	Digital Data Communication Techniques - Asynchronous transmission, Synchronous transmission-Detecting and Correcting Errors-Types of Errors-Error Detection: Parity check, Cyclic Redundancy Check (CRC) - Error Control Error Correction: Forward Error Correction and Hamming Distance.	06	20%
VI	Spread Spectrum Techniques-Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS). Basic principles of switching - Circuit Switched Networks, Structure of Circuit Switch - Packet Switching: Datagram Networks, Virtual Circuit Networks, Structure of packet switches.	07	20%
	END SEMESTER EXAM		

Question Paper Pattern

1. There will be *five* parts in the question paper – A, B, C, D, E
2. Part A
    a. Total marks : 12
    b. *Four* questions each having 3 marks, uniformly covering modules I and II;All*four* questions have to be answered.
3. Part B
    a. Total marks : 18
    b. *Three*questions each having 9 marks, uniformly covering modules I and II; T*wo* questions have to be answered. Each question can have a maximum of three subparts.
4. Part C
    a. Total marks : 12
    b. *Four* questions each having 3 marks, uniformly covering modules III and IV;All*four* questions have to be answered.
5. Part D
    a. Total marks : 18
    b. *Three*questionseach having 9 marks, uniformly covering modules III and IV;*Two* questions have to be answered. Each question can have a maximum of three subparts
6. Part E
    a. Total Marks: 40
    b. *Six* questions each carrying 10 marks, uniformly covering modules V and VI; *four* questions have to be answered.
    c. A question can have a maximum of three sub-parts.
7. There should be at least 60% analytical/numerical questions.

KTU STUDENTS

QUESTION BANK

MODULE I				
Q:NO:	**QUESTIONS**	**CO**	**KL**	**PAGE NO:**
1	Identify 5 components of Data communication system.	CO1	K5	2
2	What is the difference between half duplex & Full duplex transmission modes?	CO1	K3	3
3	Define periodic signals	CO1	K2	4
4	Explain Time and frequency Domain	CO1	K3	7
5	Explain Transmission Impairments	CO1	K5	11
6	Explain SNR Ratio.	CO1	K2	13
7	How to find channel capacity for Noisy Channel	CO1	K5	14
MODULE II				
1	Explain Transmission media	CO2	K2	17
2	Write note on Coaxial cable	CO2	K4	18
3	Describe Optical fiber cable	CO2	K2	19
4	Define Antennas	CO2	K5	21
5	Write note on Terrestrial Microwave	CO2	K5	22
6	Explain Wireless propagation.	CO2	K3	24
7	Calculate the LOS transmission free space loss.	CO2	K5	26
MODULE III				
1	What is meant by signal encoding techniques?	CO3	K3	29
2	List the types of Line coding schemes.	CO3	K3	31
3	Explain conversion of Digital data to analog signals	CO3	K2	34
4	Calculate the Bandwidth for ASK.	CO3	K3	36
5	Write note on FSK and BFSK.	CO3	K5	36
6	Explain Sampling theorem	CO3	K3	39
7	Write a note on Delta modulation	CO3	K2	42

MODULE IV				
1	Define multiplexing.	CO4	K2	48
2	Explain FDM process.	CO4	K1	49
3	Write note on WDM.	CO4	K2	51
4	The data rate for each i/p connection is 3kbps.if 1 nit at a time is multiplexed. what is the duration of each i/p slot?	CO4	K3	53
5	Explain Frame synchronizing	CO4	K1	56
6	Explain CDMA	CO4	K2	61
7	What is Data representation, encoding and decoding?	CO4	K3	63
MODULE V				
1	Define digital data communication techniques.	CO5	K4	71
2	Explain Synchronous transmission.	CO5	K2	73
3	Describe Error detection mechanism.	CO5	K3	74
4	Give example and explain Cyclic code encoder using Polynomials.	CO5	K2	81
5	Calculate Hamming distance.	CO5	K3	82
6	List the various error control mechanism.	CO5	K2	85
7	Explain Go-Back N ARQ.	CO5	K2	87

MODULE NOTES

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MODULE - I

→ Data Transmission
  * Comm^n model Simplex
  * half duplex & full duplex transmission
→ Periodic Analog S/ls :
  * Sine wave
  * phase
  * wavelength
  * time & frequency domain
  * Bandwidth
→ * Digital Signals
→ * Digital Data Transmission
  * Analog & Digital Data
  * Analog & Digital s/ls.
  * Analog & Digital Transmission
→ Transmission Impairments
  * Attenuation
  * Delay distortion
  * Noise
→ Channel Capacity
  * Nyquist Bandwidth
  * Shannon's Capacity formula

Questions:

1. Identify 5 components of data comm^n s/m.
2. What is the diff. b/w half duplex & full duplex transmission modes ?
3. The period of a s/l is 100ms. What is the fr. in kHz?

$$F = \frac{1}{T} = \frac{1}{100} = .01 \times 10^3 = 10^{-2} \times 10^3 = 10^{-5}\,s$$

→ First into seconds

$$T = 100ms = 100 \times 10^{-3} = 10^2 \times 10^{-3} = 10^{-1}\,s$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} = 10\,Hz = 10 \times 10^{-3} = 10^{-2}\,kHz$$

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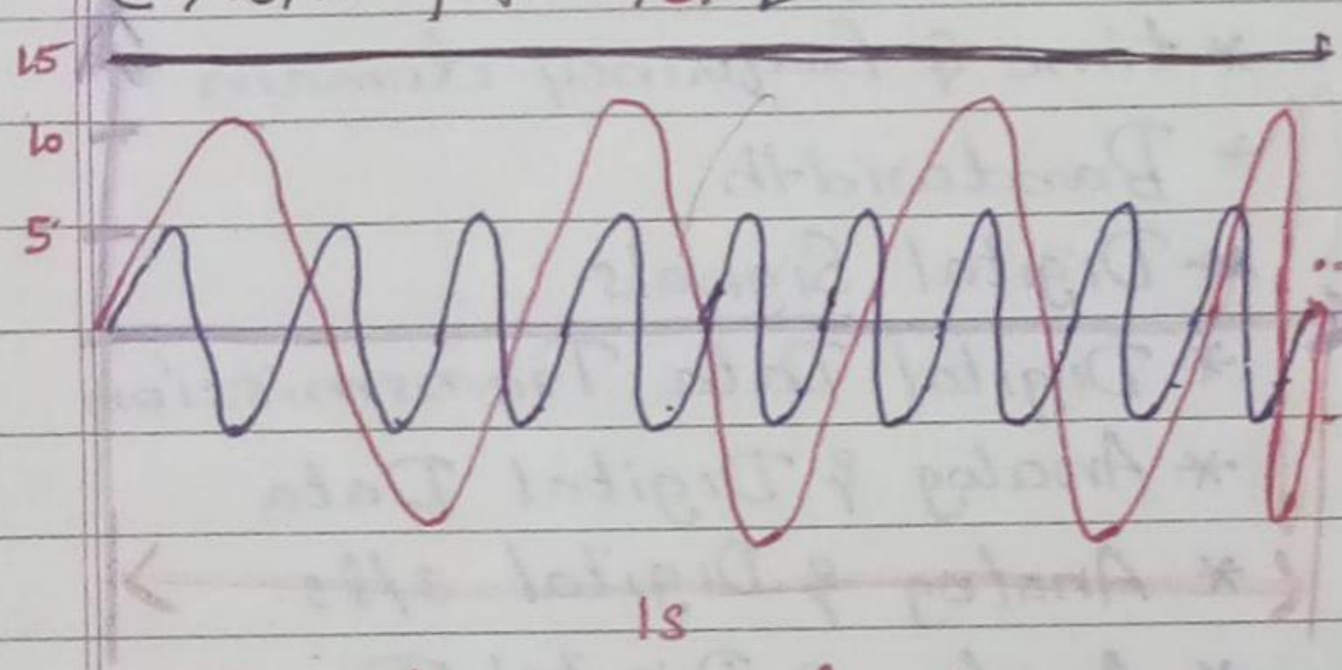
4. A sine wave is offset 1/6 cycle w.r.to time 0. What is its phase in degrees & radians?.

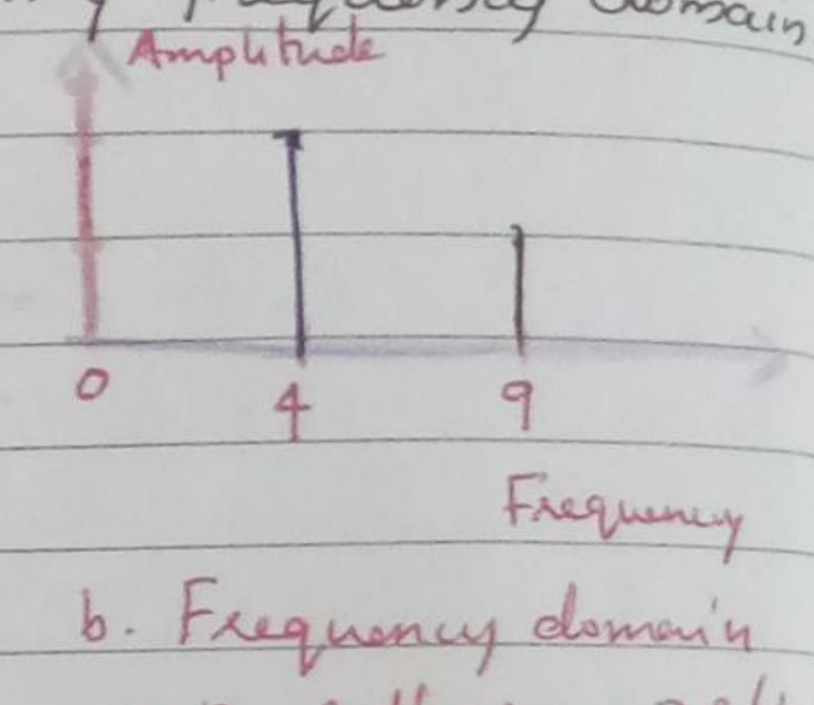
⇒ One complete cycle — 360°

1/6 cycle — 1/6 × 360° = 60° = 60 × 2π/360 = π/3 rad = 1.046 rad

(1° = 2π/360 rad)

5. Represent 3 sine waves, each with diff amplitude & fr. (5, 10, 15 & fr. 0, 4, 9) in Time domain & frequency domain.





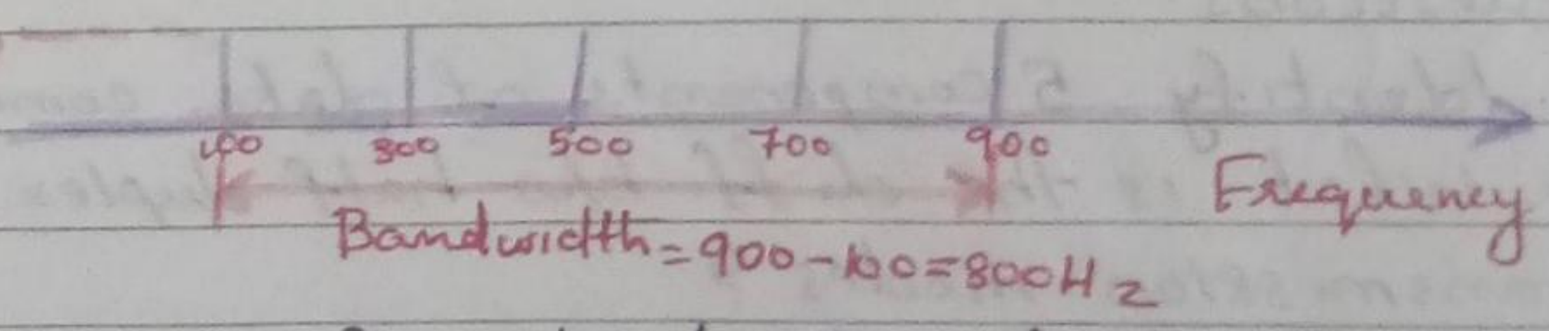
a) Time domain rep^n of 3 sine waves with frequencies 0, 4, & 9.

b. Frequency domain rep^n of the same 3 S/Ls.

6 If a periodic S/L is decomposed into 5 sine waves with fr. of 100, 300, 500, 700 & 900 Hz, what is its bandwidth? Draw spectrum, assuming all components have a max. amplitude of 10V

f_h – Highest fr. f_l – lowest fr. B – bandwidth

$B = f_h - f_l = 900 - 100 = 800\,Hz$



7. A periodic S/L has a bandwidth of 20Hz. The highest fr. is 60Hz. What is the lowest fr.? Draw the spectrum if the S/L contains all fr.s of the same amplitude.

$B = f_h - f_l$ $B = 20\,Hz$ $f_h = 60\,Hz$ $20 = 60 - f_l$ ∴ $f_l = 60 - 20 = 40\,Hz$



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(B-29)
37 We have a channel with 4KHz bandwidth. If we want to send data at 100Kbps, what is the min. SNR_{dB}? & what is SNR.

$$DataRate = B \log_2(1+SNR)$$

$$100\,Kbps = 4\,KH_2 \log_2(1+SNR)$$

$$\log_2(1+SNR) = \frac{100}{4} = 25$$

$$1+SNR = 2^{25}$$

$$SNR = 2^{25}-1$$

$$SNR_{dB} = 10\log_{10} SNR = 10\log_{10}(33554431)$$

$$= 10(7.5257)$$

$$= 75.25$$

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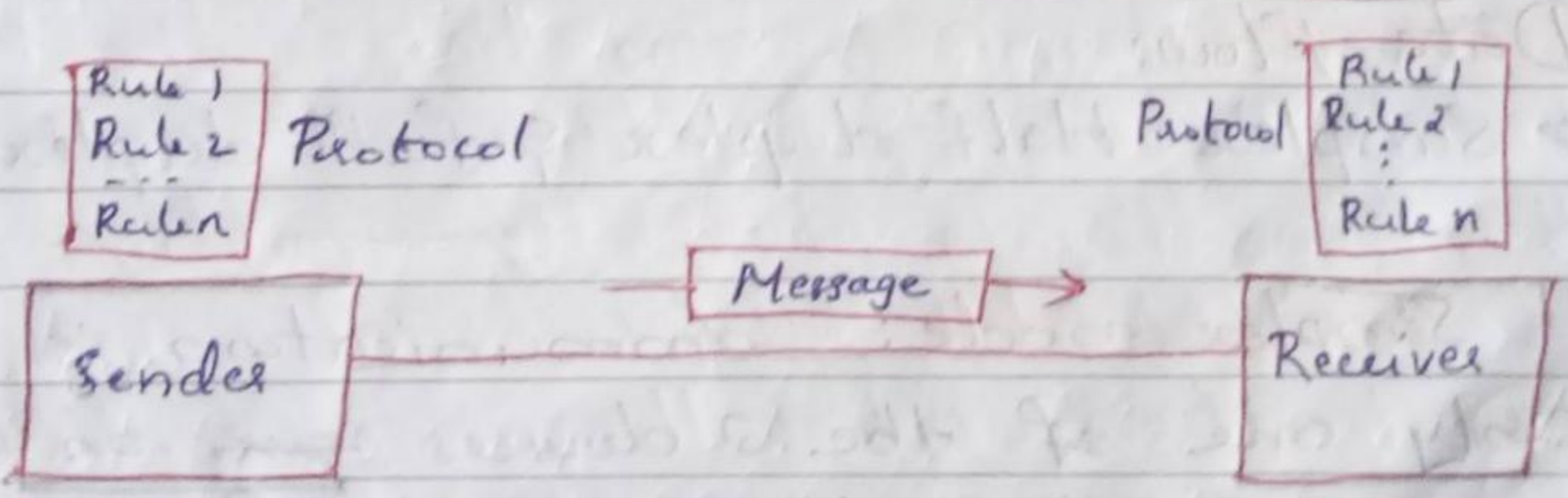
Data Transmission

Data transmission occurs b/w transmitter & receiver over some transmission medium.

Data comm^{n}s are the exchange of data b/w 2 devices via some form of transmission medium such as a wire cable. The effectiveness of a data comm^{n}s s/m depends on 4 fund. characteristics.

1. Delivery: s/m must deliver data to the correct destination.
2. Accuracy: deliver data accurately. Data that have been altered in transmission & left uncorrected are unusable.
3. Timeliness: The s/m must deliver data in a timely manner. Eg: In case of audio & video.
4. Jitter: ~~reffe~~ refers to the variation in the pkt arrival time. Eg: uneven delay in the delivery of audio or video pkts.

A data comm^{n} s/m has 5 components:



* Message: Inf^{n} to be communicated. e.g; text, no.s, pictures, audio & video.
* Sender: the device that sends the data msg. e.g; computer, workstation, video camera & so on.
* Receiver: the device that receives the msg. e.g; computer, workstation, telephone & so on.

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* Transmission Medium: physical path by which a msg travels from sender to receiver.
eg: twisted pair wire, coaxial cable, radio waves.
* Protocol: set of rules that govern data comm^ns. It represents an agreement blw the commu. devices.

Data Representation:

* Text: bit pattern (0s & 1s)
- Unicode (32 bits for a symbol or character)
- ASCII
* Numbers: bit patterns - directly to a binary no.
* Images: bit patterns - matrix of pixels - resolution.
Color images - RGB
- YCM (Yellow, Cyan & Magenta)
* Audio: continuous s/l.
* Video: Continuous entity or combination of images, each discrete entity arranged to convey the idea of motion.

Data Flow:

> Simplex Half duplex & full duplex transmission

Simplex mode: communication is unidirectional Only one of the 2 devices ~~can~~ on a link can transmit, the other can only receive.
Eg: keyboards & traditional monitors.
↓ introduce i/p
↓ only accept o/p.
The simplex mode can use the entire capacity of the channel to send data in one direction.

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Half duplex mode:

Each station can both transmit & receive, but not at the same time. When one device is sending, the other can only receive & vice versa.

→ The entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time. Eg: Walkie-talkie & CB radios.

Full duplex:

Both stations can transmit & receive simultaneously. Signals going in one direction share the capacity of the link with s/ls going in other direction.

This sharing can occur in two ways: Either the link must contain 2 physically separate transm^n paths one for sending & the other for receiving.

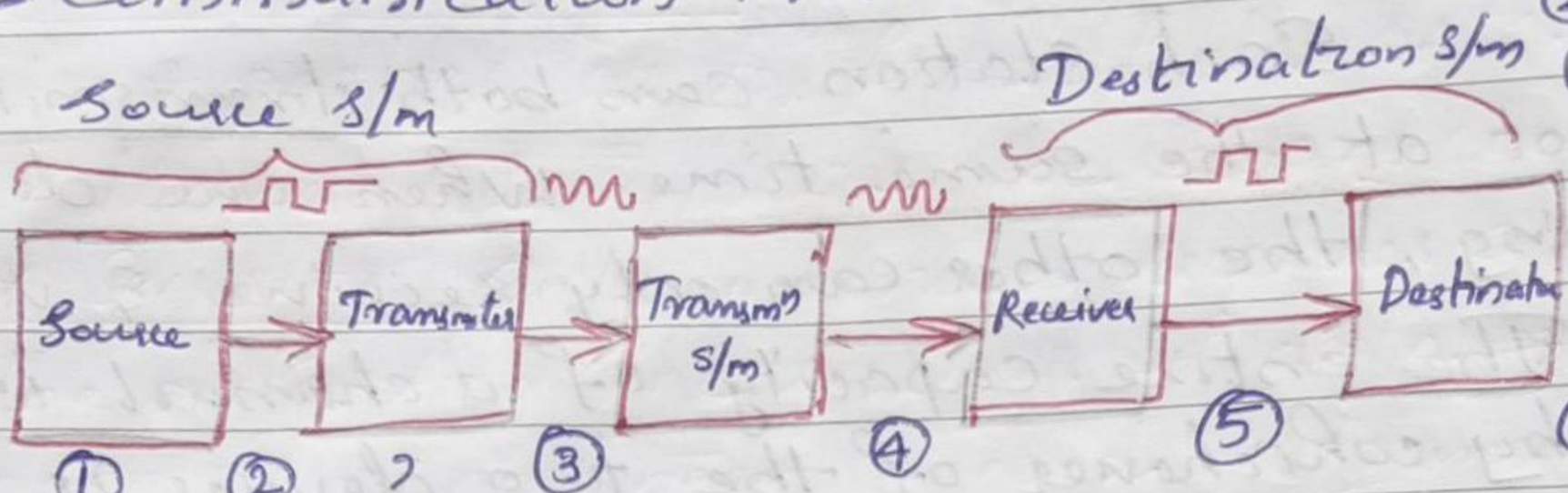
The capacity of the channel is devided blw s/ls traveling in both directions.

eg: telephone n/w - both can talk & listen at the same time.

The capacity of ~~a~~ channel must be devided b/w the 2 directions.

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> Communication Model



Key elements:

* Source: generates that data to be transmitted.
  eg: telephones & PCs.
* Transmitter: Transmitter transforms & encodes the inf^n in such a way as to produce electromag. s/ls that can be transmitted across some sort of transmission s/m. Eg: a modem takes a g digital bit stream from an attached device such as a PC & transforms that bit stream into an analog s/l that can be handled by the telephone n/w.
* Transmission s/m: A single transm^n line or a complex n/w connecting source & dest^n.
* Receiver: Accepts the s/l from the transm^n s/m & converts it into a form that can be handled by the dest^n device. eg: A modem will accept an analog s/l coming from a n/w or transmission line & convert it into a digital bit stream.
* Destination: Takes the incoming data from the receiver.

Communications Tasks:

* Transmission s/m utilization: refers to the need to make efficient use of transmission facilities

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that are typically shared among a no. of communicating devices.

* Interfacing: i/f with the transmission s/m. - electromagnetic s/ls propagated over a transmission medium.

* S/l generation: The properties of the s/l, such as form & intensity, must be such that the s/l is 1) capable of being propagated through the transm s/m & 2) interpretable as data at the receiver.

* Synchronization: b/w transmitter & receiver.

* Exchange Mgmt: If data are to be exchanged in both directions over a period of time, the 2 parties must cooperate. For eg:, for 2 parties to engage in a telephone conversation, one party must dial the no. of the other, causing s/ls to be generated that result in ringing of the called phone. The called party completes a conn^{n} by lifting the receiver.

* Error detection & Correction: - errors cannot be tolerated.

* Flow Control: to assure that the source doesn't overwhelm the dest^{n} by sending data faster than they can be processed & absorbed.

* Addressing & Routing: When more than 2 devices share a transm^{n} facility, a source s/m must indicate the identity of the intended dest^{n}. The transm^{n} s/m must assure that the dest^{n} s/m, & only that s/m, receives the data. - The transm^{n} s/m may itself be a n/w through which various paths may be taken. A specific route through this n/w must be chosen.

* Recovery: techniques are needed in situations in which an inf^{n} exchange, such as a db trans^{n} or file transfer, is interrupted due to a fault in th s/m.

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* Msg formatting: has to do with an agreement b/w 2 parties as to the form of the data to be exchanged or transmited, such as the binary code for characters
* Security: Only intended receiver actually receives the data. And the receiver of data ~~is~~ - the received data have not been altered in transit & that the data actually come from the purported sender.
* N/w Mgmt: - configure the s/m, monitor its status, react to failures & overloads & plan for future growth.

> Periodic Analog Signals:

* Prerequisite * ⇒ Physical Layer

→ One of the major functions of the phy. layer is to move data in the form of electromagnetic s/ls across a transmission medium. The data usable to a person or appl^n are not in a form that can be transmitted over a n/w. For eg: a photograph must first be changed to a form that transmission media can accept. Transmission media work by conducting energy along a physical path. For transmission, data needs to be changed to s/ls.

→ Periodic s/l completes a pattern within a measurable time frame, called a period & repeats that pattern over subsequent identical periods. The completion of one full pattern is called a cycle.

→ A non periodic s/l changes without exhibiting a pattern or cycle that repeats over time.

- Commonly use periodic analog s/ls & non periodic digital s/ls.

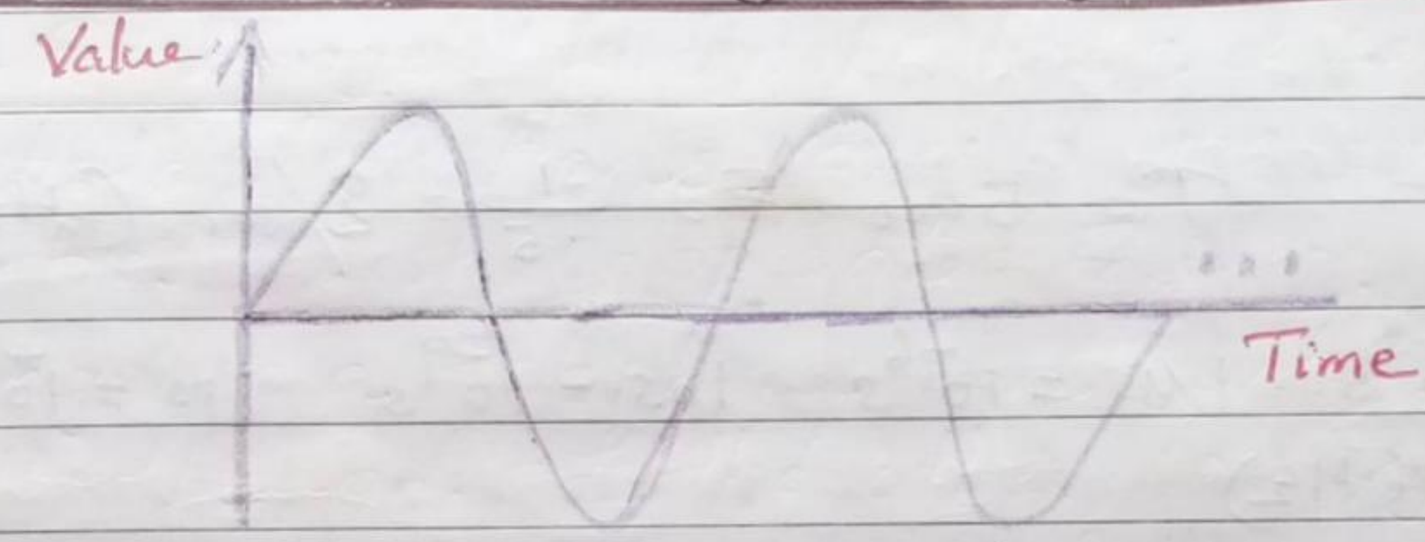
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Periodic analog s/ls can be classified as simple or composite. A simple periodic analog s/l, a sine wave cannot be decomposed into simpler s/ls. A composite periodic analog s/l is composed of multiple sine waves.

*> Sine Wave:

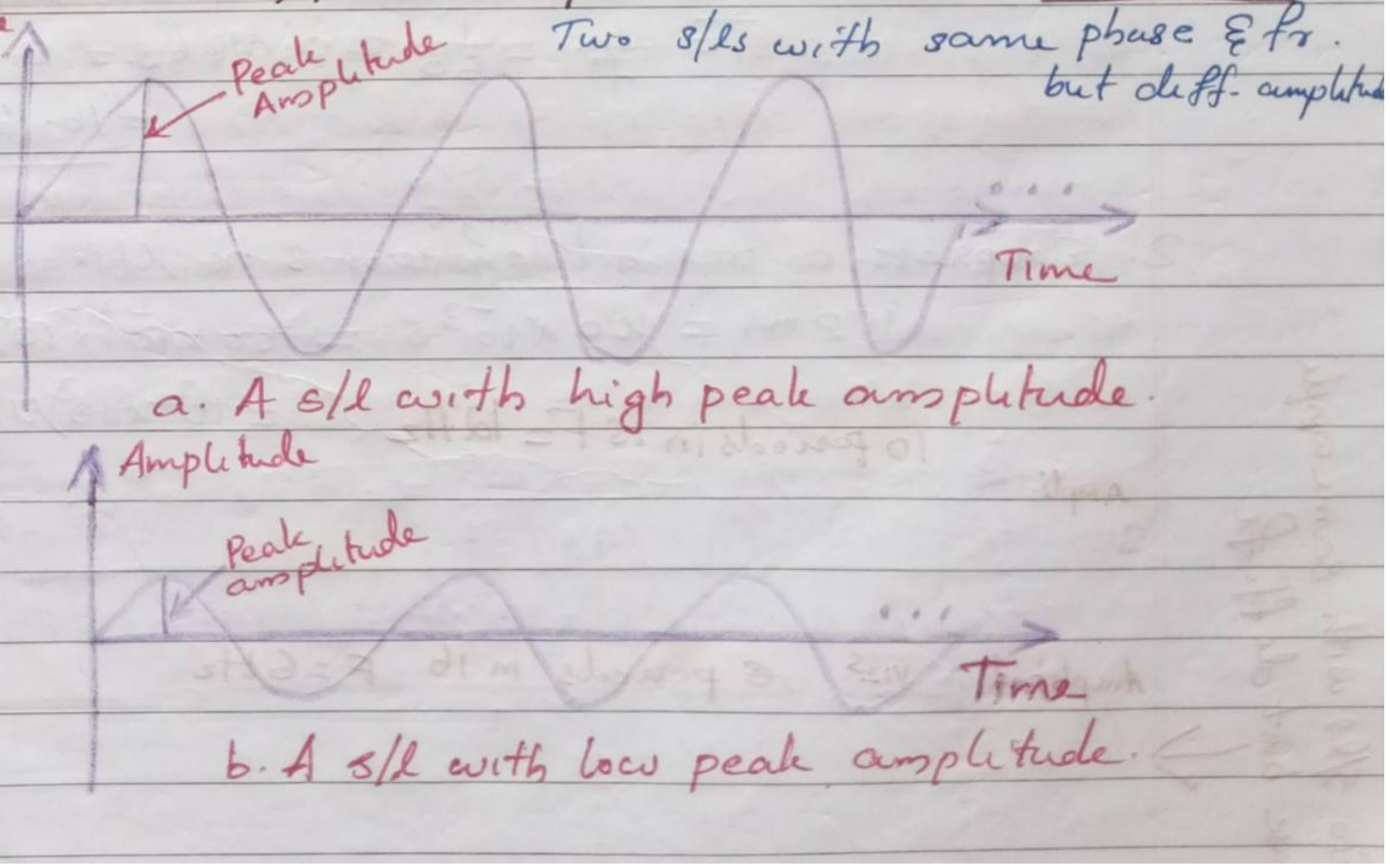
→ simple oscillating curve, consistent & continuous change over the course of a cycle.

→ Each cycle consists of a single arc above the time axis followed by a single arc below it.



A sine wave can be represented by 3 parameters
* the peak amplitude * frequency * Phase.

Peak Amplitude: of a s/l is the absolute value of its highest intensity, proportional to the energy it carries. For electric s/ls, peak amplitude measured in volts.



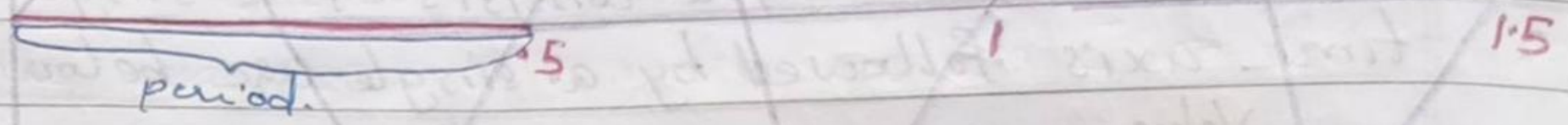
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Period & Frequency:

Period refers to the amt. of time, in sec. a s/l needs to complete 1 cycle

Frequency refers to the no. of periods in 1s.

$$f = \frac{1}{T} \; ; \; T = \frac{1}{f}$$



$T = .5 \text{ sec} \quad F = \frac{1}{.5} = 2/\text{sec.} \; (Hz)$

Period (s)

$1ms = 10^{-3}s \quad 1\mu s = 10^{-6}s \quad 1ns = 10^{-9}s \quad 1ps = 10^{-12}s$

Frequency (Hz)

$1 KiloHz = 10^3 Hz \quad 1 MHz = 10^6 Hz \quad 1 GHz = 10^9 Hz \quad 1 THz \; 10^{12} Hz$

Eg: The power at home fr. of 60Hz. The period of sine wave ?

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166s = 0.0166 \times 10^3$$

$$= \underline{16.6 ms}$$

2. Express a period of 100ms in μsec.

$100 ms = 100 \times 10^{-3} s = 100 \times 10^{-3} \times 10^6 \mu s = 100 \times 10^3 \mu s$

$= 10^2 \times 10^3 \mu s = \underline{10^5 \mu s}.$

10 periods in 1S F = 12Hz

Ampli.

Amplitud

1/2S 6 periods in 1S F = 6Hz

P = 1/6 S

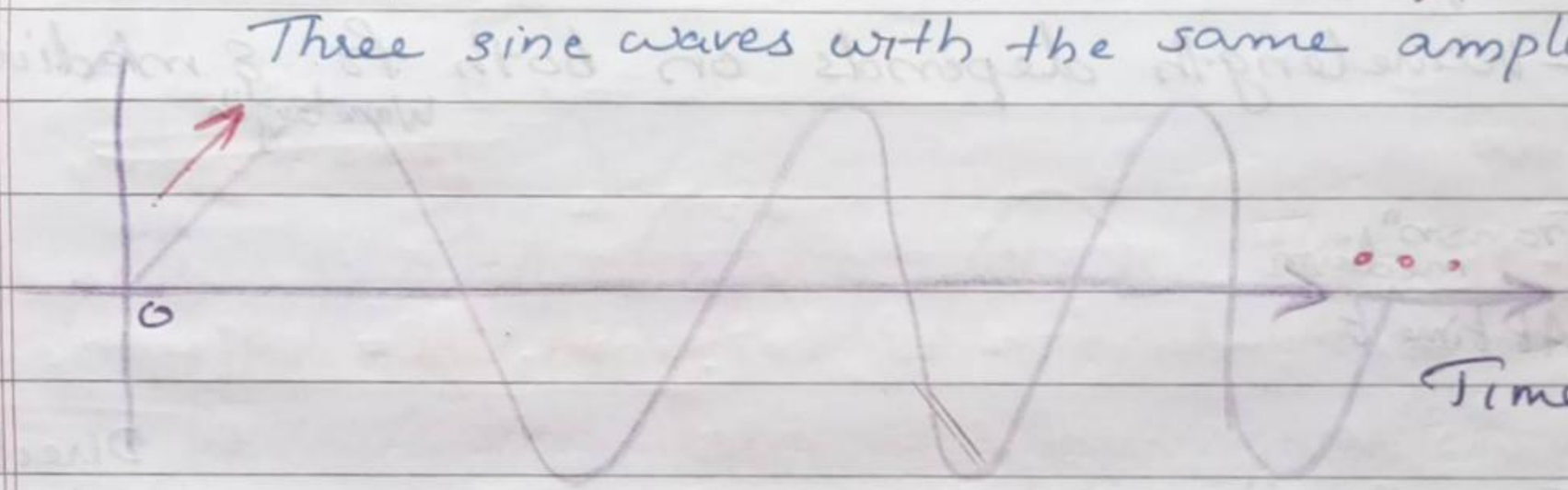
Two s/ls with same ampli & phase but diff. fr.

*> Phase:

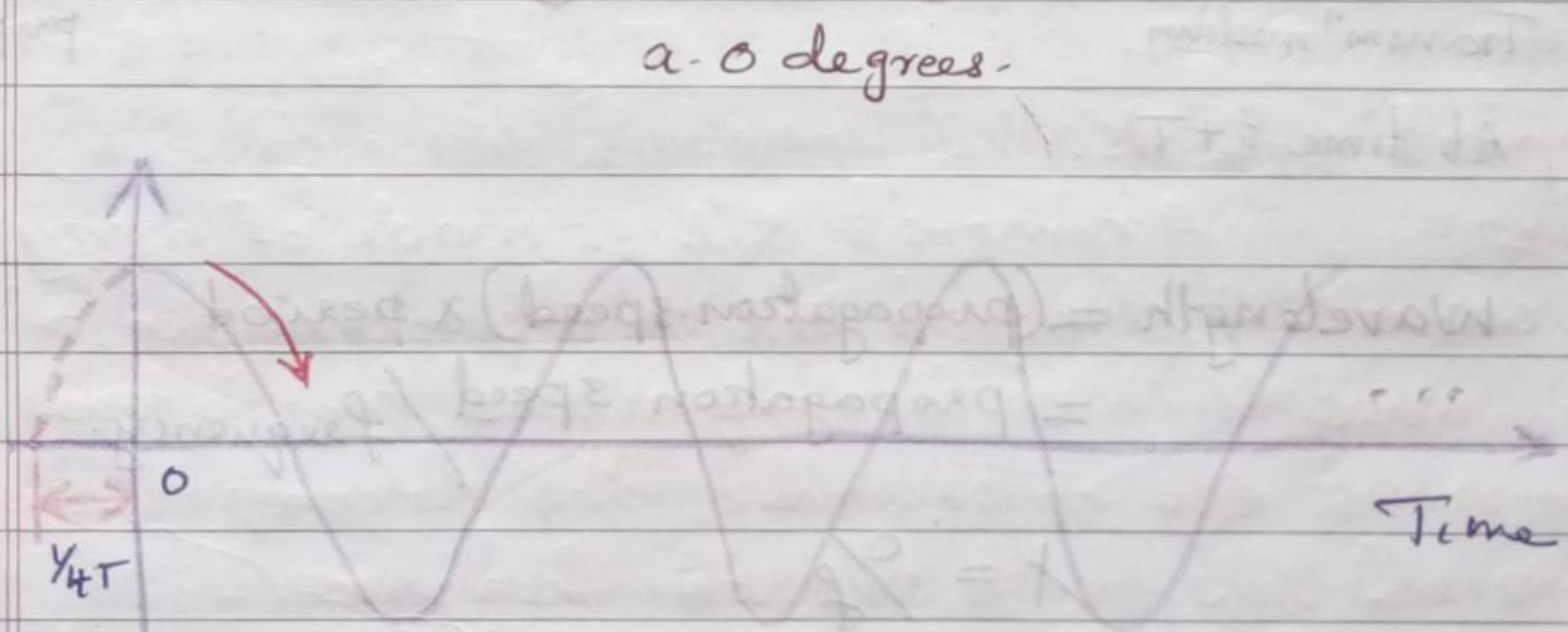
- describes the pos^{n} of waveform relative to time 0. If the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of the first cycle. Phase is measured in degrees or radians [360° — 2π rad ; 1° - 2π/360 rad; - 1 rad - 360/2π].

- A phase shift of 360° corresponds to a shift of a complete period; Phase shift of 180° corres. to a shift of one half of a period; & a phase shift of 90° corresponds to a shift of one-quarter of a period.

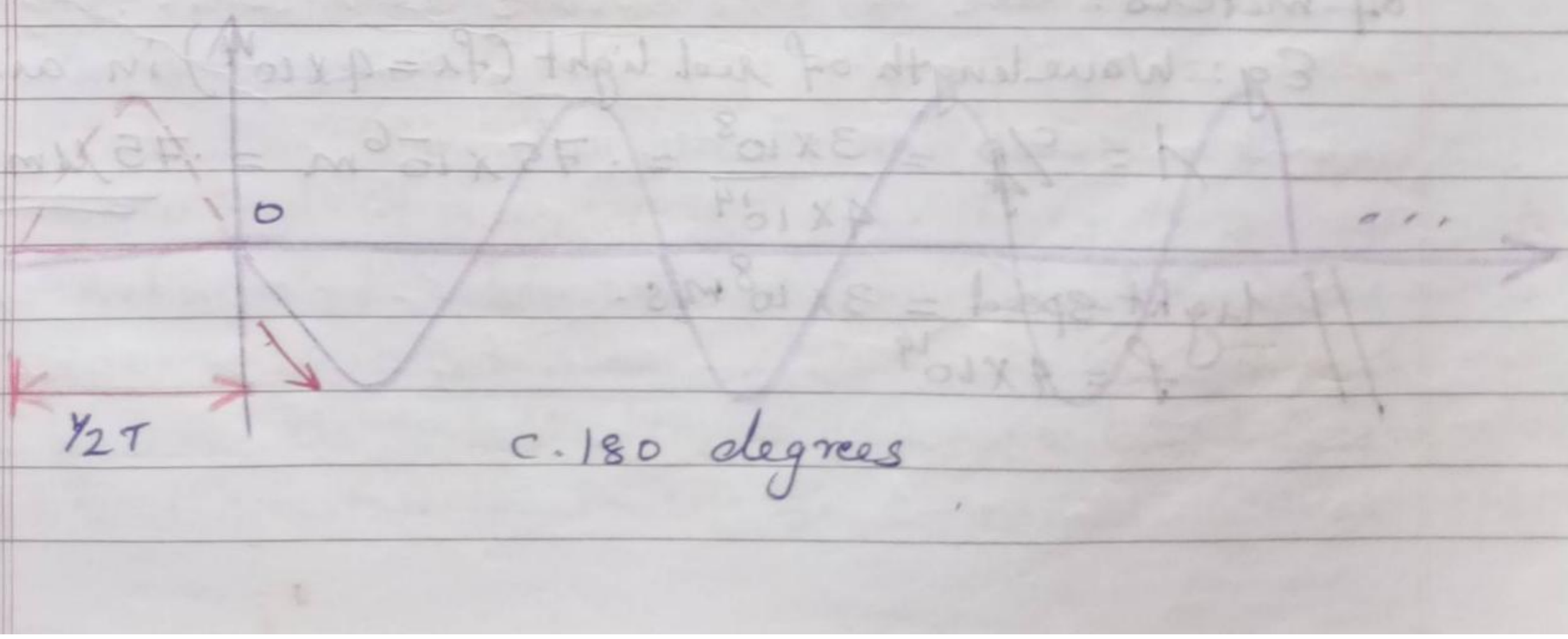
Three sine waves with the same amplitude & fr. but diff. phases.



a. 0 degrees.



b. 90 degrees



c. 180 degrees

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a) A sine wave with a phase of 0° at time 0 with a zero amplitude. Amplitude ↑

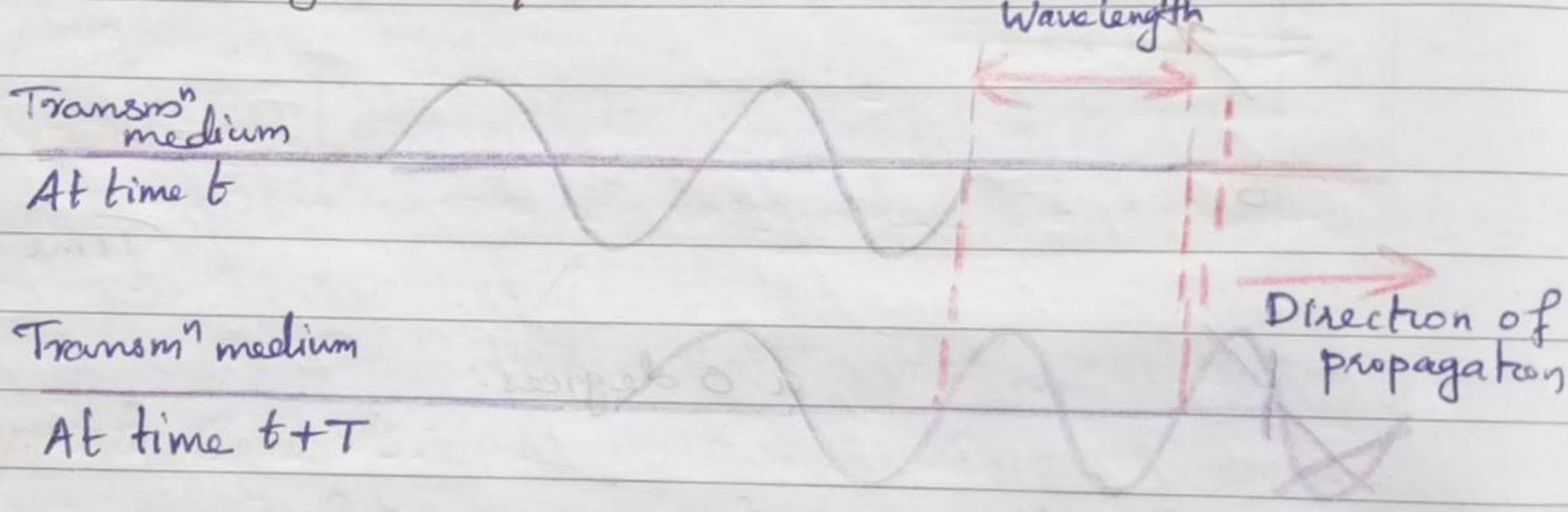
b) A sine wave with a phase of 90° starts at time 0 with a peak amplitude. Amplitude ↓ (1/4 cycle shift left)

c) A sine wave with a phase of 180° starts at time 0 with a zero amplitude. Amplitude ↓ (1/2 cycle shift left).

*> Wavelength:

— property of a s/l traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium.

-Wavelength depends on both fr. & medium.



Wavelength = (propagation speed) x period

= propagation speed / frequency.

$$\lambda = c/f$$

The wavelength is normally measured in μm instead of meters.

Eg: Wavelength of red light ($f_\lambda = 4 \times 10^{14}$) in air is

$$\lambda = c/f = \frac{3 \times 10^8}{4 \times 10^{14}} = .75 \times 10^{-6} m = .75 \mu m$$

// light speed = 3×10^8 m/s.
$f = 4 \times 10^{14}$

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*> Time and Frequency Domains:

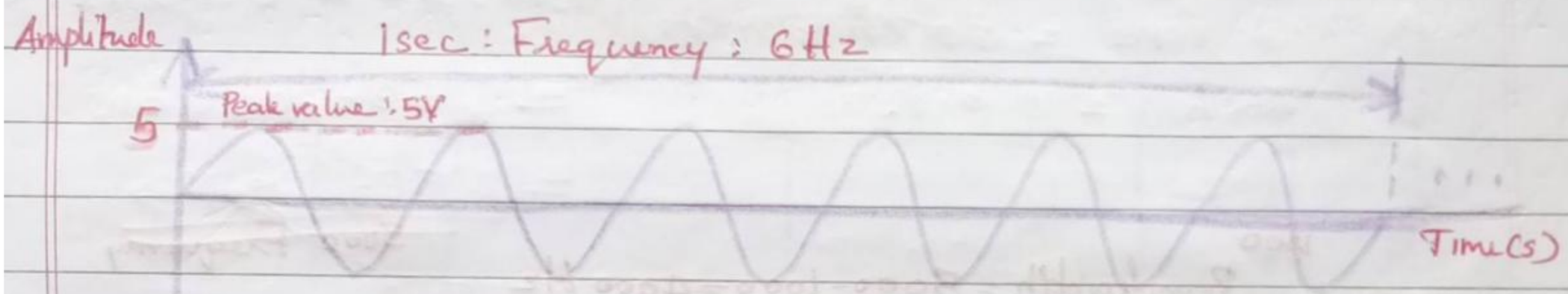
Time domain plot:

The time domain plot shows changes in s/l amplitude w.r.to time. Phase is not shown on a time domain plot.

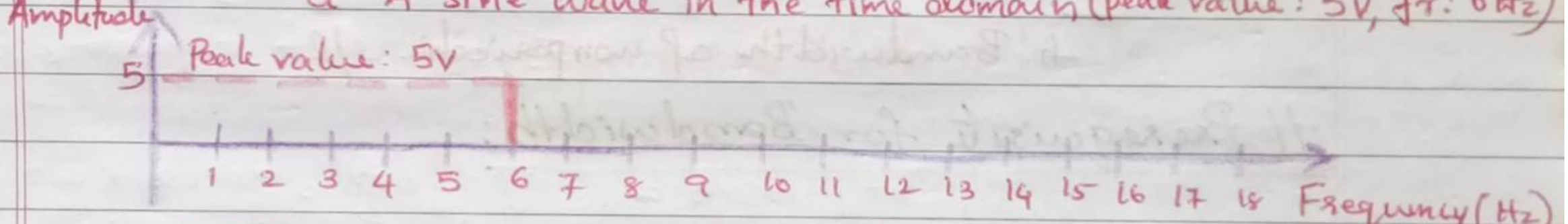
Frequency Domain plot:

- shows relationship blw amplitude & fr.
- is concerned with only the peak value & the fr.

Changes of amplitude during one period are not shown.



a. A sine wave in the time domain (peak value : 5V, fr : 6Hz)



b. The same sine wave in the fr domain (peak value : 5V
fr : 6Hz)

Adv: Frequency domain:

→ easy to plot. → immediately see the values of the frequency & peak amplitude.

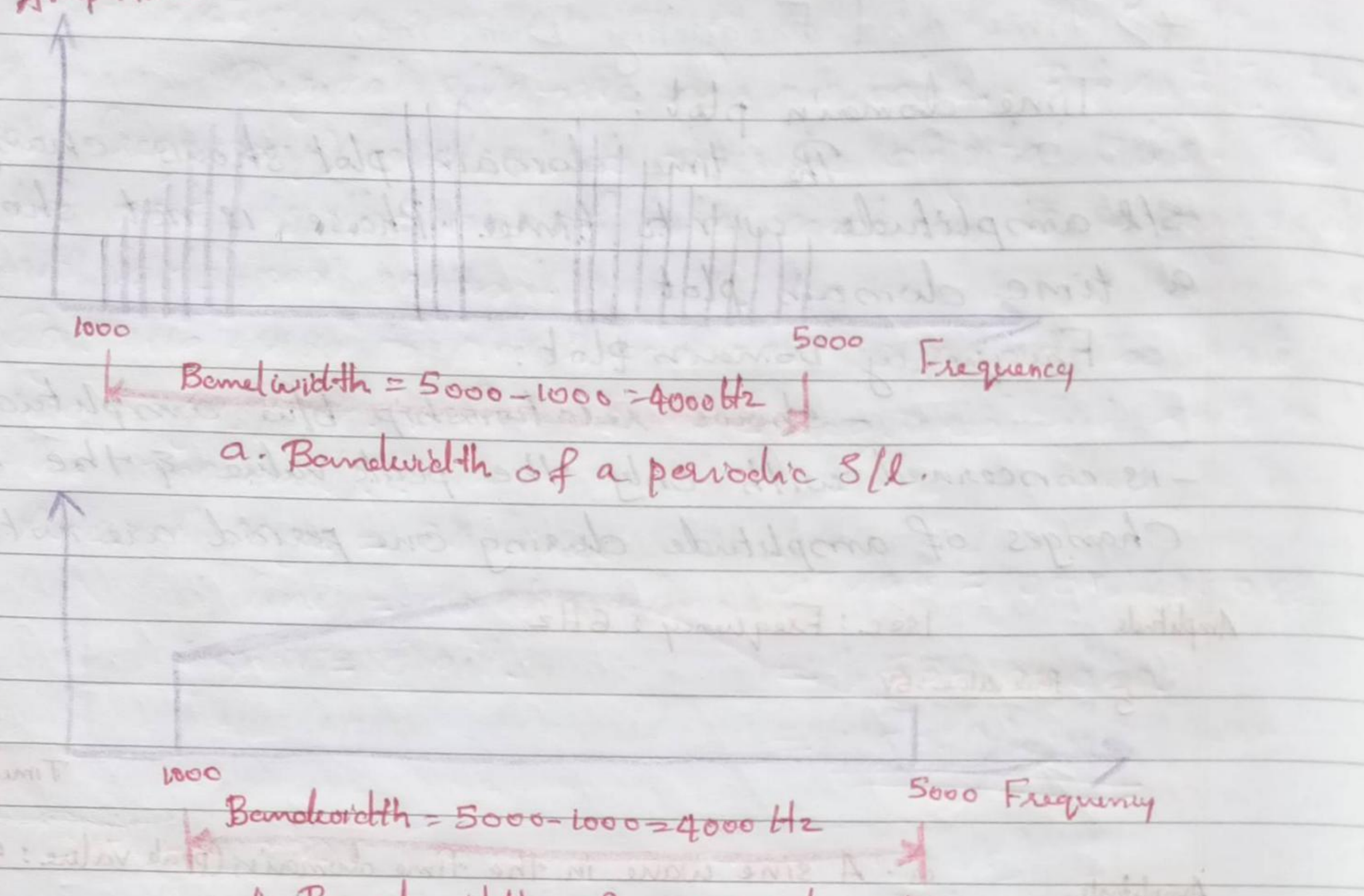
→ A complete sine wave is represented by one spike. The posⁿ of the spike shows the frequency, its height shows the peak amplitude.

*> Bandwidth:

Bandwidth is the range of frequencies contained in a composite s/l. For eg: If a composite s/l contains fr. b/w 1000 & 5000, its bandwidth is 5000 − 1000 or 4000.

→ The bandwidth of a composite s/l is the diff. b/w highest & the lowest fr. contained in that s/l.

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II Prerequisite for Bandwidth:

Composite Signals:

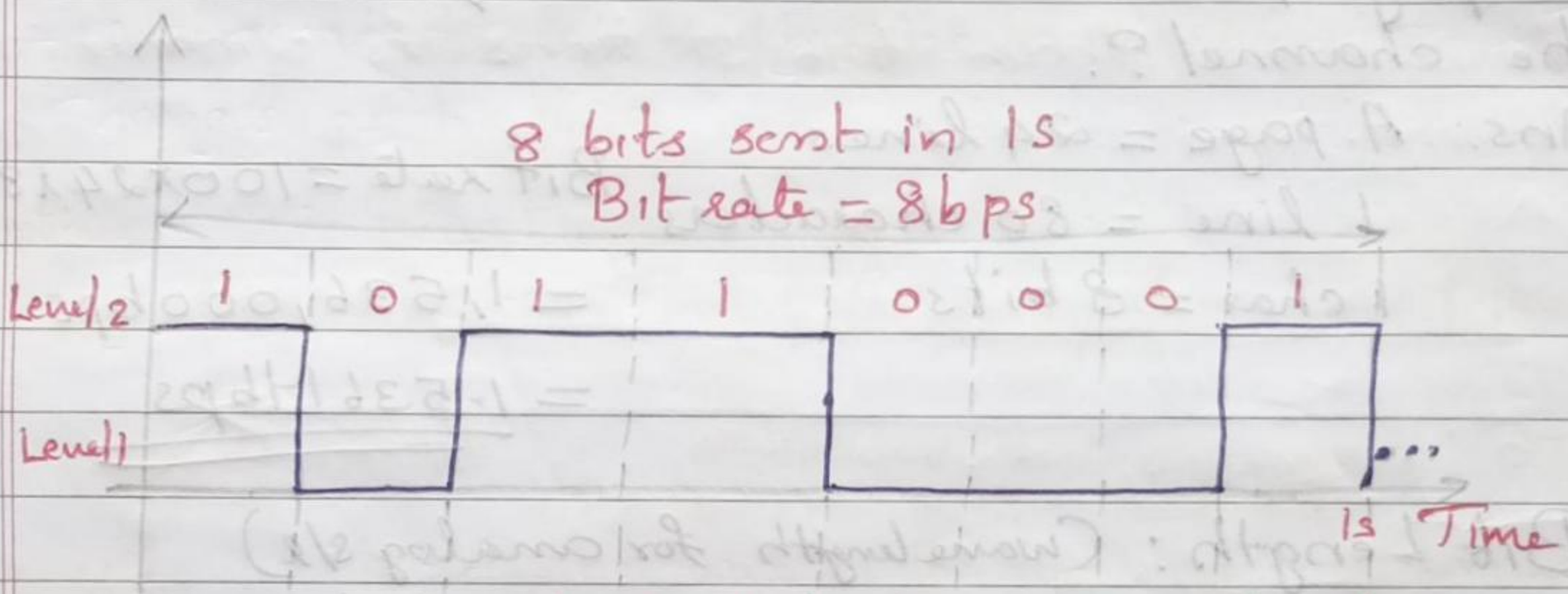
A composite s/l is made of many simple sine waves. A composite s/l is a combination of simple sine waves with diff. frequencies, amplitudes & phases If composite s/l is periodic, the decompos° gives a series of s/ls with discrete frequencies; if the composite s/l is non periodic, the decomposition gives a combination of sine waves with cont. frequencies.

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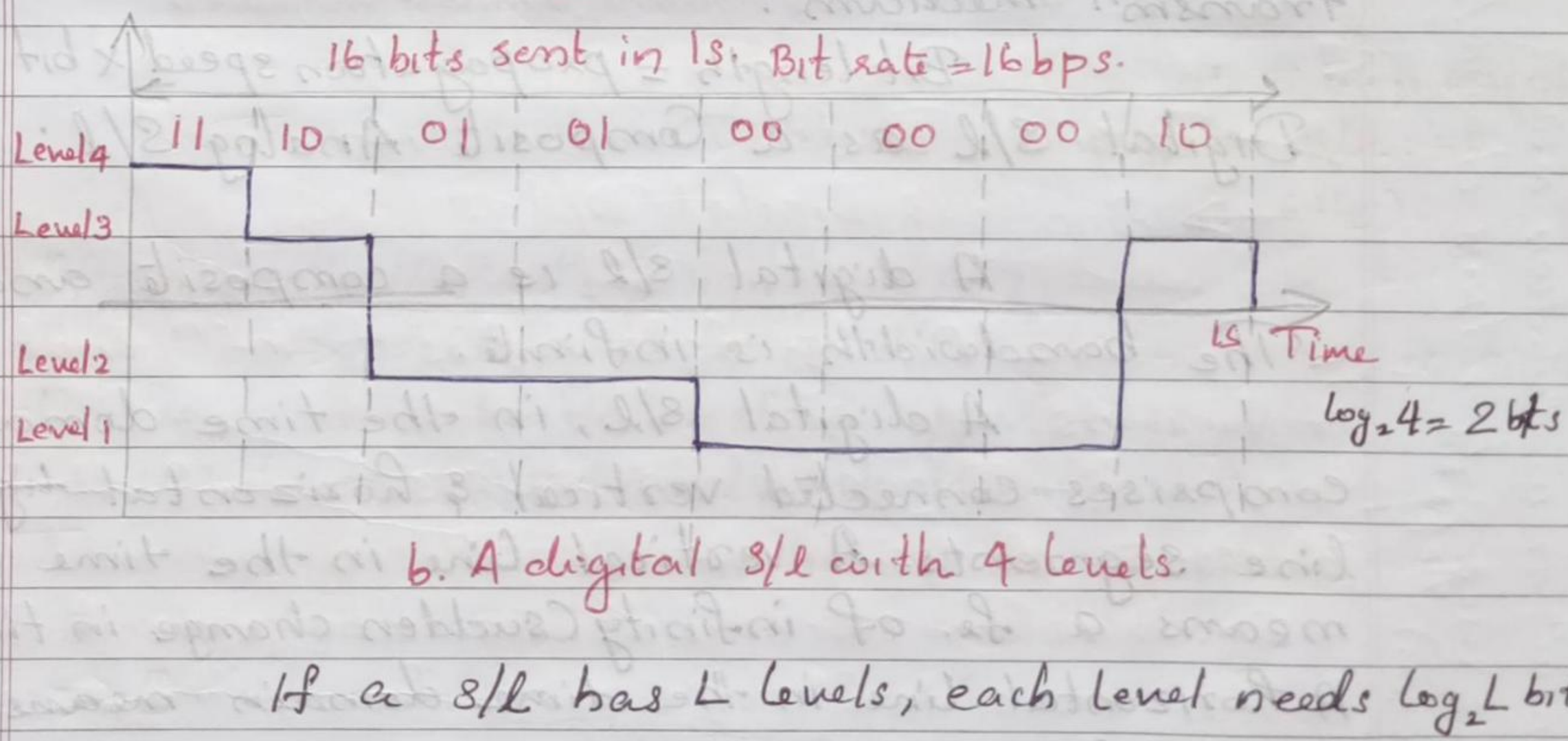
*> Digital Signals:

Information can also be represented by a digital s/l. (a 1 can be encoded as a +ve voltage & a 0 as zero voltage).

A digital s/l can have more than 2 levels. In this case, Here, we can send more than 1 bit for each level.



a. A digital s/l with 2 levels.



b. A digital s/l with 4 levels.

If a s/l has L levels, each level needs $\log_2 L$ bits.

A digital s/l has 8 levels. How many bits are needed per level?

No. of bits = $\log_2 8$ = 3 bits.

A digital s/l has 9 levels. How many bits are needed per level? $\log_2 9 = 3.17$ bits (not realistic) so 4 bits

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Bit Rate:

Digital s/ls are non periodic. Bit rate (instead of frequency) is used to describe digital s/ls. The bit rate is the no. of bits sent in 1s, expressed in bits per second.

Eg: We need to download text doc. at the rate of 100 pages/sec. What is the required bit rate of the channel?

Ans: A page = 24 lines
1 line = 80 characters
1 char = 8 bits

Bit rate = 100 x 24 x 80 x 8
= 1,536,000 bps
= 1.536 Mbps

Bit Length: (wavelength for analog s/l)

– is the distance one bit occupies on the transmn medium.

Bit length = propagation speed x bit duration

Digital s/l as a Composite Analog s/l:

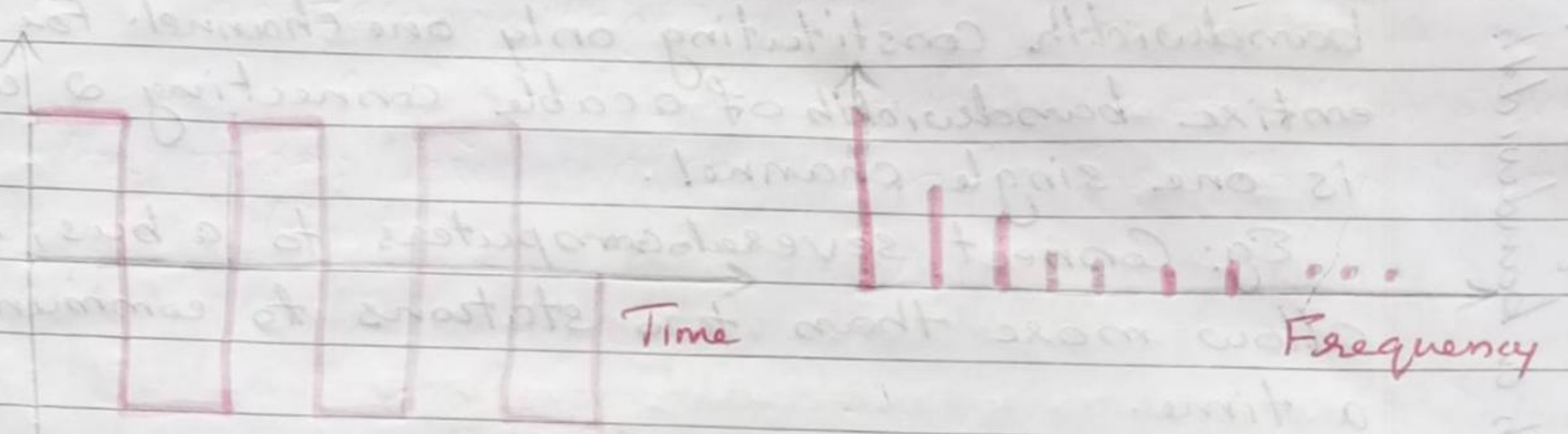
A digital s/l is a composite analog s/l.
– The bandwidth is infinite.

A digital s/l, in the time domain, comprises connected vertical & horizontal ~~tige~~ line segments. A vertical line in the time domain means a fr. of infinity (sudden change in time); A horizontal line in the time domain means a freq. of zero (no change in time).

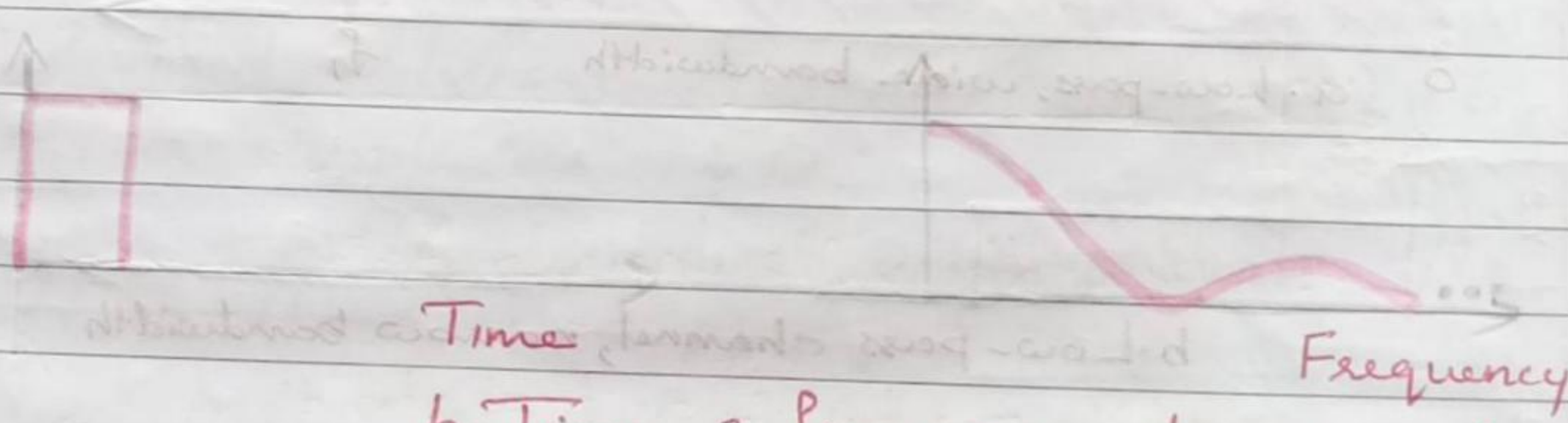
Fourier analysis – to decompose a digital s/l. If the digital s/l is periodic, which are in data commn, the decomposed s/l has a fr. – domain repn with an infinite bandwidth & discrete fr.

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If the digital s/l is non periodic, the decomposed s/l still has an infinite bandwidth, but the frequencies are continuous.



a. Time & frequency domains of periodic digital s/l.



b. Time & frequency domains of non periodic digital s/l.

