Post Midsem

1/10/19 Purnendu Sir's class

S 2–4
C 4–8
8–
K_a
K_u
?

15

Frequency measurement

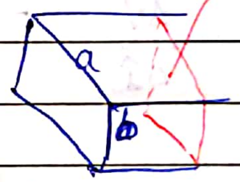
1. Wavemeter Method
2. Slotted Line method
3. Down conversion method

1) Wavemeter Method

↳ cavity type → cylindrical
↳ digital fr.

Rectangular cavity →

$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

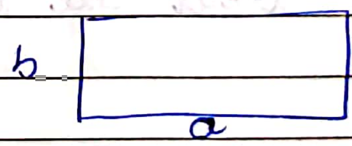


put a value & move it

WR-90 waveguide :–

$a = 2.286\ cm$

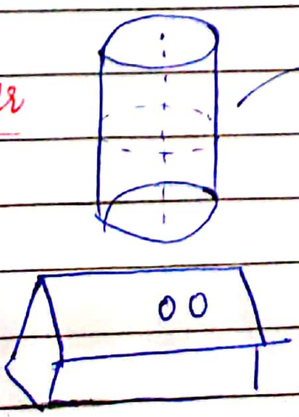
$\frac{a}{b}$ $\frac{b}{a} \approx 0.45$



$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 + \left(\frac{p}{c}\right)^2}}$$

~~circula~~
cylindrical cavity

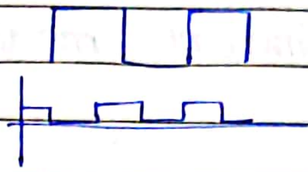
wavemeter



Length is varying
Inside cavity
coated with gold/silver/brass to have better reflection
There will be resonant frequency

?

Square wave modulation



- calliberate wavemeter with in a standard institute. Now we can measure any frequency.

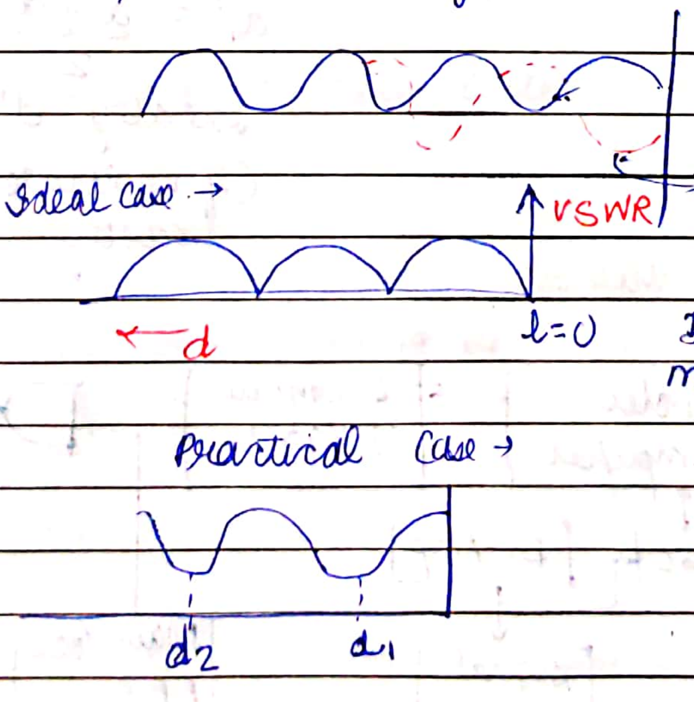
Slotted Line method

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

$$\lambda_g = 2d$$

$$d = d_1 \sim d_2 .$$

Source terminated by a load →



SW: standing wave patter will be generated

Dist b.w 2 successive max or minima = wavelength

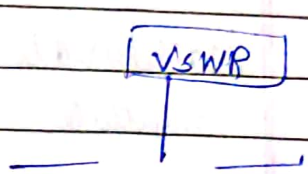
If we are measuring maxima, → power more ∴ Device can be damaged. ∴ we prefer measuring ~~mea~~ minima. Although device has sensitivity issues it won't be able to measure exact minima but won't be damaged.

$TE_{10} \rightarrow$ Dominant mode of rect. waveguide.

In $TE_{10} \rightarrow$

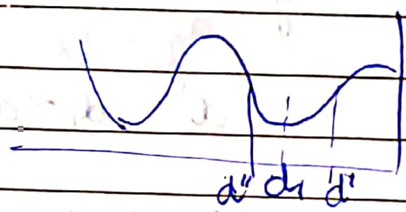
$$\lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}$$

$$= \frac{2a}{m} = 2a$$



First locate minima. (3dB)

