Long haul transmission

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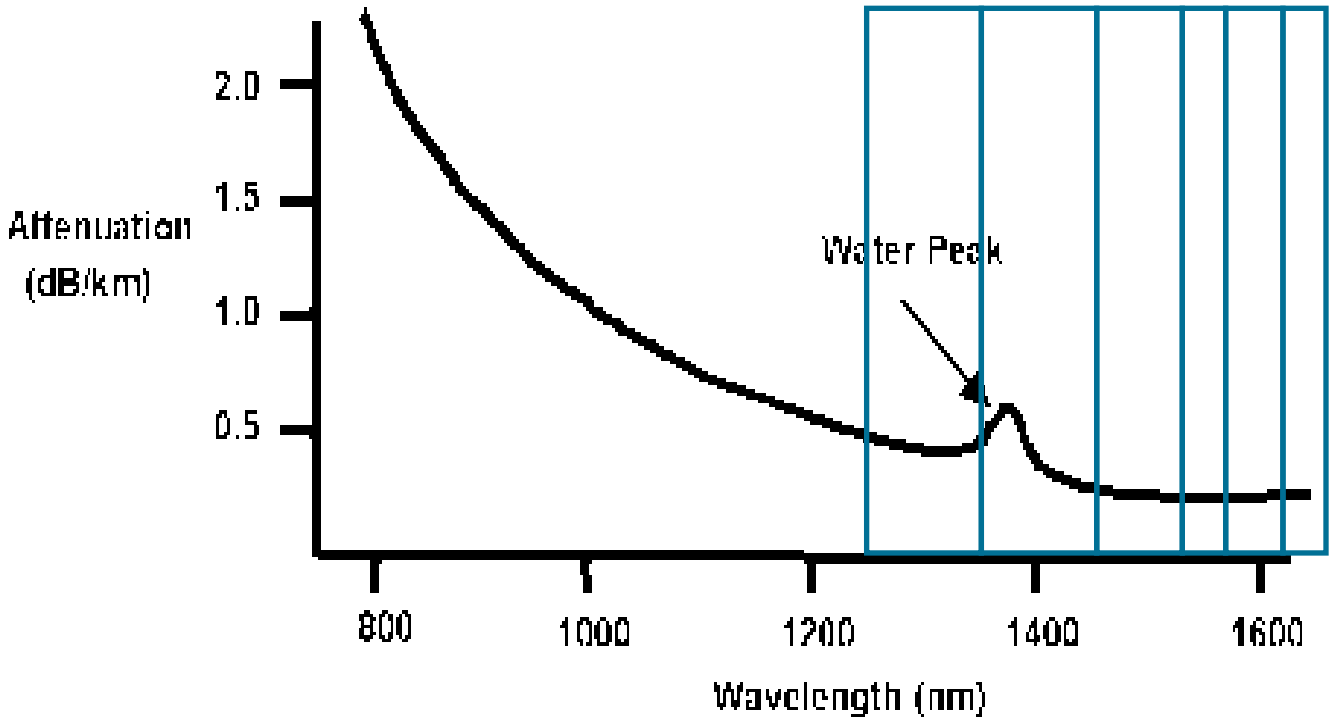
Long haul transmission