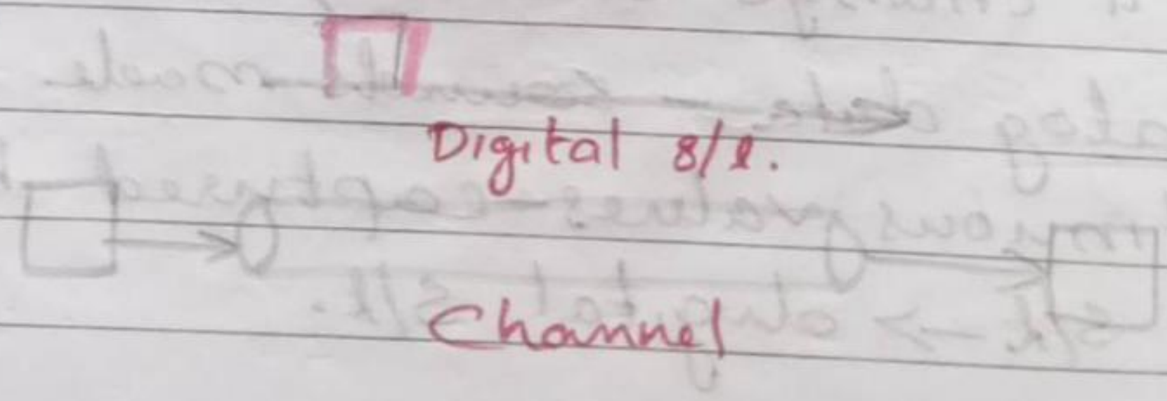
Transmission of Digital s/ls.

A g digital s/l can be transmitted by using one of two diff. approaches:

* Base band transmission or
  Broad band transmission.

→ Baseband Transmission:

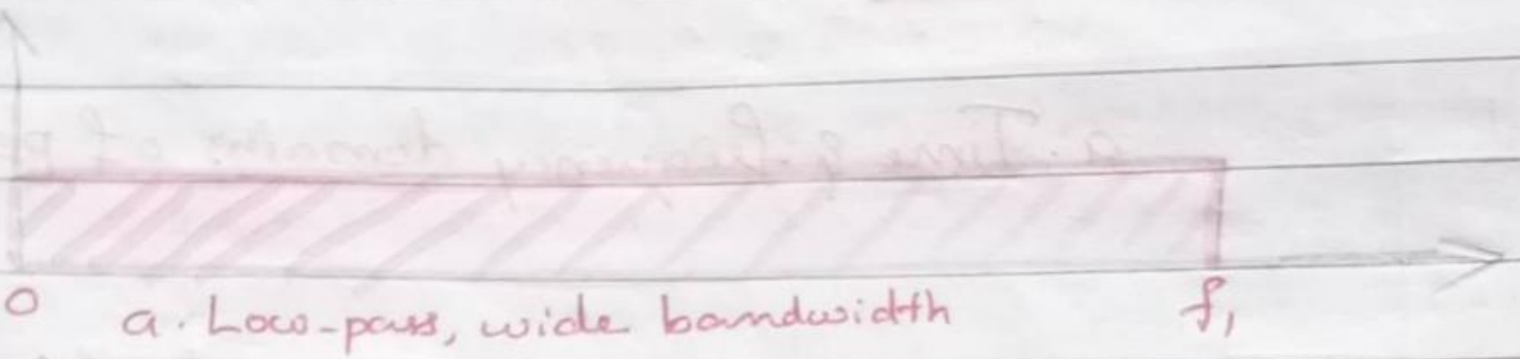
– means sending a digital s/l over a channel without changing the digital s/l to an analog s/l.



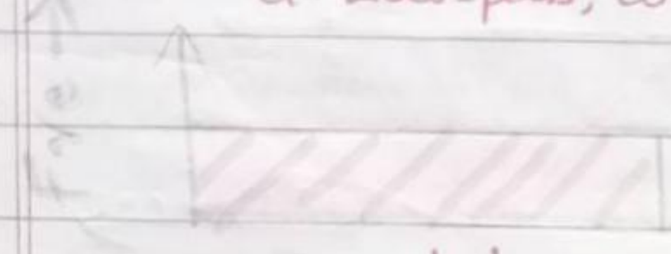
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Baseband transmission requires that we have a low-pass channel - A channel with a bandwidth that starts from zero. - A dedicated medium with bandwidth constituting only one channel. For eg: the entire bandwidth of a cable connecting 2 computers is one single channel.

Eg: Connect several computers to a bus, but not allow more than two stations to communicate at a time.



a. Low-pass, wide bandwidth



b. Low-pass channel, narrow bandwidth

> * Digital Data Transmission:

→ Analog & Digital Data:

- Analog data refers to inf^n that is continuous;

- Digital data refers to inf^n that has discrete states.

Eg: Analog clock that has hour, minute & second hands gives inf^n in a cont. form; the movements of the hands are continuous.

Digital clock that reports the hours & the minutes will change suddenly from 8:05 to 8:06.

Analog data - sounds made by a human voice - continuous values - captured by microphone - → analog s/l → digital s/l.

Broadband transmn. ⇒ uses a bandpass channel (for transmn. ⇒ uses a low-pass channel with a bandwidth starting from zero)

Digital signaling means channel is a low-pass channel

To an analog s/l that doesn't

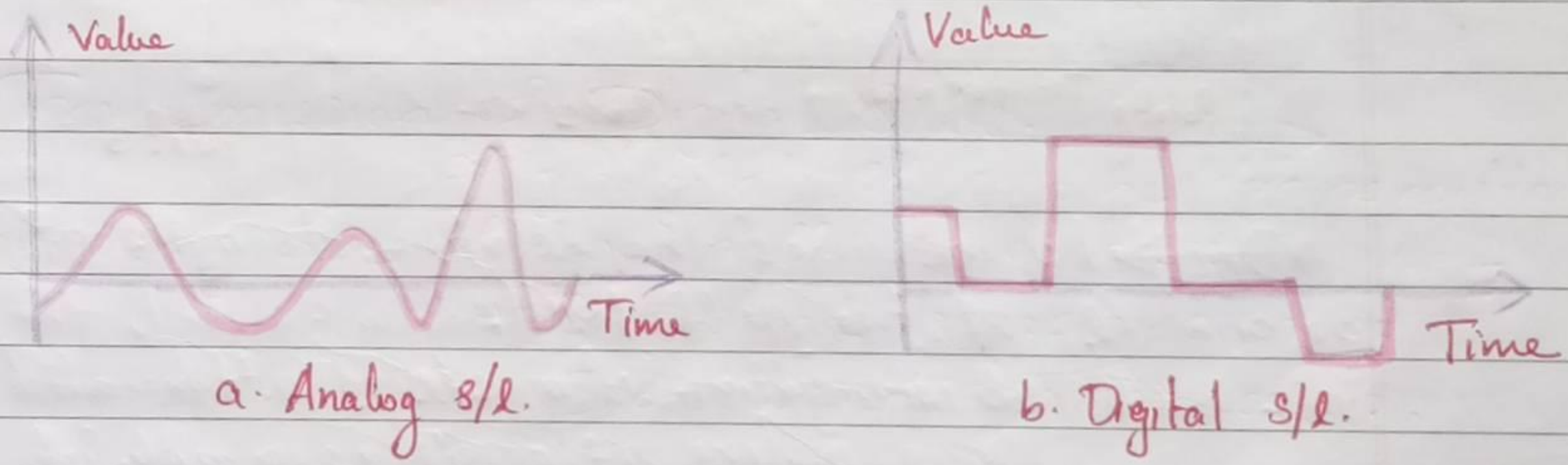
Digital data take on discrete values. Eg: data are stored in comp. memory in the form of 0s & 1s. They can be converted to a digital s/l or modulated into an analog s/l for transm^n across a medium.

* → Analog & Digital signals:

→ s/ls can be either analog or digital. An analog s/l has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through & includes an infinite no. of values along its path.

→ A digital s/l can have only a limited no. of defined values. Each value can be any no, it is often as simple as 1 & 0.

→ The simplest way to show s/ls is by plotting them on a pair of perpendicular axes. The vertical axis represents the value or strength of a s/l. The horizontal axis represents time.



a. Analog s/l. b. Digital s/l.

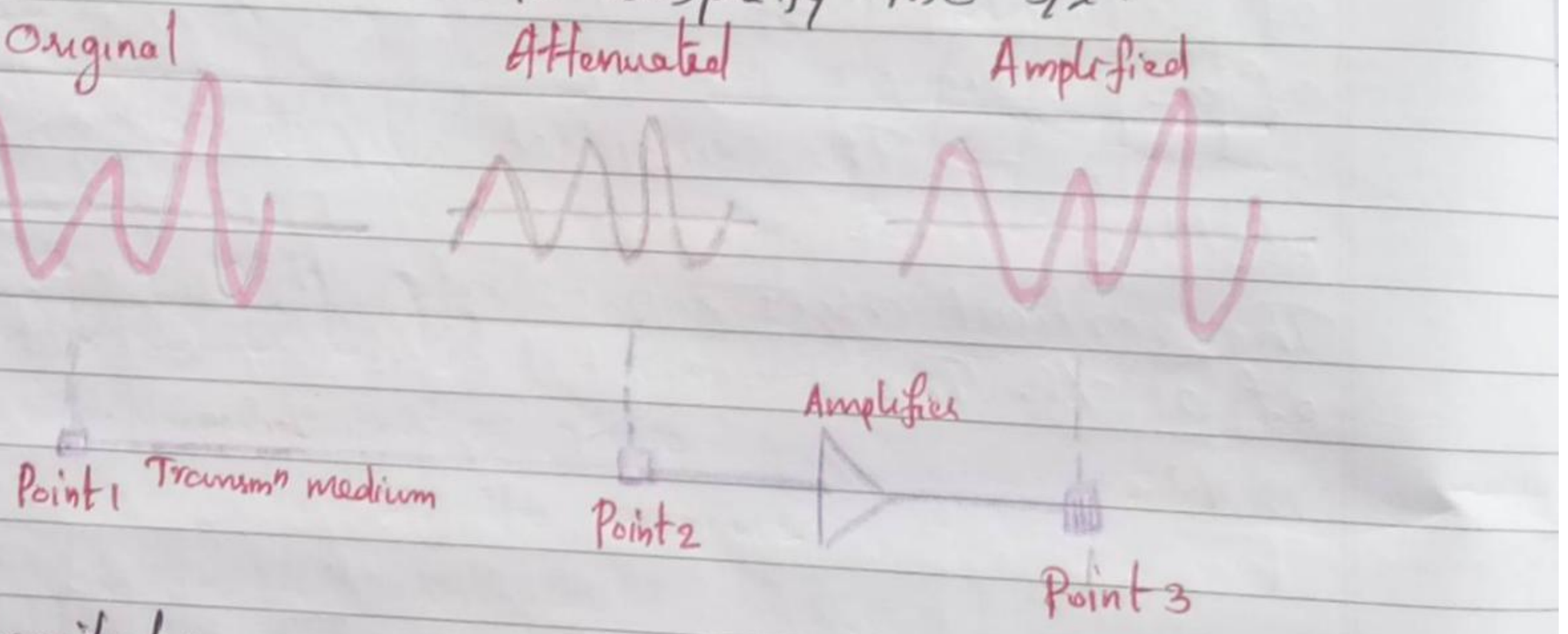
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* → Transmission Impairment

S/l impairment means that the S/l at the begining of the medium is not the same as the S/l at the end of the medium. Three causes of impairment are * attenuation * distortion * noise.

* → Attenuation:

— means loss of energy. When a S/l, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. ie; why wire carrying electric S/ls gets warm, if not hot, after a while. Some of the electrical energy in the S/l is converted to heat. To compensate for this loss, amplifiers are used to amplify the S/l.



Decibel: measures the relative strengths of 2 S/ls or one S/l at two diff. points.

dB is negative if a S/l is attenuated.

dB is positive if a S/l is amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$P_1 = P_2$ = powers of a S/l at 2 pts. 1 & 2.

Eg: A S/l travels through a transmn medium & its power is reduced to one-half. $P_2 = \frac{1}{2} P_1$ - Attenuation = ?

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{.5 P_1}{P_1} = 10 \log_{10} .5 = 10 (-0.3)$$

$$= -3 \text{ dB}$$

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Eg: A s/l travels through an amplifier, & its power is increased 10 times. This means that $P_2 = 10P_1$.
The amplific^n = ?.

$$10\log_{10}\frac{P_2}{P_1} = 10\log_{10}\frac{10P_1}{P_1} = 10\log_{10}10 = 10(1) = \underline{\underline{10\,dB}}$$

Eg: Decibel is used to measure s/l power in milliwats. It is referred to as dB_m & is calculated as $dB_m = 10\log_{10}P_m$ where P_m is the power in milliwatts. Calculate the power of a s/l if its $dB_m = -30$.

$$dBm = 10\log_{10}P_m\ ; \rightarrow dB_m = -30 \rightarrow 10\log_{10}P_m = -30$$

$$\log_{10}P_m = \frac{-30}{10} = -3 \rightarrow P_m = \log_{10}^{-1}(-3) = \underline{\underline{10^{-3}\,mW}}.$$

Eg: The loss in a cable is usually defined in decibels/km. If the s/l at the begining of a cable with -0.3 dB/km has a power of 2mW; what is the power of the signal at 5 km?

$$dB = 10\log_{10}P_2/P_1 =$$

The loss in a cable of 5km = $5 \times (-0.3) = -1.5\,dB$.

$$dB = 10\log_{10}P_2/P_1 = -1.5 \qquad \log_{10}P_2/P_1 = \frac{-1.5}{10} = -0.15$$

$P_2/P_1 =$

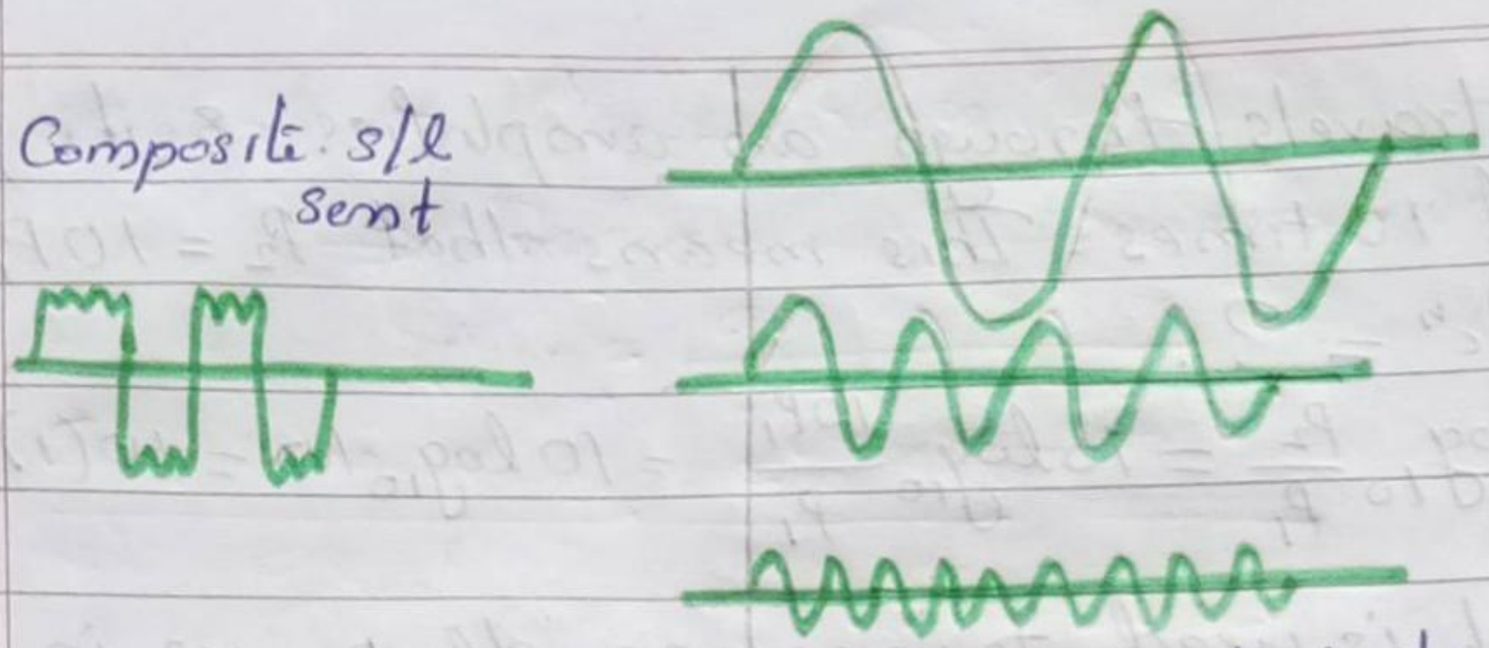
$$P_1 = 2mW \qquad P_2/P_1 = 10^{-0.15} = \underline{\underline{0.71}}$$

$$P_2 = 0.71P_1 = 0.71 \times 2mW = \underline{\underline{1.4\,mW}}$$

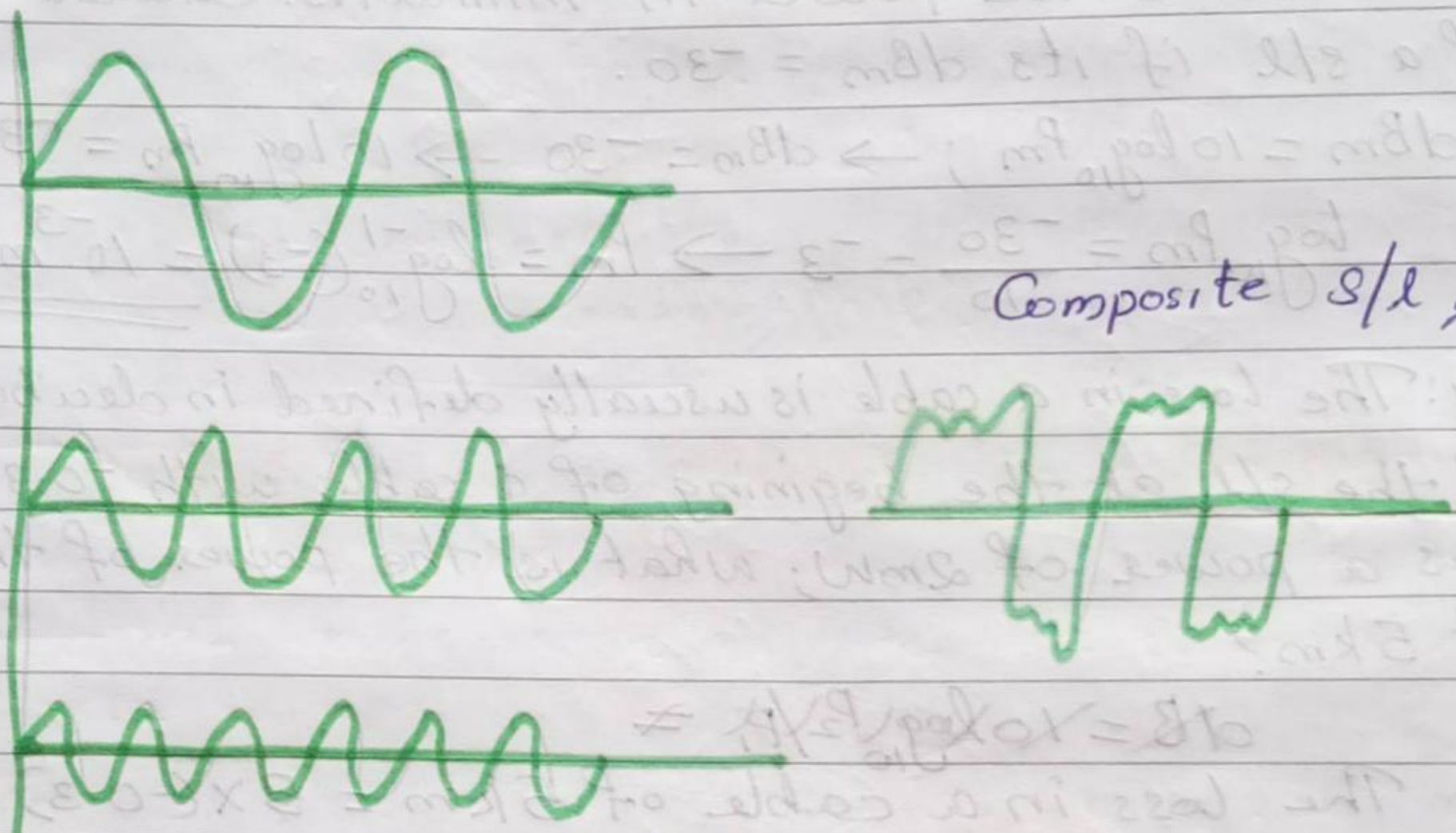
* $\rightarrow$ Distortion:

Distortion means that the s/l changes its form or shape. Distortion can occur in a composite s/l made of diff. frequencies. Each s/l component has its own propagation speed through a medium & ∴ its own delay in arriving at the final destination. S/l components at the receiver have phases diff. from what they had at the sender.

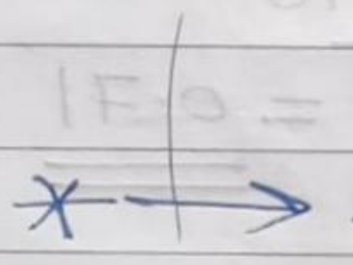
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At the sender



At the receiver



For any data transm° event, the received s/l will consist of the transmitted s/l, modified by the various distortions imposed by the transm° s/l plus additional unwanted s/ls that are inserted somewhere b/w transm° & reception. The undesired s/ls are referred to as noise.

Noise may be divided into 4 categories:

* Thermal noise * Intermodulation noise
* Crosstalk * Impulse noise.

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> Thermal noise: due to thermal agitation of electrons. Thermal noise is uniformly distributed across the bandwidths typically used in comm^n s/ms & hence is referred to as white noise.

The amount of thermal noise to be found in a bandwidth of 1Hz in any device or conductor is $N_0 = kT$ (W/Hz) (Unit = Joule)

where N_0 = noise power density in watts/1 Hz of bandwidth.

k = Boltzmann's constant = 1.38×10^{-23} J/K

T = temperature, in kelvins, whose tha

> Intermodulation noise: When s/ls at diff. frequencies share the same transm^n medium, the result may be intermodulation noise. The effect of intermodulation noise is to produce s/ls at a fr. that is the sum of diff. of two original f_1 & f_2 might produce energy at the freq. $f_1 + f_2$. This desired s/l could interfere with an intended s/l at the fr. $f_1 + f_2$.

~~> Cross talk: has been experienced~~

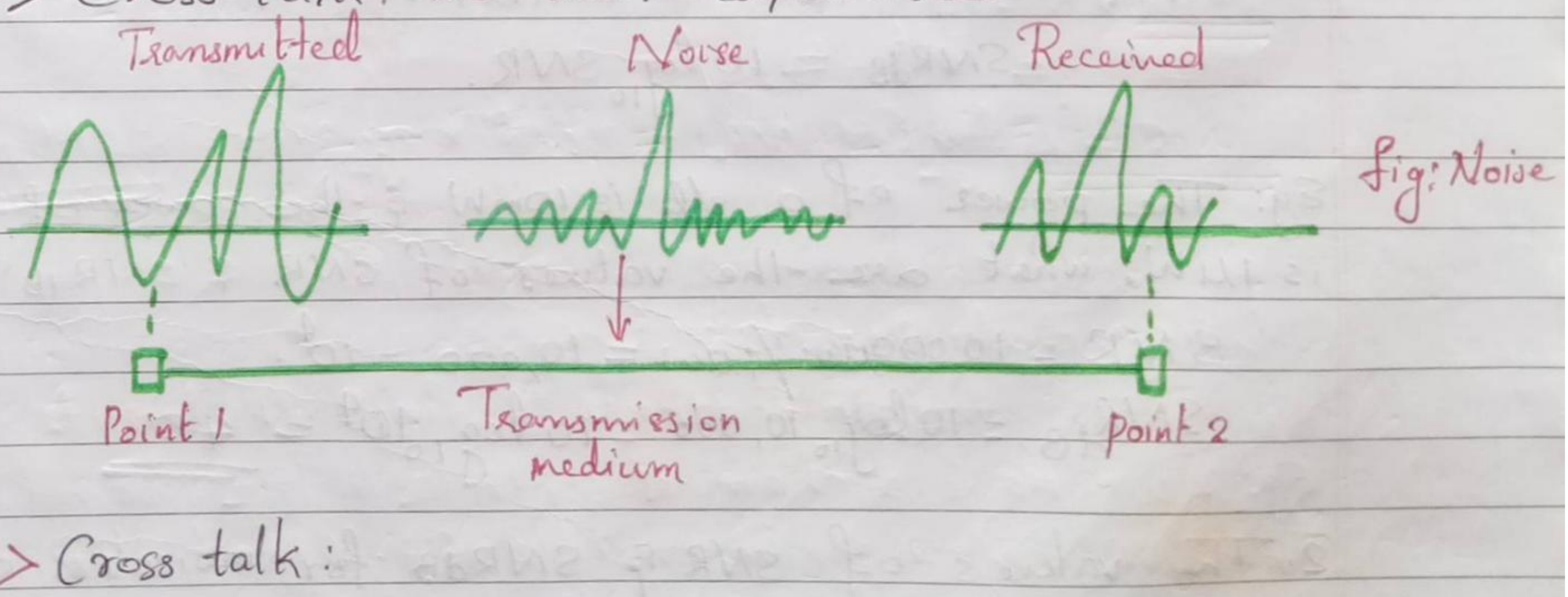


Fig: Noise

> Cross talk:

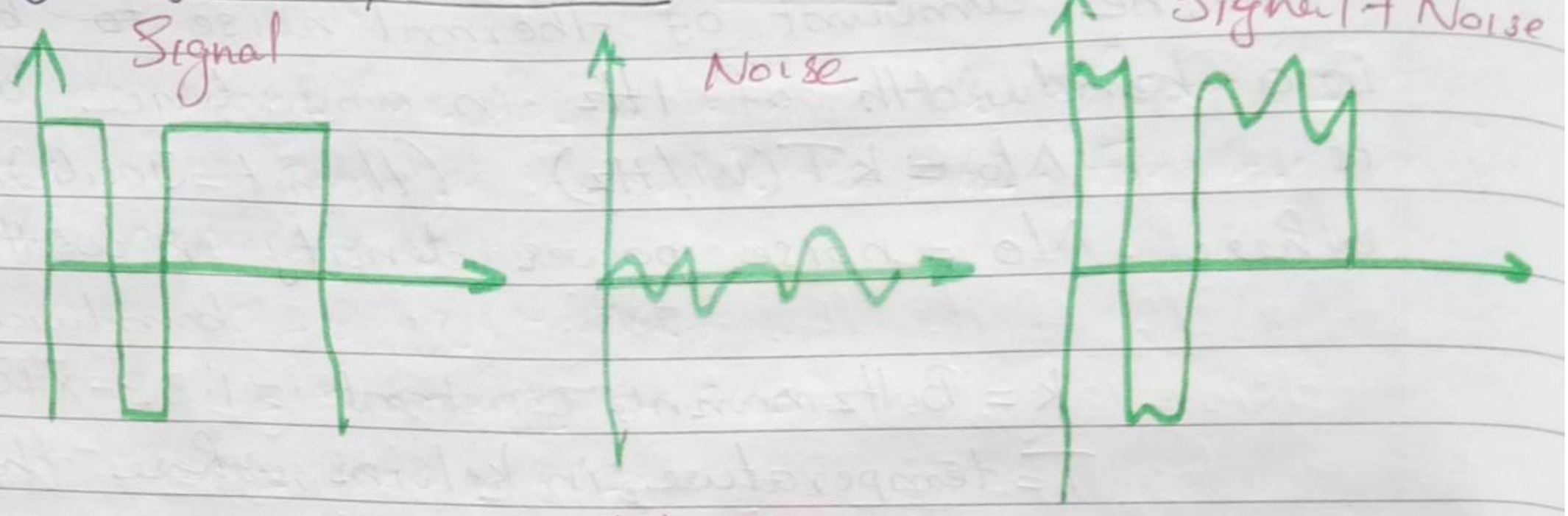
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Signal-to-Noise Ratio (SNR)

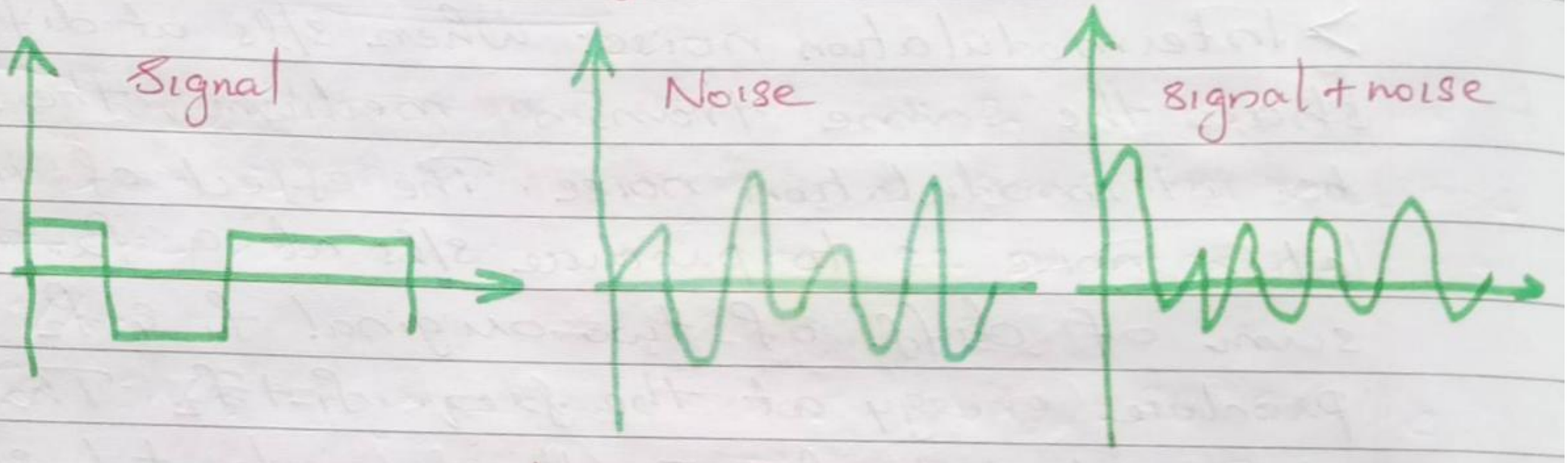
→ Ratio of s/l power to noise power.

$$SNR = \frac{\text{avg s/l power}}{\text{avg noise power}}.$$

Fig: High SNR & low SNR:



a. High SNR.



b. Low SNR

SNR is described in decibel units,

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

Eg: The power of a s/l is 10mW & the power of the noise is 1μW; what are the values of SNR & SNR_{dB}?

$SNR = 10000\mu W / 1\mu W = 10,000 = 10^4$.

$SNR_{dB} = 10 \log_{10} 10,000 = 10 \log_{10} 10^4 = \underline{40}$

2. The values of SNR & SNR_{dB} for noiseless channel?

$SNR = (\text{s/l power} / 0) = \infty$

$SNR_{dB} = 10 \log_{10} \infty = \infty$.

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*> Channel Capacity: (Data Rate)

→ how fast data can be sent, in bits/sec over a channel. Data rate depends on:

1. The bandwidth available
2. The level of s/ls
3. The qlty of the channel (level of noise).

Two theoretical formulas were developed to calculate data rate: Nyquist for a noiseless channel & Shannon for a noisy channel.

→ Noiseless Channel: Nyquist Bit Rate:

$$BitRate = 2 \times bandwidth \times \log_2 L$$

⇒ bandwidth is the bandwidth of the channel,
⇒ L is the no. of s/l levels to represent data.
⇒ BitRate is the bit rate in bits/sec.

Eg: Consider the noiseless channel with a bandwidth of 3000Hz transmitting a s/l with 2 signal levels. Calculate the max. bit Rate.

$$BitRate = 2 \times 3000 \times \log_2 2 = \underline{\underline{6000 \text{ bps}}}.$$

2) We need to send 265 kbps over a noiseless channel with a bandwidth of 20kHz. How many s/l levels do we need.?

$$BitRate = 2 \times bandwidth \times \log_2 L.$$

$$265,000 = 2 \times 20,000 \times \log_2 L$$

$$\log_2 L = \frac{265,000}{2 \times 20,000} = 6.625$$

$$L = 2^{6.625} = \underline{\underline{98.7 \text{ levels}}}$$

→ Noisy Channel: Shannon Capacity:

$$Capacity = bandwidth \times \log_2(1 + SNR)$$

Eg: Consider an extremely noisy channel in which the value of the SNR is almost zero. The noise is so strong that

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the s/l is faint.

$$C = B\log_2(1+SNR) \Rightarrow$$
$$= B\log_2(1+0) \Rightarrow$$
$$= B\log_2 1 = B \times 0 = \underline{0}$$

2. A telephone line has a bandwidth of 3000 Hz assig for data comm^ns. The SNR is 3162. For this chann the capacity is

$$C = B\log_2(1+SNR)$$
$$= 3000\log_2(1+3162)$$
$$= 3000 \times 11.62$$
$$= \underline{34,860 \text{ bps}}$$

Highest bit rate is 34,860bps. If we want t send data faster than this, we can either increase ~~that~~ the bandwidth of the line or improve the SNR.

3. The SNR is given in decibels. $SNR_{dB} = 36$ & the channel bandwidth is 2 MHz. Capacity = ?

$$SNR_{dB} = 10\log_{10} SNR$$
$$SNR = 10^{SNR_{dB}/10} = 10^{36/10}$$
$$= 10^{3.6} = 3981$$
$$C = B\log_2(1+SNR) = 2\times10^6 \times \log_2 3982 = \underline{24 \text{ Mbps}}$$

Using Both Limits:

— Both methods to find the limits & s/l le

Eg: 1. We have a channel with a 1MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate & s/l level?.

Q= Shannon formula to find upper limit.

$$C = B\log_2(1+SNR) = 10^6\log_2(1+63) = 10^6\log_2 64 = \underline{6 \text{ Mbps}}$$

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$4 Mbps = 2 \times 1 MHz \times \log_2 L$

$\log_2 L = \frac{4 Mbps}{2 MHz} = 2$

$L = \underline{\underline{4}}$

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MODULE - II

> Transmission Media:

→ Guided Transmission Media.

* Twisted Pair
* Coaxial Cable
* Optical fibre
* Wireless Transmission
* Terrestrial Microwave
* Satellite microwave

→ Wireless Propagation:

* Ground wave propagation
* Sky wave propagation
* LoS propagation.

Questions:

1. Coaxial Cable is a 2 wire transmn s/m. What is the adv. of connecting the outer conductor to ground?.
2. In satellite commns, diff. fr. bands are used for the uplink & the downlink. Discuss why this pattern occurs.
3. Determine the height of an antenna for a TV station that must be able to reach customers upto 80 km away?

$$d = 3.57\sqrt{Kh} \qquad K \geq 1.33$$

4. Why can waves with a very low fr. follow the earth's surface 2. Why are they not used for data transmn in comp. n/ws?
5. How do guided media differ from unguided media?
6. Diff- b/w omnidirectional waves & unidirectional waves?
7. What is refraction? What is reflection?
8. What are 3 major class of guided media?
9. What is the purpose of cladding in an optical fibre?
10. What is the significance of the twisting in twisted pair cable?

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11. How does sky propagation differ from line of sight propagation?.

12. Name 2 major categories of transm^n media?

13. Name the adv. of optical fiber over twisted pair & coaxial cable?

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Data Transmission

Data transmission occurs b/w transmitter & receiver over some transmission medium.

Data comm^{n}s are the exchange of data b/w 2 devices via some form of transmission medium such as a wire cable. The effectiveness of a data comm^{n}s s/m depends on 4 fund. characteristics.

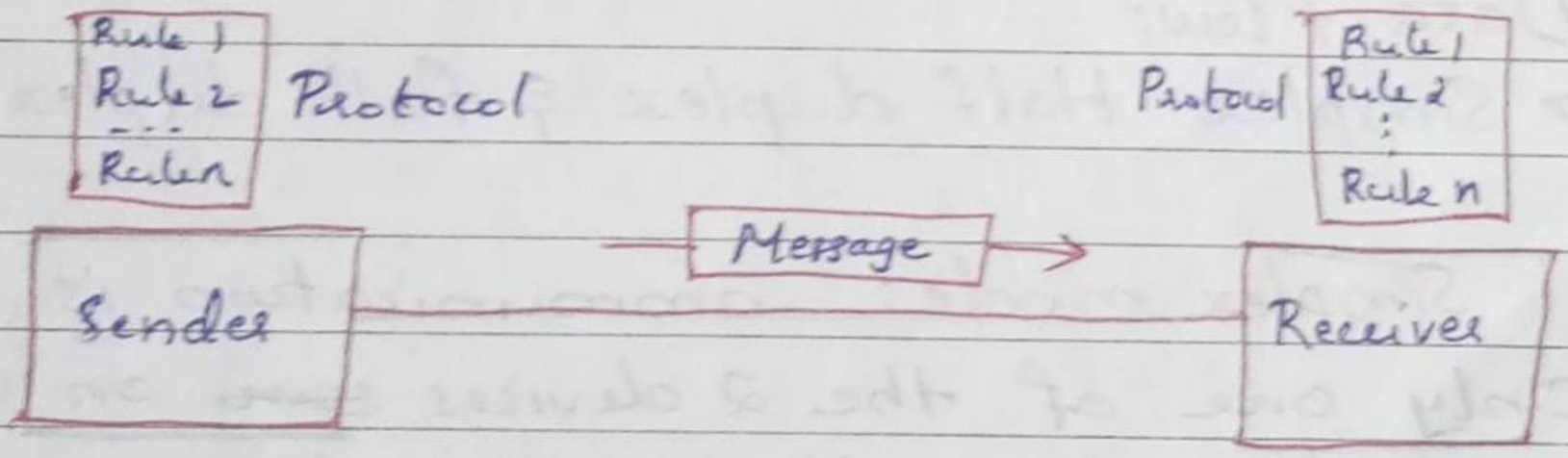
1. Delivery: s/m must deliver data to the correct destination.

2. Accuracy: deliver data accurately. Data that have been altered in transmission & left uncorrected are unusable.

3. Timeliness: The s/m must deliver data in a timely manner. Eg: In case of audio & video.

4. Jitter: ~~reffe~~ refers to the variation in the pkt arrival time. Eg: uneven delay in the delivery of audio or video pkts.

A data comm^{n} s/m has 5 components:



* Message: Inf^{n} to be communicated. i.e; text, no.s, pictures audio & video.
* Sender: The device that sends the data msg. i.e; computer, workstation, video camera & so on.
* Receiver: The device that receives the msg. i.e; Computer, workstation, telephone & so on.

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* Transmission Medium: physical path by which a msg travels from sender to receiver.
eg: twisted pair wire, coaxial cable, radio waves.
* Protocol: set of rules that govern data comm.
It represents an agreement b/w the commu. devices.

Data Representation:

* Text: bit pattern (0s & 1s)
- Unicode (32 bits for a symbol or character)
- ASCII
* Numbers: bit patterns - directly to a binary no.
* Images: bit patterns - matrix of pixels - resolution
color images - RGB
- YCM (Yellow, Cyan & Magenta)
* Audio: continuous s/l.
* Video: Continuous entity or combination of images, each discrete entity arranged to convey the idea of motion.

Data flow:
> Simplex Half duplex & full duplex transmissio

Simplex mode: communication is unidirectional
Only one of the 2 devices can on a link can transmit; the other can only receive
Eg: keyboards & traditional monitors.
↓ ↓
intended only accept o/p.
i/p
The simplex mode can use the entire capacity of the channel to send data in one direction.

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Half duplex mode:

Each station can both transmit & receive, but not at the same time. When one device is sending, the other can only receive & vice versa.

→ The entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time. Eg: Walkie-talkie & CB radios.

Full duplex:

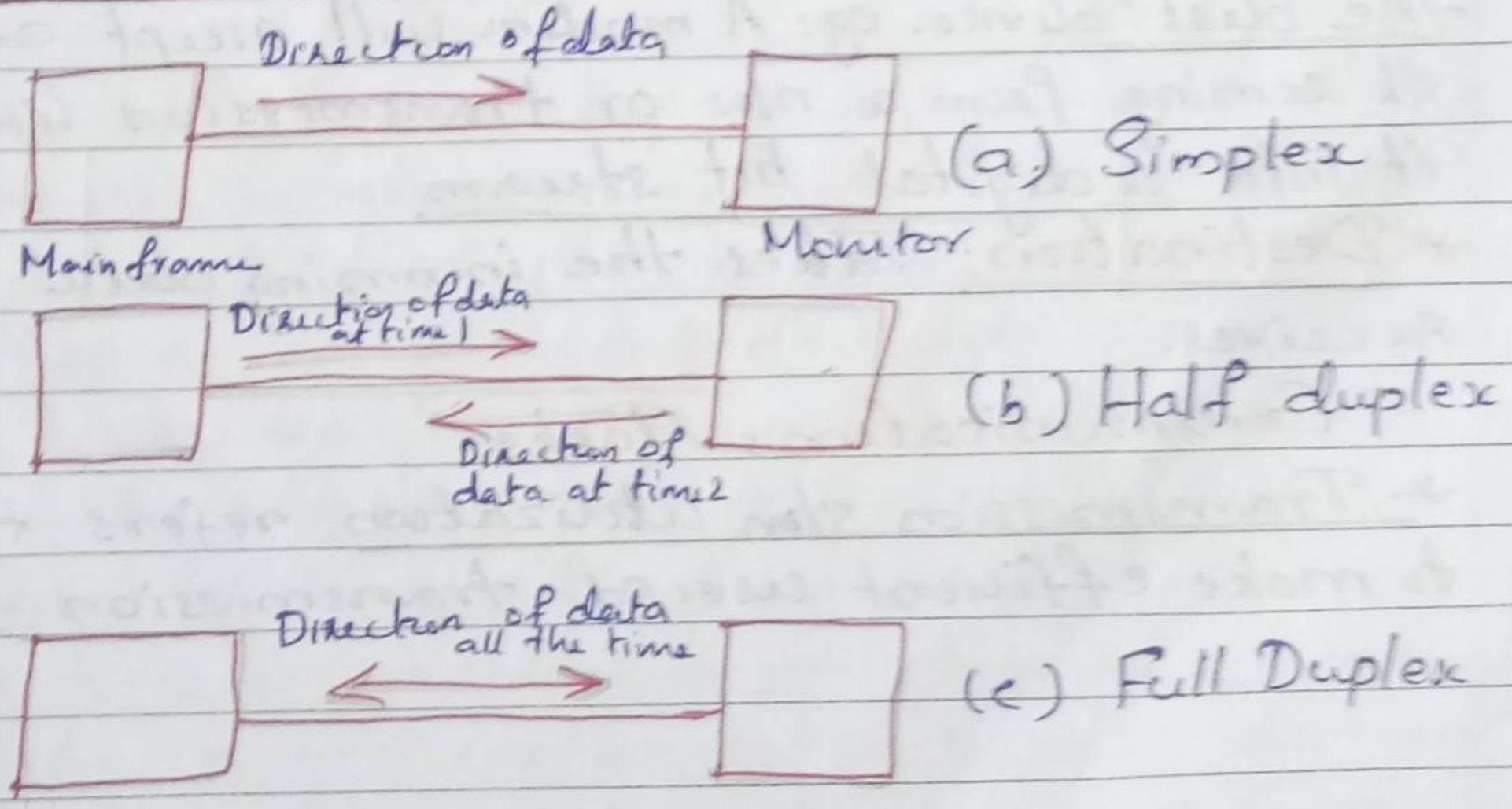
Both stations can transmit & receive simultaneously. Signals going in one direction share the capacity of the link with sls going in other direction.

This sharing can occur in two ways: Either the link must contain 2 physically separate transmn paths one for sending & the other for receiving.

The capacity of the channel is devided blw sls traveling in both directions

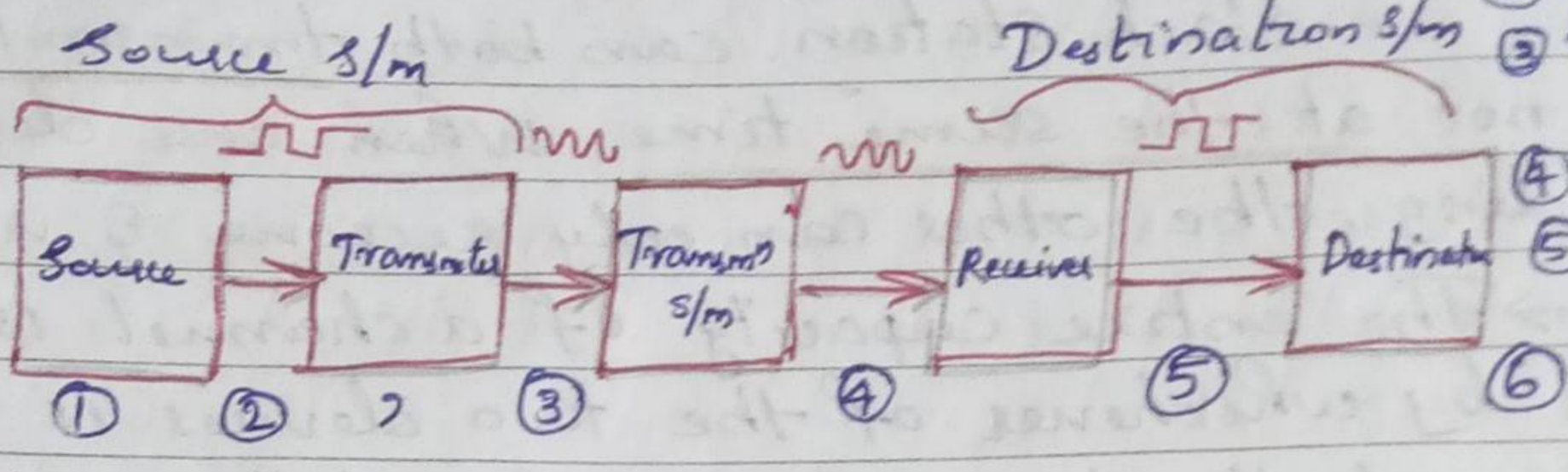
eg: telephone slw - both can talk & listen at the same time.

The capacity of ~~ca~~ channel must be devided blw the 2 directions.



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> Communication Model



Key elements:

* Source: generates the data to be transmitted.
  eg: telephones & PCs.
* Transmitter: Transmitter transforms & encodes the inf^n in such a way as to produce electromag s/ls that can be transmitted across some sort of transmission s/m. Eg: a modem takes a g digital bit stream from an attached device such as a PC & transforms that bit stream into an analog s/l that can be handled by the telephone n/w.
* Transmission s/m: A single transm^n line or a complex n/w connecting source & dest^n.
* Receiver: Accepts the s/l from the transm^n s/m & converts it into a form that can be handled by the dest^n device. eg: A modem will accept an analog s/l coming from a n/w or transmission line & convert it into a digital bit stream.
* Destination: Takes the incoming data from the receiver.

Communications Tasks:

* Transmission s/m utilization: refers to the need to make efficient use of transmission facilities

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that are typically shared among a no. of communicating devices.

* Interfacing: i/f with the transmission s/m.
- electromagnetic s/ls propagated over a transmission medium.

* S/l generation: The properties of the s/l, such as form & intensity, must be such that the s/l is
1) capable of being propagated through the transm^n s/m & 2) interpretable as data at the receiver

* Synchronization: b/w transmitter & receiver.

* Exchange Mgmt: If data are to be exchanged in both directions over a period of time, the 2 parties must cooperate. For eg:, for 2 parties to engage in a telephone conversation, one party must dial the no. of the other, causing s/ls to be generated that result in ringing of the called phone. The called party completes a conn^n by lifting the receiver.

* Error detection & Correction: - errors cannot be tolerated.

* Flow Control: to assure that the source doesn't overwhelm the dest^n by sending data faster than they can be processed & absorbed.

* Addressing & Routing: When more than 2 devices share a transm^n facility, a source s/m must indicate the identity of the intended dest^n. The transm^n s/m must assure that the dest^n s/m, & only that s/m, receives the data. - The transm^n s/m may itself be a n/w through which various paths may be taken. A specific route through this n/w must be chosen.

* Recovery: techniques are needed in situations in which an inf^n exchange, such as a db trans^n or file transfer, is interrupted due to a fault in th s/m.

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* Msg formatting: has to do with an agreement b/w 2 parties as to the form of the data to be exchang or transmited, such as the binary code for characte
* Security: Only intended receiver actually receives the data. And the receiver of data — the receive data have not been altered in transit & that the data actually come from the purported sender.
* N/w Mgmt: — configure the s/m, monitor its status, react to failures & overloads & plan for future growth.

> Periodic Analog Signals:

* Prerequisite *⇒ Physical Layer

→ One of the major functions of the phy. layer is to move data in the form of electromagnetic s/ls across a transmission medium. The data usable to a person or appl^n are not in a form that can be transmitted over a n/w. For eg: a photograph must first be changed to a form that transmission media can accept. Transmission media work by conducting energy along a physical path. For transmission, data needs to be changed to s/ls.

→ Periodic s/l completes a pattern within a measurable time frame, called a period & repeats that pattern over subsequent identical periods. The completion of one full pattern is called a cycle.

→ A non periodic s/l changes without exhibiting a pattern or cycle that repeats over time.

— Commonly use periodic analog s/ls & non periodic digital s/ls.

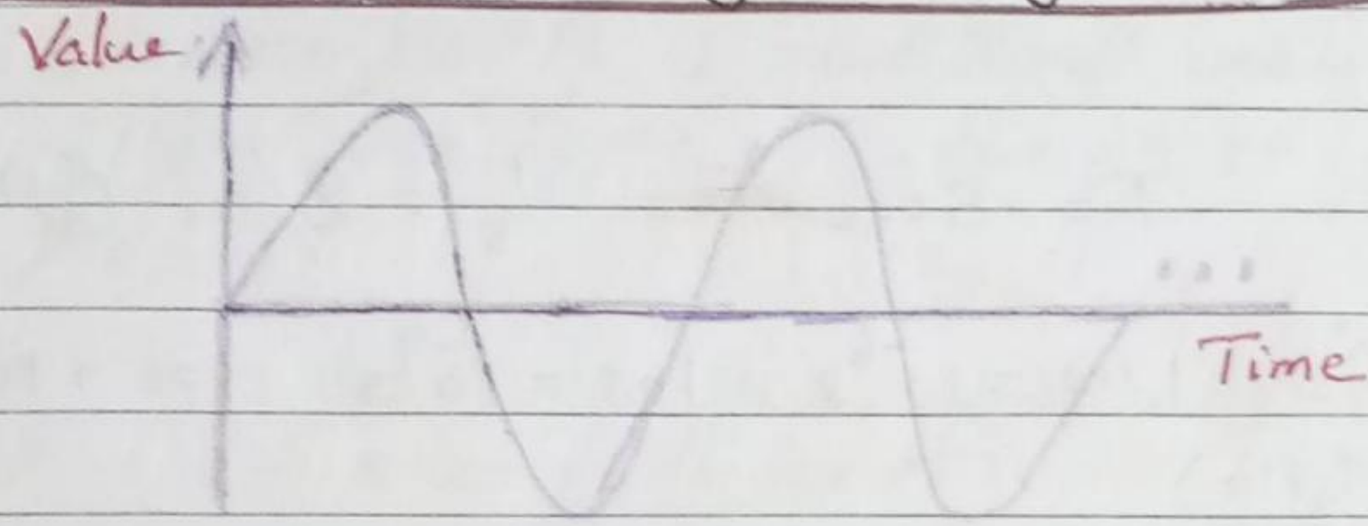
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Periodic analog s/ls can be classified as simple or composite. A simple periodic analog s/l, a sine wave cannot be decomposed into simpler s/ls. A composite periodic analog s/l is composed of multiple sine waves.

*) Sine Wave:

→ simple oscillating curve, consistent & continuous change over the course of a cycle.

→ Each cycle consists of a single arc above the time axis followed by a single arc below it.



A sine wave can be represented by 3 parameters
* the peak amplitude * frequency * Phase.

Peak Amplitude: of a s/l is the absolute value of its highest intensity, proportional to the energy it carries. For electric s/ls, peak amplitude measured in volts.

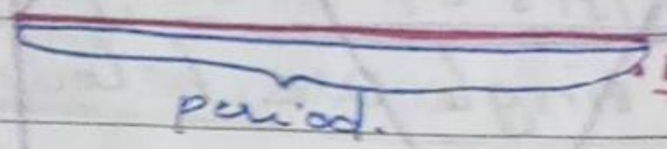
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Period & Frequency:

Period refers to the amt. of time, in sec. a s/l needs to complete 1 cycle

Frequency refers to the no. of periods in 1s.

$$f = \frac{1}{T} \; ; \; T = \frac{1}{f}$$



$T = .5 \text{ sec} \quad F = \frac{1}{.5} = 2/\text{sec.} \; (Hz)$

Period (s)

$1ms = 10^{-3}s \quad 1\mu s = 10^{-6}s \quad 1ns = 10^{-9}s \quad 1ps = 10^{-12}s$

Frequency (Hz)

$1KiloHz = 10^3 Hz \quad 1MHz = 10^6 Hz \quad 1GHz = 10^9 Hz \quad 1THz \; 10^{12} Hz$

Eg: The power at home fr. of 60Hz. The period of sine wave ?

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166s = 0.0166 \times 10^3$$

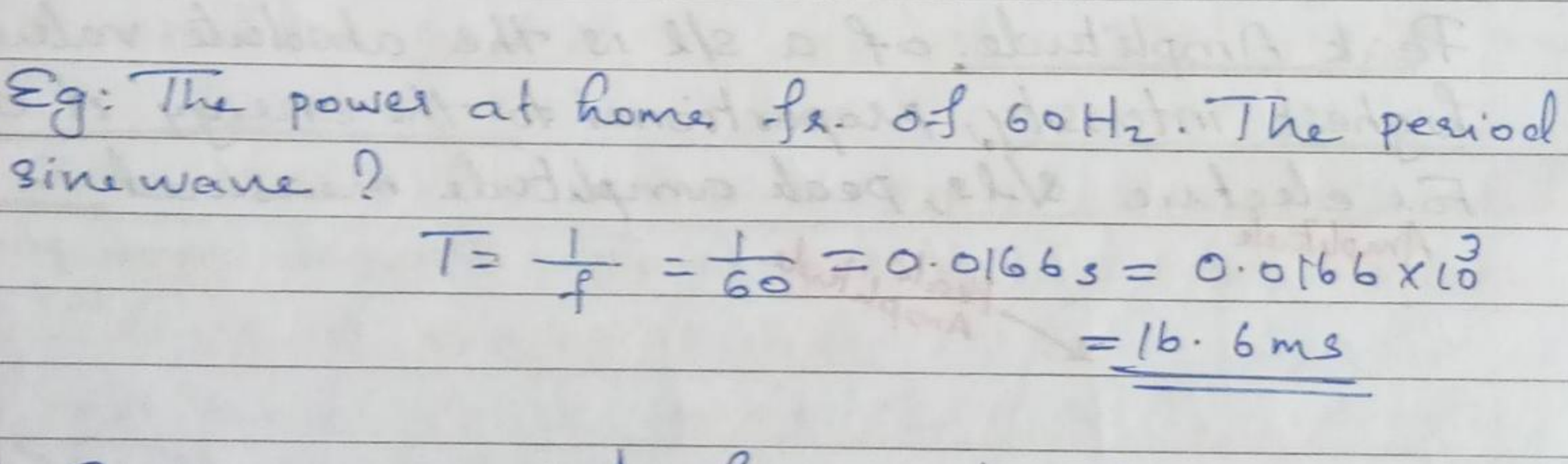
$$= \underline{16.6 ms}$$

2. Express a period of 100ms in μsec.

$100ms = 100 \times 10^{-3}s = 100 \times 10^{-3} \times 10^6 \mu s = 100 \times 10^3 \mu s$

$= 10^2 \times 10^3 \mu s = \underline{10^5 \mu s}.$

3.



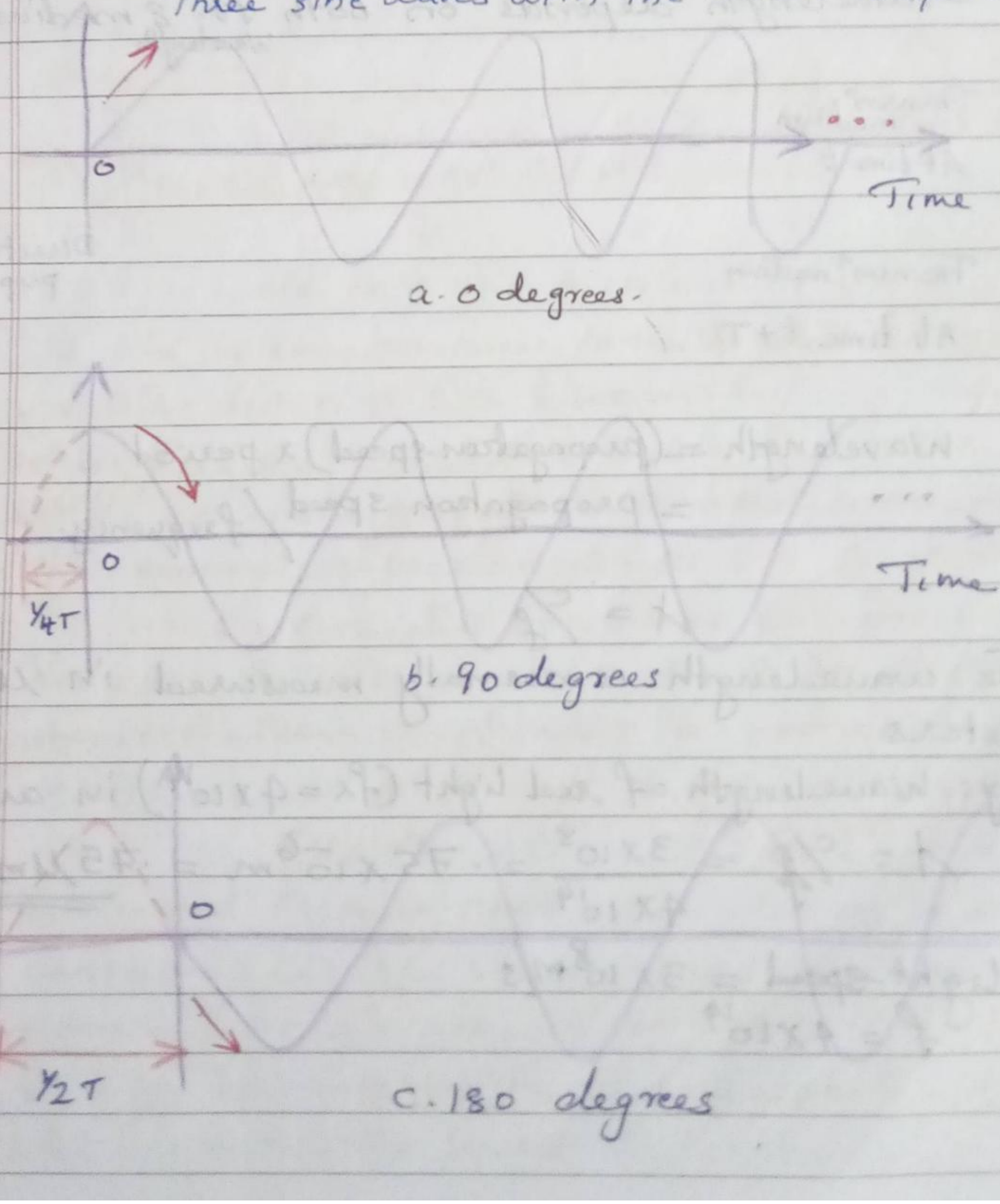
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*> Phase:

- describes the pos^n of waveform relative to time 0. If the wave as something that can be shifted backward or forward along the time axis, phase describ the amount of that shift. It indicates the status of the first cycle. Phase is measured in degrees or radians [360° — 2π rad ; 1° — 2π/360 rad; 1 rad — 360/2π].

- A phase shift of 360° corresponds to a shift of a complete period; Phase shift of 180° corres to a shift of one half of a period; & a phase shift of 90° corresponds to a shift of one-quarter of a period.

Three sine waves with the same amplitude & fr. but diff. phases.



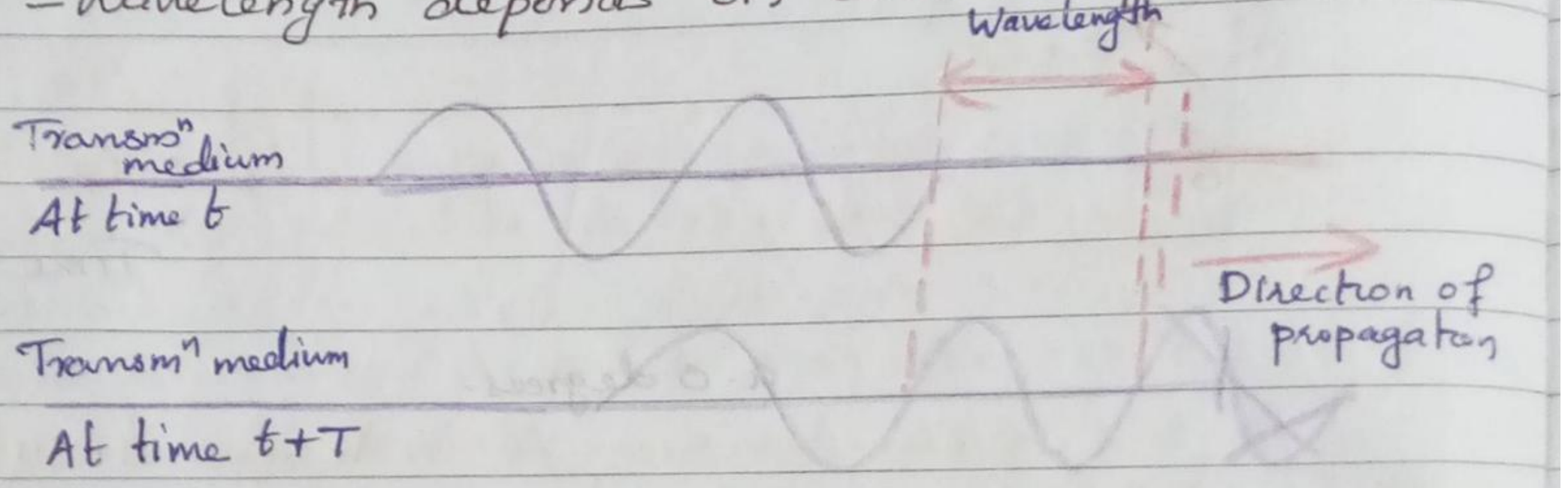
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a) A sine wave with a phase of 0° at time 0 with a zero amplitude. Amplitude ↑
b) A sine wave with a phase of 90° starts at time 0 with a peak amplitude. Amplitude ↓ (1/4 cycle shift left)
c) A sine wave with a phase of 180° starts at time 0 with a zero amplitude. Amplitude ↓ (1/2 cycle shift left).

*> Wavelength:

— property of a s/l traveling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium.

- Wavelength depends on both fr. & medium.



Wavelength = (propagation speed) x period
= propagation speed / frequency.

$$\lambda = c/f$$

The wavelength is normally measured in μm instead of meters.

Eg: Wavelength of red light ($f_r = 4 \times 10^{14}$) in air is

$$\lambda = c/f = \frac{3 \times 10^8}{4 \times 10^{14}} = .75 \times 10^{-6} m = .75 \mu m$$

// light speed = 3×10^8 m/s.
$f = 4 \times 10^{14}$

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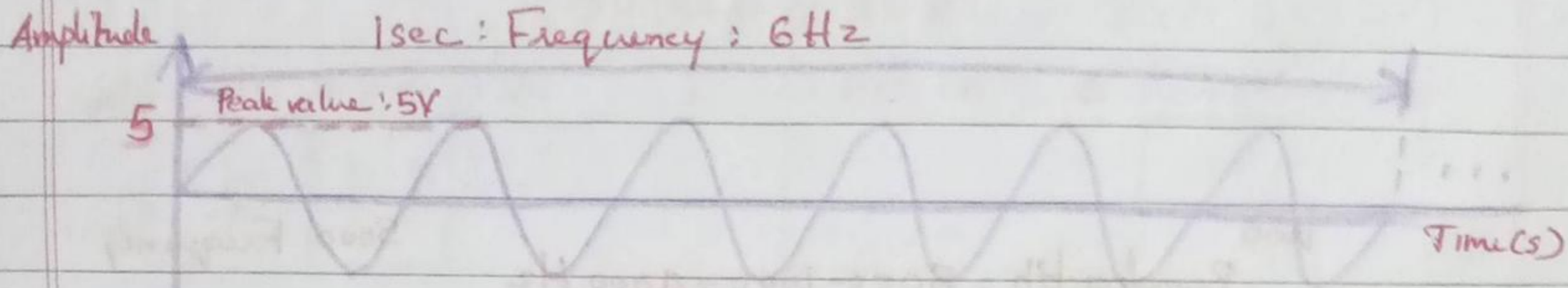
*> Time and Frequency Domains:

Time domain plot:

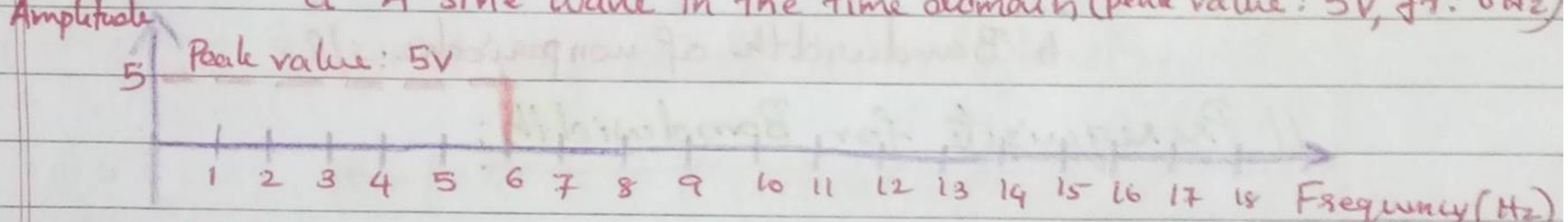
The time domain plot shows changes in s/l amplitude w.r.to time. Phase is not shown on a time domain plot.

Frequency Domain plot:

- shows relationship b/w amplitude & fr.
- is concerned with only the peak value & the fr. Changes of amplitude during one period are not shown.



a. A sine wave in the time domain (peak value : 5V, fr: 6Hz)



b. The same sine wave in the fr domain (peak value : 5V
fr : 6Hz)

Adv: Frequency domain:

→ easy to plot. → immediately see the values of the frequency & peak amplitude.