Set coarse &

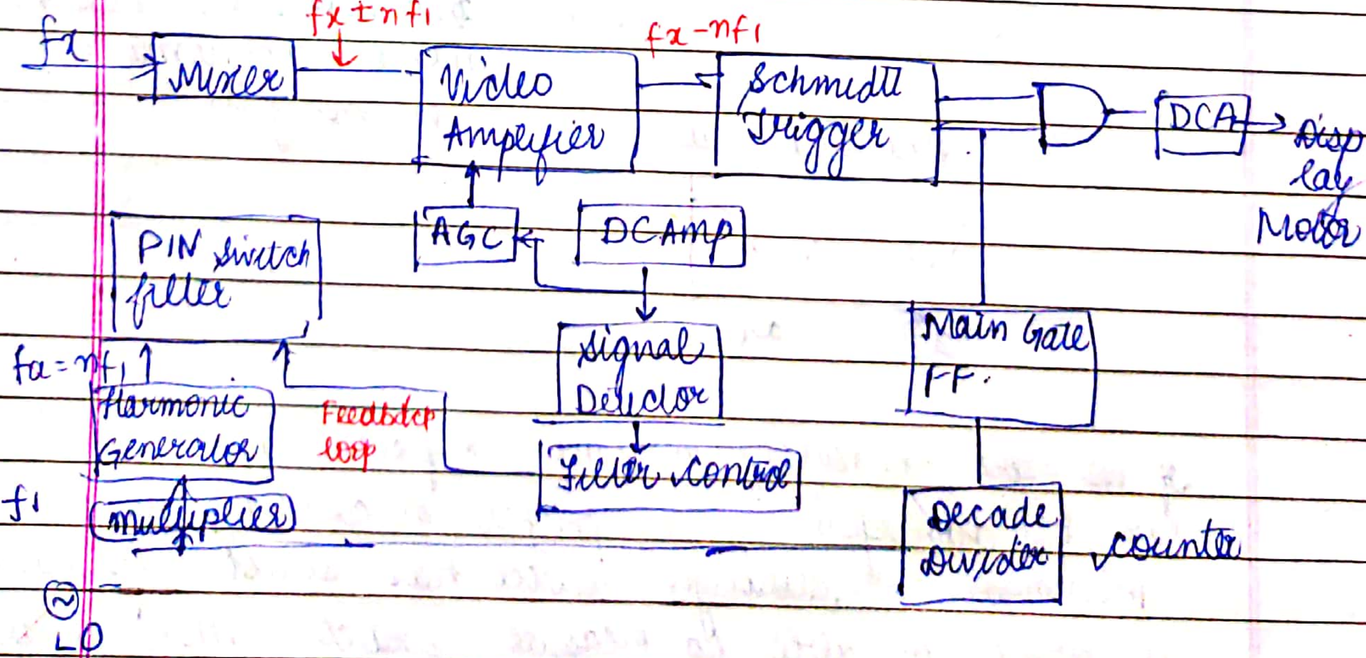


$$d_1' = \frac{d'' + d'}{2}$$

Ideally $d'' = d'$

(if we locate minima exactly)

Down Conversion Method



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$f_x - f_a = f_{IF}$

→ We need to know range of f_1 & Attenuated freq ranges.

Video Ampr is used as we want to display the signal

If $f_x - nf_1 = 0 \Rightarrow DC$

using feedback path → readings will be faster.

- Counter to divide the freq.

- Two level of feedback s/s is used.

AGC → Automatic Gain control.

Power Measurement

Microwave power measurement is ~~differe~~ difficult as f is high. $P \propto \frac{1}{f}$.

So freq of transmission is in Hz i.e 50 Hz not GHz

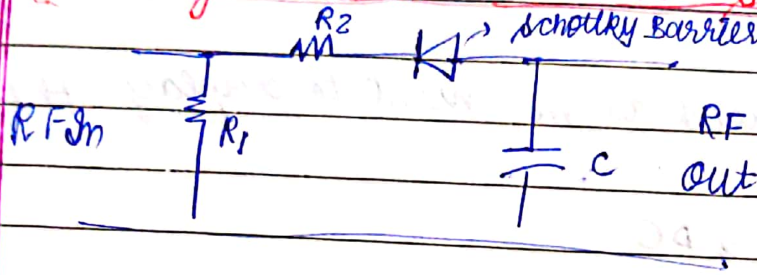
- proposal for wireless transmission.

- Direct power measurement is difficult

$$P = \frac{1}{2}\int Re(E \times H^*) \cdot ds \qquad \frac{E}{H} = \eta$$

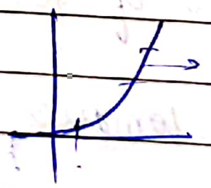
$$|P| = \frac{1}{2}\frac{E^2}{\eta} \qquad \eta = \frac{E_\theta}{H_\phi}$$

1. Schottky Barrier Diode Sensor



In normal diode cut off potential V_0 can no be varied. (i.e 0.7 for Si, 0.3 for Ge)
By adding some doping V_0 can be varied in Shottky. ∴ we are using Schottky.

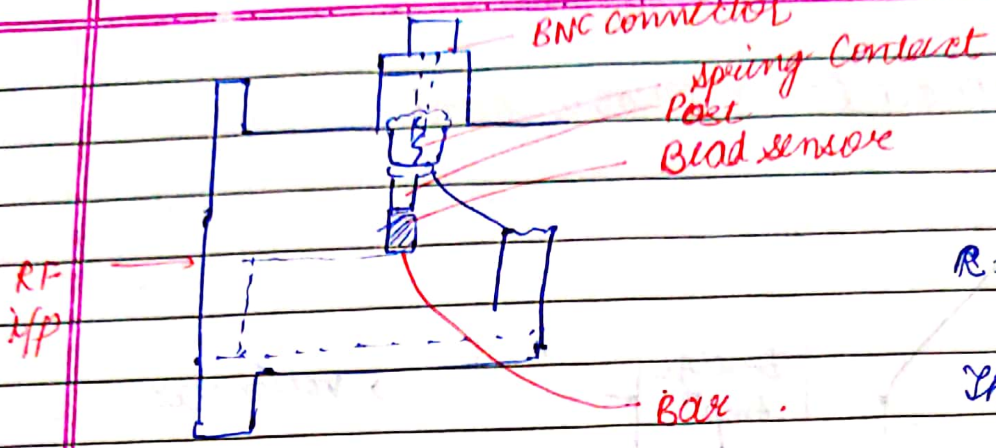
Square Law Device.



