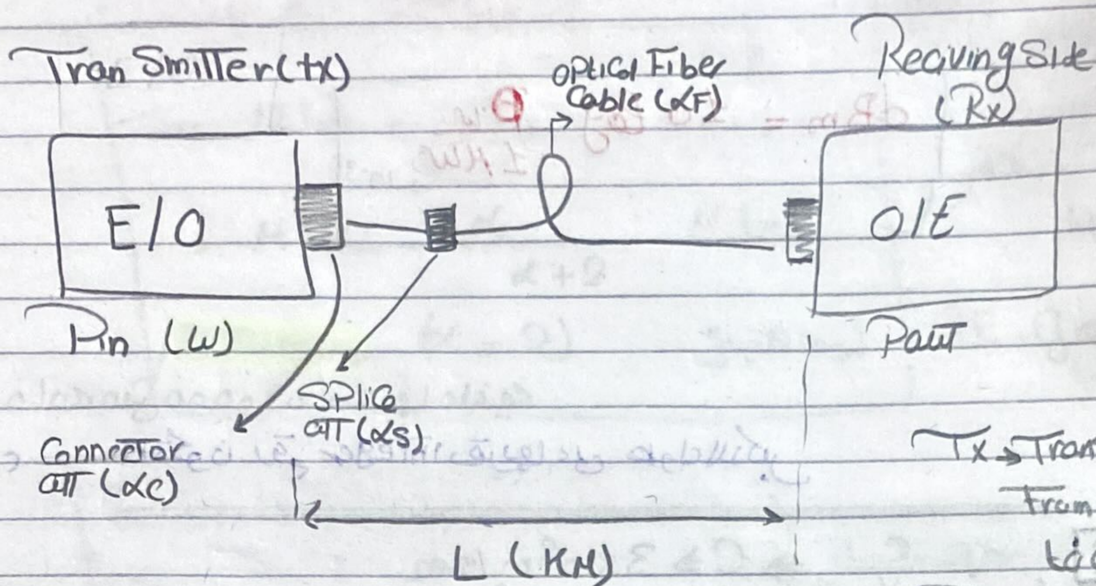
Pout < Pin → due to loss

Sec 1

Sheet 1

Calculation of attenuation in optical Fiber Communication

splices: لحام الكابل



Tx → Transfer from electric to optical

Rx العكس

$$\alpha t/dB = \alpha F \cdot L + (n-1)\alpha s + 2\alpha c + \alpha ICL + \alpha OCL$$

→ αF: optical Fiber attenuation Coefficient (dB/KM)

→ αs: Splice attinuation Coefficient (dB/splice)

→ αC: Connector attenuation Coefficient (dB/Connector)

→ αICL: input Coupling loss (dB)

→ αOCL: output Coupling loss (dB)

عدد وصلات الكابلات → n: no of sections

→ (n-1): no of splice

$$n = \frac{\text{Total Fiber length}}{\text{real length}}$$

$$\alpha t|dB = 10 \log\left(\frac{P_{in}}{P_{out}}\right) = P_{in}|dBm - P_{out}|dPM$$

$$dBm = 10 \log \frac{P.w}{1\,mW \rightarrow 10^{-3}}$$

اذا حاجه مش موجوده بتربيها ملغيه

لازم n تكون رقم integer بقربها على طول للاكبر

Sec 2 $n = \frac{c}{v} \Rightarrow C \Rightarrow 3 \times 10^8 m/sec$

refractive index

V = velocity of medium

$n_1 > n_2$

The Normalical oPerture (NA)

Core → cladding

- $NA = \sqrt{n_1^2 - n_2^2}$
- $NA = n_1 \sqrt{2\Delta}$ → يستخدموا لو اتاني n واحده بس

diFFranCe Refractive index (Δ)

$$\Delta = \frac{n_1 - n_2}{n_1}$$

the acCeptanCe angle (Φ_{max})

$\Phi_{max} = \sin^{-1}(NA)$

The normalized Frequancy (V)

- $V = \frac{2\pi a}{\lambda} NA$
- $V = \frac{\pi d}{\lambda} NA$

a → redius of core $= \frac{d}{2}$

d → diameter of Core

PAGE

DATE

NOTE The Normalized Frequency (V) For Single mode Fiber

$V = 2.405$

The No of (M_Mode)

normalized Freq

→ $M|_{SI} = \frac{V^2}{2}$

SI → STEP index

مش بتكون كسر بقربها

→ $M|_{GI} = \frac{\alpha}{\alpha+2} M|_{SI}$

Assume → $(\alpha = 2)$ لو مدهنيش

GI = Graded index

$$\frac{P_{clading}}{P_{total}} = \frac{4}{3\sqrt{M}}$$

The Fraction of Power Propagation in the Clading

لازم اضربها في 100

ال diameter بتاع cladding اكبر من Core

Sheet 1

1- قالك

$\alpha_T = \alpha_F L + (n-1)\alpha_s + 2\alpha_C + \alpha_{ICL} + \alpha_{OCL}$ (the α_C term is marked → 0; "μw" circled)