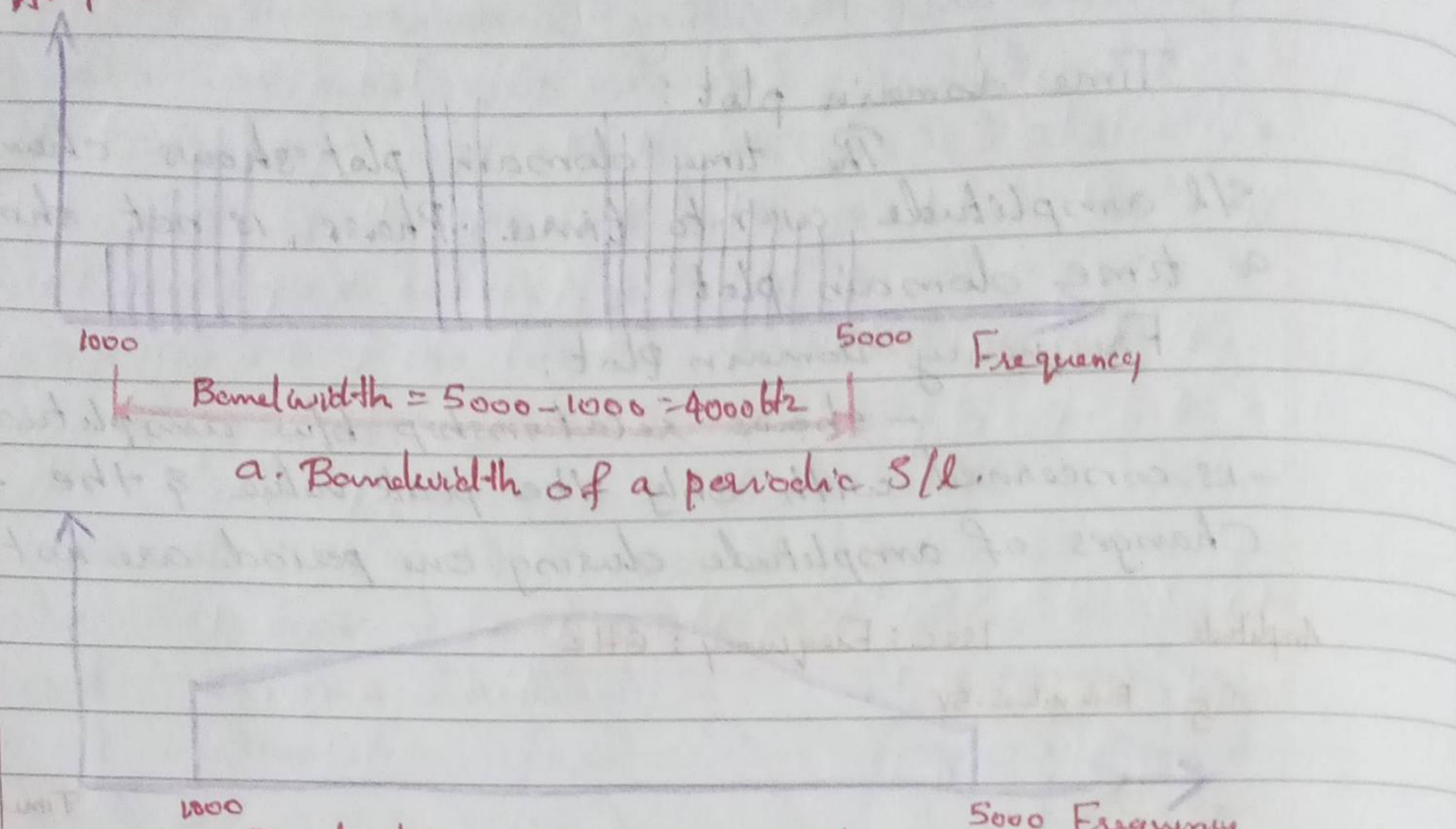
→ A complete sine wave is represented by one spike The posⁿ of the spike shows the frequency, its height shows the peak amplitude.

*> Bandwidth:

Bandwidth is the range of frequencies contained in a composite s/l. For eg: If a composite s/l contains fr. b/w 1000 & 5000, its bandwidth is 5000 − 1000 or 4000.

→ The bandwidth of a composite s/l is the diff. b/w highest & the lowest fr. contained in that s/l.

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a. Bandwidth of a periodic s/l.

1000 5000 Frequency

Bandwidth = 5000 - 1000 = 4000 Hz

b. Bandwidth of nonperiodic s/l.

II Prerequisite for Bandwidth:

Composite Signals:

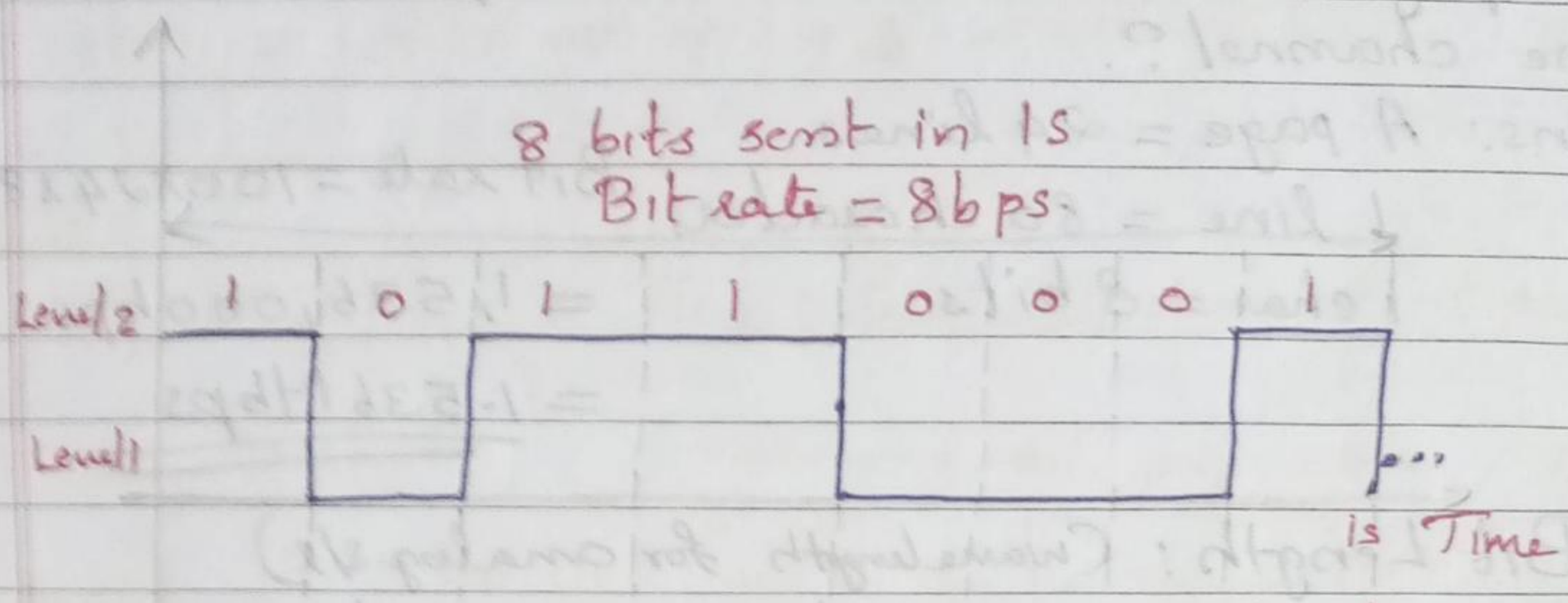
A composite s/l is made of many simple sine waves. A composite s/l is a combination of simple sine waves with diff. frequencies, amplitudes & phases If composite s/l is periodic, the decompos° gives a series of s/ls with discrete frequencies; if the composite s/l is nonperiodic, the decomposition gives a combination of sine waves with cont. frequencies.

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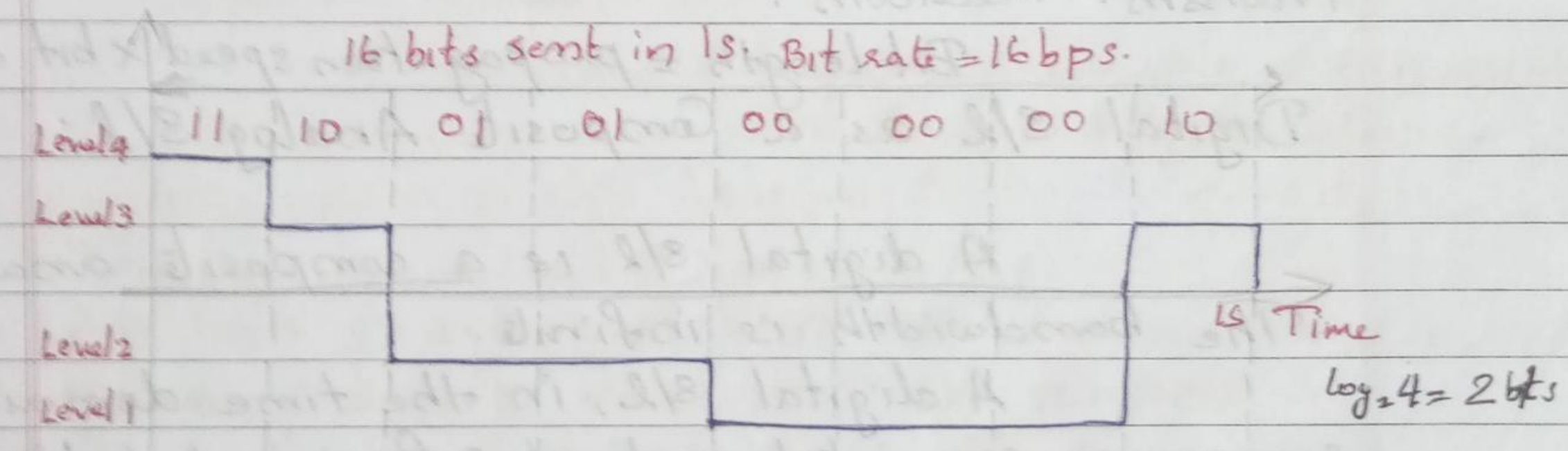
*) Digital Signals:

Information can also be represented by a digital s/l. (a 1 can be encoded as a +ve voltage & a 0 as zero voltage).

A digital s/l can have more than 2 levels. In this case, Here, we can send more than 1 bit for each level.



a. A digital s/l with 2 levels.



b. A digital s/l with 4 levels.

If a s/l has L levels, each level needs $\log_2 L$ bits.

Eg: A digital s/l has 8 levels. How many bits are needed per level?

No of bits = $\log_2 8$ = 3 bits.

A digital s/l has 9 levels. How many bits are needed per level? $\log_2 9 = 3.17$ bits (not realistic) so 4 bits

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Bit Rate:

Digital s/ls are non periodic. Bit rate (instead of frequency) is used to describe digital s/ls. The bit rate is the no. of bits sent in 1s, expressed in bits per second.

Eg: We need to download text doc at the rate of 100 pages/sec. What is the required bit rate of the channel?.

Ans: A page = 24 lines
1 line = 80 characters
1 char = 8 bits

Bit rate = 100x24x80x8
= 1,536,000 bps
= 1.536 Mbps

Bit Length: (wavelength for analog s/l)

- is the distance one bit occupies on the transmn medium.

Bit length = propagation speed x bit duration

Digital s/l as a Composite Analog s/l:

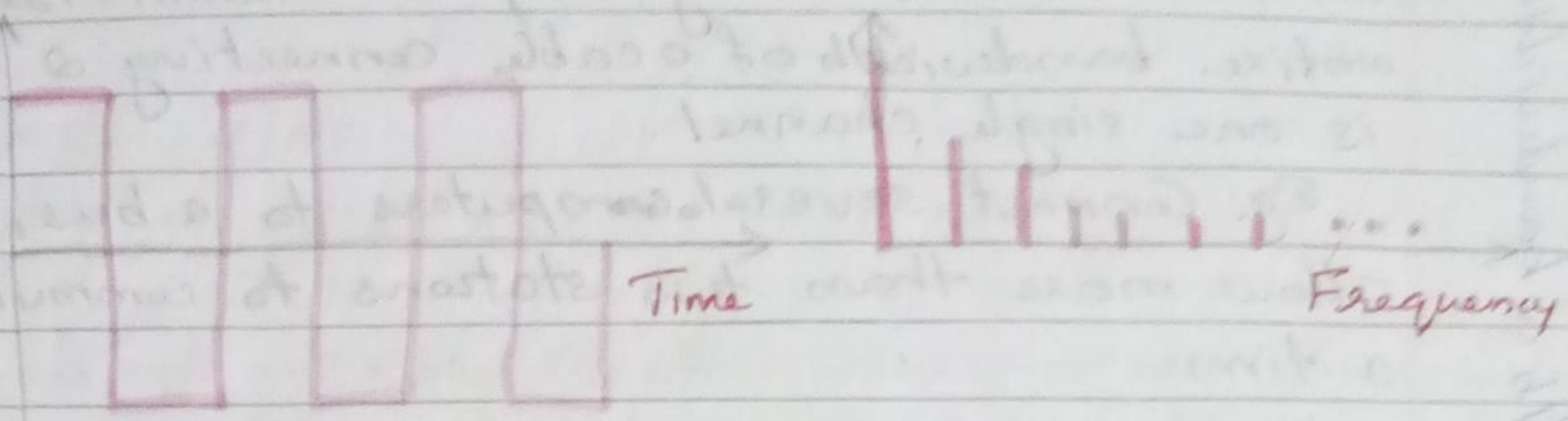
A digital s/l is a composite analog s/l
- The bandwidth is infinite.

A digital s/l, in the time domain, comprises connected vertical & horizontal ~~line~~ line segments. A vertical line in the time domain means a fr. of infinity (sudden change in time); A horizontal line in the time domain means a freq. of zero (no change in time).

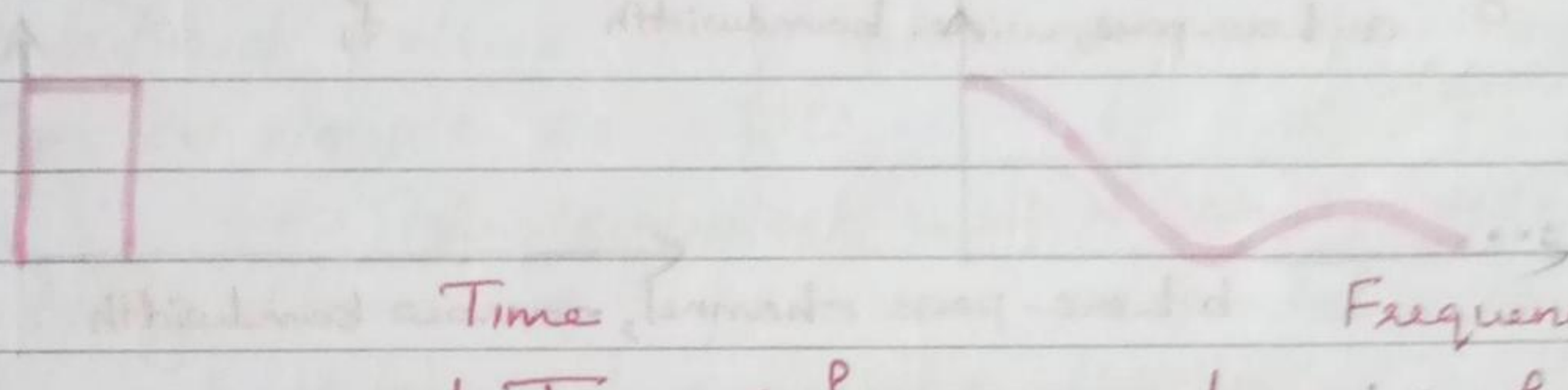
Fourier analysis - to decompose a digital s/l. If the digital s/l is periodic, which rare in data commn, the decomposed s/l has a fr. - domain rep^n with an infinite bandwidth & discrete fr.

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If the digital s/l is non periodic, the decomposed s/l still has an infinite bandwidth, but the frequencies are continuous.



a. Time & frequency domains of periodic digital s/l.



b. Time & frequency domains of non periodic digital s/l.

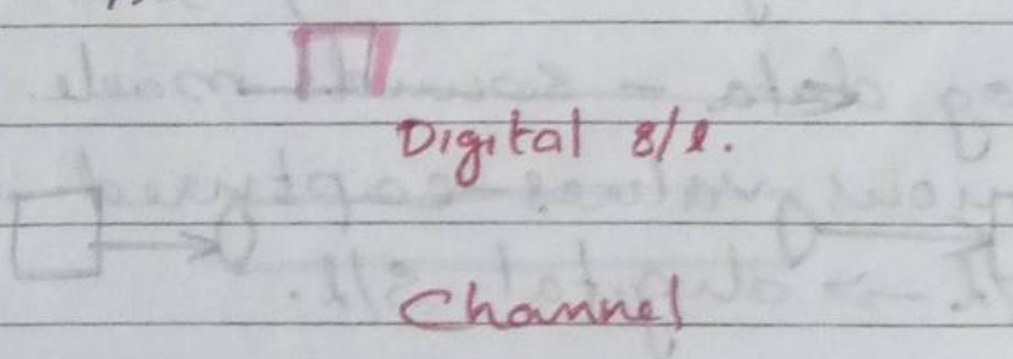
Transmission of Digital s/ls.

A g digital s/l can be transmitted by using one of two diff. approaches:

* Base band transmission or
  Broad band transmission.

→ Baseband Transmission:

- means sending a digital s/l over a channel without changing the digital s/l to an analog s/l.



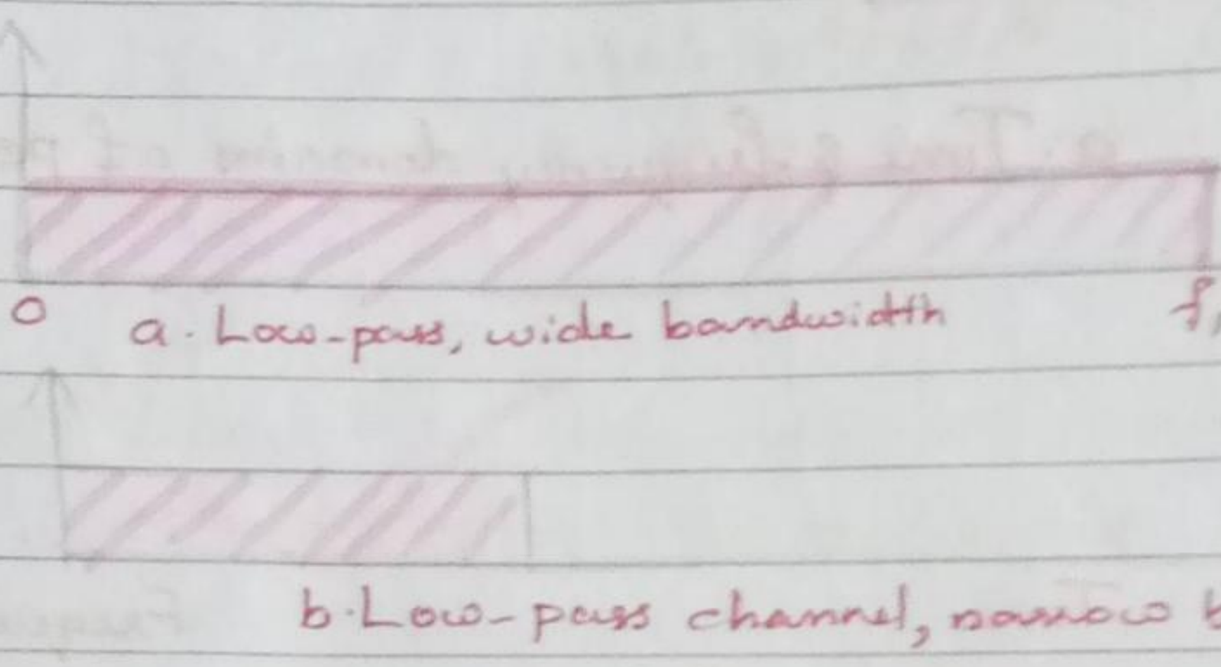
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Changing the digital s/l to an analog s/l or modulation means a bandpass channel with a bandwidth that doesn't start from zero.

Broadband transmn ⇒ used for transmn. of digital s/l that starts from zero.

Baseband transmission requires that we have a low-pass channel - A channel with a bandwidth that starts from zero. - A dedicated medium with bandwidth constituting only one channel. For eg: the entire bandwidth of a cable connecting 2 computers is one single channel.

Eg: Connect several computers to a bus, but not allow more than two stations to communicate at a time.



> * Digital Data Transmission:

→ Analog & Digital Data:

- Analog data refers to inf^n that is continuous:

- Digital data refers to inf^n that has discrete states.

Eg: Analog clock that has hour, minute & second hands gives inf^n in a cont. form; the movements of the hands are continuous.

Digital clock that reports the hours & the minutes will change suddenly from 8:05 to 8:06

Analog data - sounds made by a human voice - continuous values - captured by microphone → analog s/l → digital s/l.

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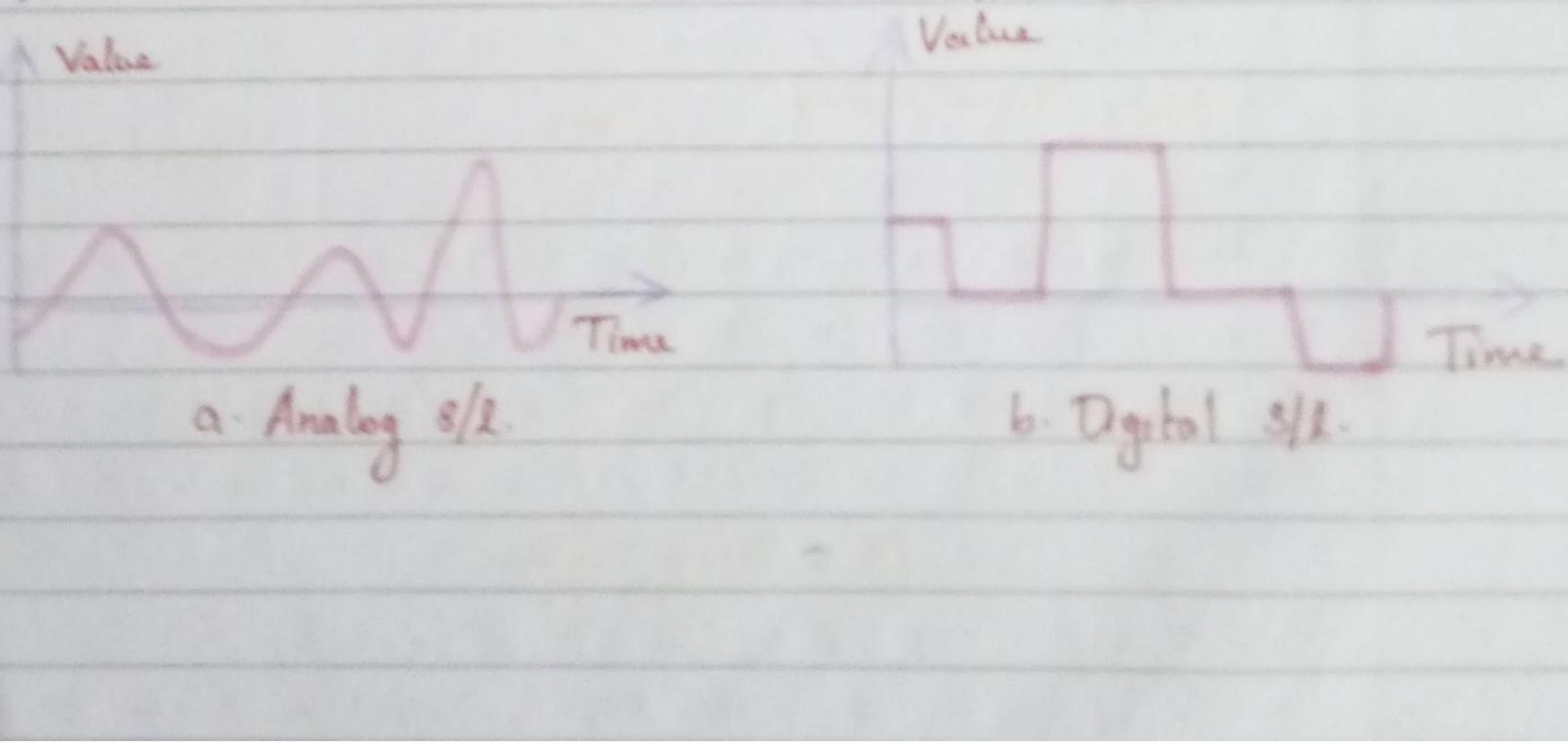
Digital data take on discrete values. Eg: data are stored in comp memory in the form of 0s & 1s. They can be converted to a digital s/l or modulated into an analog s/l for transm^n across a medium.

* → Analog & Digital signals:

→ S/ls can be either analog or digital. An analog s/l has infinitely many levels of intensity over a period of time. As the wave moves from value A to value B, it passes through & includes an infinite no of values along its path.

→ A digital s/l can have only a limited no. of defined values. Each value can be any no, it is often as simple as 1 & 0.

→ The simplest way to show s/ls is by plotting them on a pair of perpendicular axes. The vertical axis represents the value or strength of a s/l. The horizontal axis represents time.



a. Analog s/l.

b. Digital s/l.

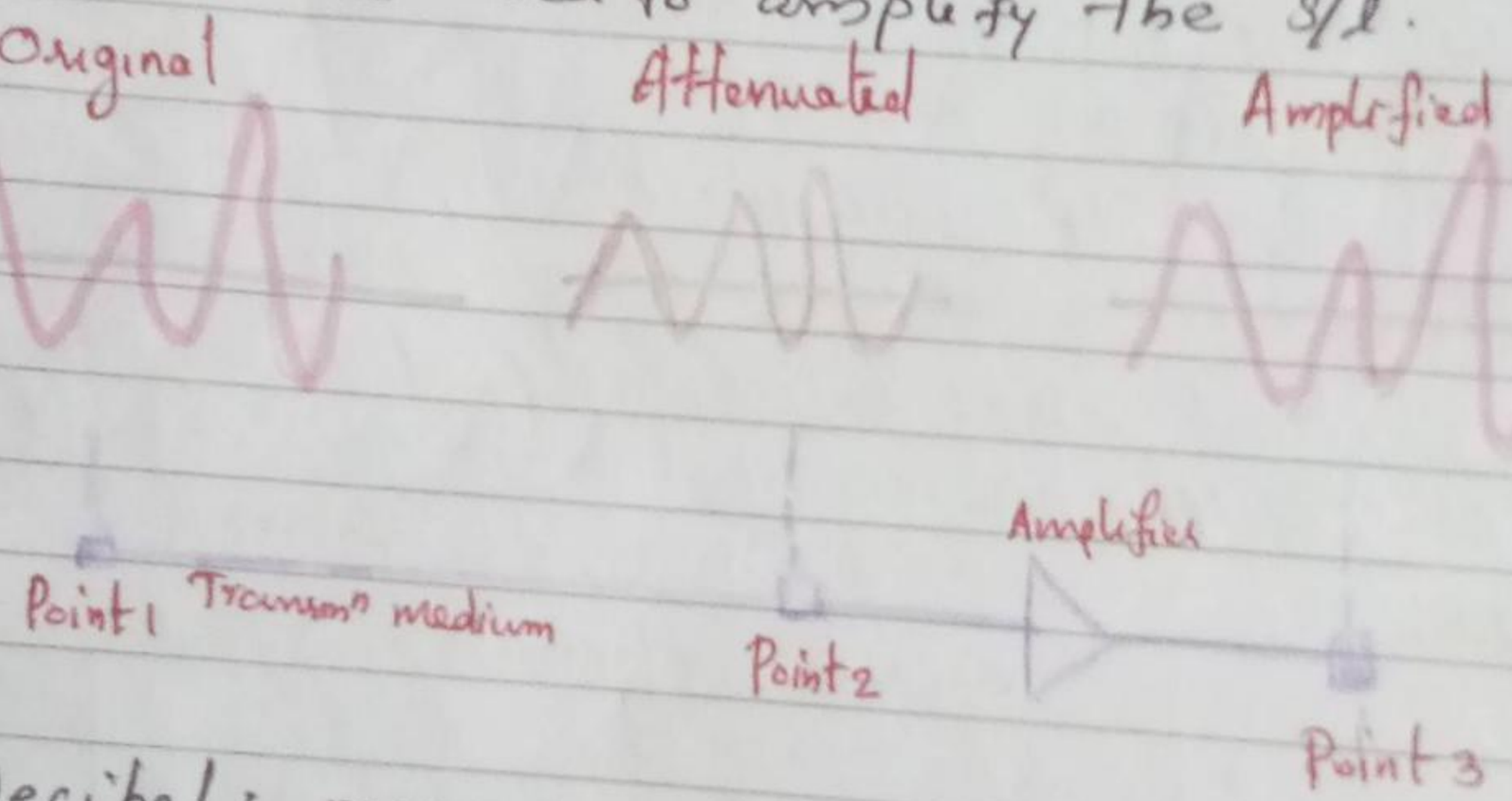
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* → Transmission Impairment

S/l impairment means that the S/l at the begining of the medium is not the same as the S/l at the end of the medium. Three causes of impairment are * attenuation * distortion * noise.

* → Attenuation:

— means loss of energy. When a S/l, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium ie; why wire carrying electric S/ls gets warm, if not hot, after a while. Some of the electrical energy in the S/l is converted to heat. To compensate for this loss, amplifiers are used to amplify the S/l.



Decibel: measures the relative strengths of 2 S/ls or one s/l at two diff. points.

dB is negative if a s/l is attenuated.
dB is positive if a s/l is amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$P_1 = P_2$ = powers of a s/l at pts. 1 & 2.

Eg: A s/l travels through a transm^n medium & its power is reduced to one-half. $P_2 = \frac{1}{2} P_1$ - Attenuation = ?

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{.5 P_1}{P_1} = 10 \log_{10} .5 = 10 (-0.3)$$

$$= -3 \text{ dB}$$

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Eg: A s/l travels through an amplifier, & its power is increased 10 times. This means that $P_2 = 10P_1$.
The amplific" = ?

$$10\log_{10}\frac{P_2}{P_1} = 10\log_{10}\frac{10P_1}{P_1} = 10\log_{10}10 = 10(1) = \underline{10dB}$$

Eg: Decibel is used to measure s/l power in milliwats. It is refersed to as dB_m & is calculated as $dB_m = 10\log_{10}P_m$ where P_m is the power in milliwatts. Calculate the power of a s/l if its $dB_m = -30$.

$dB_m = 10\log_{10}P_m$; $\rightarrow dB_m = -30 \rightarrow 10\log_{10}P_m = -30$

$$\log_{10}P_m = \frac{-30}{10} = -3 \rightarrow P_m = \log_{10}^{-1}(-3) = \underline{10^{-3}mW}.$$

Eg: The loss in a cable is usually defined in decibels/km. If the s/l at the begining of a cable with -0.3 dB/km has a powes of 2mW; what is the power of the signal at 5km?

$dB = x0x\log_{10}P_2/P_1 =$

The loss in a cable of 5km = $5 \times (-0.3) = -1.5$ dB.

$dB = 10\log_{10}P_2/P_1 = -1.5$ $\quad \log_{10}P_2/P_1 = \frac{-1.5}{10} = -0.15$

$P_2/P_1 =$

$P_1 = 2mW$ $\quad P_2/P_1 = 10^{-0.15} = \underline{0.71}$

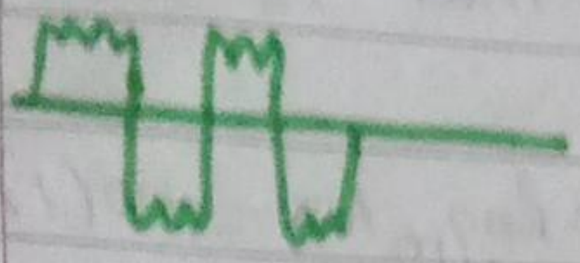
$$P_2 = 0.71P_1 = 0.71 \times 2mW = \underline{1.4mW}$$

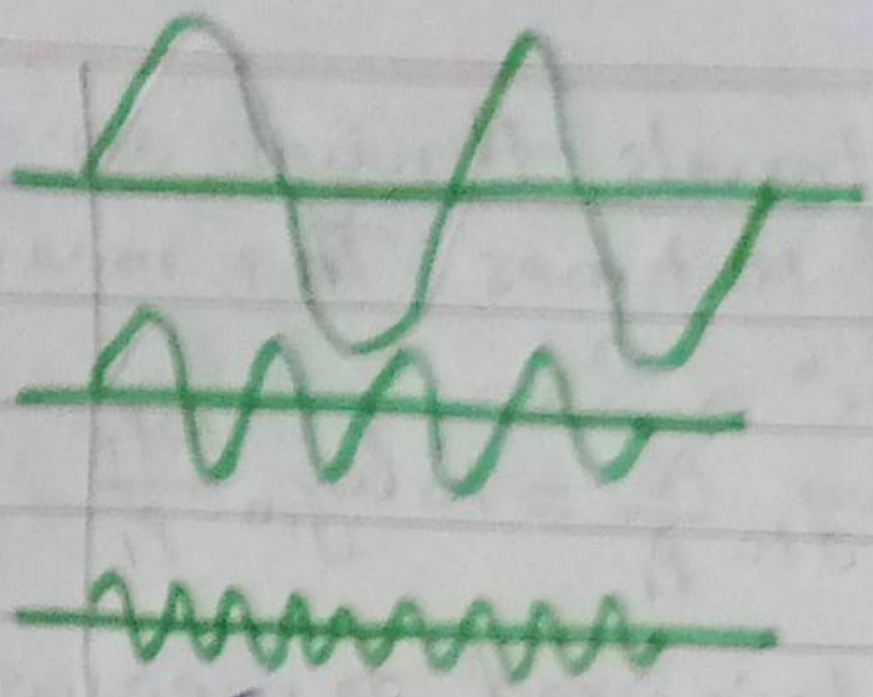
* $\rightarrow$ Distortion:

Distortion means that the s/l changes its form or shape. Distortion can occur in a composite s/l made of diff. frequencies. Each s/l component has its own propagation speed through a medium & $\therefore$ its own delay in arriving at the final destination. s/l components at the receiver have phases diff. from what they had at the sender.

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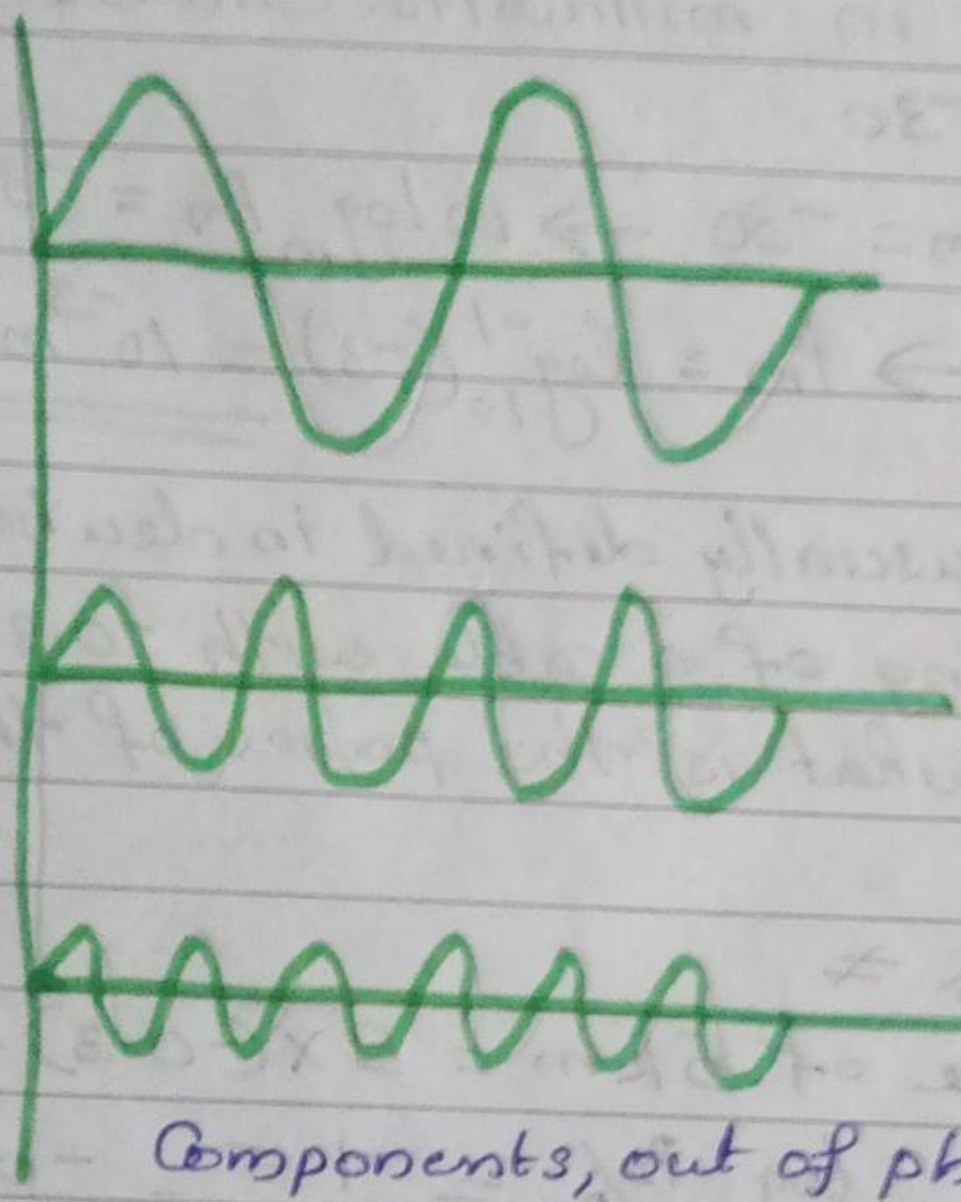
Composite s/l sent



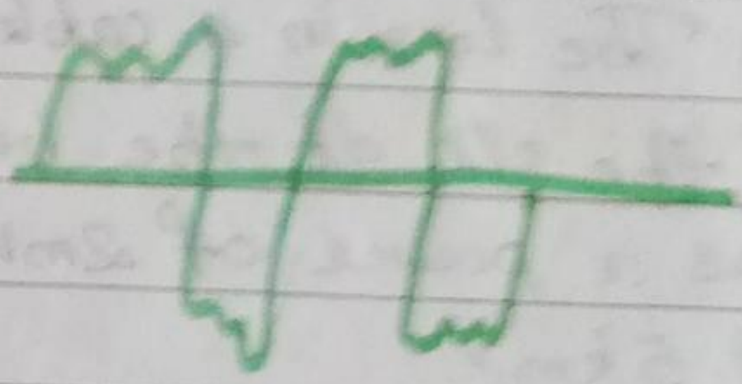


(Components, in phase)

At the sender

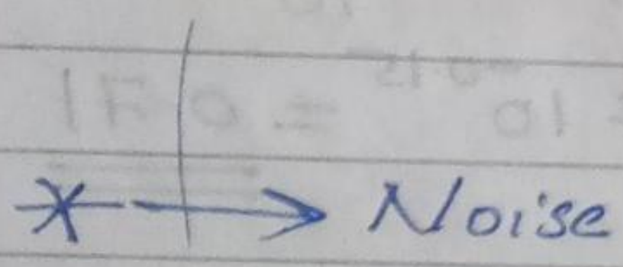


Composite s/l received



Components, out of phase

At the receiver



For any data transmn event, the received s/l will consist of the transmitted s/l, modified by the various distortions imposed by the transmn s/m plus additional unwanted s/ls that are inserted somewhere blw transmn & reception. The unwanted s/ls are referred to as noise.

Noise may be divided into 4 categories:

* Thermal noise * Intermodulation noise
* Crosstalk * Impulse noise.

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> Thermal noise: due to thermal agitation of electrons. Thermal noise is uniformly distributed across the bandwidths typically used in comm^{n} s/ms & hence is referred to as white noise.

The amount of thermal noise to be found in a bandwidth of 1Hz in any device or conductor is

$$N_0 = kT \text{ (W/Hz)} \quad (\text{Unit} = \text{Joule})$$

where N_0 = noise power density in watts/1 Hz of bandwidth.

k = Boltzmann's constant $= 1.38 \times 10^{-23}$ J/K

T = temperature, in kelvins., where tha

> Intermodulation noise: When s/ls at diff. frequencies share the same transm^{n} medium, the result may be intermodulation noise. The effect of intermodulation noise is to produce s/ls at a fr. that is the sum of diff. of two original f_1 & f_2 might produce energy at the freq. $f_1 + f_2$. This desired s/l could interfere with an intended s/l at the fr. $f_1 + f_2$.

~~> Cross talk: has been experienced~~

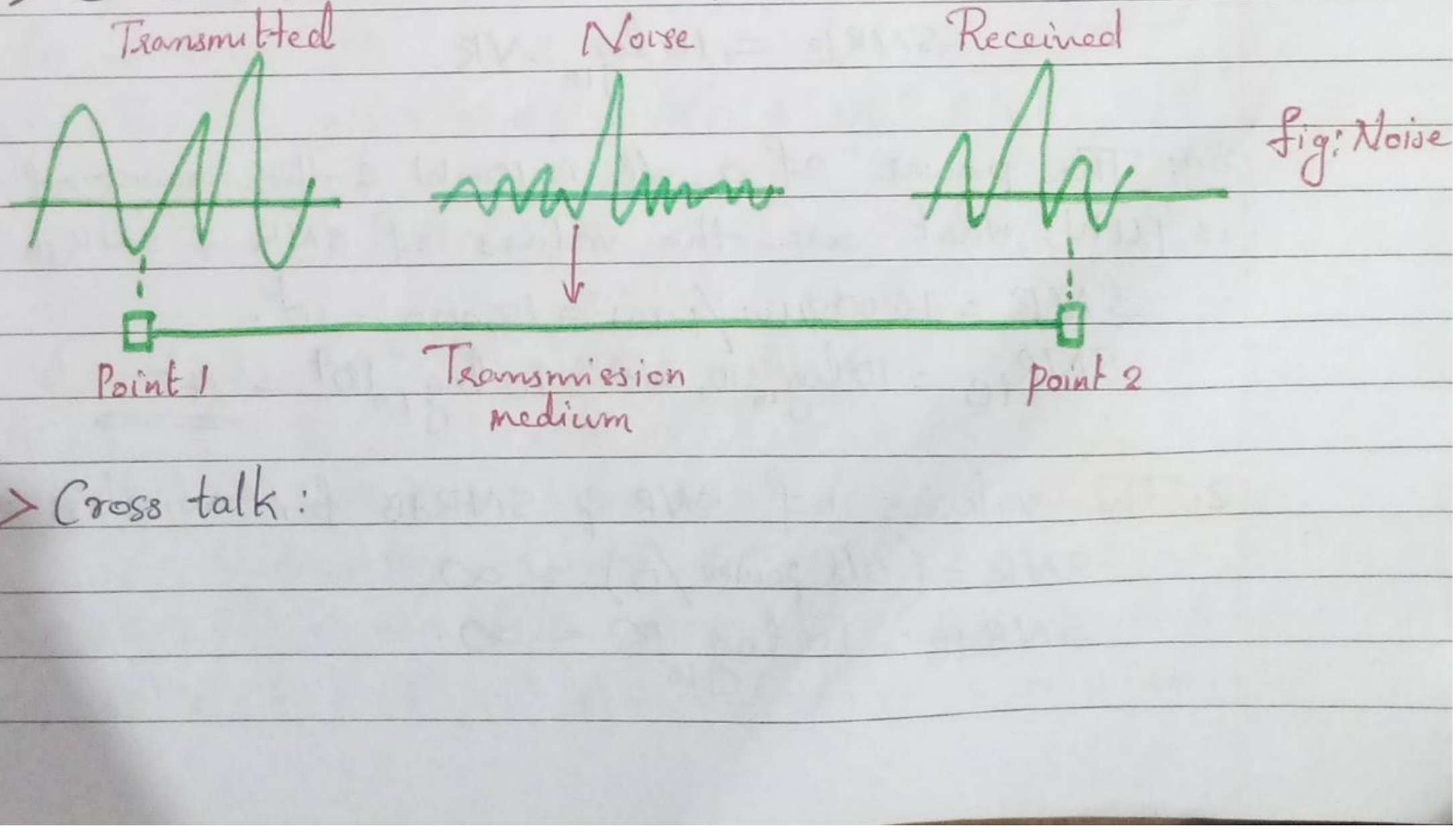


fig: Noise

> Cross talk:

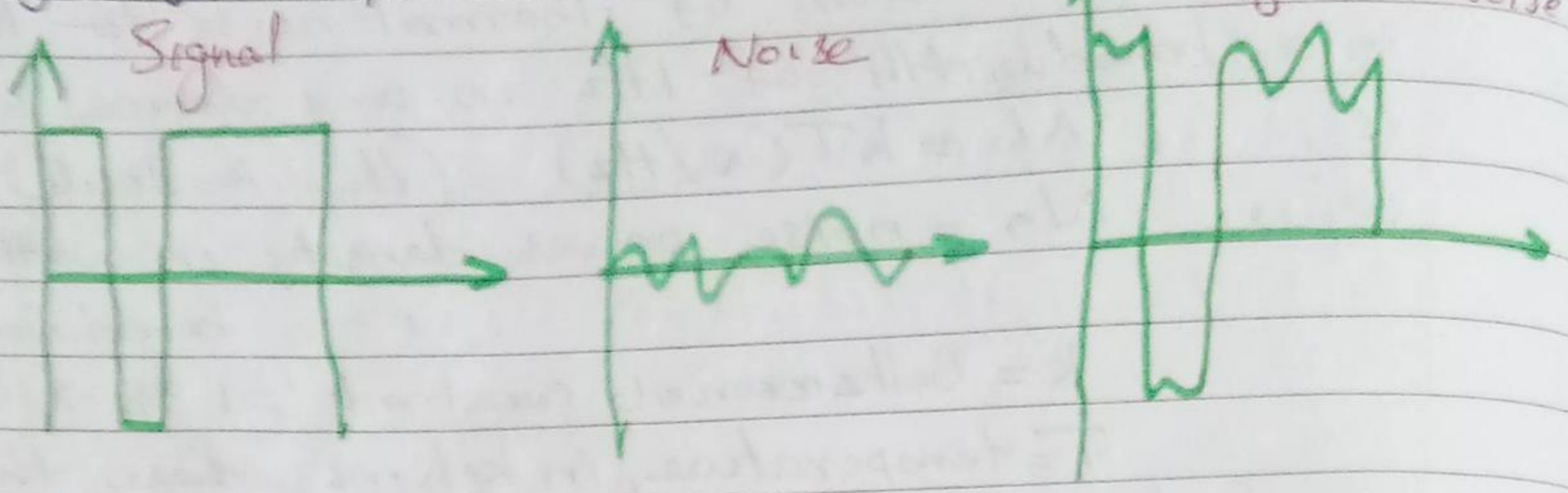
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Signal-to-Noise Ratio (SNR)

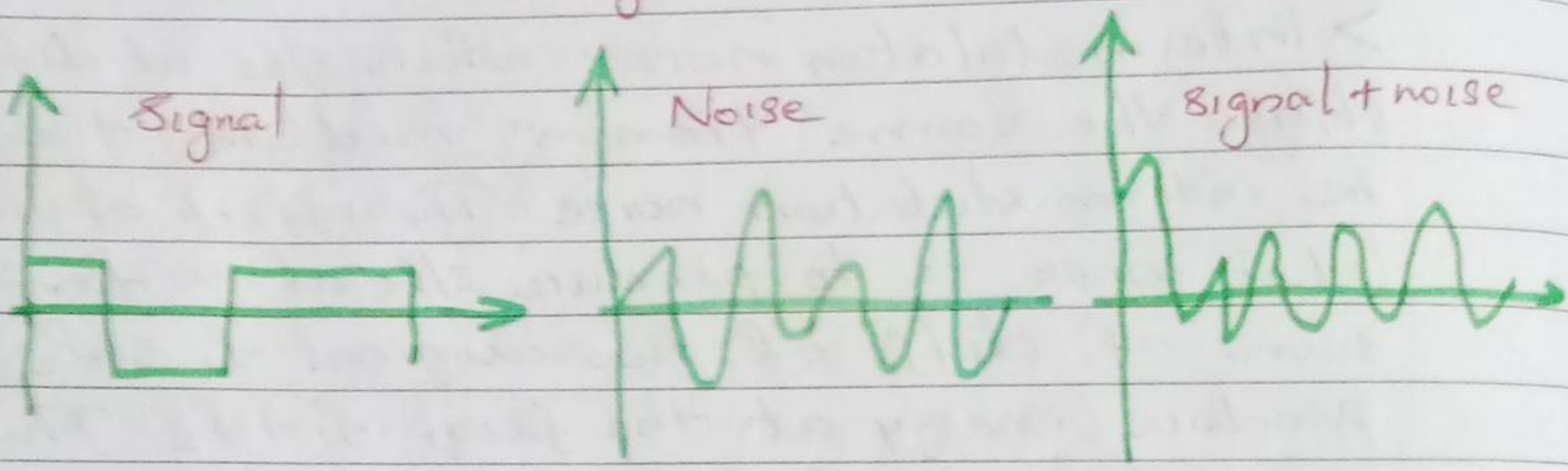
→ Ratio of s/l power to noise power.

$$SNR = \frac{\text{avg s/l power}}{\text{avg noise power}}.$$

Fig: High SNR & low SNR:



a. High SNR.



b. Low SNR

SNR is described in decibel units,

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

Eg: The power of a s/l is 10mW & the power of the noise is 1μW; what are the values of SNR & SNR_{dB}?

$SNR = 10000\mu W / 1\mu W = 10,000 = 10^4$.

$SNR_{dB} = 10 \log_{10} 10,000 = 10 \log_{10} 10^4 = \underline{40}$

2. The values of SNR & SNR_{dB} for noiseless channel?

$SNR = (\text{s/l power}/0) = \infty$

$SNR_{dB} = 10 \log_{10} \infty = \infty$.

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*> Channel Capacity: (Data Rate)

→ how fast data can be sent, in bits/sec over a channel. Data rate depends on:

1. The bandwidth available
2. The level of s/ls
3. The qlty of the channel (level of noise).

Two theoretical formulas were developed to calculate data rate: Nyquist for a noiseless channel & Shannon for a noisy channel.

→ Noiseless Channel: Nyquist Bit Rate:

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L.$$

⇒ bandwidth is the bandwidth of the channel,
⇒ L is the no. of s/l levels to represent data.
⇒ BitRate is the bit rate in bits/sec.

Eg: Consider the noiseless channel with a bandwidth of 3000Hz transmitting a s/l with 2 signal levels. Calculate the max. bit Rate.

$$\text{BitRate} = 2 \times 3000 \times \log_2 2 = \underline{6000 \text{ bps}}.$$

2) We need to send 265 kbps over a noiseless channel with a bandwidth of 20kHz. How many s/l levels do we need.?

$$\text{BitRate} = 2 \times \text{bandwidth} \times \log_2 L.$$

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\log_2 L = \frac{265{,}000}{2 \times 20{,}000} = 6.625$$

$$L = 2^{6.625} = \underline{98.7 \text{ levels}}$$

→ Noisy Channel: Shannon Capacity:

$$\text{Capacity} = \text{bandwidth} \times \log_2(1 + \text{SNR})$$

Eg: Consider an extremely noisy channel in which the value of the SNR is almost zero. The noise is so strong that

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the s/l is faint.

$$C = B\log_2(1+SNR) =$$
$$= B\log_2(1+0) =$$
$$= B\log_2 1 = B \times 0 = \underline{0}$$

2. A telephone line has a bandwidth of 3000 Hz assigned for data comm^ns. The SNR is 3162. For this channel the capacity is

$$C = B\log_2(1+SNR)$$
$$= 3000 \log_2(1+3162)$$
$$= 3000 \times 11.62$$
$$= \underline{34,860 \text{ bps}}$$

Highest bit rate is 34,860bps. If we want to send data faster than this, we can either increase ~~thor~~ the bandwidth of the line or improve the SNR.

3. The SNR is given in decibels. $SNR_{dB} = 36$ & the channel bandwidth is 2 MHz. Capacity = ?

$$SNR_{dB} = 10 \log_{10} SNR$$
$$SNR = 10^{SNR_{dB}/10} = 10^{36/10}$$
$$= 10^{3.6} = 3981$$
$$C = B\log_2(1+SNR) = 2 \times 10^6 \times \log_2 3982 = \underline{24 \text{ Mbps}}$$

Using Both Limits:

— Both methods to find the limits & s/l level

Eg: 1. We have a channel with a 1MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate & s/l level?.

Ans = Shannon formula to find upper limit.

$$C = B\log_2(1+SNR) = 10^6 \log_2(1+63) = 10^6 \log_2 64 = \underline{6 \text{ Mbps}}$$

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$$4\,Mbps = 2 \times 1\,MHz \times \log_2 L$$

$$\log_2 L = \frac{4\,Mbps}{2\,MHz} = 2$$

$$L = 4$$

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MODULE - II

> Transmission Media:

→ Guided Transmission Media.

* Twisted Pair
* Coaxial Cable
* Optical fibre
* Wireless Transmission
* Terrestrial Microwave
* Satellite microwave

→ Wireless Propagation:

* Ground wave propagation
* Sky wave propagation
* LoS propagation.

Questions:

1. Coaxial Cable is a 2 wire transmn s/m. What is the adv. of connecting the outer conductor to ground?.
2. In satellite commns, diff. fr. bands are used for the uplink & the downlink. Discuss why this pattern occurs.
3. Determine the height of an antenna for a TV station that must be able to reach customers upto 80 km away?

$$d = 3.57\sqrt{Kh} \qquad K \geq 1.33$$

4. Why can waves with a very low fr. follow the earth's surface? Why are they not used for data transmn in comp. n/ws?
5. How do guided media differ from unguided media?
6. Diff. b/w omnidirectional waves & unidirectional waves?
7. What is refraction? What is reflection?
8. What are 3 major class of guided media?
9. What is the purpose of cladding in an optical fibre?
10. What is the significance of the twisting in twisted pair cable?

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11. How does sky propagation differs from line of sight propagation?.
12. Name 2 major categories of transmn media?
13. Name the adv. of optical fiber over twisted pair & coaxial cable?

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> Transmission Media

→ is the physical path b/w transmitter & receiver

- → Guided media ✓
- → unguided media ✓

Guided media: electromag. waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable & optical fibre.

Unguided media: Wireless transmission occurs through the atmosphere, outer space or water.

The characteristics & quality of a data transm^n are determined both by the characteristics of the medium & the characteristics of the s/l.

A no. of design factors relating to the transm^n medium & the s/l determine the data rate & distance.

* Bandwidth: All other factors remaining constant, the greater the bandwidth of a s/l, the higher the data rate that can be achieved.

* Transmission impairments: Impairments, such as attenuation, limit the distance. For guided media, twisted pair generally suffers more impairment than coaxial cable which in turn suffers more than optical fibre.

* Interference: For guided media, ~~but is also a problem~~ interference is can be caused by emanations from nearby cables. For eg: twisted pairs are often bundled together & conduits often carry multiple cables.

* No of Receivers: A guided medium can be used to construct a pt. to pt. link or shared link with multiple attachments. ~~In~~ Each attachment introduces some attenuation & distortion on the line, limiting distance or data rate

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* → Guided Transmission Media:

→ electromagnetic waves are guided along a solid medium, eg: copper twisted pairs.

→ For guided transmn media, the transmn capacity in terms of either data rate or bandwidth, depends critically on the distance and on whether the medium is pt to pt- or multipoint.

The three guided media commonly used for data transmission are twisted pair, coaxial cable, & optical fibre.

* Twisted Pair: Fig

→ least expensive

Physical Description:

- consists of 2 insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single comm^n link.
- A no. of these pairs are bundled together into a cable by wrapping them in a tough protective sheath.
- The twisting tends to decrease the crosstalk interference b/w adjacent pairs in a cable.
- twist length varies from 5 to 15 cm
- thickness - .4 to .9 mm.

Applications:

- medium for both analog & digital s/ls
- Telephone n/w & comm^n within buildings

Telephone s/ns:

Individual residential s/ns, individual residential telephone sets are connected to the local telephone exchange or end office by twisted pair wire. These are referred to as subscriber loops.

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→ Within an office building each telephone is also connected to a twisted pair, which goes to an in house private branch exchange (PBX) s/m or to a central facility at the end office. These twisted pair installations were designed to support voice traffic using analog s/ling.

Transmission Characteristics:

— to transmit both analog & digital transmission

Analog - amplifiers are required about every 5 to 6 km

Digital - repeaters are required every 2 or 3 km

— limited distance, bandwidth & data rate

— ~~strong fn~~ attenuation is a strong fn of frequency.

— reduces low-frequency interference. The use of diff. twist lengths in adjacent pairs reduces crosstalk.

Unshielded & Shielded Twisted Pair:

Unshielded Twisted Pair is ordinary telephone wire. — is subject to external electromagnetic interference including interference from nearby twisted pair & from noise generated in the environment.

— to improve the characteristics of this medium is to shield the twisted pair with a metallic sheathing. This shielded twisted pair provides better performance at higher data rates.

— It is more expensive.

EIA - Electronic Industries Association published EIA-568 Commercial Building Telecomm Cabling Standard which specifies the use of voice grade UTP & STP for in building appl.

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EIA-568 recognizes 3 categories:
category 3: UTP cables & associated connecting hw whose transmn characteristics are specified upto 16MHz
category 4: " " " upto 20MHz.
category 5: " " " upto 100MHz.

* Coaxial Cable:

- Consists of 2 conductors, but constructed differently to permit it to operate over wider range of frequencies.
- A Hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- Inner conductor is held in place by spaced insulating rings or a solid electric material.
- The outer conductor is covered with a jacket or shield.
- diameter 1 to 2.5 cm.

Applications:
- Television Transmn
- Long-distance telephone transmn.
- Short-run comp. s/m links.
- Local Area N/ws.

Transmn Characteristics:
- transmit both analog & digital s/ls.
- used at higher frequencies & data rates.
- less susceptible to interference & crosstalk than twisted pair.
- Constraints on performance- attenuation, thermal noise, intermodulation noise
- Amplifiers are needed for long distance transmn.

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* Optical Fiber:

Physical Description:

— thin (@ to 125 μm)

— flexible medium of guiding an optical ray.

— made by glasses & plastics.

— fibers of ultrapure fused silica. (lowest loss)

— Cylindrical shape & consists of 3 concentric sections → core, the cladding & the jacket.

* core: has a diameter in the range of 8 to 50 μm.

* cladding: Each fibre is surrounded by cladding ie; a glass or plastic coating that has optical properties diff. from those of the core & a diameter of 125 μm.

* The i/f b/w core & cladding ⇒ reflector to confine light

* Outermost layer Jacket: composed of plastic & other material layered to protect against moisture, abrasion, crushing & other environmental dangers.

Applications:

* Long distance telecomm^ns.

* military appl^ns. ✓

Unique features of Optical fibre (differentiates from other 2)

* Greater Capacity: ✓

Datarate ↑ ⇒ upto of Gbps over upto of kms.

Datarate few Mbps over 1 km for twisted & coaxial.

* Smaller size & lighter weight: ✓

→ thinner than Coaxial & bundles of twisted pair

→ reduction in weight reduces structural support reqmts.

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* Lower Attenuation : lower for optical fibre than for coaxial & twisted pair. & constant for a wide range.

* Electromagnetic Isolation: not affected by electro. magnetic fields.

— not vulnerable to interference, impulse noise, or crosstalk.

* Greater repeater spacing: Fewer repeaters mean lower cost & fewer sources of error.

Five categories of appl^n

* long haul trunks: in telephone n/w, long haul routes average about 1500 km in length & offer high capacity.

* Metropolitan trunks: avg length of 12km & have 100,000 voice channels in a trunk group.

* — installed in underground conduits & are repeaterless joining telephone exchanges or metropolitan area.

* Rural Exchange trunks: ckt length range from 40 to 160km & link towns & villages.

* Subscriber loops: directly from the central xchang to a subscriber.

* Local Area N/ws: have the capacity of 100Mbps to 10Gbps & can support 100s or 1000s of stations in a large office building.

Transmission Characteristics:

— transmits a s/l encoded beam of light by total internal reflection. Total internal reflection can occur in any transparent medium (higher index of refrat

— Optical fibre acts as waveguide for frequencies in the range of 10^{14} to 10^{15} Hz.

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Process: Light from a source enters the cyl. glass or plastic core. Rays at shallow angles are reflected & propagated along the fiber. Other rays are absorbed by the surrounding material. This form of propagation is called step index multimode.

- Multimode transmn has multiple propagation paths each with diff. path length & to traverse the path. This causes s/l elmts (light pulses) to spread out in time, which limits the rate at which data can be accurately received. This type of fiber is suited for transmn over very short distances.

* Single mode transmission: superior performance
- there is single transmn path with single mode transmn
- No distortion
- used for long distance appl's - telephone & cable television.

* Graded index multimode transmn: varying the index of refraction. The higher index makes the light rays moving down the axis more slowly than those near the cladding.

- used in LANs.

* Two diff types of light source: LED & ILD (Injection Light Diode) Both are semiconductor devices that emit a beam of light when a voltage is applied.

LED - low cost, operates over a greater temp. & longer operational life.

ILD - laser principle, efficient & greater data rates.

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> Wireless Transmission.

→ Three general ranges of frequencies:

1. 1GHz (10^9 Hz) to 40GHz → microwave frequencies
- Suitable for pt. to pt transm^n.
- used for satellite comm^n.

2. 30MHz - 1GHz → radio range.

3. 3×10^{11} to 2×10^{14} Hz → Infrared portion of the spectrum
- used for pt. to pt & multipoint appl^{n}s.

→ For unguided media, transm^n & reception are achieved by means of an antenna.

Twisted Pair:

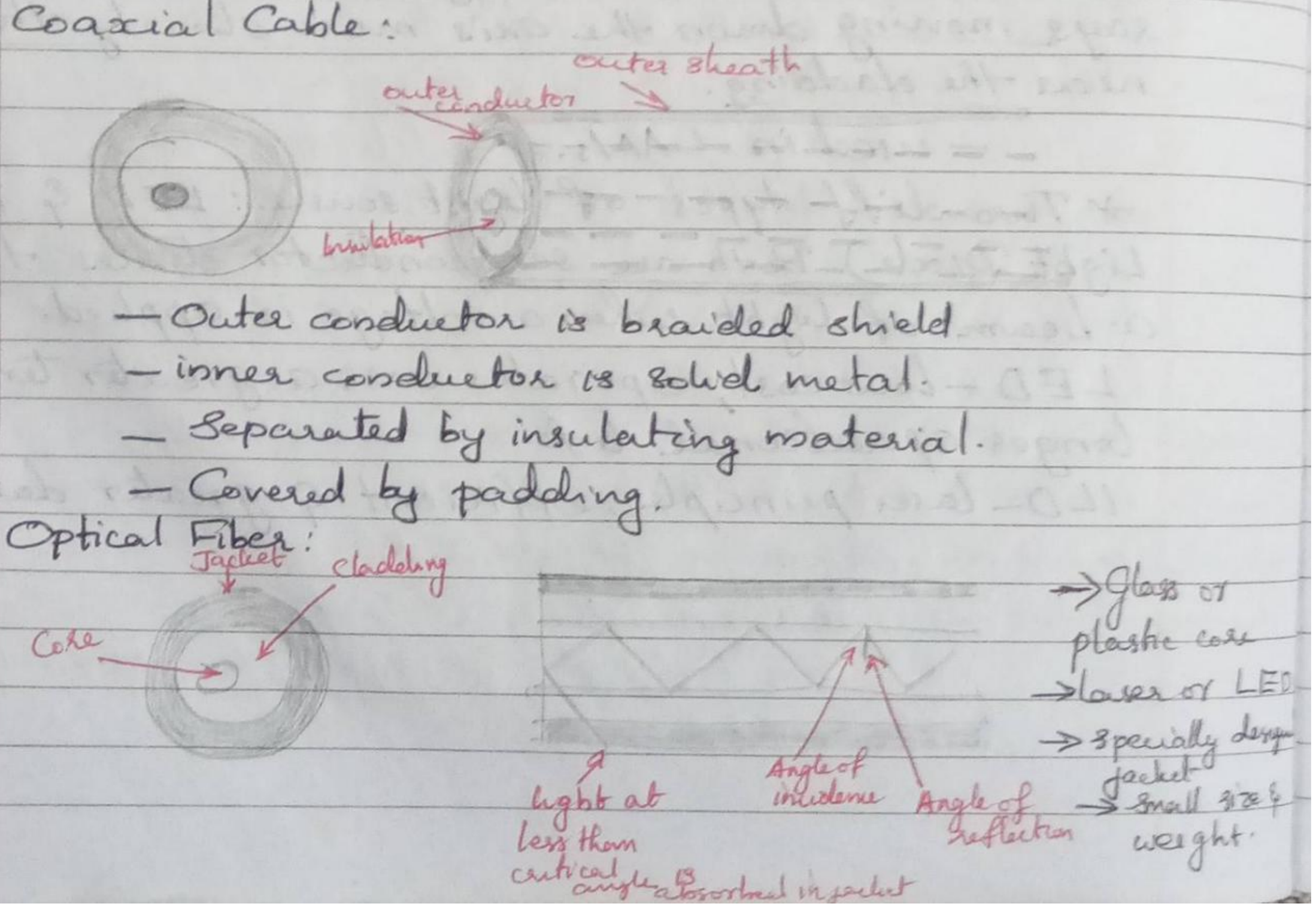


- separately insulated
- Twisted together
- often bundled into cables
- Usually installed in building during construction.

Coaxial Cable:

- Outer conductor is braided shield
- inner conductor is solid metal.
- Separated by insulating material.
- Covered by padding.

