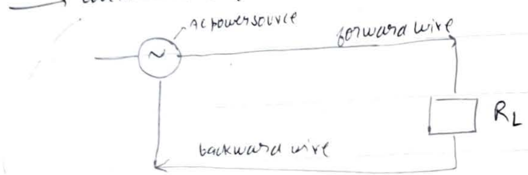
① → WIRED NETWORK COMMUNICATION

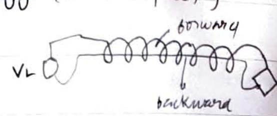
MUNICATION —— └→ WIRED MEDIUM $\xrightarrow{a)}$ Unshielded Twisted Pair (UTP-7) ↗ in telephone

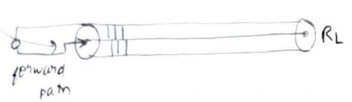
ORK: Set of autonomous computer ~~connected~~ connected with serial communication links

- twisted to improve quality of wire, to avoid / cancel back EMF & improve quality of signal ( CAT-6, CAT-7 are latest )

$\xrightarrow{b)}$ Coaxial cable (TV cable) —— (twisted pair)




$\xrightarrow{c)}$ Optical Fiber ( light travels through total internal reflection )

- light travels in 1 direction ( 2 wires for bidirectional )
- voltage will be converted to light by laser
- used for large distance transmission

In a), b) voltage, & current travel in electrical form

In c) voltage travels in light form

└→ WIRELESS MEDIUM $\xrightarrow{a)}$ space E field (electrical) ↗ electromagnetic signal

H field (magnetic)

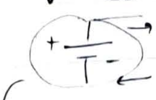
In E field, voltage = electrical field

In H field, current = electrical field

NO communicat$^n$ is possible through constant voltage ↗ it won't have any changes (AXIOM OF COMMUNICAT$^N$)

we send info via time-varying voltage, current, light, E field, H field

$V \rightarrow DC$ , $Vi \rightarrow AC$



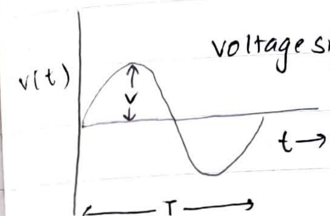

└ circuit notation

$V(t)$ ( varies with time ) ( magnitude & direct$^n$ varies with time )

AC is denoted by $i(t)$

$i(t) = v(t)/R$ if voltage is sinusoid, current would also be sinusoid

└ Ⓐ




time period = time for 1 cycle

voltage signal in a generator (sine wave signal)

( both mag. & dir. changes )

( sinosuidal signal ) . $V(t) = \underline{V} \sin\left(\frac{2\pi t}{T}\right)$

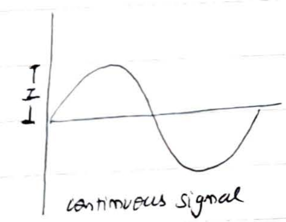
amplitude ↗ $= V \sin(2\pi f t)$

T → 1 cycle

1 sec → $1/T$ cycle → cyclic freq. = no of cycles in second of AC signal = Hz = f

t sec → $t/T$ cycle

in Ⓐ $i(t) = \frac{v(t)}{R} = \frac{V}{R} \sin 2\pi f t = I \sin 2\pi f t$ ↗ voltage current across R




AMPLITUDE: Highest deviat$^n$ from 0 point

= | max. deviation |

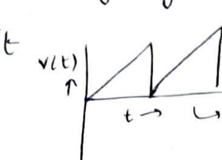
ELEMENTS OF ELECTRONIC CIRCUIT

we will consider everything in AC circuit

R → Resistor (Resistance) → Ω (ohm)

C → Capacitor (capacitance) → F (Faraday)

I → Inductor (Inductance) → Henry

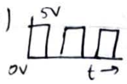



└ this is also a time varying signal

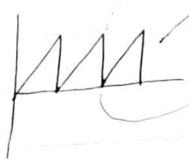
- sine signal is most fundamental analog signal
- holds principle of continuity

SIGNAL → ANALOG (continuous in nature)


SIGNAL → DIGITAL (DISCRETE) level 1 = L1 = 5V (for eg) level 0 = L0 = 0V




- Any analog signal can be represented as a combination of fundamental sine signal
- In digital signal, signal is discrete (it doesn't hold principle of continuity)
- Digital signal is non-continuous, non-analog. Fundamental eg of discrete signal is digital signal




Any time varying signal is denoted by $v(t)$ & its current is $i(t)$

For capacitance $v(t) = \frac{Q(t)}{C}$ → this if constant, then $v(t)$ would be constant
↳ voltage-current across C

A capacitor comprises of 2 metallic plates & separated by an insulator.

More charge on 1 plate of capacitor ∝ voltage across the capacitor

$$q(t) \propto v(t)$$

$$\frac{q(t)}{C} = v(t) \quad \text{— } (\beta)$$

~~dt time~~ : ~~charg flow = dq(t)~~ charge flow in $\Delta t = \Delta Q$

charge flow in 1 sec = $\frac{\Delta Q}{\Delta t} = \frac{dq}{dt}$,

$$i(t) = \frac{dq(t)}{dt}$$

$i(t) = \Delta t \to 0$

$$q(t) = \int d\,q(t) = \int i(t)\,dt$$

in $(\beta)$ $$v(t) = \frac{\int i(t)\,dt}{C}$$

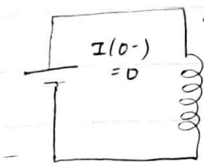
$$\Rightarrow i(t) = \frac{C \cdot d\{v(t)\}}{dt}$$

Any coil will give rise to a ~~conductor~~ inductor $\quad v(t) = L \frac{di(t)}{dt}$ — $(\gamma)$ → BACK EMF
↳ in fans, fridges

CONDUCTANCE $(\delta) = \frac{1}{R}$ (can also be swapped with R for elements of circuit)

voltage across inductor ∝ change in current across inductor

$$v(t) = L \cdot \frac{d\,i(t)}{dt} \quad (\text{in } (\gamma))$$




after starting current

$I(0+) = \frac{V}{R}$ $\quad \therefore \frac{V}{R} - 0$ change in current occurs in 0+ time $\quad 0^+ - 0^- = 0^+$

$\frac{\frac{V}{R} - 0}{0^+}$ = -ve change in current
↳ ∞ rate of change of current
⇒ ∞ BACK EMF which tries to oppose current
∴ current doesn't ↑ instantaneously.

$L\frac{di}{dt} = V_L(t)$ → voltage current across inductor

~~IN WIRELESS CIRCUITS~~

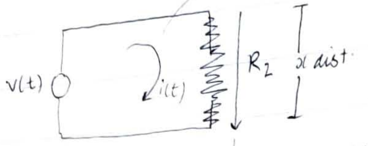
$i_R(t) = \frac{V_R(t)}{R}$ → Across R

$V_C(t) = \frac{1}{C}\int i_C(t)\,dt$ → Across C

$V_L(t) = L\frac{d\,i_L(t)}{dt}$ → Across inductor conduction current

$i(t) = v(t)/R_L$

$\underbrace{e(t)}_{\text{electric field at time 't'}} = \frac{dv(t)}{\underbrace{dx}_{\text{distance differential}}}$




direction of electric current, field

Current flow direction is opp to charge flow direction

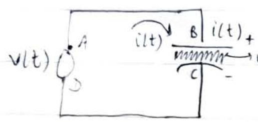
Direct$^n$ of magnetic field using Hand Rules

→ direction of magnetic field is tangent to the electric current direction

$p(t) = v(t) \cdot i(t)$ (power)

$= v(t)\, i(t) \cos\theta$ ($\theta = 0$ here)

$= v(t)\, i(t)$ ∴ power is guided as it is in direct$^n$ of V & I




A to B : conduction current as path contains free charges

B to C : $i(t) = C \cdot \frac{dv(t)}{dt}$ (time varying)

but there are no charges,

∴ imaginary current / displacement current

But acc. to Kirchoff's law, outgoing current should be same as incoming current. Capacitor can't be charged instantaneously.

At time 0, $i(0) = \frac{V}{R}$ → current deposit at plate of capacitor

→ potential diff is created.

COULOMB'S LAW Given 2 charges $q_1, q_2$ at a dist 'r' from each other

Force of interact$^n$ b/w them $= F = \frac{\epsilon\, q_1 \cdot q_2}{r^2}$

If $q_2 = 1$, $F = \frac{\epsilon\, q_1}{r^2}$ = electric charge

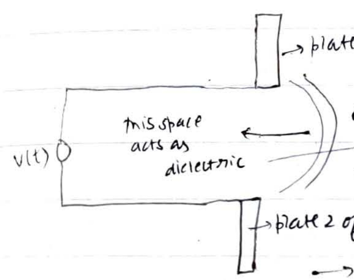
→ dielectric constant

→ results in varying electric charge ⇒ varying electric field (through the plates) with no current flow b/w both plates of capacitor

∴ charge flow through C is same as that at B (through continuity field)

∴ Insulator has both magnetic field & current

Time varying conduct$^n$ current = Time varying displacement current




displacement current ⇒ $h(t)$ → magnetic field

different insulating medium would have different $\epsilon$ values

• $h(t) = \frac{\mu\, m}{r^2}$ → mag. field in space → depends on medium

cross prod

$\vec{p}(t) = \vec{e}(t) \times \vec{h}(t)$

$|p(t)| = e(t) \cdot h(t) \sin\theta$

electric field, magnetic field, & electromagnetic power flow in ⊥ directions → can flow through any insulator

Maxwell's Laws of Electromagnetic Theory * (self)

energy $= e(t) = \int p(t)\, dt$ (power is rate of consumpt$^n$ of energy)

electrical mode of power only travels through conductor.