$\alpha_F = 1.5\ dB/KM$
$P_{in} = 0.5mW$
$P_{out} = ??$
$L = 8KM$
real length = 2KM
$\alpha_S = 0.1\ dB$ Per Splice
$\alpha_{ICL} = 1\ dB$
$\alpha_{OCL} = 2dB$

$$n = \frac{\text{Total length}}{\text{real length}} = \frac{8}{2} = 4KM$$

$$\alpha_T = ((1.5) * 8) + (4-1) * 0.1 + 1 + 2$$
$$= 15.3\ dB$$

$$\alpha_T = 10\log\frac{P_{in}}{P_{out}} = P_{in}|dBM - P_{out}|dBM$$

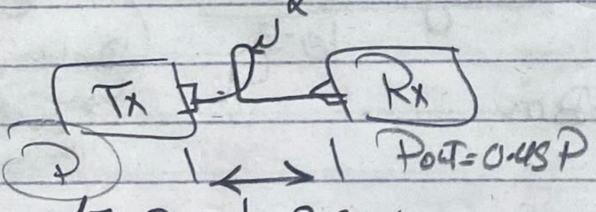
$$P_{out}|dBM = 10\log\frac{0.5mW}{1mW} - 15.3$$

$$= -18.31\ dBM$$ اعطالي (dB)

$$P_{out_{mw}} \Rightarrow 10\log x = -18.31$$ عايزاه (m)

$$= 0.01478\ mW$$
$$= 14.78\ \mu W$$

2-



فقد 55% من us

$\alpha_F = ??$
Real $L = 3KM$
$\alpha_S = 0.2dB/Splice$
$\alpha_{ICL} = 1dB$
$\alpha_{OCL} = 0.8dB$

$$n = \frac{3.5}{3} = 1.17 \simeq 2$$ $L = 3.5KM$

لازم اقربها لكبير

$$\alpha_T = 10\log\frac{P_{in}}{P_{out}} = 10\log\frac{P}{0.45P} = 3.47dB$$

$$\alpha_T = \alpha_F * L + (n-1)\alpha_s + 2\alpha_C + \alpha_{ICL} + \alpha_{OCL}$$

$$??\ 3.5 + (2-1) * 0.2 + 0 + 1 + 0.8 = 3.47$$

$$\alpha_F = 0.42\ dB/KM$$

الحلول ل 3-

$\alpha_T = 10 \log \frac{P_{in}}{P_{out}} =$

$10 \log \frac{1\,mW}{0.1\,mW} = 10\,dB$

$\alpha_F = 0.5\,dB/KM$
$P_{in} = 1\,mW$
$P_{out} = 0.1\,mW$
$L = ??$

$\alpha_c, \alpha_s, \alpha_{ICL}, \alpha_{OCL}$ → Zero

$\alpha_t = \alpha_F L + \alpha_s(n-1) + 2\alpha_c + \alpha_{ICL} + \alpha_{OCL}$
(0) (0) (0) (0)

$10 = 0.5L$
$L = 20\,KM$

4-

$n = \frac{12}{3} = 4\,KM$

$L = 12\,KM$
$\alpha_F = 1.5\,dB/KM$
$P_{in} = ??$
$P_{out} = 0.3\,\mu W$
real length = 3 KM
$\alpha_s = 0.1\,dB/splice$

The CouPling losses ar 2dB → Transmeter (α_{ICL}) → Receiver (α_{OCL})

$\alpha_t = 12 * 1.5 + (4-1)(0.1) + 2 + 2 = 22.3\,dB$

$\alpha_t|_{dB} = P_{in}|_{dBm} - P_{out}|_{dBm}$

$22.3 = P_{in}|_{dBm} - 10\log \frac{0.3\times10^{-6}}{10^{-3}}$

لماتى احول ل W بيكون معطاها dBm احولها هكون mW

$P_{in}|_{dBm} = -12.93\,dBm$

$P_{in} \Rightarrow 10^{\frac{-12.93}{10}} = 0.051\,mW$
$= 50.93\,\mu W$

PAGE
DATE

5 (50/125) → SI

$n_1 = 1.48$
$n_2 = 1.465$
$\lambda = 1320 nm$

NA = ?
θ_{max} = ??
M = ?? → STEP

$\frac{P_{clading}}{P_{total}}$
d Core ⇒ ??
↳ STEP index Single moode

50/125 → diameter
↙ core ↳ Clading

50 → Core الصغير
→ Clading الكبير

(d = 50 μm) → a = 25 μm ← متكونش مذكرش ال units

$\rightarrow NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.48)^2 - (1.465)^2} = 0.21$

