Assignment 4

Bryan Jay
260738764

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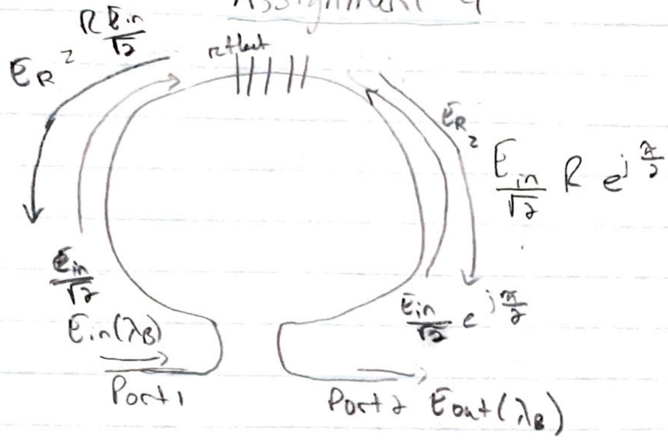


Port 1:

$$E_{out_{port1}}(\lambda_B) = \frac{E_{in}R'}{2} + \frac{E_{in}R'}{2} e^{j\frac{\pi}{2}} e^{j\pi/2} = \cancel{\frac{E_{in}}{2} + \frac{E_{in}}{2} e^{j\pi}}$$

system is out of phase by π

$$\boxed{E_{out/port1}(\lambda_B) = 0}$$

Port 2:

$$E_{out/port2}(\lambda_B) = \frac{E_{in}}{2} e^{j\frac{\pi}{2}} + \frac{E_{in}}{2} e^{j\frac{\pi}{2}} = E_{in} e^{j\frac{\pi}{2}}$$

$\Downarrow$

system is in phase.

$$\boxed{E_{out/port2}(\lambda_B) = E_{in} e^{j\frac{\pi}{2}}}$$

2 - a) $n_{eff} = 1,45$ $\lambda_B = 1550nm$

$\lambda_B = 2 n_{eff} \Lambda$

$\Rightarrow \Lambda = \frac{\lambda_B}{2 n_{eff}} = \frac{1550 \times 10^{-9} m}{2(1,45)} = \boxed{0,534 \mu m}$

b) $P_{in} = 1mW$ $R = 99\%$ reflecting

i) $P_{through/add} = ?$ $P_{through/input} = ?$

We know $R = 99\%$ so 1% traverses through

$P_{through/input} = 1mW(0,01) = 0,01 mW$

We know $R = 99\%$

$P_{through/add} = (2mW)(0,99) = 1,98 mW$

$crosstalk = \frac{0,01 \cancel{mW}}{1,98 \cancel{mW}} = 0,00505$

$\boxed{crosstalk = -22,967 dB}$

ii) $P_{drop/input} = (1mW)(0.99) = 0,99 mW$

$P_{drop/add} = (2mW)(0,01) = 0,02 mW$

$crosstalk = \frac{P_{drop/add}}{P_{drop/input}} = \frac{0,02 \cancel{mW}}{0,99 \cancel{mW}} = 0,0\overline{202}$

$\boxed{Crosstalk = -16,95 dB}$

c) i) $P_{through/input} = 1mW(0,01)(0,01)$ $P_{through/add} = 1,98 mW$

$= 10^{-4} mW$

$crosstalk = \frac{P_{through/in}}{P_{through/add}} = \frac{10^{-4} \cancel{mW}}{1,98 \cancel{mW}} = 5,05 \times 10^{-4}$

$\boxed{crosstalk = -42,967 dB}$

ii) Since there is the addition of the terminated ends there will not be any power that will appear on the other side. As the signal is sent to the terminated end in the middle section the Pdrop/add = 0

$\boxed{\text{Crosstalk} = 0}$

3-a) $Q = \frac{V_1 - V_D}{\sigma_1} = \frac{V_D - V_0}{\sigma_0}$

$V_D = \frac{\sigma_0 V_1 + \sigma_1 V_0}{\sigma_0 + \sigma_1}$

$Q = \frac{\dfrac{\sigma_0 V_1 + \sigma_1 V_0}{\sigma_0 + \sigma_1} - \dfrac{V_0(\sigma_0 + \sigma_1)}{\sigma_0 + \sigma_1}}{\sigma_0}$

$= \frac{\sigma_0 V_1 + \cancel{\sigma_1 V_0} - V_0 \sigma_0 - \cancel{\sigma_1 V_0}}{(\sigma_0 + \sigma_1)\sigma_0}$

$= \frac{\cancel{\sigma_0} V_1 - V_0 \cancel{\sigma_0}}{(\sigma_0 + \sigma_1)\cancel{\sigma_0}} = \frac{V_1 - V_0}{\sigma_0 + \sigma_1}$

$Q = \frac{1{,}5V - 0{,}3V}{0{,}04 + 0{,}06} = 12$ $\boxed{Q = 12}$

b) Gaussian statistics.

$BER = p(1)P(0|1) + p(0)P(1|0)$

$= \frac{\exp(-\frac{Q^2}{\sigma})}{Q\sqrt{2\pi}}$

$BER = \frac{e^{-\frac{12^2}{2}}}{12\sqrt{2\pi}} = \boxed{1{,}7886 \times 10^{-33}}$

Hilroy

c) $BER = \frac{1}{2\sqrt{\pi SNR}} e^{-SNR}$

$2\sqrt{\pi SNR}\ BER = e^{-SNR}$

$\ln(2\sqrt{\pi SNR}\ BER) = -SNR$

$\ln(2) + \frac{1}{2}\ln(\pi SNR) + \ln(BER) = -SNR$

$\frac{1}{2}\ln(\pi SNR) + SNR = -\ln(2) - \ln(BER)$

Work by trial and error to solve SNR

$\boxed{SNR = 24,8}$

d) 1) Increase fiber insulation to shield from external noise

2) Increase the signal power to increase S of the signal

4-a) ~~Refer~~ Refer to Matlab code.