- Attenuation
- Amplification
- Regeneration

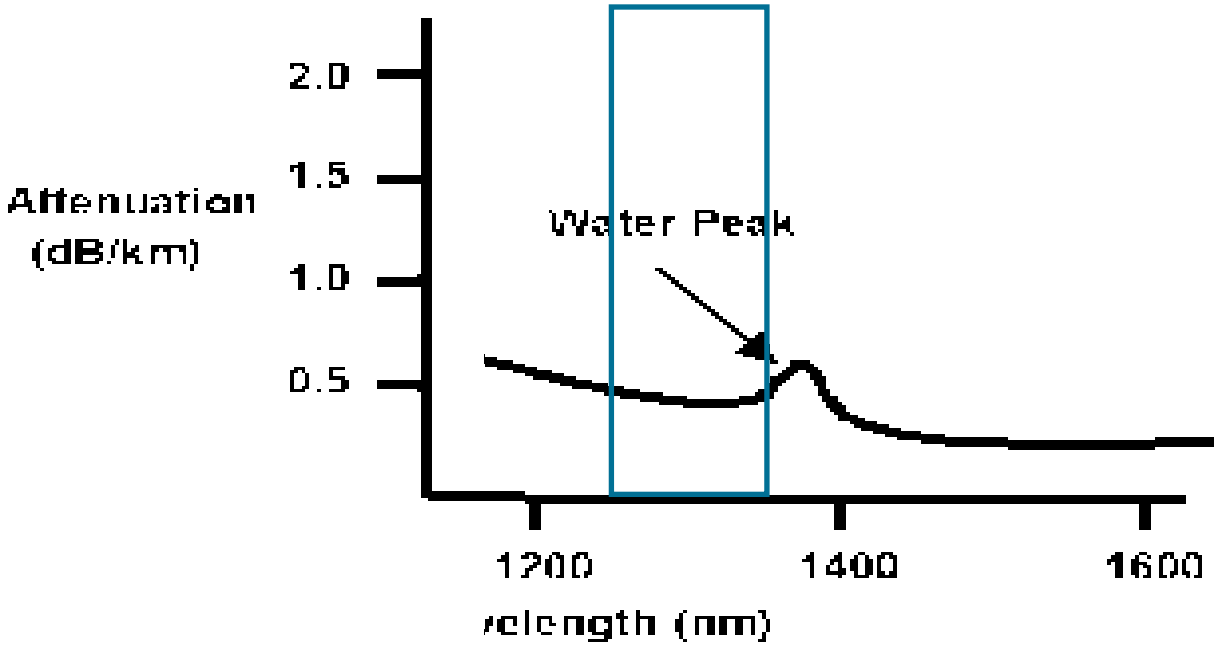
Attenuation

- Typical single mode fiber attenuation (G.652)



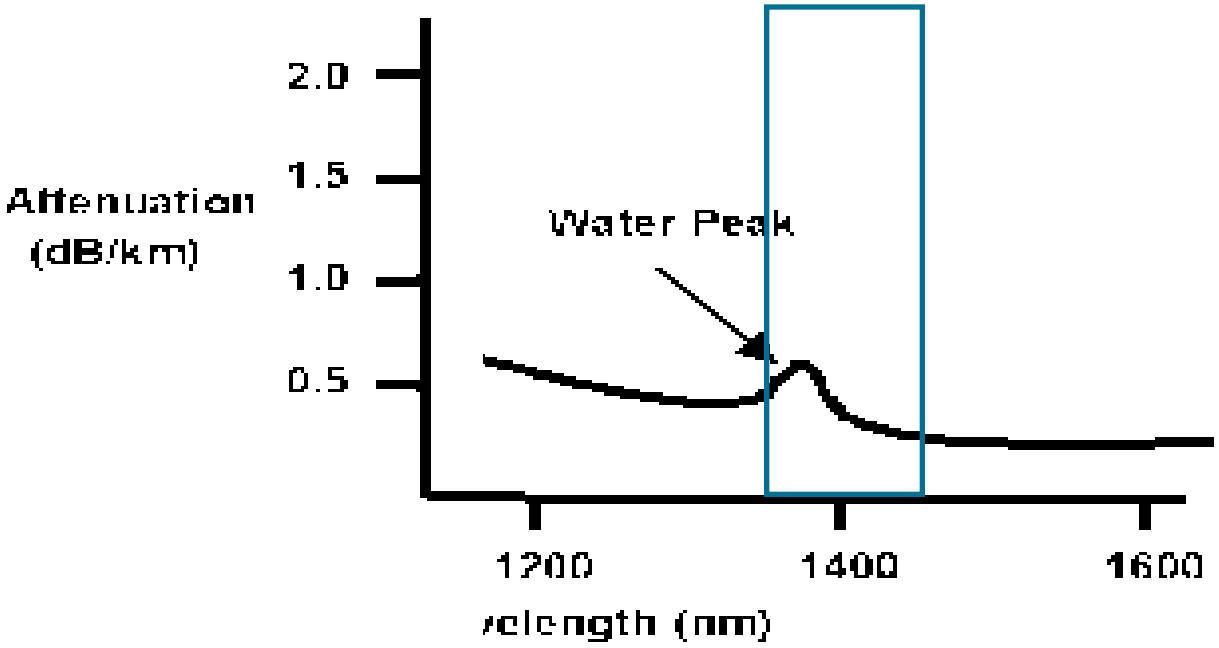
- Consists of 6 relevant bands for optical communication

