22/1/20

MCS - 20

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Mobile & Satellite Communication Network

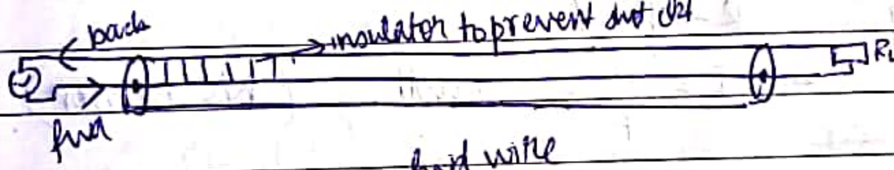
Communication → Wired Network Communication
- wired Medium → unshielded Twisted Pair cable (UTP)

Communication → Wireless

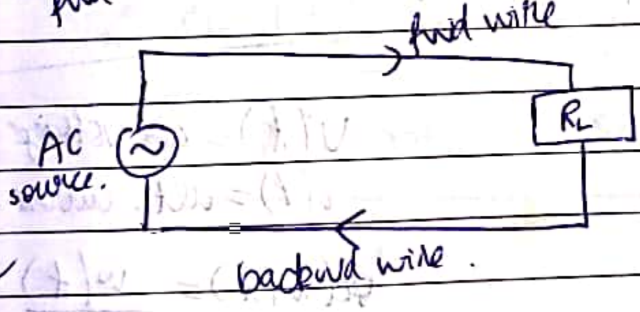
Network - autonomous computer connected through several links (links made through various medium

Wired medium

1. UTP
2. co-axial cable (eg TV lines



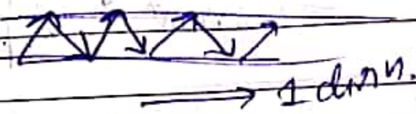
metallic wire inside cylindrical pi...



load (consumes power.

3. Optical Fibre

In optical medium, light travels only in 1 dirⁿ, through Total Internal reflection



- used for large distance commⁿ.

at one end el. s/g conv to light s/g & at receiving end a light s/g conv back to el. s/g. Therefore 1 optical fibre in fwd dirⁿ & 1 optical fibre for backward dirⁿ

Wireless

Medium is space

signal here is called Electro Magnetic field

E field (el. field) — Voltage

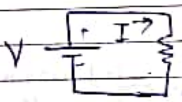
H field (Mag field) — Current

Time varying el or mag field carries s/g

Note:

No commn is possible for constt source supply

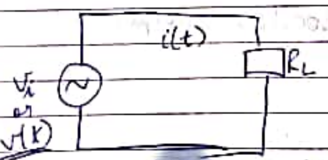
Axiom of Commn → if no change is signal, then commn is not possible / meaningful.



V → constt

R → fixed

$\Rightarrow I = \frac{V}{R}$ = constt. (No commn)



$v(t)$ = alt. voltage

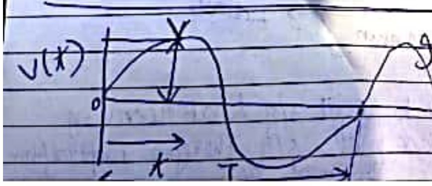
$i(t)$ = alt. current

alt $i(t) = \frac{v(t)}{R}$

Now with AC source

time varying & dirn varies

$\Rightarrow$ Commn is possible



In generator.

sinosuidal s/g

T = Time period of sinusoidal s/g

= Time for 1 signal

$\therefore \boxed{v(t) = \underbrace{V}_{\text{Amplitude of wave}} \sin\left(\frac{2\pi t}{T}\right)}$ — (1)

In every cycle dirn & mag of current changes in the signal.

In 1 T sec → 1 cycle

1 sec → $\left(\frac{1}{T}\right)$ cycle $= f$

t secs → $\left(\frac{t}{T}\right)$ cycles.

\# of cycles per sec of AC voltage s/g is called cyclic frequency. SI unit is Hertz (Hz).

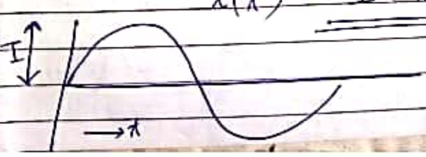
$\therefore$ eq (1) can be rewritten as.

$\boxed{v(t) = V \sin 2\pi f t}$ — (2)

If voltage is sinusoidal $\Rightarrow$ Current is also sinusoidal

$i(t) = \frac{v(t)}{R} = \left(\frac{V}{R}\right) \sin 2\pi f t$

$i(t) = I \sin 2\pi f t$



$I = \frac{V}{R}$ (ohm's law)

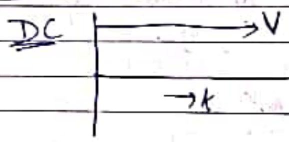
Amplitude = highest deviation ~~of~~ from 0 value

= $|$max deviation ~~of~~ from zero scale$|$

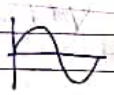
Elements in a Ckt — value of Resistor is Resistance

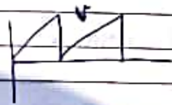
		Unit
R -	~~Resistance~~ Resistor	Ω (ohms)
C -	Capacitor	F (Faraday)
~~I~~	~~Inductor~~	
I	Inductor.	H (Henry)

DC



For Commⁿ, we'll use sine signal (continuous s/g)

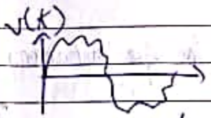




(time varying s/g) (Not continuous) (saw tooth s/g) ultra

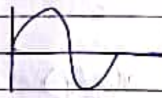
Signal are of 2 types.

① Analog (Continuous)



(Noise affected s/g but is continuous)

Any s/g which holds Principle of continuity of calculus is analog in nature.

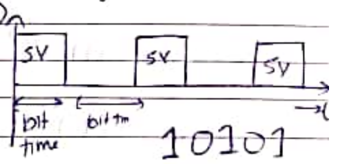


Sine s/g is the most basic & fundamental analog s/g

Any cont s/g is actually a collection of sine s/g.

Lt hand Lt = Rt hand Lt (at all pts ⇒ Continuity).

② Digital [logical 1 → 5V, logical 0 → 0V]



10101

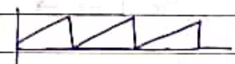
It is a discrete s/g → Non continuous (non analog)

Shape → square / Rectangle

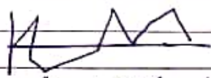
eg → Digital data

another eg

eg



eg



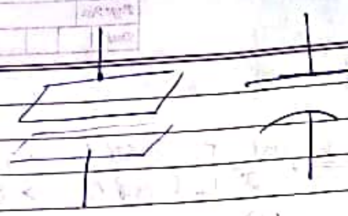
Lt hand Lt ≠ Rt hand Lt (at any pt ⇒ Non-cont s/g)

~~Imp~~ CCP

① $i(t) = \frac{v(t)}{R}$ $\Rightarrow v(t) = i(t).R$ time varying s/g

$v(t) = \frac{q(t)}{C}$

(ii)



voltage across cap $\propto$ amt of charge put across

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

$$v(t) = \left(\frac{1}{C}\right) q(t)$$

$$= \frac{1}{C} \int i(t)\, dt$$

suppose in time Δt charge is ΔQ for small time $dt \rightarrow dq(t)$

in 1 sec $\rightarrow \frac{\Delta Q}{\Delta t}$ in 1 sec $\rightarrow$

$$\Rightarrow i(t) = \frac{\Delta Q}{\Delta t} \quad (\Delta t \rightarrow 0)$$

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

$$\Rightarrow dq(t) = i(t)dt$$

$$\Rightarrow \int dq(t) = \int i(t)\, dt$$

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

$$v(t) = \frac{1}{C} \int i(t)\, dt$$

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

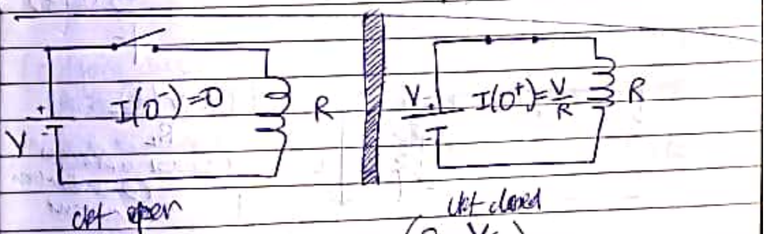
(iii) All coils are called Inductor.

eg choke of fan, compressor of AC, refrigerator.

$v(t) = L \frac{di(t)}{dt}$ $v(t)$ = back emf

$\delta = \frac{1}{R}$ (conductor)

voltage across inductor $\propto$ change of current across inductor



change in current $= \left(0 - \frac{V}{R}\right) = \frac{V}{R}$ in

time $(0^+ - 0^-) = 0^+$ (a bit greater than 0)

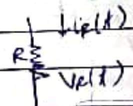
$\Rightarrow$ Rate of change of current $\rightarrow \infty$ $\left(\frac{0 - \frac{V}{R}}{0^+}\right)$

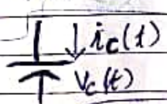
= ∞ back emf
⇒ opposes current

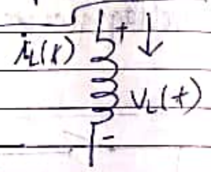
⇒ Current through Inductor never changes instantly.

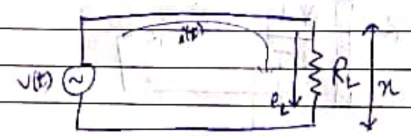
$V_L(t) = L\frac{d(i)}{dt}$. Even for AC voltage source / there will back emf.

Crux

* $i_R(t) = \frac{V_R(t)}{R}$ ⟶ 

* $V_C(t) = \frac{1}{C}\int i_C(t)$ ⟶ 

* $V_L(t) = L\frac{di_L(t)}{dt}$ ⟶ 



$i(t) = \frac{v(t)}{R_L}$

here current is known as conduction current

$e = \frac{dv}{dx}$ = voltage / length

el field

$e(t) = \frac{dv(t)}{dx}$

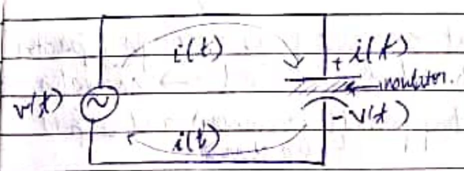
Ampere circuital law - mag field $\int h(t)$

d. power

$p(t) = v(t) \cdot i(t)$ (dot product dirn is same $v(t) \cdot i(t) \cos 0$ $v(t) \cdot i(t)$)

el. power & el field is along the wire & also mag field is along the wire
⇓
Guided Electromagnetic field.

