1

Ch 3 Data & signals

1 What is the Relecation Between period & Freque

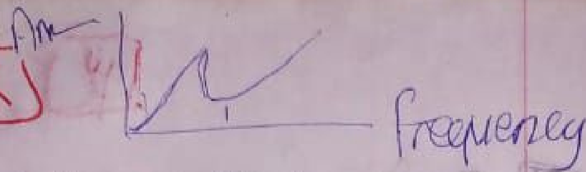
The period of a signal is the inverse of its Frequency & Vice versa

$T = \frac{1}{F}$ $F = \frac{1}{T}$

2 What does the Amplitude of signal Measure?
What does the Frequency of signal Measure?
What does the phase of signal Measure?

- The Amplitude of signal measure The Value (intensity) of The Signal at any point
- The Frequency measure The number of periods in one second (1/sec).
- The phase measure The position of The waveform (Signal) Releative to Time Zero (0).

2



3 How Can a Composite signal be Decomposed into its individual Frequencies?

- Fourier Series Gives The Frequency Domain of a periodic signal & Fourier Analysis Gives the Frequency Domain of nonperiodic Signal.

4 Name Three Types of Transmission impairment?

1 Attenuation
2 Distortion
3 Noise -

5 Distinguish Between Baseband Transmission & Broadband Transmission?

* BaseBand Transmission	* Broadband Transmission
↳ means sending The Digital // Analog signal without Changing (modulation) using The low pass Channel.	↳ means modulate The Signal (Converting Digital ⇄ Analog) using The bandpass Channel.

٣

6) Distinguish Between a low pass Channel & Band-pass Channel?

* low-pass Channel	* band pass Channel
↳ ~~Has~~ Channel has a Bandwidth Starting From Zero (0 — □)	↳ Channel has Bandwidth Doesn't Start From Zero (□ → □)

7) What does the Nyquist Theorem have To do with Communication?

Nyquist Theorem → Define The maximum Bit Rate of a Noiseless Channel.

Bit Rate = 2 * Bandwidth * $\log_2 (L)$ → Signal level

8) What does The Shannon Capacity have to do with Communication?

Shannon Capacity → Determine The Theoretical Maximum Bit Rate in Noisy Channel (capacity)

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

٤

9) Why do optical signals used in Fiber optic Cables have a very short wavelength?

↳ optical fiber signal have very High Frequencies when Frequency is very High The wavelength is very low (short).

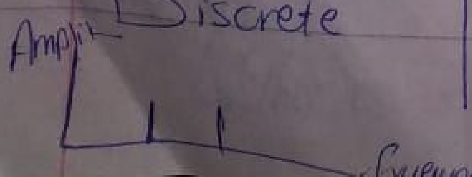
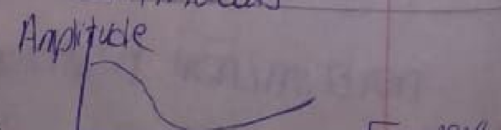
$\lambda = c / f$ ↳ V/C → The propagation speed in The Media.

$\lambda \propto \frac{1}{f}$

10) Can we say if a signal is periodic or Non-periodic by Just looking at its Frequency Domain plot?

How ???

Yes:

Signal is periodic if its Frequency Domain plot Is Discrete	Signal is non-periodic if its Frequency Domain plot is Continuous
	

17

When send a Voice signal from a Microphone to a Recoder. No Modulation is involved.

This is a Baseband Transmission

14 We send a Digital signal from one station in a LAN to another station.
Is This Baseband or Broadband Transmission.

When send Digital signal from one station to another station. No Modulation is involved

This is Baseband Transmission.

15 We modulate several Voice signals & send them through the air.
Is This Baseband or Broadband Transmission?

When we modulate several Voice signals & send them through the Air, here modulation is involved.

This is Broadband Transmission.

10

11 Is The Frequency Domain plot of a voice signal Discrete or Continuous?

The Frequency Domain of voice signal is normally Continuous Because voice is Nonperiodic signal.

12 Is The Frequency Domain plot of an Alarm System Discrete or Continuous?

Alarm system is periodic

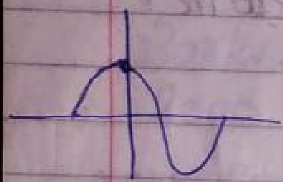
This means Its Frequency Domain plot is Discrete.

