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Nonlinear Propagation of 1 Tbps Superchannels based on 240 Gbps PM-16QAM subcarriers on PSCF with Hybrid Erbium/Raman Fiber Amplification

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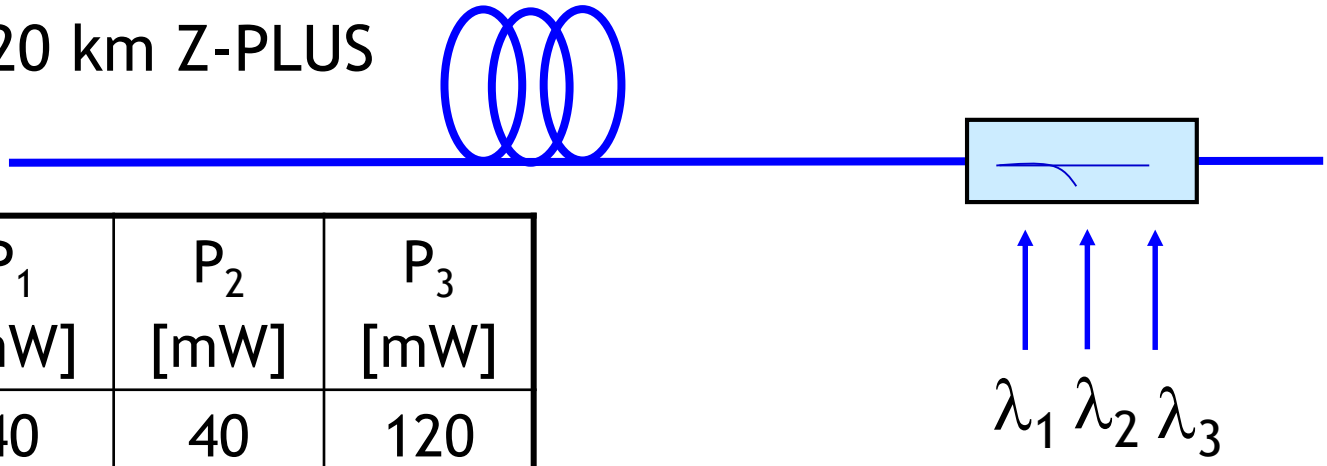
Summary

- We evaluate by simulations the maximum reachable distance of 1 Tbps Superchannels based on 240 Gbps PM-16QAM subcarriers in PSCF links.
- 240 Gbps = 200 Gbps for payload + 20% FEC overhead
- Subcarrier spacing: $1.1 \cdot R_S$
- Net spectral efficiency: 6 bit/s/Hz
- Use of PSCF and Hybrid Raman/EDFA amplification
- Maximum reachable distance: 3600 km @ BER=10^{-2}

Raman Amplifier Setup

120 km Z-PLUS

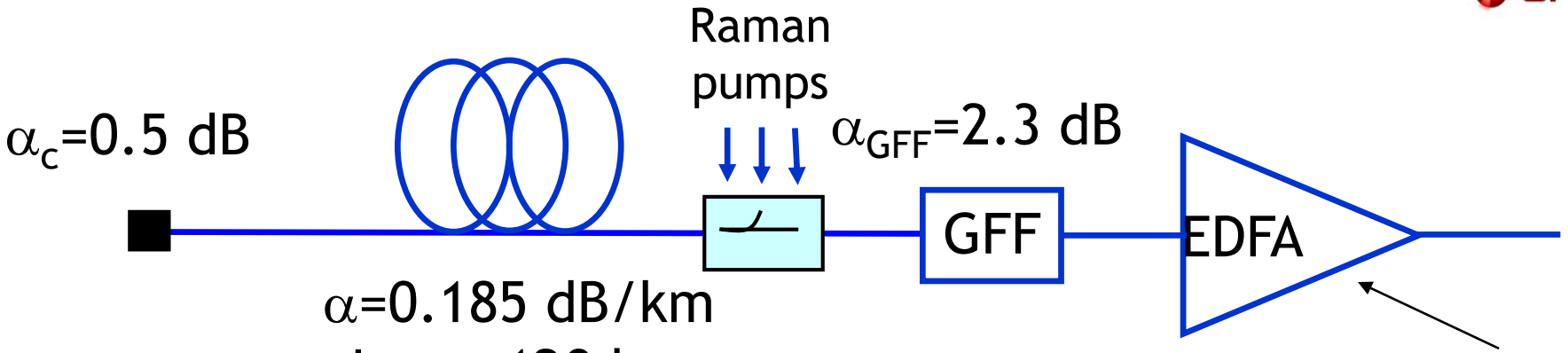


P_{pump} [mW]	P_1 [mW]	P_2 [mW]	P_3 [mW]
200	40	40	120
400	80	80	240
600	120	120	360
800	175	175	450
1000	220	220	560
1200	280	280	640
1400	345	355	700
1600	400	400	800