In schottky →
diode resistance also depends on $temp^r$.

upto −70 dBm power can be measured using this method.

2. Bolometer sensor
Resistance is changing with $temp^r$ & type of material → Bolometer
In Bolometer Thermistor is also ~~used~~ there but it's type is different from normal thermistor.



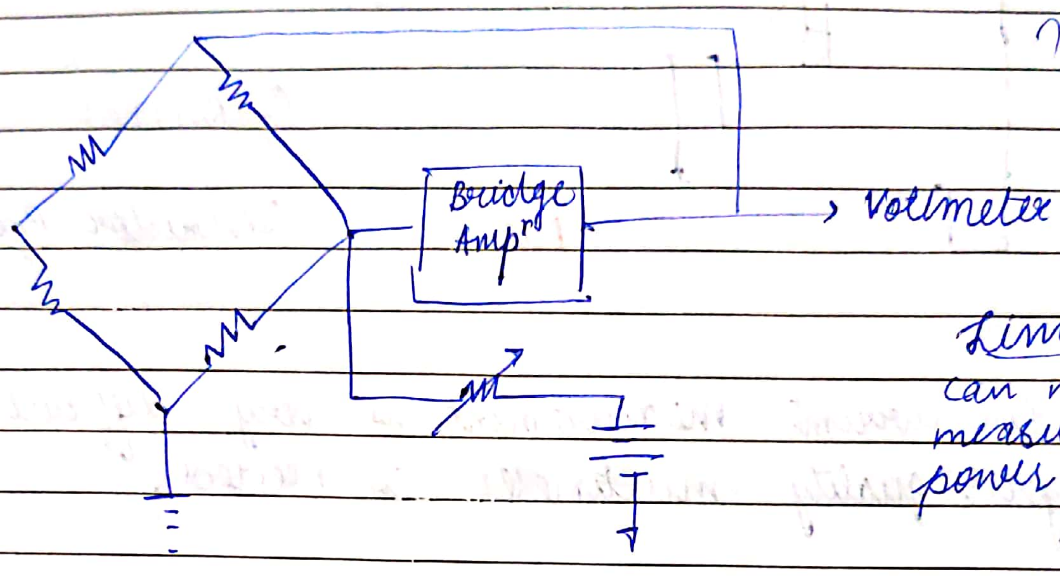
$R = R_0(1+\alpha t)$.

Thermistor Barettes.

- Low current measurement is very difficult. So good quality multimeter is needed.
- We can calliberater
- sensitivity is -20dBm.
- Whatever change will be absorbed by spring

