Problem 1

a. You need to operate a transmission link working at 8 Gb/s, over copper cable. The maximum bandwidth slot you can use is 5GHz. The value of d for your modulator is equal to 1. You want to achieve a BER of 10^{-5}. The total link length is 500m, the cable loss is 0.1 dB/m. The receiver sensitivity is –70 dBm, and it has a noise figure of 3 dB. The launch power is 0.0001 mW and the SNR at the launch is 80 dB.

Show why this link does will not work!

Data:

R= 8 Gb/s,

B= 5GHz

d=1,

BER = 10^{-5}

L=500m

α= 0.1 dB/m

$P_{min\,RX}$= –70 dBm

NF_{RX}= 3 dB.

P_{in}= 0.0001 mW

SNR_{TX}= 80 dB.

$$\boldsymbol{B = (1 + d)S}$$

$$\boldsymbol{R = nS}$$

$$\boldsymbol{S = \frac{R}{n}}$$

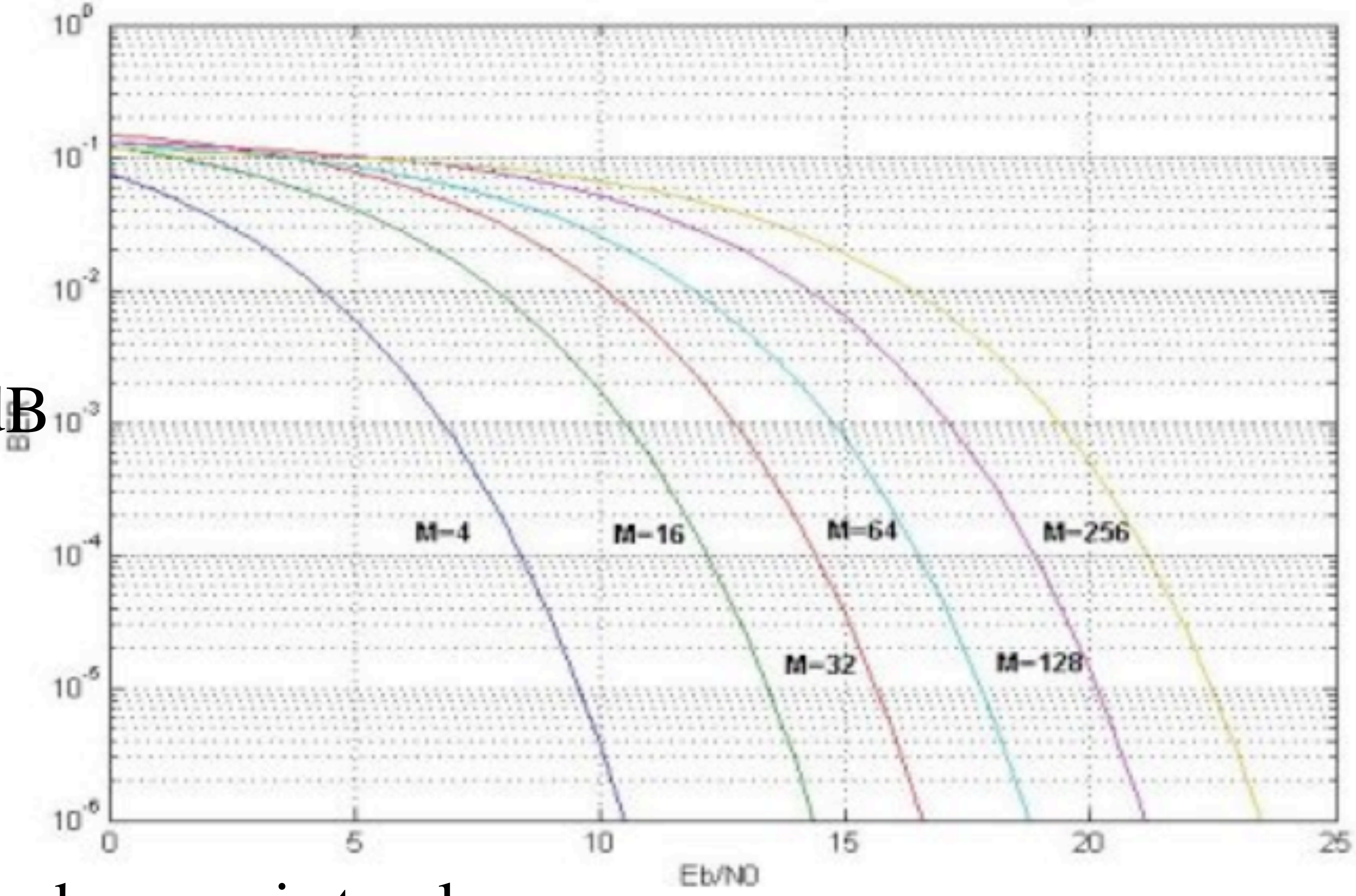
$$\boldsymbol{B = (1 + d)\frac{R}{n}}$$

$$\boldsymbol{n = (1 + d)\frac{R}{B} = \frac{2R}{B} = \frac{16}{5} = 3.2}$$

n=4 => $2^4 = 16$ =>we need to use 16 QAM

For the system to work:

1. The **received power** needs to be higher than receiver sensitivity
2. **SNR at the receiver** needs to be higher than the required SNR for given modulation format and BER.



Required SNR= 14 dB (16QAM)

$P_{min\ RX}$= –70 dBm

SNR_{RX}= SNR_{TX} -loss- NF_{RX}

Loss=L* α =500m *0.1dB/m=50dB

SNR_{RX}=80-50-3=27dB >>14dB

P_{in}= 0.0001 mW => -40dBm

P_{RX} = -40-50=-90dBm <<-70dBm

System will not work as the received power is too low.