## ELECTROMAGNETIC FIELD/WAVE

energy is transferred through EM wave.

There are 2 types of energy transfer — particle mode (I) / wave mode (II)

(I) particle carries the energy from one place to another

m   s

$E = \frac{1}{2}mv^2$    $(ut + \frac{1}{2}at^2)$

$\vec{v}$   $E = \underbrace{F \cdot s}_{mf}$

$m_1$ → energy transferred by muscular energy $= \frac{1}{2}mv^2$

Momentum $= mv$

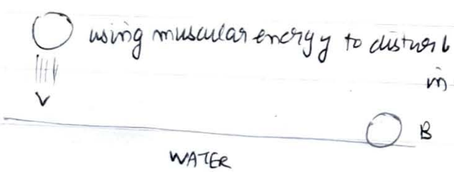
$m_2$    Momentum conservation

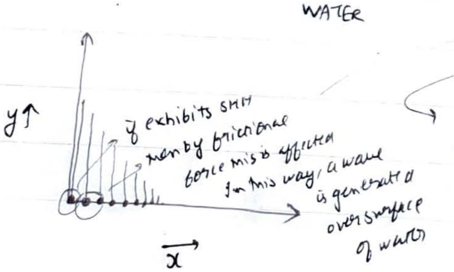
Initial Momentum $= 0$    $m_1 v_1 = m_2 v_2$

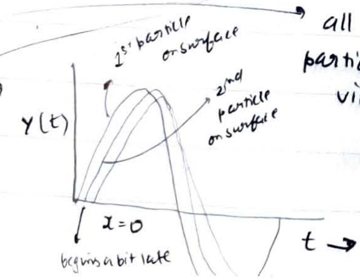
Energy transferred to $m_2 = \frac{1}{2} m_2 v_2^2$

(II) Heavy mass elements exhibit particle nature. Wave nature exists when mass $\xrightarrow{\text{tends to}} 0$

using muscular energy to disturb the surface of water, resulting in wave generation in SHM



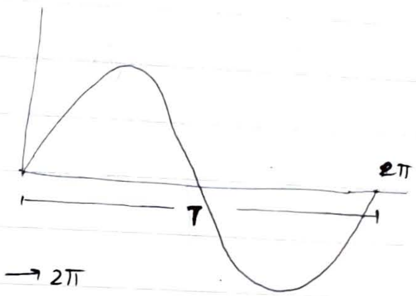




all water particles will start vibrating.

- Direction of water wave = Direction of energy flow = Direction of the peak of the wave.
- None of the particle is moving (from mean position), but energy is still being transferred. This can be noticed by a movement in position of ball B.

$Y(t) = Y \sin 2\pi f t$
at $x = x'$
at $t = t'$
$y(x) = Y \sin \frac{2\pi}{\lambda} x$




$e(t) = E \sin 2\pi f t$

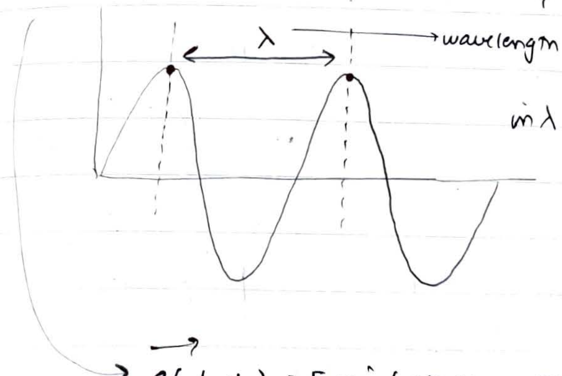
at a time $t = t'$

$e(x) = E \sin(2\pi/\lambda)\, t$

$T \rightarrow 2\pi$

$1 \rightarrow 2\pi/T$

$t \rightarrow \frac{2\pi}{T} \cdot t = 2\pi f t$   as $f = \frac{1}{T}$




in $\lambda$, there is → $2\pi$ change in ∠

$1 \rightarrow 2\pi/\lambda$

$x \rightarrow \frac{2\pi}{\lambda} \cdot x$

$\vec{e}(t, x) = E \sin\left(2\pi f t + \frac{2\pi}{\lambda} \cdot x\right)$

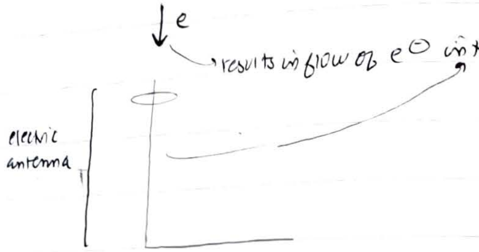
↳ movement results in both time & space variation.

$\vec{Y}(t, x) = Y \sin\left(2\pi f t + \frac{2\pi}{\lambda} x\right)$

$\vec{h}(t, x) =$

~~Wave formed~~ Wave form : same phase points. Locus of all peak pts = sphere

When the radius of sphere → very large, surface of sphere appears to be a plane. Eg. Earth.



Lowered value due to the compenent value

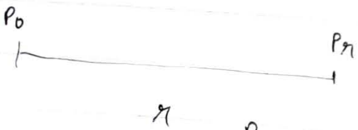
Voltage = $v = \int e \, dx$

$\boxed{f = 0 \Rightarrow T = \infty \quad \text{constant voltage DC}}$

Range of frequencies: 0 → 6 | medium wave | N KHz | shortwave | MHz | TV, FM (low freq | high freq | ultra high freq) | 60 GHz — based on amplitude modulation — 10 GHz

> 2 GHz : ~~beam spreads~~ microwave, sharp beam, LOS (Line of sight ~~Light of~~)

Wifi, satellite comm. : apps of Microwave




$= \frac{t P_0}{r^2}$ power decreases with distance

$\frac{P_0}{4\pi r^2}$

① vary with distance (free space, clear sky)
② Fog & rain (absorbs the microwave power)
③ vegetation (also extract)

] VARIATION IN POWER (PROPAGATION CHARACTERISTICS)

| | FREE SPACE | CLEAR SKY |
|---|---|---|
| DISTANCE | ✓ | ✓ |
| FOG & RAIN | ✓ | × |
| VEGETATION | × | ✓ |
| RECEIVING END IN SKY | × | |

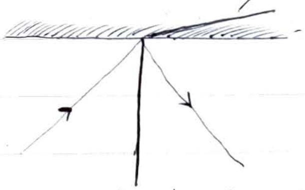
Fading due to multiple paths = Multipath fading

conductor → Metal   Insulator → wall, glass

$\underset{\text{velocity}}{V} = f\lambda = \frac{\lambda}{T} \quad (\because f = \frac{1}{T})$

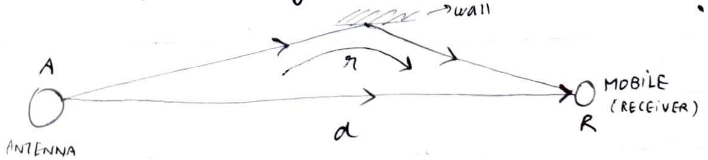
Light follows laws of reflection & refraction

velocity is constant in different mediums




Multiple waves interfere & cancel out

Metal surface has only reflection & no refraction




general eqn
$e(t, x) = E \sin\left(2\pi f t + \frac{2\pi}{\lambda} x\right)$

for the direct wave $e(t, d) = E \sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right)$

for indirect wave $e(t, r) = E \sin\left(2\pi f t + \frac{2\pi}{\lambda} r\right)$

$$e_{effective} = e_d + e_r \quad \text{—— (1)}$$

Let $r > d$

CASE 1 $\quad r = d + \lambda$ ($2\pi$ phase difference)

putting in (1)

$$e_{effective} = E\left(\sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right) + \sin\left(2\pi f t + \frac{2\pi}{\lambda}(d+\lambda)\right)\right)$$

$$= E\left(\sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right) + \sin\left(2\pi f t + \frac{2\pi d}{\lambda} + 2\pi\right)\right)$$

$$= E\left(\sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right) + \sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right)\right) \quad (\because \sin(2\pi + x) = \sin x)$$

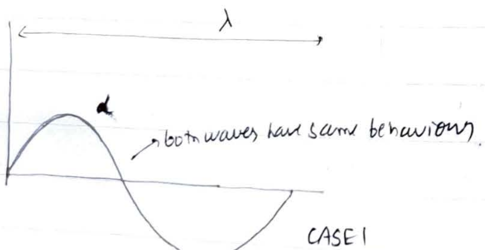
$$= 2E \sin\left(2\pi f t + \frac{2\pi}{\lambda} d\right) \quad \text{(additive interference)}$$

CASE 2 $\quad r = d + \frac{\lambda}{2}$ ($\pi$ phase difference) putting in (1)

$$e_{effective} = E\left(\sin\left(2\pi f t + \frac{2\pi d}{\lambda}\right) + \sin\left(2\pi f t + \frac{2\pi d}{\lambda} + \pi\right)\right)$$

