$\lambda \longrightarrow m$

Wavelength (الطول الموجي)

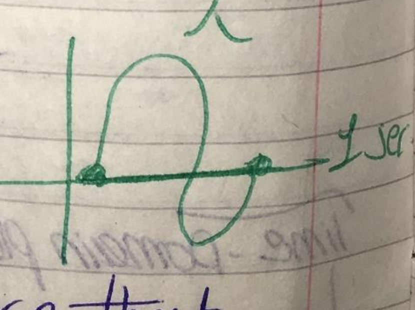
↳ another Characteristic of Signal Traveling Through a Transmission Medium.

Wave length = propagation speed x period

$$\text{period} = \frac{1}{\text{Frequency}}$$

$$\text{Wavelength} = \frac{\text{Speed}}{\text{Frequency}} \text{ — (speed of light)}$$

$$\lambda = \frac{c}{F} = C \cdot T$$



Wavelength: is The Distance that a simple signal Can Travel in one period.

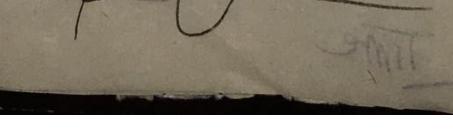
$C = 3 \times 10^8 \ m/s$

المسافة اللي ال Signal بتقطعها

في زمن دورة واحدة

(T) one period = 1 in 1 sec

$\lambda = \frac{c}{f} = C \cdot T$



$\boxed{75}$

Ex:

$\lambda \longrightarrow m$

$c \longrightarrow m/s$

$f \longrightarrow Hz$

Speed = 3×10^8 m/s

Frequency = 4×10^{14} Hz

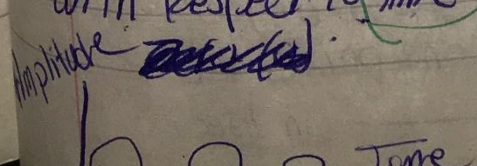
$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{4 \times 10^{14}} = \boxed{}\ m$$

* **Time & Frequency Domains:**

Sine wave Represented by:
- Amplitude
- Frequency/period
- phase

Time-Domain plot

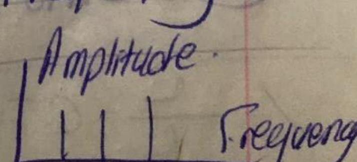
↳ Shows Changes in Signal Amplitude with Respect to Time



Frequency Domain plot

↳ Concerned with peak Amplitude value & The Frequency

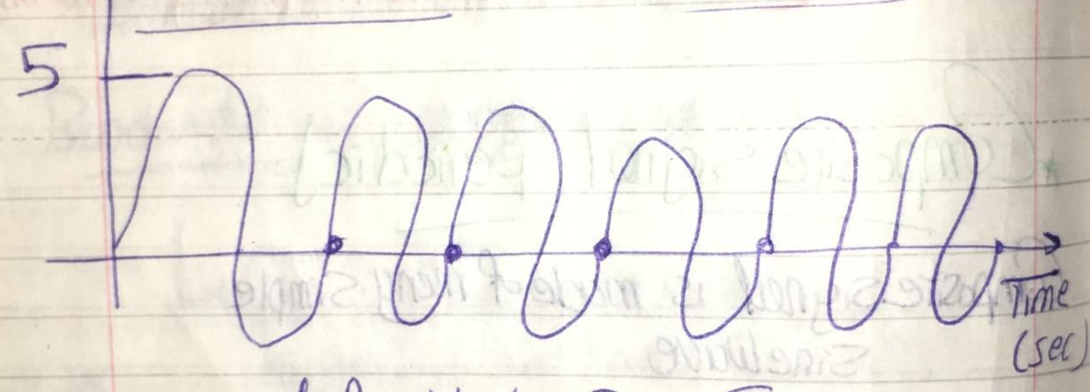
- Changes



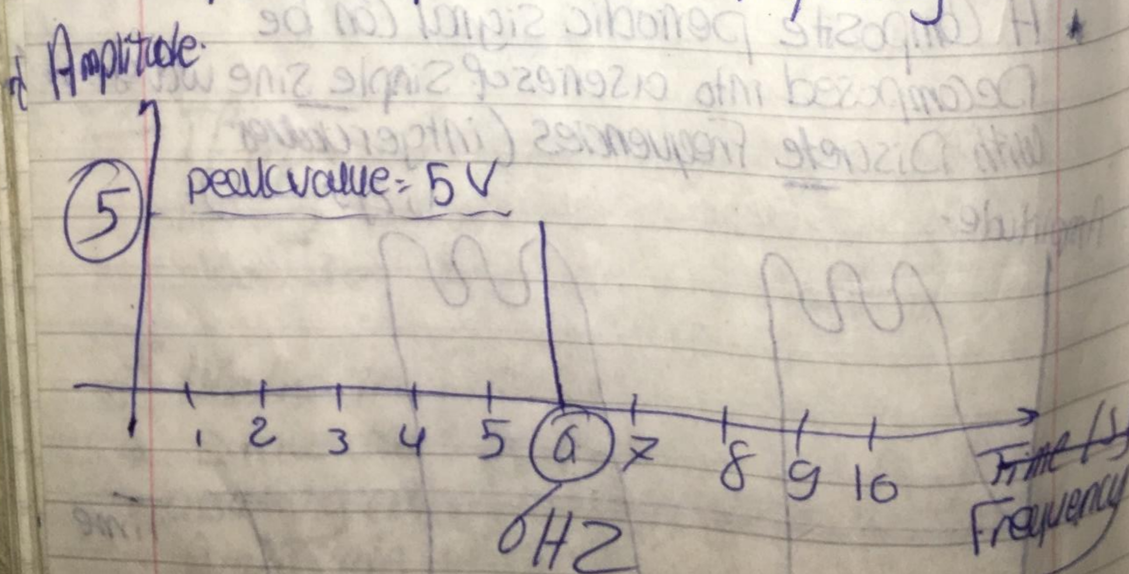
Amplitude (V)

$T = \frac{1}{t} = \frac{1}{6} = sec.$

6 (cycles)
6 periods Frequency = 6HZ



peack Amplitude = 5 Frequency = 6HZ.