b) Design the communication link that achieves the required performance, preferring if possible amplifiers to regenerators for their lower cost. The amplifier has a gain of 25 dB, and a NF of 8 dB. The regenerator brings the signal power and SNR back to the transmitter launch values and has the same NF and sensitivity as the receiver.

Data:

NF_{amp}= 8 dB

G= 25 dB

Because receiver SNR is high we can use amplifier to boost the received power (amplifier will reduce the SNR)

New SNR is now: $SNR_{RX} = SNR_{TX} - loss - NF_{amp} - NF_{RX}$

$SNR_{RX} = 80-50-8-3 = 19dB > 14dB$

$P_{RX} = -40-50+25 = -65dBm > -70dBm$

Problem 2

- You need to design a transmission link over copper cable capable of delivering a data rate of at least 10 Gb/s. Assume the maximum baud rate you can use is 2 Gbaud and the link length is 1500 m. The copper cable loss is 0.1 dB/m, the receiver sensitivity is -70 dBm, the power of the transmitter is 4 mW, the Signal-to-noise ratio (SNR) at the transmitter is 80dB and the receiver noise figure is 3 dB.
- Select a suitable modulation (considering the plot in the figure above) and design a link that achieves a maximum Bit Error Rate (BER) of 10^{-5}, using the minimum number of regenerators and/or amplifiers. The amplifiers have a noise figure of 5 dB and gain of 30dB, while the regenerators have the same characteristics of the receivers and transmitters described above.

Data:

