Tutorial 9, CS1031

1. Optical link design

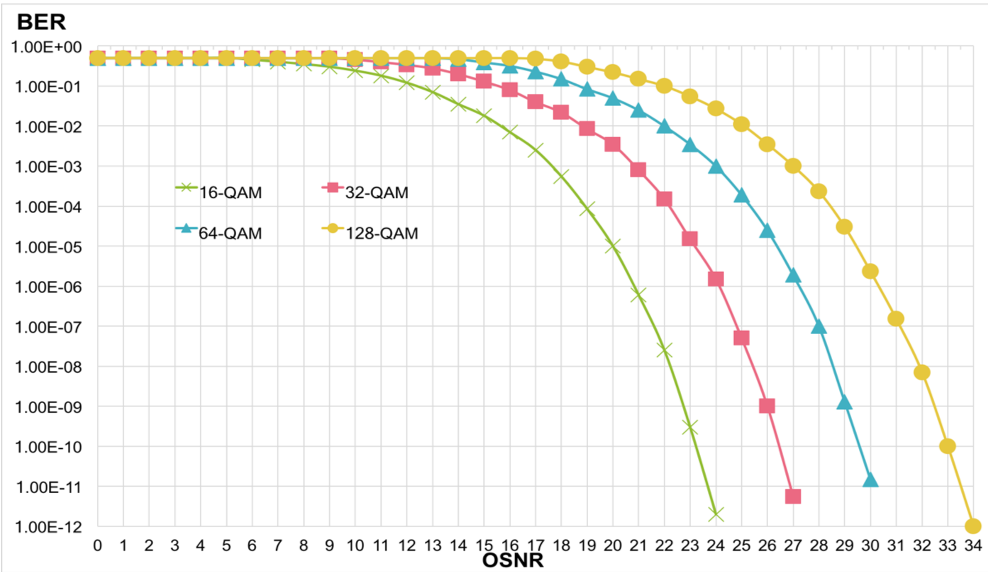
You need to operate a transmission link working at 12 Gb/s, over fibre. Your transmitter maximum rate is 2 Gbaud, and you want your system to achieve a BER of 10^{-9}.

The total link length is 80km, the fibre loss is 0.25 dB/km. The receiver sensitivity is –27 dBm, and the launch power is 8 mW.

a. Calculate whether the system will work without amplifiers, considering a power budget margin of 2 dB.

b. You need to extend the system to work up to a distance of 250km, and you can use only one amplifier, which has a noise figure of 6 dB and a gain of 30dB. Calculate whether the transmission can occur at 12 Gb/s with BER of 10^{-9}, considering an OSNR margin of 3 dB.

If not, calculate whether the system can work at a lower rate, stating the maximum rate achievable.



Solution:

a. For this case the system is power limited rather than OSNR limited, so we only need to check whether the power is higher than the receiver sensitivity at the end.

P_recv= P_launch - loss - power_margin > sensitivity.

The power needs to be converted into dB, so:

8 mW = 1*2*2*2 = 0+3+3+3 = 9 dBm.

The loss is 0.25dB/km * 80km = 20 dB

P_recv=9dBm – 20dB – 2dB = -13dBm > -27dBm so the transmission will work.

b) For 250 km the loss is 62.25 dB, so the system cannot work without an amplifier.

Since we now add an amplifier, which will add noise, the system could be OSNR limited, so we also need to check the OSNR equation.

We first check if the total power is enough:

P_recv=P_launch-loss+gain_ampl-power_margin =

= 9dBm - 62.25dB + 30dB – 2dB = -25.25dBm > -27dBm so this works.

Now the OSNR:

OSNR = P_launch - Loss_span - NF_ampl + 58 - OSNR_margin

the loss of the span is the distance before reaching the amplifier. The amplifier is considered to be in the middle, so the distance is 125km and the loss = 0.25 * 125 = 31.25 dB.

OSNR = 9 - 31.25 - 6+ 58 – 3 = 26.75dB

This now needs to be checked against the OSNR threshold, from the graph.

In order to achieve a bit rate of 12Gb/s with a 2 Gbaud transceiver, we need a 64-QAM modulation (which encodes 6 bits per symbol).

From the plot, achieving a BER of 10-9 with a 64-QAM requires 29 dB of OSNR, which is not available in the system. Thus 12 Gb/s cannot be achieved.

However, the 32-QAM modulation requires an OSNR 26 dB at BER 10-9, which is achievable by the system.

Since the 32-QAM encodes 5 bits per symbol, the maximum rate is: 2Gbaud x 5 = 10 Gb/s.

2. Long reach optical link design

An optical transmission link operates at a BER of 10^{-6} and the transmitter maximum symbol rate is 10GBaud.

a) Referring to the SNR/BER figure below, calculate the maximum bit rate achievable over a link length of 100 km, if the fibre loss is 0.25 dB/km, the receiver sensitivity is –23 dBm, and the launch power is 4 mW. Assume a 3dB power budget margin.

b) You now need to extend the link to a total distance of 2000km. Calculate the minimum number of amplifiers and/or regenerators needed to achieve the same bit rate as the system designed in the exercise a) above. Assume the amplifier NF is 7 dB, the maximum gain is 25 dB, the minimum amplifier spacing possible is 50 km and the OSNR margin required is 2 dB.

a). For this case the system is power limited rather than OSNR limited, so we only need to check whether the power is higher than the receiver sensitivity at the end.

P_recv= P_launch - loss - power_margin > sensitivity.

The power needs to be converted into dB, so 4 mW = 1*2*2 = 0+3+3 = 6 dBm.

The loss is 0.25 * 100 = 25 dB

$P_{recv}=6 - 25 - 3 = -22dBm > -23dBm$ so the transmission will work.

Since the SNR is not an issue the highest bit rate can be achieved, of 10 x log2(128) = 70Gb/s

b) Because the distance is too long, amplifiers need to be added. The system is likely OSNR limited so the OSNR is the equation to check first.
The OSNR required, from the figure above, considering 128 QAM and BER of 10-6, is 30 dB.

The OSNR equation (with a 80 km spacing between the amplifiers) is:
OSNR=6 - 0.25 x 80 – 7-14+58-2=21dB<30
so it doesn't work
If we try the minimum span of 50 km we get:
OSNR=6-12.5-7-16+58-2=26.5dB<30,
Still it won't work

We then need to try a regenerator at half distance = 1000 km.
Trying for 50 km we get: OSNR=6-12.5-7-13+58-2=29.5dB<30dB, so it won't work.
We notice that every time we half the total span we gain 3 dB, so a 500 km regeneration spacing should work:
OSNR=6-12.5-7-10+58-2=32.5dB>30dB.
So we need to divide the link into 4 spans, with in total 3 regenerators and 40 amplifiers (10 per span).
For the power we just need to make sure that is above the receiver sensitivity for one span (the other spans are the same).
P=6-125(total loss) + 25(gain) x 10 (amplifiers) -3 (margin) = 4-125+250-3=128dBm >>-23dBm
So this equation is also satisfied.