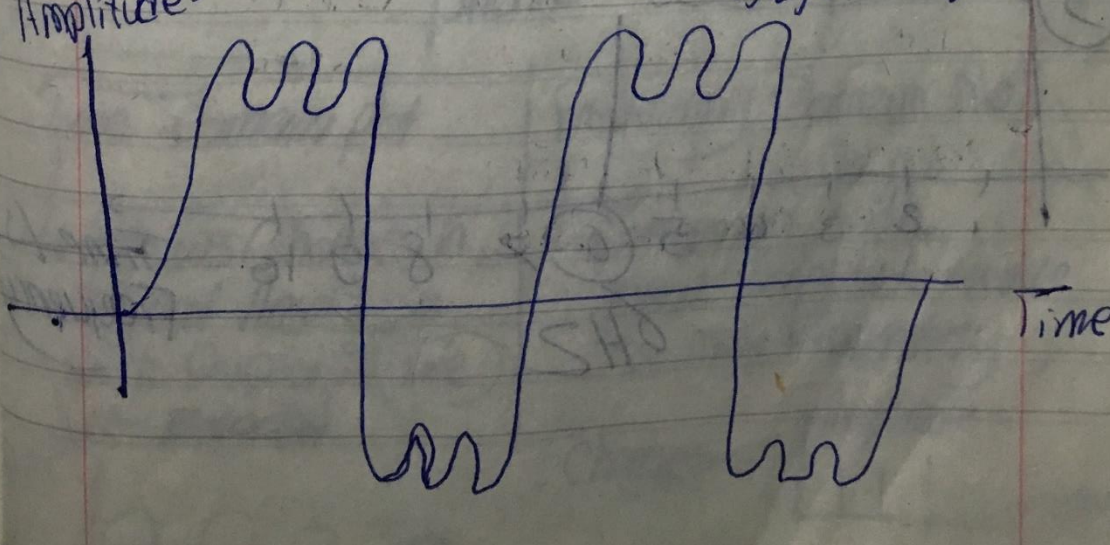


Note: A Complete sine wave in the Time Domain Can be Represented by one single spike in The Frequency Domain.

* Composite signal (periodic):

Composite signal is made of meny simple sine wave

* A Composite periodic signal Can be Decomposed into a series of Simple sine waves with Discrete Frequencies (intger values 1, 2, 3 ——).



78

* Bandwidth → Composite Signal

↳ Bandwidth The Range of Frequencies Contained in Composite signal.

Bandwidth of Composite signal

↳ The Difference Between The Highest & The lowest Frequencies in The signal.

26, 27, 28

Ex: If aperiodic Composite Signal is Decomposed into 5 sine waves with Frequencies 100 300 500 700 900 Hz.

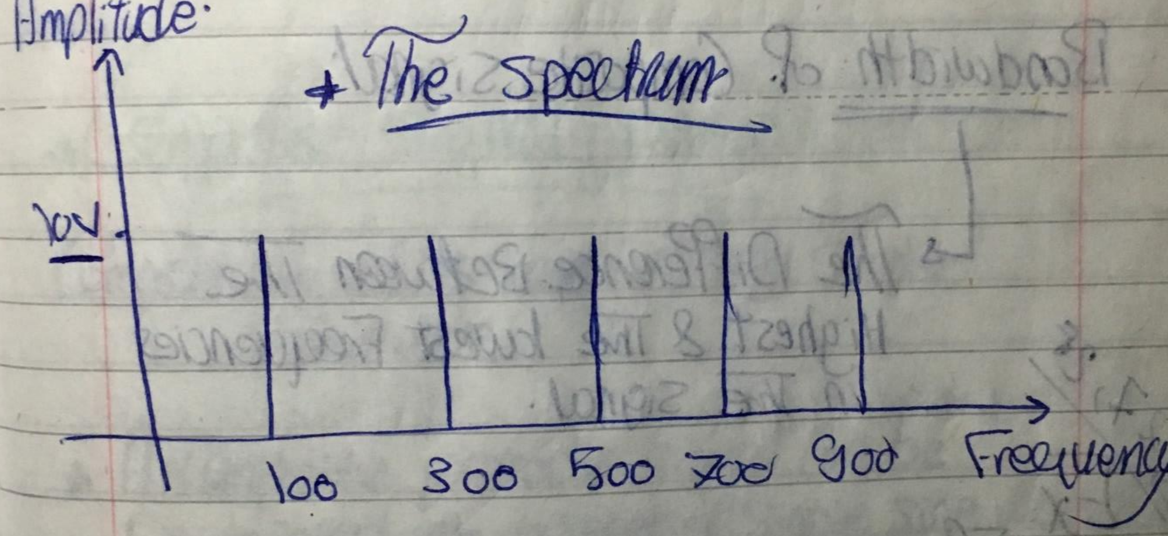
* What is the Bandwidth?
* Draw the spectrum
- assuming all Components have a maximum Amplitude of 10 V

B = 800 A = 10

Solution:

Bandwith = High f − low f
= 900 − 100 = 800HZ

+ The spectrum



Ex: A periodic signal has Bandwidth of 20HZ, The highest Frequency is 60 HZ, what is the lowest frequecy? Draw the spectrum of all frequencies have The same Amplitude.

Bandwidth = 20 HZ   low f = ????