Instead if we place capacitor.



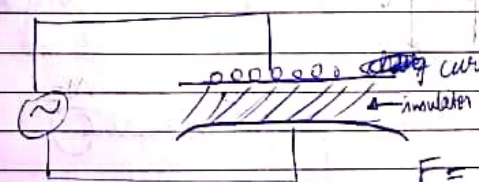
current constituted by free electrons is called conduction current.

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

$i(t) = C\frac{dv(t)}{dt}$

(outgoing current)

~~Although~~ Current flowing through insulator is imaginary) (displacement current)



current accumulated / deposits on upper plate

$F = \frac{\epsilon Q_1 Q_2}{r^2}$

(Colomb's law).

Q_1 Q_2

ϵ = dielectric constt. (depends upon medium)

Q ——— 1 unit, distance r

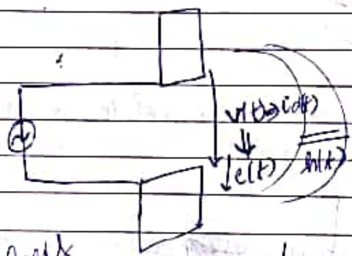
$$F = \frac{\epsilon Q \cdot (1)}{r^2}$$

varying charge will get ~~developed~~ deposited at one plate which will give rise to varying current

$\therefore$ 2nd plate will also get charge developed due to el field

$\therefore$ Actually current does not flow through capacitor But charge gets deposited due el. field $\Rightarrow$ through insulator current is also getting passed (imaginary) and el. field is also developed (disp current)

(Time varying conduction current) = (Time varying disp current)



dielectric (air space is the medium)

Here el. field & mag field are exposed to space N along with

m_1 —— r —— m_2

$$F = \frac{\mu m_1 m_2}{r^2}$$

if $m_2 = 1$

$h(t) = \mu m_1$

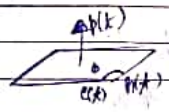
$\mu \Rightarrow$ depends upon medium

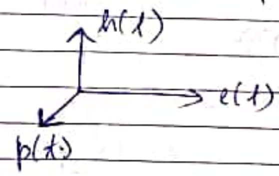
(power)

$$\vec{p}(t) = \vec{e}(t) \times \vec{h}(t) \quad \text{(cross product)}$$

$$\|p(t)\| = e(t)\, h(t) \sin\phi$$

$p(t)$ is $\perp$ to $e(t) - h(t)$ plane.





Energy: $E(t) = \int p(t)\,dt$

Power = Rate of consumption of Energy.

Power in the prev ckt will be radiated ~~through~~ in the space

EM power can't penetrate conductor, it reflects back completely.
But Insulator can do the reverse.

In, Congested areas, due to multiple fading, power does not enter.

corpuscular = particle mode.

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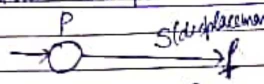
Through EM wave — we transfer EM energy

1) Particle mode of Energy transfer } Modes of transfer of Energy
2) wave mode of energy transfer

1) Particles move from source to destination.



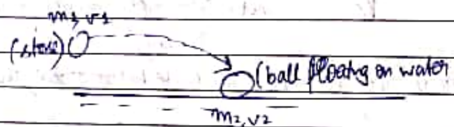
velocity = v

Energy (E) = $\frac{F \cdot S}{m f}$

m = mass

$s = ut + \frac{1}{2} f t^2$

$$\boxed{E = \frac{1}{2} m v^2}$$



A.T. law of conservation of Momentum.

$m_1 v_1 = m_2 v_2$

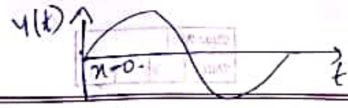
body actually moves from src to destination.

2) When mass → 0 both particle & wave mode of energy transfer can be observed (dual nature)

Electrons → both particle & wave mode of energy transfer.
and photon

When you disturb the still water / elastic medium)

It will start simple harmonic motion (SHM)



sinusoidal motion.

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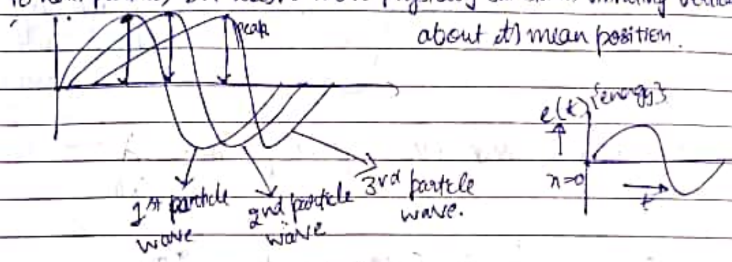
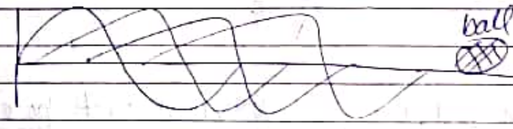
Due to disturbance in source point, energy will transfer to next particle, but does not move physically but starts vibrating vertically about its mean position.



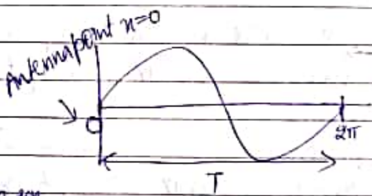
The peak corresponding to each wave moves in 1 dirn. & ball will start moving eventually due to energy transfer.



$Y(t) = Y \sin 2\pi f t$

At $x = x'$

$Y(x) = Y \sin \frac{2\pi}{\lambda}$



In time = T $\xrightarrow{\text{angle gen}}$ 2π

In time = 1 → $\frac{2\pi}{T}$

in time t → $\frac{2\pi t}{T}$

as $\frac{1}{T} = f$ (freq)

⇒ $2\pi f t$

At $x = x'$

$\boxed{e(t) = E \sin 2\pi f t}$ (variation wrt time)

At $t = t'$

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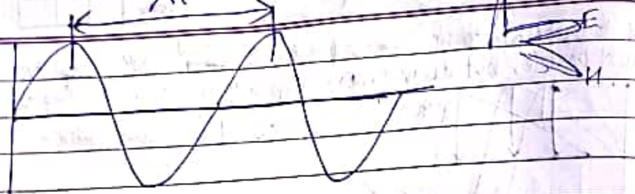
λ (wavelength)



dist b/w 2 consecutive in phase points $= \lambda$
change in angle " " " " $= 2\pi$

In unit time change in angle $= \frac{2\pi}{\lambda}$

for $x \longrightarrow \frac{2\pi x}{\lambda}$

$$\boxed{e(x) = E \sin \frac{2\pi x}{\lambda}}$$ (variation wrt space)

Variation together in terms of space & time

$$\boxed{\vec{e}(t,x) = E \sin\left(2\pi f t + \frac{2\pi . x}{\lambda}\right)}$$ (El. field) (Wave eqn)

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

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

(Mag field)

Note:

$$\boxed{v = f\lambda}$$

$T \longrightarrow \lambda$
$1 \longrightarrow \frac{\lambda}{T}$
$v \rightarrow \frac{\lambda}{T} = \lambda f$

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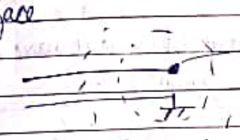
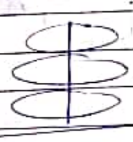
Wavefront $\rightarrow$ same phase pts
adjoining peak points will form a sphere.
But if radius $\approx$ v-v large it tends to appear as a planar surface

$r \Rightarrow$ very-2 large



Over long distances, wave appear to move as plane.



(space) E, M

(voltage induced)

H field induced at the

(sender antenna)

(Rcvr antenna)

$e\cos\theta \Rightarrow$ component of current

If at Rcvr end, e field is not $\perp$ like

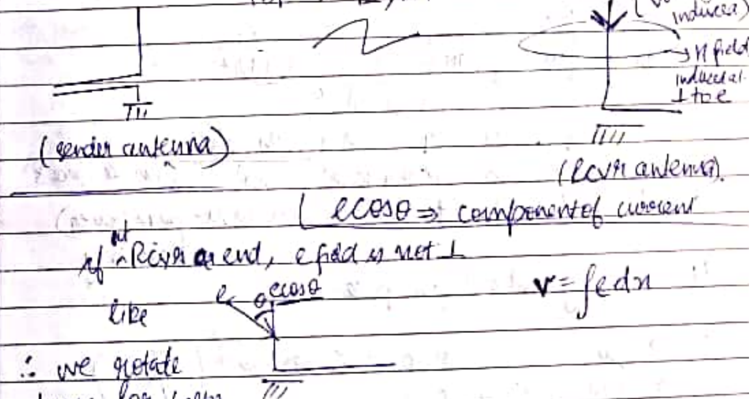
$e\cos\theta$

$v = \int e\,dx$

$\therefore$ we rotate antenna for better s/g catching

$f = 0 \Rightarrow \frac{1}{T} = 0 \Rightarrow T = \infty$

$\Rightarrow$ DC voltage



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EM spectrum — near the surface of earth — medium — ionosphere — shortwave — TV, FM Radio — LF (low freq) — HF = high freq — Ultra — UHF — super — SHF

0 —— ~KHz —— MHz —— 2 GHz —— MHz —— 40 GHz —— 60 GHz

$\longrightarrow f$

A wave having freq > 2 GHz is called microwave & its beam is very sharp. (Line of Sight Commⁿ)

P_0 (Antenna 1) —— r —— (Antenna 2) $P_r = \frac{C P_0}{r^2}$

(when env. clean).

Power ↓ with ↑ in distance

If Antenna spherical propagation $P_0 \to \frac{P_r}{(4\pi)r^2}$ (const)

Variation in Power of Microwave

(1) In a free space & clear sky, vary with distance

(2) fog & rain (absorbs microwave power) {has free space}

(3) Vegetation (leaves of trees also absorb μ-wave power) {has clear sky}

(4) clear sky but not free space

(1) → has both free space & clear sky

(2) → has only free space

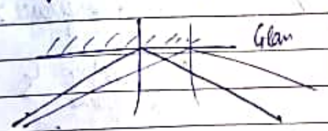
(3) → has only clear sky

(4) Fading due to multiple paths (Multipath Fading) due to obstacles like mountains, buildings, homes, etc.