15/10/17

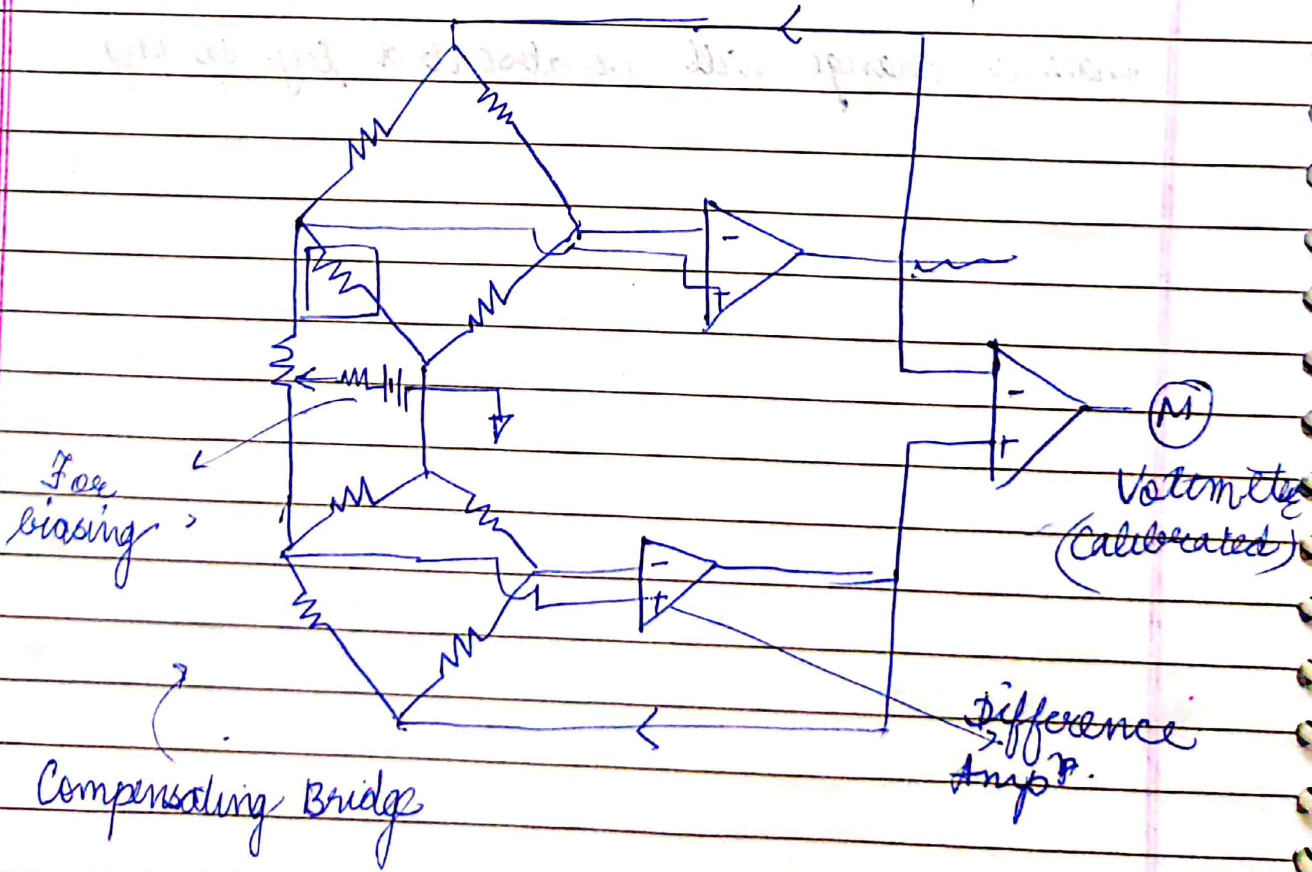
Microwave Power Measurement



Limitatn
can not measure high power.

$1\,GHz < \mu wave < 300\,GHz$

Beyond 300 GHz → Tera Hz for communicatn



Power Measurement →

1. Bolometric → Barretter
→ thermistor

2. Schottky Barrier

3. calorimetric → Calorimetric
→ Calorimetric wattmeter

4. Power Meter (Extension of Bolometric)

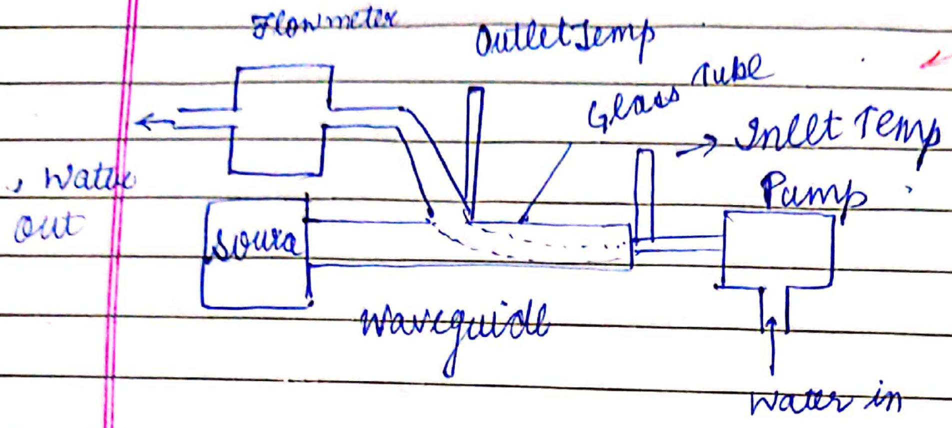
Accuracy → tending to a particular value.

Precision →

using Bolometer sensor → can not measure for wide range.

one sol^n → use of wheatstone bridge.

→ Calorimeter



Dynamic – To measure high power.

$P = 4.187\, v d C_p T$ ⟶ will give mass.