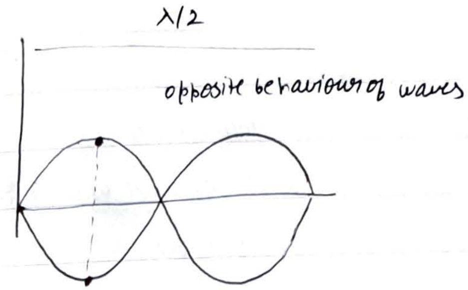
$$= E\left(\sin\left(2\pi f t + \frac{2\pi d}{\lambda}\right) - \sin\left(2\pi f t + \frac{2\pi d}{\lambda}\right)\right) \quad (\because \sin(\pi + x) = -\sin x)$$

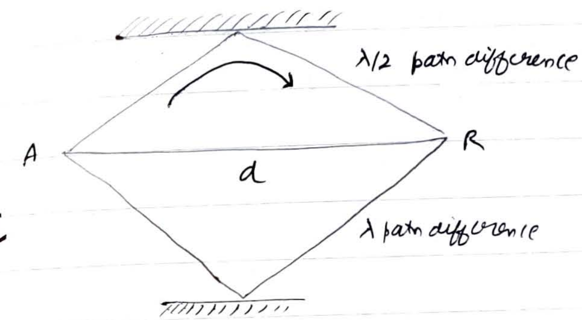
$$= 0 \quad \text{(zero signal strength)}$$




CASE 1

CASE 2




There will be 3 eqns.

#IMP.

$$e(t, d) = E \sin\left(2\pi f t + \frac{2\pi d}{\lambda}\right) \quad \text{—— (1)}$$

$$e(t, d + \lambda/2) = E \sin\left(2\pi f t + \frac{2\pi d}{\lambda} + \pi\right) \quad \text{—— (2)}$$

$$e(t, d + \lambda) = E \sin\left(2\pi f t + \frac{2\pi d}{\lambda} + 2\pi\right) \quad \text{—— (3)}$$

On adding (1) & (2) & (3) $\Rightarrow$ ~~(1) & (2)~~ (1) + (2) = 0

(3) is simplified to (1), ∴ there will be no multiple ~~increasing~~ fading.

If given $d, d + \frac{\lambda}{2}, d + \frac{\lambda}{4}$

↓ ↓ cancel out

↳ $\pi/2$ phase difference wave → no multiple ~~increasing~~ fading

Voice ~~F~~

+ve Interference → good signal

-ve Interference → Destructive interference.

There always exist some signal underground upto some level / depth

Eg: in Metro, antenna is spread within stations, some stations have receivers for this purpose.

Propagation characteristics : ① Distance ② Fog & rain ... Multiple Fading ] as before.

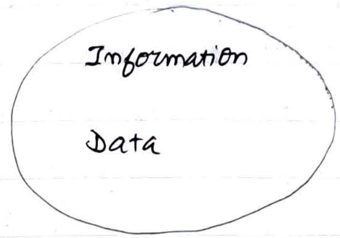
VOICE FREQUENCY RANGE

300 Hz ——————— 21 KHz

300 Hz → can be assumed to be 0, ∴

music also has this range of frequency.

COMPUTER




KNOWLEDGE

101010..... pattern ⇒ data , 101010... = Roll no. or Marks ⇒ Information

- data + meaning attached ⇒ Info.
- Knowledge ⇒ relationship b/w different information

eg :

| DISTANCE | FORCE OF GRAVITY |
|---|---|
| — | — |
| — | — |

Only this table given ⇒ Info. when we discover a relation b/w dist. & force of gravity ⇒ Knowledge

$g = \frac{GM}{R^2}$ ⟶ example of Knowledge

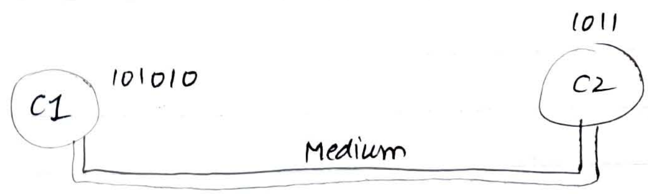
↳ accelerat^n due to gravity

as G, M → constants for Earth

$\Rightarrow g \propto 1/R^2$

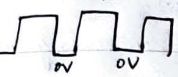
In computer : Logical 0 : L0 = 0V , Logical 1 : L1 = 5V — TTL (Transistor Transistor Logic)

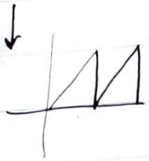
L0 ⇒ -12V , L1 ⇒ +12V — CMOS



For transmitting data through medium, data has to be ———? by some physical quantity (V, I, E-field, Magnetic-field, light) in a convenient form (suitable value)
(V = voltage, I = current)
, put on transmission medium is called signal

SIGNAL
- Analog → continuous   $s = f(t)$ → eg: sine wave, cos wave, any cont. signal
- Discrete (discontinuous) → digital   $s(t) = f(t)$
  ↳ others

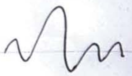


(Discrete triangular wave)

ANALOG SIGNAL TYPES → sine

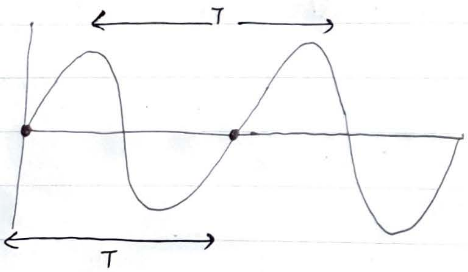
↳ other continuous signal



DIGITAL : signal
$s(t) = f(t)$

$s(t) \leq f(t+T) = f(t)$ [This shows periodicity]
T → constant (time pd. of repetition)

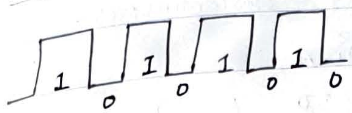
Sine is a continuous periodic signal



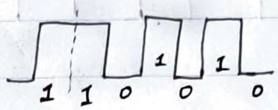

$f(t+T) = f(t)$

• Tanenbaum

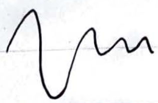
Periodic digital signal




Non-periodic digital signal



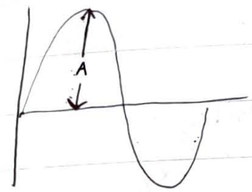

other continuous signals :

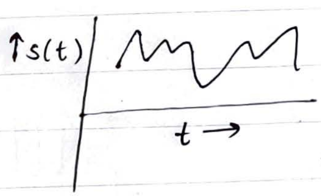


→ periodic
→ non-periodic

• sine signal is a continuous periodic analog signal
↳ fundamental signal for communicatⁿ having a signal frequency

freq, $(f) = \frac{1}{T}$ & Power (P) $\propto A^2$ where
A = Amplitude



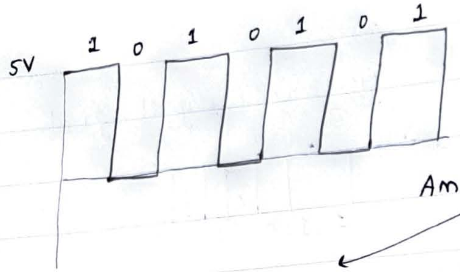

→ If it is periodic, then according to Fourier series,

$$s(t) = \frac{C}{2} + \sum_{m=1}^{\infty} A_m \sin 2\pi m f t + \sum_{m=1}^{\infty} B_m \cos 2\pi m f t$$

when $C \neq 0$, ~~DC signal~~ Discontinuous signal

for continuous signal, $C = 0$

for sine signal, $C = 0$ & cos factor $= 0$




On solving, $c = 2.5$

( $\Rightarrow$ discontinuous ), $B_n = 0$

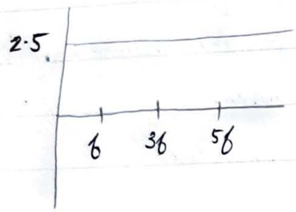
$A_m$ : $A_1 = A$ — amplitude for freq $= f$

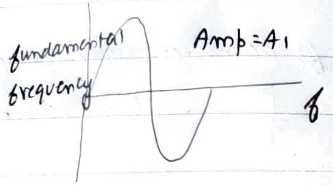
$A_2 = 0$

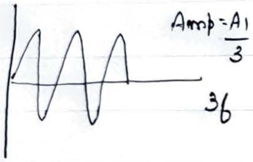
$A_3 = A_1/3$ — $3f$

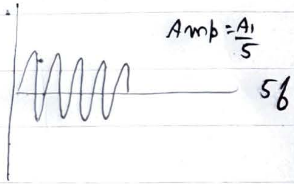
$A_5 = A_1/5$ — $5f$

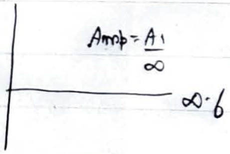
even components $= 0$



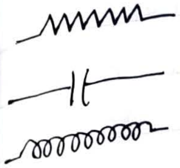

Due to sharp change in 0 to 1 or 1 to 0 we have $\infty$ frequencies.

Bandwidth of signal $= BW_{signal} = f_H - f_L = \infty - 0 = \infty$

$f_H$ → f highest freq.

$f_L$ → lowest freq.