Conductor → Metal

Insulator → Wall, glass

(A) Light follows reflection & refraction, so does μ-wave.



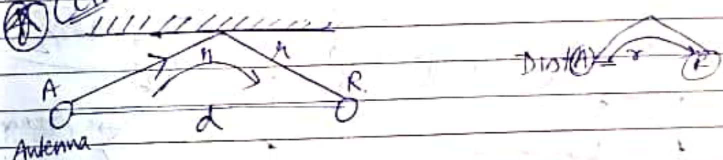
EM waves { In Insulator — reflection + refraction; In Metal → No refraction, only reflection }

Refraction obeys snell's law

In glass → ∥ᵉˡ beam incident ⟹ ∥ᵉˡ beam reflected

In rough surface → ∥ᵉˡ beam ⟹ scattered.

(B) CLIP



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

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

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

$$\boxed{e_e = e_d + e_r}$$

effective

case (1) $r > d$

$r = d + \lambda$

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

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

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

case 2

if $r = d + \frac{\lambda}{2}$ {destructive interference}

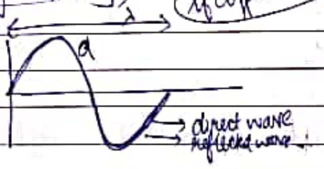
$e_e = E\left[\sin\left(2\pi f t + \frac{2\pi d}{\lambda}\right) + \sin\left(2\pi f t + \frac{2\pi}{\lambda}\left(d + \frac{\lambda}{2}\right)\right)\right]$

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

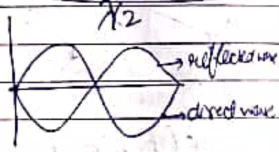
$= 0$ [Multipath fading]

Diagramatically

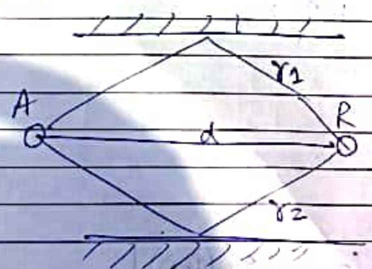
if difference $= \lambda$



if difference $= \lambda/2$



Q. If we have 2 direct waves ??



$r_1 \to \lambda/2$

$d \to$ direct wave

$r_2 \to \lambda$

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

$e_{r_1} = E\sin\left(2\pi f t + \frac{2\pi}{\lambda}\left(d + \frac{\lambda}{2}\right)\right)$ — (2)

$e_{r_2} = E\sin\left(2\pi f t + \frac{2\pi}{\lambda}(d + \lambda)\right)$ — (3)

Adding (1) + (2) + (3)

other 2 will cancel out

$\Rightarrow$ No multipath fading, one wave will be left.

Q. d, $r_1 = d + \frac{\lambda}{2}$, $r_2 = d + \frac{\lambda}{4}$

Adding the 3, These will cancel out

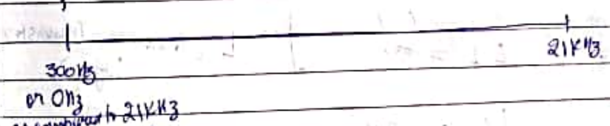
This will be left

$\lambda \to 2\pi$

$\frac{\lambda}{4} \to \frac{\pi}{2}$

No multipath fading

frequency (voice box (larynx) or music)



frequency / voice box larynx (Music)

300 Hz ——— 21 KHz.

or 0 Hz

as compared to 21 KHz

5/2/20

Knowledge

Computer — Information — Data

In

(101010)... pattern ⇒ data

101010 = Roll No. or Marks ⇒ Information.

(data) + (meaning attached) ⇒ (Information.)

(Knowledge) → relationship b/w different information

eg	Distance	Force of gravity
	—	—
	—	—

only this table given ⇒ Information

when we discover a relation b/w Dist & Force of gravity ⇒ knowledge

$g = \frac{GM}{R^2}$ → eg of Knowledge

accn due to gravity.

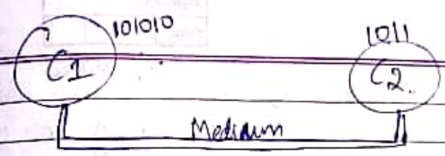
as G, M → const for each

$g \propto \frac{1}{R^2}$

In computer.

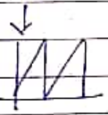
{Logical 0} (L0) = 0V
{Logical 1} L1 = 5V] TTL (Transistor–Transistor logic)

L0 ⇒ −12V
L1 ⇒ +12V] CMOS



[For transmitting data through medium,
data has to be encoded by some physical quantity (V (voltage), I (current), E field, H/I-field, light)
in a convenient form (Suitable value), put
on transmission medium is called (signal)]

Signal
- (Analog) → Continuous $s = f(t)$ → eg sine wave, cosine wave → any cont s/g
- (Discrete) (Discontinuous) → (Digital) $s(t) = f(t)$ → 15V (L1) 0V (L0)
  - → others. ↓ eg



Discreet (triangular wave).

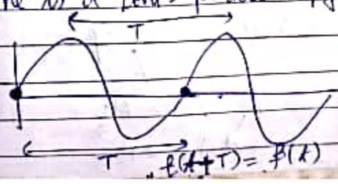
Analog s/g types → sine
→ other cont. s/g eg

Dig s/g — $s(t) = f(t)$

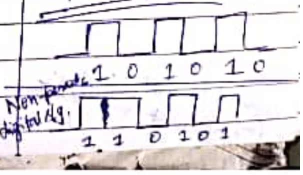
$s(t) \leq f(t+T) = f(t)$ — This shows Periodic s/g

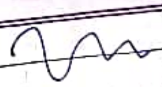
T → const (Time period of repetition.

Sine is a cont. periodic s/g.

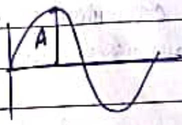


Periodic digital s/g.

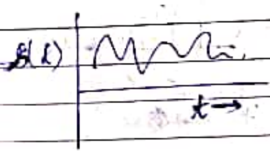


other cont. s/g:  → periodic → non periodic.

* Sine s/g is a continuous periodic analog s/g.
  ↳ fundamental s/g for commⁿ having a s/g freq.

freq $(f) = \frac{1}{T}$, 

and → Power $(P) \propto A^2$
A = Amplitude



If it is periodic, then acc to Fourier series

$$s(t) = \frac{C}{2} + \sum_{n=1}^{\infty} A_n \sin 2\pi n f t + \sum_{n=1}^{\infty} B_n \cos 2\pi n f t$$

C = const

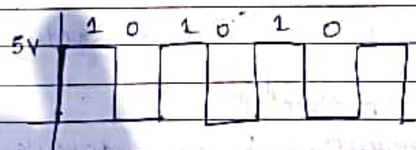
when $C \neq 0 \Rightarrow$ DC s/g.

for cont s/g $\Rightarrow C = 0$

for sine s/g $C = 0$ & cos factor $= 0$.

$f = \frac{1}{T}$
T = time period of periodic s/g

(Tannenbaum Book)



On solving, $C = 2.5$ ($\Rightarrow$ DC value)

$B_n = 0$

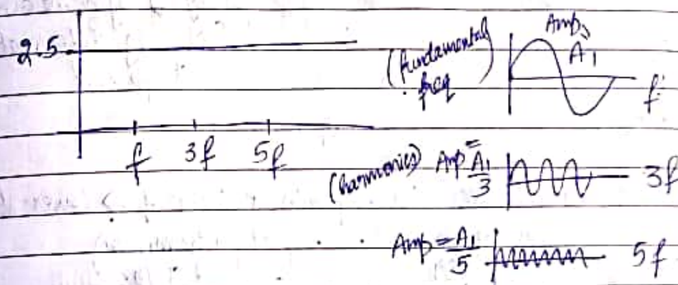
$A_n : A_1 = A$ — amplitude for freq = f

$A_2 = 0$

3f → $A_3 = \frac{A_1}{3}$

5f → $A_5 = \frac{A_1}{5}$

Even components = 0



(fundamental freq) Amp = A_1 — f

(harmonics) Amp = $\frac{A_1}{3}$ — 3f

Amp = $\frac{A_1}{5}$ — 5f

Due to sharp change in (0 to 1) or (1 to 0) sine wave we have ∞ frequencies

Amp = $\frac{A_1}{\infty} = 0$ — ∞f

Bandwidth of s/g.

$$(BW_s)_{ideal} = f_H - f_L$$
$$= \infty - 0$$
$$= \infty$$

f_H — highest freq.
f_L = lowest freq.

Note:
For non-periodic wave → for one duration → periodic, for other duration → other periodicity. Hence every wave can be represented in terms of sine wave.

Note:
If $BW = \infty \Rightarrow$ transmission medium can't work with it.

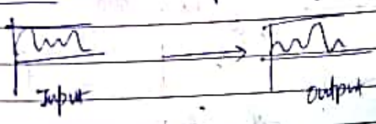
(Resistance) → dissipates power (conv to heat)

(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 s/g with varying frequency by same amt. (No s/g deformation at o/p side)



Inductor ⇒ when encounters s/g with higher freq ⇒ lowers its powers by more amt. ⇒ (s/g deformation at o/p side)

eg

wave freq	Power
f	P/2
3f	P/7

similarly for Capacitance

As f ↑ ⇒ (Amp ↓) & (Power ↓ ∝ $(Amp)^2$)

If harmonic power is ≤ 1% of fundamental frequency s/g ⇒ No significance

∴ We define a cut-off frequency

eg if 1% is cut-off freq

$f_c = 9f$ ⇒ $\frac{A_1}{(9)^2} = \left(\frac{1}{81}\right) A_1$

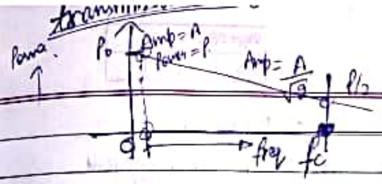
= >1% (till here s/g will contribute)

$\boxed{0 \text{ ——— } f_c\ (9f)}$ $BW_{s(e)} \Rightarrow f_c - 0 \Rightarrow f_c$

$f_{10}, f_{11}, \ldots$ does not matter.