Band O - Original



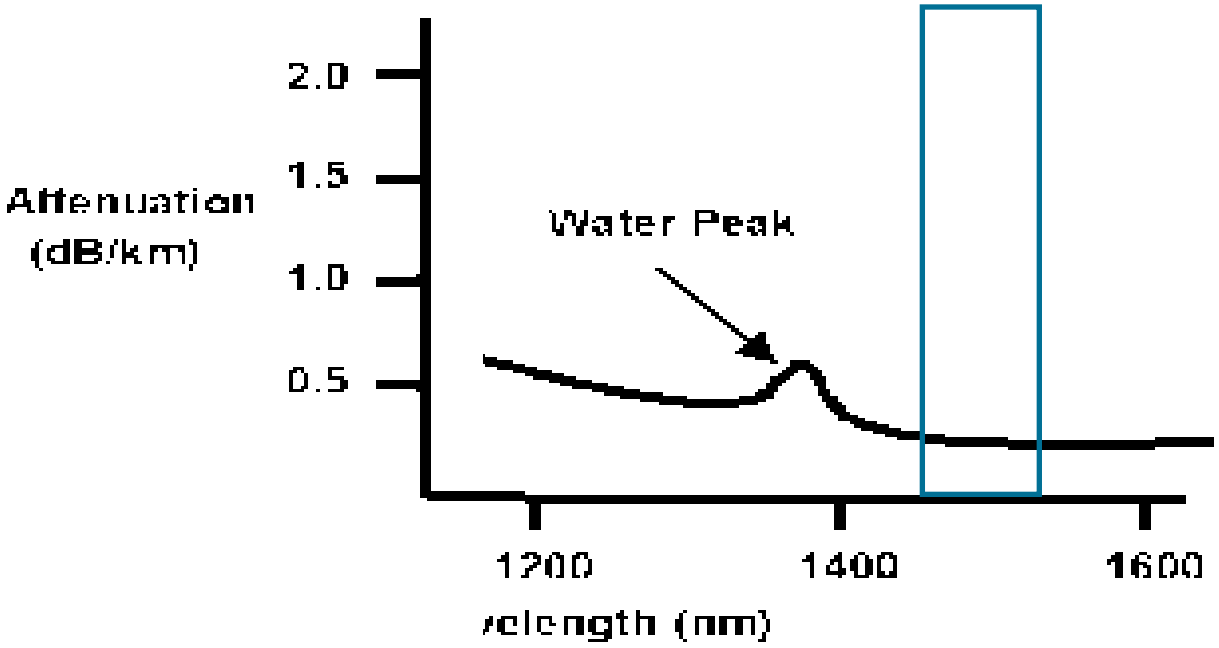
- O band – original, 1260 to 1360 nm
  - Currently used for short haul transmission (1310 nm)
  - High attenuation ≈ 0,5 dB/km
  - No/low dispersion, which isn't good for DWDM applications due to X-talk

E band - Extended



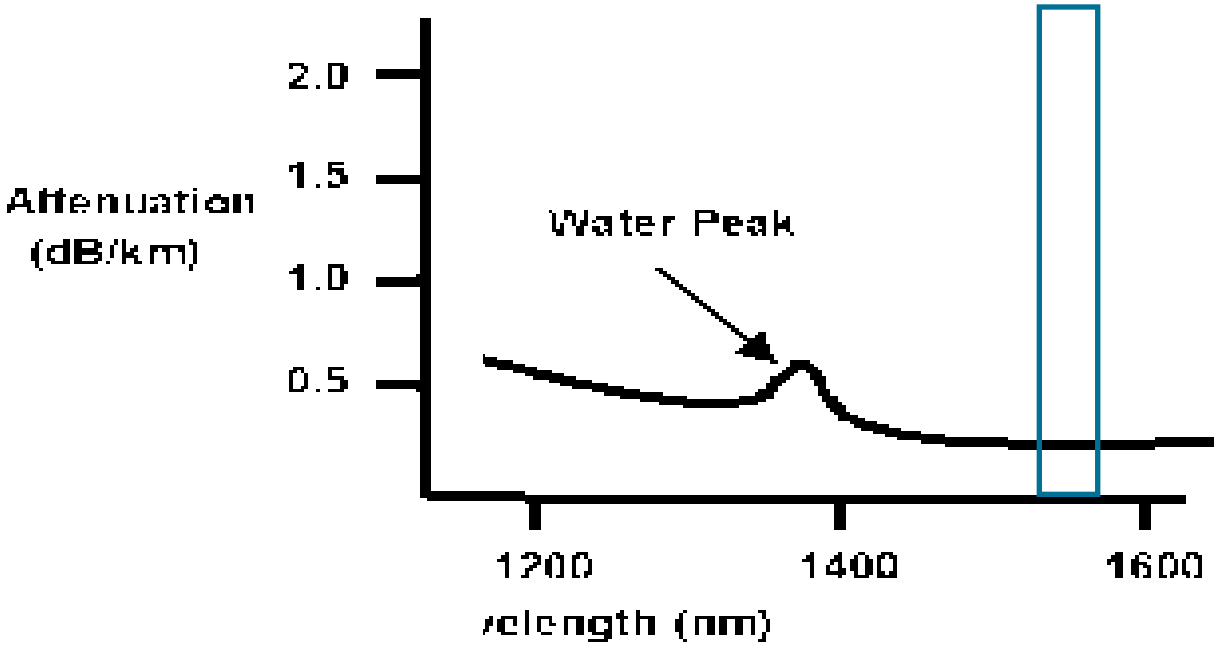
- E band extended 1360 to 1460 nm
  - Water peak present on standard fiber