- For non-periodic wave → for one duration : periodic, for another duration : other periodicity. Hence, every wave can be represented in terms of sine wave
- If $BW = \infty$ $\Rightarrow$ transmission medium can't work without it.



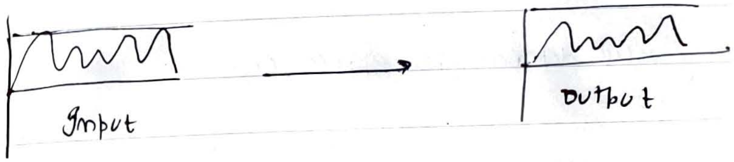
( Resistance ) → dissipates power in terms of heat

( Capacitor ) → half cycle : E field, half cycle : H field

( Inductance ) → one form to another conversion

There is a leading & lagging feature b/w voltage & current

RESISTANCE : Lowers power of signal with varying frequency by same amount ( NO signal deformation at ~~opposite~~ output side )




INDUCTOR : when encounters signal with higher frequency $\Rightarrow$ lowers its power by max. amt $\Rightarrow$ signal deformation at ~~opposite~~ output side

| WAVE FREQUENCY | POWER |
|---|---|
| $f$ | $p/2$ |
| $3f$ | $p/7$ |

similarily for capacitance

As '$f$' increases, amplitude decreases & power $\propto (\text{Amplitude})^2$

If Harmonic power is $\leq 1\%$ of fundamental frequency signal ⇒ No significance ∴ we define a cut off frequency eg if 1% is cut off freq

$f_c = 9f \Rightarrow \frac{A_1}{9^2} = \frac{A_1}{81} \Rightarrow 1\%$ (till here signal will contribute)

$0 \longrightarrow f_c$ (9f)  $BW_{se} = f_c - 0 = f_c$

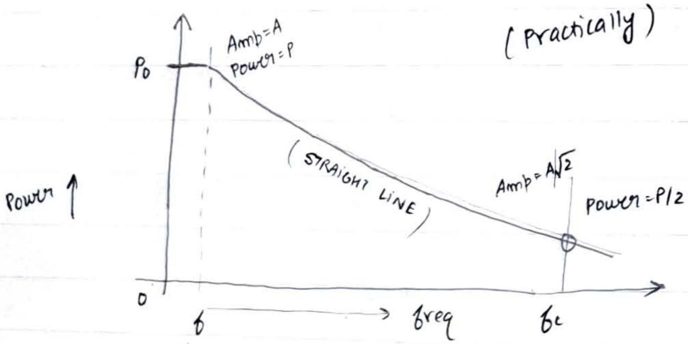
↓ effective

$f_{10}, f_{11} \ldots$ donot matter

- Cut off frequency value depends upon application

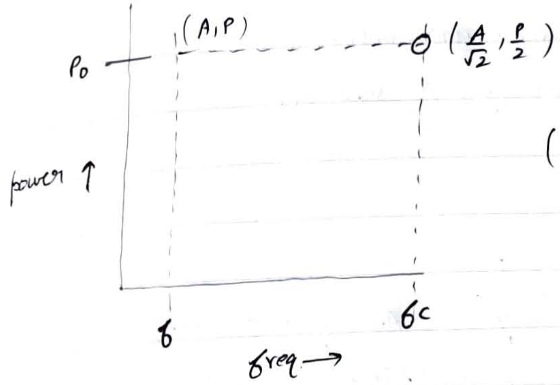
TRANSMISSION LINE CHARACTERISTICS

(Practically)




At freq = f, Power = P, Amp = A

At freq = fc, Power = P/2, Amp = $A/\sqrt{2}$




( Ideal Transmission line characteristics (theoretically))

transmission media → coaxial, UTP, twisted pair
↳ involves (R, L, C)

$BW_{t(e)} = f_c - 0 = f_c$
↓ effective

$BW_{s(e)} \leq BW_{t(e)}$

effective BW of transmission

effective BW of signal

$BW_{s(e)} \leq BW_{t(e)}$ condition so that signal deformation does not occur.

signal will be undisturbed / undistorted

Voice ( produced by nature intrinsically ) = Analog

composite ⇒ multiple frequencies together

Music voice (composite) 0 to 21.5 KHz ≈ 20 KHz

BW = ~~20 KH~~ 21.5 KHz

telephone voice (composite)

BW = 0 to 4 KHz

lower frequency ≡ max power ≡ max contribution

↳ voice recognition = lower freq are sufficient

Harmonics determine voice quality.

SIGNAL → voice → last page

↳ video (intrinsically) → Analog = 0-5 MHz

↳ Data (intrinsically) → Digital = $0 - f_c$

(if bits/sec (bps) is low ⇒ $f_c$ is low)

BW

space frequency → 60 GHz (generated), although ∞ can be sent

twisted pair → 500 MHz

coaxial → upto 2 GHz

optical fibre → 1 fibre = 10 GHz

ANALOG $\xrightarrow{\text{voice, video}}$ Analog transmission (trans. wrt medium) — form in medium

↳ Analog communication (~~from~~ source wrt destination form)

DATA → Digital : source (digital) destination (digital) (Digital comm.)

Transmission { coaxial, twisted pair, optical fibre } Digital or Analog transmission

- Analog signal is transmitted in analog form
- Digital signal is transmitted in analog/digital form.

ANALOG COMMUNICATION : voice & video are analog in nature

(TRANSMISSION — through media; COMMUNICATION — end to end)

air vibrations (in microphone, conversions take place)

↳ light is converted to electrical signal

↳ telephone : 0-4 KHz

Music : 0-20 KHz I our hearing range

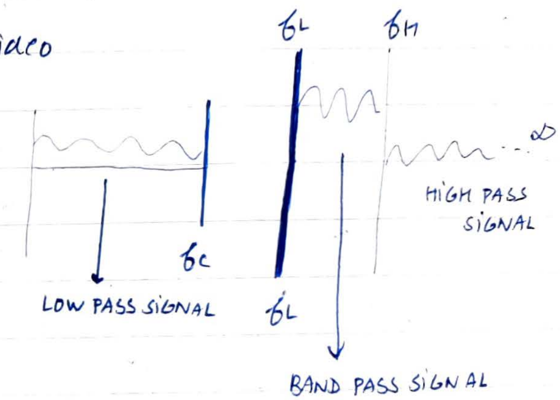
↳ it is a composite 'sin' signal

voice is identified by fundamental lower frequency

video : 0-5 MHz

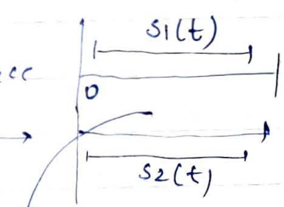
TV (television) = Music + video

3 QUALITIES OF SIGNALS




| MUSIC SIGNAL | STATION | |
|---|---|---|
| $s_1(t)$ | $T_1$ | 0-20 KHz |
| $s_2(t)$ | $T_2$ | 0-20 KHz |

↳ suppose we transmit it directly through space




There is no way to separate 2 analog signals if they get mixed up

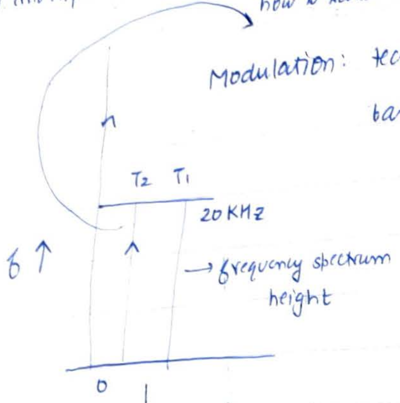
signals get mixed up for the rest of the transmission (interference)

ITU : Int'l Telecommunication Union (to coordinate amongst freq. range for diff. countries)

Broadcasting in coaxial cable should be done s.t interference is avoided for multiple stations.

how to transmit multiple signals of same freq. height?

Modulation: technique to convert low pass signal to band pass signal. Height of band pass signal is decided by the modulation technique



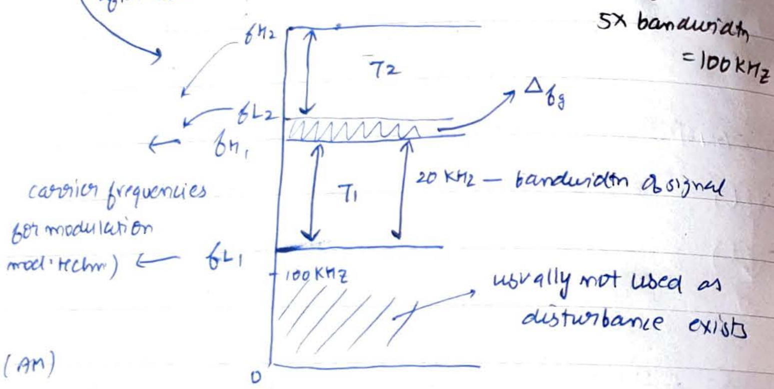

$f_{sm}$ = 4 KHz for voice

$f_{sm}$ = 20 KHz for music

↓

5x bandwidth = 100 KHz

after modulation




(AM)

AMPLITUDE MODULATION

If we choose $f_{c_1}$ as carrier freq. wave, low pass signal will convert to band pass signal of freq. range: $f_{L_1}$ to $f_{L_1}$ + (bandwidth of signal)
($f_{c_1}$) ($f_{H_1}$)

$f_{C_2} = f_{c_1}$ + bandwidth of signal + $\Delta f_g$

gap to avoid interference

$f_{H_2} = f_{C_2}$ + (bandwidth of second signal)

$\Delta f_g$ : guard band : the freq. range intentionally left b/w 2 transmitting signals to avoid interference

Through AM, multiple channels are created in space.