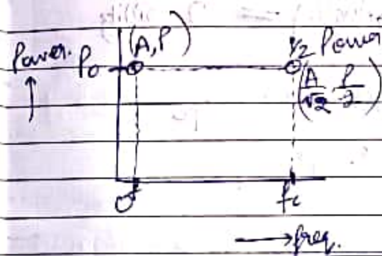
Note: Cutoff freq value depends upon application

transmission ... (Practically)



At freq = f Power = P ⇒ Amp = A

At freq = f_c Power = P/2 ⇒ Amp = $\left(\frac{A}{\sqrt{2}}\right)$



(Ideal transmission line characteristics (Theoretically))

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

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

$\boxed{BW_{s(e)} \leq BW_{t(e)}}$ ↑ condition so that s/g deformation does not occur

eff. BW of s/g: 0 … ; eff. BW of transmission line: 0 …

$BW_{s(e)} \leq BW_{t(e)}$ ⇒ Signal will be undisturbed or undistorted

signal → Voice (Intrinsically) = Analog (produced by nature)

- telephone voice (composite): BW = 0 to 4 KHz
- Music voice (composite) — 0 to 21.5 KHz ≈ 20 KHz; BW = 21.5 KHz

composite = multiple freq together.

lower freq ≡ maxpower ≡ max contribution
→ voice recognition = lower freq are sufficient

Harmonics determine voice quality
[last page]

Signal
→ voice
→ Video (intrinsically) → Analog ≡ 0–5MHz
→ Data (intrinsically) → Digital → 0 — f_c
(if bit/sec (bps) is low ⇒ f_c is low)

BW
Space freq → 60GHz (generated) although ∞ can be sent
twisted pair – 500MHz
coaxial → up to 2GHz
optical fibre → 1 fibre = 10 GHz

Analog → voice & video → Analog transmission (transmission → w.r.t medium form in the medium)
Analog → Analog communication (src to destination form, w.r.t form)

Data → Digital source Digital Destination Digital (Digital commⁿ)

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

Analog s/g is transmitted in analog form.
Digital s/g " " " analog/digital form

space → can't transmit in digital form.
even if digital s/g is to be transmitted, we have to do analog transmission.

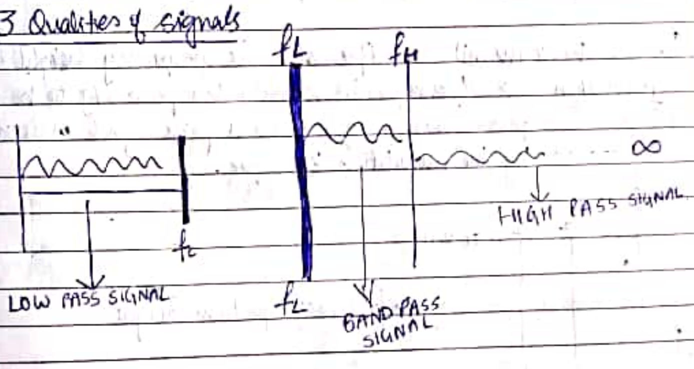
7/2/20

Analog Transmission (through media)
Analog Communication (end-to-end)

Air vibrations
(in u-phone, conversions take place)
voice & video are analog in nature
↳ light is converted to el. signals
↳ Telephone : 0–4KHz
Music : 0–20KHz] our hearing range
→ it is a composite sine s/g

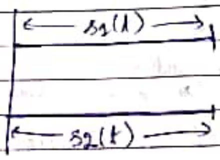
→ Voice is identified by fundamental lower frequency
• Video : 0–5MHz
• TV : =(Music + Video)

* 3 Qualities of signals



Suppose we transmit it directly through space

Music signal	Station	
$S_1(t)$	T_1	0–20 KHz
$S_2(t)$	T_2	0–20 KHz



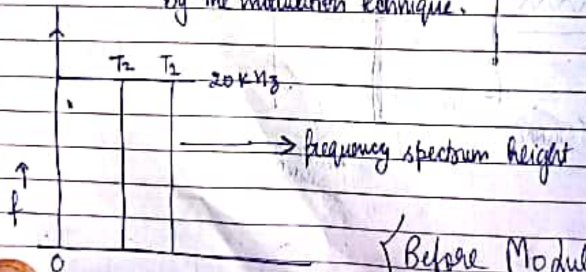
Signals get mixed up for the rest of transmission (Interference)

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

ITU : International TeleCommunication Union
(to coordinate amongst frequency range for diff countries)

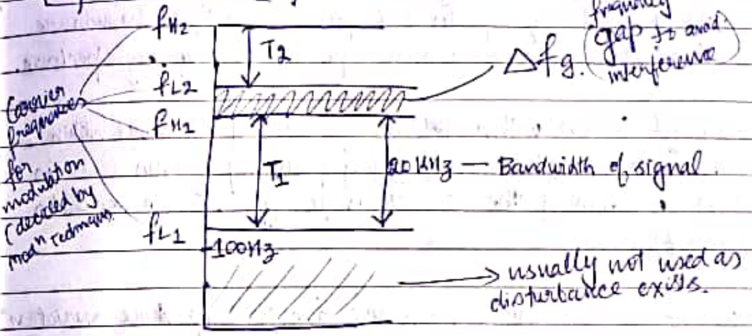
Broadcasting in coaxial cable should be done such that the interference is avoided for multiple stations

Q. How to transmit multiple of same frequency height?
Modulation → technique to convert low pass s/g to band pass signal. Height of band pass signal is decided by the modulation technique.



{Before Modulation}

{After Modulation}



* Amplitude Modulation (AM) — used for AM Radio broadcast; used in video broadcast of TV

If we choose f_{C1} as carrier frequency, low pass s/g will convert to band pass s/g of frequency range as follows :-
$\{f_{C1} = f_{L1}\}$

$$\underset{(f_{C1})}{f_{L1}} \text{ to } \underset{(f_{H1})}{f_{L1} + (\text{BW of s/g})}$$

$$f_{C2} = f_{C1} + \text{BW of s/g} + \Delta f_g$$
(gap to avoid interference)

$$f_{H2} = f_{C2} + (\text{BW of 2nd signal})$$

Δf_g = guard band (the freq range intentionally left b/w 2 transmitting s/g 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 frequency spectrum.

Guard band is less within stations of same city & more within 2 cities. 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 freq over the oscillator (freq generating)
↳ decides tuning frequency

Tuning Parameters → Crystal, Inductor, Capacitor } Value of tuning parameters depends on these values.

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

ANALOG MODULATION

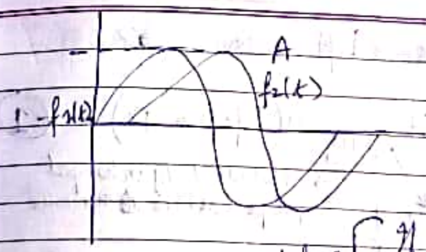
ANALOG MODULATION → AM, FM, PM (not used commonly but ~ FM)

For modulation, we require

original s/g is a composite s/g: $s(t)$ (original signal) → [Modulator (AM/FM/PM)] ← $C(t) = C\sin(2\pi f_c t + \phi_c)$

$(S\sin(2\pi f_s t + \underbrace{\phi_s}_{\text{phase, not req here}}))$

$C(t) = \overset{\text{Amplitude}}{C}\sin(2\pi \underset{\text{frequency}}{f_c} t + \overset{\text{phase}}{\phi_c})$



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

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

Note: If $f_2(t)$ wave starts before $f_1(t)$ wave, then
$f_2(t) = A\sin(2\pi f t + \phi)$

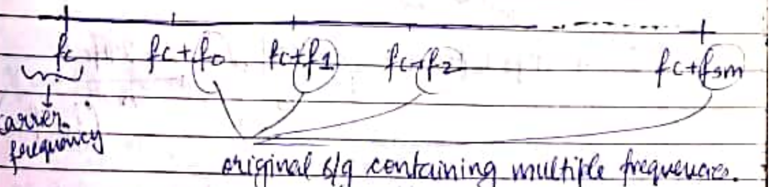
(A notation of s/g growth w.r.t a reference f(t)).

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

$[\sin(90+\theta) = \cos\theta]$

Series of frequency remains the same in the modulated s/g as well, the phase of original signal doesn't matter.

Carrier has a single frequency, while original s/g has multiple frequencies, therefore, modulated frequencies are obtained.



Channel BW $= \underbrace{(f_c + f_{sm})}_{f_{max}} - \underbrace{f_c}_{f_{min}} = f_{sm}$

In AM, frequency & phase are kept constant

Modulated wave of AM $= [C + K_{a\,s(t)}] \sin(2\pi f_c t + \phi_c)$ — (1)

$m(t)_a$

const of modulation

amplitude of s/g is changed proportional to this value

In FM, amplitude & phase are kept const

$m(t)_f = C \sin(2\pi(f_c + K_{f\,s(t)})t + \phi_c)$ — (2)

In PM, amplitude & freq → const

$m(t)_p = C \sin(2\pi f_c t + (\phi_c + K_{p\,s(t)}))$ — (3)

In (1), we can obtain multiple sine waves via trigonometry, comparatively easier to break as 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

amplitude of i/p signal

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

$(f_c > f_{sm})$

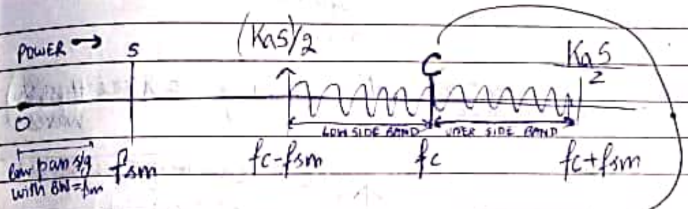
$= C \sin 2\pi f_c t + \frac{2}{2} K_a S \cdot \underbrace{\sin 2\pi f_{sm} t}_{B} \cdot \underbrace{\sin 2\pi f_c t}_{A}$

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

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

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

Time Domain representation



Carrier point of Band pass signal

original signals are present either in lower side or upper side band

BW of the signal → $(f_c + f_{sm}) - (f_c - f_{sm})$

$= 2 f_{sm}$

$f_c - f_{sm}$ → to know the starting point for $2 f_{sm}$ bandwidth.