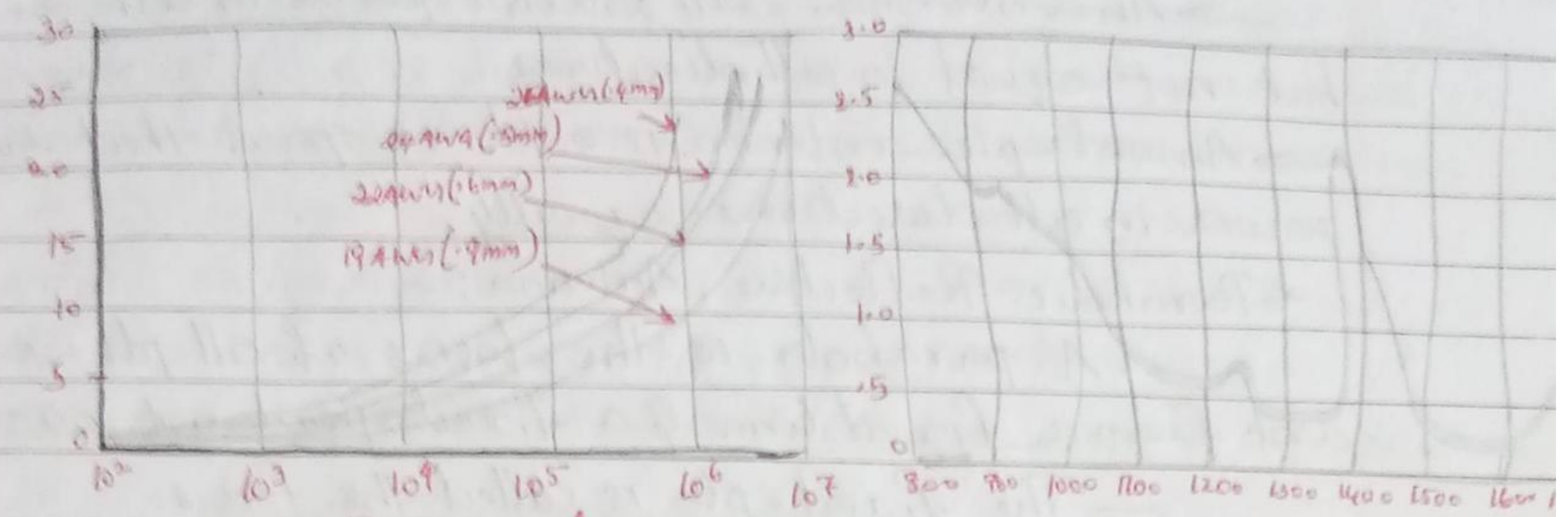
Optical Fiber:



→ Glass or plastic core
→ laser or LED
→ Specially design jacket
→ Small size & weight.

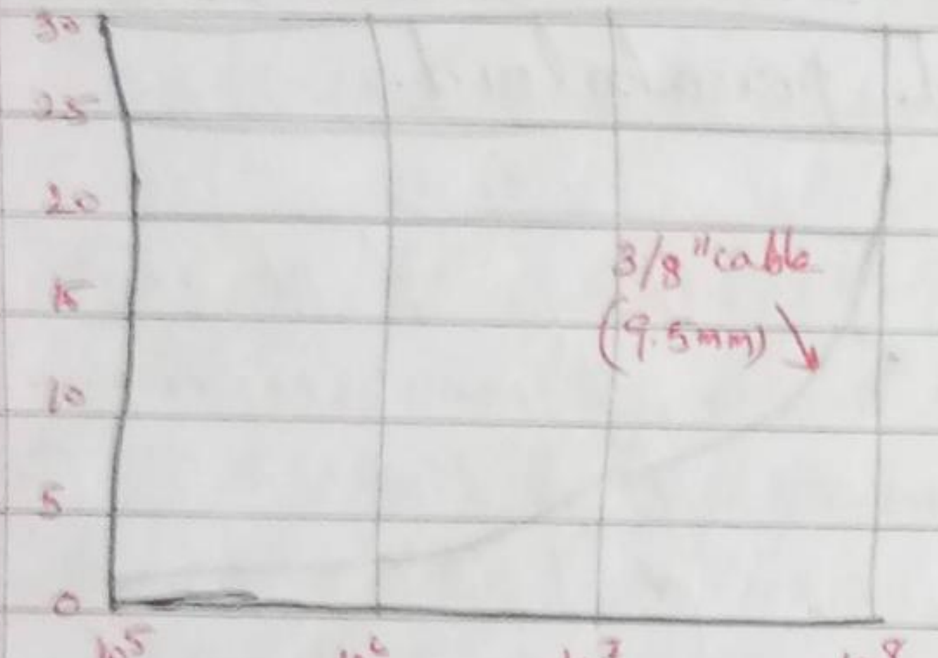
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Figure : Attenuation of Typical Guided Media:

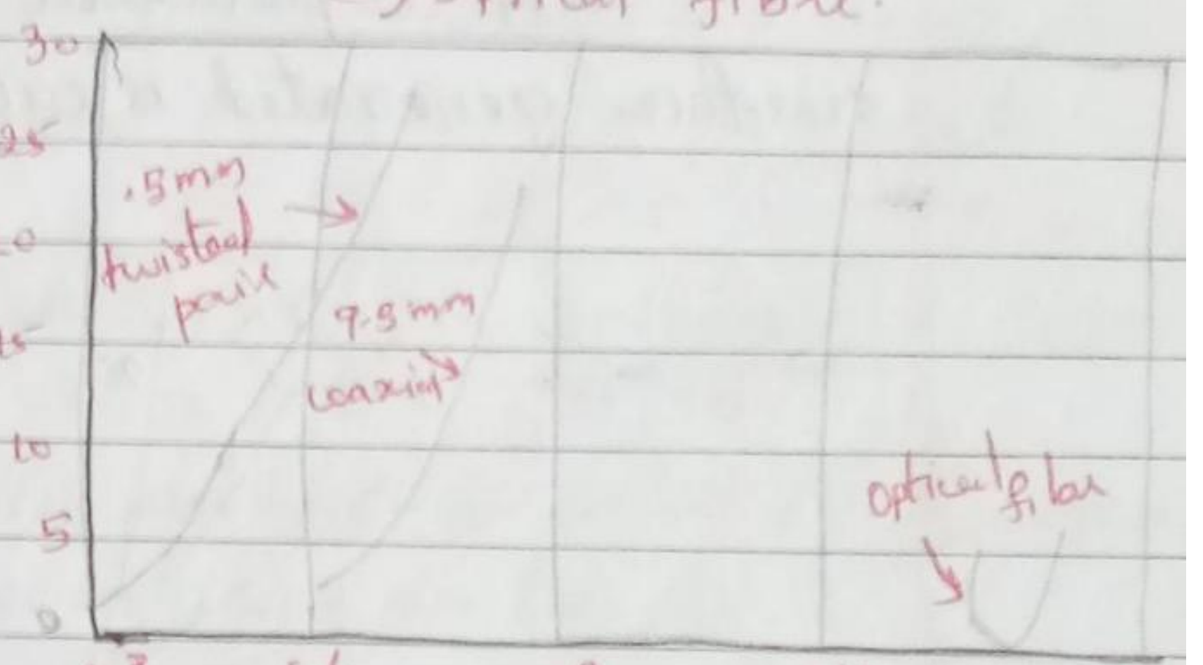


(a) Twisted pair

(c) Optical fibre.



(b) Coaxial cable



(d) Composite graph

* Antennas:

An antenna can be defined as an electrical conductor or s/m of conductors used either for radiating electromagnetic energy or for collecting electromag. energy.
→ For transmission of a s/l, radio fr. electrical energy from the transmitter is converted into electromagnetic energy by antenna & radiated into the surrounding envt.
→ For reception of a s/l, electromagnetic energy on the antenna is converted into radio-fr. electrical energy & fed into the receiver.

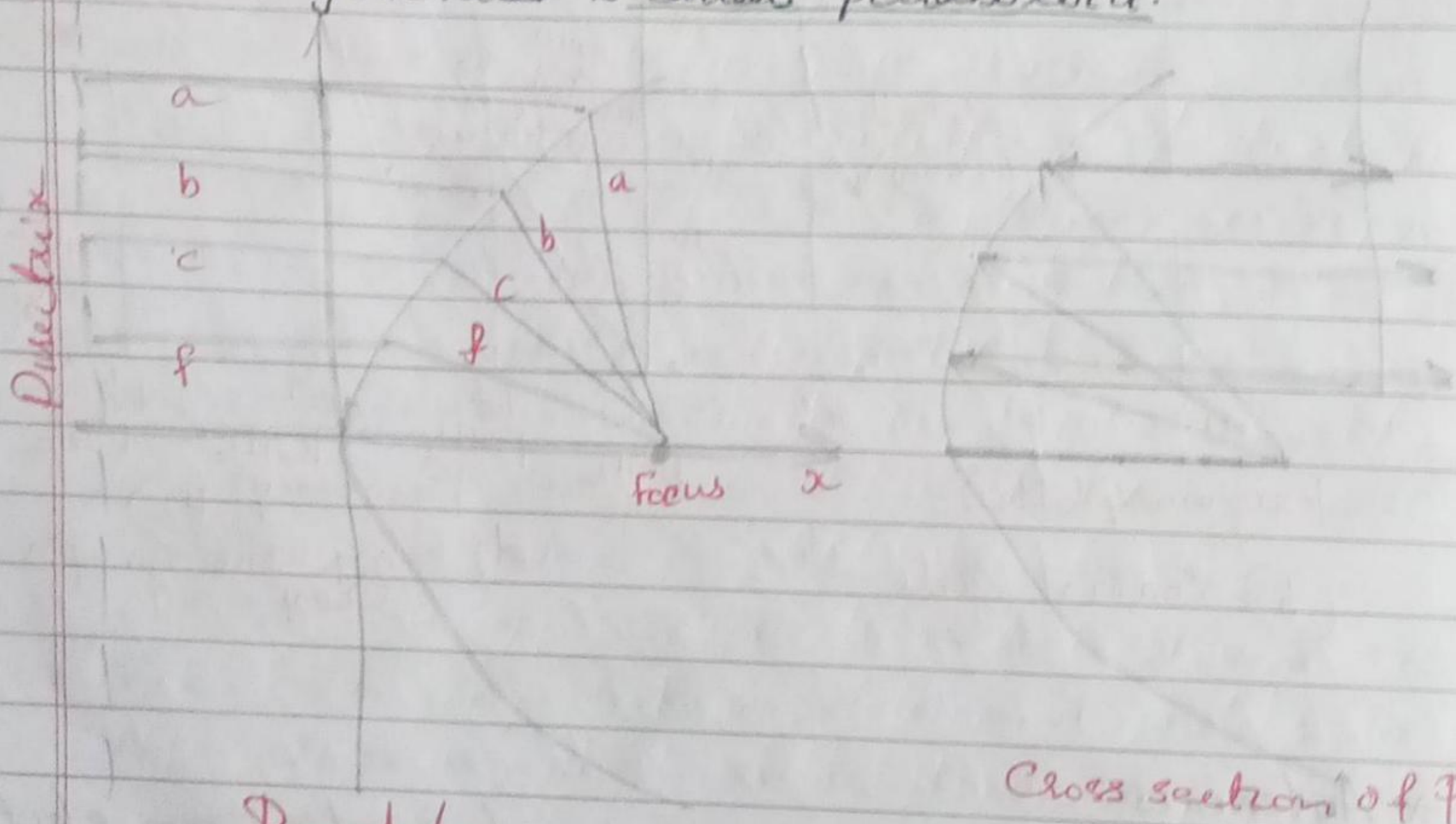
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→ Energy from surrounding to input terminal.
→ it transfers from the o/p terminal to surrounding
→ An antenna will radiate power in all directions but not equal in all directions.
→ An isotropic antenna is a pt. in space that radiates power in all directions equally.

* Parabolic Reflective Antenna:

A parabola is the locus of all pts. equidistant from a fixed line & a fixed point not on the line.

— The fixed pt. is called the focus.
— The fixed line is called the directrix.
— If a parabola is revolved about its axes, the surface generated is called paraboloid.



Cross section of parabolic antenna — reflective property.

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* Antenna Gain:

— a measure of directionality of an antenna.

- Antenna gain is defined as the power o/p, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna.
- Effective area related to antenna gain.
- The effective area of an antenna is related to the phy. size of the antenna & to its shape.

The relationship blw at antenna gain & effective area is $G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f A_e}{c^2}$

G = antenna gain A_e = effective area f = carrier fr.
c = speed of light (3×10^8 m/s) λ = carrier wavelength.

For eg: the A_e of an ideal isotropic antenna is $\lambda^2/4\pi$ with a power gain of 1;

the A_e of parabolic antenna with a face Area A is $.56A$, with a power gain of $7A/\lambda^2$

Eg: For parabolic reflective antenna with a diameter of 2m, operating at 12GHz, what is the effective area & the antenna gain?

Face Area = $\pi r^2 = \pi \times (d/2)^2 = \pi \times (2/2)^2 = \pi \times 1^2 = \pi$

Effective area = $.56A = .56 \times \pi = .56\pi$

wavelength $\lambda = c/f$ // $c = 3 \times 10^8$ m/s, $f = 12 \times 10^9$ Hz

$\lambda = \frac{3 \times 10^8}{12 \times 10^9} = .025$ m

$G = (7A)/\lambda^2 = (7 \times \pi)/(.025)^2 = 35,186$

$G_{dB} = 45.46$ dB

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* Terrestrial Microwave

Physical Description:

- size is about 3m in diameter.
- The antenna is fixed rigidly & focuses a narrow beam to achieve line of sight transm^n to the receiving antenna.
- located at substantial heights above ground level to extend range b/w antennas.
- To achieve long-distance transm^n, a series of microwave relay towers is used.
- Pt to point uwave links are together over the desired distance.

Applications:

- Long-haul telecomm^n service.
- alternative to coaxial cable/optical fiber.
- requires fewer amplifiers or repeaters.
- require line of sight transm^n.
- used for voice & TV transm^n.
- used for short pt. to pt. links b/w buildings.
  - ↳ closed circuit TV
  - ↳ LAN (data link)
- Bypass Application: A business microwave link to a long distance telecomm^n facility in the same city bypassing the local telephone company.

Transmission Characteristics:

- covers a substantial portion of the electro mag. spectrum.
- Frequency range 1 to 40 GHz.

Ref Table 4.6

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The main loss is attenuation.

$$\text{Loss} = 10 \log \left(\frac{4\pi d}{\lambda}\right)^2 \text{dB}.$$

d - distance

λ - wave length

→ Loss varies as the square of the distance.

→ The repeaters or amplifiers may be placed farther apart for microwave s/ms - 10 to 100 km.

→ Attenuation is increased with rainfall.

→ Another impairement Interference - transm^n areas overlap & interference is always a danger. Thus frequency bands is strictly regulated.

↳ for long haul telecomm^{n}s - 4GHz to 6GHz.

- 12GHz - used as a component of cable TV s/ms.

- Microwave links are used to provide TVs/ls to CATV installations; the s/ls are then distributed to individual subscribers via coaxial cable.

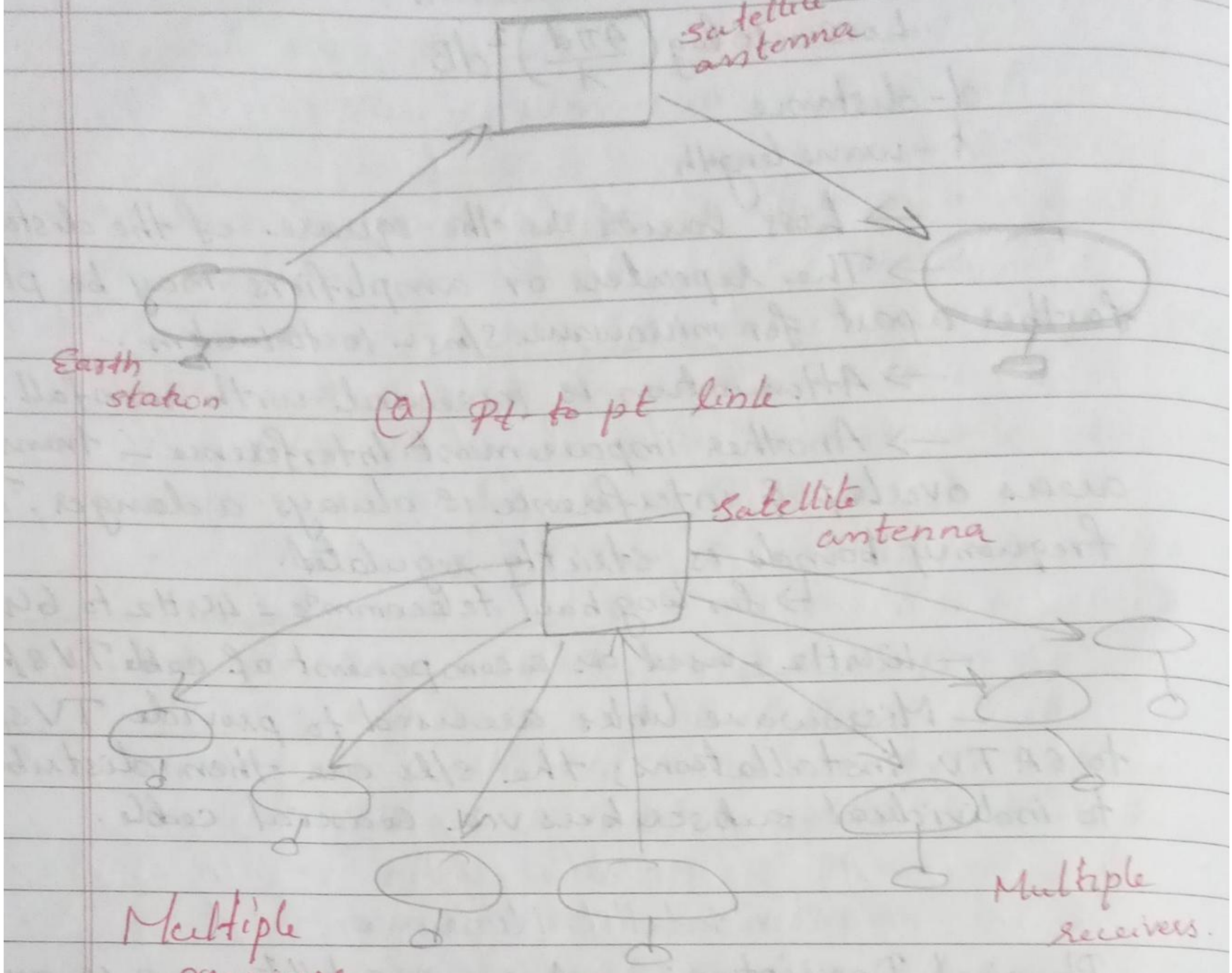
* Satellite Microwave

Physical Description: - A comm^n satellite is a μwave ~~sa~~ relay station. It is used to link to or more ground based μwave transmitter/receivers known as earth stations or ground stations. The satellite receives transm^{n}s on one freq. band (uplink), amplifies or repeats the s/l, & transmits it on another fr. (downlink).

- A single orbiting satellite will operate on a no. of fr. bands, called transponder channels or simply transponders.

Fig shows 2 common configs. for satellite comm^n. In the first, the satellite is being used to provide a pt. to pt. link b/w 2 distant ground based antennas. In the IInd, comm^n b/w one ground based transmitter & a no. of ground based receivers.

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(a) Pt to pt link

(b) Broadcast link.

— For comm^n satellite, it is generally required that it remain stationary with respect to its pos^n over the earth. Else it would not be within the line of sight of its earth stations at all times. To remain stationary, the satellite must have a period of rotation equal to the earth's period of rotation. This match occurs at the height of 35,863 km at the equator.

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Applications:

* Television Distributions
* Long-distance telephone transmn
* Private business nws.
* Global positioning.

Television Distributions:

— A nw provides programming from a central location. Pgms are transmitted to the satellite & then broadcast down to a no. of stations, which then distribute the pgms to individual viewers.

Telephone transmn: — used for pt. to pt. trunks b/w telephone exchange offices in public telephone n/ws.

Business Data Appl^ns: Satellite providers can divide the total capacity into a no. of channels & lease these channels to individual business users. A user equipped with antenna at a no. of sites can use a satellite channel for a private n/w.

Global Positioning S/m: 3 segments.

* satellites above the earth's surface.
* A ctrl segment maintains GPS through a S/m of ground monitor stations & satellite upload facilities.
* The user receivers — both civil & military.

→ Each satellite transmits a unique digital code seq. of 1s & 0s precisely timed by an atomic clk, which is picked by a GPS receiver's antenna & matched with the same code seq. generated inside the receiver. By lining up or matching the S/ls, the receiver determines how long it takes the S/ls to travel from the satellite to the receiver - Measure

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Transmn Characteristics:

→ range for satellite transmn – 1 to 10GHz.

→ Below 1GHz, significant noise from natural sources.

→ Above 10GHz the attenuation by atmospheric absorption & precipitation.

→ earth to satellite transmn – 5.925 to 6.425GHz

→ satellite to earth – 3.7 to 4.2GHz

Satellite Categories:

* GEO Satellites: To ensure constant commn, the satellite must move at the same speed as the Earth so that it seems to remain fixed above a certain spot. Such satellites are called geostationary.

* MEO Satellites: Medium-Earth-Orbit satellites are positioned b/w 2 Van Allen belts. A satellite at this orbit takes approximately 6-8 hrs to circle the Earth.

Eg: GPS.

* LEO Satellites: has a cellular type of access, similar to cellular phone.

> Wireless Propagation:

A s/l radiated from an antenna travels along one of 3 routes: Ground wave, Sky wave or line of Sight.

* Ground wave Propagation:

– Radio wave travel ~~from the source to destn~~ in through the lowest portion of the atmosphere.

– Waves with low fr. follow the earth's surface & can propagate long distances. Eg: submarine commn or AM radio.

– frequency – upto ~~20~~ MHz.

– Electromagnetic induces a current in the

earth's surface, the result of which is to slow wave-front near the earth, causing the wavefront to tilt downward & hence follow earth's curvature.

— Electromagnetic waves in this fr. range are scattered by the atmosphere that they donot penetrate upper atmosphere.

* Sky wave Propagation - (below 30 MHz)

— Higher fre. radio wave radiate upward into ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth. This type of transmission allows for greater distances with lower o/p power.

Eg: CB radio, BBC (International broadcast)

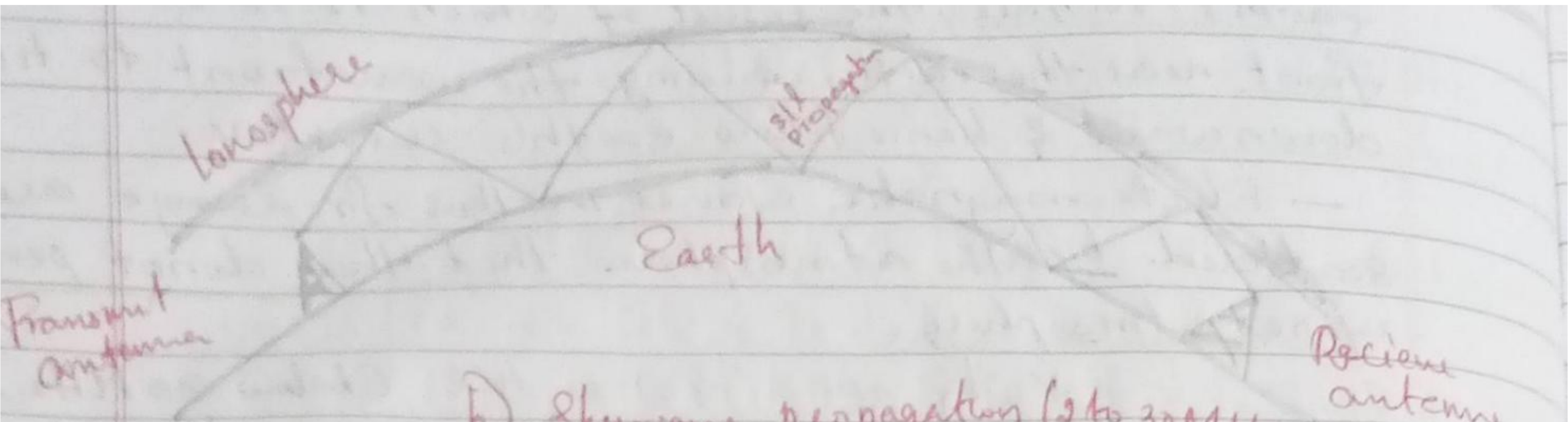
* Line of Sight Propagation:

— Very high fr. s/ls are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other.

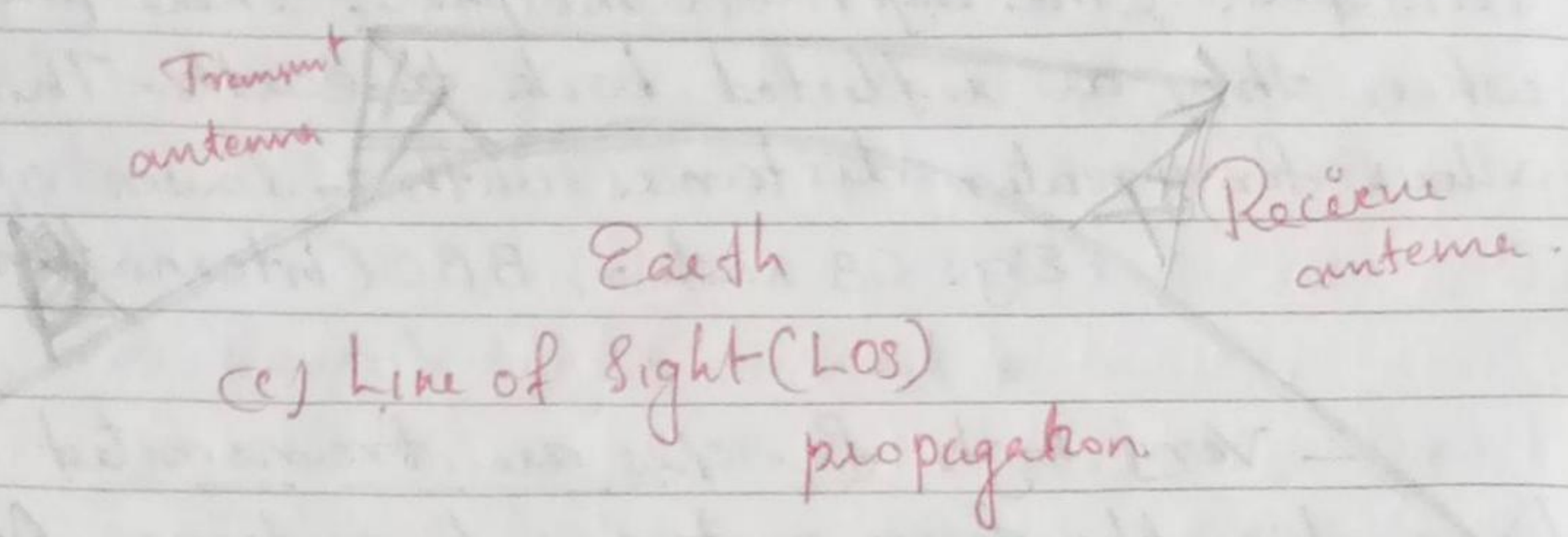
— For satellite comm^n, a s/l above 30 MHz is not reflected by the ionosphere & therefore a s/l can be transmitted b/w earth station & a satellite overhead that is not beyond the horizon.

s/l propagation

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b) Skywave propagation (2 to 30 MHz)



(c) Line of Sight (LOS) propagation

→ Refraction: occurs b/c the velocity of electromag wave is a fn of the density of the medium through which it travels.

→ When an electromag. wave moves from a medium of one density to a medium of another density, its speed changes. This causes a one time bending of the direction of the wave at the boundary b/w the 2 media.

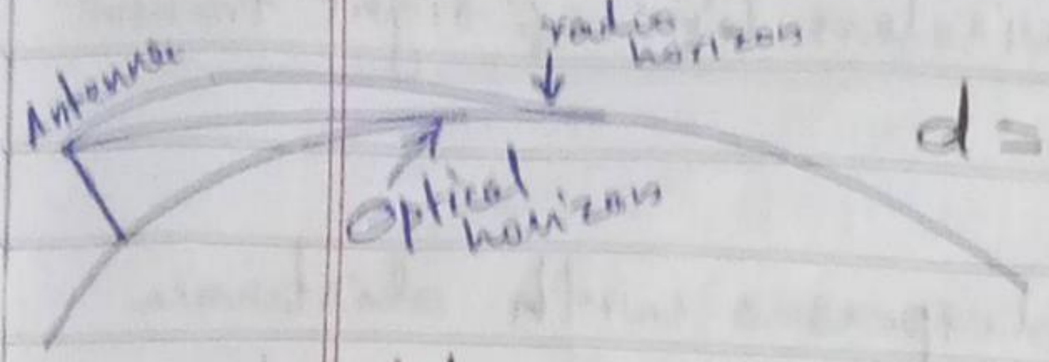
→ Optical & Radio Line of Sight:

→ With no intervening obstacles, the optical line of sight can be expressed as

$d = 3.57\sqrt{h}$ // d = the distance b/w an antenna & the horizon in kilometers & h = antenna height in meters.

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Radio line of sight to the horizon



$d = 3.57\sqrt{Kh}$ // K - adjustment factor to the account for refraction.

$K = 4/3$

Maximum distance b/w 2 antennas for LOS propagation is $3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$, where h_1 & h_2 are the heights of the 2 antennas.

Eg: What is the max. distance b/w 2 antennas for LOS transm^n if one antenna is 100m high & the other is at ground level

$d = 3.57\sqrt{Kh}$ // $K = 4/3$ (adjustment factor.
h = height of antenna.
$= 100m$.

$= 3.57\sqrt{1.33 \times 100}$

$= 3.57 \times \sqrt{133} = 41$ km

→ receiving antenna is 10m high. To achieve the same distance, how high must the transmitting antenna?

$d = 3.57(\sqrt{Kh_1} + \sqrt{Kh_2})$ // h_1 & h_2 are the hts. of antennas

$41 = 3.57(\sqrt{Kh_1} + \sqrt{1.33 \times 10})$

$\sqrt{Kh_1} = \frac{41}{3.57} - \sqrt{13.3} = 7.84$

$h_1 = 7.84^2 / 1.33 = 46.2$ m

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*Line of Sight Transmission.

— Impairments specific to wireless line of sight transm

→ Free Space Loss:

— wireless comm^n _ the s/l disperses with distance ∴ An antenna with a fixed area will receive less s/l power the farther it is from the transmitting at antenna ⟶ signal loss.

— A transmitted s/l attenuates over distance b/c the s/l is being spread over a larger & larger area. This form of attenuation is known as free space loss Free space loss can be expressed in terms of the ratio of the radiated power P_t to the power P_r received by the antenna. In decibels, by taking 10 times the log of that ratio.

$$\text{Free space loss} = \frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2} \quad (\lambda = c/f)$$

P_t = s/l power at the transmitting antenna.
P_r = s/l power at the receiving antenna.
λ = carrier wavelength in meters
d = propagation distance b/w antennas in meters
c = speed of light (3×10^8 m/s)

$$L_{dB} = 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right) = -20\log(\lambda) + 20\log(d) + 21.98\,dB$$

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

Eg: Determine the isotropic free space loss at 4 GHz for the shortest path to a synch. satellite from earth (35,863 km).

Ans: At 4 GHz, the wavelength is $(3\times10^8)/(4\times10^9) = 0.075$ m

& $\lambda = c/f$

$L_{dB} = -20\log(1) + 20\log(d) + 21.98\ dB$

$= -20\log(0.075) + 20\log(35.863) + 21.98$

$= 195.6\ dB = 135.6\ dB$

Consider the antenna gain of both the satellite & ground based antennas. Values are 44dB & 48dB respectively.

The free space loss = $L_{dB} = 195.6 - 44 - 48$

$= 103.6\ dB$

→ Atmospheric Absorption

— Additional loss b/w the transmitting & receiving antennas.

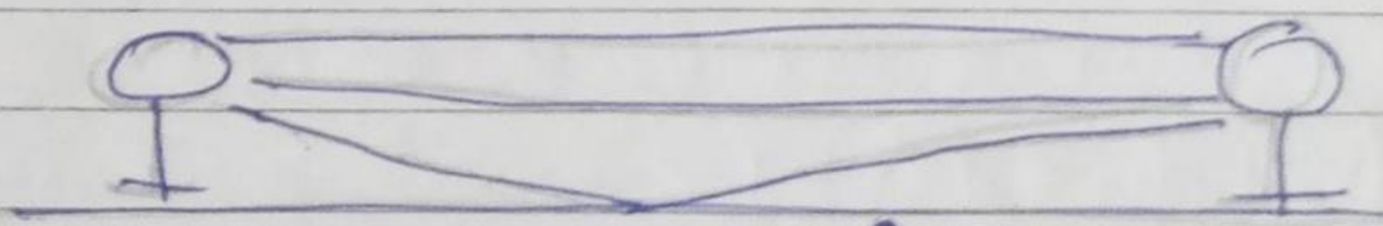
— Water vapor & oxygen contribute most to attenuation.

→ Multipath:

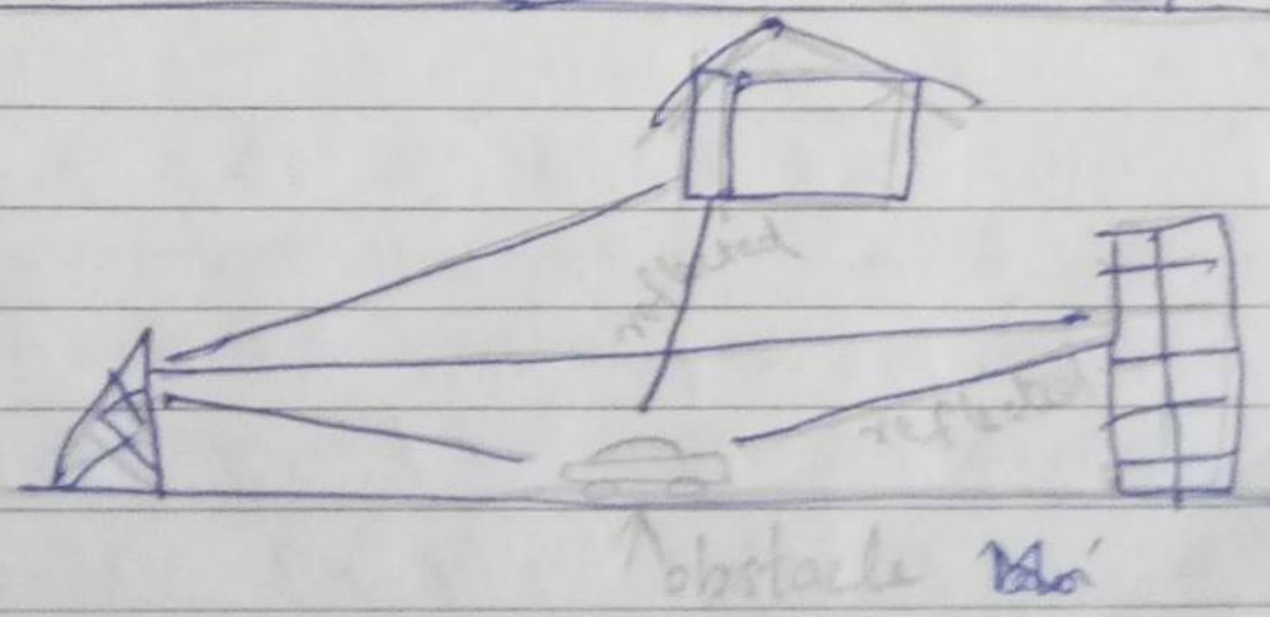
— Antennas can be placed where there are no obstacles, there is a direct line of sight path from transmitter to receiver.

— For eg: mobile telephony – obstacles

The s/l can be reflected by such obstacles so that multiple copies of the s/l with varying delays can be received.



(a) Human LoS



(b) Mobile radio.

Eg of Multipath Interference.

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* Refraction

— Radio waves are refracted when they propg through atmosphere. The refraction is caused by changes in the speed of the s/l with altitude or by other spatial changes in the atmospheric conditions.

— Speed of the s/l increases with altitude, causing radio waves to bend downward.

Fig (a) For fixed antennas in addition to direct LOS, the s/l may follow a curved path through atmosphere due to refraction & the s/l may also reflect from the ground.

Fig (b) For mobile comm's, structures & topographic features provide reflection surfaces.

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NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE

SERIES TEST – I

CS 307 : DATA COMMUNICATION

Year / Semester & Branch : III / S5 B.Tech. CSE **Date : 22/9/2017**

Time : 60 Mins **Max. Marks:20**

PART-A

Answer ALL Questions (3 x 2 = 6 Marks)

1. Differentiate between half duplex and full duplex transmission modes.
2. If a periodic signal is decomposed into 5 sine waves with frequencies of 100,300,500,700 & 900,what is its bandwidth? Draw spectrum, assuming all components have a maximum amplitude of 10V.
3. Coaxial cable is a two wire transmission system. List the advantage of connecting the outer conductor to ground?

PART- B

Answer ALL Questions (2 x 7 = 14 Marks)

4.

a. Explain Transmission Impairments. **(3 Marks)**

b. The attenuation of a signal is -10dB.What is the final signal power if it was originally 10W? **(2 Marks)**

c. A line has a signal to noise ratio of 2000 and a bandwidth of 5000KHz.What is the maximum data rate supported by this line? **(2 Marks)**

OR

5.

a. Define Channel Impairment? What are the causes of Inpairment? **(4 Marks)**

b. The loss in a cable is usually defined in dB/km. If the signal at the beginning of a cable with -0.3 db/km has a power of 2mW;What is the power of the signal at 5km? **(3 Marks)**

6

a. Discuss the significance of the twisting in twisted pair cable? **(2 Marks)**

b. List out the advantages of optical fibre over twisted pair and coaxial cable? **(3 Marks)**

c. Describe the purpose of cladding in an optical fiber? **(2 Marks)**

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OR

7.

a. Differentiate between sky propagation and line of sight propagation? (3 Marks)

b. What is the maximum distance between two antennas for LoS transmission if one antenna is 100 m high and the other is at ground level? The receiving antenna is 10m high. To achieve the same distance, how high must the transmitting antenna? (4 Marks)

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MODULE III

> Signal Encoding Techniques (124-154=31)
(104-129=25)

→ Digital Data Digital Signals:
* NRZ
* Multilevel Binary
* Biphase

→ Digital Data Analog Signals:
* ASK
* FSK
* PSK

→ Analog Data Digital Signals:
* Sampling theorem
* PCM
* Delta Modulation

→ Analog Data Analog Signals:
* AM
* FM
* PM

1. What factors determine how successful the receiver will be in interpreting the incoming s/g?.
   Ans: * S/N to Noise Ratio * Data rate * Bandwidth.
2. Distinguish b/w s/l elmt & a data element.
3. Define baseline wandering & its effect in digital transmn.
4. Distinguish b/w data rate & signal rate.
5. Define DC Component & its effect on digital transmn.
6. Define scrambling & gt give its purpose.
7. List Line coding techniques.
8. Find the 8 bit data stream for each case depicted in fig 4.3. Page : 138.

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9. We have a baseband channel with a 2MHz bandwidth. Wh is the data rate for this channel if we use one of the follo. line coding schemes?

a. NRZ-L b. Manchester

Both NRZ-I ⇒ AM1

Bandwidth = N/2

N - Datarate.

2 = N/2

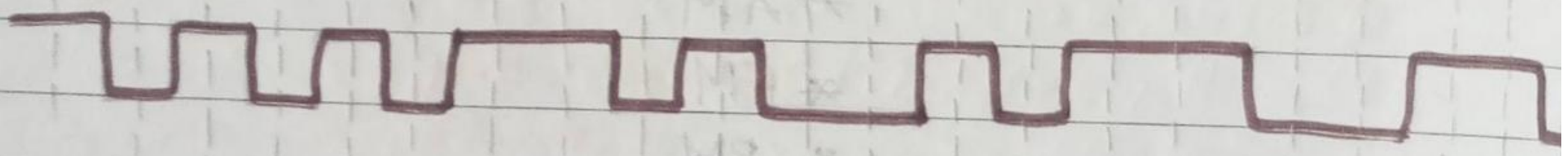
N = 4 Mbps.

B = N

Datarate = 2Mbps.

10. For the bitstream 01001110, sketch the waveforms for each coding. Assume that the s/l level for the preceding bit for ~~NZI~~ NRZI was high. the most recent preceding bit 1 (AMI) has a negative voltage; & the most recent preceding 0 bit (pseudoternary) has a -ve voltage.

11. The waveform belongs to Manchester encoding binary data stream, Determine the begining & end bit period & give the data sequence.



12. Consider a stream of binary data consisting of a log long sequence of 1s followed by a zero followed by a long string of 1s with the same assumptions of pblm 10. Draw the waveform for this seq. using

a. NRZ-L b. Bipolar - AMI c. Pseudoternary.

14. which characteristics of an analog s/l are changed to represent the digital s/l in each of follow.

1. ASK 2. FSK 3. PSK

15. Which of the 4 digital to analog transmn technique (ASK, FSK, PSK & QAM is the most susceptible to noise?

16. Define carrier s/l & its role of analog transmn.

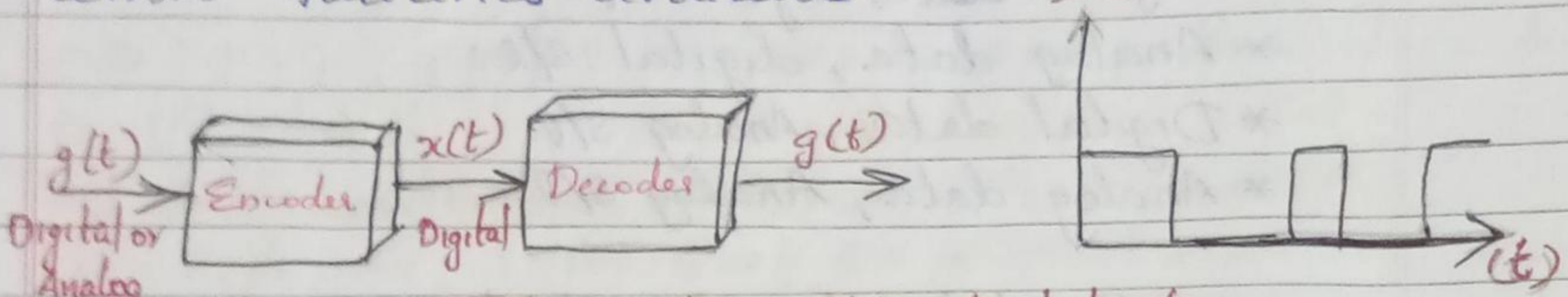
17. Which characteristics of an analog s/l are changed to represent the lowpass analog s/l in each of the follo. analog to analog conversions?

a. AM b. FM c. PM

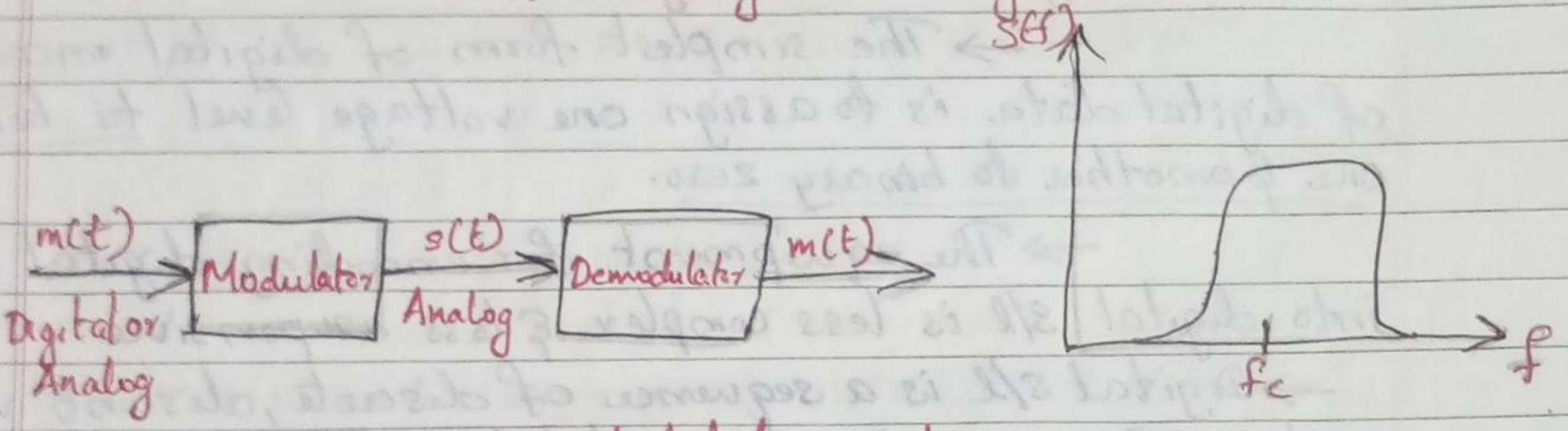
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> Signal Encoding Techniques:

Both analog & digital inf^n can be encoded as either analog or digital s/ls. Encoding technique depends on specific rqmnts to be met & media & comm^n facilities available.



(a) Encoding onto a digital s/l.



(b) Modulation onto an analog s/l.

Fig (a) Digital Signalling, a data source g(t), which may be either digital or analog is encoded into a digital s/l x(t). The form of x(t) depends on the encoding technique. ~~(to optimize)~~ The encoding may be chosen to conserve bandwidth or to minimize errors.

Fig (b) Analog signalling, - a continuous constant-fr. known as the carrier s/l. The fr. of the carrier s/l be compatible with the transm^n medium being used.

Modulation: proces of encoding source data onto a carrier s/l with fr.

fig(b): The i/p s/l m(t) may be analog or digital s/l or baseband s/l. The result of modulating the

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carrier s/l is called the modulated s/l $s(t)$.
$s(t)$ is a bandlimited s/l. The loc^n of the bandwidth on the spectrum is related to f_c & is often centered on f_c.

Four combinations are possible:
* Digital data, digital s/l:
* Analog data, digital s/l:
* Digital data, Analog s/l
* Analog data, Analog s/l:

* Digital data, digital s/ls:

→ The simplest form of digital encoding of digital data is to assign one voltage level to binary one & another to binary zero.

→ The equipment for encoding digital data into digital s/l is less complex & less expensive.

→ Digital s/l is a sequence of discrete, discont voltage pulses. Binary 1 is represented by +ve voltage (high) & Binary 0 is represented by -ve voltage (low).

→ Each pulse is a s/l element.

→ If the s/l elmts all have the same algebraic sign, i.e; all positive or negative, then the s/l is unipolar.

In polar s/ling, one logic state is represented by a +ve voltage level & other by a -ve voltage level.

→ Data s/lling rate/datarate :- bits/sec that data are transmitted.

→ The duration or length of a bit is the amt of time it takes for transmitter to emit a bit; data rate R; bit duration is $1/R$.

→ The modulation rate, is the rate at which the s/l level is changed. It is expressed in baud, which means s/l elmts per sec.

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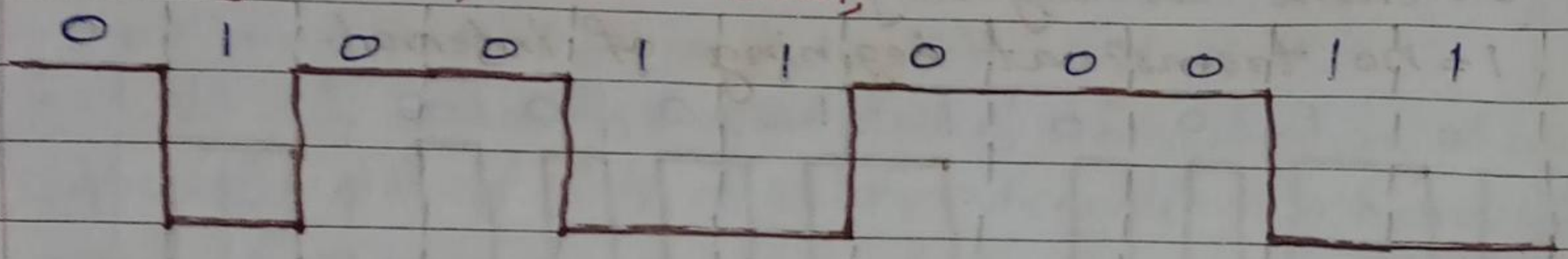
→ The tasks involved in interpreting digital s/ls at the receiver: 1. The receiver must know the timing of each bit. ie; when a bit begins & ends.

2. the receiver must determine whether the s/l level for each bit pos" is high (0) or low (1).

⇒ Signal Encoding Scheme: mapping from data bits to s/l elmts.

⇒ Nonreturn to Zero-Level-L

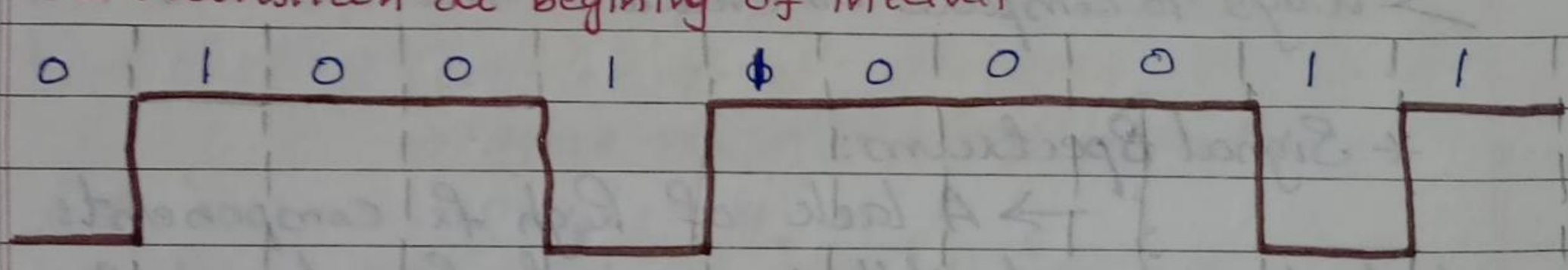
0 = High level; 1 = low level;



⇒ Nonreturn to Zero Inverted (NRZI)

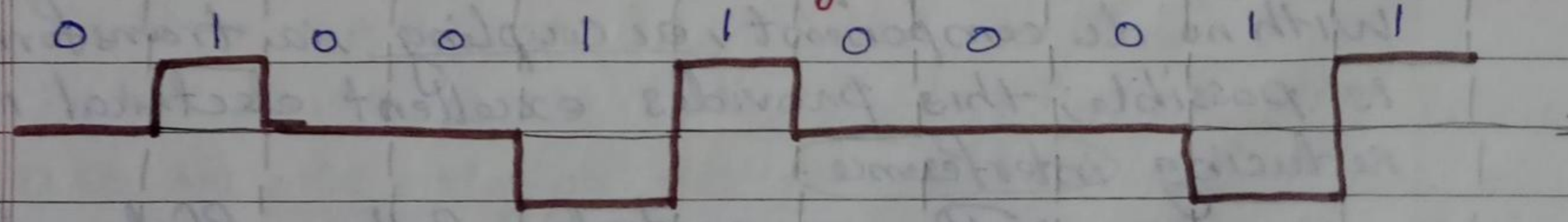
0 = no transition at begining of interval (one bit time)

1 = transition at begining of interval



⇒ Bipolar-AMI

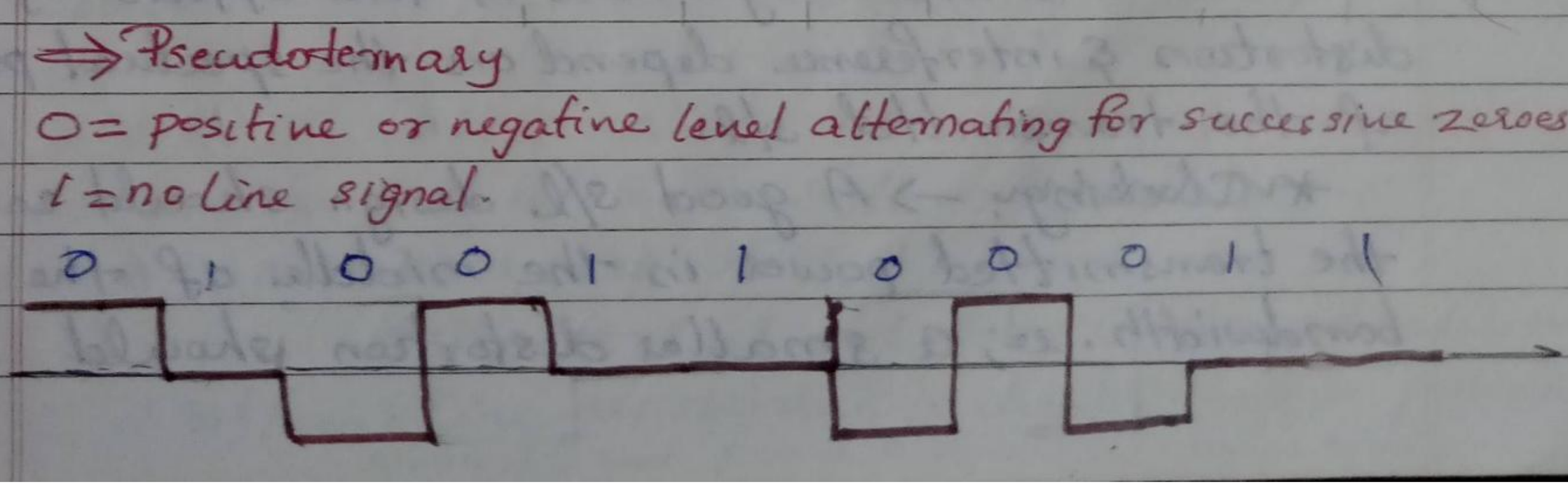
0 = no line s/l; 1 = positive/negative level, alternating successive ones.



⇒ Pseudoternary

0 = positive or negative level alternating for successive zeroes

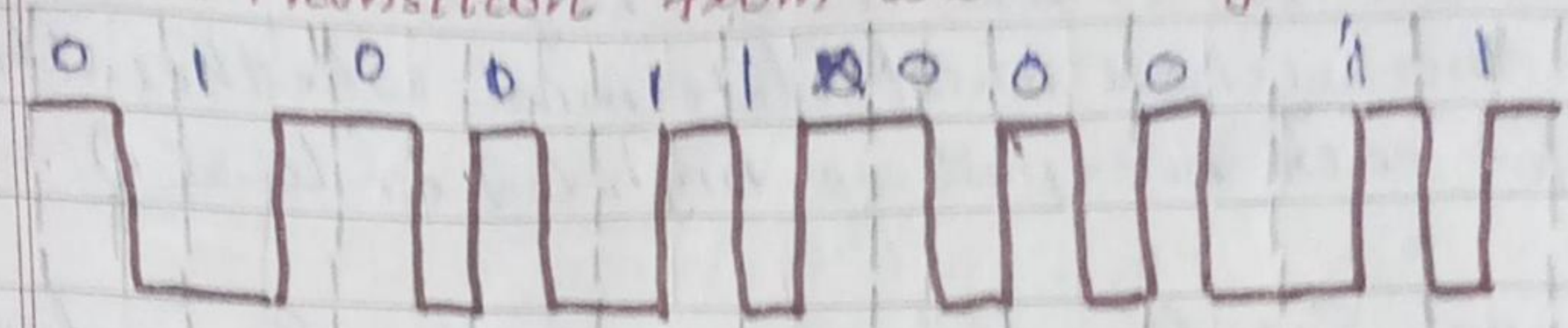
1 = no line signal.



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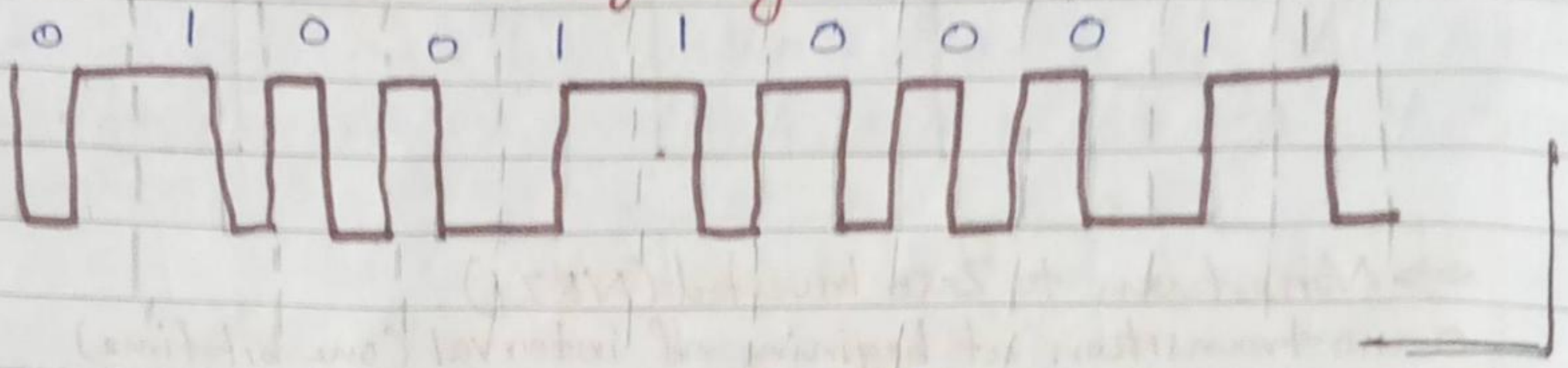
⇒ Manchester

0 = transition from high to low in middle of interval
1 = transition from low to high in immiddle of interval



⇒ Differential Manchester

Always trans^n in middle of interval
0 = trans^n at begining of interval
1 = no trans^n at begining of interval.



> Ways to compare or evaluate the various techniques:

* Signal Spectrum:

→ A lack of high fr. components means that less bandwidth is required for transm^n.

→ With a dc component to the s/l, there must be direct phy. attachment of transm^n components. With no dc component, ac coupling via transformer is possible; this provides excellent electrical isolation, reducing interference.

→ The magnitude of the effects of s/l distortion & interference depend on the spectral properties of the transmitted s/l.

* Clocking: → A good s/l design should concentrate the transmitted power in the middle of the transm^n bandwidth. ie; a smaller distortion should be -

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* Baseline Wandering: A long string of 0s & 1s can cause a drift in the baseline & make it difficult for the receiver to decode correctly. needed to prevent baseline wandering.
- present in the received s/l. To meet this objective, codes can be designed with the aim of shaping the spectrum of the transmitted s/l.

* Clocking:

→ to determine the begining & end of each bit position.

→ One expensive approach is to provide a separate clock lead to synchronize the transmitter & receiver.

→ Alternative is to provide some synch. mechanism that is based on the transmitted s/l.

* Error Detection:

→ is useful to have some error detection capability built into the phy. encoding scheme. This permits errors to be detected more quickly.

* S/l interference & noise immunity:

- Certain codes exhibit superior performance in the ~~performance~~ presence of noise.

* Cost & Complexity:

→ Higher the s/ling rate to achieve a given data rate, the greater the cost.

→ Some codes require a s/ling rate that is greater than actual data rate.

> NRZ (Non Return to Zero)

→ unipolar scheme ie; all the s/l levels are on one side of the time axis, either above or below. → The +ve voltage defines bit 1 & the zero voltage defines bit 0.

→ It is called NRZ b/c signal doesn't return to zero at the middle of the bit.

→ very costly.

→ The normalized power (power needed to send 1 bit/unit line resistance) is double that for polar NRZ.

Normalized power = $\frac{1}{2} V^2$ (V - amplitude)

In decoding digital s/l, the receiver calculates a running avg of the received s/l power. This avg is called the baseline. The incoming s/l power is evaluated against this baseline to determine the value of the data elmt.

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* Polar Schemes:

— the voltages are on both sides of the time axis. For eg: 0 can be the +ve voltage level for 1 can be -ve.

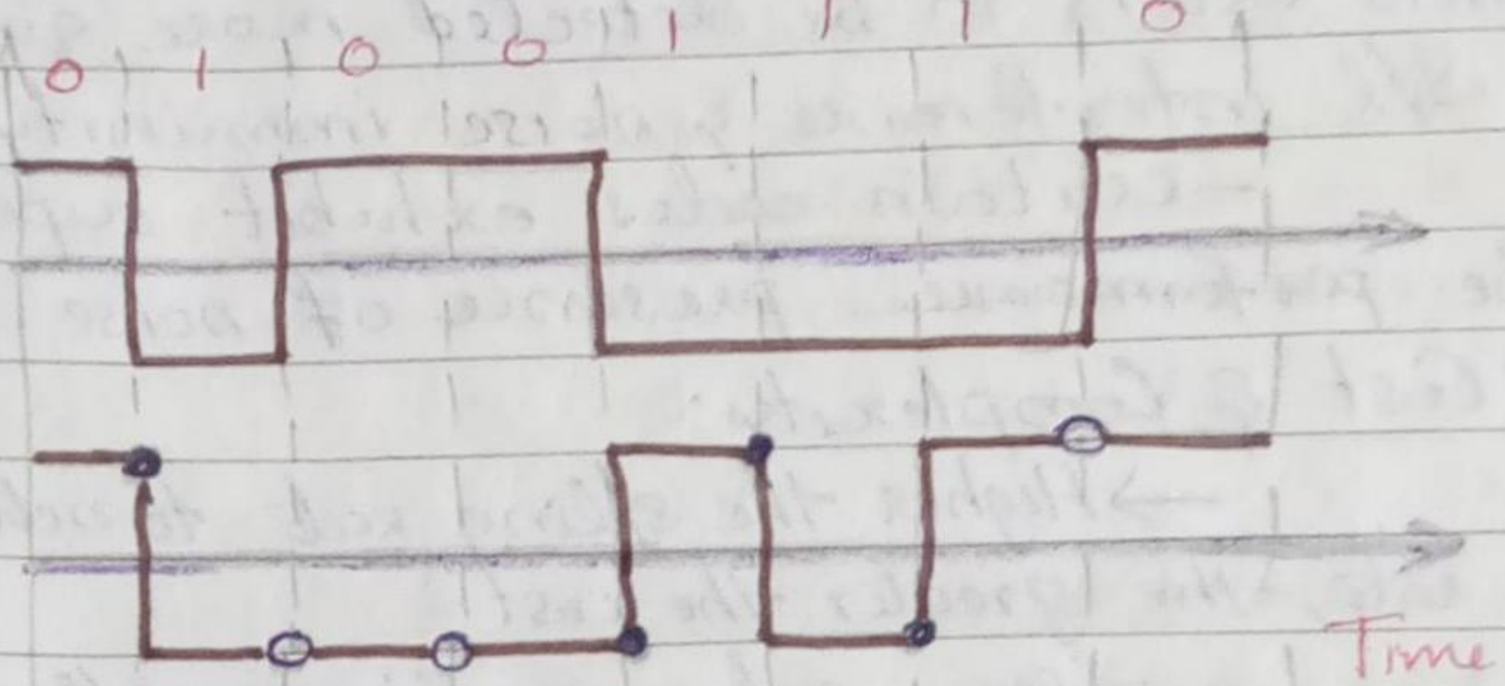
Polar NRZ-L & NRZ-I

In polar encoding we use 2 levels of voltage amplitude.

Two versions: NRZ-Level & NRZ-Invert.

NRZ-Level ⟹ the level of voltage determines the value of the bit.

NRZ-I ⟹ change or lack of change in the level of the voltage determines the value of the bit. If there is no change bit is 0; if there is a change, the bit is 1.



○ No inversion: Next bit is 0

● Inversion: Next bit is 1.

* Comparison based the Criterion.

→ Baseline wandering is a pblm for both variations, it is twice as severe in NRZ-L. If there is a long seq. of 0s or 1s in NRZ-L, the avg s/l power becomes skewed. The receiver might have difficulty discerning the bit value.

- In NRZ-I this pblm occurs only for a long seq. of 0s;

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→ The Sychronization pblm: (sender & receiver clks are not synchronized) also exists in both schemes. Long seq. of 0s can cause a pblm in both schemes, a long seq. of 1s affects only NRZ-L.

→ Another pblm with NRZ-L occurs when there is a sudden change of polarity in the s/m. For eg: If twisted pair cable is the medium, a change in the polarity of the wire results in all 0s interpreted as 1s & all 1s interpreted as 0s.

Data Rate: no. of data elmts (bits) sent in 1s. The unit bits/sec. ⇒ N. (bit rate)

Signal Rate: no. of s/l elmts sent in 1s. The unit is baud. (pulse rate, modulation rate or baud rate) ⇒ S

'r' ⇒ is a ratio which is the no. of data elmts carried by each s/l elmt.

Eg: 1 data elmt carried by 1 s/l elmt r = 1

1 " " 2 s/l elmt r = 1/2

2 " " 1 s/l elmt r = 2

Relationship b/w data rate & s/l rate

$S = c \times N \times \frac{1}{r}$ baud. c ⇒ case factor

S = no. of s/l elmt

Eg: A s/l is carrying data in which one data elmt is encoded as one s/l elmt (r = 1). If the bit rate = 100 kbps. what is the avg value of baud rate if c is b/w 0 & 1?

$S = c \times N \times \frac{1}{r}$ baud.

$c = \frac{0+1}{2} = 1/2$ (Assume). N = 100 kbps; r = 1

$S = 1/2 \times 100 \times 10^3 \times 1/1 = 50000$ baud

$= 50$ kbaud

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Min. Bandwidth $B_{min} = C \times N/ \times \frac{1}{\gamma}$

Max Datarate $N_{max} = \frac{1}{C} \times B \times \gamma$

> Multilevel Binary (Bipolar Scheme)

→ 3 voltage levels: +ve, -ve & zero.

→ S/l level for one data for one data elmt is at zero

→ S/l level for other elmt alternates b/w +ve & -ve.

⇒ Two variations: AMI & Pseudoternary.

AMI: Alternate Mark Inversion:

A binary 0 is represented by no line S/l, & binary 1 is represented by a +ve or -ve pulse. The binary pulses must alternate in polarity.

Advantages: no loss of synch. if a long string of 1s occurs. Each 1 oe introduces a transition, & the receiver can resynchronize on that trans^n.

— b/c the 1 S/ls alternate in voltage from +ve to -ve, there is no net dc component. The bandwidth of the resulting S/l is less than the bandwidth for NRZ.

— Pulse alteration property provides a simple means of error detection. whether it deletes a pulse or adds a pulse, causes a violation of this property.

Pseudoternary:

Binary 1 is represented by the absence of a line S/l, & the binary 0 by alternating +ve & -ve pulses.

> Biphase:

2 variations: Manchester & differential Manchester

Manchester:

— trans^n at the middle of each bit period. The midbit trans^n serves as a clocking mechanism & also as data: a low to high trans^n represents a 1 & a high to low represents a 0.

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Differential Manchester:

— 0 is represented by the presence of a trans^n at the beginning of the bit period, & a 1 is represented by the absence of a trans^n at the beginning of the bit period.

0 ⇒ ⌊ 1 ⇒ ⌈ (Manchester)

Advantages:

1. Synchronization: Bc there is a predictable trans^n during each bit time, the receiver can synch. on that trans^n ⇒ self clocking codes.
2. No dc component.
3. Error detection

Modulation Rate (D)

$$D = \frac{R}{L} = \frac{R}{\log_2 M}$$

D = Modulation rate
R = data rate, bps
M = no. of s/l elmts = 2^L
L = No. of bits/s/l elmt

Scrambling:

A log sequence of 0s upsets the synchronization. A solution that substitutes long zero level pulses with a combination of other levels to provide synchronization. This sol^n is called scrambling. Two common scrambling techniques are B8ZS & HDB3.