13 We send a Voice signal from a microphone to a Recoder. Is this Baseband or Broadband Transmission?

Λ

18 What is The phase shift for The following?

a) A sine wave with Max Amplitude at Time zero

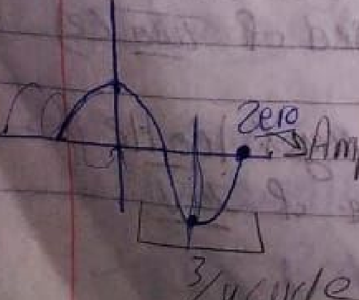


phase = 90° ($\pi/2$)

b) A sinewave with max Amplitude after 1/4 cycle.

phase = 0° (zero Degree).

c) A Sinewave. with Zero Amplitude after 3/4 cycle & increasing



phase = 90° ($\pi/2$)

V

Ex:

16 Given The frequencies, Calculate The Corresponding periods:

a) 24 HZ $T = \frac{1}{f} = 1/24 = 0.0417 S \simeq 41.7 ms$

b) 8 MHZ $T = \frac{1}{f}$ $1/8\times10^{6} = 0.125\ \mu s$

c) 140 KHZ. $T = \frac{1}{f} = \frac{1}{140\times10^{3}} = 7.14\ \mu s$

17 Given The following periods & Calculate The Corresponding Frequencies.

a) 5 s $f = \frac{1}{T} = \frac{1}{5} = 0.2\ HZ$

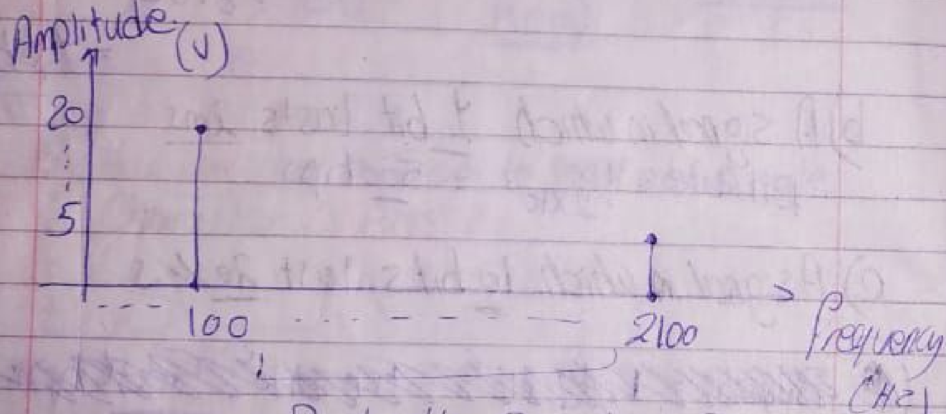
b) 12 μs $f = \frac{1}{T} = \frac{1}{12\times10^{-6}} = 83.33\ KHZ$

c) 220 ns $f = \frac{1}{T} = \frac{1}{220\times10^{-9}} = 4.55\ MHZ$

- The second one has a Maximum Amplitude of 5 V
  - Draw The Bandwidth.

Bandwidth = High f - low f

2000 = 2100 - 100



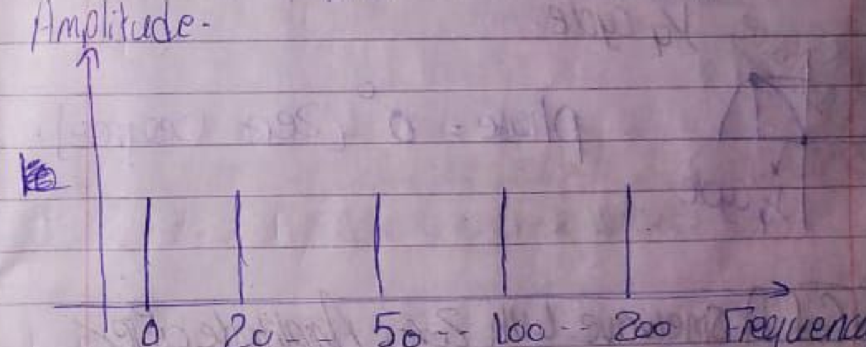
Bandwidth = 2100 - 100 = 2000 Hz

21 Which signal has a wider Bandwidth, a sinewave with Frequency of 100 Hz or a sinewave with a frequency of 200 Hz?

Each Signal is a simple in This Case:
The Bandwidth of a Simple Signal is Zero
So The Bandwidth of The Both signals are The same.