Bandwidth Notation

If we (1/2) the bandwidth

Quality is affected (not much)

If quality is not priority (as comp to freq range), we select only 1 of lower side or upper side band {mostly upper side band}

11/2/20

Frequency Modulation

used in (90 MHz – 108 MHz — FM Radio broadcast)
~~90~~ = 10

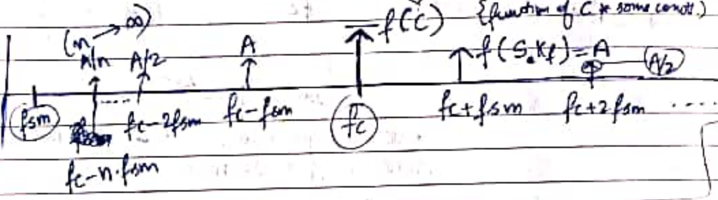
Eqn of FM wave.

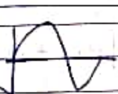
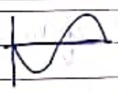
$$m_{f(t)} = C \sin 2\pi (f_c + K \cdot f_{s(t)}) t \quad \{(+\phi \to \text{zero})\}$$

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

amplitude of i/p s/g.

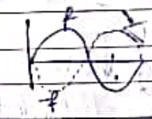
Note: This above eqn represent more changes (≡ more # sine waves) as compare to amplitude modulation



Note: (+freq) ⇒  | (-freq) ⇒ 

Meaning of (-frequency) ⇒ 180° out of phase w.r.t original s/g

$BW_{ms} \Rightarrow \infty - (-\infty) = \infty$
(BW of modulated s/g)

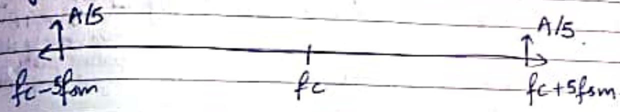


We can't produce this much high frequency although we have ∞ BW available

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

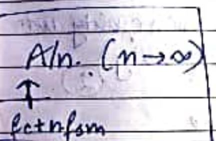
As freq ↑ ⇒ Amp ↓ proportionally

Practically, it has been observed that for n=5, we have a good quality signal.



Effective BW of signal = $BW_{mse} = 10 f_{sm}$

Practically / Effective BW of freq modulated s/g = 5 fsm
observed



5 (Music BW)
= 5 (20 KHz)
= 100 KHz

Note: In AM, quality of s/g is more affected ∵ Amplitude is affected by noise but in FM, Frequency is less affected by noise. hence (FM) quality > (AM) quality

TV voice — 5 KHz.

~~AM Radio Music TV — 5 KHz.~~

AM	Music	- 20 KHz.
FM	Music	- 100 KHz (5 × 20 KHz).

3 combinations for TV as Music & TV video — Both AM, FM–AM, AM–FM

1. | | | | |
|---|---|---|---|
| TV | Music | AM. | — 20 KHz |
| TV | video. | AM | — 5 MHz. |

] 5.02 MHz

3 combinations for TV Music & TV Video:
- AM – AM
- FM – AM → best ✓
- AM – FM

(1)

TV	Music	(using FM)	120KHz	5.1 MHz
TV	Video	(AM)	5MHz	

(BEST option for Transmission)

(2)

TV	Music	(using AM.)	20KHz	25.02 MHz
TV	Video	(using FM)	25 MHz	~~very high BW~~

eyes won't be able to perceive quality of video signal using FM

(3)

~~TV Music (using.~~
~~TV Video~~

In (1) & (2) 5.1 MHz ~ 5MHz & 5.02 ~ 5MHz & video is in AM for both (which is okay)

(2) − (1) = 0.08 MHz ⇒ results in high quality audio

$(\text{Voice Quality})_1 < (\text{Voice quality})_2$

⇒ (2) is preferable

IMP?

Q What should be the choice for TV transmission. Why?

Ans → (2) (Explain using above cases & Reasons accordingly.

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

- TV has analog transmission & analog communication. We notice screen flickering in TV screens (but no change in audio) whenever Air conditioner or refrigerator compressor is switched ON/OFF because screen is AM

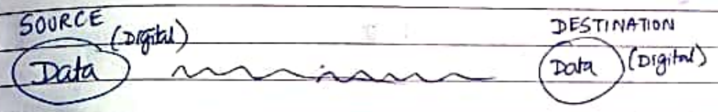
Phase Modulation (PM)

$$m_{p(t)} = C \sin 2\pi \left[f_c t + \phi + K_p s(t) \right]$$

∵ of Equipment cost, PM is not preferred.

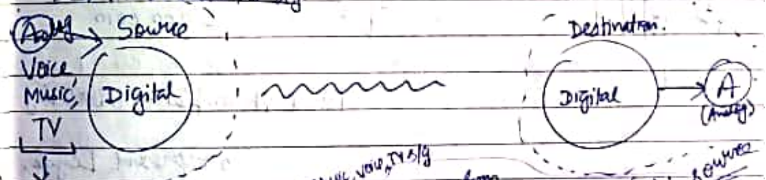
- Data can't be sent to space in digital form.

Data
- Source – Digital   Dest^n – Digital
- in Space transmission → analog form



Digital Comm^n. (transmission is NOT digital)

Digital Comm^n of Music (Exact dgm 4 pages ahead)
↳ ~~transmission~~ not dig.



Analog from actual source point.

[To transmit^n, we convert music, voice, TV s/g from analog to digital] (At source node)

(At destination node) Again at Destination, we receive data in digital form, we again conv digital back to analog (for Music, TV screen, voice).

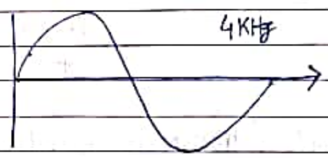
~~Transmission~~ → Q How to convert Dig to Analog & vice versa
(A) Q. (+) of Digitiz. Q Why digitize
Transmission – Analog or Digital?

Source end. Originally Analog convert to Digital.

using Nyquist thm, we digitize. (Analog to Digital)

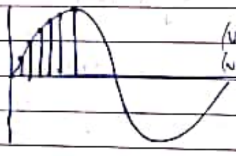
- Voice – BW → 4KHz. (mono)
- Music – BW → 20KHz. (stereo)
  - ↳ Music has 2 channels.

Nyquist thm



We take samples & represent each sample using 8-bit notation

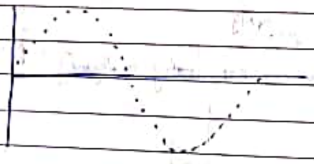
step ①



eg voice s/g	0 →	0000 0000 (Digitized s/g)
(voice s/g = 1)	→	(00000001)
(voice s/g = 2)	→	0000 0010

More # samples ⇒ Better Quality

step ②



(To represent 1 cycle, say we take 'n' samples & 8 bits are used to represent each sample.

1 cycle → $\underbrace{n \times 8 \times 4K} = 32nK$ bps.

If $n = 10$ → 320 K bps

If $n = 20$ → 640 K bps

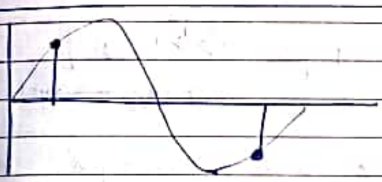
If n → vv large ⇒ BW is vv high

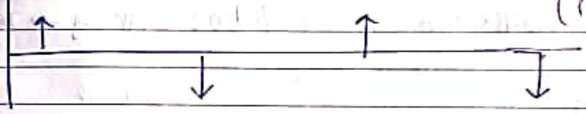
Acc to Nyquist thm,

→ In 1 cycle, take $n = \left(\frac{1}{2} \times \text{max freq of s/g}\right)$.

$\therefore n = \frac{1}{2} \times 4K = 2K$

bit rate = 32n Kbps
= 32×2 Kbps
= 64 Kbps.





Q. How to represent original s/g using such small value of n (samples)?

Ans ① + ②

① Using Fourier Analysis on the periodic wave, we can obtain the fundamental frequency ~~to get the original s/g~~ or a series of sine waves with frequencies (f, 2f, 3f, ...). Then with cutoff frequency.

② At o/p side, Apply a filter such that, we can get original signal back.

4KHz (Analog) (frequency) → 64 Kbps (bit rate) (Digital)

For 20KHz signal; n = 40K samples/sec (ask?)

Digital Bit rate for Music = $2 \times 20 \times 16$ Kbps = 640 Kbps

└ In Music → 16 bit representation

Stereo Music (2 channels)

↳ bitrate = (2) × 2×20×16 Kbps. (# of channels)

(in TV – stereo music) = 1280 Kbps

(Compression scheme for Music) → mp3 $\xrightarrow{1280\text{Kbps}}$ (128 Kbps)

~~analog~~ digital

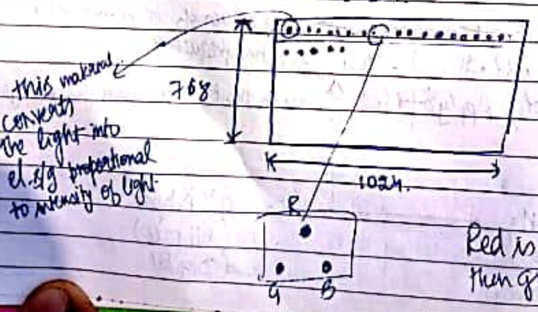
On decompressing mp3 → we get original signal.

Video Digitization (Video: Analog → Digital)

Analog ——————▷ Digital

eg $1024 \times \frac{3}{4}$ (aspect ratio) {screen Resolution}

= 1024×768 = no. of photosensitive materials on the screen



Red is filtered first then green & Blue

Each photosensitive material has 3 colour sensitive component (RGB I° colours)

filters are placed accordingly to, allow only Red / Green/Blue

R → $\propto e^R$

B → $\propto e^B$

G → $\propto e^G$

1st 8 bits for Red

Next 8 bits for Green

Next 8 bits for Blue.

⇒ (1 photosensitive point / 1 pixel) will require 24 (= 8+8+8) bits to encode

∴ Entire screen will require → $(24 \times 1024 \times 768)$ bits (1 frame).

Since video ⇔ multiple frames in a succession eg 50 frames/sec.

Since intensity does not disappear quickly, we get an optical illusion that video ≡ continuous moving playing but actually we see 50 different frames in one second.

{If frame speed = 50 FPS}

No. of bits/sec = $(24 \times 1024 \times 768 \times 50)$ {v high bit rate}

{2 Mbps to 6 Mbps}

∴ we use video conversion algos → (MPEG4)

To avoid flicker on TV screen.

↳ ~~first~~ refresh alternate rows of frame.

– first all odd rows & then all even rows.