FREQ. DIVISION MULTIPLEXING :- By dividing total freq. spectrum of space, multiple channels are created. Each channel is a small portion of freq. spectrum

Guard Band is less within stations of same city & more within 2 cities stations.

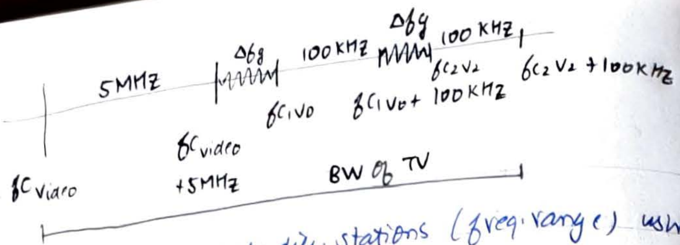
Each oscillator has a tuning frequency. This device is used for determining the carrier frequencies. Each oscillator has a crystal

Carrier frequency might misbehave due to temperature variation of crystal which might affect the signal quality of 2 neighbouring signals. ∴ Guard Band is maintained.

Crystal is used to tune the carrier frequency over the oscillator (frequency generating)
↳ decides tuning frequency.

TUNING PARAMETERS → Crystal
→ Inductor
→ capacitor

Value of tuning parameters depends on these values




A single signal can be tuned to diff. stations (freq. range) using different values of tuning parameters.

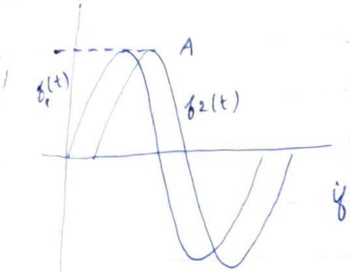
ANALOG ~~COMM~~ MODULATION → AM
→ FM
→ PM (not used commonly but ~ FM)

for modulation we require

$s(t) \rightarrow$ MODULATOR (AM/FM/PM)

it is a composite signal ← original signal $(S\sin(2\pi f_s t + \underbrace{\phi_s}_{\text{phase, not needed here}}))$

$c(t) = \underset{\text{amplitude}}{C}\sin(2\pi \underset{\text{freq.}}{f_c} t + \underset{\text{phase}}{\phi_c})$




$f_1(t) = A\sin(2\pi f t)$

$f_2(t) = A\sin(2\pi f t - \phi)$

if $f_2(t)$ wave starts before $f_1(t)$ wave

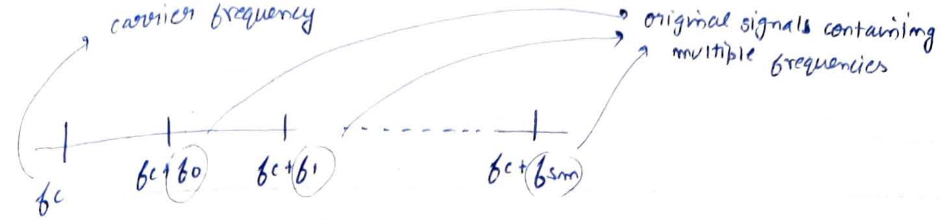
then $f_2(t) = A\sin(2\pi f t + \phi)$

↳ a notation of signal growth w.r.t a reference point

a cosine signal $= A\cos(2\pi f t) = A\sin(2\pi f t + \frac{\pi}{2})$

series of frequency remains the same in the modulated signal as well, ∴ the phase of the original signal doesn't matter

Carrier has a single frequency., while original has multiple freq. ∴ multiple modulated frequencies are obtained.




CHANNEL BANDWIDTH $= (f_c + f_{sm}) - f_c = f_{sm}$

In AM, frequency & phase are kept constant

$m(t)_a$: modulated wave of AM $= [C + K_a s(t)] \sin(2\pi f_c t + \phi_c)$ — ①

$K_a$: constant of modulation

amplitude of signal is changed proportional to this value

In FM, Amplitude & phase are kept constant

$m(t)_f = C\sin(2\pi(f_c + K_f s(t))t + \phi_c)$ — ②

In PM

$m(t)_p = C\sin(2\pi f_c t + (\phi_c + K_p s(t)))$ — ③

In ①, we can obtain multiple sine waves via trigonometry, comparatively easier to break when compared to ② & ③

In AM, $(C + K_a S \sin 2\pi f_{sm} t)\cdot \sin 2\pi f_c t$ is the modulated wave

$= C\sin 2\pi f_c t + K_a S \cdot \underbrace{\sin 2\pi f_{sm} t}_{B} \cdot \underbrace{\sin 2\pi f_c t}_{A}$ $(f_c > f_{sm})$

$= C\sin 2\pi f_c t + \frac{2}{2} K_a S \cdot \underbrace{\sin 2\pi f_{sm} t}_{B} \cdot \underbrace{\sin 2\pi f_c t}_{A}$

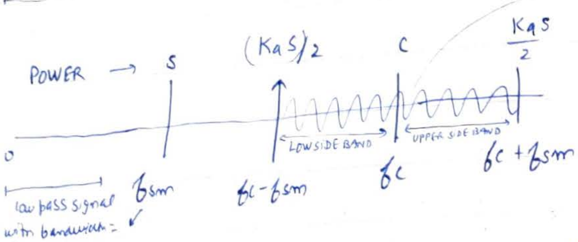
$= c \sin 2\pi f_c t + \frac{K_a S}{2} \cdot \cos(2\pi(f_c - f_{sm})t)$

$= c \sin 2\pi f_c t + \frac{K_a S}{2} \sin\left(2\pi(f_c - f_{sm})t - \frac{\pi}{2}\right)$

$= c \sin 2\pi f_c t - \frac{K_a S}{2} \sin\left(2\pi(f_c + f_{sm})t - \frac{\pi}{2}\right)$

time domain representation

time variation is not importance. frequency & power are the important factors.




→ center point of band pass signal

original signals are present either in lowerside or upper side band

BANDWIDTH OF THE SIGNAL → $(f_c + f_{sm}) - (f_c - f_{sm})$

$= 2 f_{sm}$ | $f_c - f_{sm}$

BANDWIDTH NOTATION

to know starting pt. for $2f_{sm}$ bandwidth

if we $\frac{1}{2}$ the bandwidth,

quality is affected. (not much)

If quality is not priority, we select only 1 of low side or upper side band (as compared to freq. range)

(mostly upper side band)

→ AM is used for AM radio broadcast

→ Video is also Amplitude Modulation

→ Audio in TV is FM

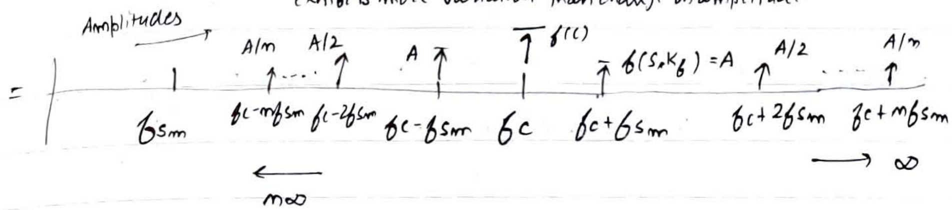
→ 90-108 MHz for FM

## FREQUENCY MODULATION

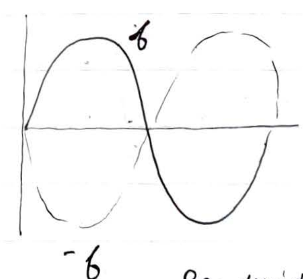
$m_f(t) = c \sin 2\pi(f_c + K_{f\,s(t)})\, t$

$= c \sin 2\pi(f_c + K_f S \sin 2\pi f_{sm} t)\, t$

exhibits more variation than change in amplitude




what is meaning of -ve frequency : 180° out of phase w.r.t original signal




As frequency ↑ses, amplitude proportionally ↓ses

power $\propto \frac{1}{(\text{frequency})^2}$

Bandwidth of modulated signal = ∞

$\boxed{m = 5}$, good quality signal

$m > 5$ : better quality signal but bandwidth increases

→ bandwidth of modulated signal (~~effective~~) = $10 f_{sm}$

bandwidth of modulated signal (effective) $= \frac{10 f_{sm}}{2} = 5 f_{sm}$

5 (Music bandwidth)

$= 5 \times 20\ \text{KHz} = 100\ \text{KHz}$

we only send the upper half of frequency band

Noise affects the amplitude much easily than frequency. ∴ FM has better signal quality w.r.t AM

| | | |
|---|---|---|
| | Telephone Voice | $\rightarrow$ 5 KHz |
| AM | Music | $\rightarrow$ 20 KHz |
| FM | Music | $\rightarrow$ 100 KHz (5 × 20 KHz) |

① TV Music (using AM) $\rightarrow$ 20 KHz
TV Video (using AM) $\rightarrow$ 5 MHz ] 5.02 MHz

② TV Music (using FM) $\rightarrow$ 100 KHz
TV Video (using AM) $\rightarrow$ 5 MHz ] 5.1 MHz

**BEST OPTION** FOR TV TRANSMISSION

③ TV Music using AM $\rightarrow$ 20 KHz
TV Vid using FM $\rightarrow$ 25 MHz ] 25.02 MHz

very high bandwidth, eyes won't be able to perceive quality of video using FM

~~TV Music Using~~
~~TV Video~~ using in ① & ② 5.1 ~ 5 & 5.02 ~ 5
& video is in AM for both (which is okay)

② − ① = 0.08 MHz results in high quality audio

Voice quality (①) < voice quality (②)

∴ ② is preferable

- Video should never be FM as we won't be able to appreciate the improvement and bandwidth would be very high.