High f = 60 HZ $\boxed{80}$

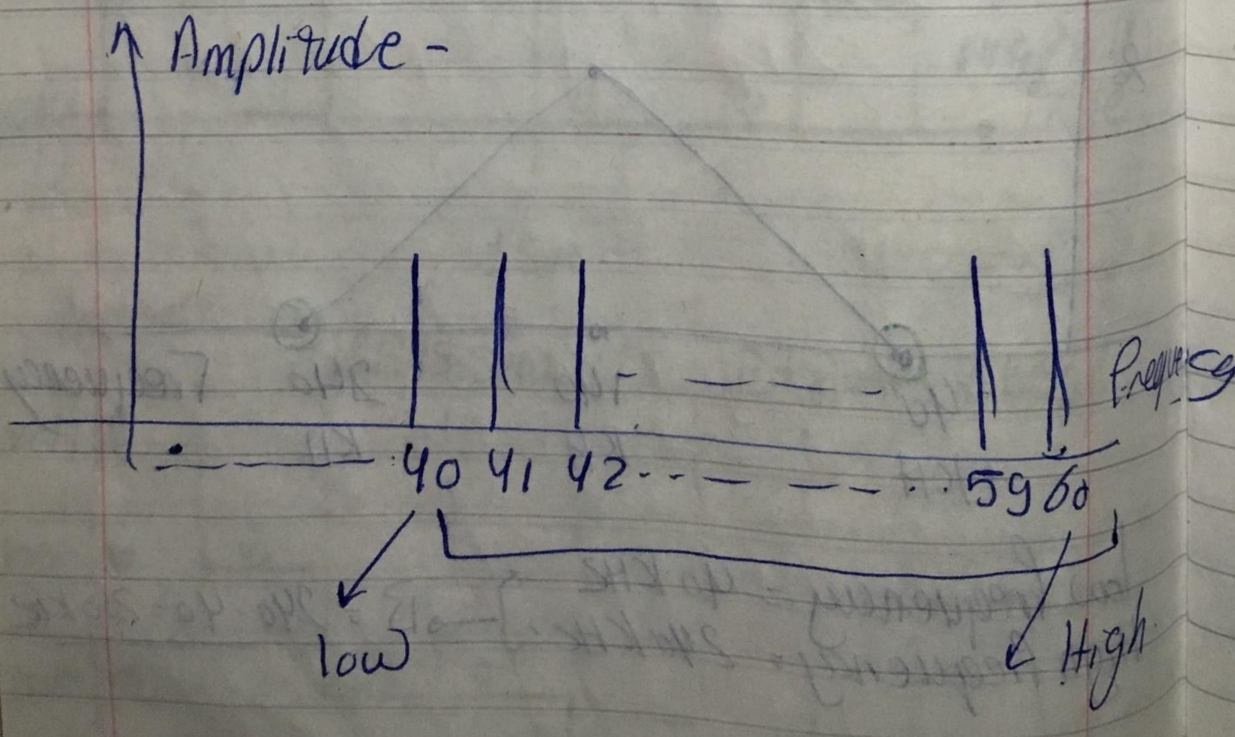
Solution:

Bandwidth = High f - low f

20 = 60 - low f

low f = 60 - 20 = 40 HZ.

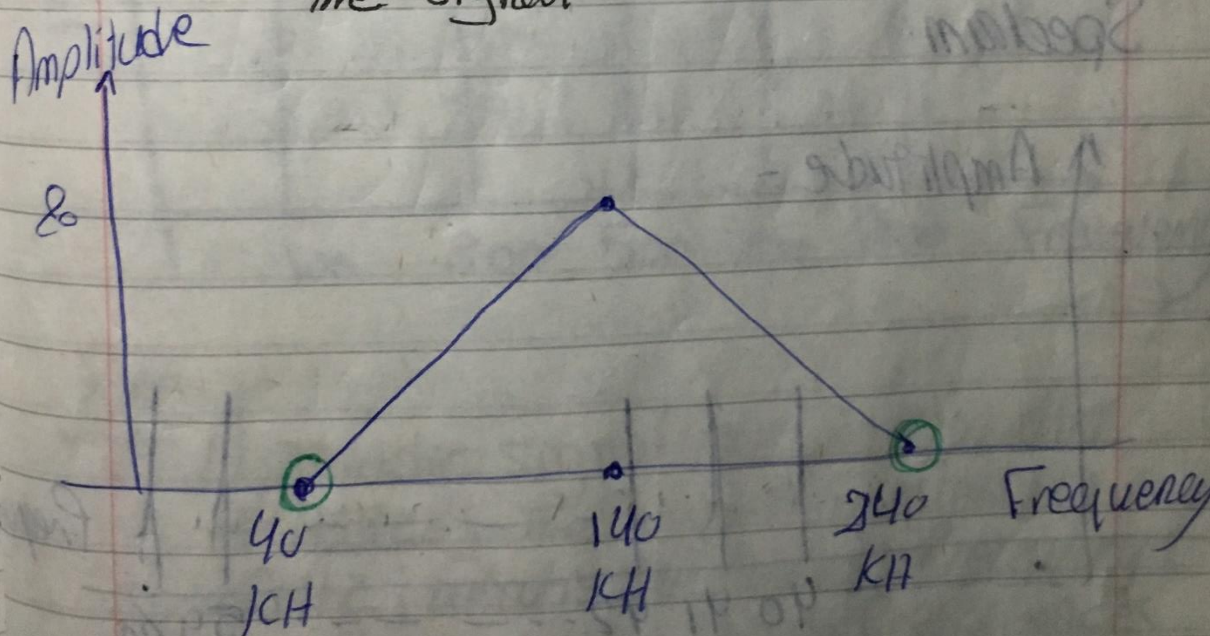
Spectrum.



81

Ex: 3.12

A nonperiodic Composite signal has Bandwidth 200 KHZ, with a Middle Frequency of 140KHZ & peak Amplitude of 20V.
The Two Extreme Frequencies have an amplitude of 0 Draw the Frequency Domain of The signal.



low frequency = 40 KHZ
High frequency = 240 KHZ } → B = 240 - 40 = 200 KHZ

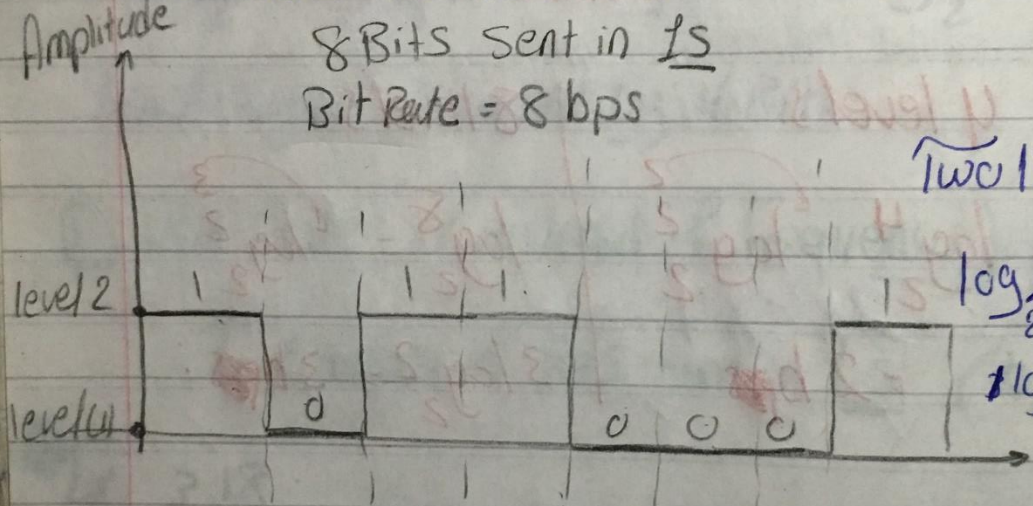
→ Discrete signal values
→ Finite values.