(25 FPS + 25 FPS)

Video Compression:

↳ send 1st fr. → send Diff of 2nd & 1st → send diff of 2nd & 3rd & so on . . . .

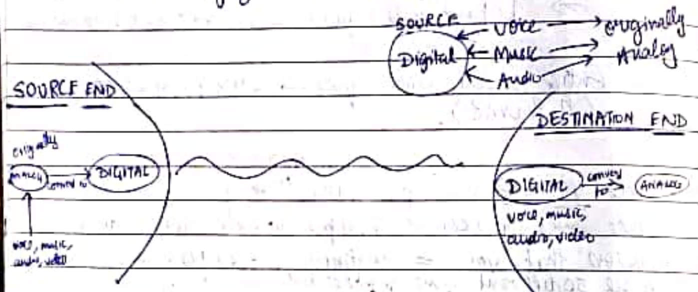
when there is not much change in 2 frames

Difference in frame is not large for still frames but high for moving frames (eg any moving object).
∴ We have variable bit rate (2 Mbps to 6 Mbps)

Contd

Digital Commⁿ of Music

We want to digitize voice, music, TV



Process of Digitization of voice & music is same & done using Nyquist thm

Through signal reshaping we can replicate 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 dist comm) → pipelining & error recovery mech → selective repeat, go back N
error detection

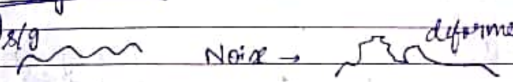
19/2/20

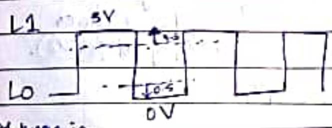
Q Why digital is better than analog?

Digital V/S Analog transmission

2 levels of difference

① At signal level {medium}

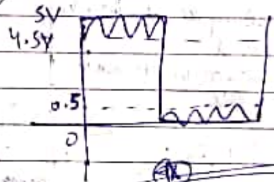


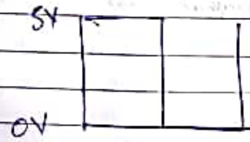


L1 – 5V (4.5V or above)
L0 – 0V (0.5V or below)

If there is
(i) (-ve noise within 0.5V during L1 transmission) ⇒ ↑ voltage level to nullify effect
and/or
(ii) (+ve noise within 0.5V during Lo transmission) ⇒ ↓ voltage level to nullify effect

Result of This.





For signal shaping: 4.5V is ↑ to 5V (L1), 0.5V is ↓ to 0V (L0)

This is called signal shaping

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

② At data level {processing}

There is no analog computer that can store the s/g & process it

(+)

All digital computers can store digital data & process it

Signal shaping is possible for dig s/g

(+) Error

Digital s/g	Analog s/g
1. Dig s/g can be stored & processed by dig computer (reshaping possible)	1. Analog s/g can be stored & processed by computer (reshaping not possible).
2) Encryption is possible during transmission for security	2. NA
3) Error detection is possible	NA
3) Data compression.	3.

[Digital bps & Analog BW (in Hz)]

Empirical rule/formula

When data is compressed, the BW of signal is reduced.

At Recv'send, data decompression is done to get original data.

Compression - 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 (eg CRC)

Dmux	Digital s/g	Analog s/g
①	reshaped	Not reshaped
②	Store & processing	NA
③	Error detection	NA
④	Error recovery	NA
⑤	Enc – Dec.	NA
⑥	Data compression & decompression	NA

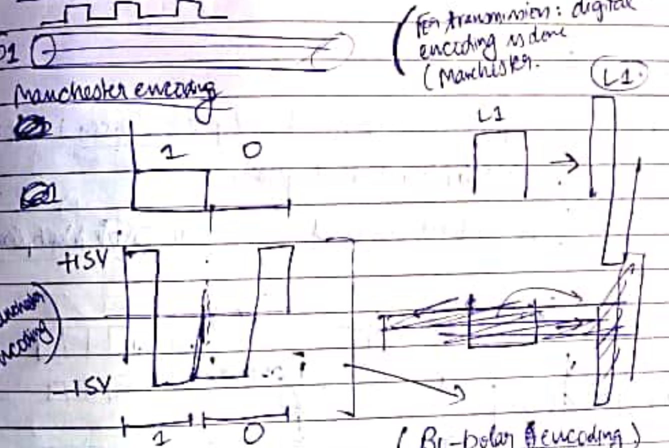
Digital transmission

- wired (optical fibre, coaxial).
- space.

dig wired transmission

(For transmission: digital encoding is done (Manchester.

Manchester encoding



(Bi-polar encoding)

Sender clock & Recv clock may have varying speed.

⇒ Character-by-character data is sent in a limited way.

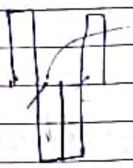
Asynchronous transmission ⟺ Bipolar encoding

(Bit stuffing) eg 8 bit at sender is sent ⟺ 12-bit processed by recv.

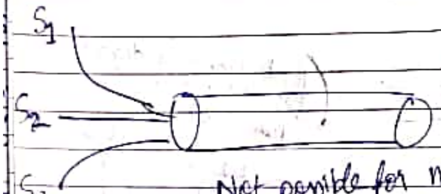
DM Read - Manchester encoding types

(Multiple character transmission) ⟺ (sync transmission)

In Manchester, along with data clock is transmitted.

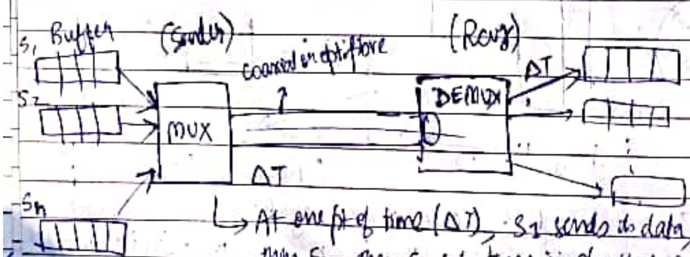


Manchester is sync transmission



Not possible for multiple sources to send data simultaneously, FDM not possible

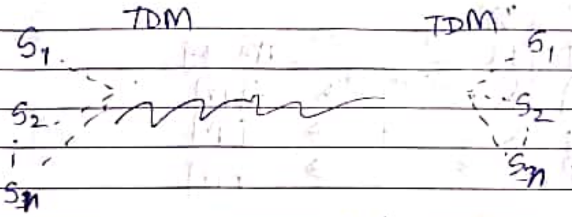
Hence TDM is used (Time Divi Multiplexing)



↳ At one pt of time (ΔT), S_1 sends its data, then S_2, then S_n ∴ time is divided.

∴ At Rcvr end,
in first ΔT time → S_1 Buffer is filled
in next ΔT time → S_2 " "
" " " → S_n " "

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



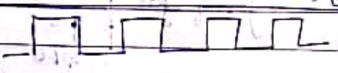
There is a possibility that ≥1 buffers are null at src end.
∴ To avoid error, padding is used to send some dummy character / dummy data to the rcvr.
∴ TDM is called STDM
↳ Synchronous TDM.

Note:
STDM is not possible in space.

	Data	Technique	Media
① Multiple src data	Analog	FDM	wired, space
② Multiple src data	Digital	FDM	space (TDM not possible in space).

For ② to be feasible

∴ Digital data → Digital Modulator → Analog (Now FDM can be applied)



(low pass) 0 ——— fmax (of dig s/g after Fourier analysis).

Scanned by CamScanner

Digital s/g is internally low-pass signal

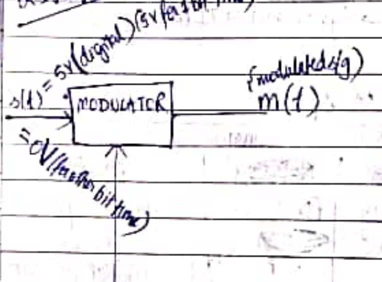
Dig s/g is conv to band-pass analog s/g & then FDM is applied by Digital Modulator

Digital Modulator

	Digital		Analog
(Amp shift Key)	ASK	⟵ analogous ⟶	AM
(Freq shift Key)	FSK	⟵⟶	FM
(Phase Shift Key)	PSK	⟵⟶	PM

21/2/20

ASK

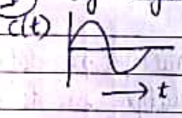


$C(t) = C\sin(2\pi f_c t + \phi)$

(sender)

Modulation is not cont. It is bit by bit

(1) (Band) Signalling element



1 cycle of carrier = 1 signaling element = either logical 1 / logical 0 is sent using 1 cycle

we can also send logical 1/0 bit during half cycle

(2) Signalling rate: # s/g element transmitted per second. (baud rate)

Baud rate

Signalling rate $= f_c$ (freq of carrier).

[if 1 cycle transfer 1 bit]

Note: $= 2f_c$ (if half cycle transfer 1 bit).

For simplicity, $\phi = 0$

$C + K_a s(t) = $ Amplitude.

For logical 1

$s(t) = 5V$

$C + K_a * 5V = $ Amplitude.

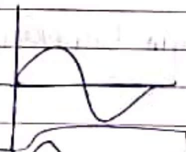
For logical 0

$s(t) = 0$

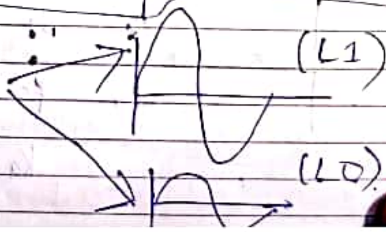
$Amp = C + K_a * 0V$

$= C =$ original amplitude of carrier

Original signalling elt

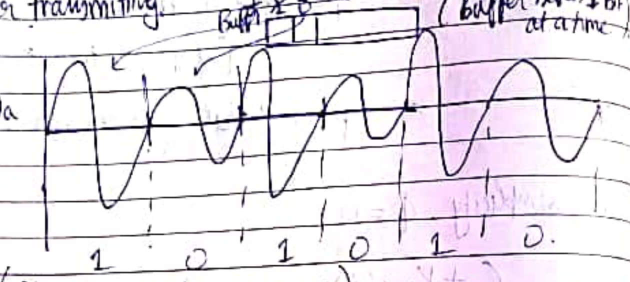


Modulated signaling elt



For transmitting 10101010 (buffer sends 1 bit at a time)

Buffer



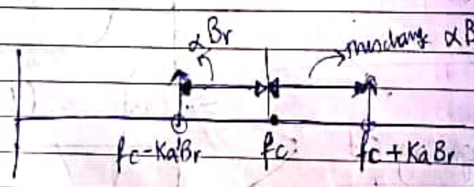
(It is a composite sine wave)

Note: Max. changes occur in alternating bit pattern 10101010 or 010101...