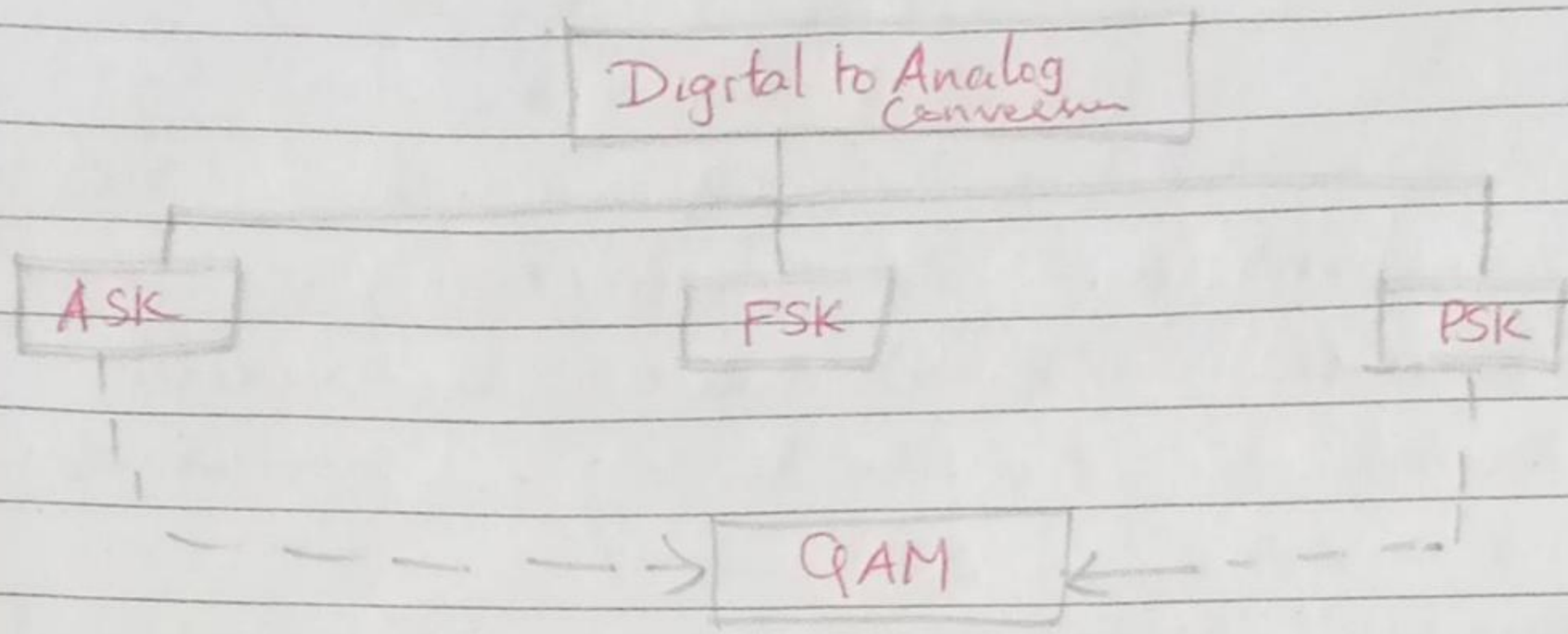
B8ZS: Bipolar with 8 zero substitution:

— Eight consecutive zero level voltages are replaced by the sequence 000VB0VB. The V in the sequence denotes violation; this is a nonzero voltage that breaks an AMI rule of encoding. The B in the sequence denotes Bipolar, which means nonzero level voltage in accordance with the AMI rule.

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1. Amplitude Shift keying
2. Freq. Shift keying
3. Phase Shift keying

⇒ Combining both amplitude & phase ⇒ Quadrature amplitude modulation.



Aspects:

~~Data element~~ S/l elmt: the smallest unit of a S/l that is const.

Data elmt: the smallest piece of inf^n to be exchanged, the bit.

Data Rate / Signal Rate:

$S = N \times \frac{1}{r}$ baud. // N – data rate

$r = \log_2 L$

L – type of S/l elmt not the level.

Ex: An analog S/l carries 4 bits/S/l elmt. If 1000 S/l elmts are sent/sec. find the bit rate.

$S = 1000$; $r = 4$ $B = N = ?$

$S = N \times \frac{1}{r}$ • $1000 = N \times \frac{1}{4}$

$N = 4 \times 1000 = 4000$ bps

2) An analog S/l has a bit rate of 8000 bps & a baud rate of 1000 baud. How many data elmts are carried by each S/l elmt? How many S/l elmts do we need?

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$S = 1000$ baud $N = 8000$ bps $r = ?$

$S = N \times \frac{1}{r}$ $\quad 1000 = 8000 \times \frac{1}{r}$

$r = N/S = \frac{8000}{1000} = 8$ bits/baud.

$r = \log_2 L \Rightarrow L = 2^r = 2^8 = 256$

Bandwidth: The required bandwidth for analog transm^n of digital data is ~~of~~ $\propto$ to the S/l rate.

Carrier S/l: The sending device produces a high fre. S/l that acts as a base for the inf^n s/l. The base s/l is called carrier s/l or carrier fr. Digital inf^n then changes the carrier s/l by modifying one or more of its characteristics (amplitude, fr. or phase). This kind of modific^n is called modulation (shift keying).

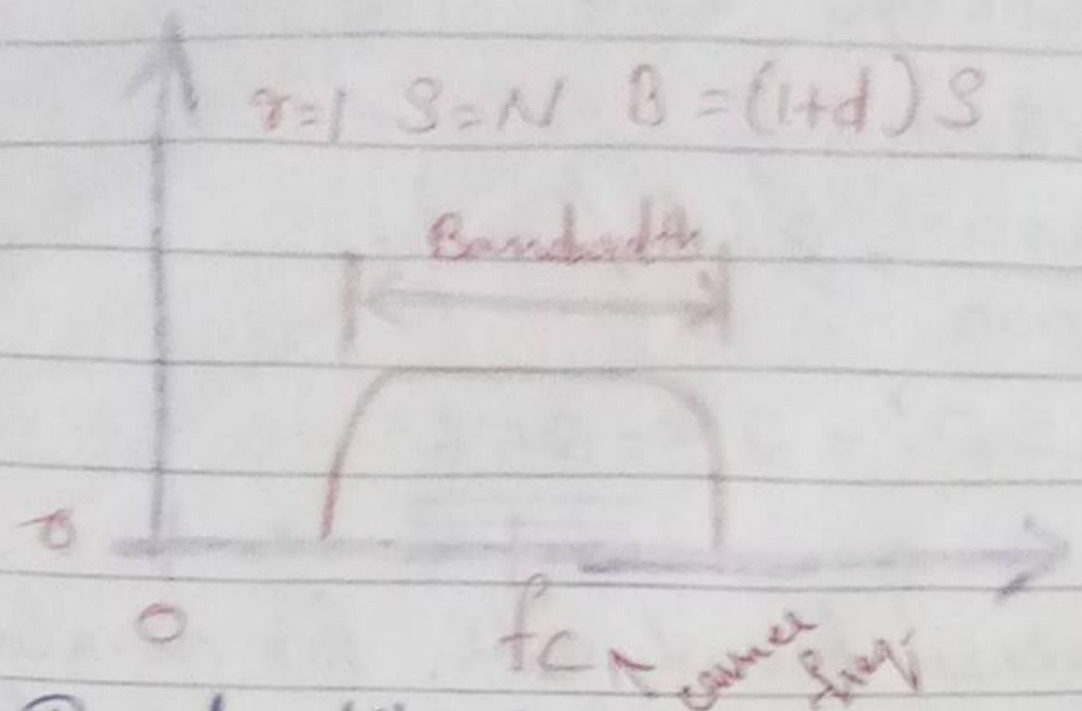
* Amplitude Shift Keying:

→ The amplitude of the carrier s/l is varied to create s/l elmts. Both fr. & phase remain constant while the amplitude changes.

→ Binary ASK:

— several levels/kinds of s/l elmts, each with a diff. amplitude, ASK is implemented using only 2 levels. This is referred to as binary amplitude shift keying (BASK) or on-off keying. The peak amplitude of one s/l level is zero; the other is same as the amplitude of the carrier fr.

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Bandwidth for ASK:

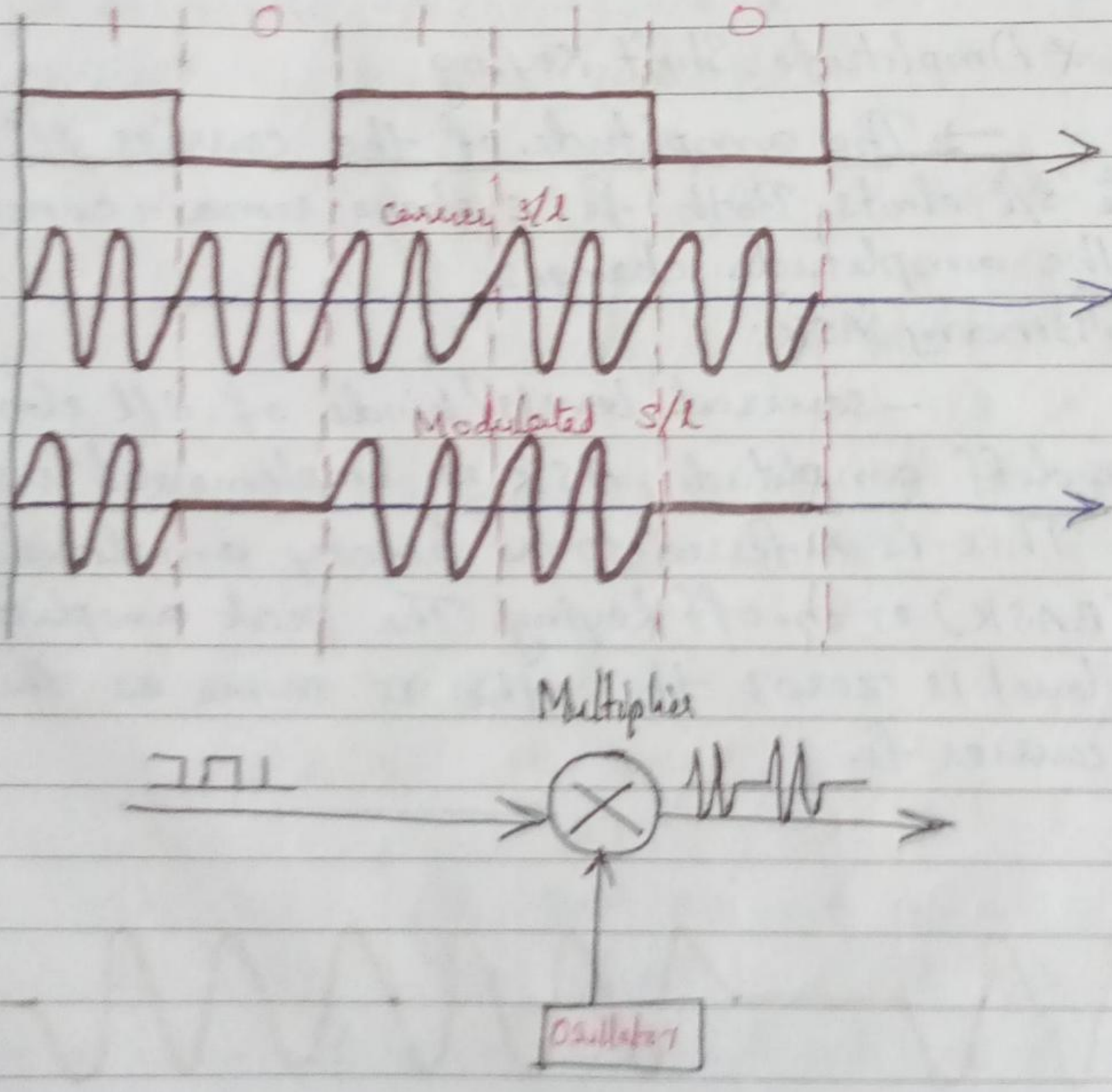
→ Bandwidth is proportional to B/L rate (baud rate)

d ⇒ depends on modulation & filtering process. Value of d is b/w 0 & 1. S ⇒ B/L Rate.

$$B = (1+d) \times S.$$

B has min. value S & max value 2S.

Implementation



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Examples:

An available bandwidth of 100kHz which spans from 200 to 300kHz. What are the carrier fr. & the bit rate if we modulated our data by using ASK with d=1? (r=1)

The middle of the band width (200-300kHz) at 250kHz. This means that our carrier fr. can be at 250kHz.

$\therefore$ Bandwidth $B = (1+d) \times S$

$100 = (1+1) \times S$

$100 = 2 \times N \times \frac{1}{r}$ $\quad // S = N \times \frac{1}{r}$

$= 2 \times N \times \frac{1}{1} = 2N$

$N = 100/2 = \underline{50 kbps}$

In ASK, 2 binary values are represented by 2 diff. amplitudes of the carrier fr. One of the amplitudes is zero; i.e; one binary digit is by the presence of the carrier, the other by the absence of the carrier. The resulting transmitted s/l for one bit time is

$$s(t) = \begin{cases} A \cos(2\pi f_c t) & \text{binary 1} \\ 0 & \text{binary 0.} \end{cases}$$

Multilevel ASK:

→ more than 2 levels.

→ uses 4, 8, 16 or more diff. amplitudes for the s/l & modulate the data using 2, 3, 4 more bits at a time. & r=2, r=3, r=4 & so on

Appl" ASK:

→ transmit digital data over optical fiber.

→ LED: One s/l elmt is represented by a light pulse while the other is represented by the absence of light.

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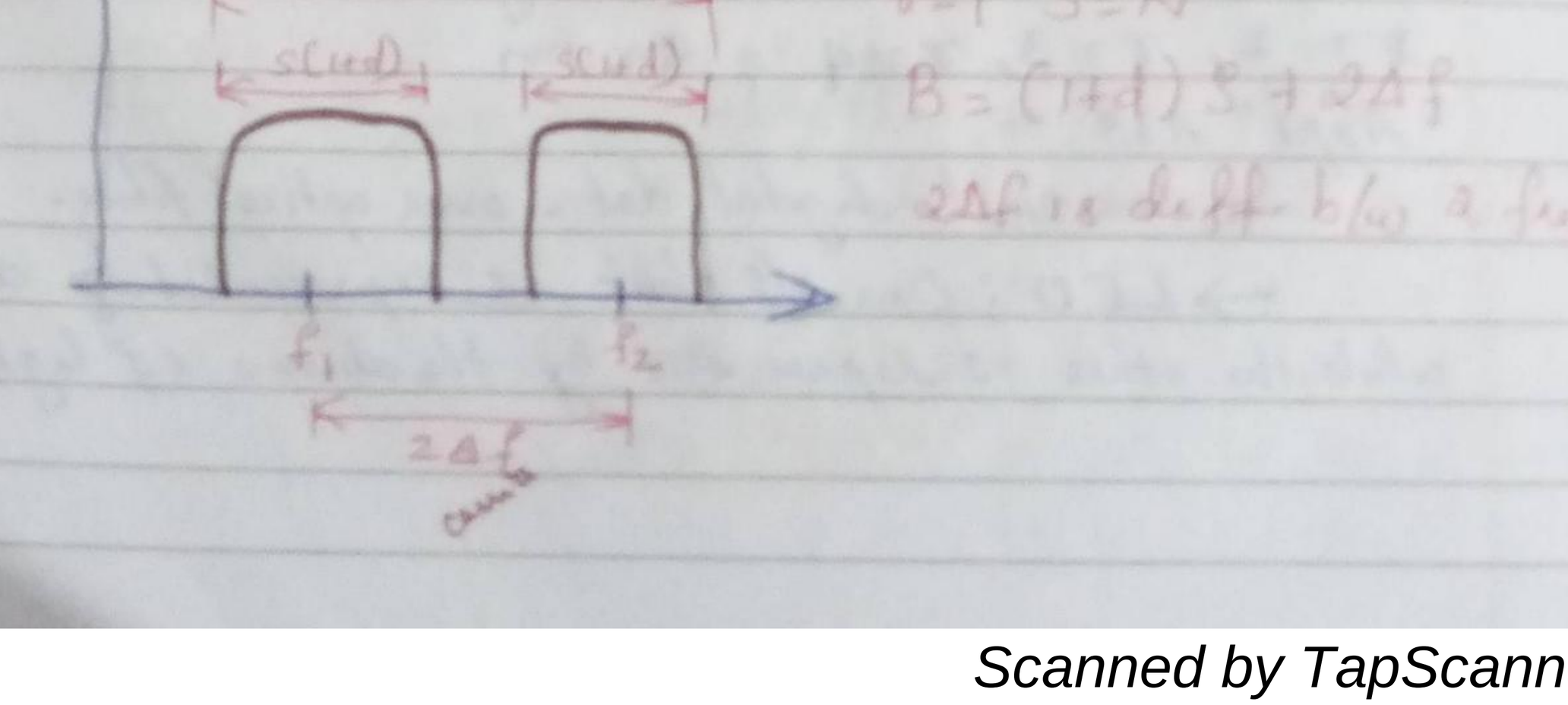
* Frequency Shift Keying:

In FSK, the fr. of the carrier s/l is varied to represent data. The fr. of the modulated s/l is const. for the duration of one s/l elmt, but changes for the next s/l elmt if the data elmt changes. Both peak amplitude & phase remain constant for all s/l elmts.

$$BFSK \quad s(t) = \begin{cases} A\cos(2\pi f_1 t) & \text{binary 1} \\ A\cos(2\pi f_2 t) & \text{binary 2.} \end{cases}$$

f_1 & f_2 are typically offset from the carrier fr. f_c by equal but opposite amnts.

Binary FSK : consider 2 carrier freq.s: f_1 & f_2.
first carrier if the data elmt is zero; use second if the data elmt is 1.



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Available Bandwidth of 100kHz which spans from 200 to 300kHz. What should be the carrier fr. & the bit rate if we modulated our data by using FSK with d=1?

mid pt. - 250kHz. $2\Delta f = 300-250 = 50$

or $250-200 = 50$kHz

$B = (1+d) \times S + 2\Delta f = 100$

$\Rightarrow (1+1) \times S + 50 = 100$

$2S = 100 - 50 = 50$

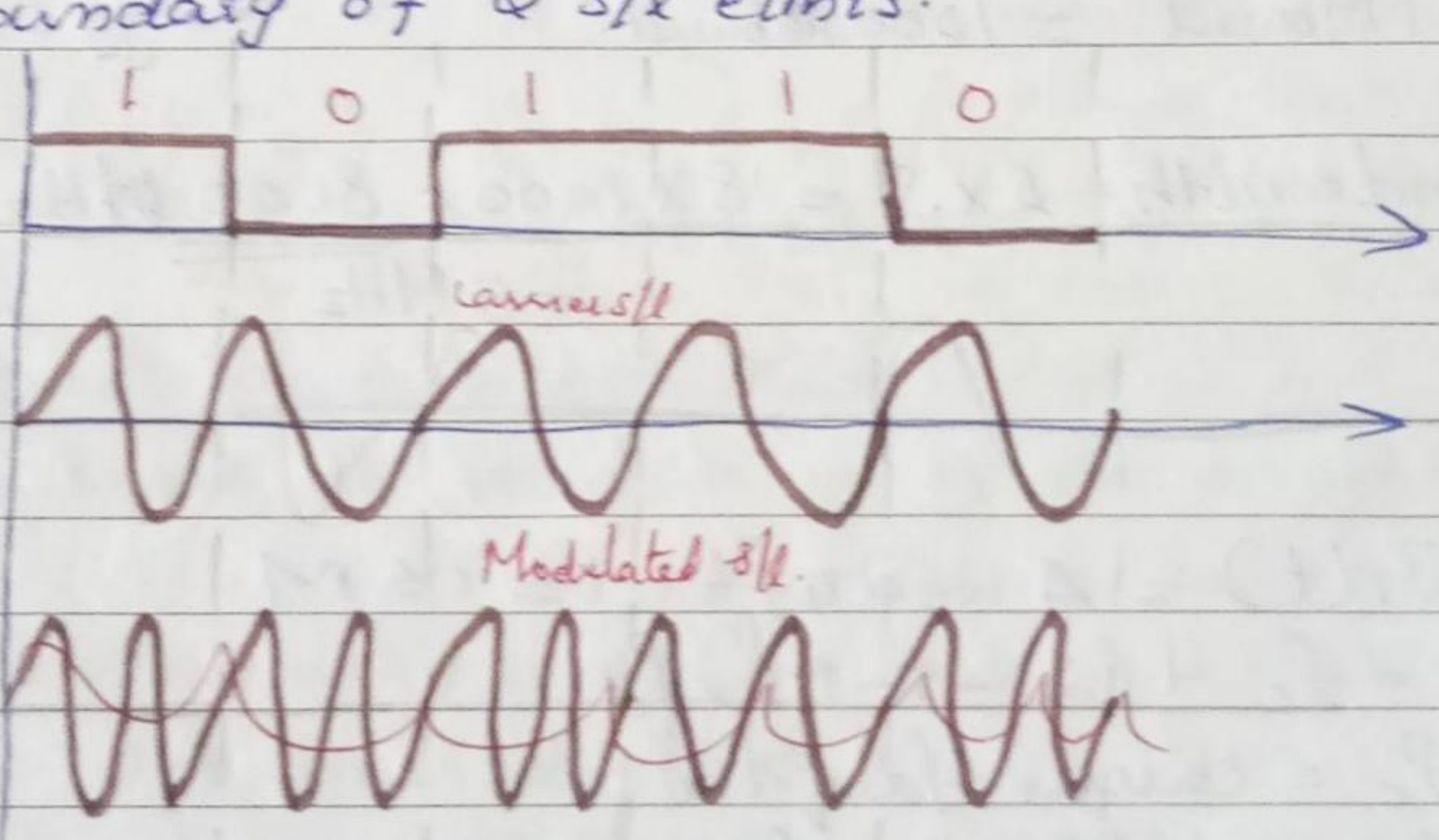
$S = 50/2 = 25$ kbps

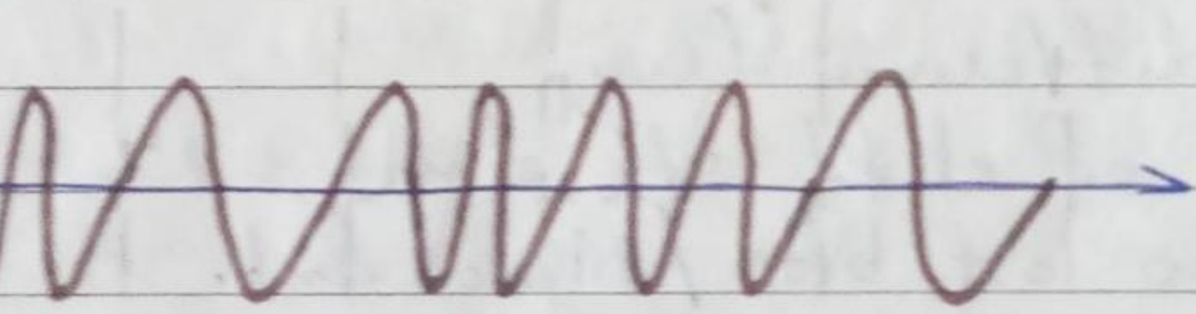
Implementation: 2 ways.

* noncoherent & coherent.

In noncoherent BFSK, there may be discontinuity in the phase when one s/l elmt ends & the next begins.

In coherent BFSK, the phase continues through the boundary of 2 s/l elmts.





VCO changes its fr. acc. to the i/p voltage.

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* Multilevel FSK:

→ uses more than 2 frequencies for eg:
4 diff. fr.s f_1, f_2, f_3 & f_4 to send 2 bits at a time.
To send 3 bits at a time, we can use 8 fr.s
The bandwidth with d=0

$$B = (1+d) \times S + (L-1)2\Delta f$$
$$= (1+0) \times S + (L-1)S \quad // \text{min value of } 2\Delta f \text{ needs to be } S$$
$$= S + LS - S = \underline{\underline{L \times S}}$$

Eg: We need to send data 3 bits at a time at a bit rate of 3Mbps. The carrier fr. is 10MHz. Calculate the no. of levels, the baud rate & the bandwidth.

$L = 2^3 = 8$

Baud rate $S = N \times \frac{1}{r} = 3 \times \frac{1}{3}$ // $r = \log_2 L$
$= \log_2 8 = \underline{\underline{3}}$

1 Mbaud = 1000 baud.

Bandwidth $= L \times S = 8 \times 1000 = \underline{\underline{8000}}$ Hz
$= 8$ MHz

MFSK, $s_i(t) = A \cos 2\pi f t \quad 1 \le i \le M$
$f_i = f_c + (2i - 1 - M) f_d$
f_c = carrier freq.
f_d = difference freq.
M = no. of diff. s/l elmts $= 2^L$
L = no. of bits / signal elmt.

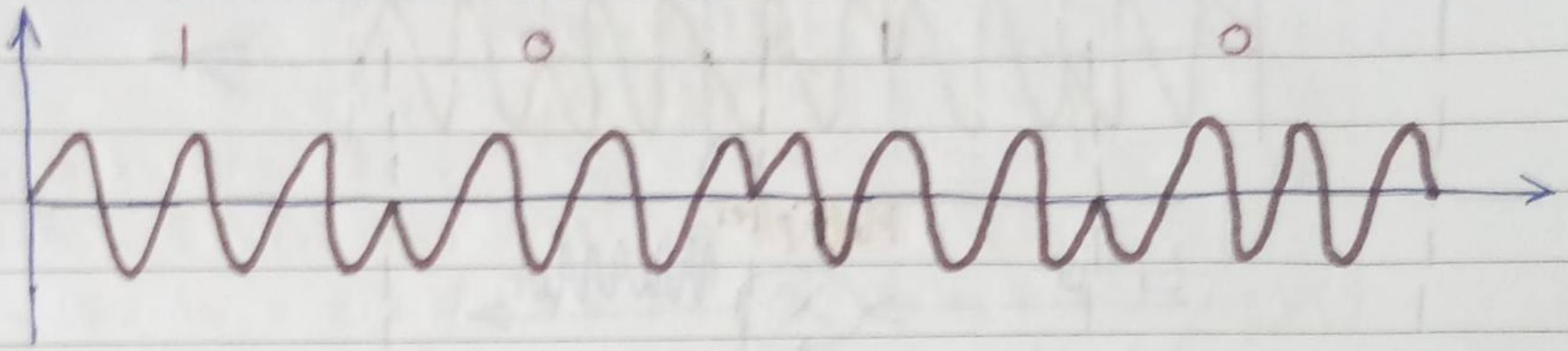
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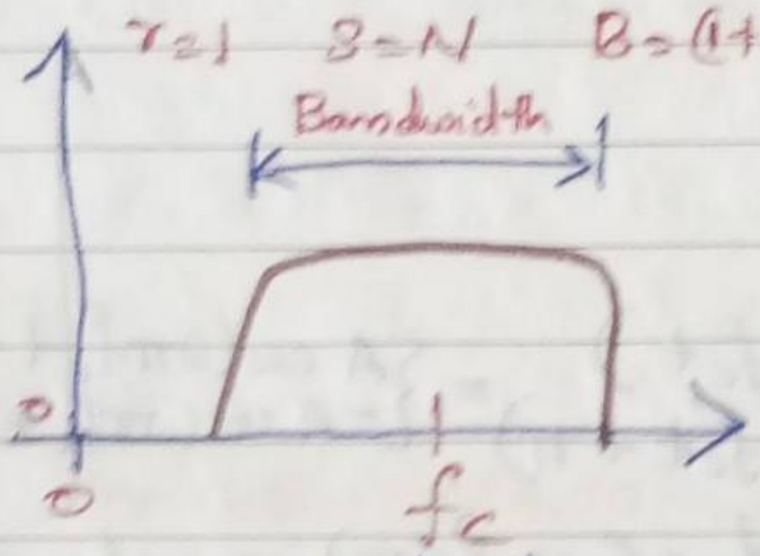
* Phase Shift Keying:

The phase of the carrier is varied to represent 2 or more diff. s/l elmts. Both peak amplitude & fr. remain const. as the phase changes.

Binary PSK:

— only 2 s/l elmts, one with a phase of 0°, & the other with a phase of 180°





← Bandwidth: is same as that for binary ASK, but less than that for BFSK. No bandwidth is wasted for separating 2 carrier s/ls.

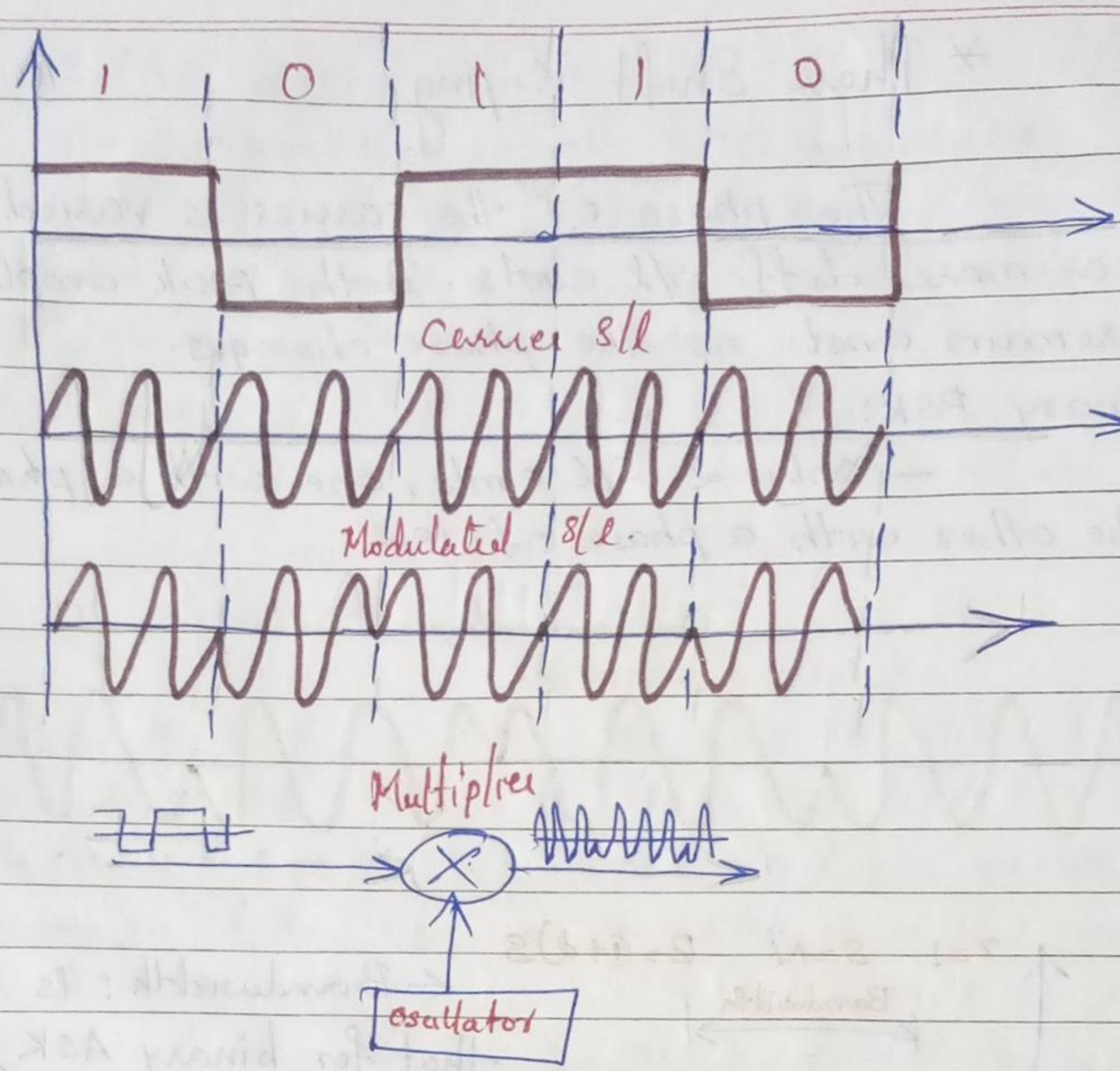
→ Less susceptible to noise.

→ In ASK, bit detection is by the amplitude of the s/l; in PSK, it is the phase. Noise can change amplitude easier than it can change the phase.

~~*~~ Implementation:

— the s/l elmt with phase 180° can be seen as complement of the s/l elmt with phase 0°. The polar NRZ s/l is multiplied by the carrier frequency; the 1 bit (+ve voltage) is represented by a phase starting at 0°; the 0 bit (−ve voltage) is represented by a phase starting at 180°.

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$$\text{BPSK } s(t) = \begin{cases} A\cos(2\pi f_c t) \\ A\cos(2\pi f_c t + \pi) \end{cases} = \begin{cases} A\cos(2\pi f_c t & \text{binary 1} \\ -A\cos(2\pi f_c t & \text{binary 0} \end{cases}$$

B/c a phase shift of 180° (π) is eqt. to flipping the sine wave or multiplying it by −1, the rightmost expr" can be used.

Four level PSK: More efficient bandwidth can be achieved if each s/ling elmt represents more than one bit. For eg: instead of a phase shift of 180°, as allowed in BPSK; a common encoding technique known as quadrature phase shift keying (QPSK), uses phase shifts separated by multiples of $\pi/2$ (90°).

$$\text{QPSK } s(t) = \begin{cases} A\cos(2\pi f_c t + \pi/4) & 11 \\ A\cos(2\pi f_c t + 3\pi/4) & 01 \\ A\cos(2\pi f_c t + 5\pi/4) & 00 \\ A\cos(2\pi f_c t - \pi/4) & 10 \end{cases}$$

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Multilevel PSK: to transmit 3 at a time using eight diff. phase angles. ~~ea~~ Each angle can have more than one amplitude.

Performance:

Transmsn bandwidth B_T for ASK

ASK $B_T = (1+r)R$ // R = bit rate

r = by which the s/l is filtered $0 < r < 1$.

MPSK $B_T = \left(\frac{(1+r)}{L}\right)R = \left(\frac{1+r}{\log_2 M}\right)R$

// L — no. of bits encoded / s/l.

// M — no. of diff. s/l elmts.

MFSK $B_T = \left(\frac{(1+r)M}{\log_2 M}\right)R$

> Analog Data Digital s/ls:

→ process of transforming analog data into digital s/ls. (Digitization).

→ Two techniques → Pulse Code Modulation
→ Delta Modulation.

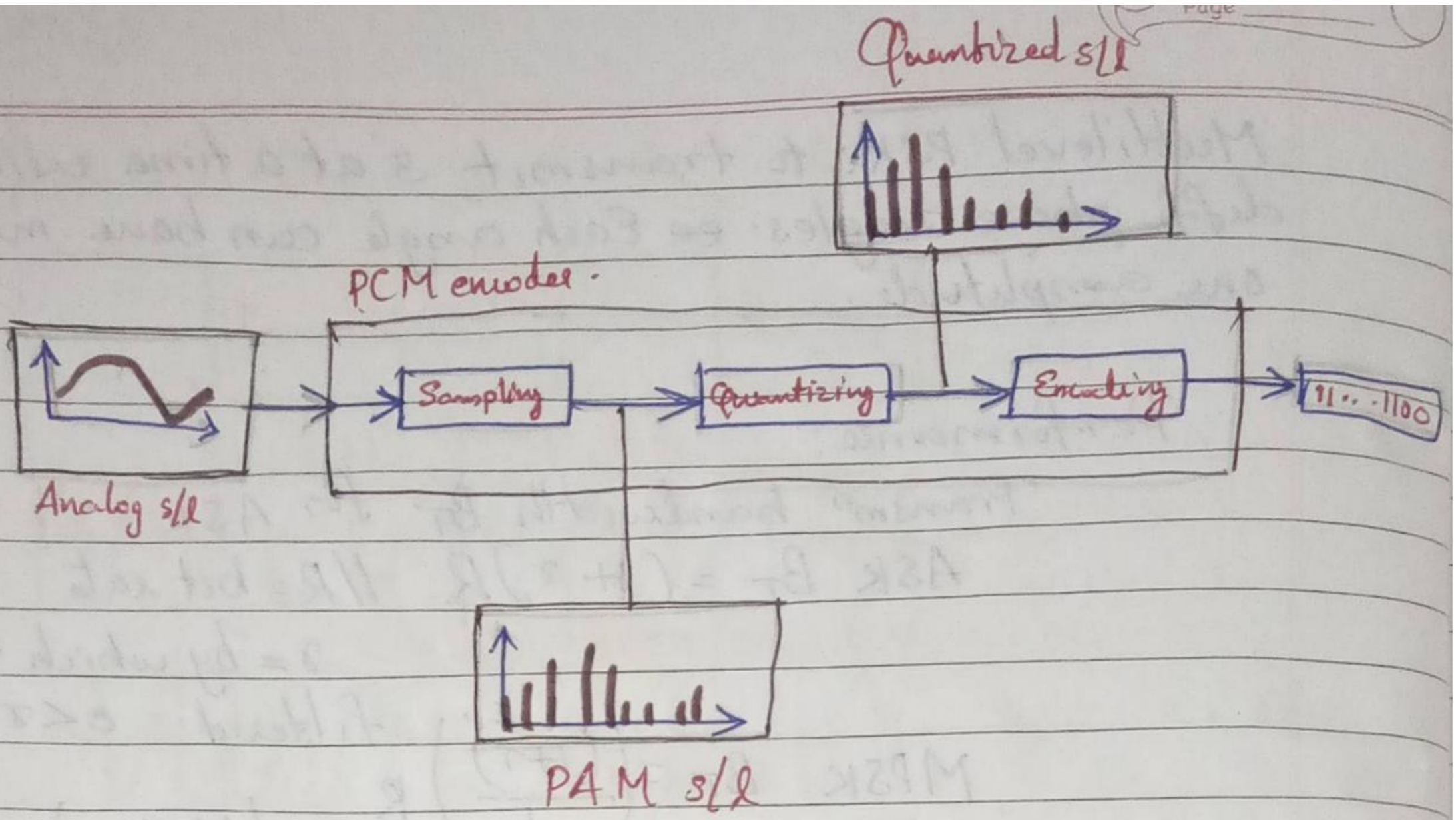
→ The device used for converting analog data into digital form for transmsn & subsequently recovering the original analog data from the digital is known as codec (coder-decoder).

* Pulse Code Modulation (PCM).

A PCM encoder has 3 processes:

1. The analog s/l is sampled.
2. The sampled s/l is quantized.
3. The quantized values are encoded as stream of bits.

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* Sampling Theorem: If a s/l $f(t)$ is sampled at regular intervals of time & at a rate higher than twice the highest s/l frequency, then the samples contain all the inf^n of the original s/l. The fn $f(t)$ may be reconstructed from these samples by the use of a lowpass filter.

→ The analog s/l is sampled every T_s s, where T_s is the sample interval/period. (sampling fr - $f_s = 1/T_s$)

There are 3 sampling methods: ~~idela~~

- ideal, natural & flat-top

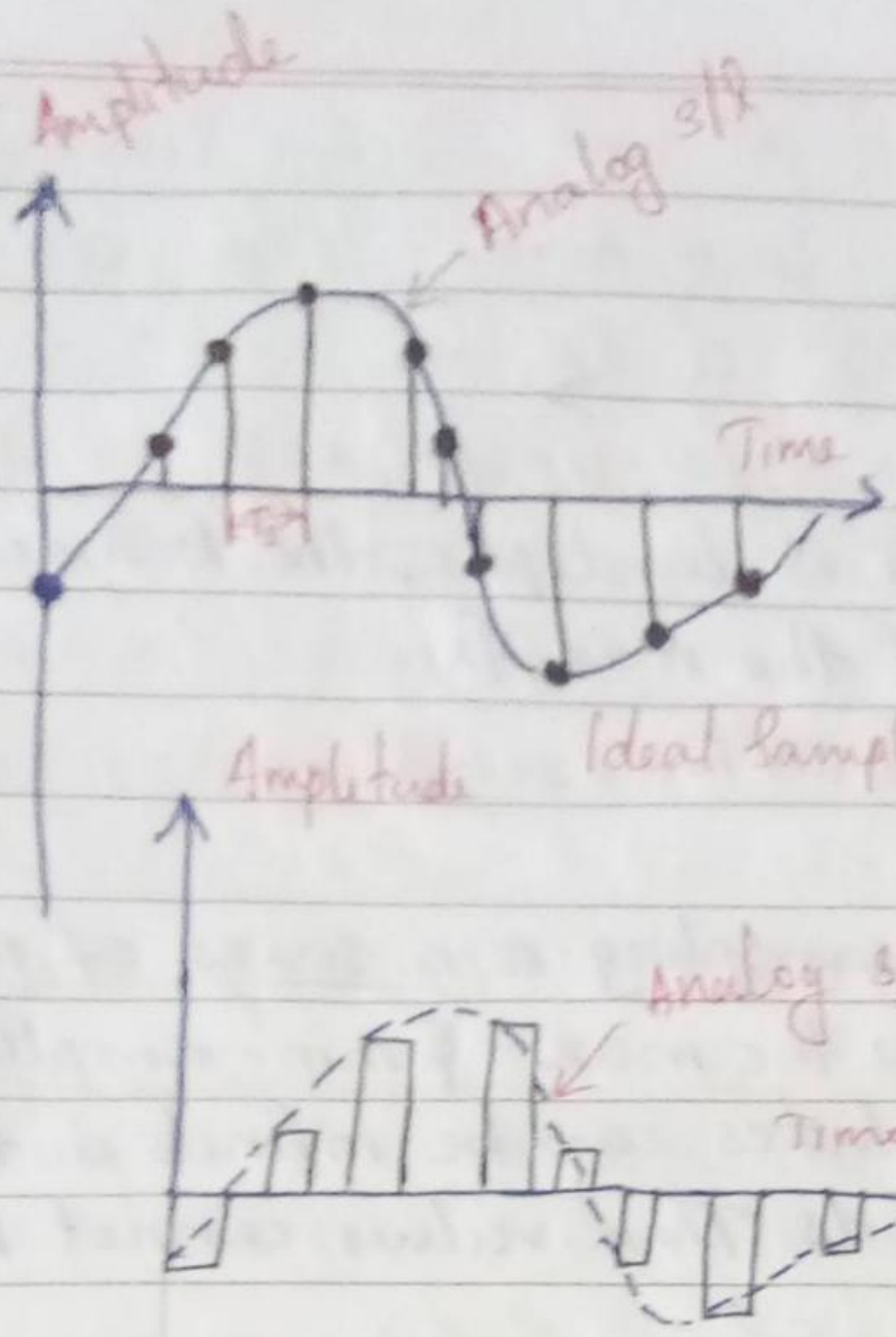
— In ideal sampling, pulses from the analog s/l are sampled. - cannot be ~~as~~ easily implemented.

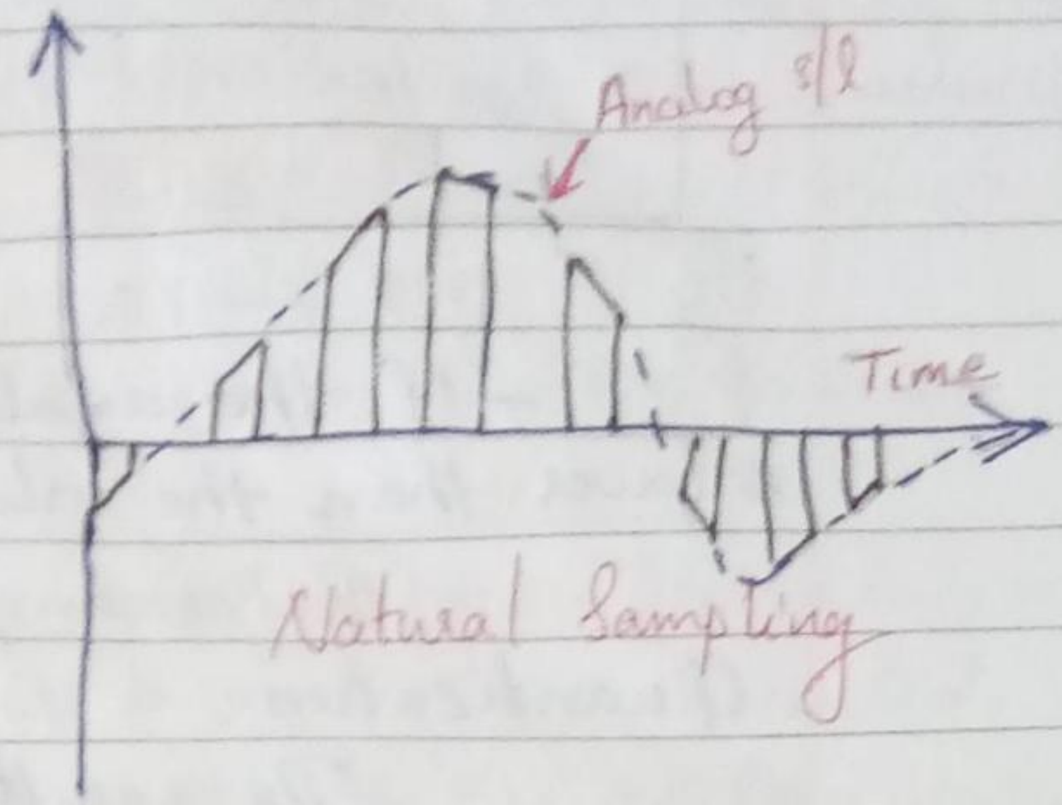
— In natural sampling, a high speed switch is turned on for only the small period of time when the sampling occurs. The result is a seq. of samples that retains the shape of the analog s/l.

— Sample & hold: creates flat top samples by using a circuit.

— The sampling process referred to as pulse amplitude modulation.

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Sampling Rate:

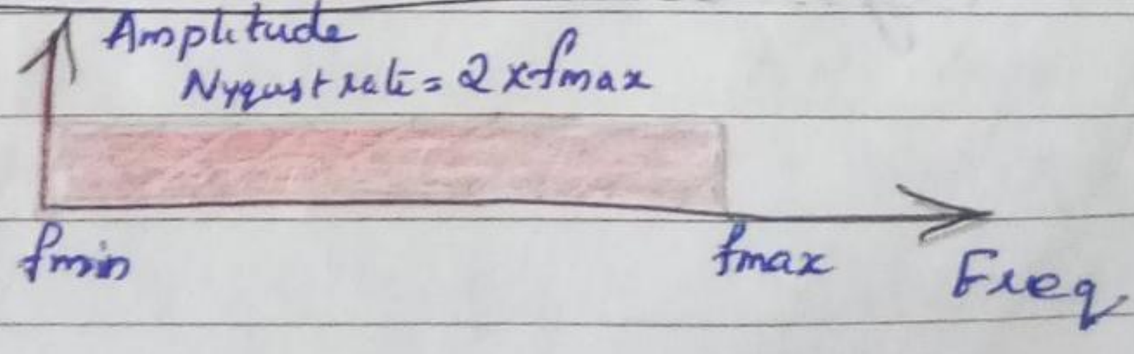
$T_s \Rightarrow$ sample interval/period. The inverse of the sampling interval is called sampling rate or sampling fr. $\Rightarrow f_s = 1/T_s$

Acc. to Nyquist theorem, to reproduce the original analog s/l, ~~one~~ one condⁿ is that the sampling rate be at least twice the highest fr. in the original s/l.

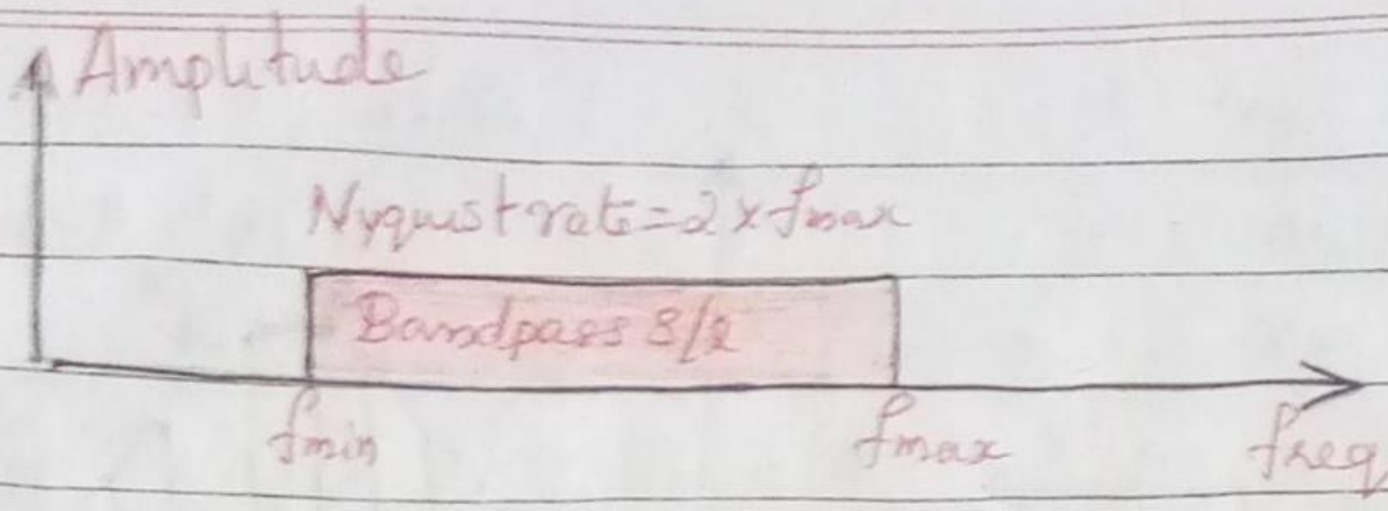
→ We can sample a s/l only if the s/l is band limited. ie; A s/l with an infinite bandwidth cannot be sampled.

→ The sampling rate must be atleast 2 times the ff highest fr., not the bandwidth.

→ If the analog s/l is low-pass, the bandwidth & the highest fr. are the same value.



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- If the analog S/l is band pass, the bandwidth value is lower than the value of the max. fr.

Ref example 4-6 (Forouzan).

Quantization:

The result of sampling is a series of pulses with amplitude values b/w the max- & min- amplitudes of the S/l. The set of amplitudes can be infinite with nonintegral values b/w the 2 limits. These values cannot be used in the encoding process.

Steps: 1. We assume that the original analog S/l has instantaneous amplitudes b/w Vmin & Vmax.

2- We devide the range into L zones, each of height Δ (delta)

$$\Delta = \frac{V_{max} - V_{min}}{L}$$

3. We assign quantized values of 0 to L-1 to the midpt. of each zone.

4. We approximate the value of the sample amplitude to the quantized values.

As a simple eg: assume that we have a sampled S/l & the sample amplitudes are b/w -20 & +20V. We decide to have 8 levels (L=8). This means

$$\Delta = \frac{20 - -20}{8} = \frac{40}{8} = 5V$$

Fig: 4-26.

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Quantization Levels: L - no. of levels, depends on the range of the amplitudes of the analog s/l & how accurately need to recover the s/l. If the amplitude of a s/l fluctuates b/w 2 values only, we need only 2 levels;

Voice has many amplitude values, we need more quantization levels. ($L = 256$).

Quantization error: Approximation process - i/p values are the real values; the o/p values are the approximated values. The o/p values are chosen to be the middles value in the zone. If the i/p is also at the middle of the zone, there is no quantization error; otherwise there is an error.

See eg: 4.26 (Forouzan).

$$SNR_{dB} = 6.02 n_b + 1.76 dB$$

Eg: 4.12

A telephone subscriber line must have an SNR_{dB} above 40. What is the min. no. of bits / sample?

$$SNR_{dB} = 6.02 n_b + 1.76 = 40$$

$$6.02 n_b = 40 - 1.76 \; ; \; n_b = \frac{40 - 1.76}{6.02} = \underline{\underline{6.35}}$$

ie; 7 or 8 bits.

Uniform Versus Nonuniform Quantization:

Companding means reducing the instantaneous voltage amplitude for large values; at the send by compressing

Expanding is the opposite process.

Non uniform Quantization can be achieved by Companding & expanding.

Encoding: last step in PCM. After each sample is quantized & the no. of bits/sample is decided, each sample can be changed to an n_b-bit code word. For eg: Quantization code of 15 is encoded as 010 - - - . No. of bits per sample is determined from the no. of Quantization levels.

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$n_b = \log_2 L$.

Bit rate = Sampling rate x no. of bits/sample.

$= f_s \times n_b$.

Eg: Digitize human voice. What is bit rate assuming 8 bits/sample?

Human voice - $f_s \Rightarrow 0 - 4000$ Hz (Low pass)

Sampling rate $\geq 4000 \times 2 = 8000$ Samples/s.

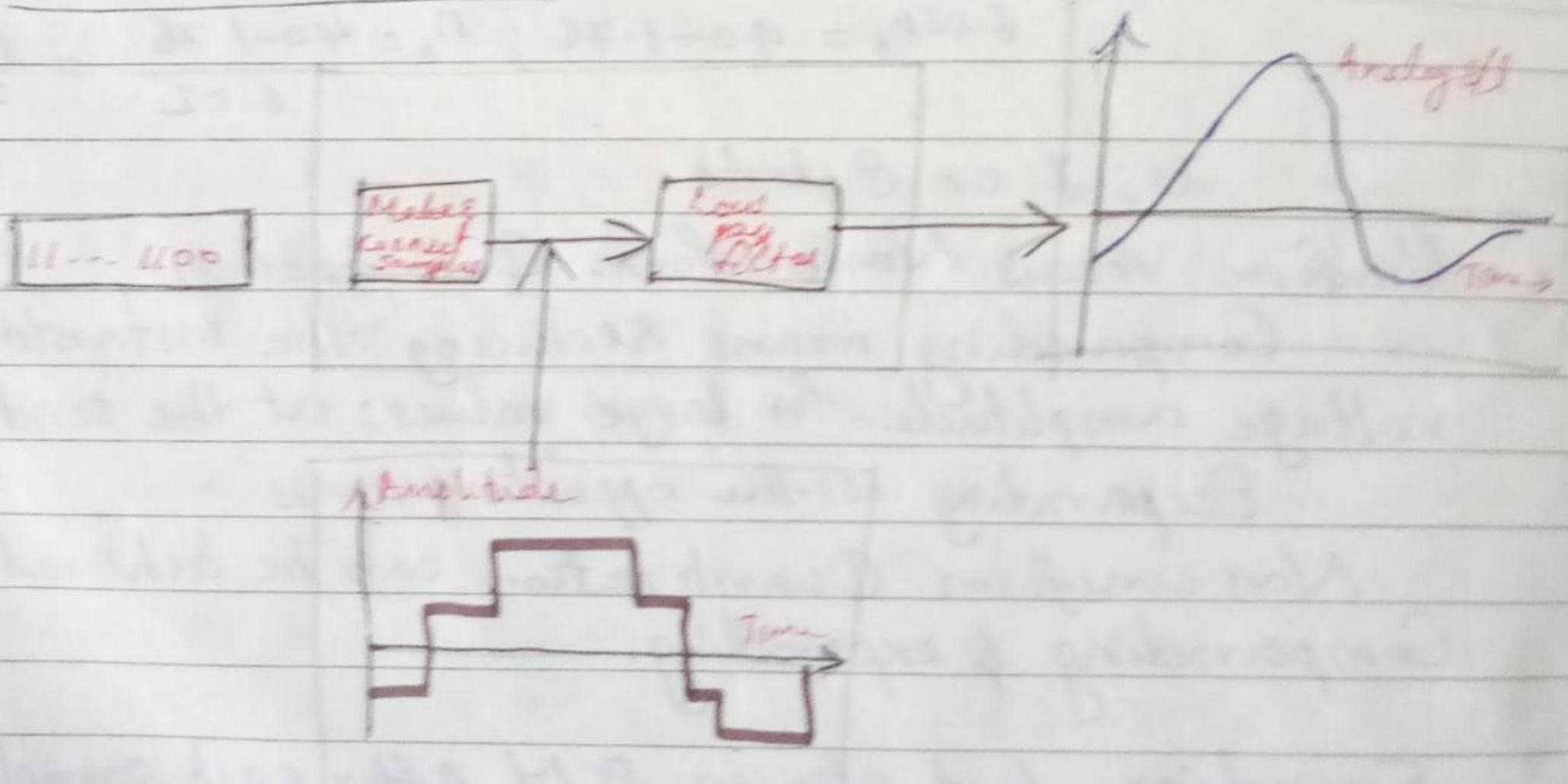
($2 \times f_{max}$) Nyquist theorem.

Bit rate $= 8000 \times 8 = 64000$ bps $=$ 64 kbps.

Original S/L Recovery:

- requires PCM decoder.
- first convert the code words into a pulse that holds the amplitude until the next pulse.

The filter has the same cutoff f_s as the original S/L at the sender.



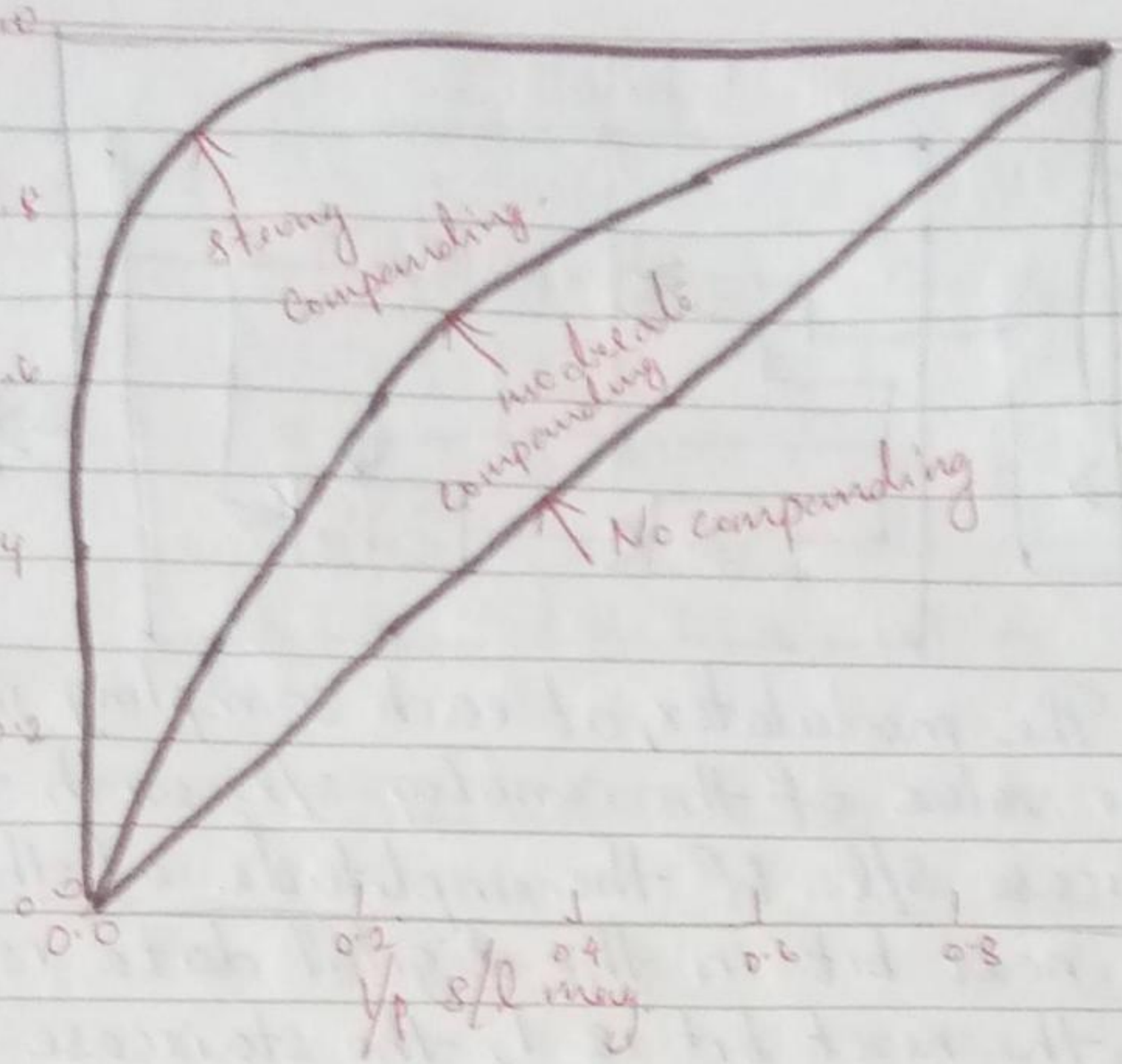
PCM Bandwidth

- $B_{min} = C \times N \times \frac{1}{\gamma} = C \times n_b \times f_s \times \frac{1}{\gamma} = C \times n_b \times 2 \times B_{analog} \times \frac{1}{\gamma}$.

$B_{min} = n_b \times B_{analog}$.

$\left(\frac{C=1}{\gamma=2}\right)$

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Typical Companding I.

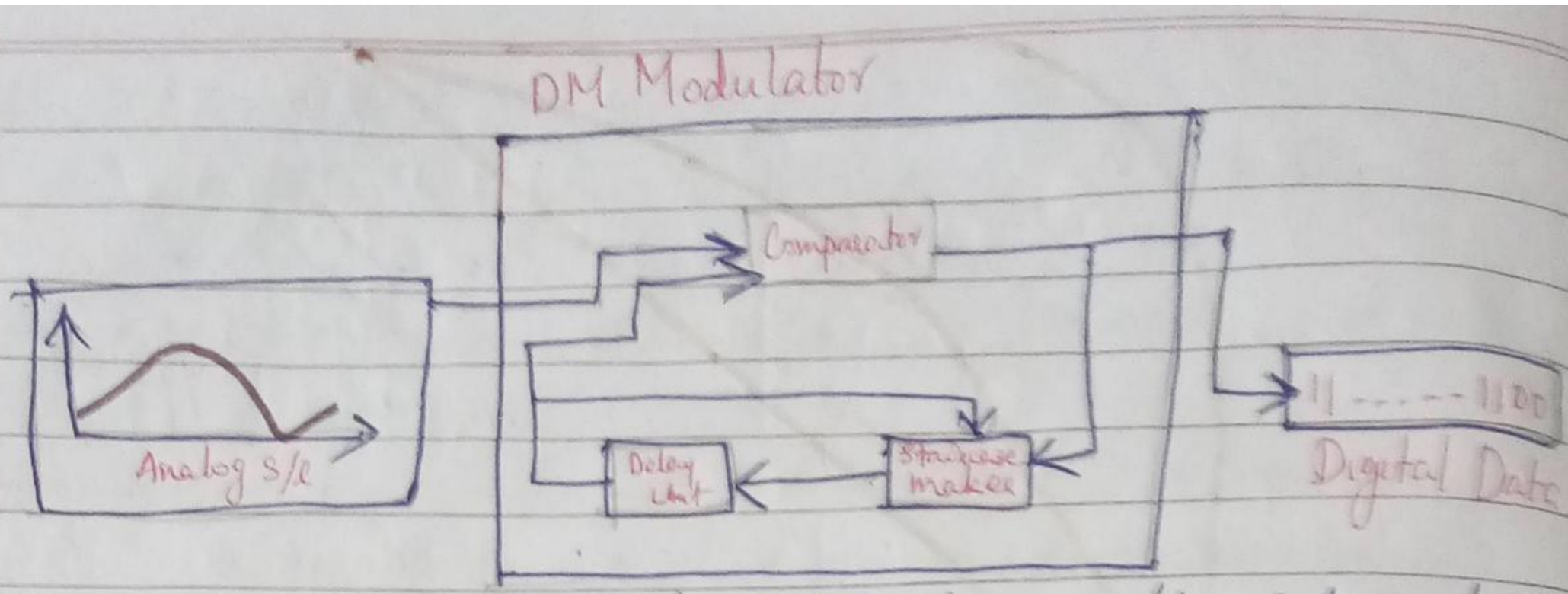
Companding is a process that compresses the intensity range of s/l by imparting more gain to weak s/ls than to strong s/ls on i/p.

* Delta Modulation:

With delta modulation, an analog i/p is approximated by a staircase fn that moves up or down by one quantization level (δ) at each sampling interval (T_s). Staircase fn. behavior is binary. The o/p of delta modulation can be represented as a single binary digit for each sample. A 1 is generated if the staircase fn is to go up during the next interval; a 0 is generated otherwise.

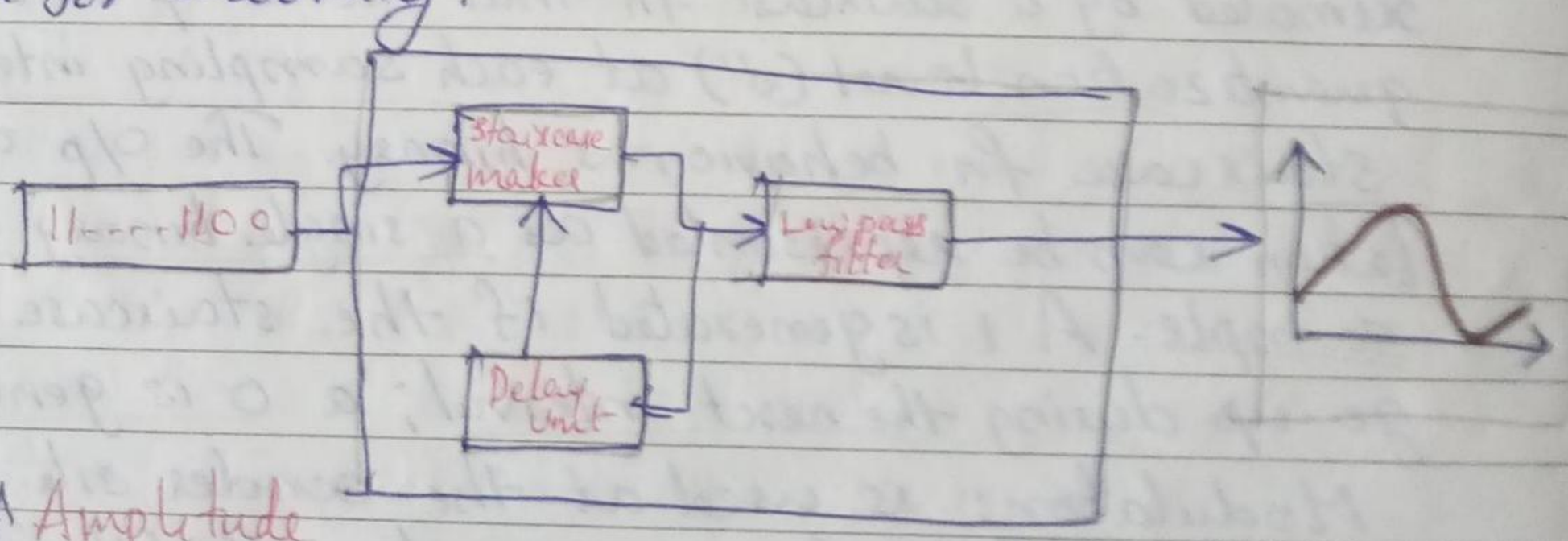
Modulator: is used at the sender site to create a stream of bits from an analog s/l. The process records small +ve or -ve changes, called delta(δ). If the delta is +ve; the process records a 1; if it is -ve, the process records a 0. The modulator builds a 2nd s/l that resembles staircase. Finding the change is then reduced to comparing the i/p s/l with the gradually made staircase s/l.