$\boxed{82}$

* Digital signal:

* Digital signal Can have than Two levels. or more than Two levels.

8 Bits sent in 1s
Bit Rate = 8 bps



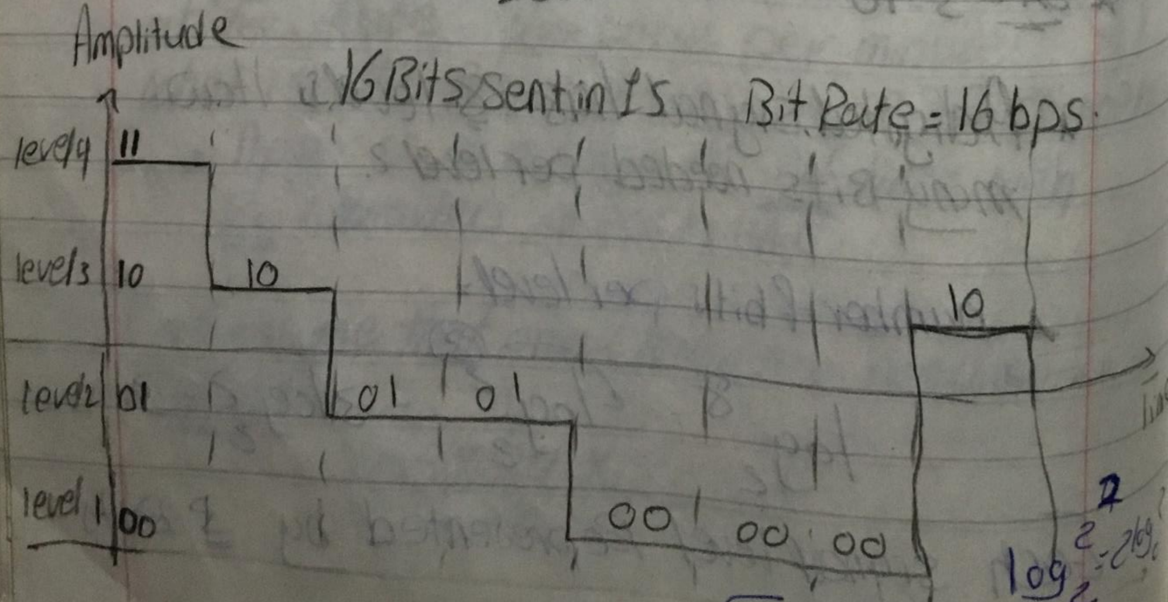
Two levels.

$\log_2 2 = \log_2 2^1$

$1\log_2 2 = \boxed{1}$

1 Sec.

16 Bits sent in 1s   Bit Rate = 16 bps



Four levels.

$\log_2 2^2 = 2\log_2 2 = \boxed{2}$

83

* Number of Bits per level = $\log_2 n$ → number of levels.

Ex: 4 levels

$\log_2 4 = \log_2 2^2 = 2$ bps

8 levels.

$\log_2 8 = \log_2 2^3 = 3\log_2 2 = 3$ bps.

* Ex: 3.16

* A digital signal has 8 levels, How many Bits needed per level?

* number of bits per level =

$$\log_2 8 = \log_2 2^3 = 3\log_2 2 = 3$$

Each signal level Represented by 3 Bits.

84

Ex: 3.17

. A Digital signal has 9 level.
How meny Bits need perlevel?

$\log_2 9$ هناخد أقرب ناتج $\log_2 2^4 = 4 \log_2 2 = 4$

Each signal Represent by 4 Bits

[1] Bit Rate: (instead of Frequency)

↳ Number of Bits sent in 1 s (bps).

Ex: 3.18

Assume we need Download text Documents at The Rate 100 page per minute.
what is the Required Bit Rate of The Chennel

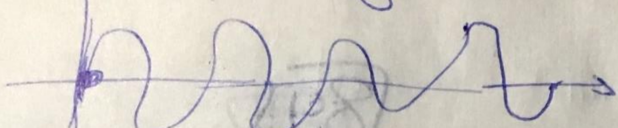
* Apage is an average of 24 lines with 80 Charalters in each line.

If we assume that one Character Requires 8 Bits.

$100 \times 24 \times 80 \times 8 =$

$\boxed{}$ bps.

B = 4KHz · Analogue voice Digital signal



Ex. 3.19

A Digitized voice channel, is made by a 4KHz Bandwidth Analog Voice signal. We need to sample the signal at Twice The highest Frequency (Two Samples per hertz). We assume that each sample requires 8 Bits, what is the Required Bit Rate.

Bit Rate = $2 \times 8 \times 4000 = \boxed{\quad}$ bps.

Two samples

8 Bit for each sample.

4KHz = 4000 Bandwidth.

* Bit length:

↳ The Distance one Bit occupies on The Transmission Medium -

22, 23 / Bit length = propagation speed x Bit Duration

* Digital signal as Composite Analog signal.

- Based on Fourier Analysis.