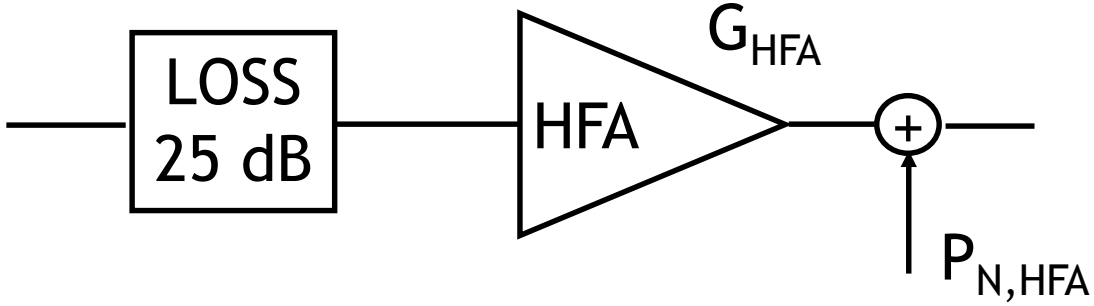
λ_1 = 1425 nm
λ_2 = 1436 nm
λ_3 = 1459 nm

Counter-propagating depolarized Raman pumps

Span setup



Properly adjusted in order to have transparency conditions