S band - Short



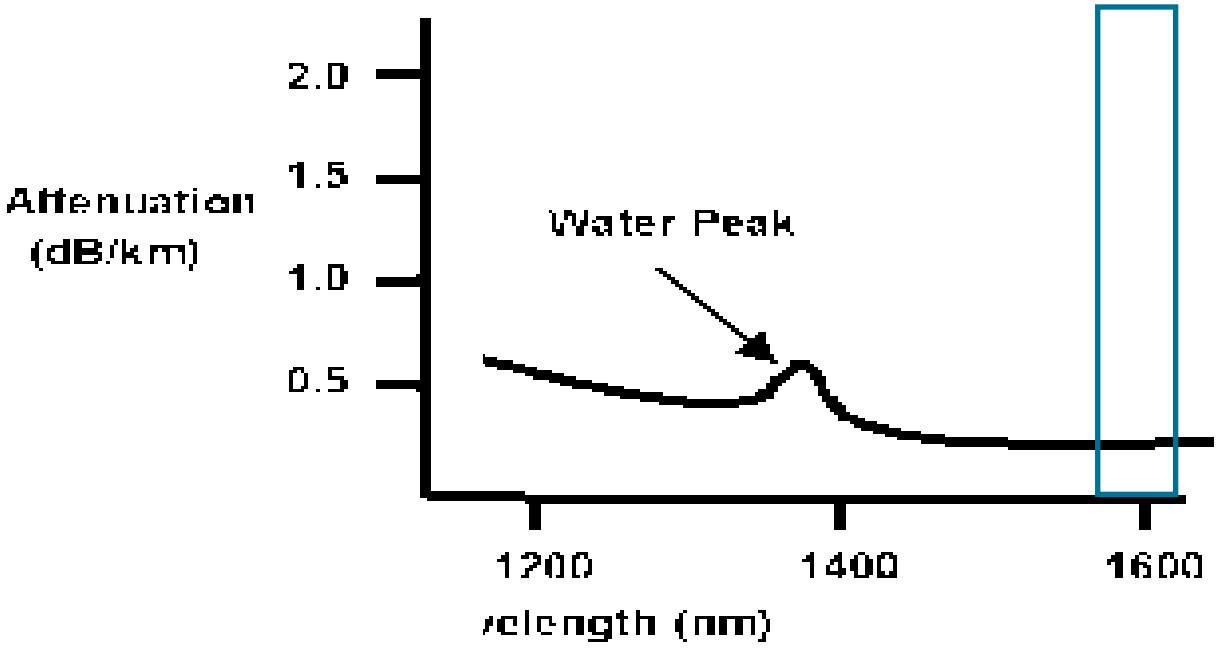
- S band - short wavelengths 1460 to 1530 nm
  - Low attenuation but C band lower and flatter
  - Thulium doped fiber amplifiers (TDFA)