In order for error free transmission $BER \approx 10^{-12}$

$BER = 10^{-12}$

$BER_{dB} = -120dB$

for $BER_{dB} = -120dB$, the $OSNR_{dB} \approx 19,8dB$

$\boxed{OSNR_{dB} = 19,8dB}$

b) $OSNR = 16.01\ dB$

$BER = 4,0457 \times 10^{-4}$

Question 4 - Part a

```
BW = 20e9; % hz
ext_r_db = 20; % db (extinction ratio)
dist = 250; % km
BW_def = 12.5e9; % hz (optical bandwidth from the definition)

OSNR_db = 10:0.2:25; % dB
OSNR = 10.^(OSNR_db/10); % convert DB to non log component
ext_r = 10^(ext_r_db/10);

% find Q and BER
Q = sqrt((BW_def*OSNR*(1 - sqrt(ext_r))^2)/(BW*(1+ext_r)))
```

```
Q = 1×76
    2.2388    2.2910    2.3443    2.3990    2.4548    2.5120    2.5705    2.6304 ···
```

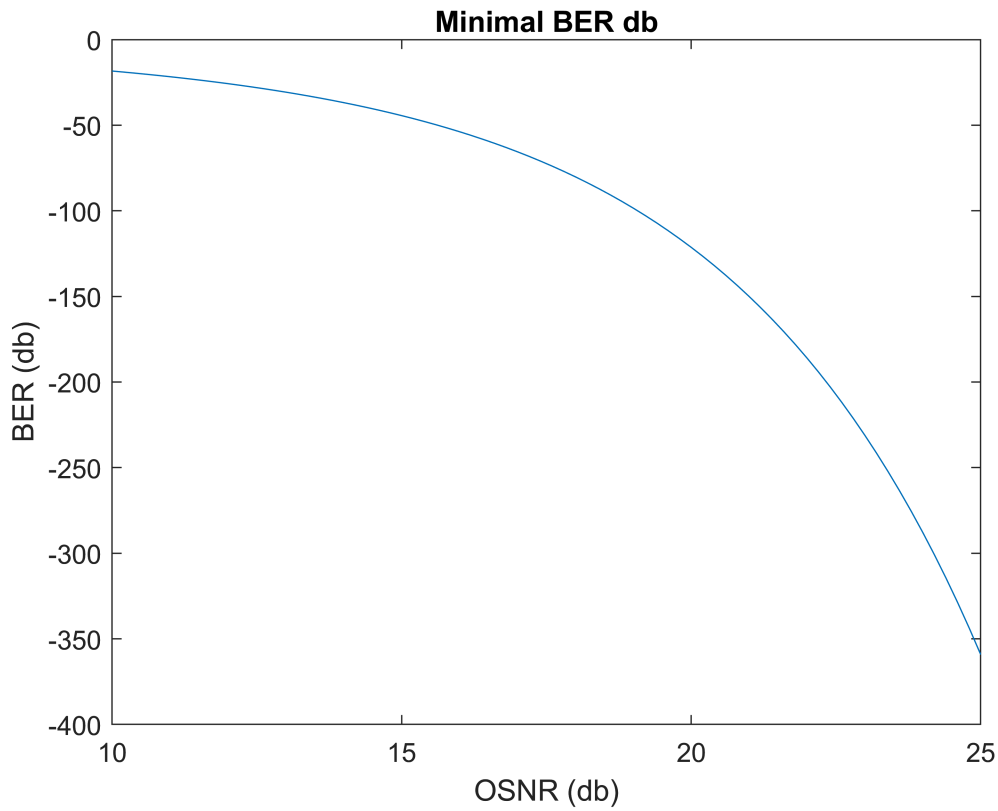
```
BER = exp(- Q.^2 / 2) ./ (Q * sqrt(2*pi))
```

```
BER = 1×76
    0.0145    0.0126    0.0109    0.0094    0.0080    0.0068    0.0057    0.0048 ···
```

```
BER_db = 10 * log10(BER)
```

```
BER_db = 1×76
  -18.3754  -18.9883  -19.6254  -20.2879  -20.9768  -21.6936  -22.4393  -23.2155 ···
```

```
plot(OSNR_db, BER_db)
title('Minimal BER db')
xlabel('OSNR (db)')
ylabel('BER (db)')
```



Part b

```
P_in_db = 12; % dbm
alpha = 0.18; % db/km
n = 5;
noise_f_db = 4; % db

losses = alpha * dist; % db

OSNR_db = 60 + P_in_db - noise_f_db - losses - 10 *log10(n) % use the approximate 60
```

```
OSNR_db = 16.0103
```

```
OSNR = 10^(OSNR_db/10); % convert DB to non log component

% find Q and BER
Q = sqrt((BW_def*OSNR*(1 - sqrt(ext_r))^2)/(BW*(1+ext_r)))
```

```
Q = 4.4724
```

```
BER = exp(- Q.^2 / 2) ./ (Q * sqrt(2*pi))
```

```
BER = 4.0457e-06
```