v → Rate of flow

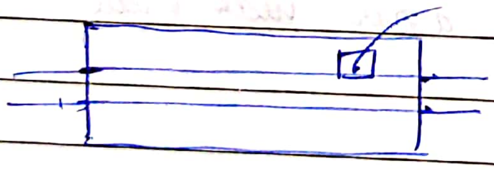
d → Specific gravity

T → Temp rise °C ⟶ continuously changing

C_p → Specific Heat

Static

Thermocouple is placed



$$P = \frac{4.187\, m C_p T}{t}$$

– static value

VSWR Measurement → Low
→ Medium
→ High

$1 \le S \le 3$ – L

$3 \le S \le 10$ – M

> 10 – High

→ single minima method

$1 \le S \le \infty$

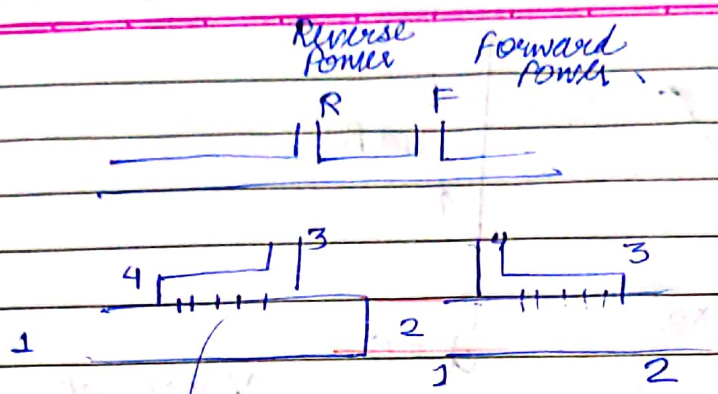
$$\frac{V_{max}}{V_{min}} = S.$$

$$S = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Scanned by CamScanner

PW

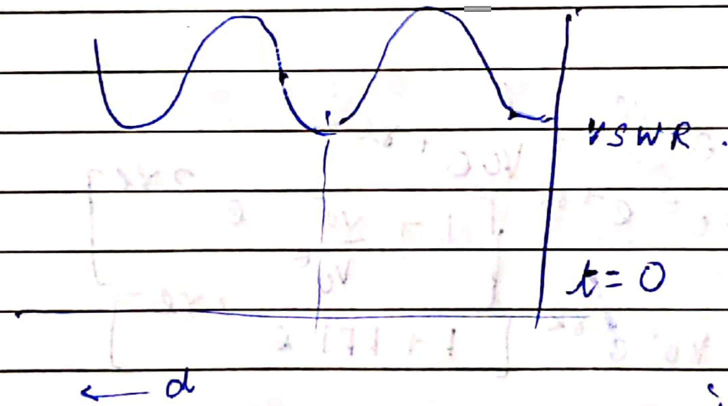
Can measure RP & FP →



- Reflectometer Measurement
- or Direct'al coupler

Port 4 → match Terminator

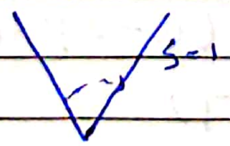
Multiple holes at equal distance

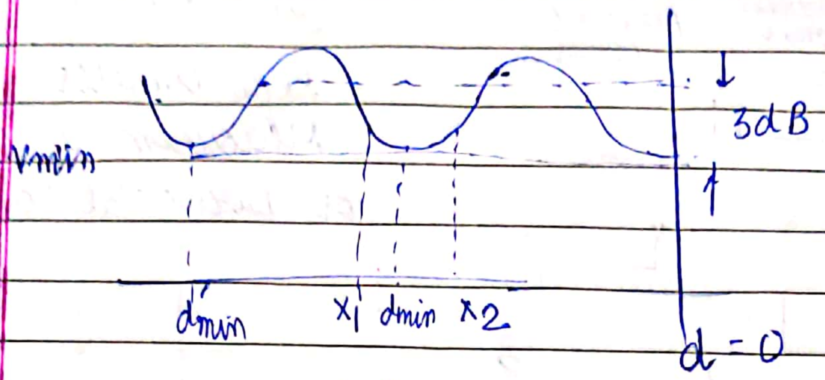


If sensitivity of measuring device is not good, we might not be able to measure Vmin as it is in μV.

so terminate using gain coarse & fine → 1st minima

- First set to a reference value. Then move left/right





Vincident → similar to V_0^+

$$\Gamma = \rho e^{j\phi}$$

$$|V(x)| = |V_{inc}|\, |1 + \rho e^{j(\phi - 2\beta x)}|$$

$$|V(x)| = |V_{inc}|\, |1 +$$

$$V = V_0^+ e^{-\gamma l} + V_0^- e^{+\gamma l}$$

$$= V_0^+ e^{+\gamma l}\left[1 + \frac{V_0^-}{V_0^+} e^{-2\gamma l}\right]$$

$$= V_0^+ e^{\gamma l}\left[1 + |\Gamma| e^{-2\gamma l}\right]$$

$$\rightarrow |V(x)| = |V_{inc}|\left[1 + 2\rho \cos(\phi - 2\beta x) + \rho^2\right]^{1/2}$$

$$|V_{min}| = |V_{inc}|(1 - \rho)$$

$$m = \frac{|V(x_1)|}{|V_{min}|}$$

$$= \frac{\left[1 + 2\rho\cos(\phi - 2\beta x_1) + \rho^2\right]^{1/2}}{(1 - \rho)}$$

$$\rho\text{ (Reflect}^n\text{ Coeff.)} = \frac{S-1}{S+1}$$

$$S = \frac{1+\rho}{1-\rho} \qquad \rho = |\Gamma|$$

$$m = \left[\frac{1 + 2\left(\frac{S-1}{S+1}\right)\cos\left(\phi - 2\beta x_1\right) + \left(\frac{S-1}{S+1}\right)^2}{\left(1 - \left(\frac{S-1}{S+1}\right)\right)}\right]^{1/2}$$

$$m^2 = \frac{1 + 2\rho\cos(\phi - 2\beta x_1) + \rho^2}{(1-\rho)^2}$$

$$\Rightarrow \quad 1 + \rho^2 - m^2\underbrace{(1-\rho)^2}_{1+\rho^2-2\rho} = -2\rho\cos(\phi - 2\beta x_1)$$

$$(1-m^2)\rho^2 + 2\rho\cos(\phi - 2\beta x_1) + (1-m^2) + 2\rho m^2 = 0$$

$$S = \left[\frac{m^2 - \cos^2\frac{2\pi(x_1 - x_{min})}{\lambda g}}{\sin\left[\frac{2\pi(x_1 - x_{min})}{\lambda g}\right]}\right]^{1/2}$$

where $\Delta x = 2(x_1 - x_{min})$

$$\beta = \frac{2\pi}{\lambda g}$$

$$S = \left[\frac{m^2 - \cos^2\frac{\pi\Delta x}{\lambda g}}{\sin^2\frac{\pi\Delta x}{\lambda g}}\right]^{1/2}.$$