19 What is The Bandwidth of a signal that Can be decomposed into 5 Sine waves with Frequencies 0, 20, 50, 100 & 200 Hz?
All peak Amplitude are the same.
Draw the Bandwidth.

Bandwidth = High f - low f
= 200 - 0 = 200 Hz.



20 A periodic Composite signal with a Bandwidth of 2000 Hz is Composed of two (2) Sinewaves.
- The first one has frequency of 100 Hz with Max Amplitude of 20V

Bit Rate = $\frac{\text{Number of Bits}}{1 \text{ sec (Time)}}$ = (Bit Duration)

23) A Device sending out Data at Rate of 1000 bps:

a) How long Does it Take to send out 10 Bits?

$t = \frac{10}{1000} = 10 \times 10^{-3} = 0.01 \text{ sec}$

10ms

$1000 = \frac{10}{t}$

b) How long does it Take to send out single Character (8 Bits)?

$t = \frac{8}{1000} = 8 \times 10^{-3} = 8 \text{ ms}$

c) How long does it Take to send out a file of 100,000 Characters.

N. of Bits = 100 000 X 8 = 800 000 Bits

$t = \frac{800\,000}{1000} = 800 \text{ Sec}$

Bit Rate = $\frac{\text{Number of Bits}}{\text{Time}}$

22) What is The Bit Rate for each of The Following Signals?

a) A signal in which 1 bit lasts 0.001 s.

Bitrate = 1/(Bit Duration) = $\frac{1}{0.001}$ = 1000 bps = 1 Kbps

b) A signal in which 1 bit lasts 2ms

Bit Rate = $\frac{1}{2 \times 10^{-3}}$ = 500 bps

c) A signal in which 10 bits last 20 μs

~~Bit Duration = Total Time / Number of Bits = 20×10^{-6} / 10~~

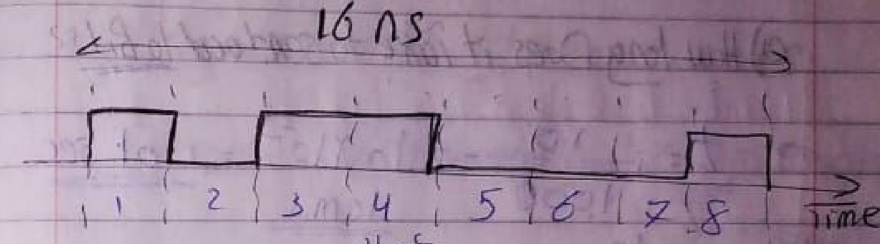
Number of Bits

Bit Rate = $\frac{10}{20 \times 10^{-6}} = 500 \times 10^{3}$ bps

Time

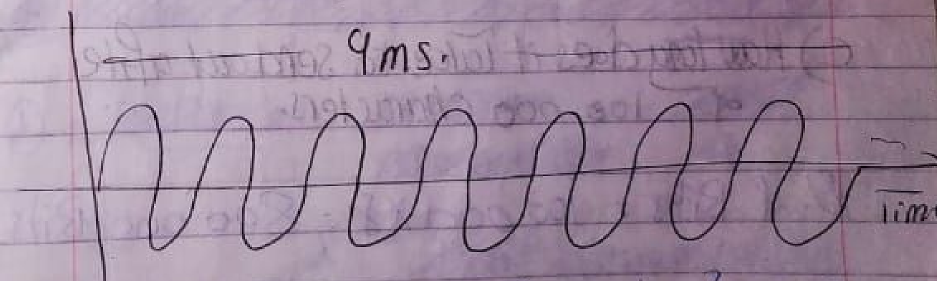
500 Kbps

[24] What is the Bitrate for the signal in the Figure.