C band - Conventional



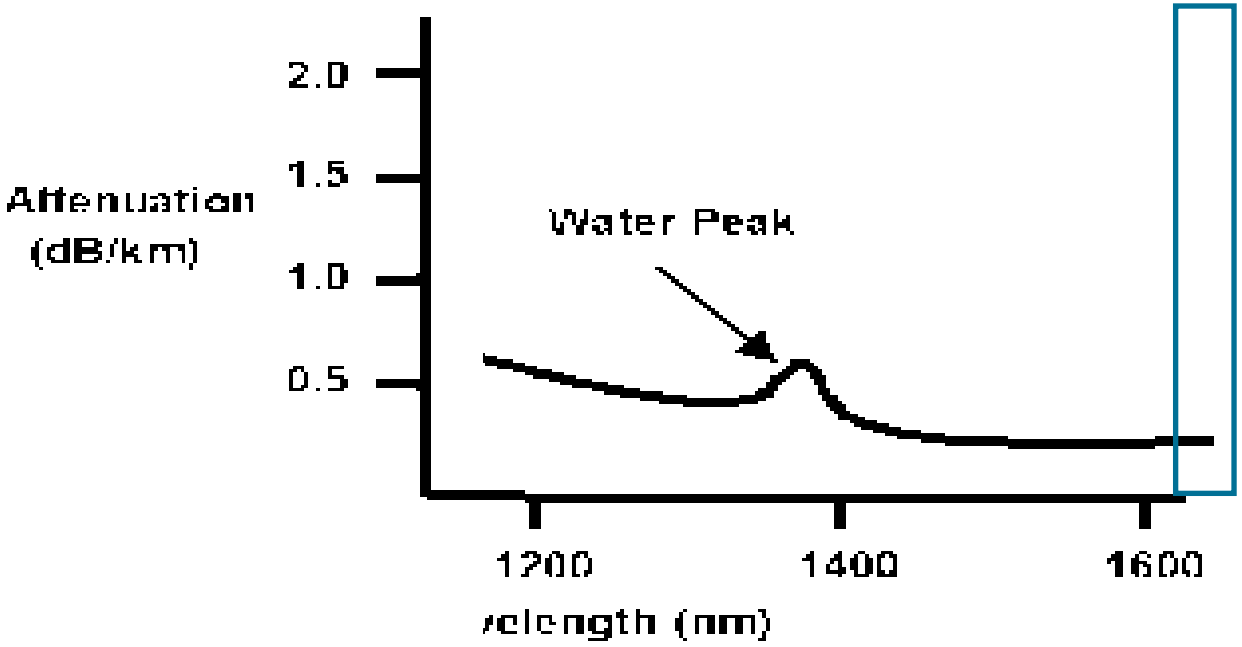
- C band - conventional ("erbium window") 1530 to 1565 nm
  - Low and flat, can be covered by a single Erbium Doped Fiber Amplifier (EDFA)

L band - Long

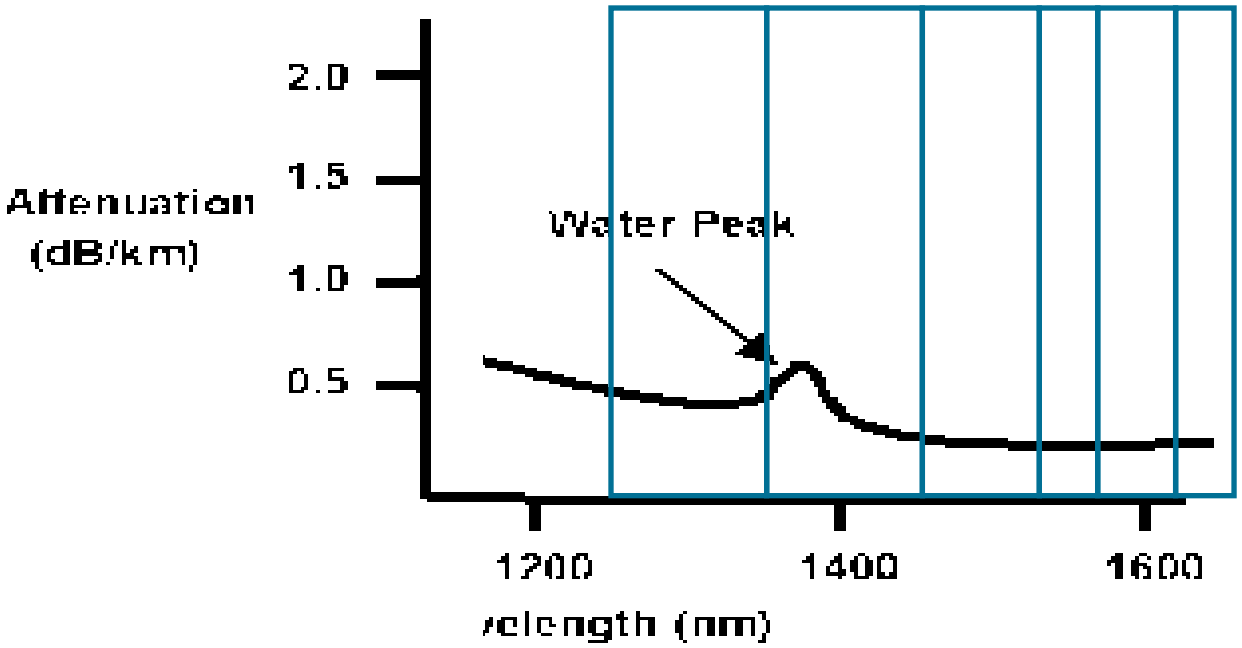


- L band - long wavelengths 1565 to 1625 nm
  - Require additional tuned EDFA, introducing additional losses
  - Or full C-L Raman amplification