$$= \left[\frac{m^2 - 1 + \sin^2\frac{\pi\Delta x}{\lambda g}}{\sin^2\frac{\pi\Delta x}{\lambda g}}\right]^{1/2} = \left(1 + \frac{m^2 - 1}{\sin^2\frac{\pi\Delta x}{\lambda g}}\right)^{1/2}$$

if $\Delta x \to 0$

$$\frac{\pi \Delta x}{\lambda g} \to 0$$

$$\sin \frac{\pi \Delta x}{\lambda g} \to \frac{\pi \Delta x}{\lambda g}$$

$$S = \left[1 + \frac{1}{\sin^2 \frac{\pi \Delta x}{\lambda g}} \right]^{1/2} \qquad m = \sqrt{2}$$

$$\approx \left[\frac{1}{\sin^2 \frac{\pi \Delta x}{\lambda g}} \right]^{1/2}$$

$$\approx \frac{1}{\cancel{\frac{1}{2}} \sin\left(\frac{\pi \Delta x}{\lambda g}\right)}$$

$\frac{\lambda g}{2}$, Dist b/w 2 successive minimas.

$$= \frac{1}{\cancel{2}} \cdot \frac{\lambda g}{\pi \Delta x} = \cancel{2(x_1 - x_2)}$$

$$= \frac{2(d_{min}' - d_{min})}{\pi \Delta x}$$

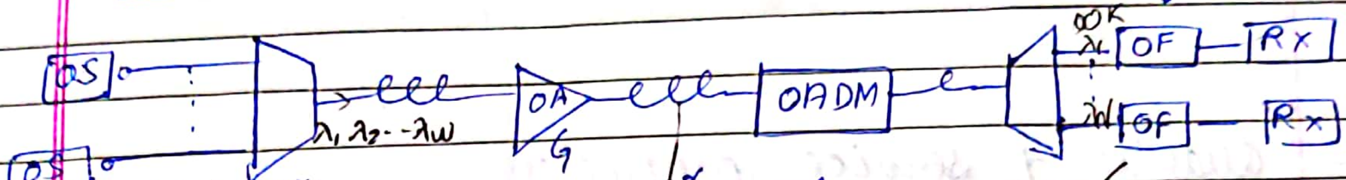
Gangopadhyay Sir's class.

Multi Wavelength single link system

17/10/19

Point to Point Link

optical filter



optical MUX

$e^{-\alpha} \cdot G = 1$

Insertion Loss

IP/WDM (IP/fibre)

IP/Ether (wireless)

Fibre should:
- attenuat"
- Dispersion
- PMD
- Fault detect"

CWDM $\uparrow\lambda_1$ 4nm $\uparrow\lambda_2$

DWDM (Dense) $\uparrow\uparrow$ → 100 GHz

SNDD superDense $\uparrow\uparrow$ $\lambda_1 \lambda_2$

optical source
LED/Laser

- Non linear effects (SPM/XPM/FWM)
- Attenuation / ~~Distortion~~ Dispersion

Rx can be
- PIN-FET
- APD-FET
- coherent Rx

- OA (optical Amp')
  - EDFA
  - DRA → used for undersea comm
  - SOA

optical add & Drop Multiplexer

In OADM → we can add som of local signals & we can also draw some of the signals.

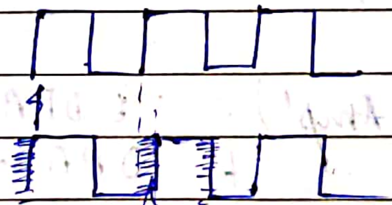
- Quality of service parameters

- Rx Sensitivity
  - eye diagram → eye is open → good reception
    - eye is closed → bad reception

~~Rx Sensitivity~~ ~~→ ey~~ . BER → $10^{-12} - 10^{-15}$

BER Test set → equipment which directly measures BER of s/s .

- Responsivity
- Jitter .



Freq aquisition
& Phase aquisition

Timing Jitter

Dynamic Lock .

Jitter variance → σ (Rms value of Jitter)

$$\frac{\sigma}{T} < 0.5$$

there is ~~vare~~ .

- OOK
- PSK
- QPSK
- OFDM

phase coherent s/s are used nowadays .

$$n = n(\omega) + n_2 I$$

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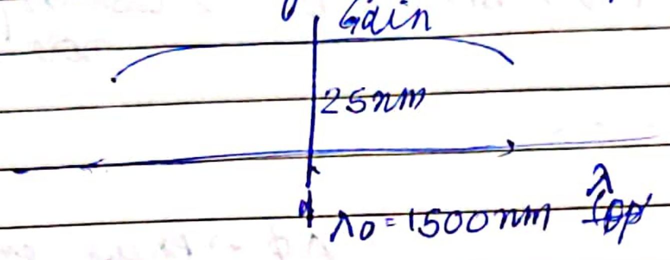
25nm is BW of optical ampⁿ.



- OA generates ASE noise.

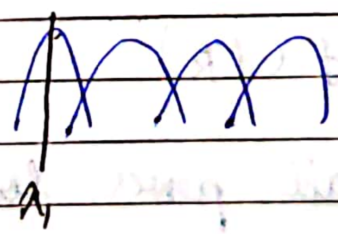
$$P_{ASE} = (2 n_{sp} h \nu (G-1) B_{op})$$

- At Rx there is a polarisation controller

injecting a pump signal → higher gain.