Bits
Bit Rate = $\frac{8 \rightarrow \text{Bits}}{16 \times 10^{-9}} = 500 \times 10^{6} = \underline{500\ Mbps}$

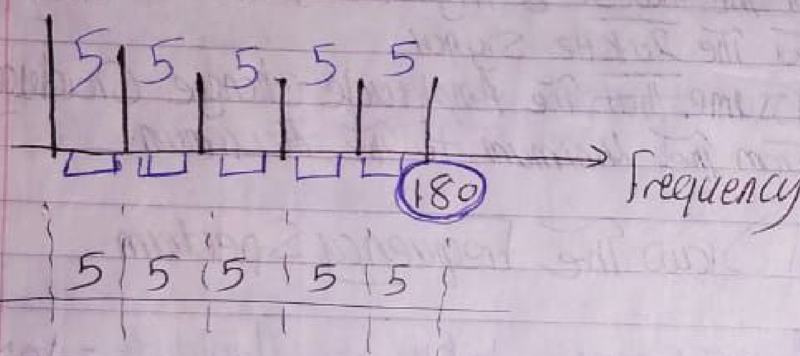
[25] What is the frequency of the signal in the Figure?



The Signal makes 8 cycles (periods) in 4ms.

$F = \frac{8}{4 \times 10^{-3}} = 2000\ Hz$
$= \underline{2\ KHz}$

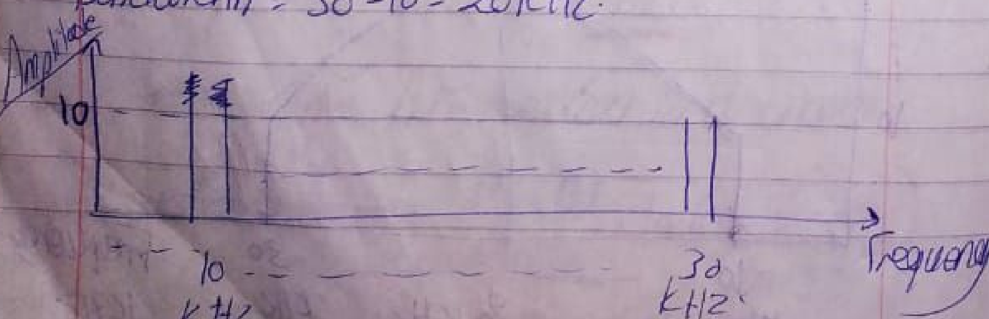
[26] What is the bandwidth of the Composite Signal in the Figu



The bandwidth is = 5 x 5 = 25 Hz

[27] A periodic Composite signal Contains frequencies from 10 to 30 KHz. each with an Amplitude of 10V Draw the Frequency spectrum.

Bandwidth = 30 - 10 = 20 KHz.



Bit Rate = $\frac{N}{2}$ Bandwidth

Data Rate = Bandwidth * 2

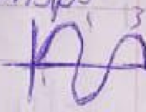
17

(29) A TV Channel has a bandwidth of 6 MHz. If we send a Digital Signal using one Channel, what are the Data Rates if we use one Harmonic, Three Harmonics & Five Harmonics?

Bandwidth = 6 MHz

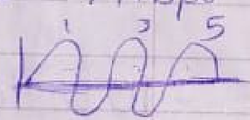
* 1 Harmonics

↳ Datarate = 2 × 6 = 12 Mbps



* 1, 3 (Three Harmonics)

↳ Data Rate = $\boxed{(2\times6)}/3 = 4$ Mbps



* 1, 3, 5 (Five Harmonics)

↳ Data Rate = (2×6)/5 = 2.4 Mbps

(30) A signal Travels from point A to point B. At point A, The Signal power is 100 W. At point B, The power is 90 W.

What is The Attenuation in decibels?

$$\text{Attenuation} = 10\log_{10}\frac{P_2(B)}{P_1(A)} = 10\log_{10}\left(\frac{90}{100}\right)$$

$$= -0.45 \text{ dB}$$

Ch (3)

10

(28) A non-periodic Composite signal Contains frequencies From 10 to 30 KHz. The peak Amplitude is 10 V For The lowest & Highest signals & 30 V For The 20 KHz Signal. Assume that The Amplitude change Gradually From The Minimum to The Maximum.