U band - ultra long



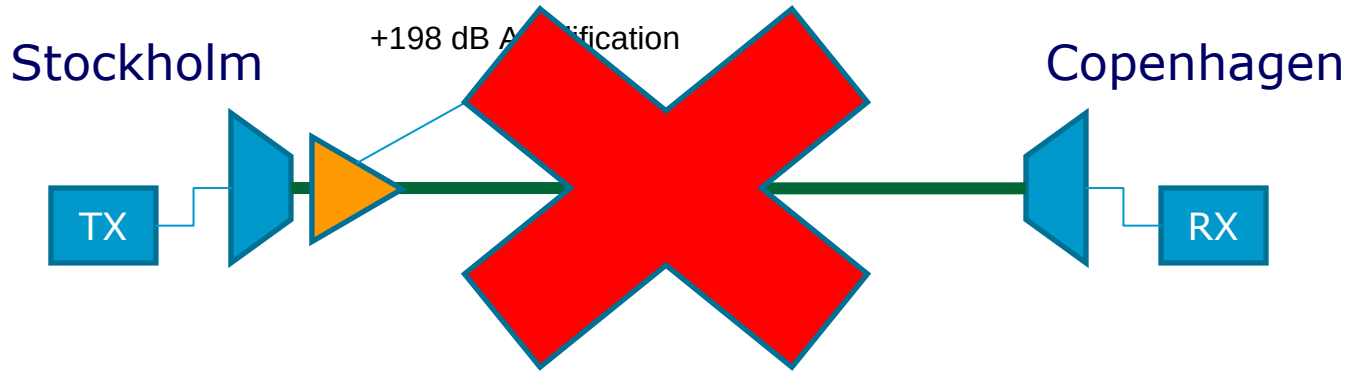
- U band ultra long wavelengths 1625 to 1675 nm
  - TDFA


Attenuation
(dB/km)
2.0
1.5
1.0
0.5
Water Peak
1200
1400
1600
/elength (nm)

C band transmission

- C – band is the current ”de facto” band for DWDM applications
- Low dispersion ≈ 0,22 dB / km
- Moderate dispersion ≈ 18 ps/nm/km of dispersion
- Fits window with high gain EDFAs