R= 10 Gb/s,

S= 2 GBaud

BER = 10^{-5}

L=1500m

α= 0.1 dB/m

$P_{min\ RX}$= $P_{min\ Reg}$= –70 dBm

NF_{RX}= $NF_{Reg.}$= 3 dB

NF_{amp}= 5 dB

G= 30 dB

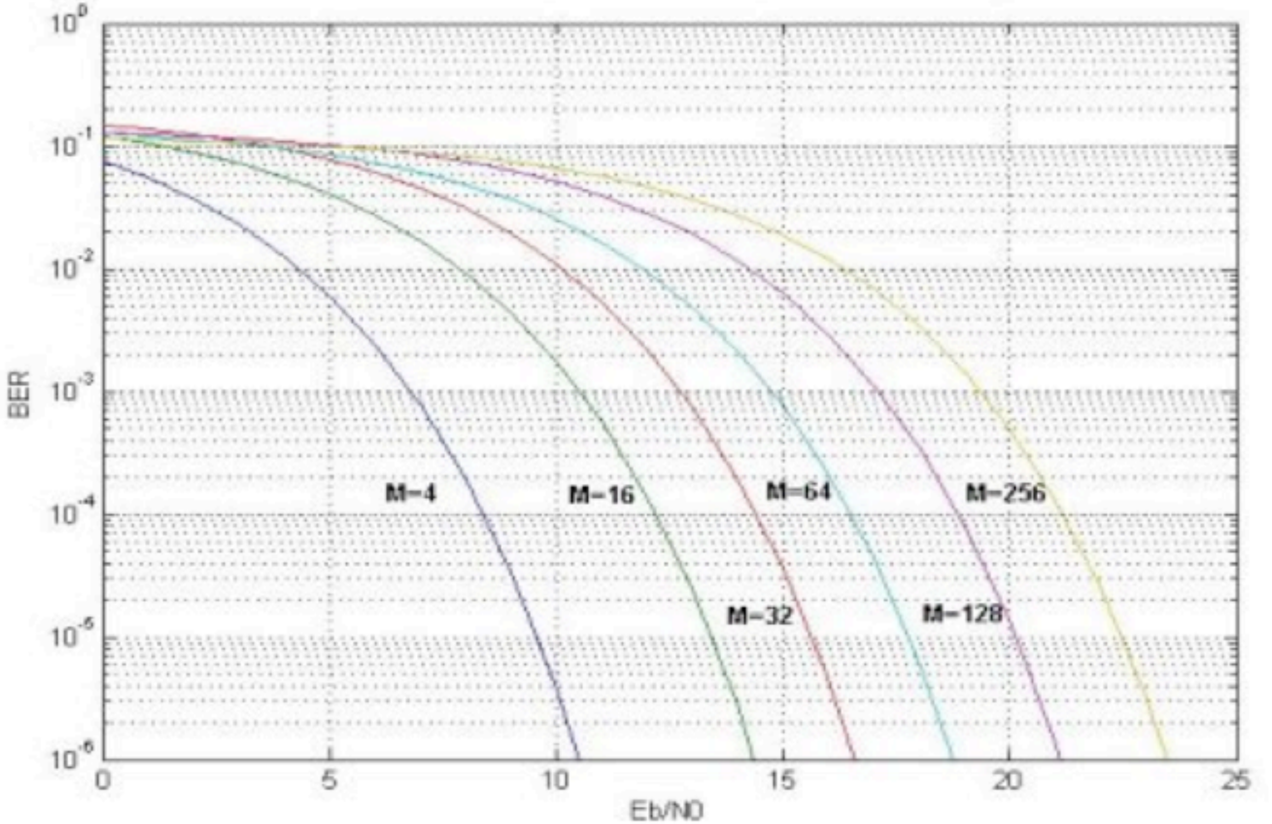
P_{in}= 4 mW

SNR_{TX}= 80 dB.

$$n = \frac{R}{S} = \frac{10}{2} = 5\,\frac{bits}{symbol}$$

n=4 => $2^5 = 32$ =>we need to use 32 QAM

Required SNR= 16 dB (32QAM)



Required SNR= 16 dB

$P_{min\ RX}$= –70 dBm

SNR_{RX}= SNR_{TX} -loss- NF_{RX}

Loss=L* α =1500m *0.1dB/m=150dB

SNR_{RX}=80-150-3=-73dB <<16dB

P_{in}= 4 mW => 6 dBm

P_{RX} = 6 – 150 = -144 dBm <<-70dBm

Both power and SNR too low!

We cannot use amplifier as it will increase the power but reduce SNR!

We can only use regenerator!

Regenerator's sensitivity is $P_{min\ Reg}= -70$ dBm

So it has to be placed before the power drops below that value;

$P_{RX} = 6 - x = -70 = 76$ dB

Required SNR at the regenerator is same as the Rx so 16 dB. Thus regenerator has to be placed before the SNR of the signal drops below 16 dB:

$SNR_{RX}=80-x-3=-16dB \Rightarrow x =< 61$ dB

Loss of 61 dB is acquired after 610 m. For simplicity let's place the regenerator after 600 m:

$P_{RX} = 6 - 60 = -54 > -70$ dB

$SNR_{RX}=80-60-3 = 17$ dB > 16 dB

Since the output of the regenerator is the same as the output of the Tx, after another 600m another regenerator will be needed.

The power at the Rx will be:

$P_{RX} = 6 – 30 = -24$ dBm >> -70dBm

(L= 1500 – 2*600 = 300m => loss =300m*0.1 dB/m = 30 dB)

SNR_{RX}= 80-30-3 = 47 dB >> 16 dB