TV has analog transmission & analog communication

we notice screen flickering in TV screen (& no change in audio) when AC or fridge compressor is switched on/off ∵ screen is AM.

## PHASE MODULATION

$$m_p(t) = C \sin 2\pi (f_c t + \phi + K_p s) t)$$

↳ not done due to equipment cost

Data can't be send to space in digital form

DIGITAL in original form — DIGITAL form

DATA (SOURCE) $\longrightarrow$ DATA (DESTINATION)

## DIGITAL COMMUNICATION OF MUSIC

we want to digitise voice, music, TV

SOURCE

Digitise ← voice, Music, Audio → originally analog

SOURCE END

originally ANALOG $\xrightarrow{\text{convert to}}$ DIGITAL

voice, music, Audio, video

DESTINATION

DIGITAL $\xrightarrow{\text{convert to}}$ ANALOG

voice, music, Audio, video

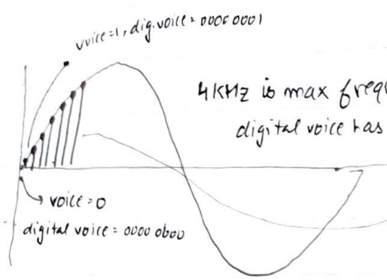
Process of digitisation of voice & music is same using Niquest Thm.

① How to digitise ?
② Advantage of digitisation ?
③ why digitise ?

---

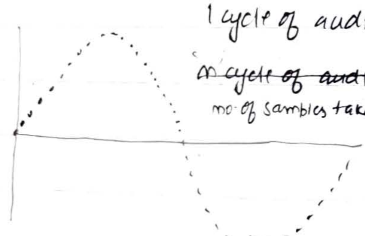
①

Voice has 4 KHz bandwidth ( mono )
Music " 20KHz " ( stereo )
↳ dual channels




4KHz is max frequency
digital voice has 8 bit expression

→ more the sampling, better the quality

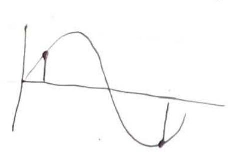


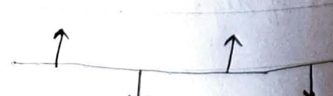
1 cycle of audio = 8 bits reqd.
~~m cycle of audio~~ = 8m ~~bits reqd.~~
no. of samples taken

↓
bandwidth
$= m \times 8 \times 4$ KHz
$= 32\,m$ KHz
if m >>> 0 ⇒ bandwidth very large

∴ this method is not preferred

Nyquest Thm : take m=2 = 64 ~~bps~~ Kbps , i.e. take only 2 samples per cycle





Periodic wave

we perform fourier analysis over the periodic waves after which we get a series of waves ( sine waves ) ( f, 2f, 3f .... ) Apply a filter at O/P at 4 KHz at the end to filter out the original signal

4 KHz ⟶ 64 Kbps
analog — digital bit rate

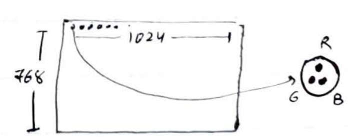
20KHz ⟶ m = 40 K samples / s

Digital Bit Rate for Music = $2 \times 20 \times 16$ Kbps
for stereo Music = $2 \times (2 \times 20 \times 16)$ Kbps

• mp3 ⟶ audio compression scheme 1280 Kbps ⟶ 128 Kbps
Video analog ⟶ digital

$1024 \times \left(\frac{3}{4} \times 1024\right) = 1024 \times 768$ (resolution)

R ⟶ $\alpha e^R$
G ⟶ $\alpha e^G$
B ⟶ $\alpha e^B$




red color is filtered first ~~and~~ all are filtered to proportional to electrical signal for that signal

↳ all are 8 bit digitally converted
∴ 1 pixel requires 24 bits for digital conversion
∴ after each 24 bits conversion, it is transmission

To convert a line = $24 \times 1024$ bits are to be stored
To convert a frame = $(24 \times 1024) \times 768$
since video is a series of frame ( eg: 50fps )
↳ $50 \times 24 \times 1024 \times 768$ bps
2 Mbps

2 Mbps ⟶ 6 Mbps

mpeg4 ⟶ video compression scheme

To avoid flickering of TV screen

↳ refresh alternate rows of frame

↳ first all odd rows & then all even rows

(25fps + 25fps)

Compression

↳ first send frame1 ⟶ send then difference of 2ND & 1ST ⟶

then send diff of 2ND & 3RD ....

Difference in frame is not large for still frames but high for moving frames ∴ we have variable bit rate (2Mbps to 6Mbps)

Through signal reshaping, we can repeat the signal to some extent, if -ve & +ve noise is within 0.5V level.

In case of more noise, Error recovery protocol (sliding window protocol (window size = 1) ⟹ stop & wait protocol)

For satellite link (long distance comm.) ⟶ | pipelining | ⟶ error recovery methods, selective repeat

go BACK N

(error detection)

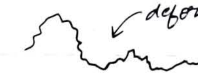
Q - why is digital better than Analog ?

DIGITAL V/S ANALOG TRANSMISSION

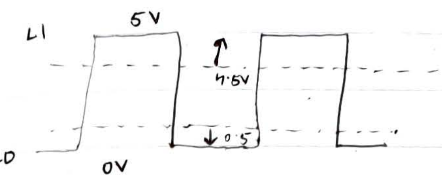
There exist 2 levels of difference

1) AT SIGNAL LEVEL { medium }

ANALOG ⟶ 

NOISE ⟶ 







L1 ⟶ 5V ( 4.5V or above )

LO ⟶ 0V ( 0.5V or below )

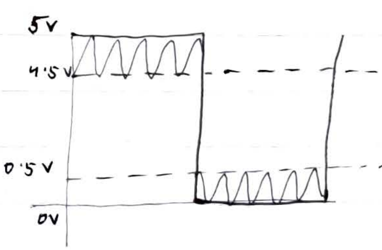
If there is

- -ve noise within 0.5V during L1 transmission
  ↳ increase voltage level to nullify effect

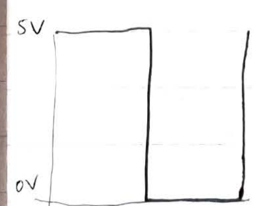
AND / OR

- +ve noise within 0.5V during LO transmission
  ↳ decrease voltage level to nullify effect

⟶ the result of this









For signal shaping : 4.5V is increased to 5V (L1) & 0.5V is reduced to 0V (LO)

This is called signal shaping. The process of reshaping signal & amplifying is called Digital signal regeneration. It is done by a device called repeater

—— 2) AT DATA LEVEL { processing }

There is no analog computer that can store the signal & process it

All digital computers can store digital data & process it. Signal shaping is possible for digital signal

| DIGITAL SIGNAL | ANALOG SIGNAL |
| --- | --- |
| • can be stored & processed by a digital computer (reshaping possible) | • can't be stored & processed by a computer (reshaping not possible) |
| • Encryption is possible during transmission for security | • NA |
| • Error detection is possible | • NA |

DATA COMPRESSION : Digital bps $\propto$ Analog Bandwidth (in Hz)

Empirical Rule (Formula)

When the data is compressed, the bandwidth of signal is reduced

At Receiver's end, decompression is done to get original data.

COMPRESSION is of 2 types

→ Lossy (still they work fine with voice & video)

↳ not useful for bank, military & other confidential areas

→

Error Detection is also an exclusive feature of Digital Data (by CRC)

| DIGITAL SIGNAL | ANALOG SIGNAL |
| --- | --- |
| • Reshaped | • Not Reshaped |
| • Store & Processing | • NA |
| • Error Detection | • NA |
| • Error Recovery | • NA |
| • Encoding - Decoding | • NA |
| • Data compression & decompression | • NA |

DIGITAL TRANSMISSION → wired (optical fibre, coaxial)

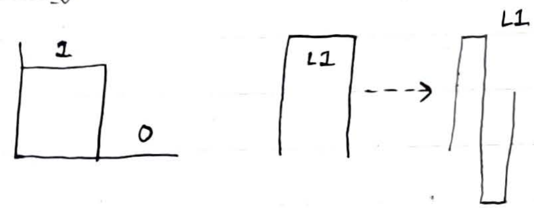
↳ space

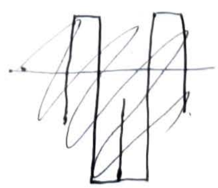
WIRED DIGITAL TRANSMISSION 

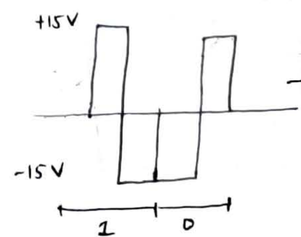
$S_1$ 

For transmissions, digital encoding is done (Manchester)

Manchester Encoding






→ Bipolar Encoding

• Read Manchester Encoding types

Sender clock & receiver clock may have varying speed in a limited way.