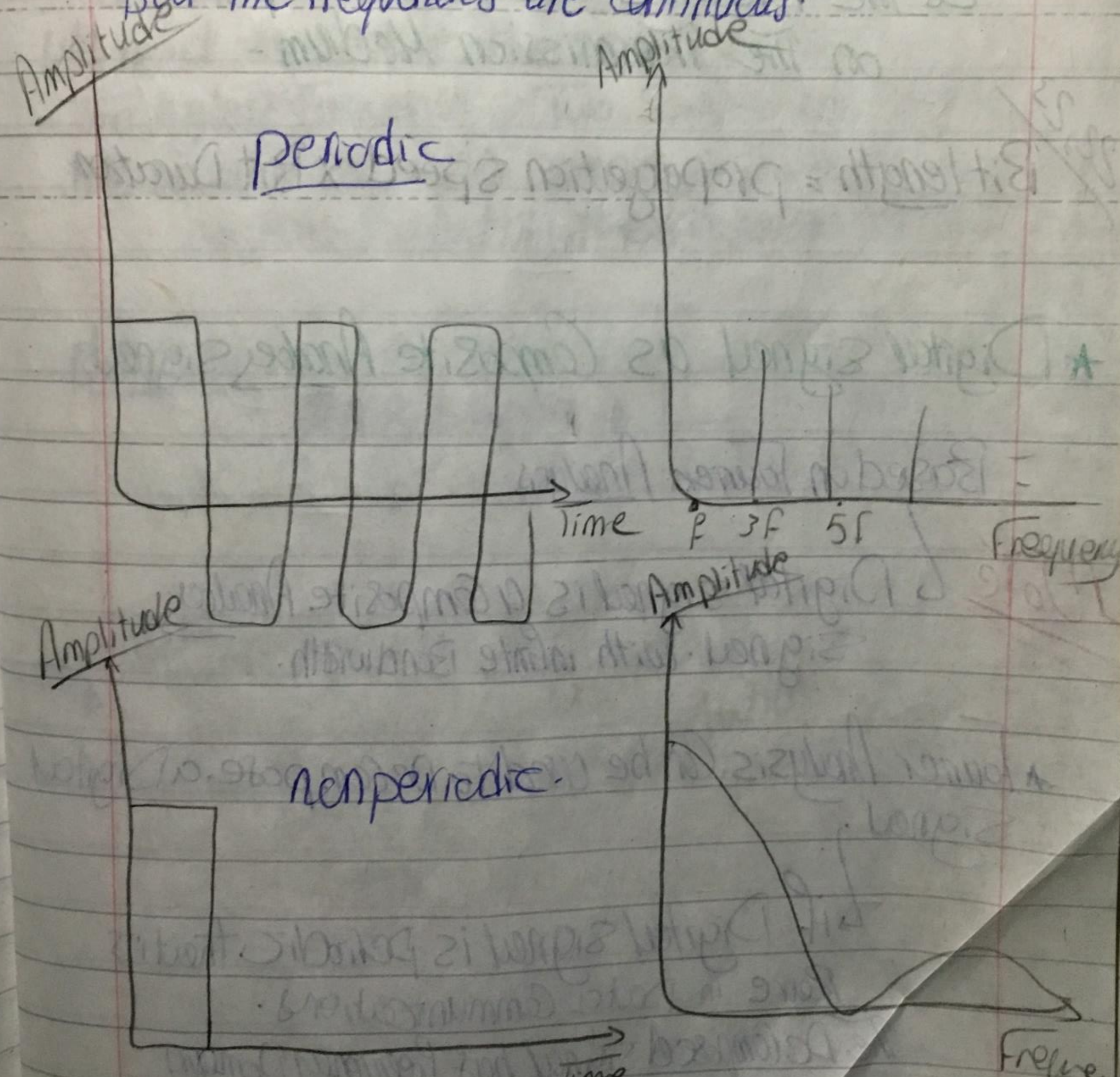
Note ↳ Digital signal is a Composite Analog Signal with infinite Bandwidth.

* Fourier Analysis Can be used to DeCompose a Digital Signal.

↳ if Digital signal is periodic that is Rare in Data Communications.

The DeComposed signal has Frequency Domain Representation with an infinite Bandwidth & Discrete Frequencies.

↳ if The Digital signal is Nonperiodic , The Decomposed signal has an infinite Bandwith But the Frequencies are Continuous.



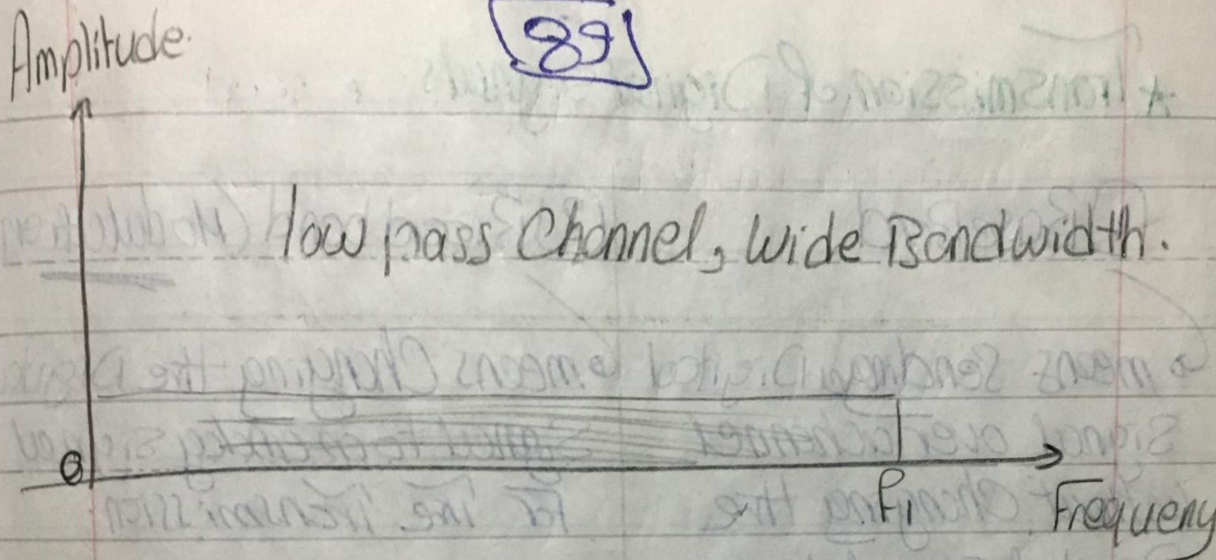
→ (o.f.) . I.K.S.