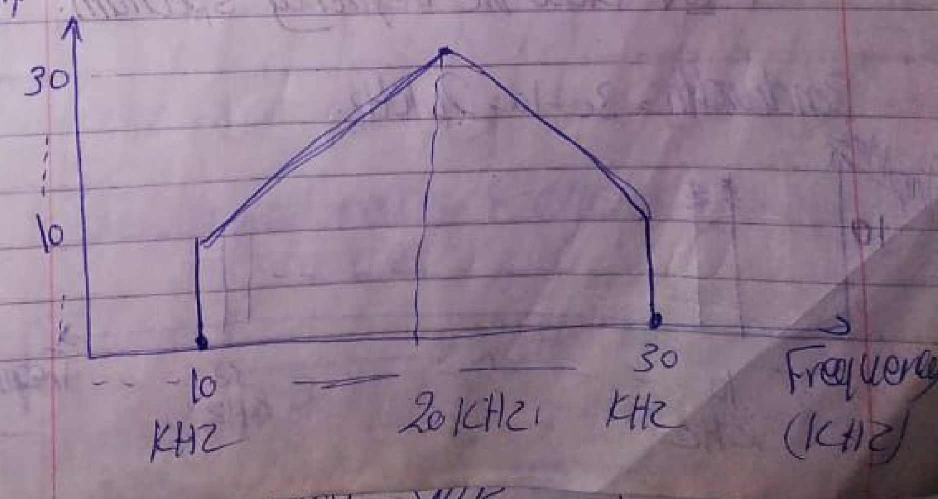
Draw The Frequency Spectrum.

- lowest Signal = 10 KHz → Amplitude = 10 V
- Highest signal = 30 KH → Amplitude = 10 V

Bandwidth = 30 − 10 = 20 KHz

↳ Amplitude = 30 V

Amplitude (V)



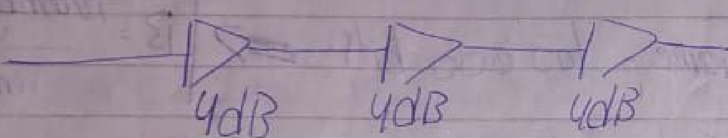
Ch (3)

9

(VI)

[32] A signal has passed Through Three Cascaded Amplifiers each with a 4dB Gain:

- What is the total Gain?
- How much is the Signal Amplified? (output signal)



Three (3) Amplifier:

(+) → Amplified

① Total Gain = $4 \times 3 = 12$ dB

② Signal Amplified: $10 \log_{10}\left(\frac{P_2}{P_1}\right)$

$(+)\ 12 = 10 \log_{10}\left(\frac{P_2}{P_1}\right)$

$\div 10$

$1.2 = \log_{10}\left(\frac{P_2}{P_1}\right)$

$10^{1.2} = \frac{P_2}{P_1}$

$\Rightarrow P_2/P_1 = \boxed{15.84}$

Rule

$\log_a b = c$

$a^c = b$

(IV)

[31] The Attenuation of a signal is -10 dB. What is the Final Signal power if it was originally 5 W?

Attenuation $= 10 \log_{10}\left(\frac{P_2}{P_1}\right)$

$P_1 = 5\,W$ Attenuation $= -10$ dB.

$-10 = 10 \log_{10}\left(\frac{P_2}{5}\right)$

$-10 = 10 \log_{10}\left(\frac{P_2}{5}\right)$

$\div 10$

$-1 = \log_{10}\left(\frac{P_2}{5}\right)$

$\frac{P_2}{5} = 10^{-1} \Rightarrow P_2 = 5 \times 10^{-1}$

$P_2 = 0.5\,W$

Rule

$\log_a b = c$

$\therefore a^c = b$

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

[20]

35 A line has a wavelength of 1 μm in Air.
(a) How Far Can the Front of The wave Travel During 1000 periods?

$\lambda = 1\,\mu m = 1\times10^{-6}\,m$

(T) periods = 1000

$\boxed{\lambda = C \cdot T}$

Distance = $1\times10^{-6} \times 1000 = 1\times10^{-3}$ m
= 1 mm

36 A line has a signal-To-Noise Ratio (SNR) of 1000 & a Bandwidth of 4000 KHz
What is The Maximum Data Rate supported by This line? ↳ shannon

* SNR = 1000 * Bandwidth = 4000 KHz

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

$C = 4000 * \log_2(1+1000) = 39.8$ Kbps

≃ 40 Kbps

[19]

33 If The bandwidth of The Channel is 5 Kbps
How long does it Take to send a Frame of 100,000 bits out of This Device?

Bandwidth = 5Kbps = 5×10^3 bps

Frame = 100 000 bits ⟹ $B = \frac{\text{Number of Bits}}{\text{Time}}$

t (Time) = $\frac{100\,000}{5\times10^3} = 20\,s$

34 The light of Sun takes approximately eight (8) minutes to Reach the earth.
What is The Distance Between The Sun & The earth?