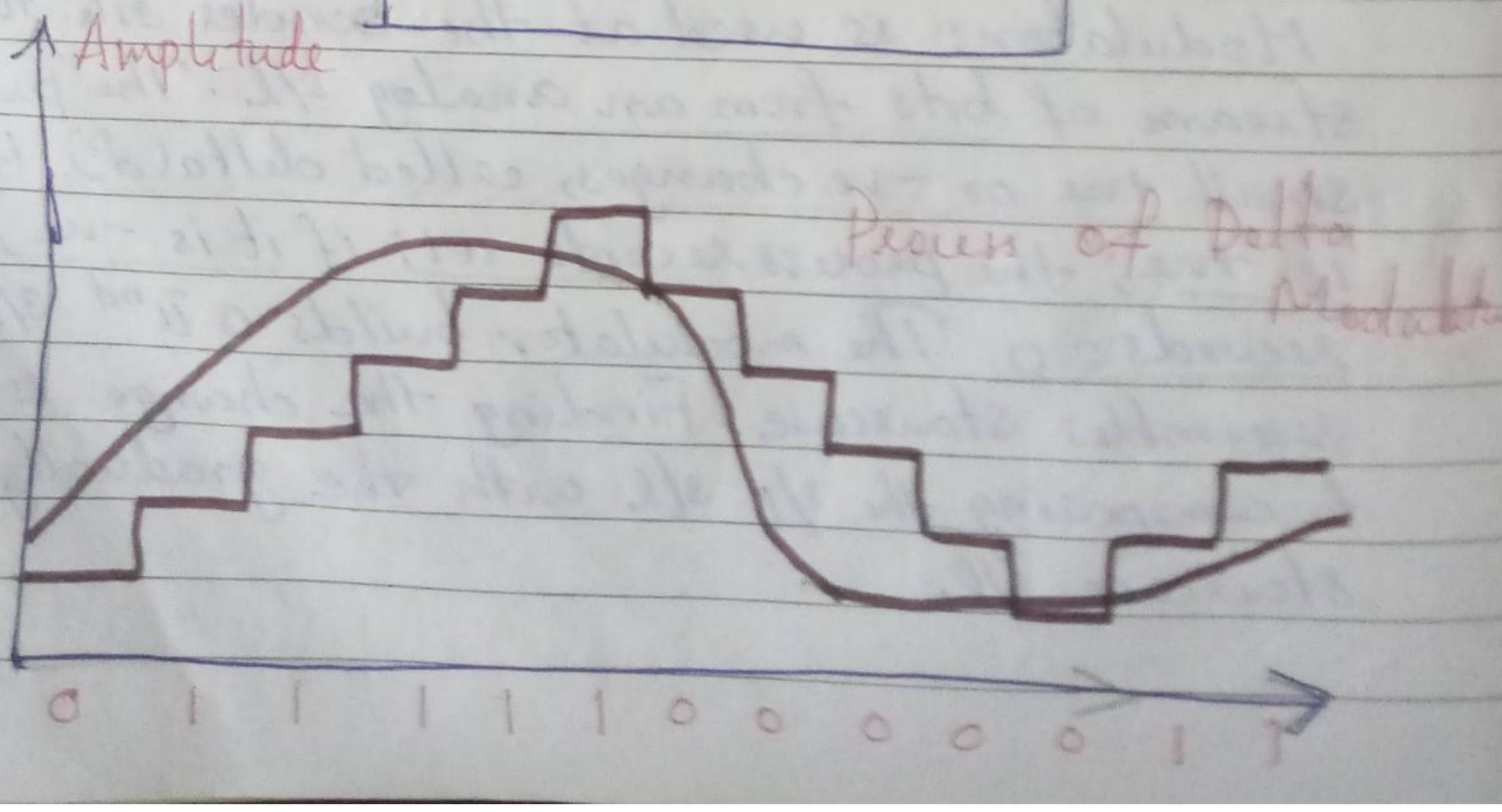
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The modulator, at each sampling interval, compares the value of the analog S/L with the last value of the staircase S/L. If the amplitude of the analog S/L is larger the next bit in the digital data is 1; otherwise it is 0. If the next bit is 1, the staircase maker moves the last pt. of staircase S/L Δ up; if the next bit is 0, it moves Δ down.

Demodulator: takes digital data & using the staircase maker & the delay unit, creates the analog S/L. The created analog S/L needs to pass through a low-pass filter for smoothing.





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* Analog Data Analog Signals:

Analog to analog conversion can be accomplished in 3 ways:

→ Amplitude Modulation
→ Frequency Modulation
→ Phase Modulation.

Modulation is defined as the process of combining an i/p s/l $m(t)$ & a carrier fr. f_c to produce a s/l $s(t)$ whose bandwidth is usually centered on f_c.

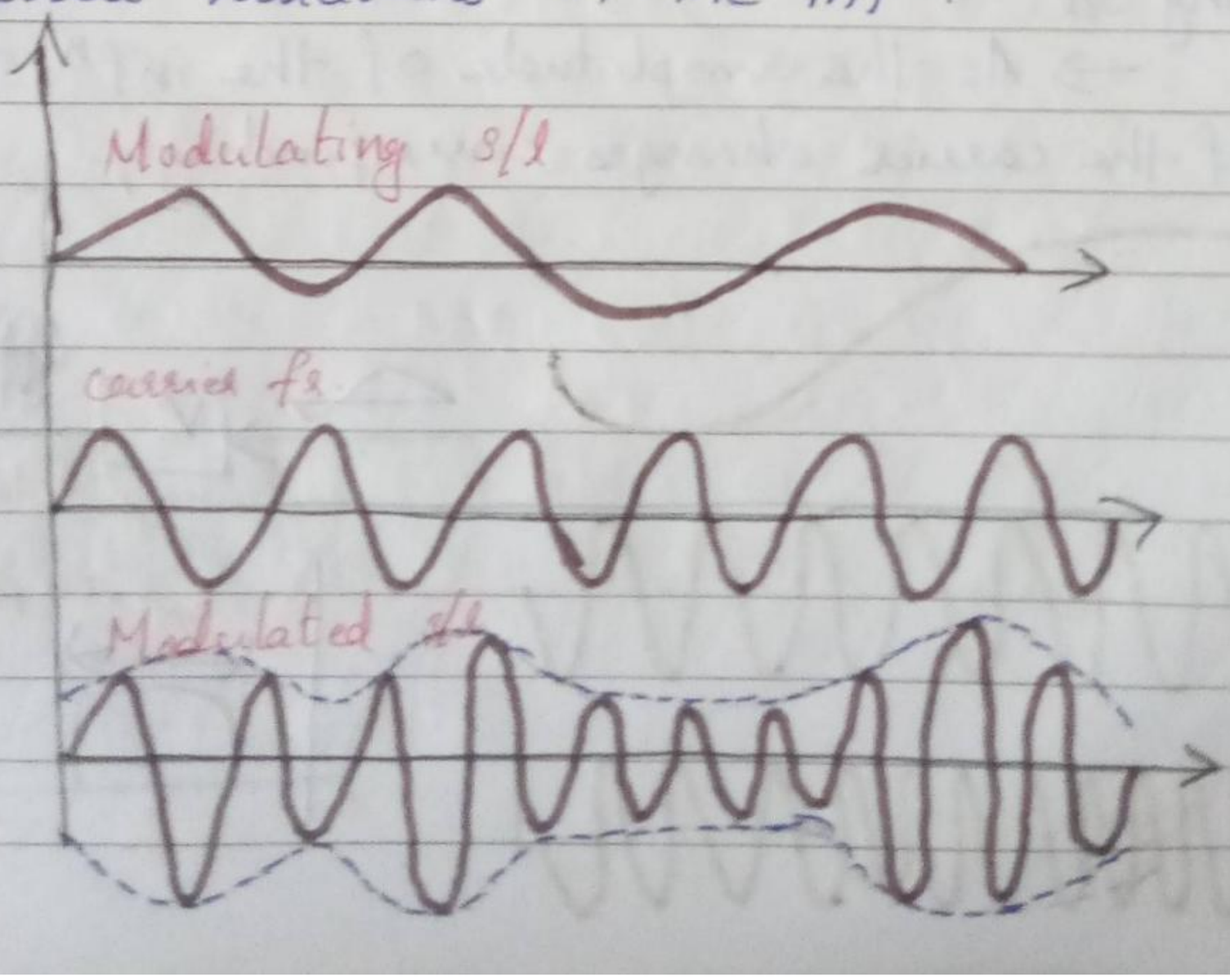
Reasons for analog modulation of analog s/ls.

→ A higher fr is needed for effective transmn. For unguided transmn, it is impossible to transmit baseband s/ls; the required antennas would be many kilometers in diameter.

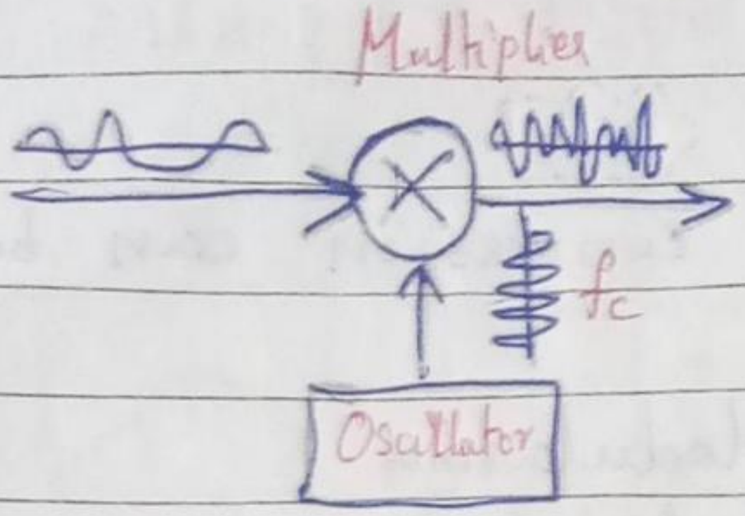
→ Modulation permits Fr. division multiplexing.

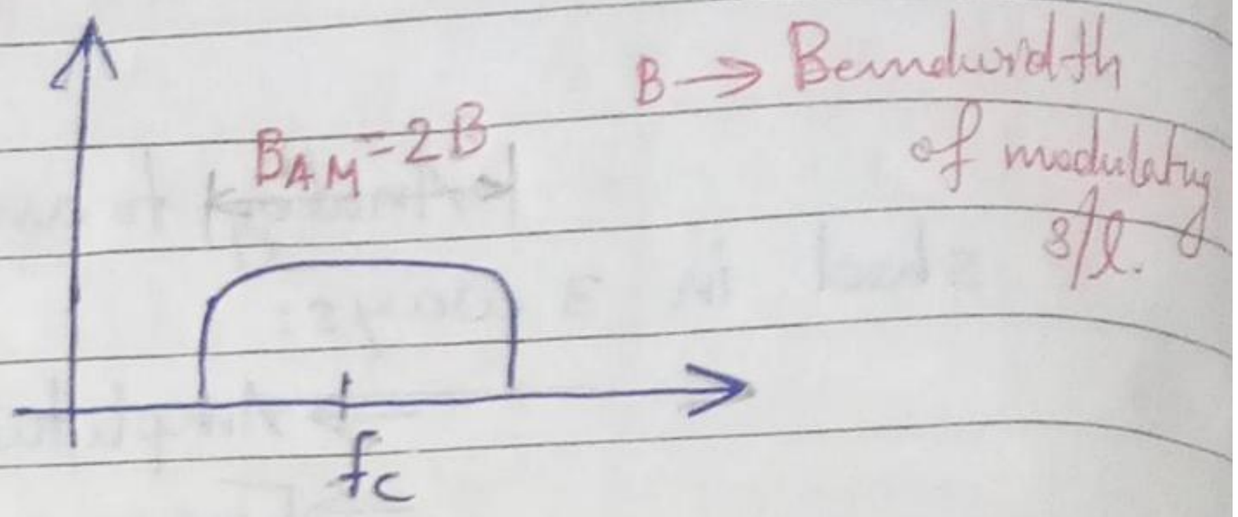
* Amplitude Modulation

→ The carrier s/l is modulated so that its amplitude varies with the changing amplitudes of the modulating s/l. Only the amplitude changes to follow variations in the inf".



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AM Bandwidth: The modulation creates a bandwidth that is twice the bandwidth of the modulating s/l & covers a range centered on the carrier frequency.
The total bandwidth required for AM can be determined from the bandwidth of the audio s/l; $B_{AM} = 2B$.

* AM $s(t) = [1 + n_a x(t)] \cos 2\pi f_c t$

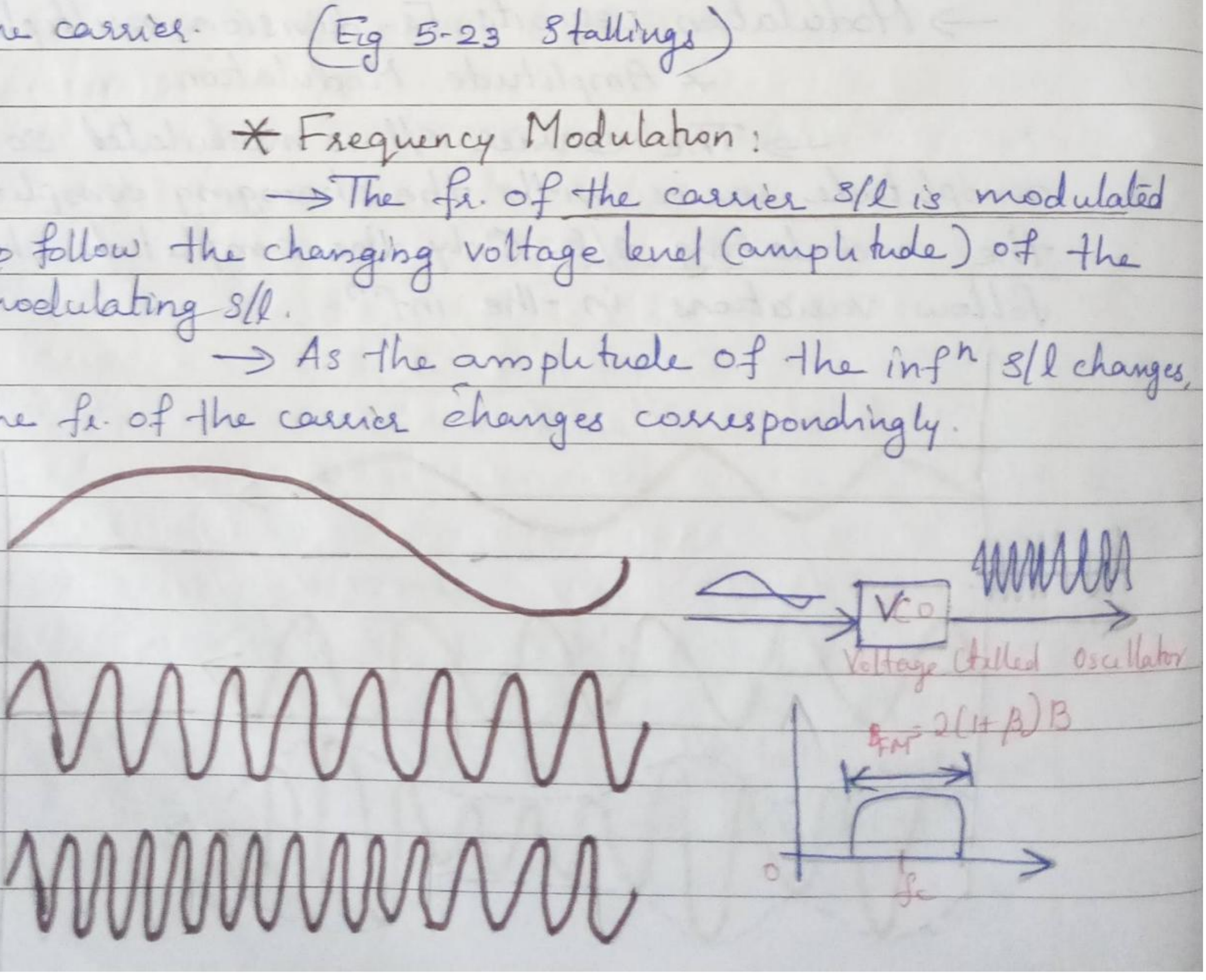
where $\cos 2\pi f_c t$ is the carrier & $x(t)$ is the i/p s/l (carrying data) both normalized to unity amplitude.

→ The parameter n_a, known as the modulation index, is the ratio of the amplitude of the i/p to the carrier. (Eg 5-23 Stallings)

* Frequency Modulation:

→ The fr. of the carrier s/l is modulated to follow the changing voltage level (amplitude) of the modulating s/l.

→ As the amplitude of the inf^n s/l changes, the fr. of the carrier changes correspondingly.



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FM is implemented by using a voltage Ctelled osullator as with FSK. The fr. of the osullator changes acc to the I/P voltage which is the amplitude of the modulating s/l.

FM Bandwidth:

The total bandwidth required for FM can be determined from the bandwidth of the audio s/l:

$B_{FM} = 2(1+\beta)B$. // β is the factor depends on modulation technique with a common value of 4.

*Phase Modulation:

→ The phase of the carrier s/l is modulated to follow the changing voltage level (amplitude) of the modulating s/l. As the amplitude of the inf° s/l changes, the phase of the carrier changes correspondingly.

→ In FM, the instantaneous change in the carrier fr. is ∝ to the ampletude of the modulating s/l; In PM the instantaneous change in the carrier fr. is ∝ to the derivatives of the amplitude of the modulating s/l.

$B_{PM} = 2(1+\beta)B$

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Questions:

18. What is the required bandwidth for the follo. cases if we need to send 6000 bps? Let d=1

a. ASK

$B = (1+d) \times S$

~~So 6000 bps~~

$S = N \times 1/r$

$r = 1$

$S = N = 6000 bps$

$B = (1+1) \times 6000$

$= 12000 Hz$

b. FSK with $2\Delta f = 4KHz$

$B = S(1+d) + 2\Delta f$

$S = N = 6000 bps$

$2\Delta f = 4KHz$

$d = 1$

$B = 6000(1+1) + 4$

~~$= 12000 + 8$~~

~~$= 12008 Hz$~~ 16000 Hz

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(18) 19. Calculate the bit rate for the given baud rate and type of modulation.

a. 2000 baud, FSK

$S = N$

Bitrate $N = \underline{2000 \text{ bps}}$.

b. ASK

$S = N$

$N = \underline{2000 \text{ bps}}$

c. BPSK

$S = N$

$N = \underline{2000 \text{ bps}}$.

(19) 20. What is the no. of bits/baud for the follo. techniques?

a. ASK with 8 diff. amplitudes.

~~Baud rate = 8~~

Multilevel ASK

$r = \underline{3}$

// r is the no. of data elmts carried in one s/l.

b. FSK with 16 diff. fr.

$r = \log 4 = \underline{4}$

c) PSK with 8 diff phases.

$r = \underline{3}$

(20) 21. Find the bandwidth for the follo. situations if we need to modulate a 8kHz voice.

a) AM

$B_{AM} = 2B$

$B = 8\text{kHz}$

$B_{AM} = 2 \times 8 = \underline{16\text{KHz}}$

b) FM (set $\beta = 5$)

$B_{FM} = 2(1+\beta)B$

$= 2 \times (1+5) \times 8$

$= 2 \times 6 \times 8$

$= \underline{96\text{KHz}}$

c) PM (set $\beta = 1$)

$B_{PM} = 2(1+\beta)B$

$= 2 \times (1+1) \times 8$

$= \underline{32\text{KHz}}$

(21) 22. The telephone line has 4KHz bandwidth. What is the max. no. of bits we can send using each of the follo. techniques Let $d = 0$.

a) ASK

b)

$B = (1+d) \times S$

$4 = (1+0) \times S$

$S = 4 = N$

$N = \underline{4}$

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5.15 23 An NRZ-L s/l is passed through a filter with $r = 0.5$ & then modulated onto a carrier. The data rate is 2400bps. Evaluate the bandwidth for ASK & FSK. For FSK assume that 2 fr. are 50KHz & 55KHz.

ASK

d is b/w 0 & 1.

$r = 0.5$

$S = N \times \frac{1}{r} = 2400 \times \frac{1}{0.5}$

$= 4800$ baud.

$Bandwidth_{max} = (1+d)S$ $\quad d = 0$

$= (1+1)4800$ $\quad B = S$

$= 2 \times 4800$ $\quad = 4800Hz$

$= 9600Hz$ $(d=1)$

FSK

$r = 0.5, N = 2400bps.$

$2\Delta f$ = diff b/w fr.

$= 55 - 50 = 5KHz$

$S = N \times \frac{1}{r} = 2400 \times \frac{1}{0.5}$

$= 4800$ baud

$B = (1+d)S + 2\Delta f$ $\quad d = 0$

$= (1+1) \times 4800 + 5$ $\quad B = 4800 + 5$

$= 2 \times 4800 + 5$ $\quad = 4805KHz$

$= 9605KHz$ $(d=1$

5.16 24 Assume that a telephone line channel is equalised to allow band pass data transmission over a fr. range of 600 to 3000 Hz. The available bandwidth is 2400H For $r = 1$, evaluate the required bandwidth for 2400bp QPSK & 4800bps, 8 level multilevel s/ling. Is the bandwi adequate?

Available Bandwidth = 2400Hz

$r = 1$

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$N = 2400$

$S = N \times \frac{1}{r}$

$S = \frac{2400}{1} \times \frac{1}{1} = 2400$ baud.

Bandwidth$_{min} = (1+d)\,S$.

B_{min} $d = 0$

$B_{min} = 2400$ Hz

$B_{max} = (1+1)\,2400$

$= \underline{4800 Hz}$

8 level multilevel s/ling

$L = 8$; $r = \log_2 L = \log_2 8 = 3$

$S = 4800 \times \frac{1}{3} = 1600$ baud.

B_{min} $d = 0$

$B = 1600$ Hz

B_{max} $d = 1$; $B = (1+1)\,1600$

$= \underline{3200 Hz}$

25. Why should PCM be preferable to DM for encoding analog s/ls that represent digital data?.

26. A s/l is quantized using 10 bit PCM. Find the s/l to quantization noise ratio?

Signal to quantization ratio $= 6.02n + 1.76$ dB

$= 6.02 \times 10 + 1.76$ dB

$= 60.2 + 1.76$ dB $= \underline{61.78 dB}$

27. Consider an audio s/l with spectral components in the range 300 to 3000Hz. Assume that a sampling rate of 7000 samples/sec will be used to generate a PCM s/l.

a. For SNR = 30dB, what is the no. of uniform quantization levels needed?

$SNR = 6.02n + 1.76 = 30$

$6.02n = 30 - 1.76 = 28.24$

$n = \frac{28.24}{6.02} = 4.69 \approx 5$

$L = 2^5 = \underline{32}$

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b. What data rate is required?

Sampling rate = 7000 samples/sec.

range 300 to 3000 Hz ∴ Bandpass S/l

Nyquist Data rate = $2 \times f_{max} = 2 \times 3000$

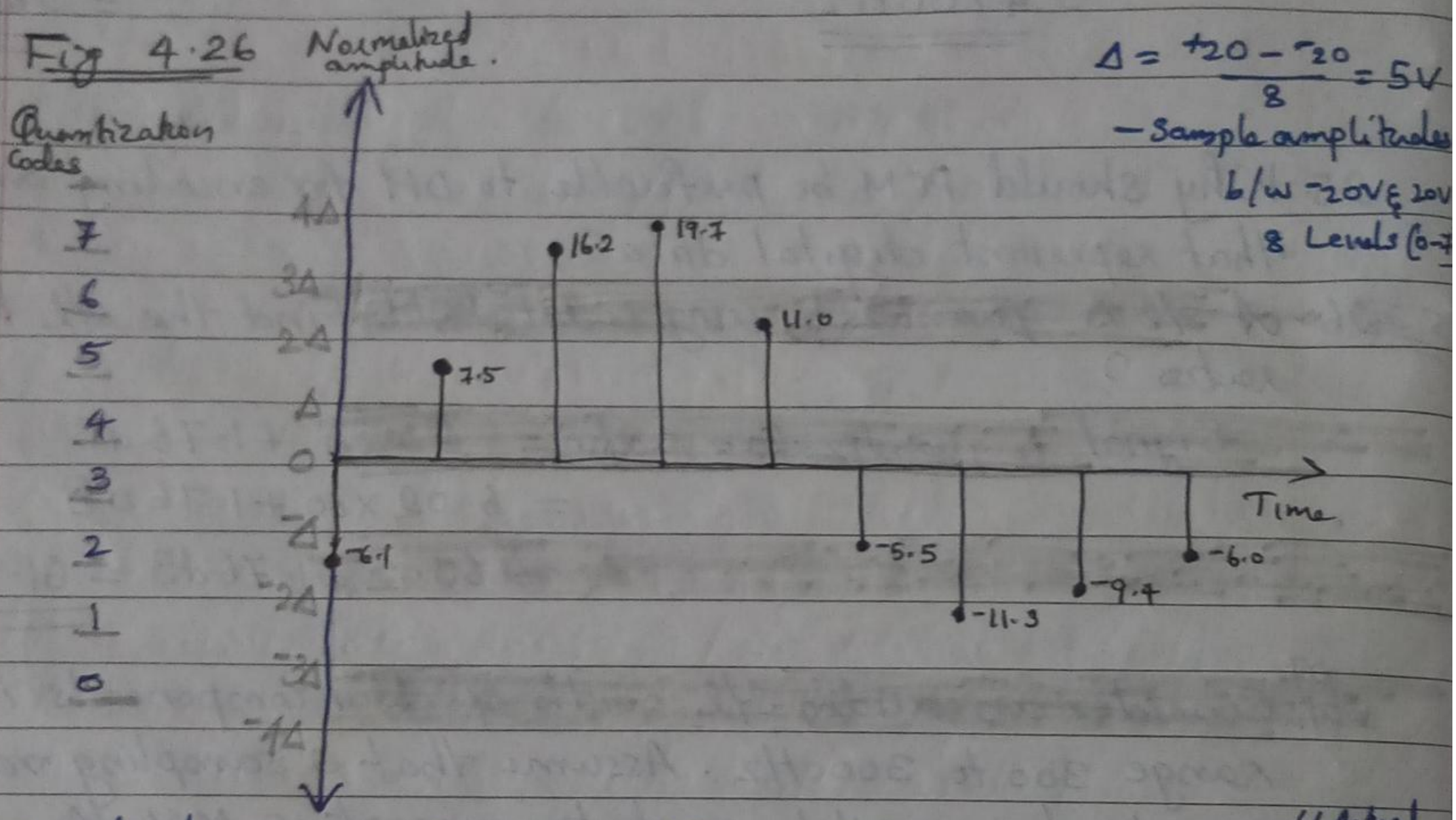
$= \underline{6000 \text{ bps}}$

5 bits/sample

Data rate = 5×7000

$= \underline{35000 \text{ bps}}$

Fig 4.26



$\Delta = \frac{+20 - -20}{8} = 5V$

- Sample amplitudes b/w -20V & 20V

8 Levels (0-7)

Normalized PAM Values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20	// Actual amplitude / Δ = $\frac{-6.1}{5} = -1.22$
Normalized Quantized values → mid value of zone	-1.50	1.50	3.50	2.50	2.50	-1.50	-2.50	-1.90	-1.50	// $\frac{-\Delta + 2\Delta}{2} = 1.5$
Normalized error (II row - I row)	-0.28	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30	// -1.50 - -1.22 = -0.28
Quantization Code	2	5	7	7	6	2	1	2	2	
Encoded words	010	101	111	111	110	010	001	010	010	

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MODULE IV

MULTIPLEXING

→ Space Division Multiplexing
→ Frequency Division Multiplexing
  * Wavelength Division Multiplexing
→ Time Division Multiplexing
  * Characteristics
  * Digital Carrier S/m
  * SONET/SDH
→ Statistical time division multiplexing
  * Cable Modem
→ Code Division Multiplexing
→ Multiple Access
→ CDMA

Questions:

1. List 3 main multiplexing techniques?
2. Describe the goals of multiplexing.
3. Define the analog hierarchy used by telephone companies & list diff. levels of hierarchy.
4. Which of the 3 multiplexing techniques is common for fiber optic links? Explain.
5. Which of the 3 multiplexing techniques is used to combine analog s/ls and to combine digital s/ls?
6. Assume that a voice channel occupies a band width of 4kHz. We need to multiplex 12 voice channels with guard bands of 500 Hz using FDM. Calculate the reqd. bandwidth.
7. In analog hierarchy (ref fig) Find the overhead (extra bandwidth for guard band or ctrl) in each hierarchy (group, supergroup, master group & jumbo group).

Ans: Group level: overhead = 48KHz − (12×4KHz) = 0Hz
Super Group level: overhead = 240KHz − (5×48KHz) = 0Hz

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Master group: overhead = 252 kHz − (10 × 240 KHz) = 120 kHz.
Jumbo Group: overhead = 16.984 MHz − (6 × 2.52 MHz) = 1.864 MHz

8. We need to use synch. TDM & combine 25 digital sources, each of 100 kbps. Each o/p slot carries 1 bit from each digital source, but one extra bit is added to each frame for synchronization. Answer the follo. qns.

1. What is size of an o/p frame in bits?

Frame size = 25 × 1 + 1 = 26 bits.

2. What is the o/p frame rate?

Each frame – 1 bit from each source 100,000 frames/s

3. What is the duration of an o/p frame?

Frame duration = 1/frame rate = 1/100 000 = 10 μs.

4. Data rate = (100 000 frame/s) × (26 bits/frame) = 2.6 Mbps

~~5. What is the o/p data rate?~~

5. What is the efficiency?

Efficiency = 25/26 =

9. Qn: (8) with 2 bit from each source & 20 digital sources.

1. Frame size = 20 × 2 + 1 = 41 bits.
2. Frame rate = 100,000/2 = 50,000 frames/s.
3. Frame duration = 1/frame rate = 1/50000 = 20 μs.
4. DataRate = (50,000 frame/s) × 41 bits/frame
   = 2.05 Mbps

10. Two channels, one with a bit rate of 150 kbps & another with a bitrate 140 kbps, are to be multiplexed using pulse stuffing TDM with no synch. bits. Answer the follo. qns.

a) Size of a frame in bits? = 1 + 1 = 2 bits (Two channels)

b) Frame rate = ~~190~~ 150,000 frames/sec.

c) Duration of frame = 1/frame rate = 1/150000 =

d) Data rate = (150000 frame/sec) × (2 bits/frame) = 300 kbps.

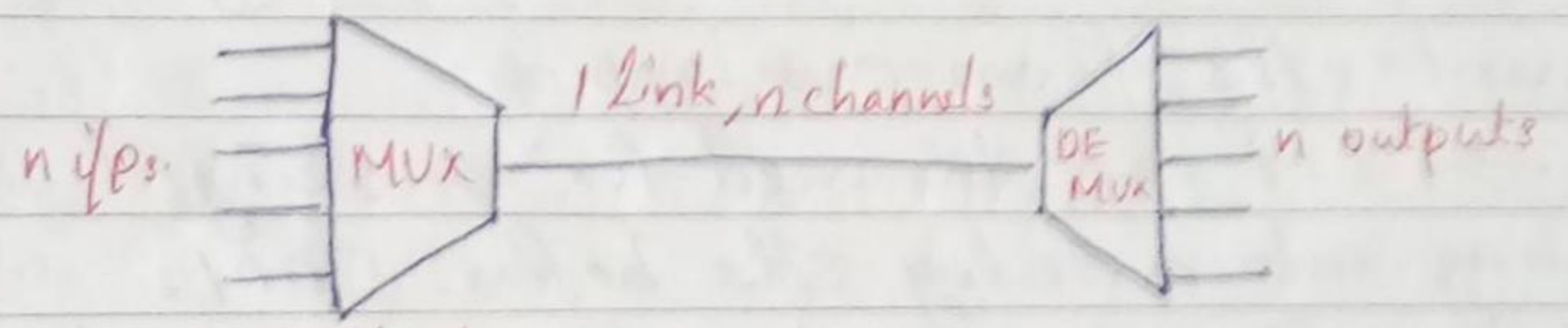
It will be greater than 290 kbps b/c of pulse stuffing

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MULTIPLEXING

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple s/ls across a single data link. Ie; describes how several users can share a medium with minimum or no interference. In multiplexing - combine several channels into one - improves efficiency.

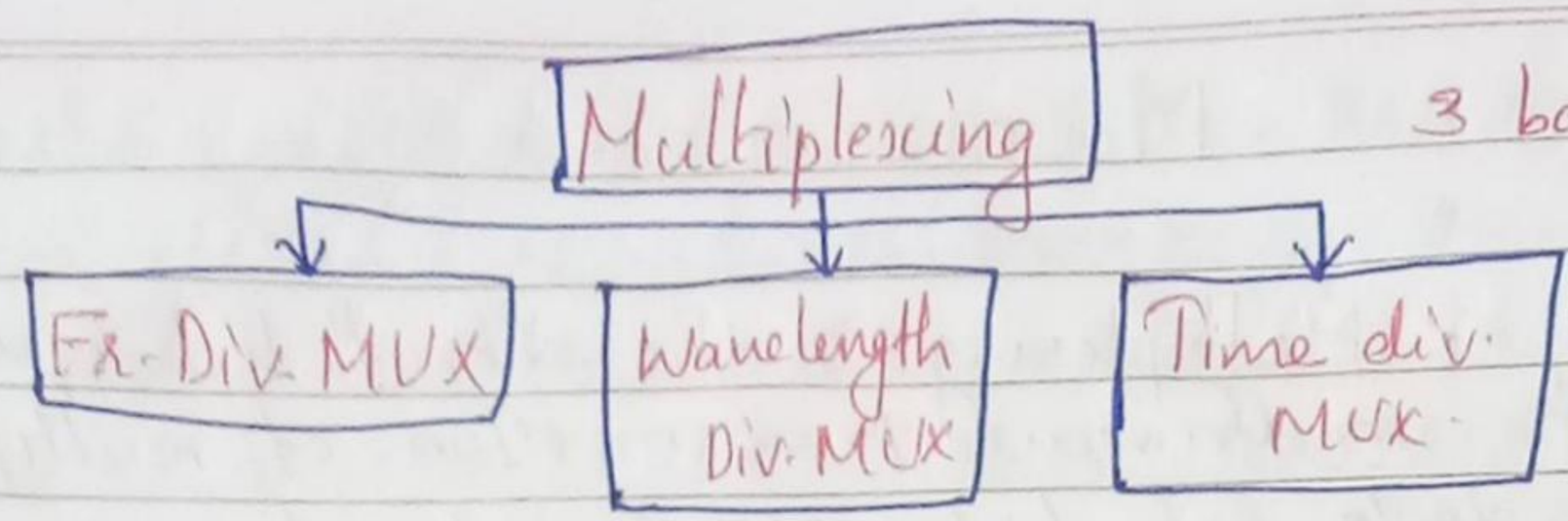
Read this: Highways with several lanes. Many users (car drivers) use the same medium (the highways) with hopefully no interference (ie; accidents). This is possible due to the provision of several lanes (space division multiplexing) separating the traffic. In addition, diff. cars use the same medium (ie; same lane) at diff. pts in time (time division multiplexing).



Multiplexing.

There are n i/ps to a MUX. The MUX is connected by a single data link to a demultiplexer (DEMUX). The link is able to carry n separate channels of data. The MUX combines data from the n i/p lines & transmits over a higher capacity data link. The DEMUX accepts the multiplexed data stream, separates the acc. to channel, & delivers data to the appropriate output lines.

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3 basic types of Multiplexing.

→ Frequency Division Multiplexing:

is an analog technique that can be applied when the bandwidth of a link is greater than combined bandwidths of the s/ls to be transmitted. In FDM, s/ls generated by each sending device modulate diff. carrier frequencies. These modulated s/ls are then combined into a single composite s/l that can be transported by the link. These bandwidth ranges are the channels through which the various s/ls travel. Channels can be separated by strips of unused bandwidth - guard bands (guard spaces) - to prevent s/ls from overlapping.

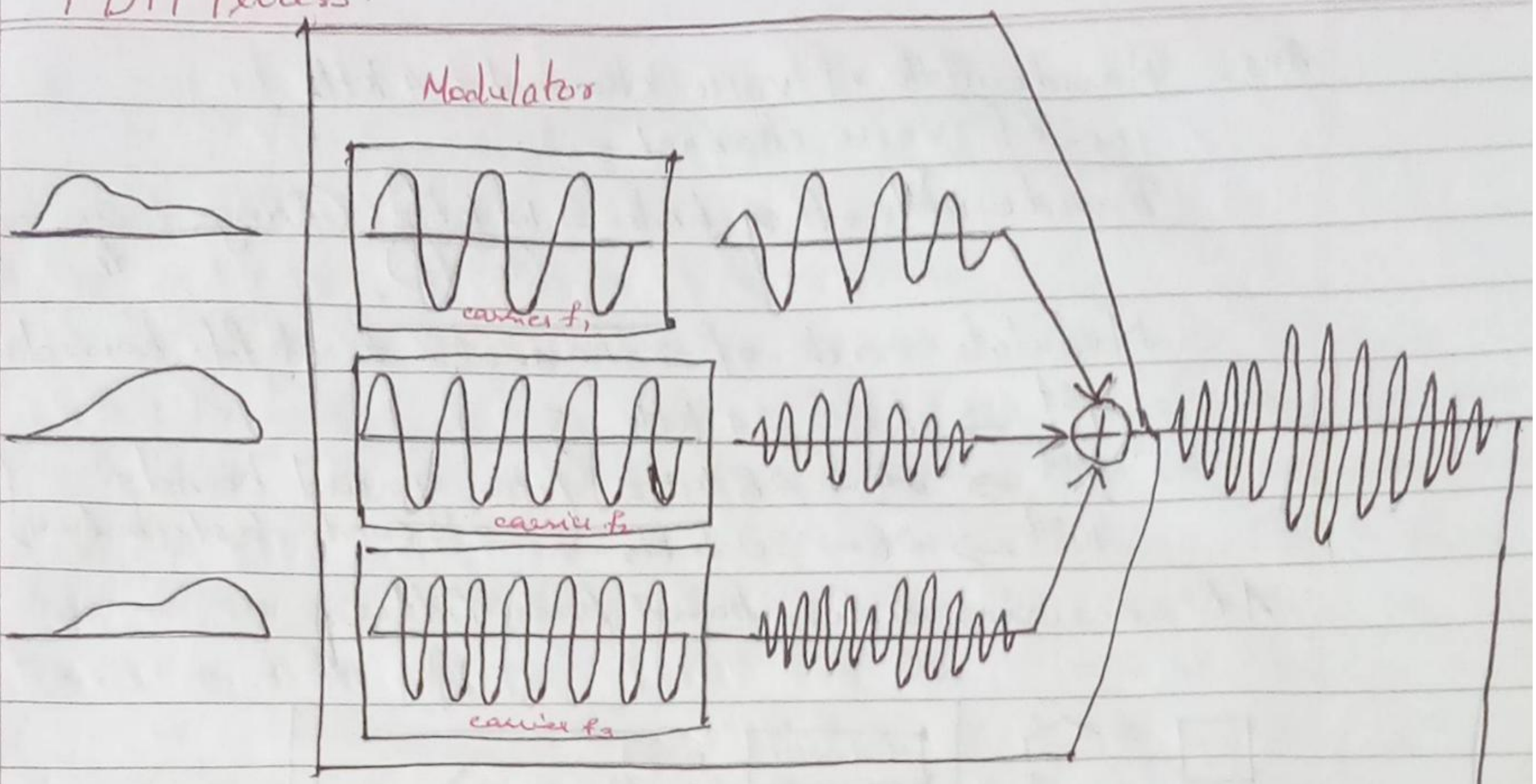
→ FDM can be used for sending digital s/ls by converting into analog s/ls before FDM.

Multiplexing Process: Each source generates a s/l of a similar fr. range. These similar s/ls modulate diff. carrier fr. (f_1, f_2 & f_3). The resulting modulated s/ls are then combined into a composite s/l that is sent out over a media link that has enough bandwidth to accomodate it.

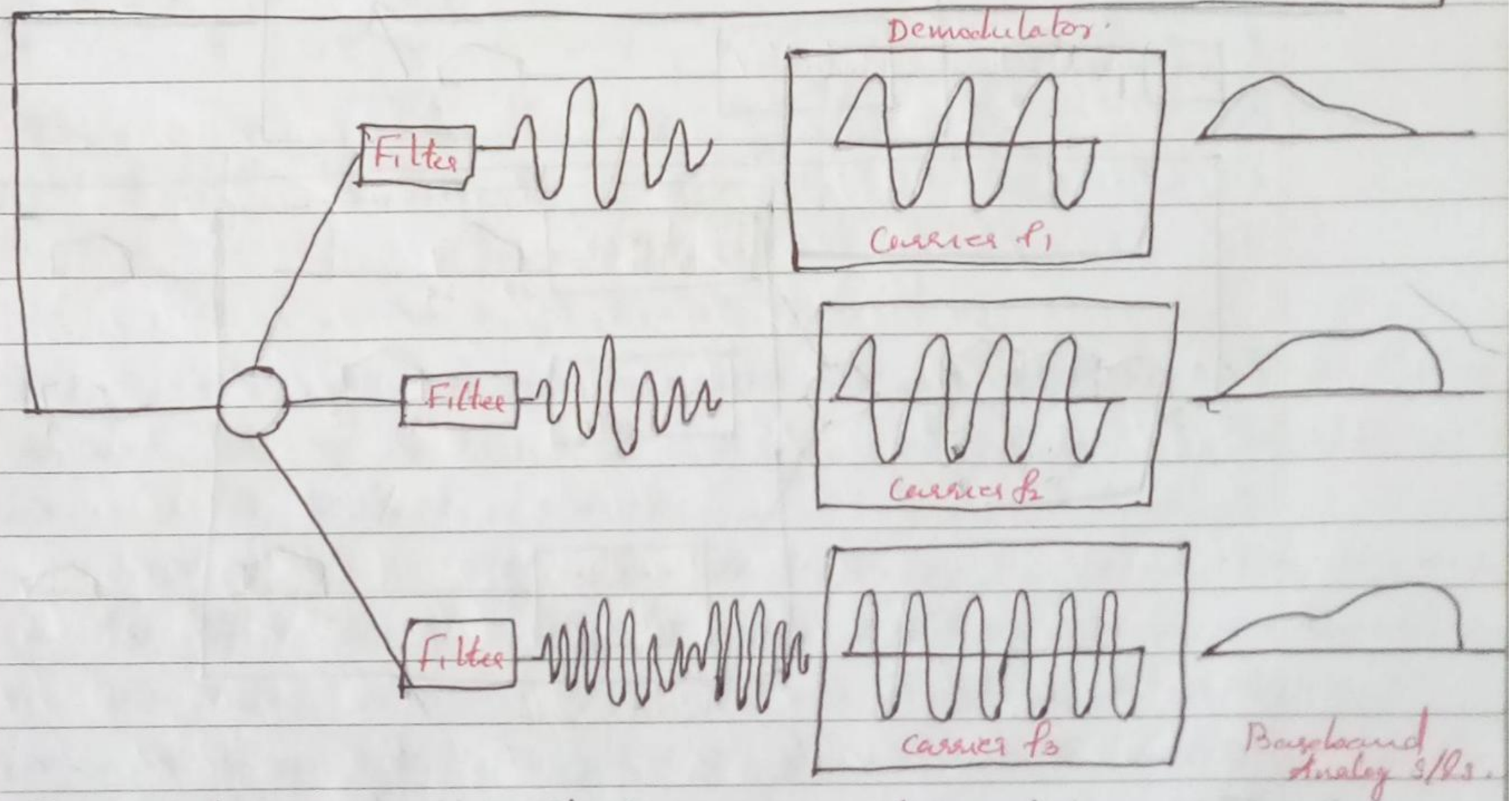
Demultiplexing Process: DEMUX uses a series of filters to decompose the multiplexed s/l into its component s/ls. The individual s/ls are then passed to a demodulator that separates them from their carriers & passes them to o/p lines.

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FDM Process.



Demultiplexing Process:



Example: Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine 3 voice channels into a link with a bandwidth of 12 kHz from 20 to 32 kHz. Show the config. using the fe domain. Assume there are no guard bands.

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Ans: Bandwidth of voice channel = 4 kHz

no. of voice channel = 3.

Bandwidth of a link = 12 kHz ($f_h - f_l$) (Range f_l 20 – 32 kHz f_h)

Modulate each of 3 channels to diff. bandwidth

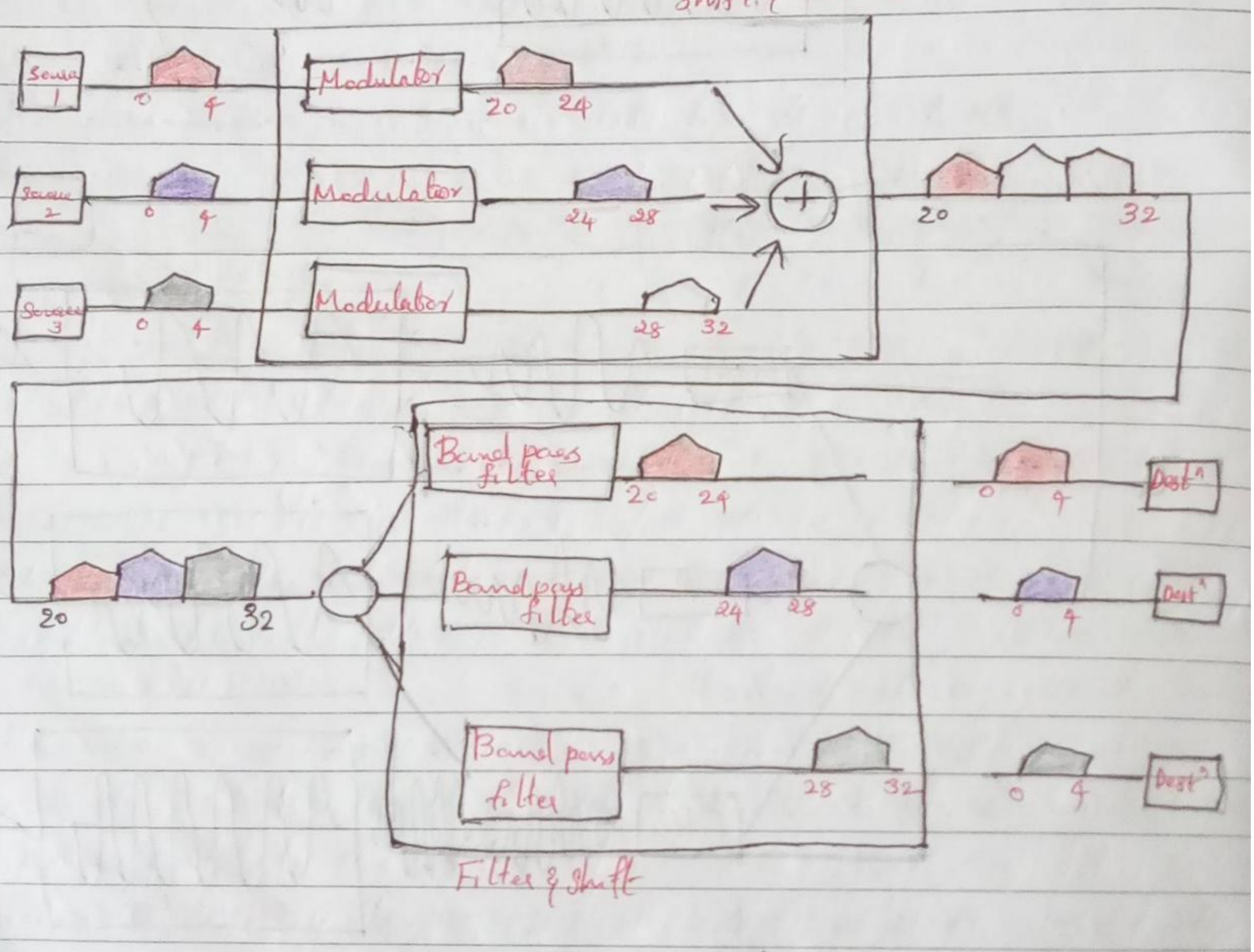
Ist → 20 – 24 kHz

IInd → 24 – 28 kHz

IIIrd → 28 – 32 kHz

} no guard bands so less const. distribution

At receiver side, band pass filter.



2. Five channels, each with 100kHz bandwidth, are to be multiplexed together. What is the min. bandwidth of the link if there is a need for a guard band of 10kHz b/w the channels to prevent interference?

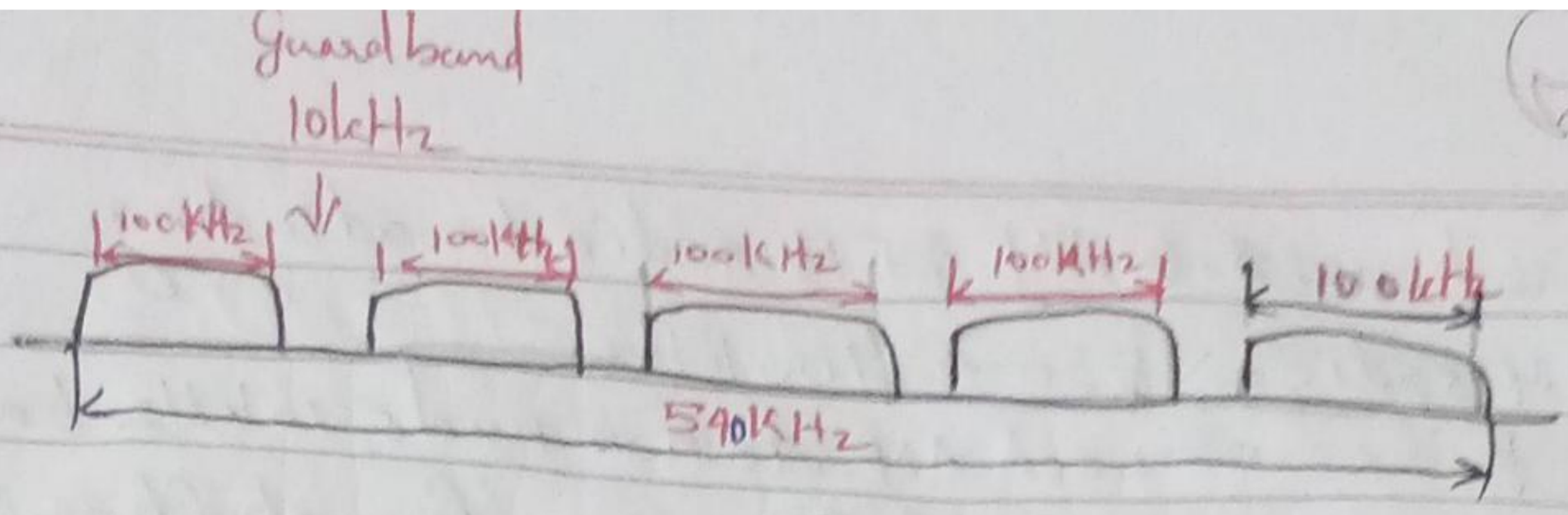
Channels = 5 (100kHz)

guard bands = 4 (10kHz

Reqd Bandwidth = 5 x 100 + 4 x 10

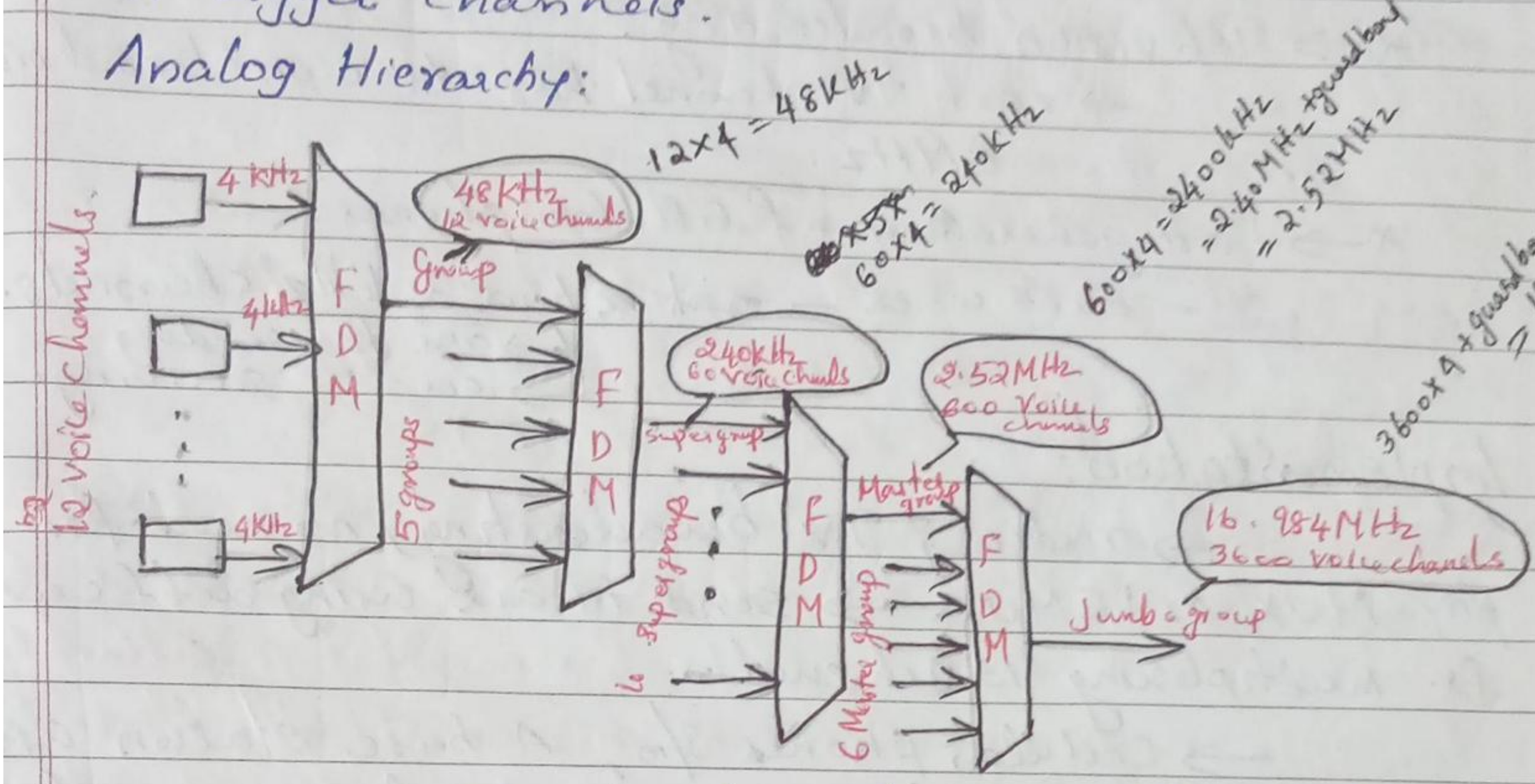
= 540kHz

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Analog Carrier S/ms: To maximize the efficiency of their infrastructure, telephone companies have traditionally multiplexed S/Ls from lower bandwidth lines onto higher bandwidth lines. In this way, many lines can be combined into fewer but bigger channels.

Analog Hierarchy:



→ 12 voice channels are multiplexed onto a higher bandwidth line to create a group. A group base 48kHz of bandwidth & supports ~~48kHz~~ of 12 voice channels.

Next level, 5 groups multiplexed to create super group of 240kHz bandwidth & supports 60 groups voice channels.

Next level, 10 supergroups multiplexed to create a master group. of 2.40MHz of bandwidth, but the need for guard bands b/w super groups increases bandwidth to 2.52 MHz. supports 600 voice channels.

Finally 6 master groups → Jumbo group ← 15.12 MHz (6x2.52 MHz) 16.984 MHz (with guard bands).

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Applications: * → AM & FM radio broadcasting.

AM radio → 530 to 1700 kHz
- each AM station needs 10kHz bandwidth.
- uses diff. carriers for — shifting & multiplexing
- receiver receives all s/ls, by tuning only one desired.

FM Radio → 88 to 108 MHz
- each station needs 200kHz.

* → Television broadcasting.
→ each TV channel has its own bandwidth of 6MHz.

* → First generation of Cellular phones.
- each user — 2 of two 30kHz channels.
↳ one for sending
↳ one " receiving.

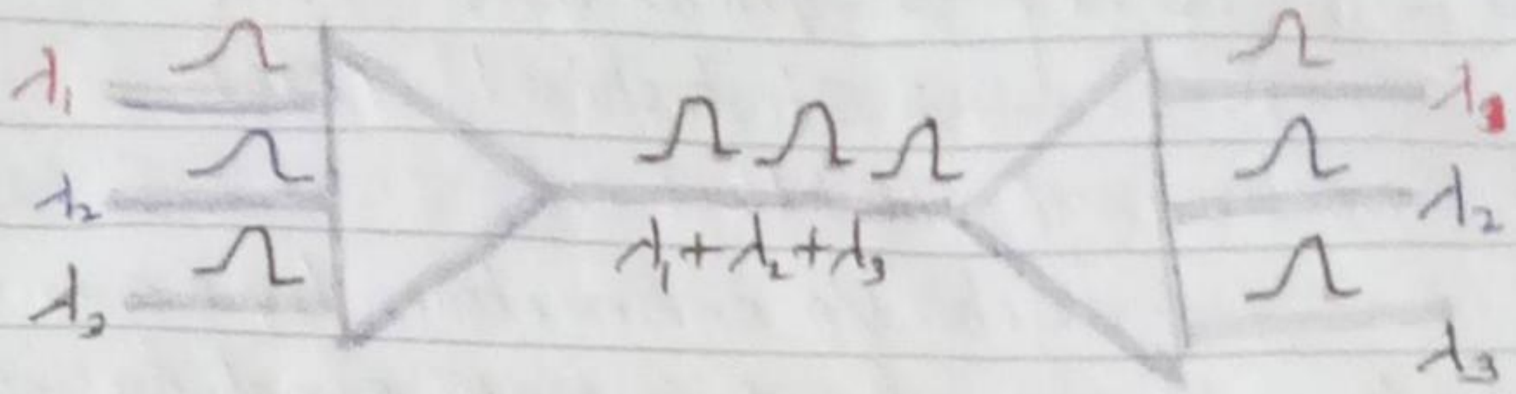
Implementation:
→ radio & Tv broadcasting, no need for a phy. MUX or DEMUX. → send to air using diff carriers for multiplexing is achieved.
→ Cellular phones s/m, A base station assigns carriers fr. to the telephone users. When a user hangs up, his/her bandwidth is assigned to another caller.

*Wavelength Division Multiplexing:

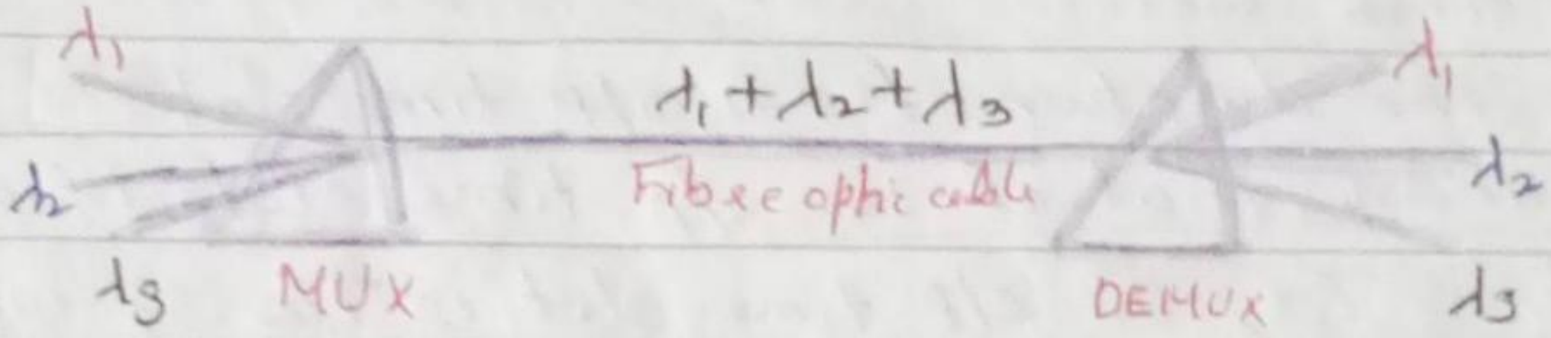
WDM is designed to use high data rate ~~capa~~ capability of fiber optic cable. Using a fiber optic cable for one single line wastes the available bandwidth. Multiplexing allows to combine several lines into one.

WDM is same as FDM. Difference — the frs are very high. Very narrow bands of light from diff. sources are combined to make a wider band of light. At the receiver, the s/ls are separated by the demultiplexer.

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→ Combine multiple light sources into single light at the multiplexer & do the reverse at the demultiplexer. The combining & splitting of light sources are easily handled by the prism. A prism bends a beam of light based on angle of incidence & the frequency.

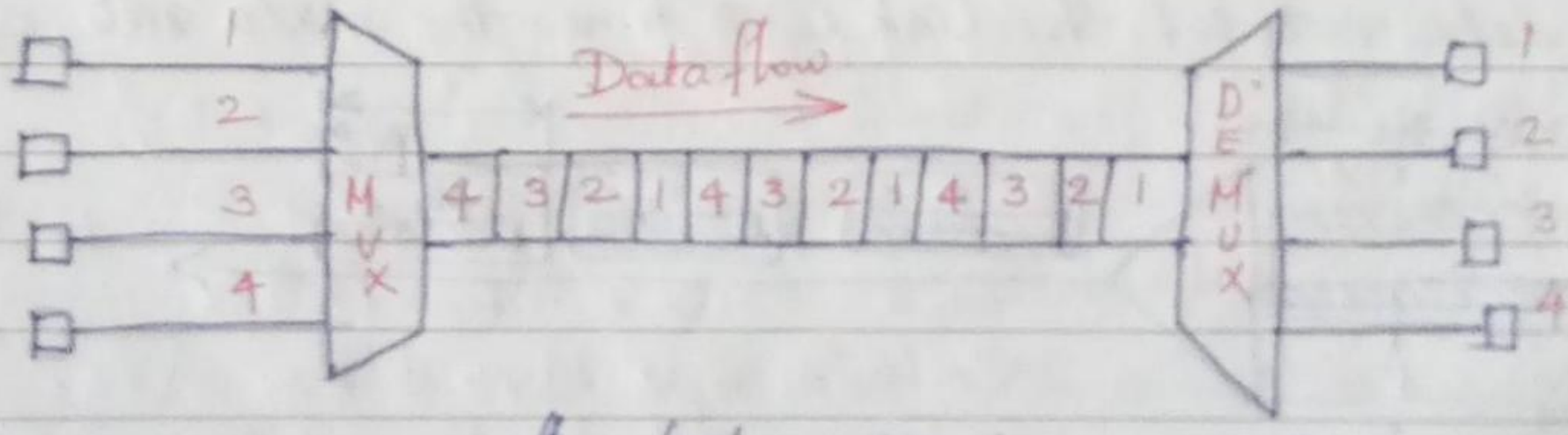


Dense WDM – can multiplex very large no. of channels, by spacing channels very close to one another. It achieves greater efficiency.

→ Time Division Multiplexing:

→ is a digital process that allows several connections to share the high bandwidth of a link.

– Time is shared; Each connection occupies a portion of time in the link.



– Digital multiplexing technique. Digital data from diff. sources are combined into one timeshared link. Analog data – sampled – changed to digital data & then multiplexed by TDM.

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TDM → Synchronous TDM
→ statistical TDM.

* → Synchronous TDM:

— each i/p connection has an allotment in the o/p even ~~one~~ if it is not sending data.

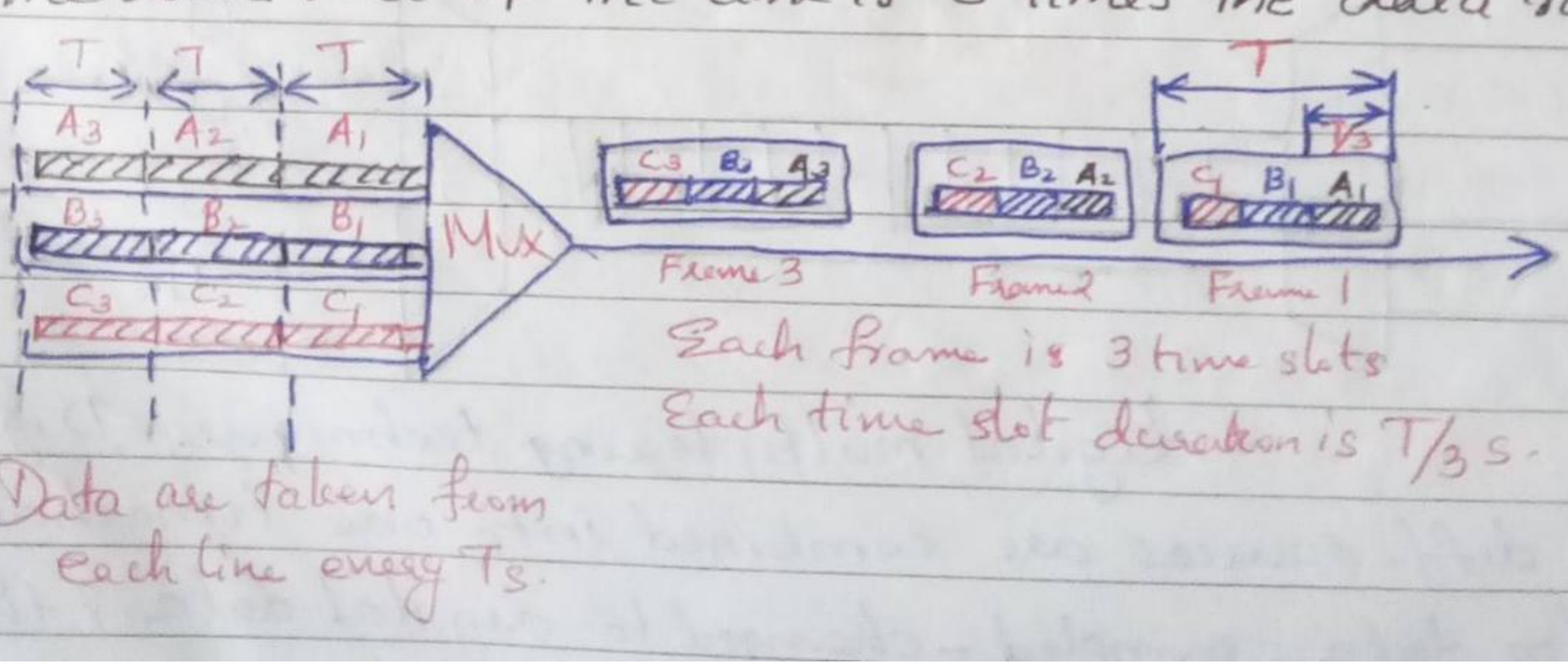
Time slots & Frames:

→ The data flow of each i/p connection is devided into units, where each i/p occupies one i/p time slot. A unit can be 1 bit, 1 char or one blk of data. Each i/p unit becomes one o/p unit & occupies one o/p time slot.