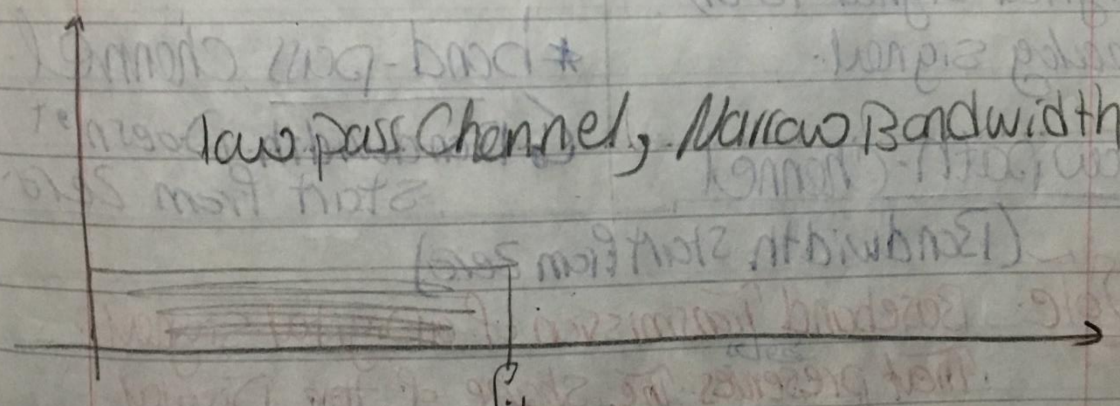
* Transmission of Digital signals.

(1) BaseBand.	(2) Broadband (Modulation)
↳ means sending a Digital Signal over a channel without Changing the Digital signal to an Analog signal.	↳ means Changing the Digital Signal to an analog signal for the Transmission.
* low path-Chennel (Bandwidth start from zero)	* band-pass Chennel. ↳ Bandwidth Doesn't Start from zero

Note: Baseband Transmission of a Digital signal that تحافظ preserves the shape of the Digital Signal is possible only if we have a low pass Channel with an infinite or very wide Bandwidth.

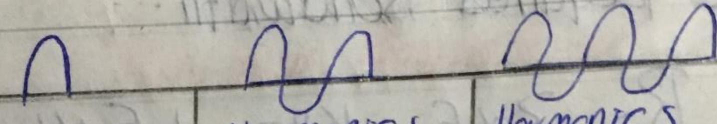
Note: In Base band Transmission, The Required Bandwidth is proportional to The Bit Rate, if we need to send bits Faster, we need more Bandwidth.


Amplitude
low pass Channel, wide Bandwidth.
0
f1
Frequeny


low pass Channel, Narrow Bandwidth
f1

Bit (Data) Rate = $\frac{\cancel{\text{Bandwidth}}\ \text{Bits}}{\text{sec}}$

<u>Table</u>: Show How Much Bandwidth we need to Send Data at Different Rates



Bit Rate (bps)	Harmonic 1	Harmonics 1,3	Harmonics 1,3,5
n = 1 Kbps	B = 500 HZ	B = 1.5 KHZ	B = 2.5 KHZ
n = 10 Kbps	B = 5 KHZ	B = 15 KHZ	B = 25 KHZ
n = 100 Kbps	B = 50 KHZ	B = 150 KHZ	B = 250 KHZ

<u>Ex</u>:

What is The Required Bandwidth of a low-pass Channel if we need to send <u>1 Mbps</u> by using Baseband Transmission?

① The minimum Bandwidth.

B = BitRate/2   1 Mbps/2 = 500 KHZ.

We need low-pass Channel with Frequencies between 0 to 500 KHZ.

$\boxed{91}$

(2) A better Result Achieved by using The First & Third Harmonics with The Required Bandwidth.

$$B = 3 \times 500\,KHZ = 1.5\,MHZ.$$

(3) A better Result Can be achieved by using , 1, 3, 5 Harmonics.

$$B = 5 \times 500 = 2500\,KHZ = 2.5\,MHZ$$

Ex 2.23

we have a low-pass channel with Bandwidth 100 KHZ, what is the Maximum Bit Rate of this Channel

The Maximum ~~Bandwidth~~ Bit Rate Can be Achieved if we use the First Harmonic.

Bit Rate = 2 * Bandwide.

$2 \times 100 = \underline{200\,Kbps}$

42

Bit Rate. $\boxed{}$ /2

Minimum Frequency

Maxmum Frequency = 2 * Bit Rate.

* Causes of impairment.

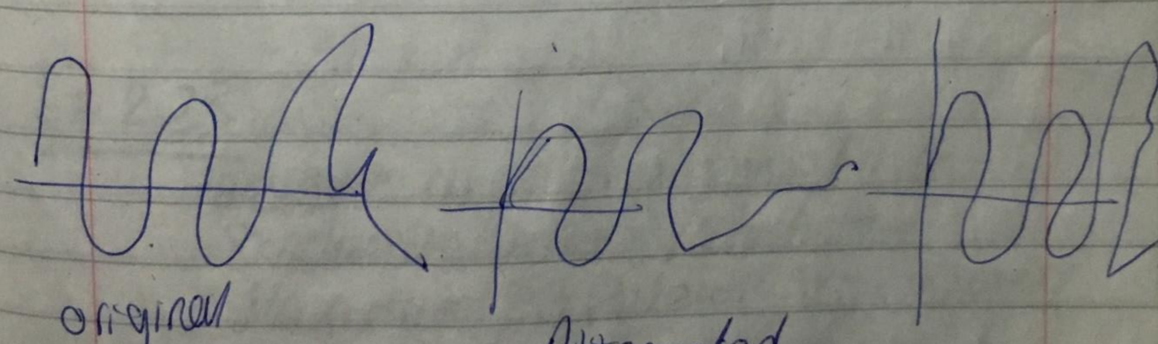
Attenuation　　Distortion　　Noise.

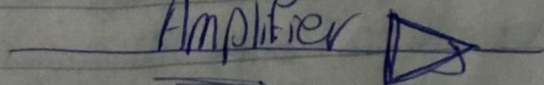
الضعف / التوهين

[1] Attenuation:

↳ means a loss of energy.

* when a signal (single / composite) travels through a medium, it loses some of its energy in overcoming the resistence of the medium.





* Decibel (dB)

measures the Relative strengths of Two signals or one signal at Two Different Points.