→ character by character data is sent

↑

Asynchronous transmission ⟺ Bipolar encoding

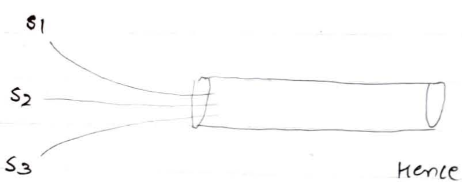
→ Bit slipping eg: 8 bits are sent at sender side ⟺ 12 bits processed by receiver

→ Multiple character transmission ⟺ synchronous transmission

In Manchester Encoding, along with data, clock is transmitted

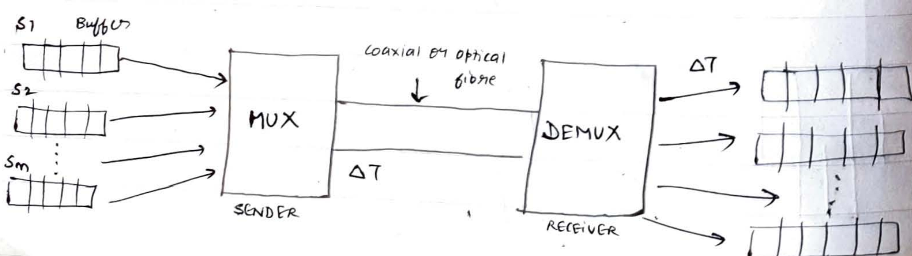
• clock signal (high to low, low to high)

→ Manchester is synchronous transmission




It's not possible for multiple sources to send data simultaneously, FDM not possible.

Hence TDM (Time Division Multiplexing) is used




At MUX, at one point of time (ΔT), S1 sends its data, then S2, then Sm
∵ time is divided.

At Receiver's End: in first ΔT time → S1's buffer is filled
in second ΔT time → S2's buffer is filled
⋮
in $n^{th}$ ΔT time → Sm's buffer is filled.

• TDM is possible only in coaxial / optical fibre. This TDM is synchronous

There is a possibility that ≥ 1 buffers are null at source end, ∴ to avoid error, padding is used to send some dummy data / characters to the receiver

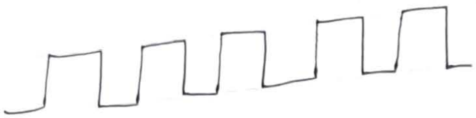
∴ TDM is called STDM (Synchronous TDM).

• STDM is not possible in space

| | DATA | TECHNIQUE | MEDIA |
|---|---|---|---|
| 1) Multiple source data | Analog | FDM | wired, space |
| 2) Multiple source data | Digital | FDM | space (TDM not possible in space) |

For 2) to be feasible,

Digital Data → DIGITAL MODULATION → Analog (Now FDM can be applied)


digital signal

low pass ) 0 —— fmax (digital signal after Fourier Analysis)

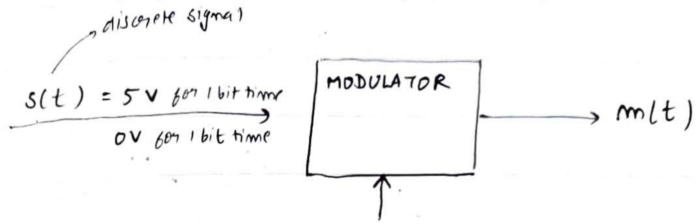
Digital signal is internally low pass signal

- Digital signal is converted to band pass analog signal & then FDM is applied by Digital Modulation

DIGITAL MODULATOR

| | DIGITAL | | ANALOG |
|---|---|---|---|
| (Amplitude shift key) | ASK | ← analogous → | AM |
| (Frequency shift key) | FSK | ←→ | FM |
| (Phase shift key) | PSK | ←→ | PM |

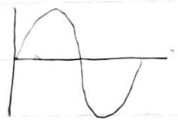
ASK (Amplitude Shift Key)




$c(t) = c \sin(2\pi f_c t + \phi)$

① BAUD / SIGNALLING ELEMENT : entity which will carry data through modulation

we can use one cycle of carrier as signalling element i.e. one complete cycle sends only 1 bit. 1 signalling element carries 1 bit

ct)  — ①

② SIGNALLING RATE / BAUD RATE : No. of signalling elements transferred per second

$\boxed{\text{logical one}}$ ⇒ 5V , $\phi = 0$ initially,

Amplitude of $m(t) = c + K_a s(t)$ ; $s(t) = 5V$

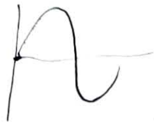
$= c + K_a \cdot 5$

$= c + 5K_a$

 higher frequency

$\boxed{\text{logical zero}}$ ⇒ 0V ; $s(t) = 0(V)$ $= c + K_a \cdot 0$

$= c$

 same as ①

we use this pattern for bandwidth calculation because

10101010 → generates max. changes (max. bandwidth reqd.)

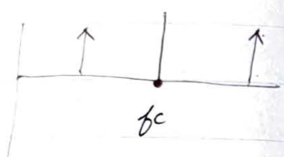
∴ we can send any signal from that bandwidth

↳ has baud rate = $B_r$


this is a composite wave, & not a pure sine wave

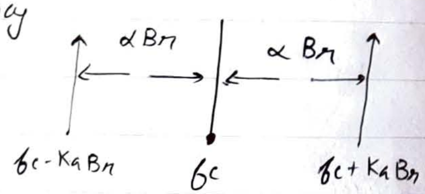
This is denoting multiple sinewaves from perspective of Fourier

m(t) is changing at the rate of $f(c)$




$2B_r$ : generates more changes w.r.t $B_r$, change will be 2X than the change in ②

Baud Rate ~~Br~~ ∝ ~~Higher~~ Frequency




if $K_a = 0$ ⇒ no modulation

$K_a = 1$ ⇒ ~~2x~~ Bandwidth $= 2 \times B_r$

$= f_c + B_r - (f_c - B_r)$

$= 2B_r$

$K_a = \frac{1}{2}$ ⇒ Bandwidth $= B_r$ $(f_c + \frac{1}{2}B_r) - (f_c - \frac{1}{2}B_r)$

$\text{Bandwidth}_{ASK} = B_r$

Baud Rate

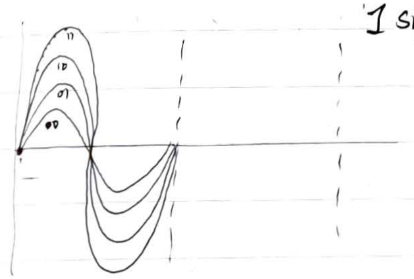
If bandwidth of a channel, $BW_{CH} = 4\,KHz$, then $B_r = 4$ KBPS

⇒ Bit Rate $= B_r \times$ (no. of bits per baud)

$= B_r$ ↳ = 1 in this case

⇒ $BW_{CH} = B_r$

If we use 4 levels of signalling instead of 2 in ② (frequency remains same)

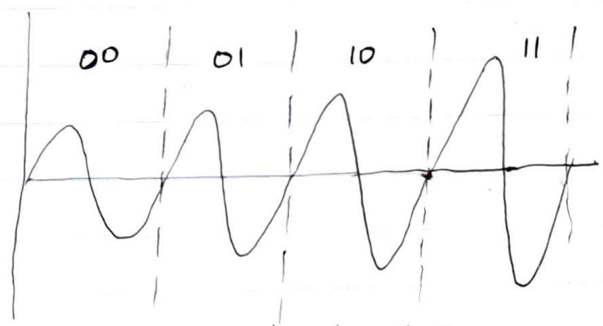



1 signal element = 2 bits

as we have $2^2 = 4$ levels

2 bits are taken from buffer

eg: Buffer = 00 01 10 11




Modems are microprocedure based controllers

~lar to 101010 of 2 level signalling only diff. being in powers

00110011 0011 : generates max bandwidth (max change pattern)

1010101010 1010 : generates min. bandwidth : continuous sine wave

4 level signalling won't have very different bandwidth from 2 level signalling

$BW_{CH} = 4KHZ$, $Br = 4$ KBPS, bit rate (br) $= (4 \times 2)$ Kbps

i.e. $Br = BW_{CH}$ & $br = BW_{CH} \times \log_2(\text{no. of levels})$

$= BW_{CH} \times \log_2(V)$

No. of signalling levels $\propto \dfrac{1}{\text{Gap } \cancel{\text{diff}} \text{ b/w 2 consecutive level's amplitude}} \propto$ Noise

Let $C_{max}$ be amplitude of highest signal level

Let $C_{min}$ " " lowest " "

$$V = \frac{C_{max} - C_{min}}{\Delta V}$$

There is a limit on no. of levels → 1) depends on power of ~~more~~ equipment

2) signal quality $\propto \frac{1}{\Delta V}$

SNR : signal to noise ratio

$$= \log_{10} \frac{\text{signal value}}{\text{noise value}}$$

VGA: 640 × 480 (3:4)

SVGA: 800 × 600

XVGA: 1024 × 768

4K: 3840 × 2160

UHD: 4096 × 2100

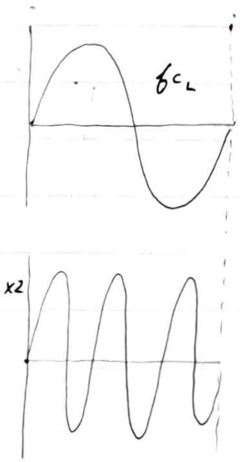
7K: 7680 × 4320

MOTOROLA 16K: 15360 × ~~1680~~ 8640

New Aspect Ratio = $\frac{3^2}{4^2} = \frac{9}{16}$

not used because given a bandwidth the baud rate reduces.