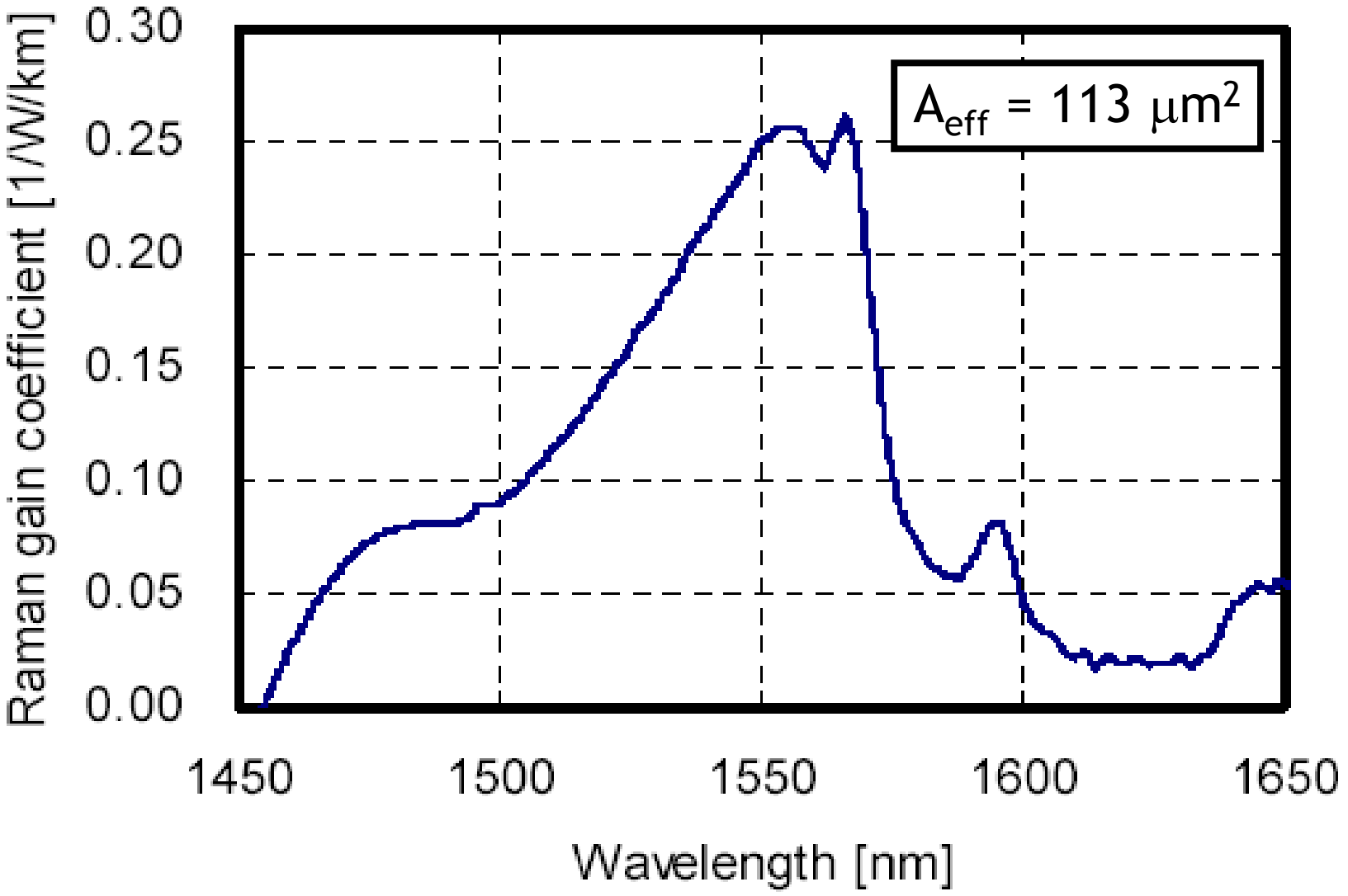


$$G_{HFA} = G_{RA} + G_{EDFA} =$$

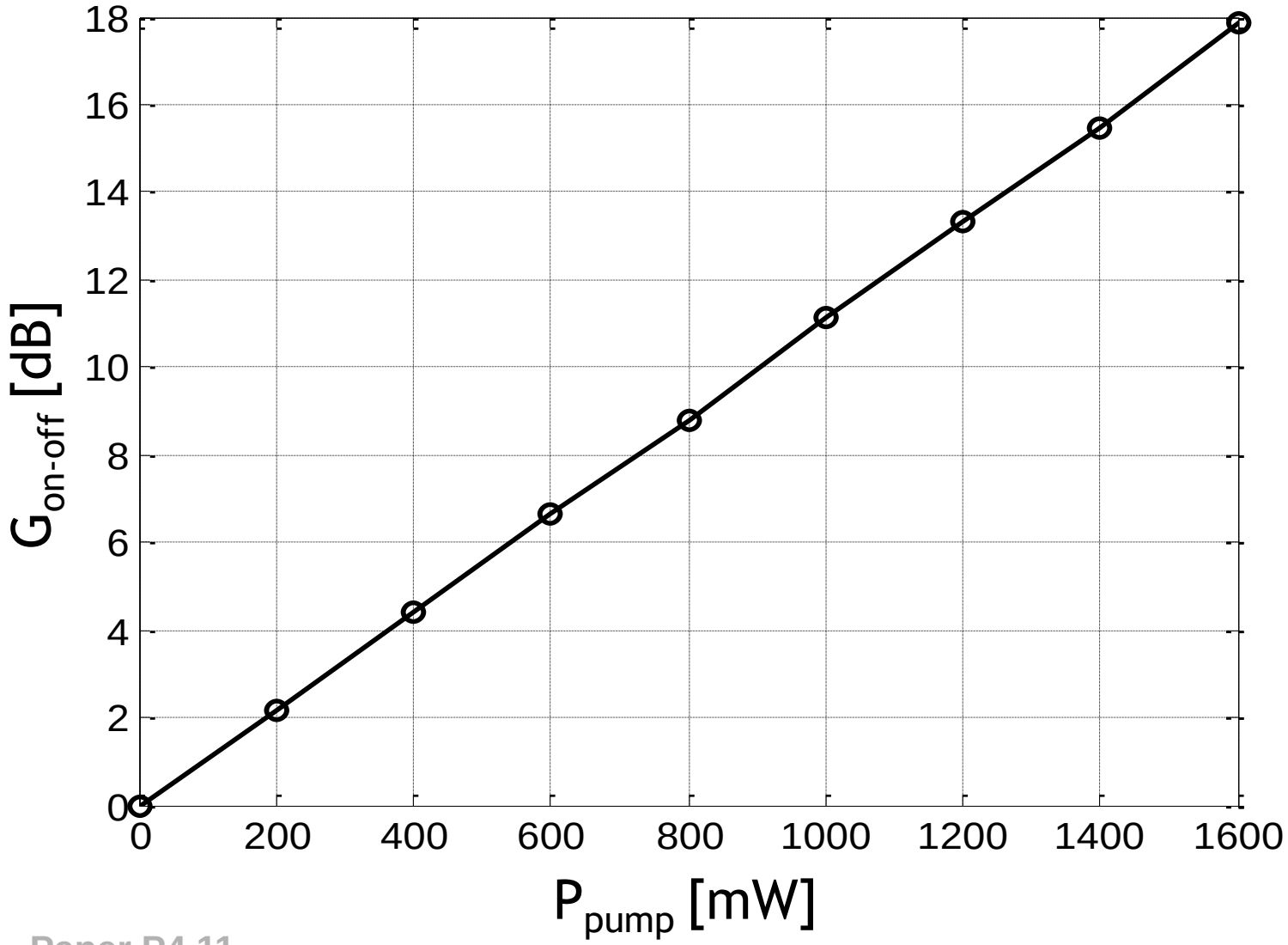
$$\alpha_c + \alpha_{GFF} + \alpha \cdot L_{span} = 25 \text{ dB}$$