→ The duration of an o/p time slot is n times shorter than that of an i/p time slot. If an i/p time slot is T s, the o/p time slot is T/n s, where n is the no. of conn^s. (travels faster).

→ A round of data units from each i/p conn^s is collected into a frame. If we have n conn^s, a frame is devided into n time slots & one slot is allocated ~~to~~ for each unit, one for each i/p line. If the duration of each i/p unit is T, the duration of each slot is T/n & the duration of each frame is T.

→ The data rate of the o/p link must be n times the data rate of conn^s to guarantee flow of data. In fig. the data rate of the link is 3 times the data rate of a conn^s



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Qn 1: Fig: the data rate for each i/p conn is 3kbps. If 1 bit at a time is multiplexed (a unit is 1 bit): what is the duration of (a) each i/p slot (b) each o/p slot (c) each frame?

Ans: a) Duration of i/p slot: 1kbps: Data rate = 1 kbps

Bit duration = 1/R = 1/1000 s = 1ms.

b) Duration of o/p slot = 1/3 of i/p time slot

= ~~1/3 ms~~ 1/3 x 1ms = 1/3 ms.

c) Each frame carries 3 o/p time slots. Duration of frame is 1/3 3x1/3ms or 1ms. is same as the duration of an i/p unit.

Qn 2:

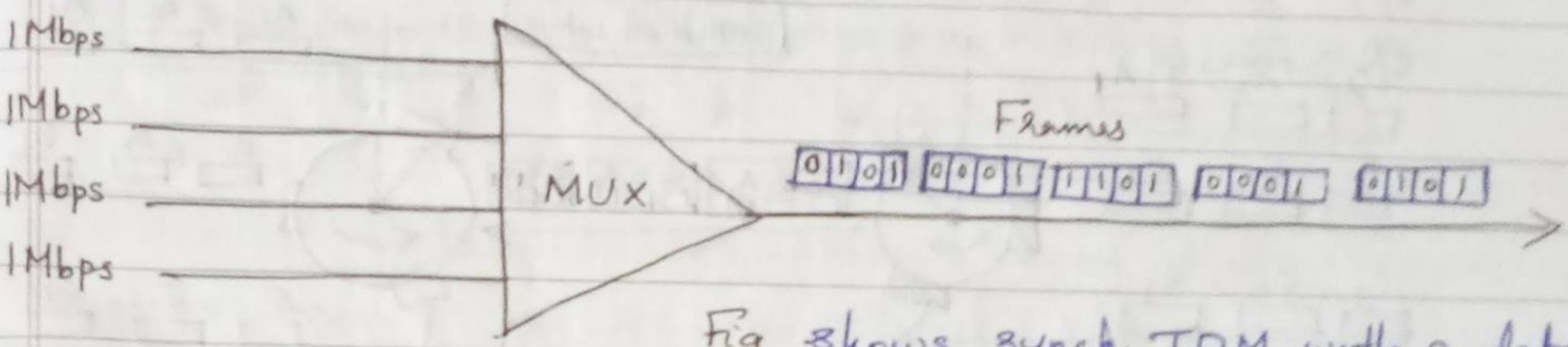


Fig shows synch. TDM with a data stream for each i/p & one data stream for the o/p. The unit of data is 1 bit. Find (a) the i/p bit duration (b) the o/p bit duration, (c) the o/p bit rate & (d) the o/p frame rate.

a) The i/p bit duration is the inverse of the bit rate:

1/1Mbps = 1 μs.

b) The o/p bit duration is one fourth of the i/p duration or 1/4 μs.

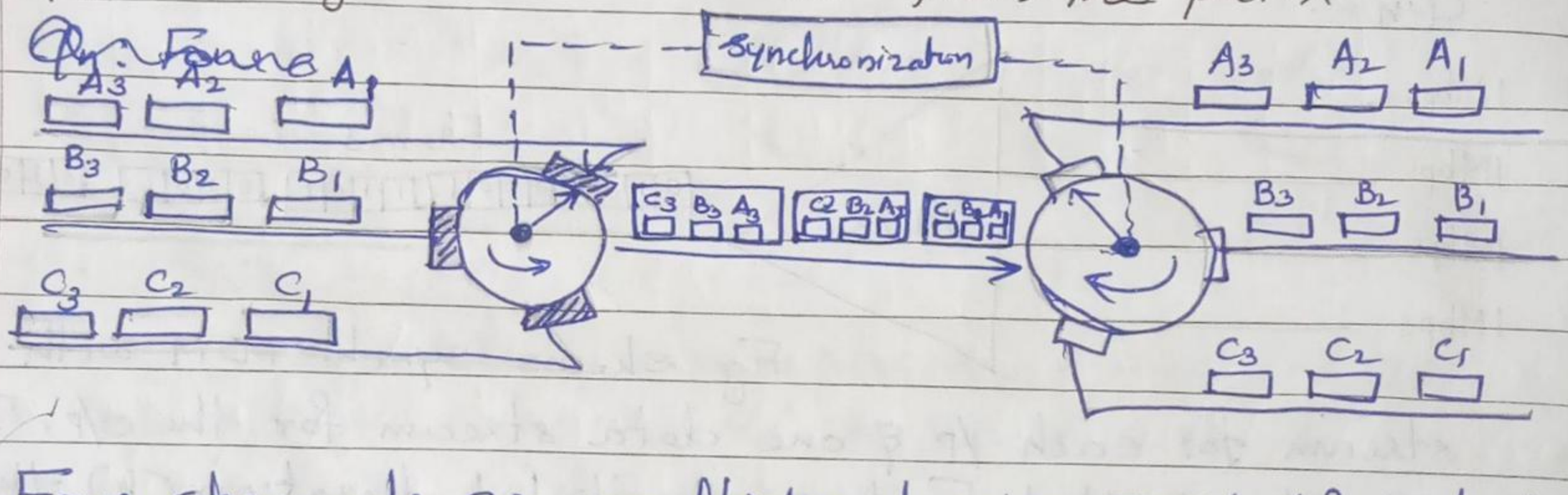
c) The o/p bit rate is the inverse of the o/p bit duration 1/4 μs or 4Mbps. This can also be deduced from the fact that the o/p rate is 4 times as fast as any i/p rate so the o/p rate = 4 x 1Mbps = 4Mbps.

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Interleaving:

TDM can be visualized as two fast-rotating switches, one on the multiplexing side & the other on the demultiplexing side. The switches are synchronized & rotate at the same speed, but in opposite directions.

On the multiplexing side, as the switch opens in front of a connection, that connection has the opportunity to send a unit onto the path. This process is called interleaving. On the demultiplexing side, as the switch opens in front of a connection, that conn" has the opportunity to receive unit from the path.



Ex: Four channels are multiplexed using TDM. If each channel sends 100 bytes/s. & we multiplex 1 byte per channel, show the frame traveling on the link, the size of the frame, the duration of the frame, the frame rate & the bit rate for the link

⇒ 1 byte from each channel

size of the frame = 4 bytes/fr or 32 bits.

⇒ 100 bytes/s from each channel. i.e; 400 bytes/s

frame rate = ~~100/4~~ $\frac{400}{4}$ = 100 frame/s.

Bit rate = 400 × 8 = 3200 bps.

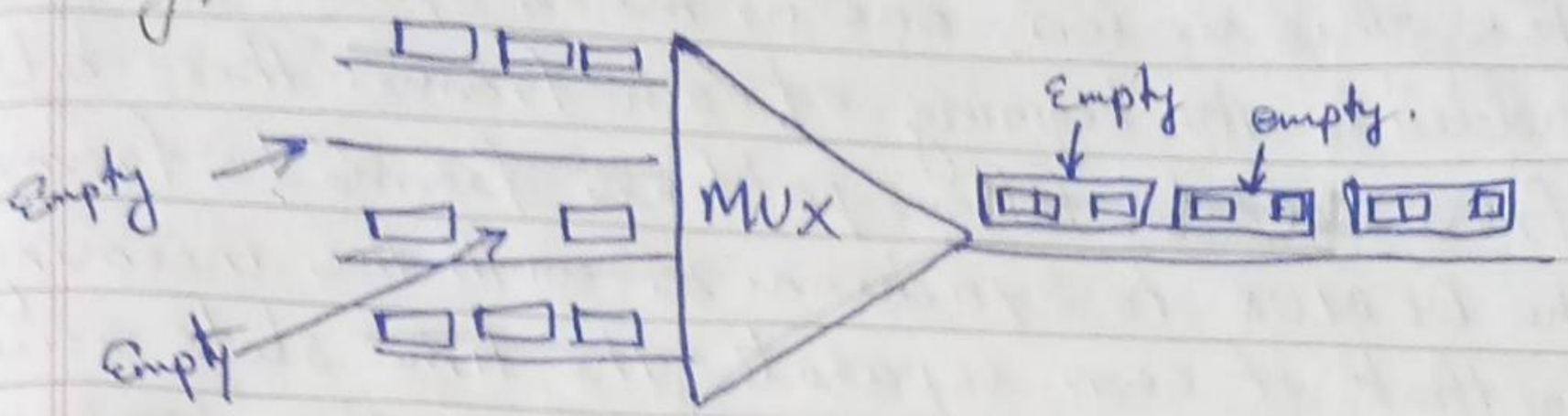
⇒ The duration of frame = 1/100 sec. (100 frames/s).

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Empty slots:

Synch. If a source doesn't have data to send, the corres. slot in the o/p frame is empty.

fig:



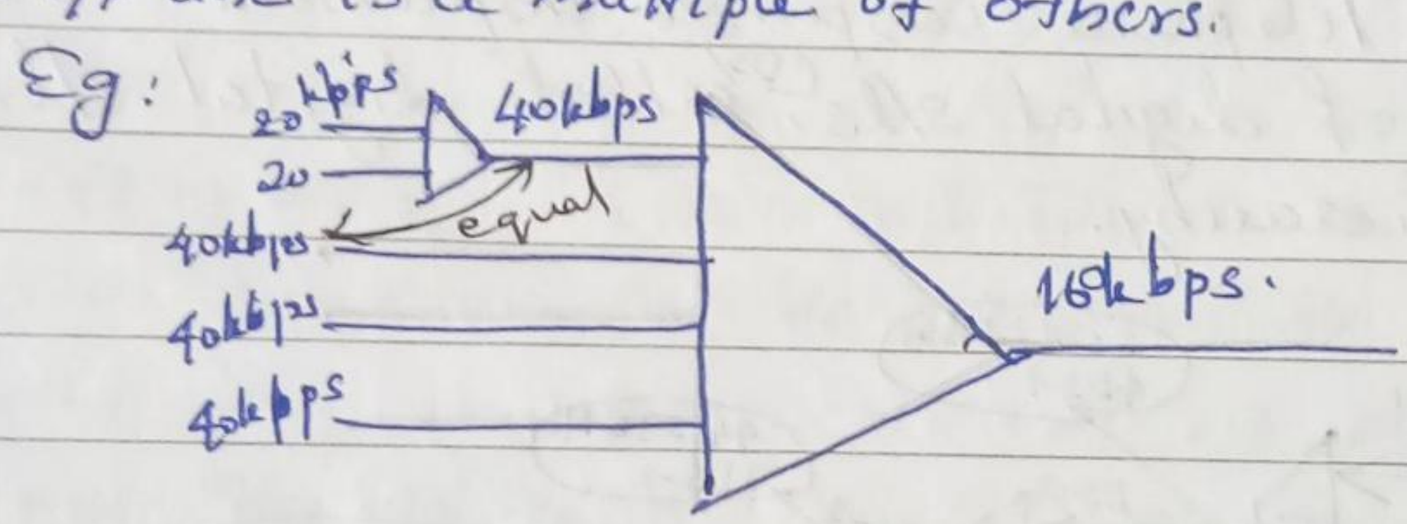
Data Rate Mgmt:

→ It is assumed that the data rates of all i/p lines were same. If data rates are not the same, 3 strategies or combination of them can be used.

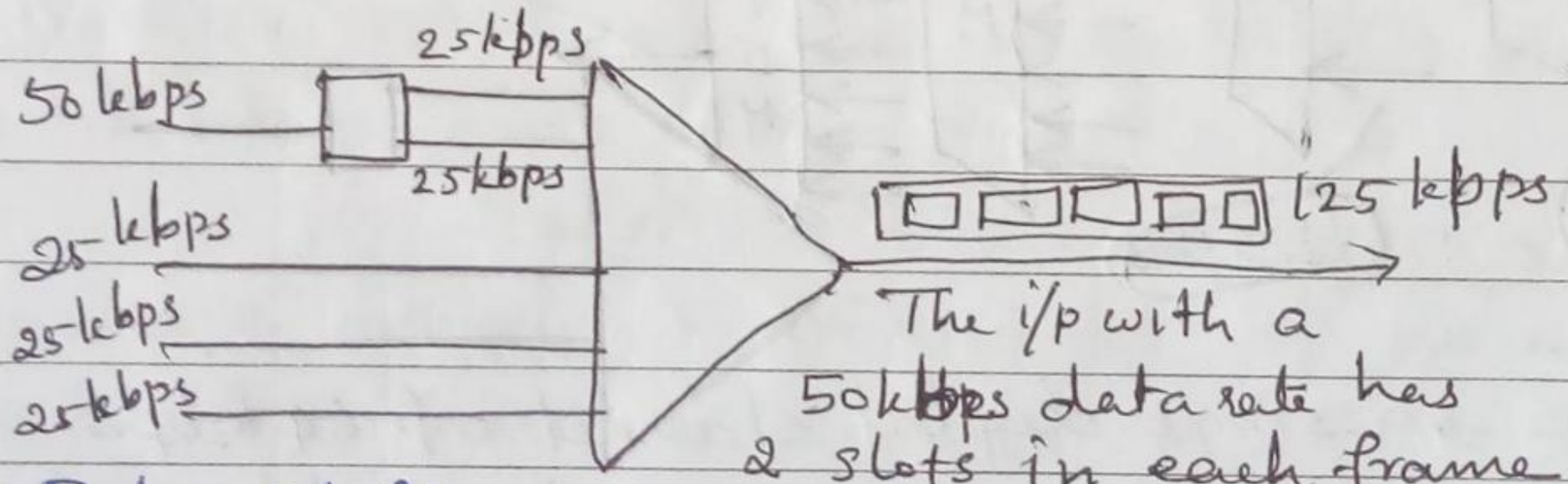
* Multilevel Multiplexing * Multiple Slot Allocation * Pulse stuffing.

* Multilevel Multiplexing: is used when the data rate of an i/p line is a multiple of others.

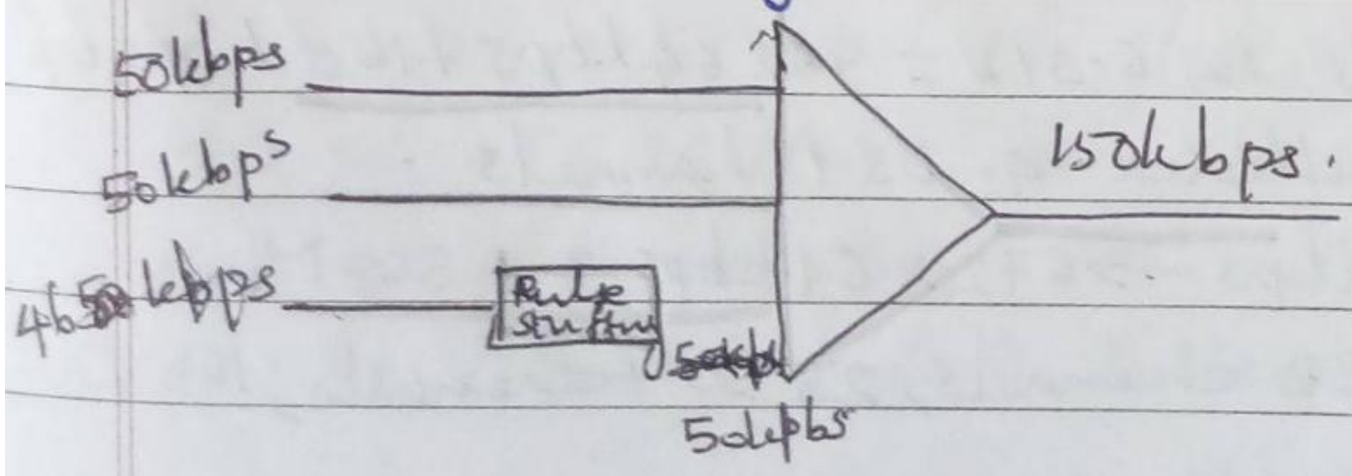
Eg:



* Mutple Slot Allocation:



* Pulse Stuffing:



Sometimes the bit rates of sources are not multiple integers of each other. Sln is to make the highest i/p data rate the dominant data rate & then add dummy bits to the i/p lines with lower rates. This will increase their rates. (pulse stuffing.

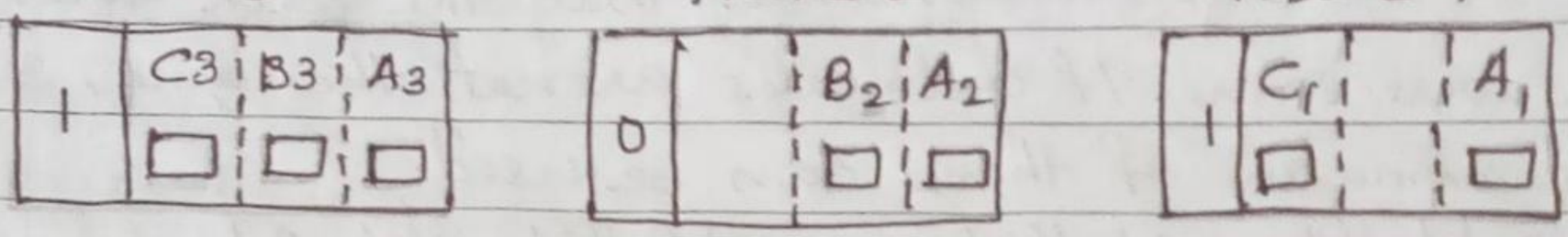
Scanned by TapScanner

* Frame Synchronizing:

If the MUX & DEMUX are not synchronized a bit belonging to one channel may be received by the wrong channel. For this reason, one or more synch. bits are usually added to the begining of each frame. These bits, called framing bits, follow pattern frame to frame, this allows the DEMUX to synchronize with the incoming stream so that it can separate the time slots accurately. This synch. infⁿ consists of 1 bit/frame, alternating 0 & 1.

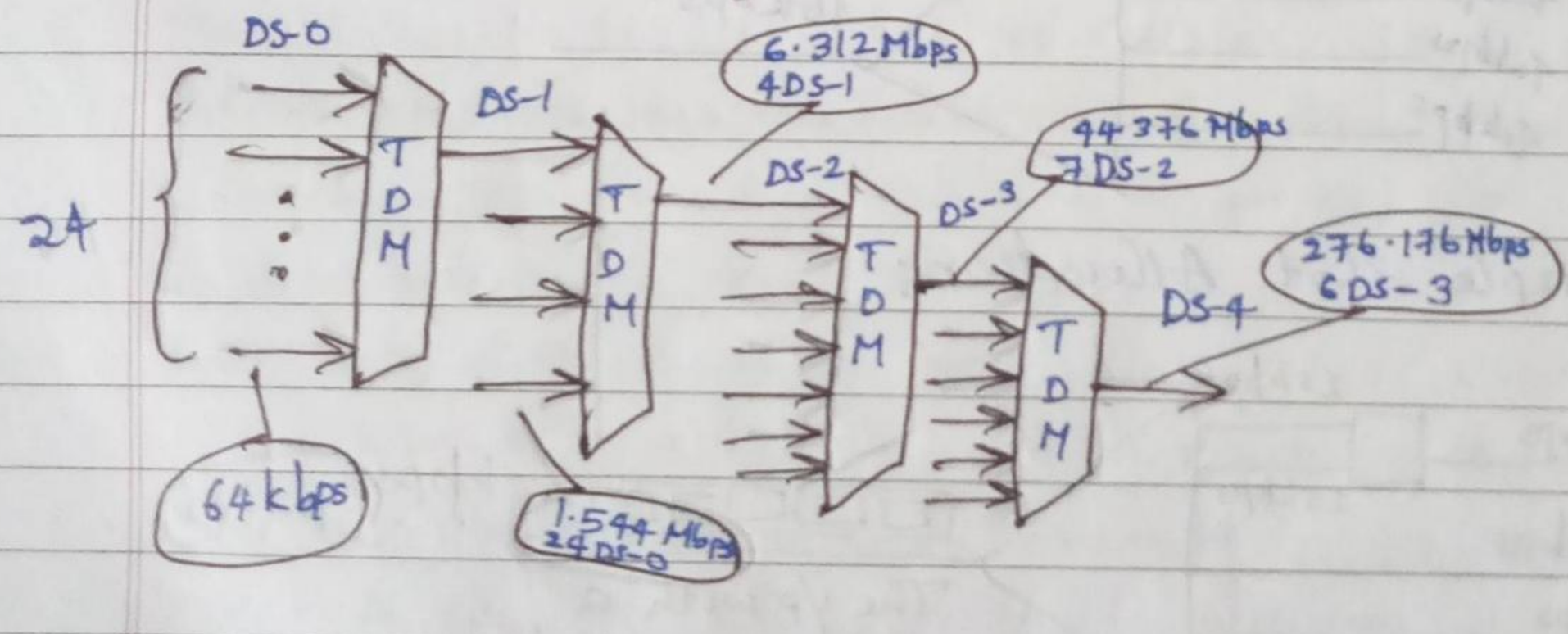
1	0	1

Synch. pattern.



Digital Carrier S/ms:

Telephone companies implement TDM through a hierarchy of digital s/ls, (DS) called digital s/l service or digital hierarchy.



→ DS-0 → a single digital channel of 64 kbps.

24 DS-0 channels → DS-1 ⇒ 1.544 Mbps ie; 24×64 kbps + 8 kbps of overhead.

→ DS-2 ⇒ 6.312 Mbps ie; 6.312 = 96×64 kbps + 168 kbps of overhead. used to multiplex 4 DS-1 channels.

→ DS-3 ⇒ 44.376 Mbps → 672×64 kbps + 1.368 Mbps
— multiplex 7 DS2 channels, 28 DS-1 channels, 168 DS-1

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DS-4 ⇒ 274.176 Mbps ⇒ 4032 x 64 + 16.128 Mbps.

T Lines: DS-0, DS-1 are the names of services.
To implement these services, the telephone companies use T lines (T-1 to T-4). These are lines with capacities matched to the data rates of the DS-1 to DS-4 services.
T-Lines for Analog Transmission:
— transmn of digital data, audio or video.

T-1 Frame:

DS-1 requires 8kbps of overhead.
The frame used on a T-1 line is usually 193 bits devided into 24 slots of 8 bits each plus 1 extra bit for synch. (24x8+1=193) Each slot contains one s/l segment from each channel. If a T-1 line carries 8000 frames, the data rate is 1.544 Mbps (193x8000 = 1.544 Mbps) — the capacity of the line.

E Lines: European version of T Lines called E lines.
Appl^n — — Second generation cellular phones. Digital version of cellular telephony devides the available bandwidth into 30kHz bands.

→ Statistical Time Division Multiplexing:

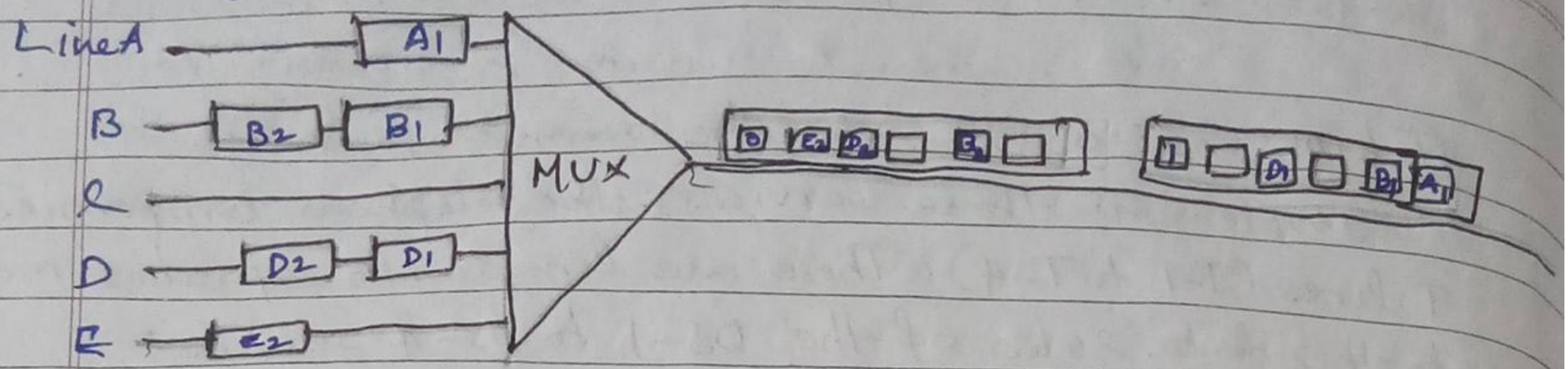
In synch. TDM, each i/p has a reserved slot in the o/p frame. This can be inefficient if some i/p lines have no data to send.

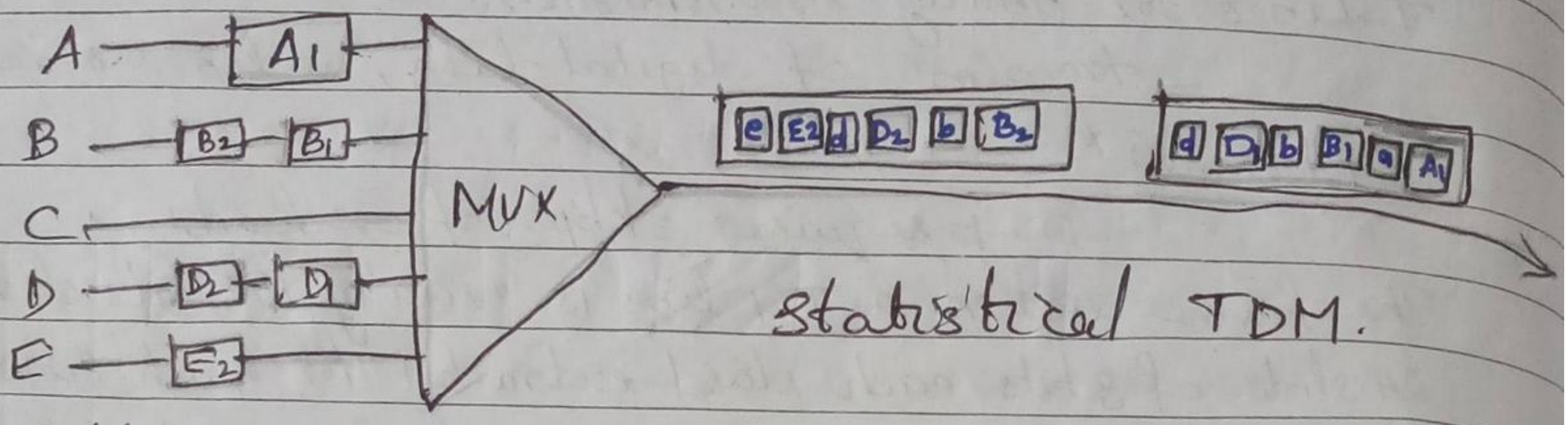
In statistical TDM, slots are dynamically allocated to improve bandwidth efficiency. Only when an i/p to line has a slot's worth of data to send is it given a slot in the o/p frame.

— the no. of slots in each frame is less than the no. of i/p lines. The MUX checks each i/p line in round robin fashion; it allocates a slot for an i/p line if the line has data to send else it skips line & checks the next line.

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Synch- TDM





Addressing:

→ An o/p slot in synch. TDM is totally occupied by data; In statistical TDM, a slot needs to carry data as well as the address of destination.

→ In statistical multiplexing, there is no fixed relationship b/w the i/ps & o/ps b/c there are no preassigned or reserved slots. So it is included the addr. of the receiver inside each slot to show where it is to be delivered. The addressing in its simplest form can be n bits to define N diff. o/p lines with $n = \log_2 N$. For eg: 8 diff. o/p lines, we need a 3 bit address.

Slot size:

- A slot carries both data & an address.
- The ratio of the data size to address size must be reasonable to make transmn efficient.

ie: eg: it would be inefficient to send 1 bit/slot as data when the address is 3 bits.

No synchronization bit:

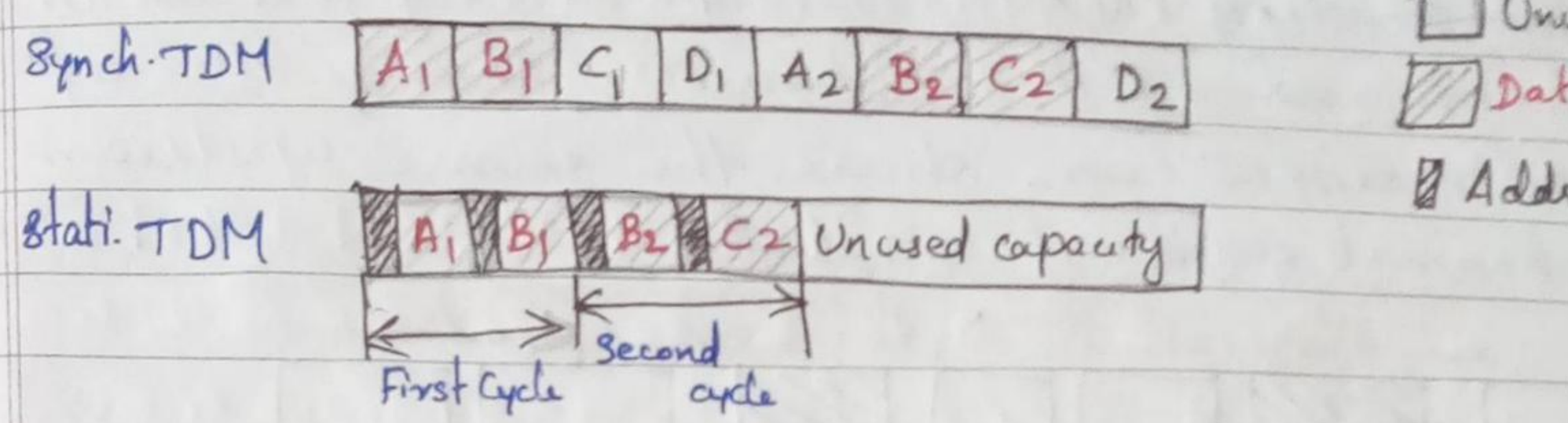
- The frames in statistical TDM need not be synchronized

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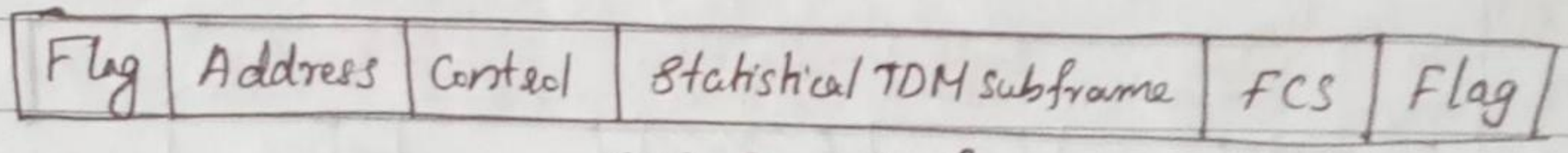
Date
Page

Bandwidth:

— the capacity of the link is normally less than the sum of the ~~capacity~~ capacities of each channel. Statistical TDM define the capacity of the link based on the statistics of the load for each channel.

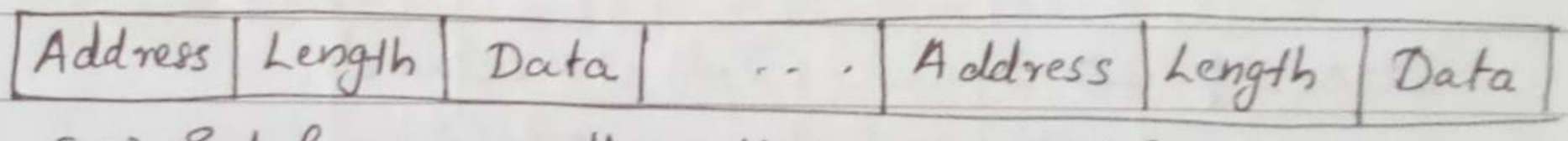


Statistical TDM Frame Formats:



(a) Overall frame.

(b) Subframe with one source/frame.



(c) Subframe with multiple sources/frame.

*Cable Modem:

Cable TV provider dedicates 2 channels, for data transfer to & from a cable modem.

— Each channel is shared by a no. of subscribers.

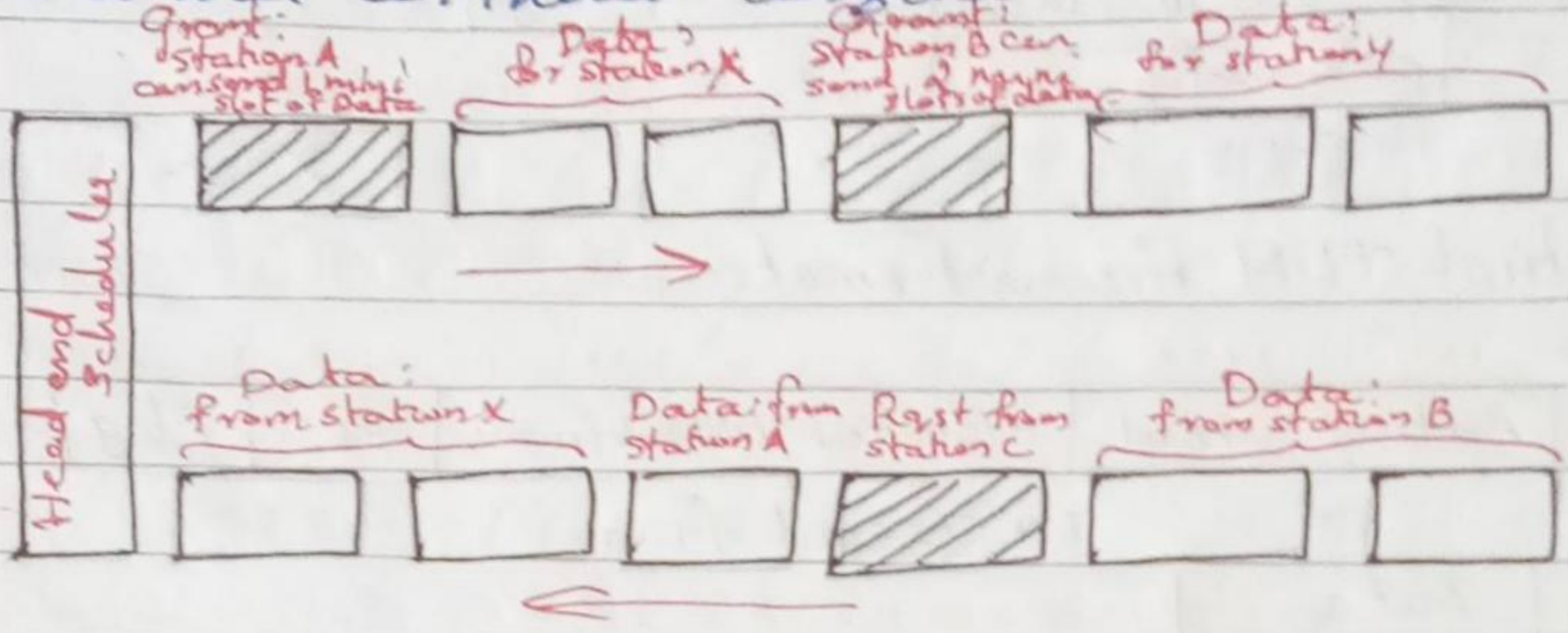
Downstream direction, — cable headend to subscriber a cable scheduler delivers data in the form of small packets.

— If more than one subscriber is active, each subscriber gets only a fraction of the downstream capacity.

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→ When a subscriber has data to transmit, it must first request time slots on the shared upstream channel. Each subscriber is given dedicated time slots for this rqst purpose.

→ The headend scheduler responds to a request pkt by sending back an assignment of future time slots to be used by this subscriber. Thus a no. of subscribers can share the same upstream channel without conflict.



→ Synch. TDM ⇒ SONET/SDH

SONET ⇒ Synch. Optical Network
→ Optical transmn std.
SDH ⇒ Synch. Digital Hierarchy.

→ SONET - hierarchy of standardised digital data rates. The lowest level → STS-1 or OC-1 (Optical carrier level 1) is 51.84 Mbps.

- group of lower rate s/ls - DS1, DS1C, DS2 + plus ITU-T rates.

- Multiple STS-1 s/ls can be combined to form an STS-N s/l. See Table 8.4 pg 239 Stallings.

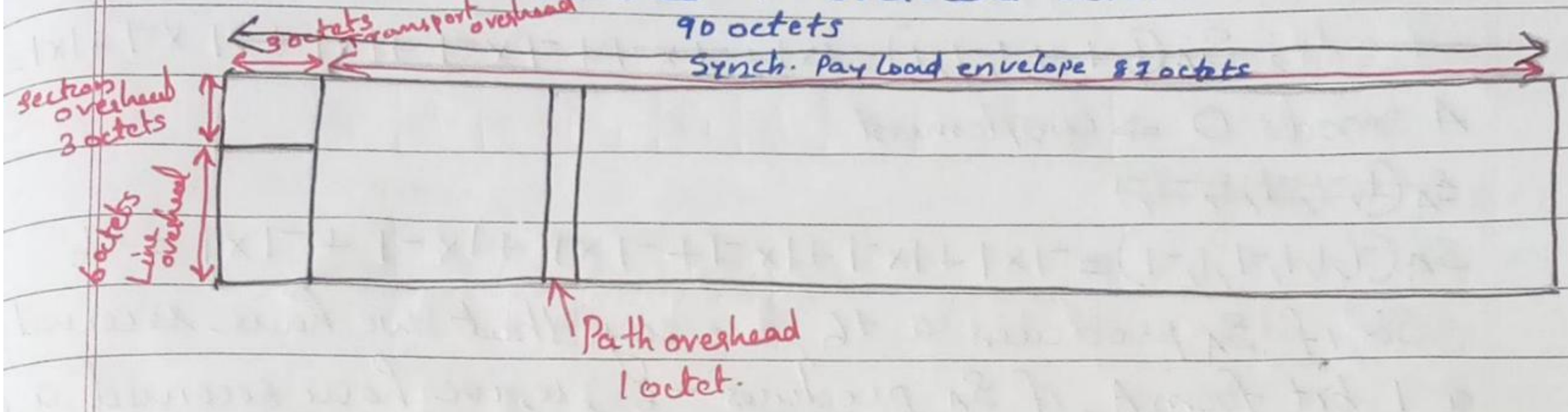
Frame format:

The basic SONET building blk is the STS-1 frame which consists of 810 octets & is transmitted once every 125 μs, for an overall data rate of 51.84 Mbps.

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The frame can logically be viewed as a matrix of 9 rows of 90 octets each with transmission being one row at a time, from left to right & top to bottom.

The first 3 columns (3 octets x 9 rows = 27 octets) of the frame are devoted to overhead octets.

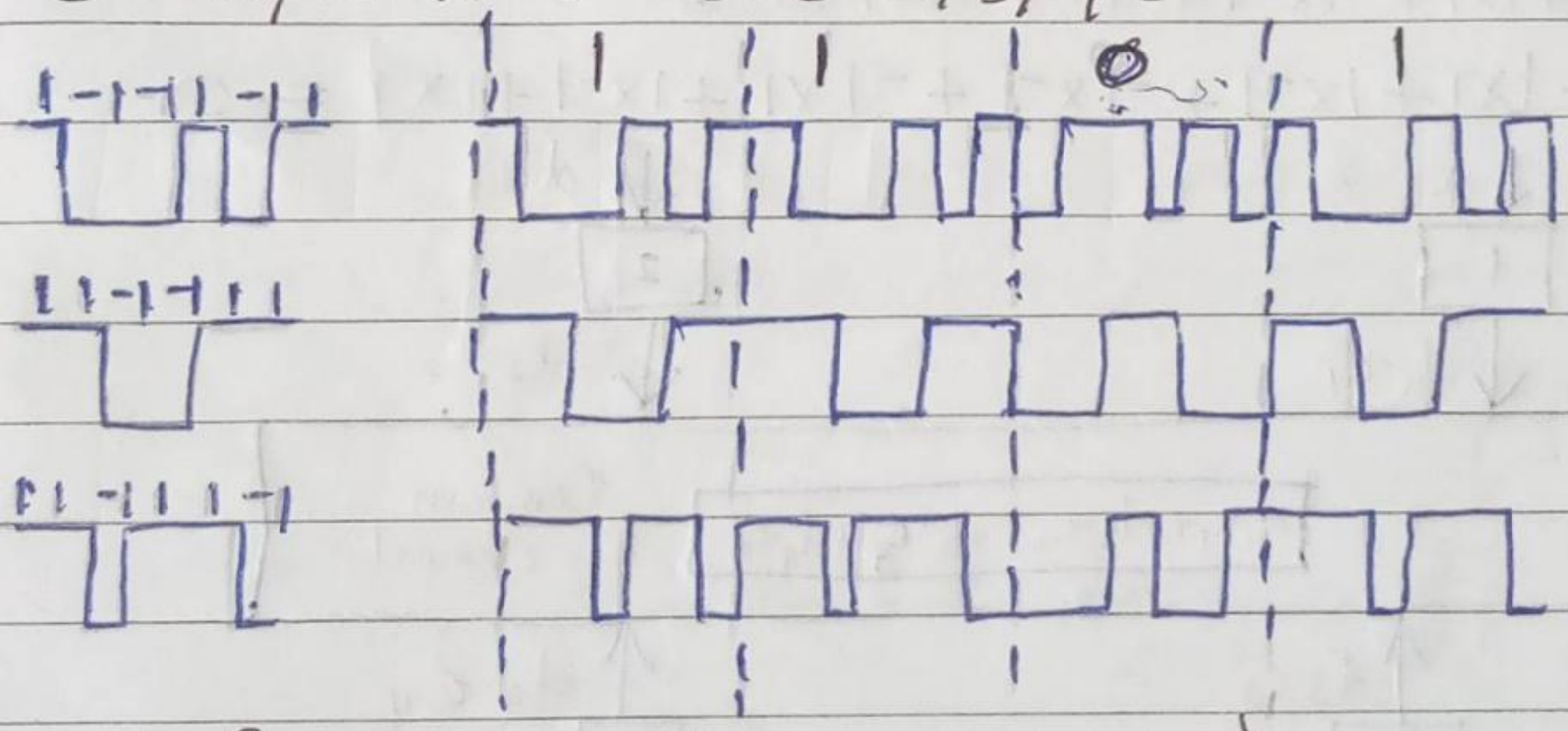


→ Multiple Access : Code Division Multiple Access (CDMA)

→ to enable multiple users to independantly use the same bandwidth with very little interference.

// Data s/l rate D, break bit into k chips acc. to fixed pattern specific to each user, called user's code.

Example: $k=6$ users A, B, & C.



Code for A $C_A = \langle 1, -1, -1, 1, -1, 1 \rangle$

B $C_B = \langle 1, 1, -1, -1, 1, 1 \rangle$

C $C_c = \langle 1, 1, -1, 1, -1 \rangle$

→ User A communicating with the base station. If A wants to send a 1 bit, A transmits its code as a chip pattern $\langle 1, -1, -1, 1, -1, 1 \rangle$. If 0 bit is to be sent, A transmits the complement of its code $\langle -1, 1, 1, -1, 1, -1 \rangle$. At the base station receiver decodes the chip patterns.

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ie; If the receiver receives a chip pattern $d = \langle d_1, d_2, d_3, d_4, d_5, d_6 \rangle$ & the receiver is seeking to communicate with a user u so that it has at hand u's code, $\langle c_1, c_2, c_3, c_4, c_5, c_6 \rangle$

Decoding fn $S_u(d) = d_1 \times c_1 + d_2 \times c_2 + d_3 \times c_3 + d_4 \times c_4 + d_5 \times c_5 + d_6 \times c_6$

A sends 1

ie; $S_A(1,-1,-1,1,-1,1) = 1\times1 + -1\times-1 + -1\times-1 + 1\times1 + -1\times-1 + 1\times1 = 6$

A sends 0 $\Rightarrow$ complement

~~$S_A(-1,1,1,-1,1,-1)$~~

$S_A(-1,1,1,-1,1,-1) = -1\times1 + 1\times-1 + 1\times-1 + -1\times1 + 1\times-1 + -1\times1 = -6$

So if S_A produces a +6, we say that we have received a 1 bit from A, if S_A produces -6, ie; we have received a 0 bit from user A. Otherwise, there is an error.

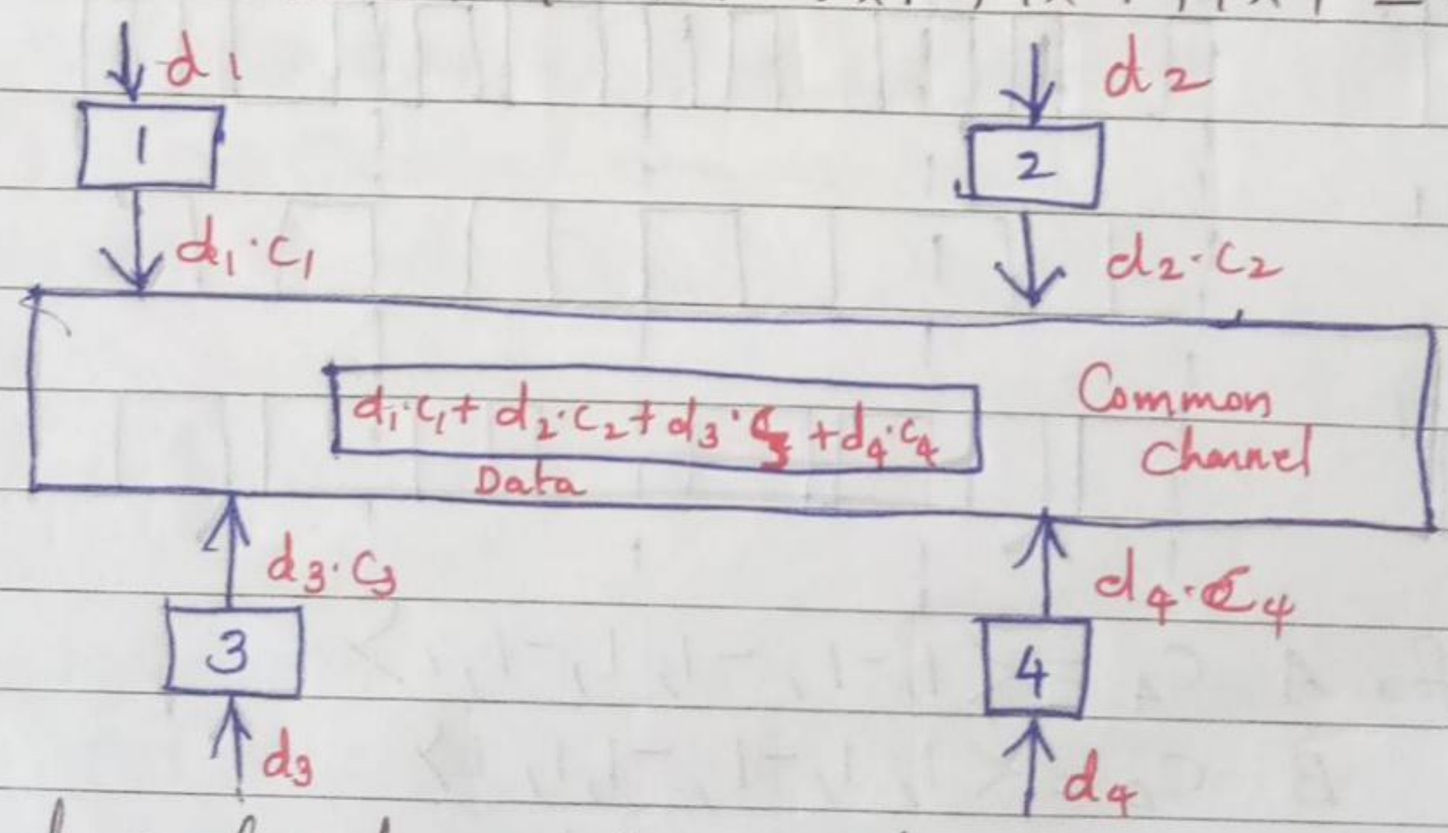
If B is sending & we try to receive it with S_A, we are decoding with wrong code, A's. If B sends a 1 bit, then

$d = \langle 1, 1, -1, -1, 1, 1 \rangle$

$S_A(1,1,-1,-1,1,1) =$ ~~$1\times1 + 1\times-1 + -1\times-1 + -1\times1 + 1\times1$~~

$= 1\times1 + 1\times1 + -1\times-1 + -1\times-1 + 1\times1 + 1\times1$

$= 1\times1 + 1\times-1 + -1\times-1 + -1\times1 + 1\times-1 + 1\times1 = 0$



Assigned codes have 2 properties

1. If we multiply each code by another we get 0.
2. " " " itself we get 4 (no. of stations)

Scanned by TapScanner

Chips: Each station is assigned a code, which is a sequence of no. called chips. ⇒ ~~Seq~~ Orthogonal sequences

1. Each seq. is made of N elmts, where N is the no. of stations.

2. If we multiply a seq. by a no. every elmt in the seq. is multiplied by that no. ie; multipl^n of a sequence by scalar.

$$2 \cdot (+1\ +1\ -1\ -1) = (2\ +2\ -2\ -2)$$

3. If we multiply 2 equal sequences, elmt by elmt, & add the results, we get N, where N is the no. of elmts in each sequence. ie; called inner product of 2 equal seq.

eg: $(+1\ +1\ -1\ -1) \cdot (+1\ +1\ -1\ -1) = 1+1+1+1 = 4$

4. If we multiply 2 diff. sequences, elmt-by elmt & add the results, we get 0.

eg: $(+1\ +1\ -1\ -1) \cdot (+1\ +1\ +1\ +1) = 1+1-1-1 = 0$

5. Adding 2 seq. means adding the corres. elmts. The result is another seq.

eg. $(+1\ +1\ -1\ -1) + (+1\ +1\ +1\ +1) = (\pm 2\ +2\ 0\ 0)$

Data Representation

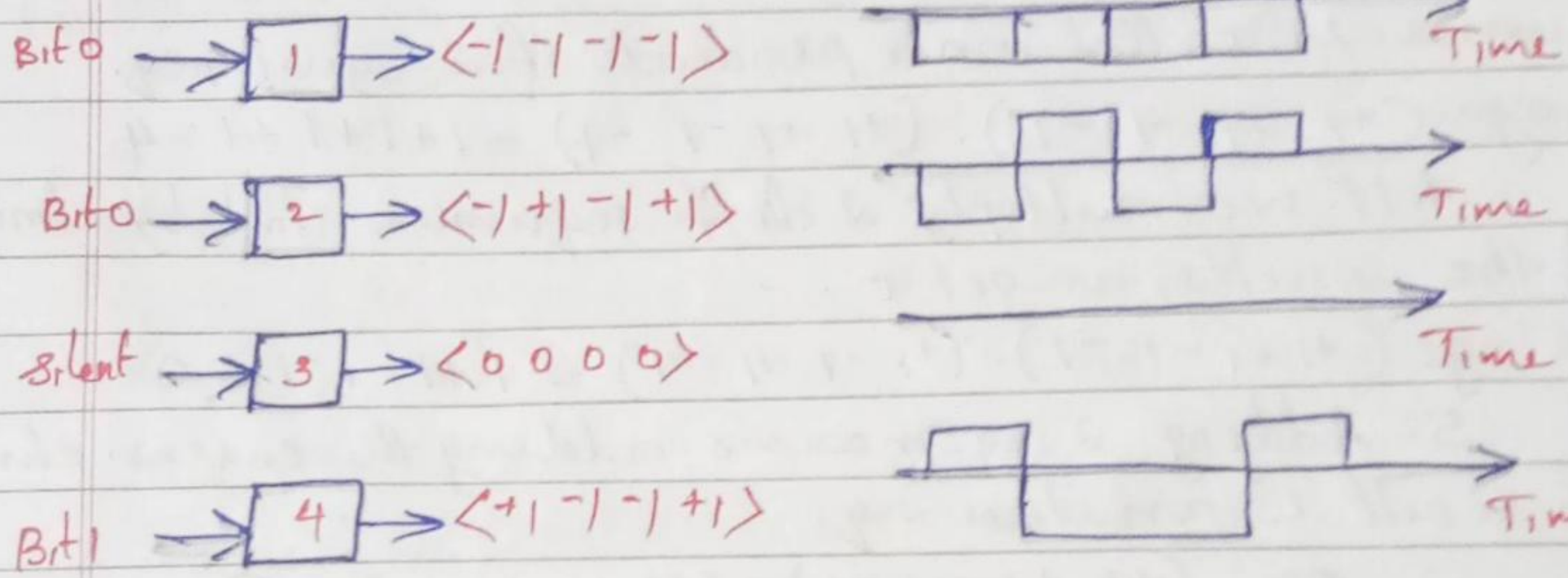
Data bit 0 $\longrightarrow$ -1 Data bit 1 $\longrightarrow$ +1 Silence $\longrightarrow$ 0

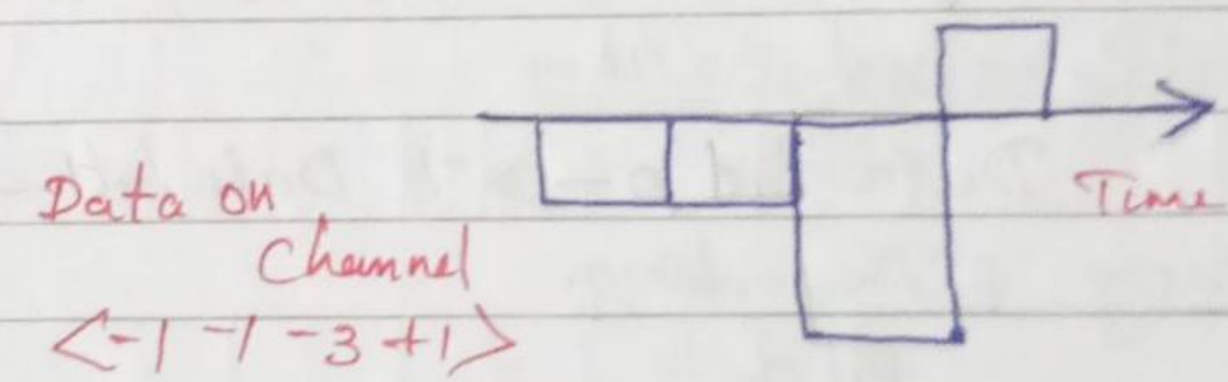
Encoding & Decoding.

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station 1 & 2 are sending 0 bit & channel 4 is sending 1 bit. Station 3 is silent. The senders site as translated to -1, -1, 0 & +1. Each station multiplies the corresponding no. by its chip, which is unique for each station. The result is new seq. which is sent to the channel.

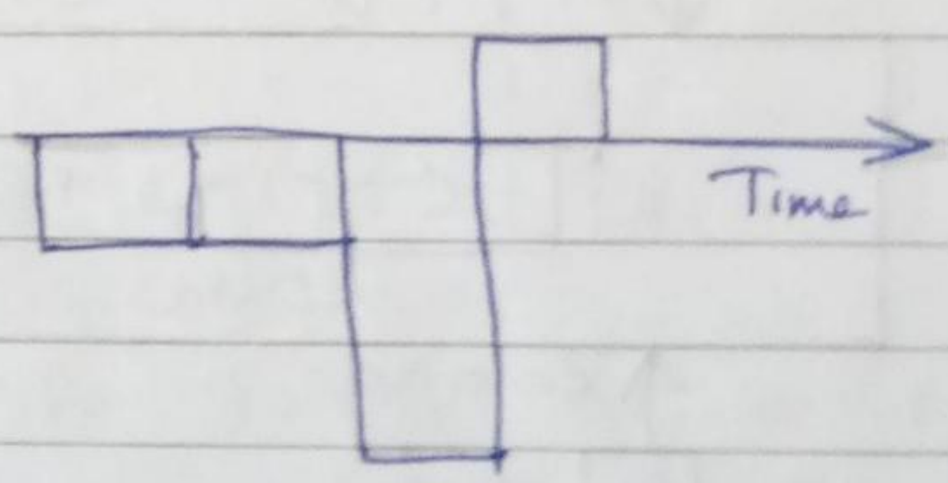
Signal Level



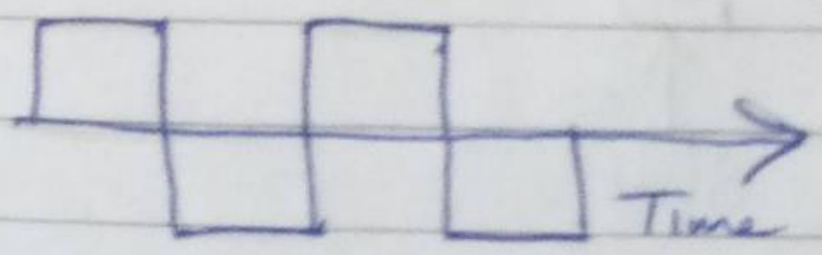


Decoding
Station 2 ⇒ inner product
<-1 +1 -1 +1>

Data on the channel
(1) <-1 -1 -3 +1>

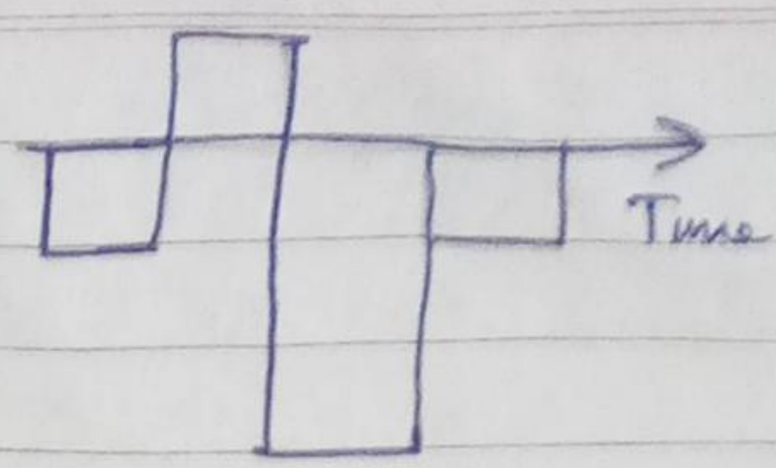


Station 2's code
(2) <+1 -1 +1 -1>



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innerpdt
result<-1 +1 -3 -1>



summing the values

$-4 \rightarrow 0$

Sequence Generation:

To generate chip sequences, we use a Walsh table, which is a 2 dimensional table with an equal no. of rows & columns.

Rules:

$$W_1 = [+1] \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

Generation of W_1, W_2, W_4 Eg:

$$W_1 = [+1]$$

$$W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

Find the chips for a n/w with 2 stations from above Eg:

a) 2 stations

<+1 +1> & <+1 -1>

b) 4 stations

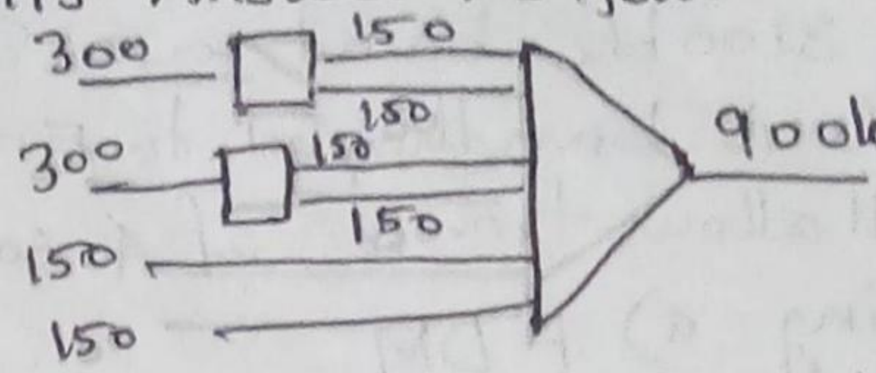
<+1 +1 +1 +1>, <+1 -1 +1 -1>, <+1 +1 -1 -1> & <+1 -1 -1 +1>

// The no. of sequences in a Walsh table needs to be $N = 2^m$.

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11. Four channels, 2 with a bit rate of 300kbps and two with a bit rate of 150 kbps are to be multiplexed using multiple slot TDM with no synch. bits. Answer the follo-

Total 7 channels of 150kbps.



a) Frame size

$= 7 \times 1 = 7$ bits

b) Frame rate = each 150kbps

$= 150,000$ frames/sec

c) Frame duration

$= 1/\text{Frame rate} = 1/150000$ sec

$=$

d) Data rate

$= (150000 \text{ frames/se}) \times (7 \text{ bits/frame})$

$=$

12. Answer the follo. qn about a T-1 line:

a) What is the duration of a frame?

T-1 line sends 8000 frames/se.

frame duration $= 1/8000 = 125\,\mu s$.

b) What is the overhead?

Each frame 1 extra bit $= 8000 \times 1 = 8000$ kbps.

13. Ref fig. Digital Hierarchy, what is the overhead for DS-1, DS-2, DS-3, & DS-4

DS-1 : Overhead $= 1.544 - (24 \times 64\text{kbps}) = 8$kbps

DS-2 : " $= 6.312^{\text{Mbps}} - (4 \times 1.544\text{Mbps}) = 136$kbps

DS-3 : " $= 44.376^{\text{Mbps}} - (7 \times 6.312\text{Mbps}) = 192$kbps

DS-4 : " $= 274.176\text{Mbps} - (6 \times 44.376\text{Mbps}) = 7.92$Mbps

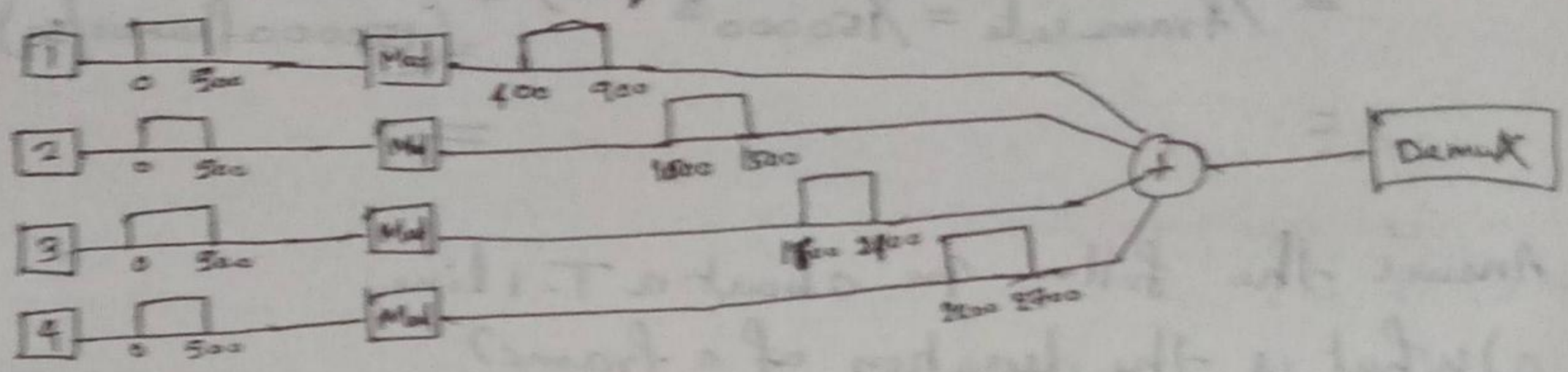
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14. The inf^n in 4 analog s/ls is to be multiplexed and transmitted over a telephone channel that has a 400 to 3100 Hz band pass. Each of the analog baseband s/ls is bandlimited to 500Hz. Design comm^n s/m that will allow transm^n of 4 sources over the telephone channel using a) FDM

Bandwidth = 3100 − 400 = 2700Hz

Each s/l = 500Hz

4 sources (Required) = 4 × 500 = 2000 Hz



15. Consider a transmission s/m using FDM. What cost fac are involved in adding one more pair of stations to the s/m?

If there is spare bandwidth, then the incremental cost of the transm^n can be negligible. The new station pair is simply added to an unused subchannel. If there is no unused subchannel it may be possible to redivide the existing subchannels creating more subchannels with less bandwidth. A new pair causes a complete new like to be added, then the incremental cost is large.

16. Why is it that the start bit & stop bits can be eliminated wh character interleaving is used in synch. TDM?

- Char. is placed in a time slot. The char. is delimited by the bounds of the time slot. No further delimiters are needed

17. Explain in terms of data link ctrl & phy. layer concepts ho error & flow ctrl are accomplished in synch. TDM?

It offers no flow ctrl/error ctrl

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Name	
Reg. No.	

NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE

SERIES TEST – II

CS 307 : DATA COMMUNICATION

Year / Semester & Branch : III / S5 B.Tech. CSE

Time : 60 Mins

Date :25/10/2017

Max. Marks:20

PART-A

Answer ALL Questions (3 x 2 = 6 Marks)

1. Define Baseline wandering & give its effect on digital transmission.
2. Distinguish between data rate & signal rate.
3. Define analog hierarchy used by telephone companies.