Approximate Time = 8 x 60 = 480 sec
Speed of light = 3×10^8 Km/sec

The Distance = $480 \times (3\times10^8)$ =
= 144 000,000 Km

Speed = $\frac{\text{Distance}}{\text{Time}}$ ⟹ Distance = Time * Sp

Data Rate = $\frac{\text{Number of Bit}}{\text{Time (Bit Duration)}}$

CP

[38] A File Contain 2 Million Bytes
How long Does it Take to Download this File using 56 Kbps Channel 2, 1 Mbps 2

File Contain = 2 Million bytes
= 2 000 000 X 8 = 16 000 000 bits

* 56 Kbps:

DataRate = $\frac{\text{Number of Bits}}{\text{sec (Time)}}$

$t = \frac{16\,000\,000}{56\,000} = 285.7$ sec
$\simeq 286 = 4.7$ M
$\simeq 5$ minute

* 1 Mbps.

$t = \frac{16\,000\,000}{1 \times 1\,000\,000} = 16$ sec

C1

[37] We measure The performence of Telephone line (4KHZ of Bandwidth)
When The Signal is 10V The noise is 5mV
What is the Maximum Data Rate supported by This telephone line?

Bandwidth = 4 KHZ (4000 HZ)
Signal = 10 V
Noise = 5 mV = 5×10^{-3} V

* $SNR = \frac{\text{Power of Signal}}{\text{Power of Noise}} = \frac{10}{5 \times 10^{-3}} = \boxed{2000}$

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

$C = 4000 * \log_2 (1 + 2000)$

C = 43.866 bps = 43 Kbps

43.8 Kbps

Ch (3)

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

(٤٢)

40) A signal with 200 mw power passes through 10 Devices each with an Average Noise of 2 Mw
- What is The SNR?
- What is The SNR_{dB}?

* $SNR = \dfrac{\text{power of signal}}{\text{power of Noise}}$

Signal power $= 200 \times 10^{-3}$ W
Noise power $= 2 \times 10^{-6}$ W $\times 10 = 20 \times 10^{-6}$ W

* $\boxed{SNR}$

$$\frac{200 \times 10^{-3}}{2 \times 10^{-6} \times 10} = \boxed{10\,000}$$

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

$$= 10 \log_{10} (10\,000) = 40 \text{ dB}$$

(٤٣)

39 / 40) A Computer Monitor has a Resolution of 1200 by 1000 pixels. If each pixel uses 1024 Colors.
How Many Bits are needed to Send The Complete Contents of The Screen?

To Represent 1024 Colors.

1200 × 1000 (screen)

* number of Bits: $2^{10} = 1024$

number of Bits To Represent 1024 colors $= \log_2 1024 =$

عدد الألوان

$\log_2 1024 = 10$ Bits
$\log_2 2^{10} = 10 \log_2 2 = 10$ Bits

$1024 = 2^{10}$
عدد
Bits = 10
لكل pixel

* Total number of Bits:

$1200 \times 1000 \times 10 = 12\,000\,000$ bits

12 Mbps

Resolution

عدد Bits
الالوان لكل pixel (Color)

[42] What is the Theortical Capacity of a channel in each of The Following Cases:

a) Bandwidth 20 KHz $SNR_{dB} = 40$

$$C = B * \frac{SNR_{dB}}{3}$$

$$C = 20 * \frac{40}{3} = 266.6 \simeq 267 \text{ Kbps}$$

b) Bandwidth: 200 KHz $SNR_{dB} = 4$

$$C = 200 \times \frac{4}{3} = 266.6 \simeq 267 \text{ Kbps}$$

c) Bandwidth = 1 MHz $SNR_{dB} = 20$

$$C = 1 * \frac{20}{3} = 6.67 \text{ Mbps}$$

[41] If The peak voltage value of a signal is 20 Times The peak voltage value of The Noise, what is the SNR? What is The SNR_{dB}?

Signal = 20 Noise

$$SNR = \frac{P(\text{signal})}{P(\text{Noise})}$$

$$SNR = \frac{V^2(\text{signal})}{V^2(\text{Noise})}$$

$$* \; SNR = \left[\frac{\text{Signal voltage}}{\text{Noise voltage}}\right]^2$$

$$SNR = \left[\frac{20}{1}\right]^2 = \boxed{20^2} = 400$$

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

$$= 10 \log_{10}(400) \approx 26.02$$

26 dB

$dB \; 10 \log SNR = \square \; dB$

(CN)

[44] We have a channel with 4 KHZ Bandwidth if we want to send Data at 100 kbps
- What is The minimum SNR_{dB}?
- What is The SNR?