→ Fourier analysis will decompose it as a series of multiple sine waves each with diff freq.

for BW calculation, we take 10101010.. for the channel BW ∵ it has max variation, hence any signal will pass through

Change in bit pattern/signal is at the rate of fc



Ka = const of modulation for ASK

If Baud rate = Br

For 2×Br → This sig will compress to half its size & twice no. of changes ⇒ twice frequency

when Ka = 1

fc−Br fc fc+Br

$BW = fc + Br - fc + Br$
$= \underline{\underline{2Br}}$

For Ka = 1/2

$BW_{ask} = fc + \frac{1}{2}Br - fc + \frac{1}{2}Br$

$= Br$

$\boxed{BW_{ask} = Br}$

eg. If $BW_{ch} = 4KHz$
channel

(Baud rate) Br = 4K Bps (4 Kilo Baud per sec)

(bit rate) b_r = Br = 4Kbps (Br = br for 2 level of signalling)

No. of bit transmitted in 1 Baud

Page No.
Date

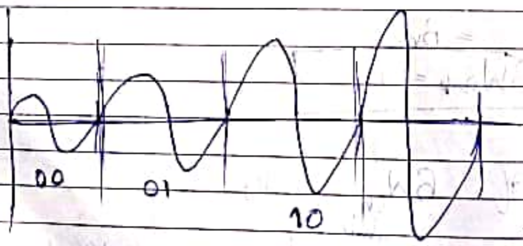
$B_r = BW_{ch}$ (More is the analog BW more digital data we can send).

2 level of signal = 1 bit per Baud.

If we do 4 level of signalling

Q: here Buffer will send 2 bit at a time.

00	01	10	11	10	

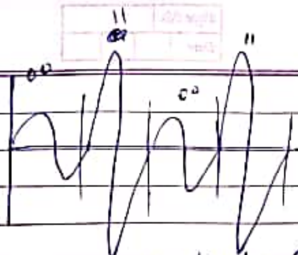


For calc BW in 4 level of signalling

Here 10|10|10|10 → won't generate max BW (here continuous sine wave (lower BW))

here 00|11|00|11 → generate max BW (∵ max change)

Page No.
Date



This is similar to 1010 pattern for 2 level of signalling. Only power differs.

eg $BW_{ch} = 4\text{ KHz}$

$B_r = 4\text{ KBPS}$

$b_r = 4 \times 2\text{ Kbps} = 8\text{ Kbps}.$

BW_{ch}.

① $B_r = BW_{ch}$

② $\boxed{b_r = BW_{ch} * \underbrace{\log_2 V}_{\text{No of bits per Baud}}}$ V = # of levels

As V↑ → gap b/w 2 levels will ↓

V → depends upon equipment power.

To ↑V ⇒ reduce the gap b/w 2 level.

$V = \left(\frac{C_{max} - C_{min}}{\Delta V}\right)$ ↑max amp ↑min amp. ΔV = gap b/w 2 levels.

If 2 levels come very close, then upper level can be considered as lower level by demodulator.

V (# of levels) depends upon:—
1) Power of equipment
2) Quality of signal

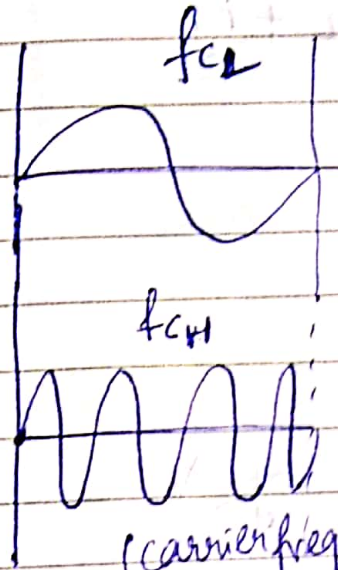
ΔV depends upon error rate

SNR (Signal to Noise Ratio) $= \log_{10} \frac{S}{N}$

28/2/20

FSK — 2 carrier — high freq / low freq.

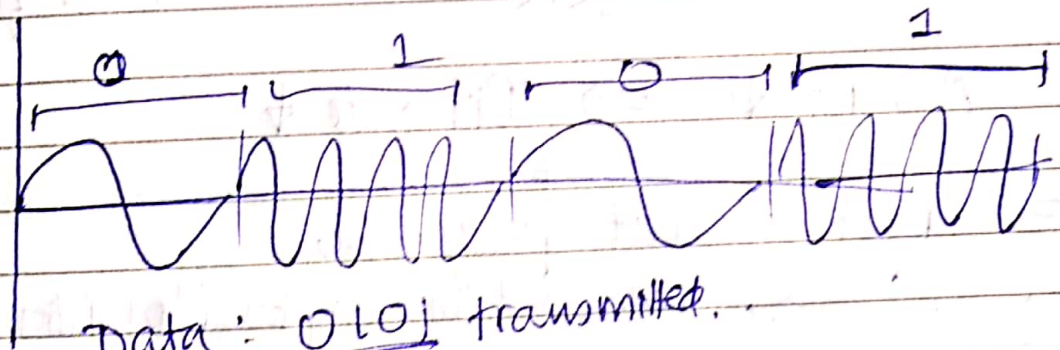
(carrier freq low)



for logical low (0)

for logical high (1).

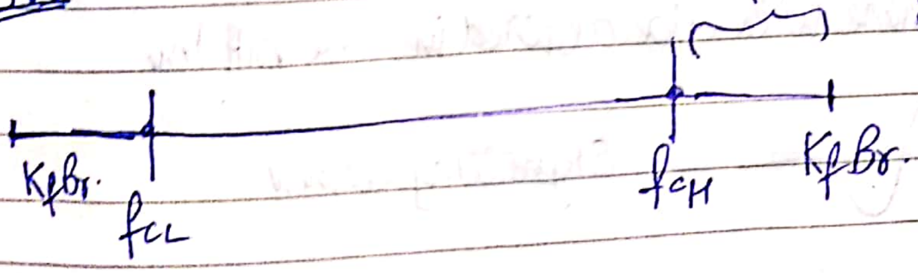
(carrier freq high)



Data: 0101 transmitted.

BW

This is variation in freq due to rapid change b/w f_{cL} & f_{cH}.



B_r = Baud Rate

$f_{cL} - K_f B_r$ $\qquad$ $f_{cH} + K_f B_r$

Take $K_f = 1/2 \Rightarrow K_f B_r = \frac{B_r}{2}$

BW of FSK

$$BW_{fsk} = f_{cH} + \frac{Br}{2} - f_{cL} + \frac{Br}{2}$$

$$= f_{cH} - f_{cL} + Br.$$

$$Br = BW_{fsk} - (f_{cH} - f_{cL})$$

Bit rate = Baud rate * $\log_2 V$

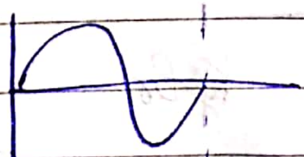
$= Br \times \log_2 2$ $V = \#$ of levels

As $Br \downarrow \Rightarrow$ Bit rate $\downarrow$

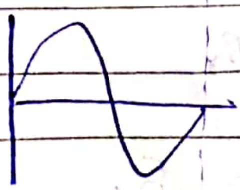
$\Rightarrow$ FSK is not preferable & is not used in Digital Modulation.

* PSK (Phase Shift Keying)

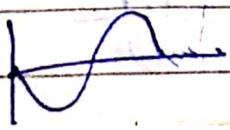
↳ phase will be altered in one bit time



signalling element



to send 0 $\Rightarrow$ same phase



to send 1 $\Rightarrow$ opposite phase

$+ \frac{Br}{2}$

$\log_2 V$

$V = \#$ of levels

rate ↓

able

Digital Modulation.

Keying)

in one bit time

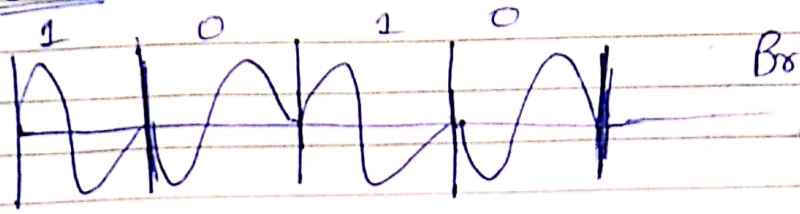
ng element

and 0 ⇒ same phase

1 ⇒ opposite phase

or vice versa

To send 10101010.

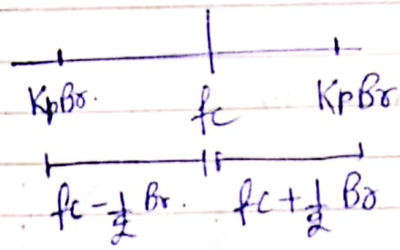


Here change is very rapid

when $B_r \Rightarrow 2B_r$.