PART- B

Answer ALL Questions (2 x 7 = 14 Marks)

4.

a. An analog signal has a bit rate of 8000 bps & a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

(3 Marks)

b. A signal is quantized using 10 bit PCM. Find the quantization noise ratio ? **(2 Marks)**

c. The telephone line has 4kHz bandwidth. What is the maximum no. of bits we can send using the following technique(d=0) ?

(2 Marks)

OR

5.

a. For the bit stream 01001100011,sketch the waveforms for coding NRZ-L,NRZ-I,AMI & Manchester Coding. Assume that the signal level for the most recent preceding bit was negative voltage for AMI.

(4 Marks)

b. Find the bandwidth for the following situations if we need to modulate a 8kHz voice.

a) AM b) FM(β=5) c) PM (β=1)

(3 Marks)

6

a. Assume that a voice channel occupies a bandwidth of 4kHz .We need to multiplex 12 voice channels with guard bands of 500Hz using FDM. Calculate the required bandwidth.

(2 Marks)

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Name	
Reg. No.	

b. Which of the three multiplexing techniques is common for fibre optic links? Explain. (3 Marks)

c. What is the purpose of interleaving in synchronous TDM ? (2 Marks)

OR

7.

a. Explain Wavelength Division Multiplexing. (3 Marks)

b. Differentiate between Synchronous TDM between Statistical TDM. (4 Marks)

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MODULE V

Digital Data Communication Techniques:

→ Asynchronous Transmission ✓
→ Synchronous Transmission ✓
→ Detecting & Correcting Errors ✓
  * Types of Errors ✓
  * Error Detection ✓
    - Parity check ✓
    - Cyclic Redundancy Check (CRC) ✓
  * Error Control Error Correction
    - Forward Error Correction &
    - Hamming Distance.

Questions:

1. In CRC, show the rel'ship b/w the follo. entities a) size of dataword & size of codeword b) Size of divisor & remainder. c) Degree of the polynomial & size of the remainder, size of divisor.
2. What is Hamming distance? What is the min. Hamming distance?
3. Distinguish blw forward error correction & error correction by retransmission.
4. How does a single bit error differ from a burst error?
5. What is the Hamming distance for each of the follo. codewords? a. d(10000, 01000) b) d(10101, 10010) c) d(1111, 1111), d) (0000, 0000).
6. Given dataword 10100011010 and the divisor 10111. n-k+1 = 5, k-p+1 = 5, n = 5+10-1 = 14
   a. Show the generation of the codeword at the sender site.
   b. " checking at the receiver site (no error).
7. Answer the follo- Qns.
   1. What is the polynomial repⁿ of 101100?
   2. What is the result of shifting 10101 0 3 bits to the left?
   3. Repeat Qn 2 using polynomials.

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4. Result of shifting 101010 four bits to the right?
5- Repeat Qn 4 using polynomials.

8. Assuming even parity, find the parity bit for each of the follo. data units.
   a. 1001011 b. 0001100 c. 1000000 d. 1110111

9. Repeat Qn 6 using polynomials.

10. Would you expect that the inclusion of a parity bit with each character would change the probability of receiving correct msg?

11. Two communicating devices are using a single bit even parity check for error detection. The transmitter sends the byte 10101010 & b/c of channel noise, the receiver gets the byte 10011010. Will the receiver detect the error? Why or why not?.

12. What is the purpose of using modulo 2 arithmetic rather than binary arithmetic in computing an FCS?

13. Explain in words why the shift reg. implementation of CRC will result in all 0s at the receiver if there are no errors. Demonstrate by eg.

14. For P=110011 & M=11100011 find the CRC.

15. Calculate the Hamming pairwise distances among the follo. codewords. a) {00000, 10101, 01010}
   b) 000000, 010101, 101010, 110110

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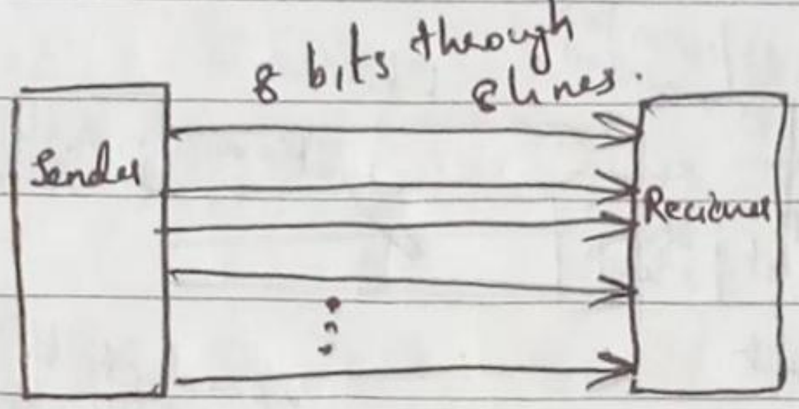
Digital Data Communication Techniques:

Data are transmitted one bit at a time over the medium. The timing of these bits must be the same for transmitter & receiver.

Data Transmission Modes:

- Parallel ✓
- Serial ✓
  - Asynchronous →
  - Synchronous →
  - Isochronous

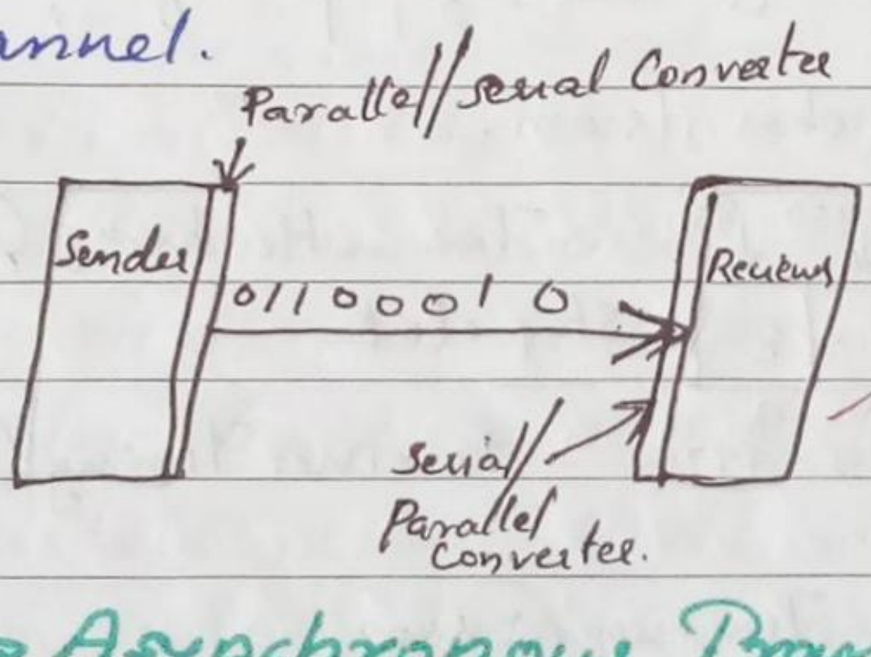
Parallel Transmission: Binary data (1s & 0s) organized into groups of n bits each. By grouping, n bits of data at a time can be sent at a time instead of 1.



Adv: Speed ✓

Disad: n comm^n lines. ✓ expensive.

Serial Transmission: One bit follows another, only one comm^n channel.



Adv: Only one comm^n channel reduces cost ✓

→ Asynchronous Transmission:

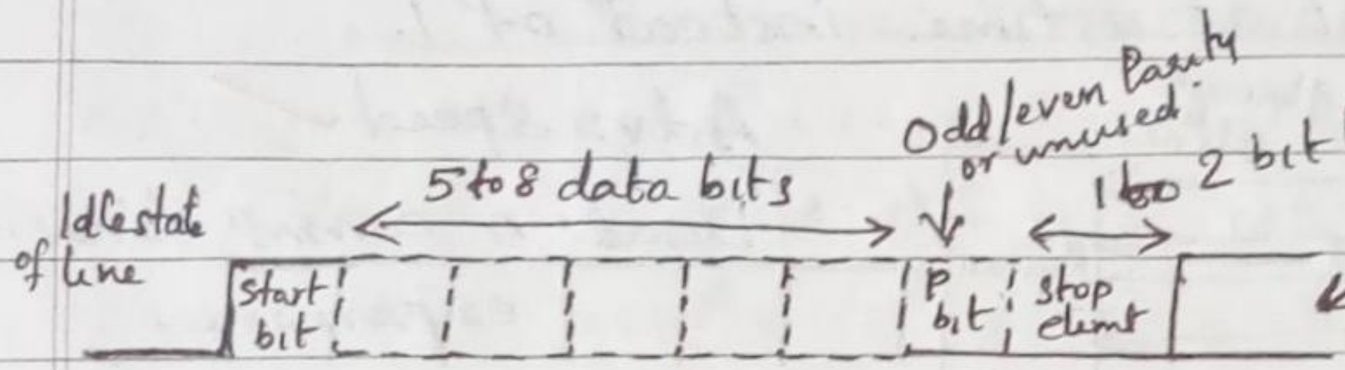
→ Timing of a s/l is unimportant. Inf^n is received & translated by agreed upon patterns. Patterns are based on grouping the bit stream into bytes. Each group, 8 bit is sent along the link as a unit.

To alert the receiver to the arrival of a new group, an extra bit is added to the begining of

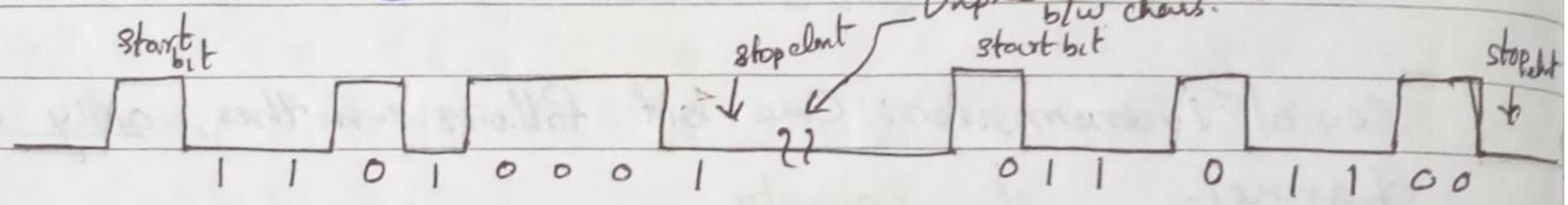
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each byte. This bit, 0 is called the start bit. One or more additional bits are appended to the end of the byte. These bits, 1s called stop bits. By this method each byte is increased to atleast 10 bits, of 8 bits is inspⁿ 2 bits or more are 1/ls to the receiver.

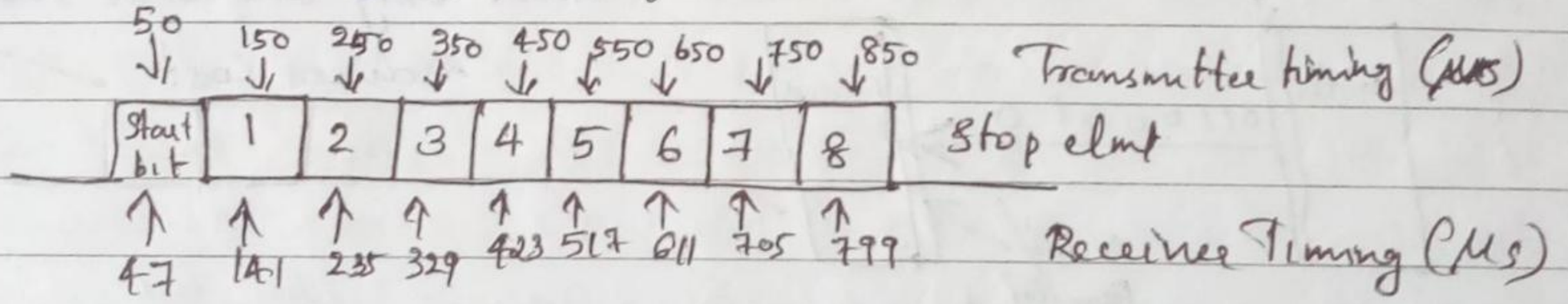
Within each byte, the receiver must be synchronized with the incoming bit stream. The receiving device resynchronizes at the onset of each new byte. When the receiver detects a start bit, it sets a timer & begins counting bits as they come in. After n bits, the receiver looks for stop bit. As soon as it detects the stop bit, it waits until it detects the next start bit



(a) Format



(b) 8 bit asynch. char streams.



© Effect of Timing Error.

fig© Two errors. If the receiver is 5% slower or faster than the transmiter, the sampling of 8th char. bit will be displaced by 45%. ✱

→ Last sampled bit is incorrectly received.
→ the bit count may be out of ~~com~~ alignment. If bit 7 is a 1 & bit 8 is a 0, bit 8 could be mistaken for a

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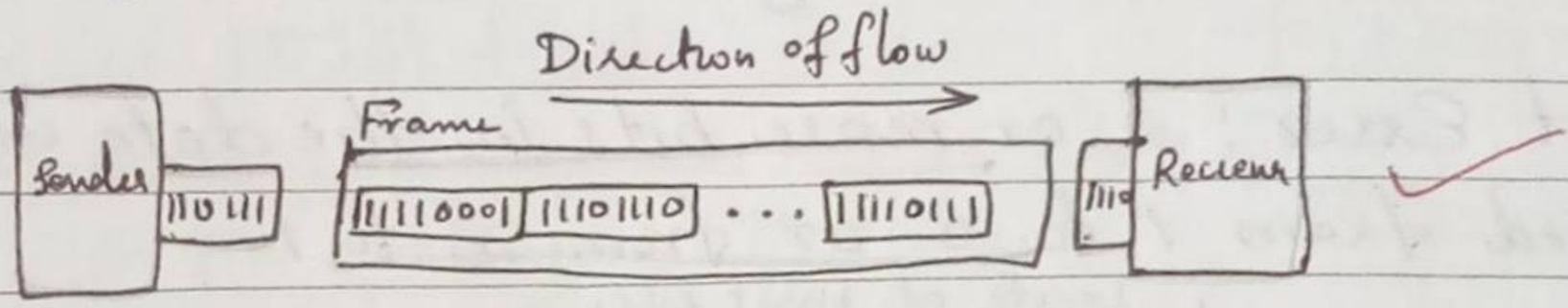
start bit. This condition is termed as framing error, as the char. + start bit & stop elmt are sometimes referred to as a frame.

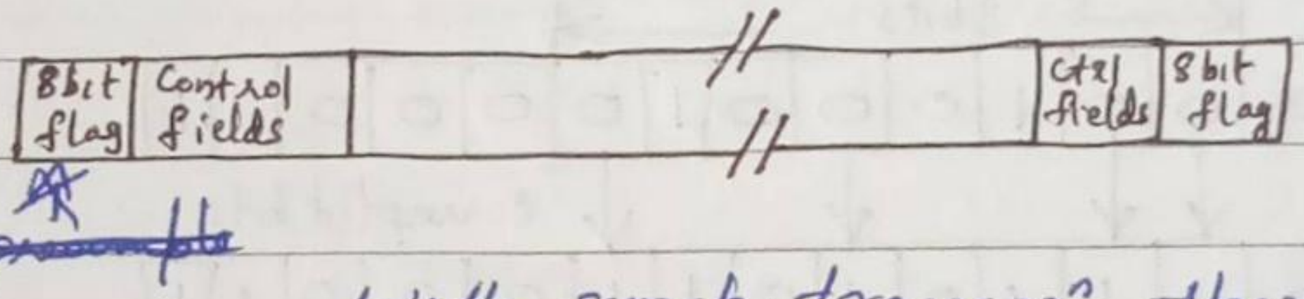
Adv: simple & cheap.

Disadv: Overhead of 2 to 3 bits/char.

→ Synchronous Transmission

→ The bit stream is combined into longer "frames" which may contain multiple bytes. Each byte is introduced onto transm^n link without a gap blw it & next one. It is left to the receiver to separate the bit stream into bytes for decoding purposes.





With synch. transm^n, there is another level of synch required, to allow the receiver to determine begining & end of a blk of data. To achieve this, each blk begins with a preamble bit pattern & generally ends with a postamble bit pattern. In adeletion, other bits are added to the blk. ~~that~~ ~~convey~~ The data + preamble + postamble & ctrl inf^n called a frame. Frame start with a preamble called flag 8 bits long same flag used as postamble.

Adv: speed

: No extra bits

→ Detecting & Correcting Errors:

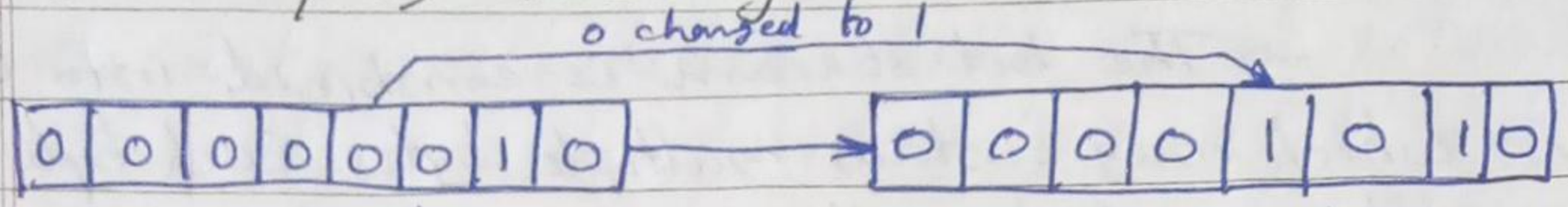
An error occurs when a bit is altered blw transm^n & reception; ie; a binary 1 is transmitted & a binary 0 is received or a binary 0 is ~~received~~ transmited & 1 is received.

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* Types of Errors:

Two general types of Errors
- Single bit errors
- Burst errors.

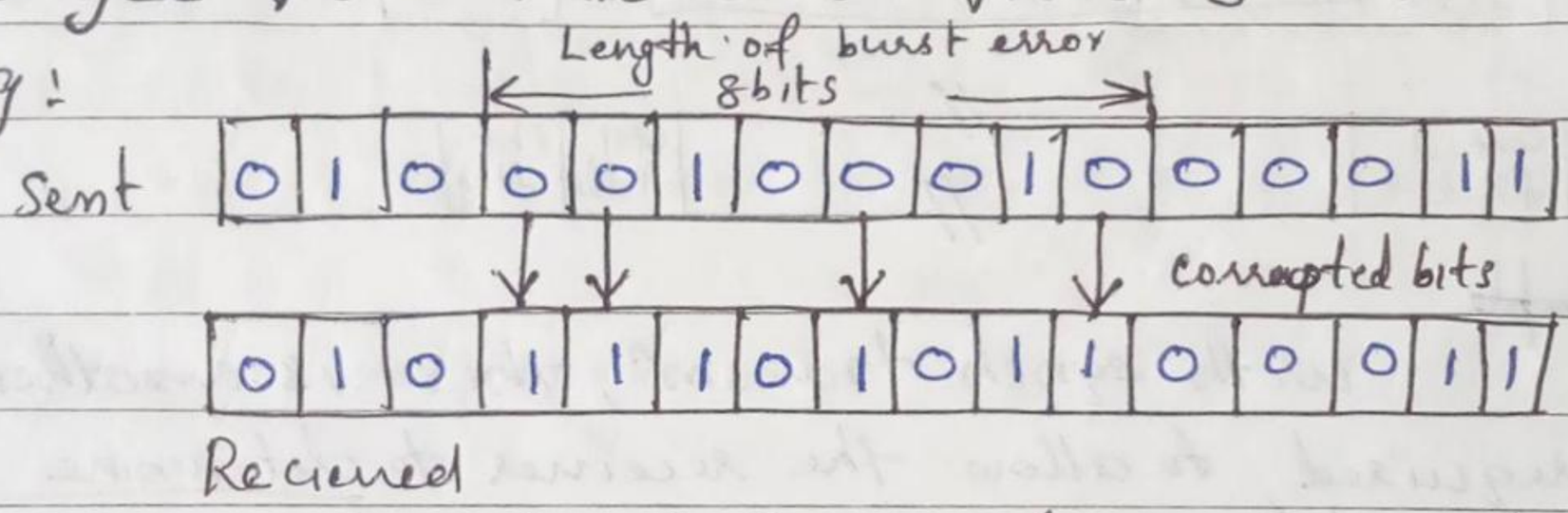
Single bit Error: Only 1 bit of a given data unit (byte, char or pkt) is changed from 1 to 0 or from 0 to 1.



→ doesn't affect near by bits.

Burst Error: 2 or more bits in the data unit have changed from 1 to 0 or from 0 to 1.

Eg:



The length of the burst is measured from the first currupted bit to the last currupted bit. (not in consecutive bits)

* Error Detection:

To be able to detect or correct errors, we need to send some extra bits with our data. These redund bits are added by the sender & removed by the receiver.

Data are transmitted as one or more cont. sequences of bits, called frames. Probabilities w.r.to errors in transmitted frames.

P_b – Probability that a bit is received in error (BER)
Bit Error Rate.

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P_1 : Probability that a frame arrives with no bit errors.

P_2 : Probability that, with an error detecting algm in use, a frame arrives with one/more undetected errors.

P_3 : Probability that, with an error detecting algm in use a frame arrives with one or more detected bit errors but no undetected bit errors.

$P_1 = (1 - P_b)^F$

$P_2 = 1 - P_1$ // F is the no. of bits/frame.

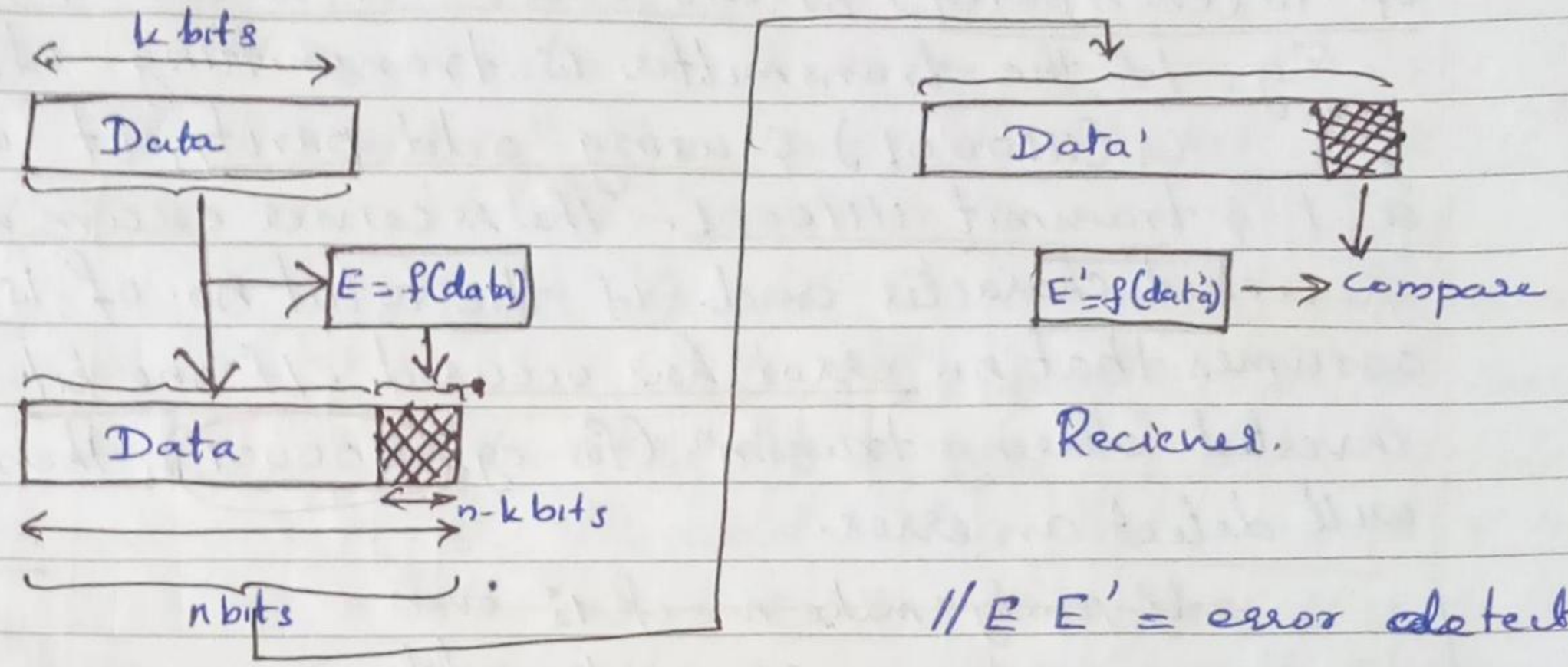


Fig: Error Detection Process.

For a given frame of bits, additional bits that constitute an error-detecting code are added by the transmitter. This code is calculated as a fn of the other transmitted bits. For a data blk of k bits, the error detecting algm yields an error detecting code of n-k bits where $(n-k) < k$. The error detecting code is also called as the check bits, appended to the data block to produce a frame of n bits, which is then transmitted. The receiver separates the incoming frame into k bits of data & n-k bits of the error detecting code. The receiver performs same error-detecting calculation on the

data bits & compares this value with the value of incoming error detecting code. A detected error occurs iff there is a mismatch.

* – Parity Check:

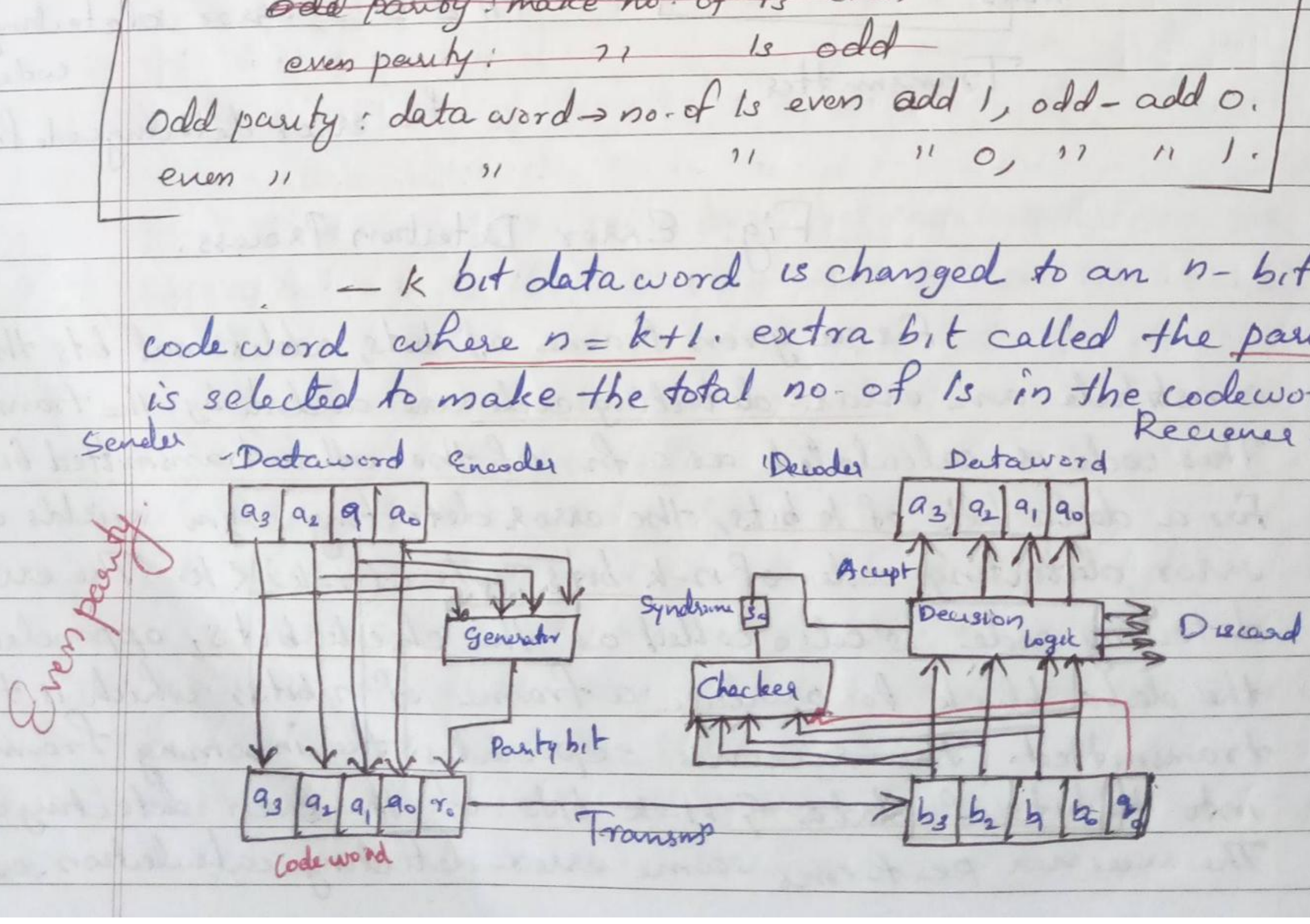
– Error-detecting scheme is to append a parity bit to the end of a blk of data. The value of this bit is selected so that the char. has an even no. of 1s (even parity) or an odd no of 1s (odd parity).

Eg: If the transmitter is transmitting character (1110001) & using odd parity, it will append a 1 & transmit 11110001. The receiver examines the received character and if the total no. of 1s is odd, assumes that no error has occured. If one bit is erroneously inverted during transm^n (for eg: 11100001), then the receiver will detect an error.

~~odd parity: make no. of 1s even~~
~~even parity: " 1s odd~~
Odd parity: data word → no. of 1s even add 1, odd – add 0.
even " " " " " 0, " " 1.

– k bit data word is changed to an n-bit codeword where $n = k+1$. extra bit called the parity bit, is selected to make the total no. of 1s in the codeword even

Sender — Dataword — Encoder — Codeword — Transmn — Decoder — Dataword — Receiver.



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The encoder uses a generator that takes a copy of a 4 bit dataword ($a_0, a_1, a_2 a_3$) & generates a parity bit r_0. The dataword bits & the parity bit create 5 bit code word. The parity bit that is added makes the no. of 1s in the codeword even. This is normally done by adding the 4 bits of the dataword (modulo-2); the result is parity bit.

$$r_0 = a_3 + a_2 + a_1 + a_0 \% 2$$

Eg: $0+1+1+1 \% 2 = 1 \therefore r_0 = 1$

$0+1+0+1 \% 2 = 0 \therefore r_0 = 0$.

If the no. of 1s is even, the result is 0; if the no. of 1s is odd, the result is 1.

The sender sends the code word. The receiver receives 5 bit codeword. The checker at the receiver does the same thing as the generator in the sender with one exception. The addition is done overall 5 bits. The result is called syndrome s_0. The syndrome s_0 is 0 when no. of 1s in the received codeword is even; otherwise, it is 1.

$$s_0 = b_3 + b_2 + b_1 + b_0 + q_0 \text{ modulo } 2$$

The ~~synchr~~ syndrome is passed to the decision logic. If the syndrome is 0, there is no error in the received codeword accepted as dataword. If the syndrome is 1, received codeword is discarded.

* — Cyclic Redundancy Check: (CRC)

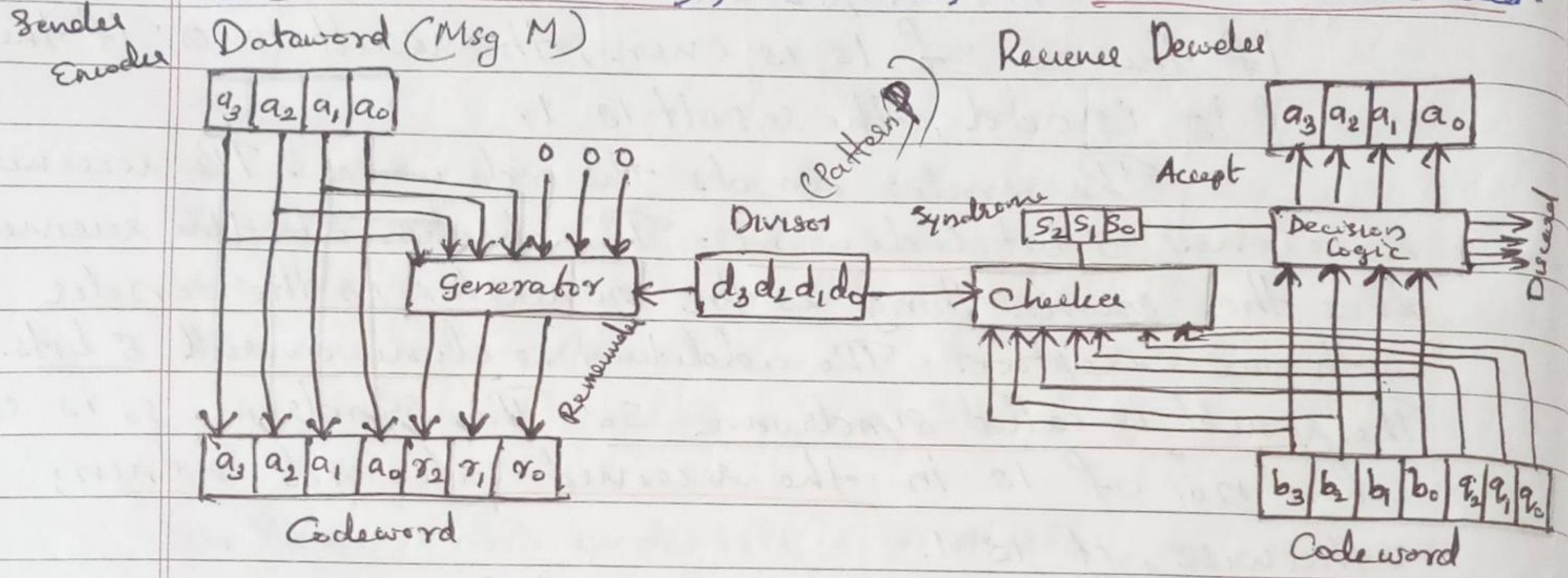
→ used in LANs & WANs.

In the encoder, the dataword has k bits (4 here) the codeword has n bits (7 here). The size of the dataword is augmented by adding (n-k) (3 here) 0s to the right hand side of the word. The n bit result is fed into the generator. The generator ~~uses~~ uses a divisor of size n-k+1 (4 here),

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predefined. The generator devides the augmented dataword by the divisor (modulo 2 devision). The quotient of the devision is descarded; the remainder is appended to the dataword to create the codeword. (n bits)

Decoder: A copy of all n bits is fed to the checker which is a replica of the generator. The remainder produced by the checker is a syndrome of n-k (3 here) bits, which is fed to the decision logic analyzer. If the syndrome bits are all 0s, the leftmost bits of the codeword are accepted as the data word (no error); otherwise, the 4 bits are discarded.



Example:

Dataword: 1001, Divisor: 1011, Dividend: augmented dataword (k bits)

n = 7 bits k = 4 bits n-k = 3 bits. 1001000 (n=7 bits)

As in decimal division, the process is done step by step. In each step, a copy of the divisor is XORed with the 4 bits of the dividend. The result of the XOR op^n (remainder) is 3 bits, which is used for the next step after 1 extra bit is pulled down to make 4 bits long. If the leftmost bit of the dividend is 0, the step cannot use the regular divisor; we need to use an all 0s divisor. When there are no bits left to pull down, we have the result. The 3 bit remainder forms the check bits (r_2, r_1 & r_0). They are appended to the dataword to create the codeword.

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Encoder

Quotient

```
      1010
1011 ) 1001000   ← Dividend augmented dataword
       1011
       -----
        0100
        0000
        ----
         1000
         1011
         ----
          0110   Leftmost bit → 0, use divisor
          0000
          ----
           110   Remainder
```

Codeword: 1001 110

Data word | remainder.

$1 \times 2 + 1 \times 2$

10 10 | 70 | 11 | 110

Decoder

Code word: 1001 110

Division

```
      1010
1011 ) 1001110   ← codeword
       1011
       -----
        0101
        0000
        ----
         1011
         1011
         ----
          0000
          0000
          ----
           000   Syndrome
```

Dataword
1001 accepted

```
      1010
1011 ) 1000110
       1011
       -----
        0011
        0000
        ----
         1111
         1011
         ----
          1000
          1011
          ----
           011   Syndrome
```

Dataword discarded.

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* Polynomials:

A pattern of 0s & 1s can be represented as a polynomial with coefficients of 0 & 1. The power of each term shows the pos^n of the bit. the coefficient shows the value of the bit.

Fig: A polynomial to represent a binary word.

1	0	0	0	0	1	1
↓	↓	↓	↓	↓	↓	↓
$1x^6$	$+ 0x^5$	$+ 0x^4$	$+ 0x^3$	$+ 0x^2$	$+ 0x^1$	$+ 1x^0$

Binary pattern & polynomial

1	0	0	0	0	1	1

$x^6 + x + 1$

short form

→ Degree of Polynomial ⟹ highest power in the polynomial.

Eg: $x^6 + x + 1$ ⟹ 6. no; 1 less than the no. of bits in the pattern. Here 7 bits.

→ Adding & Subtracting Polynomials:

Eg: Adding $x^5 + x^1 + x^2$ & $x^6 + x^4 + x^2$

$\Rightarrow x^6 + x^5$ // x^4 & x^2 are deleted.

Adding is in modulo 2.

→ Multiplying or Dividing Terms:

- just add the powers.

$x^3 \times x^4 = x^7$.

- just subtract the powers.

$x^5 / x^2 = x^3$.

→ Multiplying Two Polynomials.

Eg: $(x^5 + x^3 + x^2 + x)(x^2 + x + 1)$ modulo 2 → x^3

$= x^7 + x^6 + x^5 + x^5 + x^4 + x^3 + x^4 + x^3 + x^2 + x^3 + x^2 + x$

$= x^7 + x^6 + x^3 + x$

Dividing one polynomial by another.

We devide the 1st term of the dividend by the 1st term of the divisor to get the 1st term of the quotient. We multiply the term in the quotient by the divisor and subtract the result from the dividend. We repeat the process until the dividend degree less than the divisor degree

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→ Shifting:

Eg: shifting left 3 bits: 10011 ⟹ 10011000 $x^4+x+1 \Rightarrow x^7+x^4+x^3$

shifting right 3 bits: 10011 ⟹ 10 $x^4+x+1 \Rightarrow x$

→ Cyclic Code Encoder using Polynomials:

See Eg: of CRC

Dataword ⟹ 1001 ie ⟹ x^3+1; Divisor ⟹ 1011 ⟹ x^3+x+1.

Augmented dataword = 1001000 ie; left shifted data word 3 bits (multiplying by x^3) ⟹ x^6+x^3.

Division: 1st term $x^6/x^3 = x^3$; multiply divisor & subtract the result from devidend ⟹ x^4; degree is ≥ divisor's degree continue to divide until the degree of the remainder is less than the degree of the divisor.

Dataword x^3+1

$$
\begin{array}{r|l}
 & x^3+x \\
\hline
x^3+x+1 & x^6+\quad\quad x^3 \\
 & x^6+\ x^4+x^3 \\
\hline
 & 0+\ x^4+\ 0 \\
 & x^4+x^2+x \\
\hline
 & x^2+x
\end{array}
$$

Divisor ← Dividend augmented dataword

x^2+x Remainder

Codeword: x^6+x^3 | x^2+x

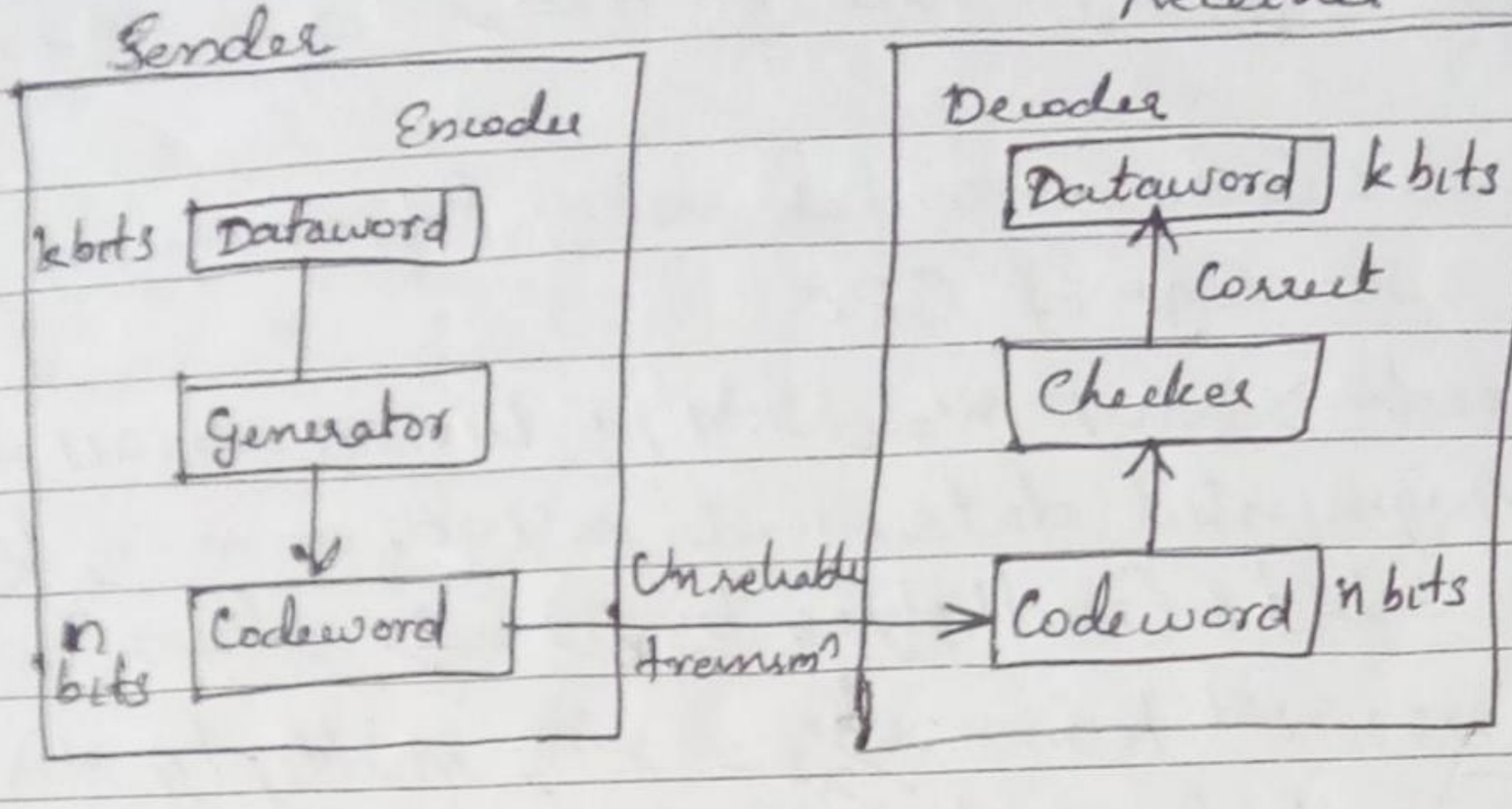
Dataword Remainder

Error Control Error Correction:

In error correction it should be identified the exact no. of bits that are corrupted & their location in the msg. If we need to correct one single error in an 8 bit data unit, we need to consider 8 possible locations; if we need to correct 2 errors in a data unit of same size, 28 possible

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In error correction, the receiver needs to find the original codeword sent.



→ Forward Error Correction:

is the process in which the receiver tries to guess the msg by using redundant bits

→ Retransmission ⇒ the receiver detects the error & asks the sender to resend the msg.

→ Hamming Distance:

→ error control

→ Hamming distance b/w 2 words is the no. of diff. b/w the corres. bits.

- b/w o x & y ⇒ d(x,y).

→ Apply XOR opn on the 2 words & count the no. of 1s in the result. Hamming distance is a value > 0.

Eg: Find the Hamming distance:

1. d(000, 011) = 2

000
011
011 ⇒ 2 1's

2. d(10101, 11110) = 3.

10101
11110
01011 ⇒ 3 1s

→ Minimum Hamming Distance: is the smallest Hamming distance b/w all possible pairs.

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Eg: Find the min. Hamming distance

$d(000,011) = 2$, $d(000,101) = 2$, $d(000,110) = 2$

$d(011,101) = 2$

$d_{min} = \underline{2}$

eg: $d(00000, 01011) = 3$ $d(00000, 11110) = 4$

$d_{min} = \underline{3}$

→ Three parameters:

* codeword size n, the dataword size k, & min. Hamming distance d_{min}.

$\Rightarrow$ ~~X~~ $c(n,k) = d_{min}$.

Eg: $C(3,2)$ with $d_{min} = 2$

$C(5,2)$ with $d_{min} = 3$.

→ Hamming Distance & Error:

When a codeword is corrupted during transmn, the Hamming distance b/w the sent & received codewords is the no. of bits affected by the error. ie; Hamming distance b/w the received codeword & sent codeword is the no. of bits that are corrupted during transmn. For eg:, if the codeword 00000 is sent & 01101 is received, 3 bits are in error & Hamming distance b/w 2 is $d(00000, 01101) = 3$.

→ Minimum distance for Error Detection:

If → upto s errors. If s errors occur during transmn, the Hamming distance b/w the sent codeword & received codeword is s. If a code is to detect upto s errors, the minimum distance b/w the valid codes must be s+1, so that the received codeword doesn't match a valid codeword. To guarantee the detection upto s errors in all cases, the minimum Hamming distance in a blk code must be $d_{min} = s+1$.

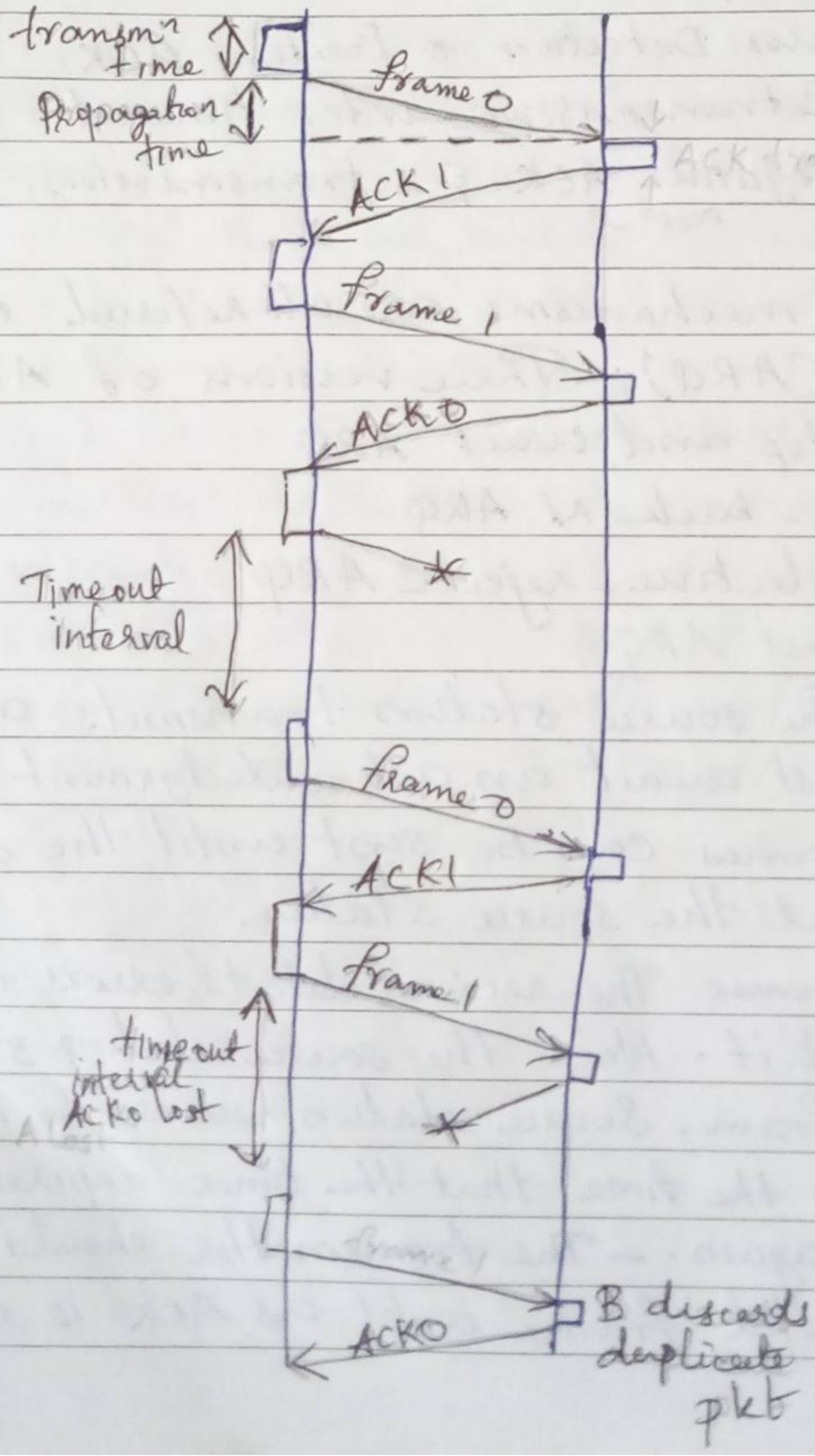
Geometrical description for error detection.

→ sent codeword is at the centre of a circle with radius s. All other received codewords that are created by 1 to s errors

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2. → Damaged ACK:

Station ~~A~~ A sends a frame. The frame is received correctly by station B. which responds with ACK. The ACK is damaged in transmit & not recognized by A, which will therefore time out & resend the same frame. This duplicate frame arrives & is accepted by B. B has therefore accepted 2 copies of the same frame. To avoid this pblm Frames are alternately labeled with 0 or 1, & the 2 ACKs are ACK0 & ACK1. An ACK0 acknowledges receipt of a frame numbered 1 & indicates that the receiver is ready for a frame numbered 0.



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Go-Back-N ARQ

In this method, a station may send a series of frames sequentially numbered modulo some max. value. ~~The no. series of frames sequentially numbered~~ The no. of unacknowledged frames outstanding.

Whole no errors occur, the destination will acknowledge incoming frames as usual (RR = Receive Ready or piggybacked ack). If the destination station detects an error in a frame, it may send (REJ = rej) for that frame. The dest^{n} station will discard that frame all future incoming frames until the frame in error is correctly received. The source station when it receives a REJ, must retransmit the frame in error plus all succeeding frames that were transmitted in the interim.

fig: 7.6 a

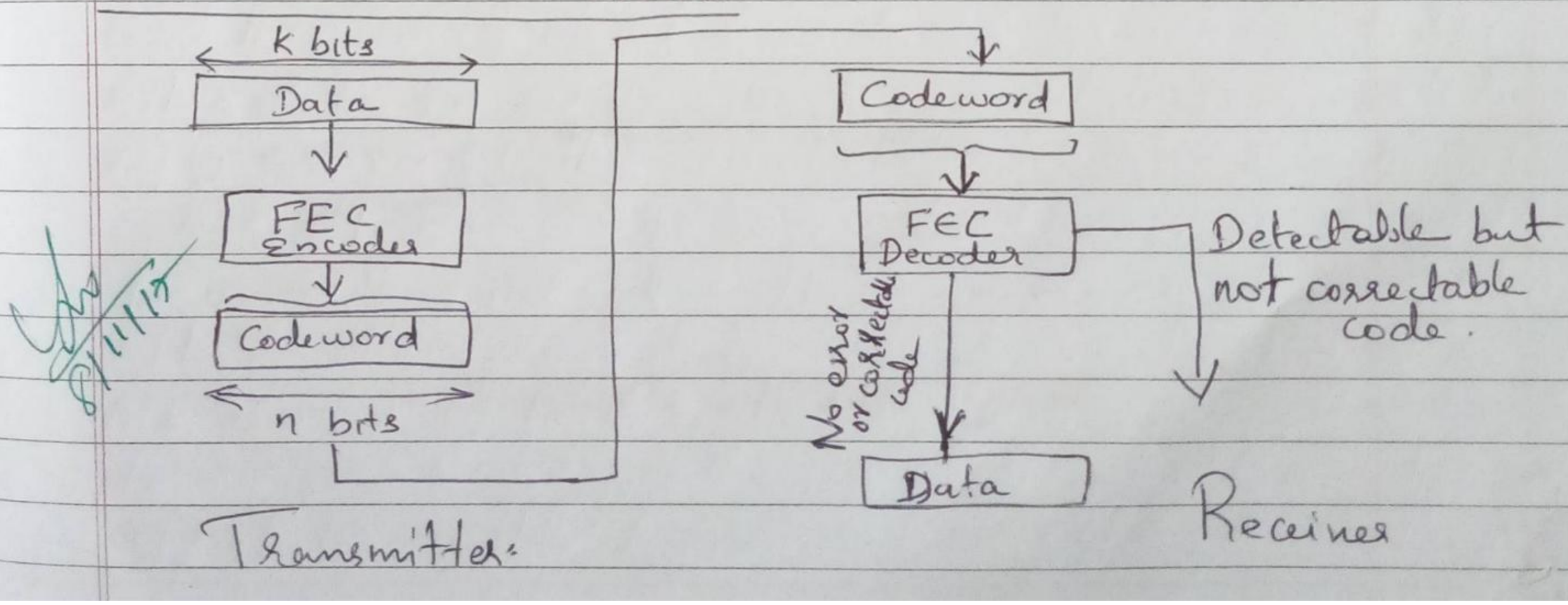
Selective-Reject ARQ

With selective-reject ARQ, the only frames retransmitted are those that receive a negative ACK, called SREJ or those that timeout.

Selective reject would appear to be more efficient b/c it minimizes the amount of retransms.

fig: 7.6 (b)

Error Correction Process



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15. A signal has a wavelength of 1μm in air. How far can the front of the wave travel during 500 periods?

16. What is the phase shift for the follo.

a. A sine wave with the max. amplitude at zero (90°).

b. " " " after 1/4 cycle. (90°)

c. " zero amplitude after 3/4 cycle.

c) 1 complete cycle = 360°

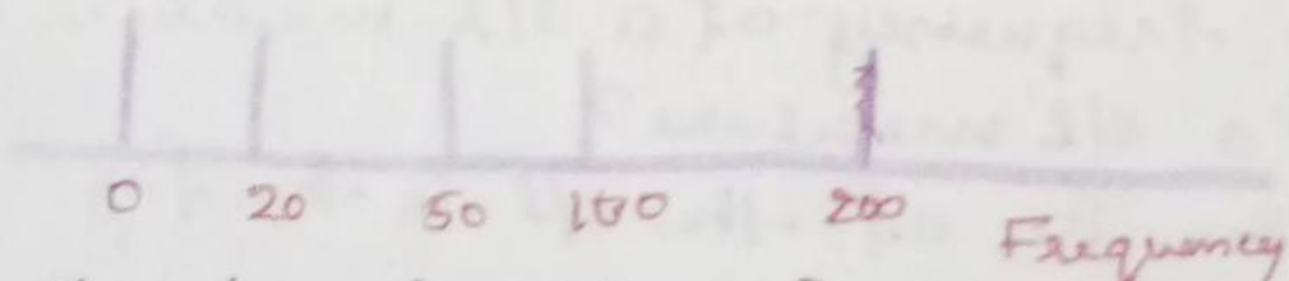
3/4 cycle = $360 \times 3/4 = \underline{\underline{270^\circ}} = 270 \times \frac{2\pi}{360^\circ} = \frac{3\pi}{20}$ rad

$= 270$

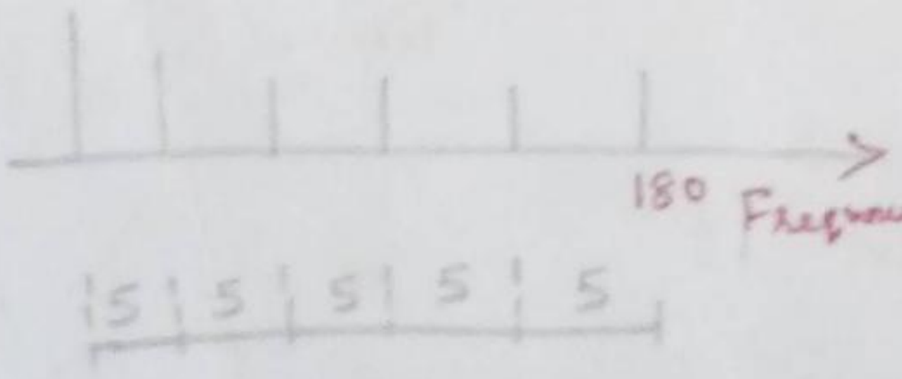
17. Which s/l has a wider bandwidth, a sine wave with a fr. of 100Hz or with fr. of 200Hz.?

(19) 18. What is the bandwidth of a s/l that can be decomposed into five sine waves with fr. at 0, 20, 50, 100 & 200Hz? All peak amplitudes are the same. Draw the Bandwidth.

$B = f_h - f_l = 200 - 0 = 200\,Hz$.



19. What is the bandwidth of the composite s/l shown in the diag?



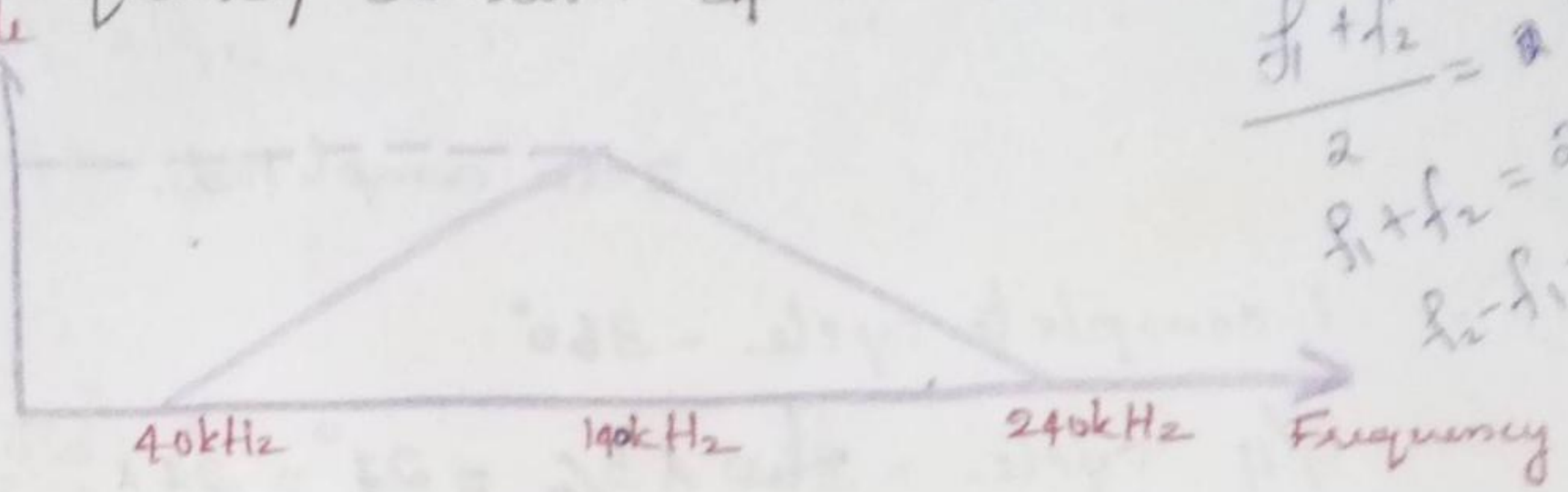
$f_h = 180 \quad f_l = 155$

$B = f_h - f_l = 180 - 155$

$= \underline{\underline{25}}$

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8. A non periodic composite s/l has a bandwidth of 200kHz with a middle fr. of 140kHz & peak amplitude of 20v. The 2 extreme fr. have an amplitude of 0. Draw the frequency domain of the s/l.



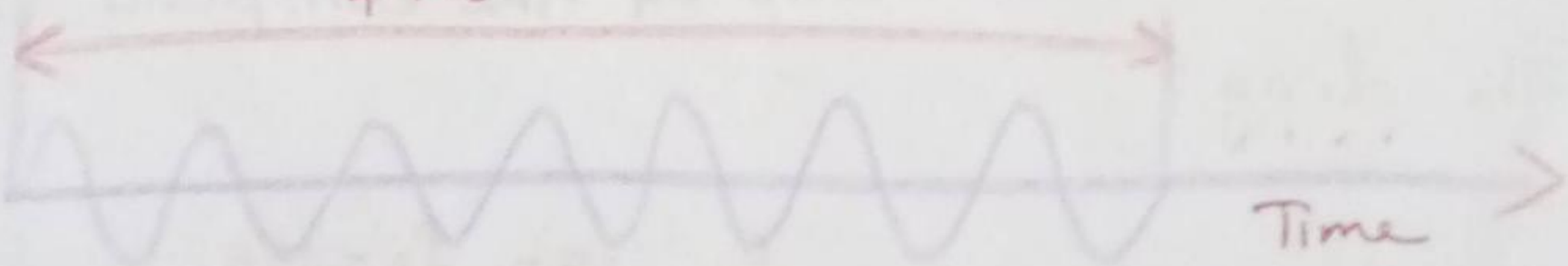
$\frac{f_1 + f_2}{2} = 140$

$f_1 + f_2 = 280$

$f_2 - f_1 = 200$

$\therefore$ $f_l = 40\,kHz$ $f_h = 240\,kHz$ $B = 200\,kHz$
(240-200)

9. What is the rel^{n}ship b/w period & frequency?
10. Is the fr. domain plot of an alarm s/m discrete or continuous?
11. Why do optical s/ls used in fibre optic cables have a very short wavelength?
12. Is the fr. domain plot of a voice s/l discrete or continuous?
13. What does the amplitude of a s/l measure? What does the frequency of a s/l measure? What does the phase of a s/l measure?
14. What is the fr. of the s/l in the fig.



No. of periods in 4 mS = 8

Fr. is no. of periods in 1s.

No. of periods in 4×10^{-3} S = 8

" in 1 S = $\frac{8}{4 \times 10^{-3}} = 2 \times 10^3$ Hz

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(P3-5)
31. A line has a s/l to-noise ratio of 2000 and a bandwidth of 5000 KHz. What is the max. data rate supported by this line?.

Bandwidth = 5000KHz

SNR = 2000

DataRate (Capacity) = Bandwidth $\times \log_2(1+SNR)$

$= 5000 \times \log_2(1+2000)$

=

(P3-10)
32. The attenuation of a s/l is −10dB. what is the final s/l power if it was originally 10W?.

$P_1 = 10W \quad P_2 = ? \quad dB = -10dB$

dB attenuation dB = −10dB

$dB = 10\log_{10}\frac{P_2}{P_1}$; ~~dB~~ $-10dB = 10\log_{10}\frac{P_2}{P_1}$

~~$-10dB = 10(\log_{10}$~~ ~~$-10dB = 10\log_{10}P_2 - 10\log_{10}10$~~

$\log 10\frac{P_2}{10} = -1 \quad \frac{P_2}{10} = 10^{-1} \quad P_2 = 10\times10^{-1} = 1W$

(P3-9)
33. A s/l travels from point A to point B. At point A, the s/l power is ~~80~~ 100W. At point B, the power is 80W. What is the attenuation in decibels?

$P_1 = 100W \quad P_2 = 80W$

$dB = 10\log_{10}\frac{P_2}{P_1}$

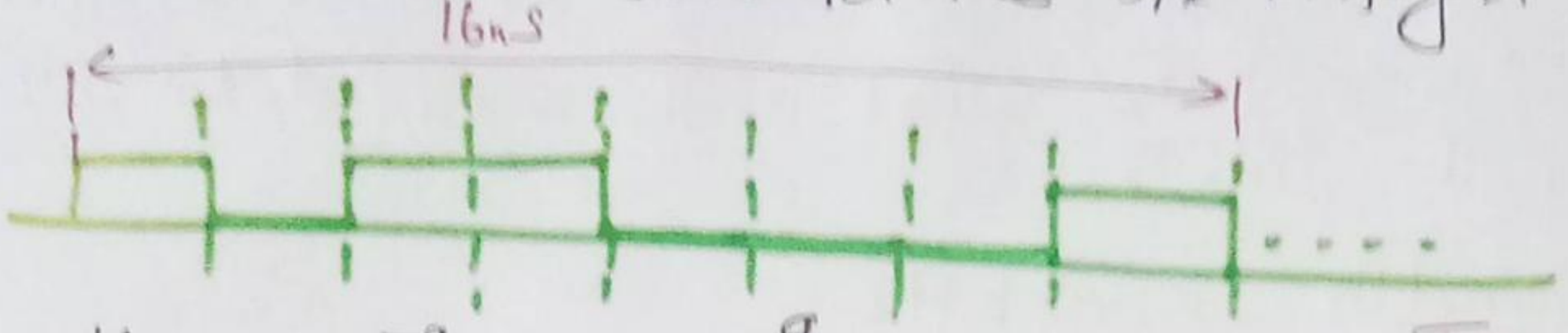
$= 10\log_{10}\frac{80}{100}$

$= 10\log_{10}(.8)$

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(P3-11)

34. What is the bit rate for the s/l in fig?.



$16ns = 10^{-9}s = 16 \times 10^{-9}s$

8 bits per $16 \times 10^{-9}s$

$$\text{Bit Rate} = \frac{8}{16 \times 10^{-9}} = 8 \times 10^{9} \text{ bits/sec}$$

$$= 500 \text{ Mbps.}$$

$\frac{1}{2 \times 10^{-9}}$

$.5 \times 10^{+9}$

$.5 \times 10^{+9} \times 10^{-6} = .5 \times 10^{-3}$

$.5 \times 10^{3} = 500$

(P3-19)

35. A signal with 200mW power passes through 20 devices, each with an average noise of 2μW. What is the SNR? What is the SNRdB?

$$SNR = \frac{200 \times 10^{-3} W}{2 \times 10^{-6} W} = \frac{100 \times 10^{-3}}{} = 10^{-1}$$

$100 \times 10^{3} = 10^{5}$

SRI $SNR_{dB} = 10 \log_{10} 10^{-1}$

P3-26

36. We measure the performance of a telephone line (4KH2 of bandwidth). When s/l is 10V, the noise is 5mV. What is the max. data rate supported by this telephone line?

s/l power = 10V noise power = 5mV = 5×10^{-3} V

SRF $SNR = \frac{\text{avg s/l power}}{\text{avg noise power}} = \frac{10V}{5 \times 10^{-3} V} = 2 \times 10^{3} = 2000$

Data Rate (Shannon capacity) $= B \log_2 (1 + SNR)$

$= 4 \times \log_2 (1 + 2000)$

$=$

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