- Stockholm – Copenhagen ≈ 900 km = 198 dB



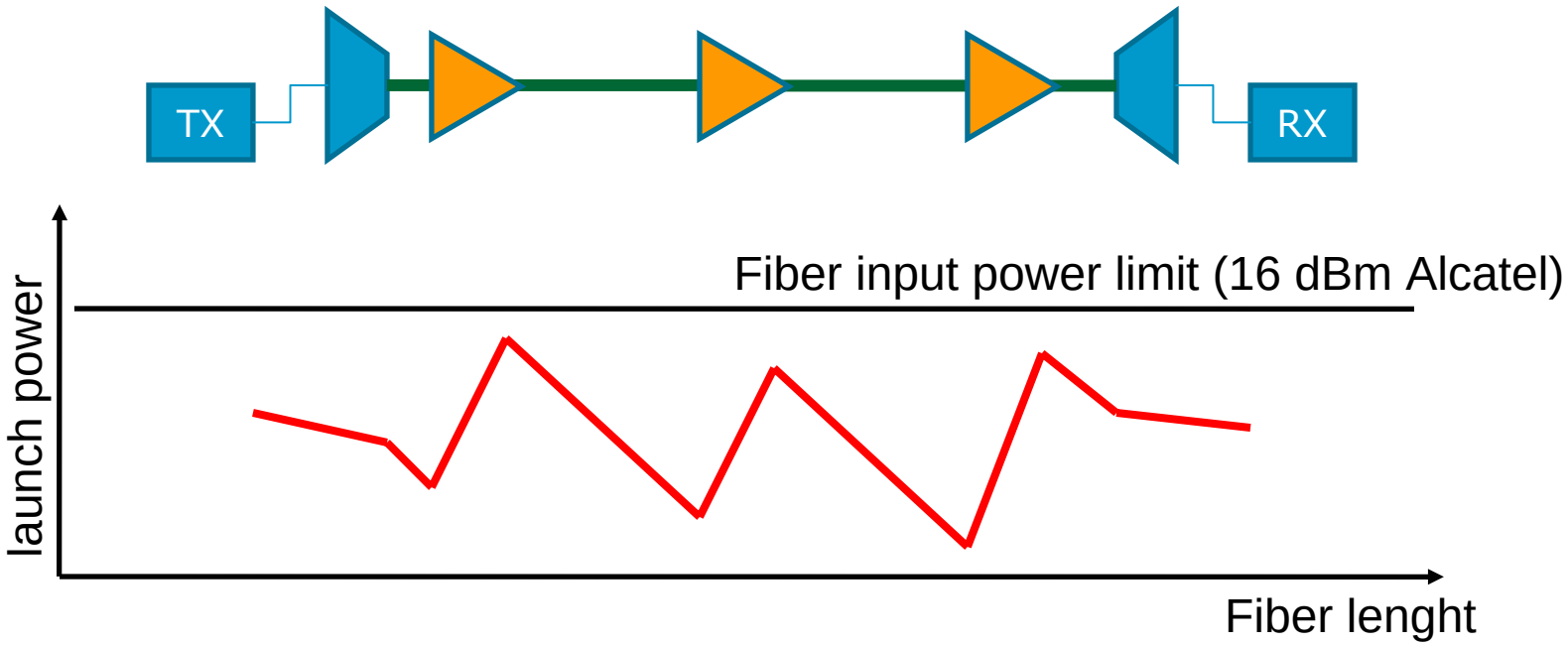
DEAL DONE? OF COURSE NOT!

Amplification

- Several fiber nonlinearities limit the allowable launch power into a fiber.
  - self-phase modulation (SPM)
  - cross-phase modulation (XPM)
  - stimulated Raman scattering (SRS)
  - stimulated Brillouin scattering (SBS)
  - four-wave mixing (FWM).

Amplification

- Fiber nonlinearities puts a limitation on launch power into the fiber, why amplification has to be distributed along the section below a certain threshold:

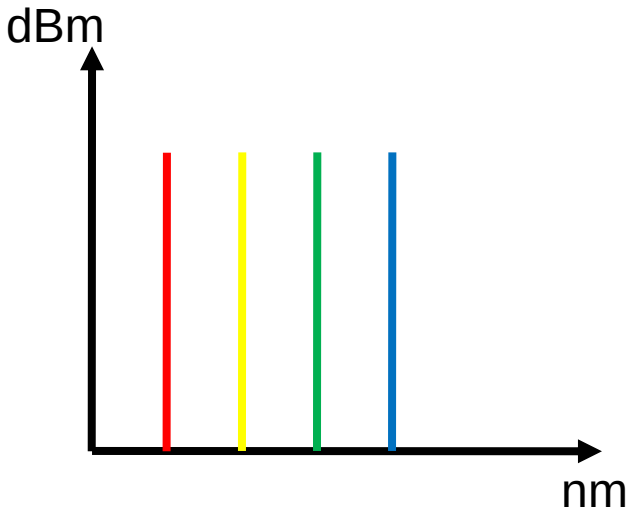


Amplification

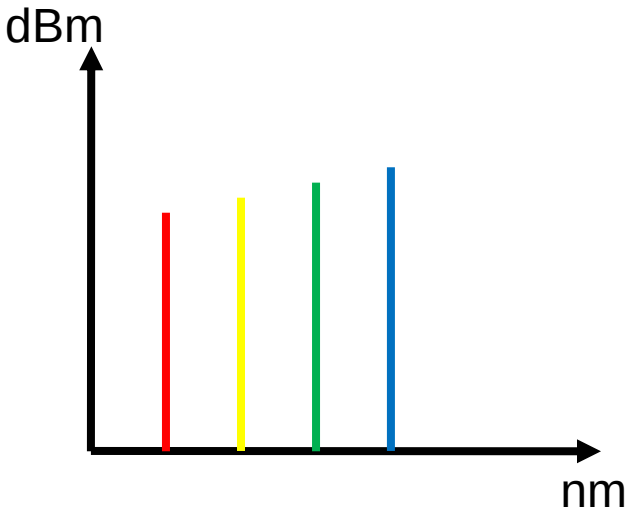
- The fiber amplifiers is not noise free, thus it is the OSNR and resulting BER at the receiver side that is our main concern.
- Operating the amplifiers at the highest possible gain yields also the highest noise.
- Vendor specific guidelines/tools for optimal placement of the amplifiers must be followed (≈ 80km, Alcatel EDFA)

Amplification

- Gain tilt - The gain of the amplifier is not flat over the used wavelengths, why different wavelengths experience different gain throughout the section. Unattended the effects of gain tilt will result over amplified/attenuated wavelengths leading to generation of nonlinear effects as mentioned above.