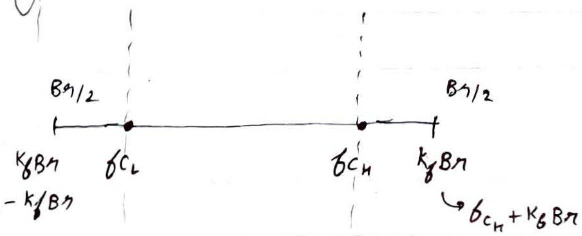
FSK (FREQUENCY SHIFT KEY) : 2 carriers — high freq, low freq




Logical low = 0 denoted by low freq.

Shift will be ×2, Bandwidth will be ×2 & Baud Rate is doubled

Logical High = 1 denoted by high freq.



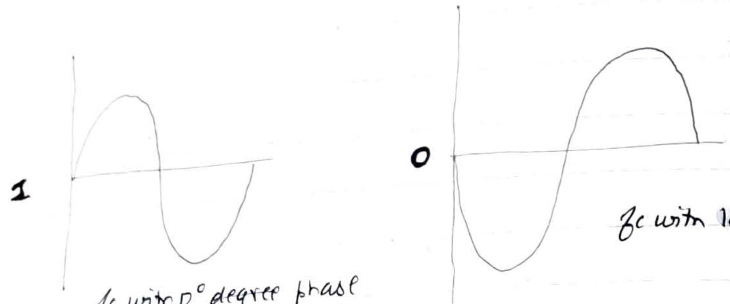

$K_f = \frac{1}{2}$

$$BW_{fsk} = \left(f_{c_H} + \frac{Br}{2}\right) - \left(f_{c_L} - \frac{Br}{2}\right) = f_{c_H} - f_{c_L} + Br$$

$$\Rightarrow Br = BW_{fsk} - (f_{c_H} - f_{c_L})$$

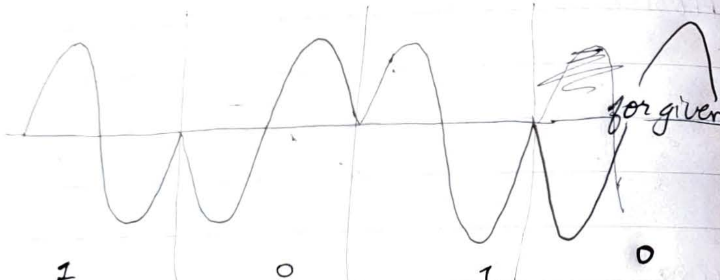
Phase is not sensitive to noise like ASK

PSK ( Phase shift key )



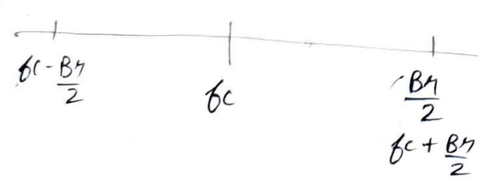

fc with 0° degree phase

fc with 180° phase

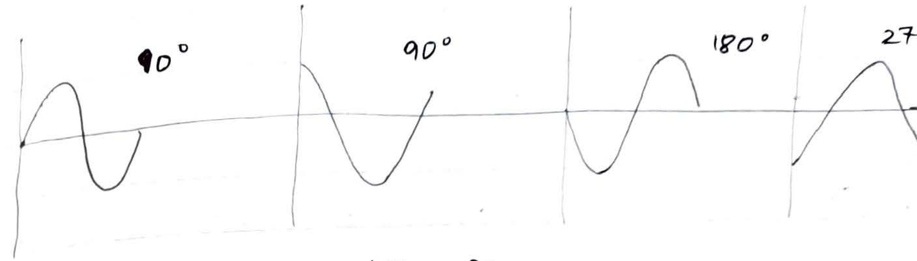



for given Br

If we 2 x Br reflects more changes




In 2 levels, we can send 2 bits per baud.



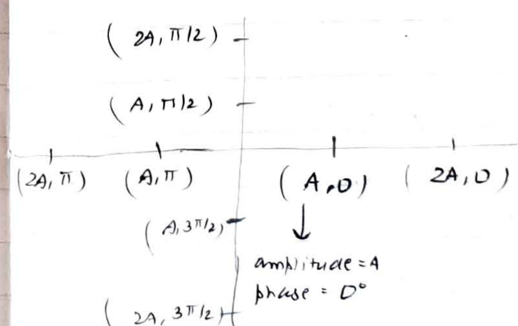

Effective Bandwidth = Br

Bit rate = Br x $\log_2 4$

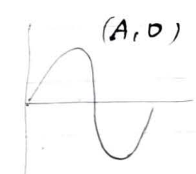
ASK v/s PSK : Choose PSK as ASK is much more sensitive to noise.

QUADRATURE AMPLITUDE MODULATION ( QAM ) ( ASK + PSK )

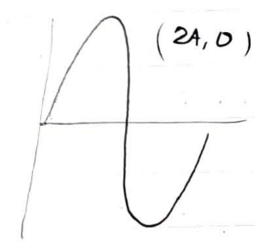
If 2 A levels & 4 P levels ∴ 8 combo.




000

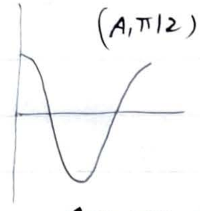



001




ADV : Instead of 1 entity, we get product of 2

010




011


ans soon for other combo.

Max phase → 000 001 010 011 100 101 110 111 → gives max BW

Baud Rate will remain same

BW ∝ Br

Bit rate = ~~BW~~ Br $\log_2 V$

= BW $\log_2 8$ in this case

= 3 BW

We can perform till $PSK_{16}$ without any issues

$QAM_8$ ⇒ levels = 8

based on QAM

~~[illegible]~~ MODEM max bit rate = 33.4 Kbps

At Digital MODEM = 56Kbps

QAM is still used in space communication

ADSL: Asynchronous Digital subscriber loop.

Telephone line is usually CAT4.

4K ~~is~~ filter is allocated before passing to telephone line

1 Gigabit − 4K ≈ 1 Gigabit

Minor syllabus till QAM

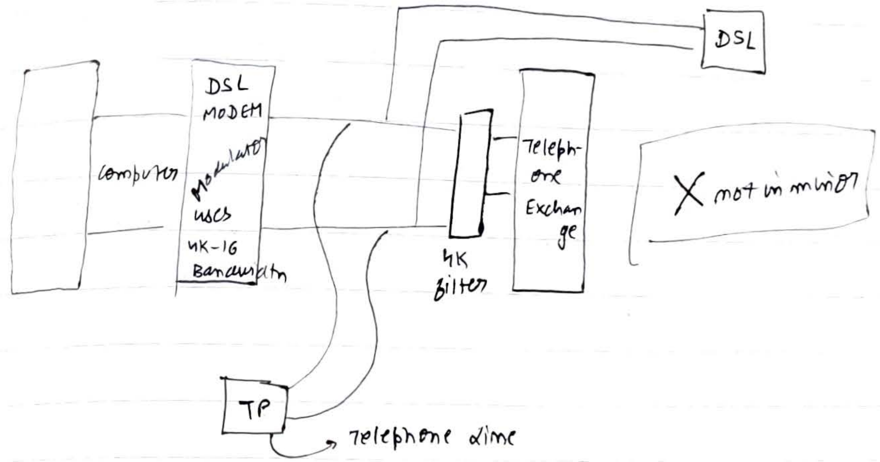
V = 64 ($2^6$) , V = 128 ($2^7$)

4K × 6 = 24 Kbps

4K×7 = 28 Kbps

Max attainable = 32 Kbps

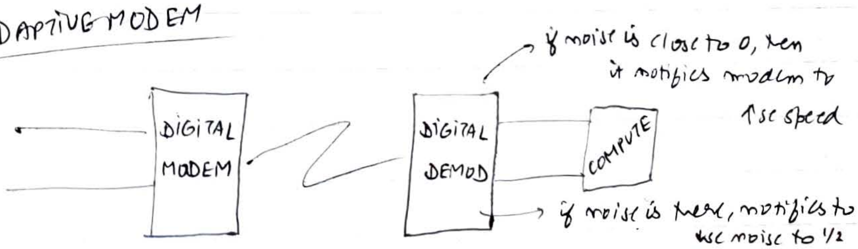
PSK8, $QAM_{16}$, $QAM_{32}$, ...... → used in space (no ASM used)




1 GHz ~~BW~~ BW is splitted into 4K splits of BW & we modulate them individually.

↳ so that noise only affects that particular split

ADAPTIVE MODEM




Initially the modem will connect at lowest speed at which noise won't affect the transfer