Note:

Decibel is (+) if signal is Amplified

(−) if signal is Attenuated

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

P_2 → Attenuation الـ

P_1 → orginal signal power

P_1, P_2 → the powers of a signal at points 1, 2

Ex: 3.26 Suppose a signal Travels Through a transmission Medium & its power is Reduced to one-half

$P_2 = \frac{1}{2} P_1$ Calculate The Attenuation

$$= 10 \log_{10} \frac{P_2}{P_1} = \frac{0.5 P_1}{P_1} = 10 \log_{10} (0.5) =$$

Ex 3-27

A signal Travels Through Amplifier & its power is increased 10 Times

$P_2 = 10 P_1$

The Amplification (Gain of power) =

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

$10 \log_{10} 10 = 10$ dB

+ → Amplified

Ex: 3.30

The lose 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 2 mW, what is the power of The Signal at 5 km?

$\boxed{96}$

The lose in Cable

Rule:

$\log_a b = \boxed{c}$

$a^c = b$

$$5 \times -0.3 = -1.5 \, dB$$

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

$$10 \log_{10} \frac{P_2}{P_1} = -1.5$$

$$\frac{P_2}{P_1} = 10^{-0.15} = 0.71$$

$$P_2 = 0.71 \times P_1 = 0.7 * 2 = \boxed{1.4 \, mW}$$

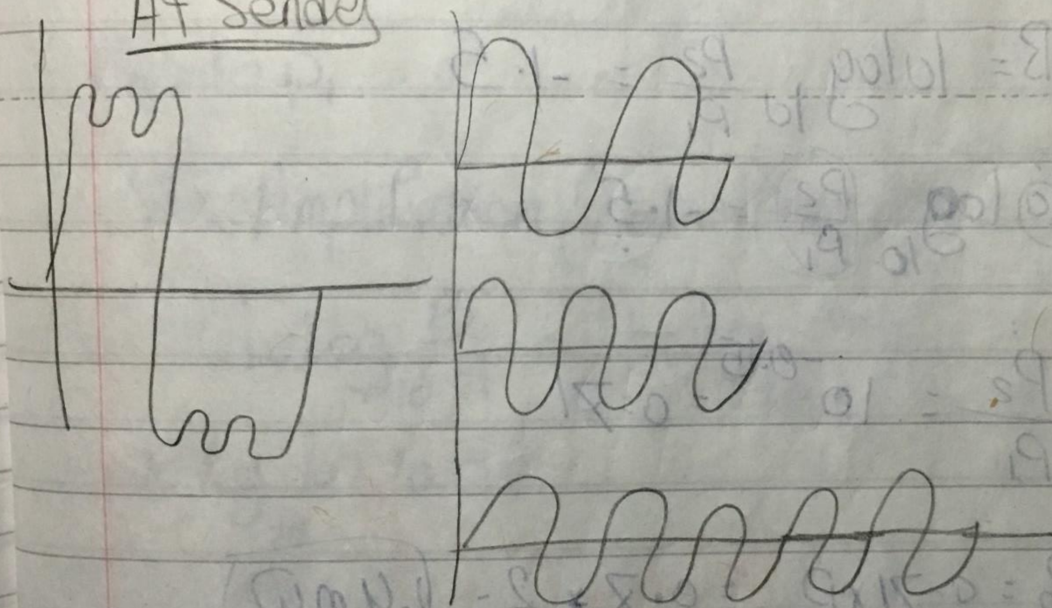
التشويه

[2] Distortion:

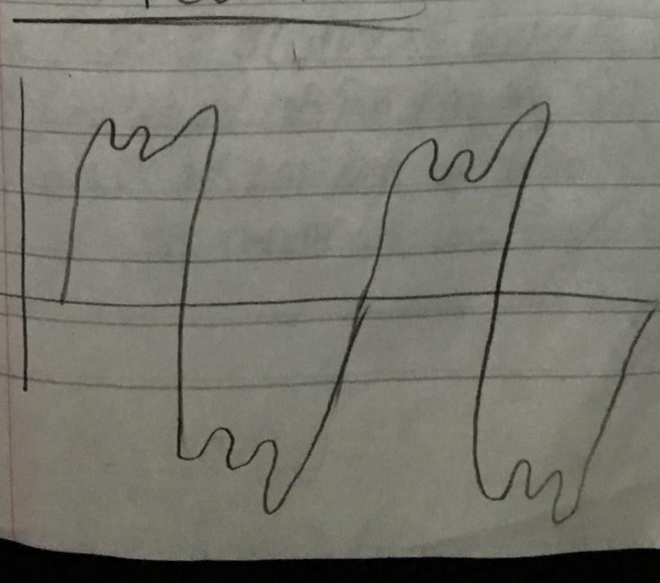
↳ means that signal changes its Form or shape.

- Distortion can occur in a Composite signal made of Different Frequencies.

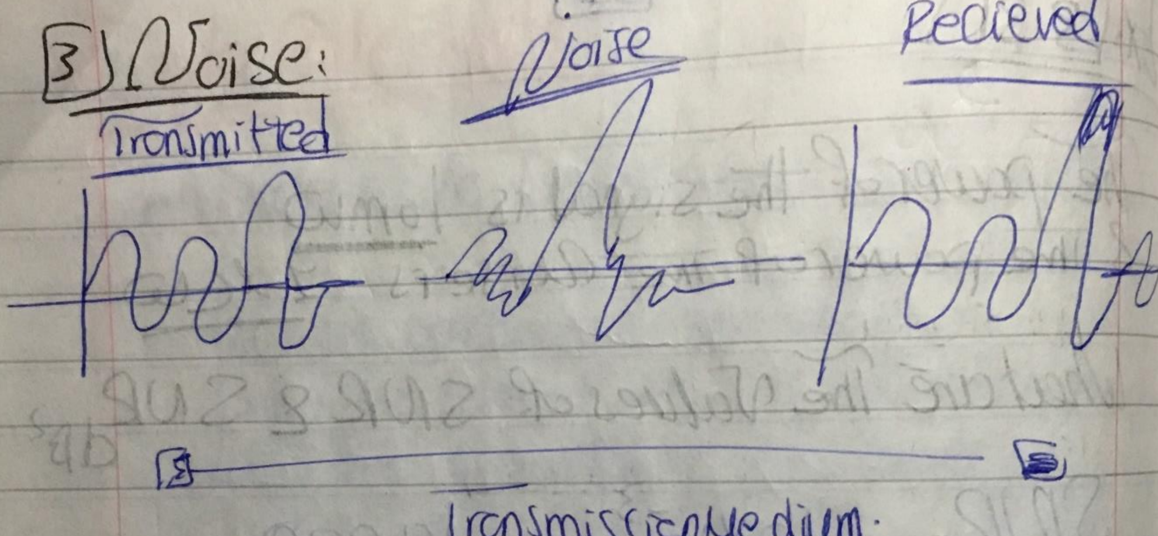
At Sender



At Receiver



3) Noise:



- SNR (signal-To-Nois Ratio).