⇓

It will imply more changes



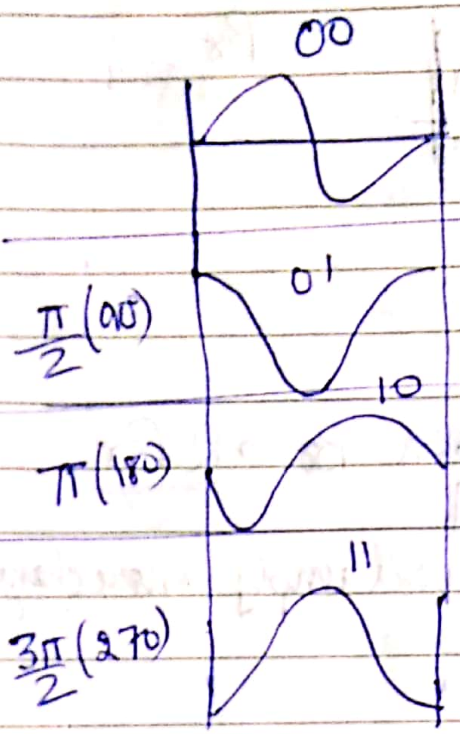
when $K_p = 1/2$

$$BW = \left(f_c + \tfrac{1}{2} B_r\right) - f_c + \tfrac{1}{2} B_r$$

$$BW_{PSK} = B_r$$

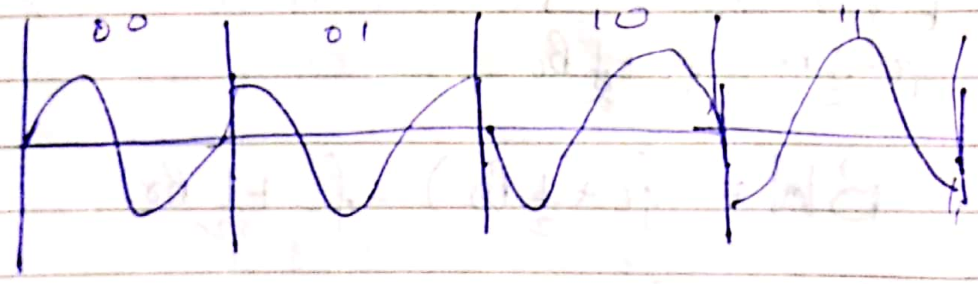
~~For Multilevel~~

For Multilevel



Bitrate
2 bit/sec ($\because$ V = 4)
\# levels

Ip data = 00 01 10 11



Bit rate = Baud rate $\times \log_2 4$

Bit rate = Br $\times$ 2

Amp is sensitive to noise.
but phase is less sensitive to noise

$\therefore$ PSK is preferable over ASK

2 amp level is safe & 4 phase level is safe

∴ we go for a constellation Modulation technique.

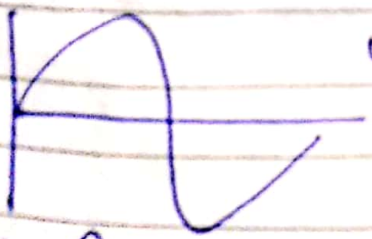
QAM (Quadrature Amp Modulation)

$V_A = 2$
$V_P = 4$] ⇒ $V = 8$ ⇒ 3 bit per Baud can be send.

(A, 0) ⇒ Amp = A & Phase = 0.
(2A, 0) ⇒ Amp = 2A & Phase = 0
(A, π/2)
(2A, π/2)
(A, π)
(2A, π)
(A, 3π/2)
(2A, 3π/2)

8 levels

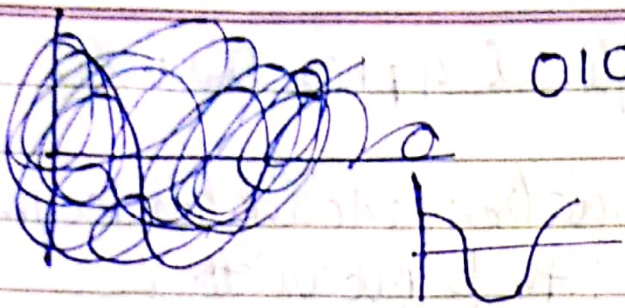
000 ⇒ Amp ⇒ A & Phase = 0



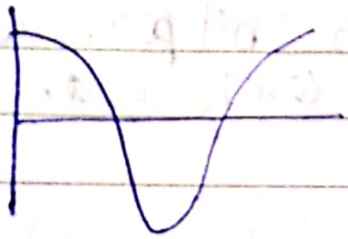
000
Phase Amplitude

(A, 0)

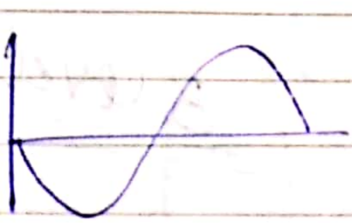
001 (2A, 0)



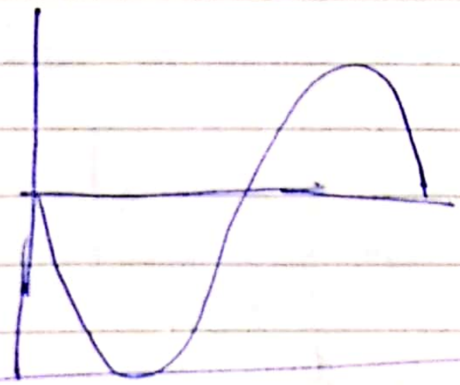
010 $(A, \pi/2)$



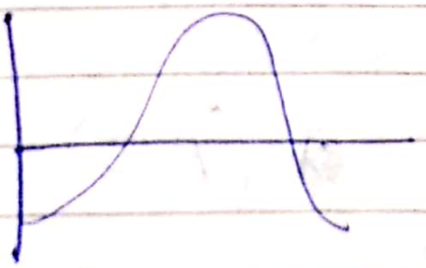
011 $(2A, \pi/2)$



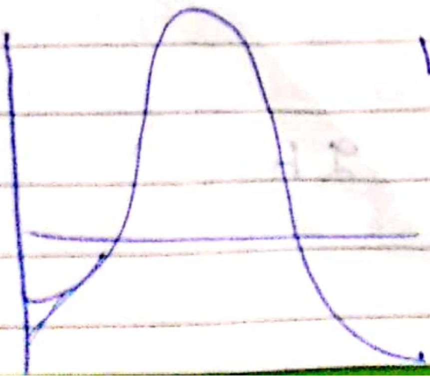
100 (A, π)



101 $(2A, \pi)$



110 $(A, \frac{3\pi}{2})$



111 $(2A, \frac{3\pi}{2})$

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000 001 010 011 100 101 110 111, This will give Max change $\Rightarrow$ Max BW.
But Baud rate will be same.

$$\text{bitrate} = B_r \times \log_2 V$$
$$= BW \times \log_2 8$$
$$\text{bitrate} = 3\,BW \quad \text{for QAM.}$$
or $3B_r$ ($\because B_r = BW$ in QAM)

PSK_{16} → 16 bit / sec.

QAM_8 → $(V=8)$ → 3 bit per Baud.

QAM_{16}

QAM_{32}

⋮

Bit rate: 28.8 Kbps.

$\log_2$

$BW \times \log_2 V$

If $BW = 4K$ & $b_r = 28.8$ Kbps, V can be calc.

[MODEM. max bit rate → 33.4 Kbps
QAM based (in earlier days)

For space transmission
L Modem – QAM,
PSK

56 Kbps – Digital MODEM

For a Modems with 33.4 Kbps bit rate.
BW = 4K
&

Telephone line: CAT-4 coaxial cable
L BW ~ GHz

DSL (Dig Subscriber Loop/Line).

QAM
V-64

$4K \times 6 = 24$ Kbps
$4K \times 7 = 28$ Kbps
$4K \times 8 = 32$ Kbps

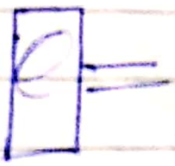
After this Digital MODEM (56 Kbps) came

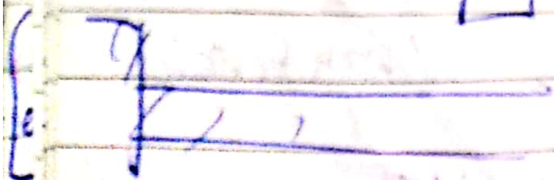
↓

After this DSL came

PSK_8 & $QAM_{16, 32 \ldots}$] ⟶ used for space transmission
ASK is not used for space "

DSL





DSL (Later) TBD

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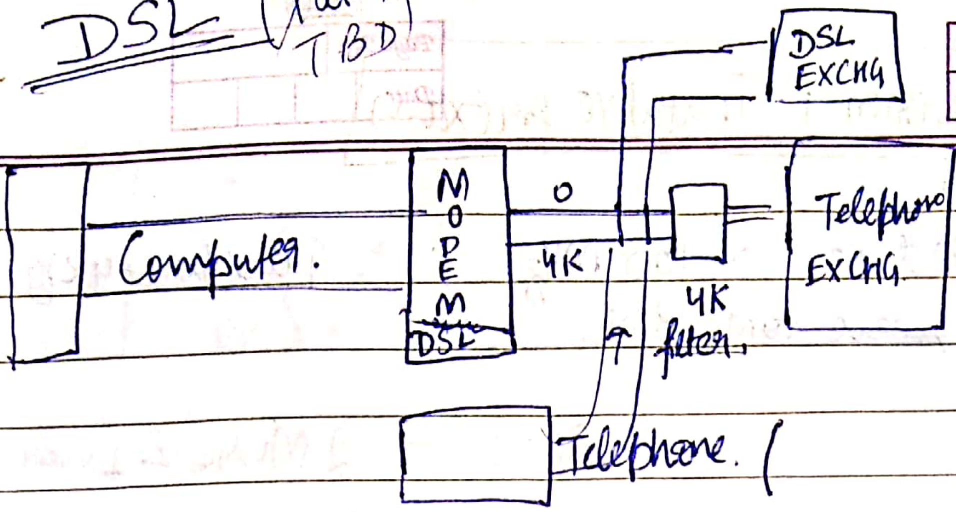
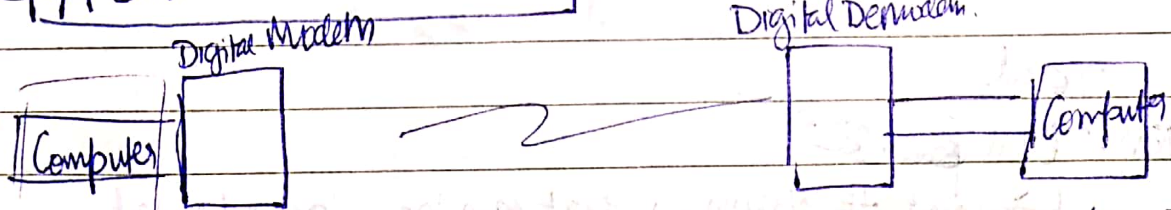


cable
y
~ GHz

DSL Exchg gets 4K to 1GHz.

MODEM gets (1GHz − 4KHz)
BW ≈ 1GHz
∴ Br ⇒ 1G Baud.

ADAPTIVE MODEM



(Modem-Demodem Protocol)

If max speed of Modem = 32Kbps.
Initially Modem will start @ 8Kbps.
Error bits is also sent along data after modulation in analog form. (check bits)

DeModem gets data with check bit & applies CRC algo to check if any noise is there

DeModem will send s/g to Modem to ↑se the speed in case no error (eg double the speed), and so on...

In case error is detected, it will ask Modem to lower its speed (eg half the speed). This technique is called Adaptive Modem