- ? Gain equalizatⁿ → Every channel enjoys equal gain.

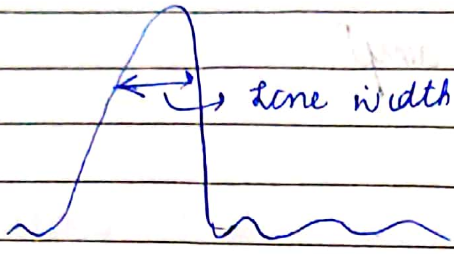
- Channel Spacing



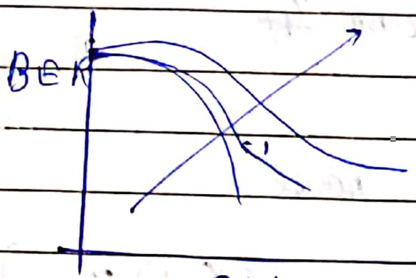
A To minimise adjacent channel interference AWG devices are used.

- Power o/p
- Spectrum
- Peak λ
- Pulse wave
- extinction ratio

Laser



→ Line width should be as less as possible
⇒ more coherent



$\Delta\phi$ → Phase error
- choose a laser for coherence comm s.t
Phase noise should be as less as possible.

- Power Budget
- Rise Time Budget

$$P_S - P_R = \underbrace{\alpha L}_{\text{Fibre loss}} + n\alpha_{CM} + K + \alpha_M$$

$$BER = f(P_R)$$

~~All~~ Add all power losses.

- Time degration, Tempr Degradation.

$$\boxed{\tau_{sys} < \tau_{allowed}} \Rightarrow$$

$$\tau_{sys} = 1.1\sqrt{t_{tx}^2 + t_{Rx}^2 + \tau_i^2 + \tau_c^2}$$

τ_i: Intermodal dispersion → due to Timing difference

τ_c: Cromatic

Standardisation Bodies :-

1. NIST (National Institute of standard (USA)
2. NPL (UK)
3. ITU
4. TIA
5. ANSI
6. IEEE.
7. ITU.

B_{op} (typically) $= 0.1$ nm

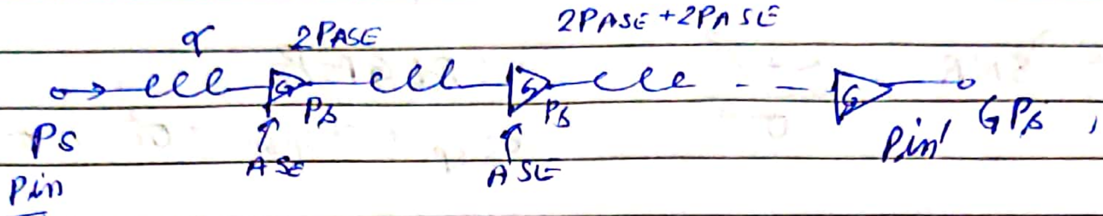
$1mW = 0\,dBm$

$\downarrow dB$

$20 = 20\log x$

$x = 10^{1}$ → 10 W

$20\log$



$e^{-\alpha L_A} = G$

OSNR = ?

$$OSNR = \frac{\cancel{GPs}}{} \quad \frac{GPs}{N \cdot 2P_{ASE}}$$

$$\frac{Pin}{N2P_{ASE}}$$

$$OSNR = \frac{Pin}{N 2 n_{sp} h\nu (G-1) B_{op}}$$

$OSNR(dB) = Pin\,(dBm) - N\,(dB) - n_{sp}\,(dB) - G\,(dB) + 58\,dBm$

Ques max transmission distance ?

$l_A = 100$ Km, $\alpha_{fibre} = 0.25$ dB/km $2n_{sp} = 5$dB

$Pin = 1$mW. Req OSNR $= 20$ dB.

$N(dB) = \underset{Pin}{0} - 20 - 5 - 25 + 58$

$= 8dB$

$\downarrow$

6.3

$1mW = 0\,dBm$

?

$$I = R_d\Big(\big|\overset{s}{\sqrt{G}\,E_s} + E_{ASE}\big|^2\Big) + i_s + i_T$$

current of combined field, i/p power-detector

short noise

thermal Noise

$$\boxed{= R_d\,GPs + I_{s.sp} + i_{s_{p,sp}} + i_{sric}}$$

spontaneous

$(s+n)^2 = s \times n + s \times s + n \times n$

$sp \to$ spontaneous

$s \to$ signal

electrical $SNR = \frac{\langle I \rangle^2}{\sigma^2} = \frac{(R_d G P_s)^2}{\sigma_{s\text{-}sp}^2 + \sigma_{sp\text{-}sp}^2 + \sigma_s^2 + \sigma_{th}^2}$

$\cancel{\sigma_s^2 = 2q[R(GP_s + P_{ASE})}$

$\sigma_{sig\text{-}sp}^2 = 4 R_d^2 \cdot G P_s S_{ASE} \Delta f$

$\sigma_{sp\text{-}sp}^2 = 4 R_d^2 S_{ASE}^2 \Delta f \left(B_{op} - \frac{\Delta f}{2}\right)$

$\sigma_s^2 = 2q\left[R_d (G P_s + P_{ASE})\right] \Delta f$

$\sigma^2 = \frac{4KT\Delta f}{R}$

$S_{ASE} = \frac{P_{ASE}}{B_{op}}$

dominating noise:

$SNR = \frac{(R_d G P_s)^2}{4 R_d^2 G P_s S_{ASE} B_e}$

$\Delta f = B_e$

$= \frac{G \cdot P_s B_{op}}{2 P_{ASE} B_e \times 2}$

$= \frac{B_{op}}{2 B_e} \times OSNR$

$i_0 \to$ mean signal current when 0 is received

$\sigma_0^2 \to$ variance Total noise variance when 0 is received.