The Ratio Between The signal power to The Noise power.

$$SNR = \frac{\text{Average signal power}}{\text{Average Noise power.}}$$

صغير
كبير

* (low) SNR ⟶ More Noise.
* High SNR ⟶ less Noise.

كبير
صغير

Ex: 3.31

The power of the signal is 10 mW
& The power of The Noise is 1 μW

What are The Values of SNR & SNR_{dB}?

$$SNR = \frac{10 \times 10^{-3}}{1 \times 10^{-6}} = 10\,000$$

$$SNR_{dB} = 10 \log_{10}(10\,000) =$$

$$10 \log_{10}(10^4) = 4 \times 10 (\log_{10} 10)$$

$$= 40 \text{ dB}$$

1. [ ] /100

* Data Rate limits:

* Data Rate Depends on 3 factors.
  - (1) The bandwidth Avaliable.
  - (2) The level of The Signals we use.
  - (3) The Quality of The Channel (The level of Noise).

* Noiseless Channel (Nyquist Bit Rate).
  - The Nyquist Bit Rate Define The Maximum Bit Rate.

$$\text{Bit Rate} = 2 \times \text{Bandwidth} \times \log_2(L)$$

$L \rightarrow$ Number of signal levels.

Ex: 3-36

We need to send 265 Kbps over a noiseless Channel with a bandwidth of 20 KHz How many signal levels do we need?

$$\text{BitRate} = 2 \times \text{Bandwidth} \times \log_2 L$$

$$265 \times 10^3 = 2 \times [20 \times 10^3] \times \log_2 L$$

$$\log_2 L = 6.625$$

Rule

$$\log_a b = c$$

$$a^c = b$$

$$2^{(6.625)} = L$$

$$L = 2^{6.625} = 98.7$$

$$\simeq \boxed{99 \text{ levels}}$$

$$2^{\square} \simeq 99 \qquad 2^7 = 128$$

Each signal Represent 7 Bits.

* Noisy Channel: (Shannon Capacity)

- We cannot have a noiseless channel.

The Channel is alway Noisy.

* Shannon Capacity:

↳ To Determine The highest Data Rate For Noisy channel

$$\text{Capacity} = \text{Bandwidth} * \log_2(1+SNR)$$

Ex: $\boxed{3.39}$

The SNR Ration is Given in decibels.

$SNR_{dB} = 36$ & The Chennel Bandwidth is 2 MHz. Calculate The Channel Capacity?

$$\log_a b = c$$

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

$$SNR = 10^{SNR_{dB}/10}$$

$$SNR = 10^{\frac{36}{10}} = 10^{3.6} = \boxed{3981}$$

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

$$= 2 \times 10^6 \times \log_2 (1 + 3981)$$

$$= 24 \text{ Mbps}$$

Ex: $\boxed{3.40}$ for practical

When The SNR is very High, we can Assume that SNR+1 is almost The same As SNR

In These Cases, The Theortical Channel capacity Can be simplified as:

$$C = \text{Bandwidth} \times \frac{SNR_{dB}}{3}$$

Ex: 3-41 We have a channel with 1 MHz Bandwidth the SNR for this Channel is 63

What are The Appropriate Bit Rate & signal level?

Bit Rate (Nyquist) = $2 \times B \times \log_2 L$??

⇒ Bit Rate = $2 \times 1 \times \log_2 L$

هنستخدم Shennon كـ لنحسب upper limit Rate.

1. $C = B \times \log_2 (1 + SNR)$

$C = [1 \times 10^6] \log_2 (1 + 63) = 10^6 \log 64 = \underline{6\ Mbps}$

2. For better performance we choose something lower 4 Mbps.

3. Nyquist (Bit Rate) = $2 \times 1 \times 10^6 \times \log_2 L$

$4 \times 10^6 = 2 \times 10^6 \log_2 L$

$2 = \log_2 L$ $\boxed{L = 2^2 = 4 \text{ levels}}$ #

106

Note The shenon Capacity Gives us the upper limit.

The Nyquist formula tells us How many signal levels we need.

* Performance

1. Bandwidth
2. Throughput
3. latency (Delay):

* Bandwidth

(Analog signal)	(Digital signal)
Bandwidth (HZ)	Bandwidth (bps)
used in Compensite signal the Renge of Frequence That a channel Can pass.	The speed of Bit TranSmission in a channel or link.

107

(2) Throughput:

↳ a measure of How Fast we Can Actually Send Data Through a network.

Ex 3.44

- network Bandwidth of 10 Mbps Can pass only an Average of 12 000 Frames per minute with each Frame Carrying an Average of 10,000 Bits

What is the Throughput:

$$\text{Throughput} = \frac{12\,000 \times 10\,000}{60} = 2 \times 10^6 \text{ bps}$$

2 Mbps

108

[3] latency (Delay).

Define How long it takes for an entire Message to Completely arrive at Destination from the time the first bit is sent out from the Source.

Latency (Delay)
- Propagation time
- + Transmission Time.
- + Queuing Time
- + processing Delay.

(1) Propagation Time:

The Time Required for a bit to Travel From The Source to The Destination

$$\text{Propagation Time} = \frac{\text{Distance}}{\text{Propagation Speed}}$$

2 Transmission Time

Time Between The first bit leaving the sender & The last bit arriving at The Reciever.

Transmission Delay = $\frac{\text{Message size}}{\text{Bandwidth}}$

3 Queuing Time

The Time needed for each intermediate or end Device to hold Message before it Can be processed.

* Propagation Time (Delay) = $\dfrac{\text{Distance}}{\text{propagation speed}}$

* Transmission Delay = $\dfrac{\text{Message Size}}{\text{Bandwidth}}$