* Bandwidth = 4000 HZ
* Data Rate = 100×10^3 bps → Capacity

$$C = B * \frac{SNR_{dB}}{3}$$

$$* SNR_{dB} = 3 * \frac{C}{B} \text{ (Data Rate)}$$

$$= 3 * \frac{100000}{4000} = 75 dB$$

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

$$75 = 10 \log_{10} SNR$$

$$7.5 = \log_{10} SNR \qquad SNR = 10^{7.5} \simeq 31622776$$

$C_1 = B * \log_2(1+SNR)$ $C \propto B$ Double → Double

(CV)

[43] We need to upgrade a channel to a higher Bandwidth, Answer The Following Question-

a) How is The Rate improved if we dobule The Bandwidth.

If we dobule The Bandwidth ⇒ The Data Rate is dobuled

$$C_2 = 2 * C_1 \quad \Big| \quad * C_1 = \underset{\text{Double}}{B} * \log_2 (1+SNR)$$

b) How is the Rate improved if we double the SNR?

- When The SNR is doubled, Data Rate increasing

$$C_1 = B * \log_2(1+\underset{\text{Double}}{SNR})$$

$$C_2 = C_1 + 1$$

Bit Rate = $\frac{\text{Bits/ثانية}}{1}$ → Bit (Duration).

٣٠

* Bit length = propagation speed * Bit Duration

* Bit Duration = $\frac{1}{\text{Bandwidth}}$ → Number of Bits.

* Bit length = propagation Speed * $\frac{1}{\text{bandwidth}}$

[a] Bit length = $2\times10^8 * \frac{1}{1\times10^6} = 200\,m$

[b] Bit length = $2\times10^8 * \frac{1}{10\times10^6} = 20\,m$

[c] Bit length = $2\times10^8 * \frac{1}{100\times10^6} = 2\,m$

Transmission Time = $\frac{\text{Message size}}{\text{Bandwidth}}$ → $\boxed{\frac{\text{Number of Bits}}{\text{Bandwidth}}}$

٢٩

[45] What is The Transmission Time of a packet Sent by a station if the length of the packet is 1 million bytes & The Bandwidth of The Channel is 200 kbps?

Byte = 8 Bits

* packet length = 1 million bytes
= 1000 000 x 8 = 8000 000 bits

* Bandwidth =
200 Kbps = 200 000 bps

* Transmission Time = packet length / Bandwidth

$= \frac{8\,000\,000}{200\,000} = 40\,sec$

[46] What is the length of a bit in a channel with propagation Speed of $2\times10^8\,m/s$

a) 1 Mbps.
b) 10 Mbps
c) 100 Mbps.

Frame Size = 5 million Bits = 5×10^6 Bits

Routers Number = 10 — Queuning Time = 2×10^{-6} s

Bandwidth = 5×10^{-3} bps — processing Time = 1 μs = 1×10^{-6} s

[48] What is The total Delay (latency) For a frame of size 5 million Bits that is being sent on a link with 10 Routers each having a Queuning time 2 μs & processing time of 1 μs

The length of The link is 2000 km

The speed of light inside the link 2×10^8 m/s

The link Bandwidth of 5 Mbps

* Which Component of The Total Delay is Dominant? which one is negligible?

Patersil μs

① - processing Time = $10 \times 1 = 10\ \mu s = 10 \times 10^{-6}$ s

② Queuning Time = $10 \times 2 = 20\ \mu s = 20 \times 10^{-6}$ s

③ Transmission Time = $\dfrac{\text{Frame size (Message size)}}{\text{Bandwidth}}$

$= \dfrac{5000000}{5 \times 10^6} = 1$ s

[47] How many Bits Can fit on a link with 2 ms Delay if The Bandwidth of The link is

a) 1 Mbps
b) 10 Mbps
c) 100 Mbps.