$Q = \frac{I_1}{\sigma_1}$

$= \sqrt{\frac{I_1^2}{\sigma_1^2}}$

$= \sqrt{SNR}$

$\frac{B_{op}}{2B_e} \times OSNR = Q^2$

$\Rightarrow \boxed{Q = \sqrt{\frac{OSNR}{2} \times \frac{B_{op}}{B_e}}}$

$$\boxed{BER = \frac{1}{2}\,\mathrm{erfc}\left(\frac{Q}{\sqrt{2}}\right)}$$

$BER \rightarrow 10^{-9} - 10^{14}$ ✓ $\qquad 10^{-3} - 10^{-4}$ ×

BER Test . $\qquad 10^{-9} - 10^{-14}$ ✓

$$\boxed{BER = \frac{N_{error}}{R \;\; \Delta T}} \rightarrow \approx 100$$

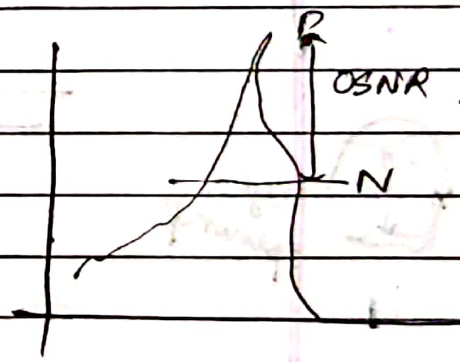
$R \rightarrow$ data rate

10 Gb/s $\qquad 10^{-12}$ BER

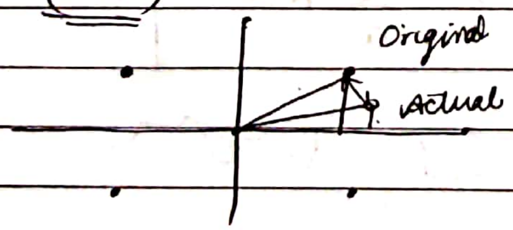
$$\Delta T = \frac{100}{10^{-12} \times 10^{10}} = 10^{4}\,s = 2.7\,hr$$

$$Q = \frac{\langle I_1 \rangle - \langle I_0 \rangle}{\sigma_1 + \sigma_0}$$

$$BER = \frac{1}{2}\,\mathrm{erfc}\left(\frac{Q}{\sqrt{2}}\right)$$



Error Vector magnitude (EVM)



$$\text{error Amp} = \sqrt{(I_i - I_A)^2 + (Q_i - Q_A)^2}$$

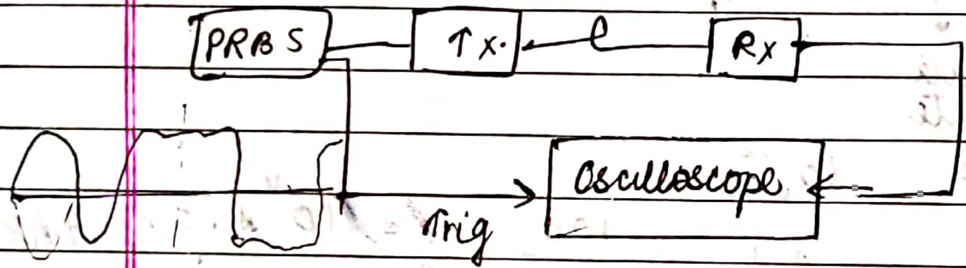
$$= \sqrt{(\Delta I)^2 + (\Delta Q)^2}$$

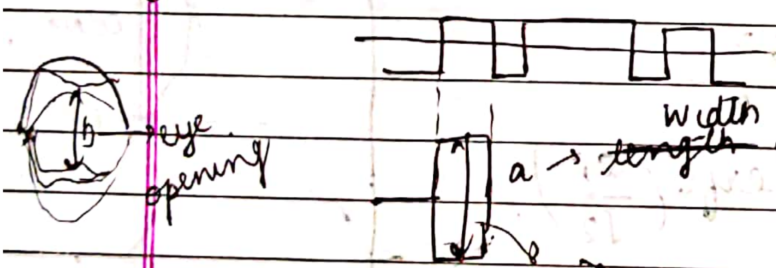
$$\text{error amp (rms)} = \sqrt{\frac{1}{N}\left(\sum_{k=1}^{n} \Delta I_k^2 + \Delta Q^2\right)}\ \%$$

IEEE 802.15.4 → ~~35%~~ EVM < 35%

to measure quality of reception.

Eye opening →





a → ~~length~~ width of eye when it is fully opened.

Full eye

$$\text{Eye opening (EOP)} = \frac{b}{a} \times 100$$

$$H_{eq}(f) = \frac{1}{H(f)\ \text{channel}}$$