Transmit power spectrum

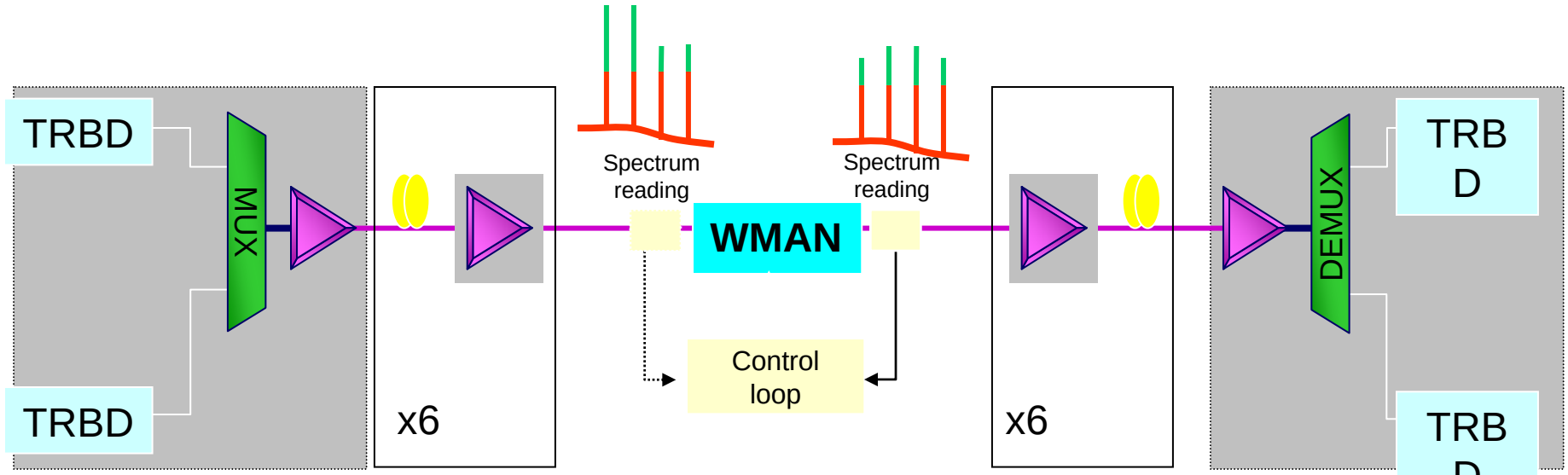


Receive power spectrum

Amplification

- Solution: Control systems that optimizes ONSR / BER on a per channel basis through the control of: VOAs and/or amplifiers and filters along the section.

- Below Alcatel implementation:
  - APA - Automatic pre-emphasis alignment
  - PGE – Programmable Gain Equalization



Amplification

- Stockholm – Copenhagen, real life:
  - 13 spans between 56 and 98 km each
  - 11 normal amplifier sites plus one mid-span ”gain equalizer” site
  - Compensated for 211 dB (0,22dB/km) plus 1 dB per span to cover fiber aging and future splice losses.

Regeneration

- 1R—Reamplify
  - Optical amplification as described above
- 2R—Reamplify and reshape
  - Optical amplification and electrical reshaping
- 3R—Reamplify, reshape, and retime
  - 2R plus electrical retiming

- Optical-Electrical-Optical conversion should be avoided due to the cost of transponders

- 2R/3R is required when the per channel ONSR/BER can't be achived in the existing design:
  - Adding more wavelengths
  - Increased attenuation of fibers
  - Adding new services e.g. 40G on a 10G design

Network Design

- Today's Next Generation DWDM networks is impossible to optimize by hand, and should be simulated with vendor specific design tools in order to take account for the attenuation, amplification and nonlinearities.

- Input should realistic but optimistic with regards to the traffic matrix, as too conservative guesstimates, could lead to non-flexible network, with hidden costs i.e. 2R/3R or new amplifier/terminal sites.

- Fiber data; Chromatic/Polarization Dispersion, attenuation values should of course be as precise as possible!

Questions?

Thank you