* Delay (Duration) = Time = $\dfrac{\text{Number of Bits}}{\text{Bandwidth}}$

* Number of Bits = Bandwidth * Delay

[a] Number of Bits = $1 \times 10^6 * 2 \times 10^{-3} = 2000$ bits

[b] Number of Bits = $10 \times 10^6 * 2 \times 10^{-3} = 20000$ bit

[C] Number of Bits = $100 \times 10^6 * 2 \times 10^{-3} = 200000$ Bit

Ch (3)

Distence → (The length of The link)

propagation

(1) ~~processing~~ Time = $\frac{\text{Distence}}{\text{Speed}}$

$$= \frac{2000 \times 10^3}{2 \times 10^8} = \frac{1}{10^2} = 0.01 S$$

Latency = Processing Time + Queuning Time + Transmission Time + propagation Tim.

$$= 10 \times 10^{-6} + (20 \times 10^{-6}) + 1 + 0.01$$

$$= 1.01 S \simeq 1 sec$$

So The Transmission Time is Dominant (طاغي) Because the packet size is Huge.

* Neligabile
  ↳ Queuning Time

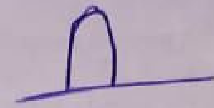
القانون لما نستخدم

Harmonic 1 ، (1,3) ، (1,3,5)

معطى

* <u>Given</u> <u>Bandwidth</u> & need To Calculate <u>Data Rate</u>

Bit Rate (Data Rate)

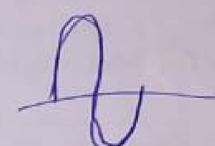


in

1. 1 Harmonic.

Data Rate = Bandwidth *2

2. 1,3 Harmonic



$$\text{Data Rate} = \frac{(\text{Bandwidth} * 2)}{3}$$

3. 1,3,5 Harmonic.

$$\text{Data Rate} = \frac{(\text{Bandwidth} * 2)}{5}$$

معطى

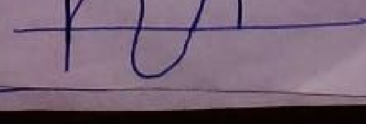
* <u>Given Data Rate & need to Calculate Bandwidth</u>

1 Harmonic

$$\text{Bandwidth} = \frac{\text{Data Rate}}{2}$$

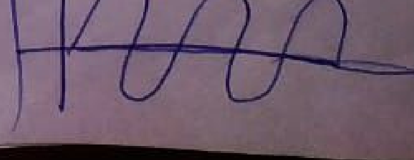
1,3 Harmonic

$$\text{Bandwidth} = \left(\frac{\text{Data Rate}}{2}\right) * 3$$



1,3,5 Harmonic

$$\text{Bandwidth} = \left(\frac{\text{Data Rate}}{2}\right) * 5$$



Ch (3) قوانين

1. $F = \frac{1}{T}$ $T = \frac{1}{F}$

2. F = Number of periods / Time

3. $\lambda = \frac{C}{F} \Rightarrow F = \frac{1}{T}$

$\lambda = C \cdot T$

4. B (Bandwidth) = High Frequency - low Frequency
→ Composite signal

5. Number of Bits ~~persend~~ For each level = $\log_2 L$ → signal levels

6. Bit length = propagation Speed * Bit Duration

7. Nyquist (Bandwidth) = $\frac{N}{2} - 0 = \frac{N}{2}$ → (Bit Rate)

8. $dB = 10 \log_{10} \frac{P_2}{P_1}$ → Attenuation → dB (-)
Amplified → dB (+)

9. $SNR = \frac{\text{Average signal power}}{\text{Average Noise power}} = \left[\frac{\text{Signal voltage}^2}{\text{Noise Voltage}^2}\right]$

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

11) Nyquist BitRate = 2 * Bandwidth * $\log_2$ (L)

↳ bps (bits-per-second)

Signal levels

12) Shannon Capacity = Bandwidth * $\log_2(1 + SNR)$

↳ bps

13) When Given in The Ex:

SNR_{dB} & Bandwidth.

Capacity = Bandwidth x $\frac{SNR_{dB}}{3}$

↳ bps

14) Throughput = $\frac{\text{Number of frames}}{\text{Time}}$ x size of each frame.

15) latency (Delay) =

① propagation Delay (time) = $\frac{\text{Distence}}{\text{propagation speed}}$ = $\boxed{}$ s

+

② Transmission Delay (Time) = $\frac{\text{Message size}}{\text{Bandwidth}}$ = $\boxed{}$ s

+

③ Queeling Time

+

④ processing Time.