$\theta_{max} = \sin^{-1} NA = \sin^{-1} 0.21 = 12.12°$

$M_{SI} = \frac{V^2}{2}$, $V = \frac{\pi d}{\lambda} NA$

$V = \frac{\pi (50 \times 10^{-6})}{1320 \times 10^{-9}} (0.21) = 24.98 \simeq 25$

ASK

$\Rightarrow M_{SI} = \frac{(25)^2}{2} = \boxed{312}$

$\frac{P_{clading}}{P_{total}} = \frac{4}{3\sqrt{M}} = \frac{4}{3\sqrt{312}} = \boxed{7.5\%}$

For Single mood
$\Rightarrow V = 2.405$

$V = \frac{\pi d}{\lambda} NA \Rightarrow 2.405 = \frac{\pi d}{1320 \times 10^{-9}} (0.21)$

$d = 4.8 \mu m$

PAGE
DATE

[6] Step index

$a = 25\,\mu m$ (Core radius)

$n_1 = 1.48 \rightarrow$ Core

$\Delta = 0.01$

$\lambda = 0.84\,\mu m$

$NA = ??$

$V = ??$

$\rightarrow NA = n_1 \sqrt{2\Delta} = 1.48\sqrt{2(0.01)} = 0.21$

$\rightarrow V = \dfrac{2\pi a}{\lambda} NA \Rightarrow \dfrac{2\pi (25\times10^{-6})}{0.84\times10^{-6}} (0.21$

$= 39.27$

$\rightarrow M_{SI} = \dfrac{V^2}{2} = \dfrac{(39.27)^2}{2} = 771.07$

$\rightarrow \dfrac{P_{clading}}{P_{total}} = \dfrac{4}{3\sqrt{M}} = \dfrac{4}{3} \dfrac{1}{\sqrt{771.07}} = 4.8\%$

[7] Singlemode $\rightarrow V = 2.405$, $d = 10\,\mu m$, $\lambda = 1.3\,\mu m$

$n_1 = 1.55$

$\rightarrow n_2 = ??$

$\rightarrow \Delta$

$\rightarrow \theta_{max}$

$V = \dfrac{\pi d}{\lambda} NA \Rightarrow \dfrac{\pi (10\times10^{-6})}{1.3\times10^{-6}} NA$

$= 2.405$

الما الوحيد دالي مش هتقفل
تقريب في n_2

$NA = 0.0995 \Rightarrow NA = \sqrt{n_1^2 - n_2^2}$

$\sqrt{(1.55)^2 - (0.0995)^2} = n_2 \Rightarrow n_2 = 1.5468$

$\Delta = \dfrac{n_1 - n_2}{n_1} = \dfrac{1.55 - 1.5468}{1.55} \times 100 = 0.206\%$

$\theta_{max} = \sin^{-1} 0.0995 = 5.71$

8 $NA = \sqrt{n_1^2 - n_2^2}$

$\sqrt{(1.55)^2 - (1.51)^2} = 0.35$

$\rightarrow \phi_{max} = \sin^{-1} 0.35 = 20.49°$

$\rightarrow V = \frac{\pi d}{\lambda} NA$

$= \frac{\pi (50 \times 10^{-6})}{0.8 \times 10^{-6}} (0.35) = 68.72$

$\rightarrow M_{SI} = \frac{V^2}{2}$ هصب النوعين لانو مصدد ش النوع

$= 2361$

$\rightarrow M_{GI} = \frac{\alpha}{\alpha + 2} M_{SI} \Rightarrow$ Assume $\alpha = 2$

Gradedindex

$= \frac{2}{2+2} (2361) = 1180$

$n_1 = 1.55$
$n_2 = 1.51$
$d = 50 \mu m$
$\lambda = 0.8 \mu m$
NA = ??
ϕ_{max}
V = ??
M = ??

9 $NA = \sqrt{n_1^2 - n_2^2} \Rightarrow \sqrt{(1.48)^2 - (1.46)^2}$

$= 0.24$

$V = \frac{\pi d}{\lambda} NA = \frac{\pi (50 \times 10^{-6})}{1300 \times 10^{-9}} (0.24)$

$\simeq 29$

$M_{SI} \Rightarrow \frac{V^2}{2}$

$= \frac{(29)^2}{2} = 420$

$M_{GI} = \frac{\alpha}{\alpha + 2} M_{SI}$

$= \frac{1}{1+2} (420) = 140$

M = ??
$\lambda = 1300$ nm
↳ GI
$\alpha = 1$
$d = 50 \mu m$
$n_1 = 1.48$
$n = 1.46$

$\frac{P_{clading}}{P_{total}}$ < GI / SI

$\frac{P_{clading}}{P_{total}} = \frac{4}{3\sqrt{M_{SI}}} = 6.5\% \Rightarrow \frac{P_{clading}}{P_t} = 11.26\%$