$$P_{N,HFA} = hfB_n\left(G_{HFA} - 1\right)F_{eq}$$

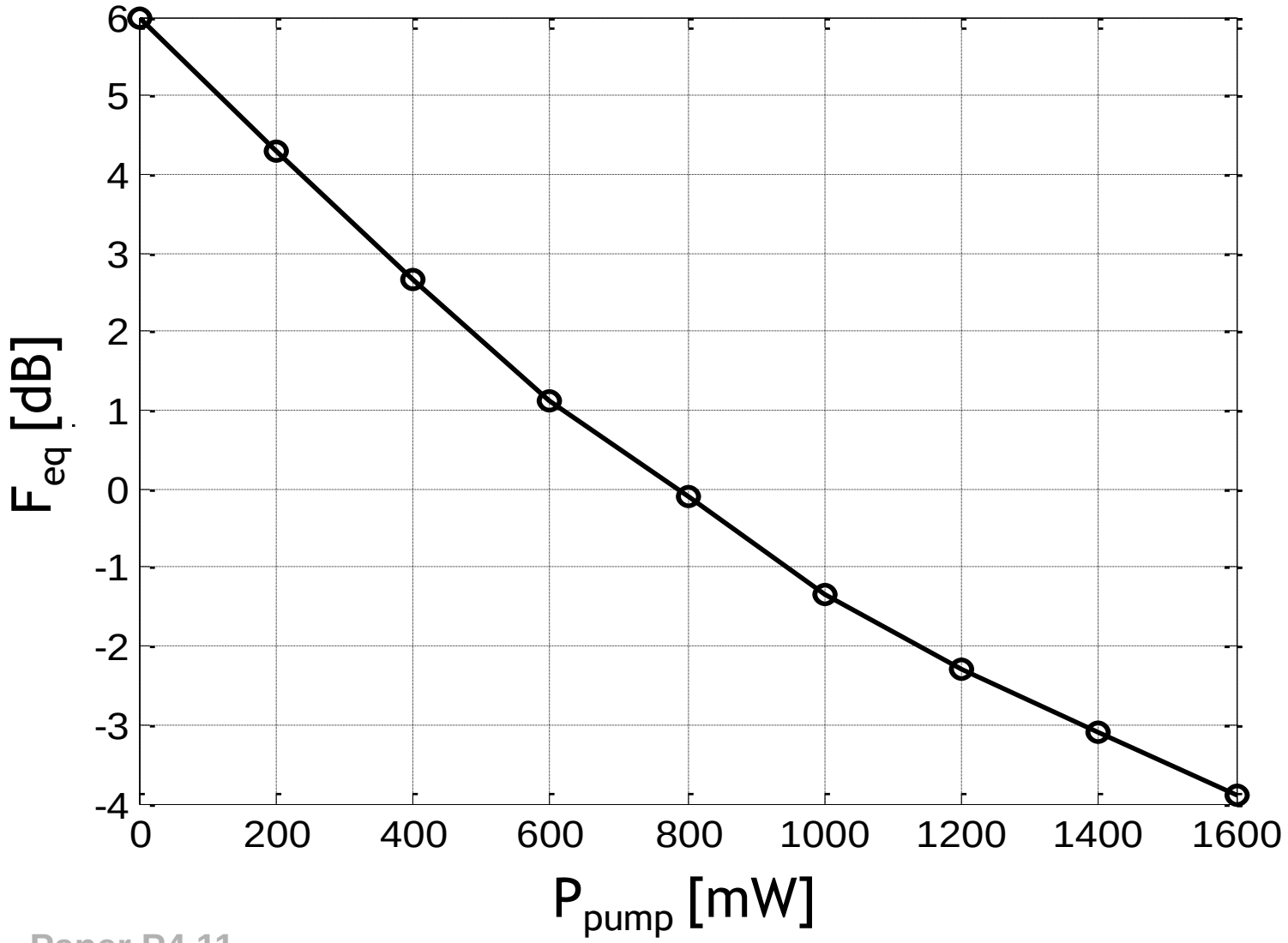
Raman efficiency on PSCF



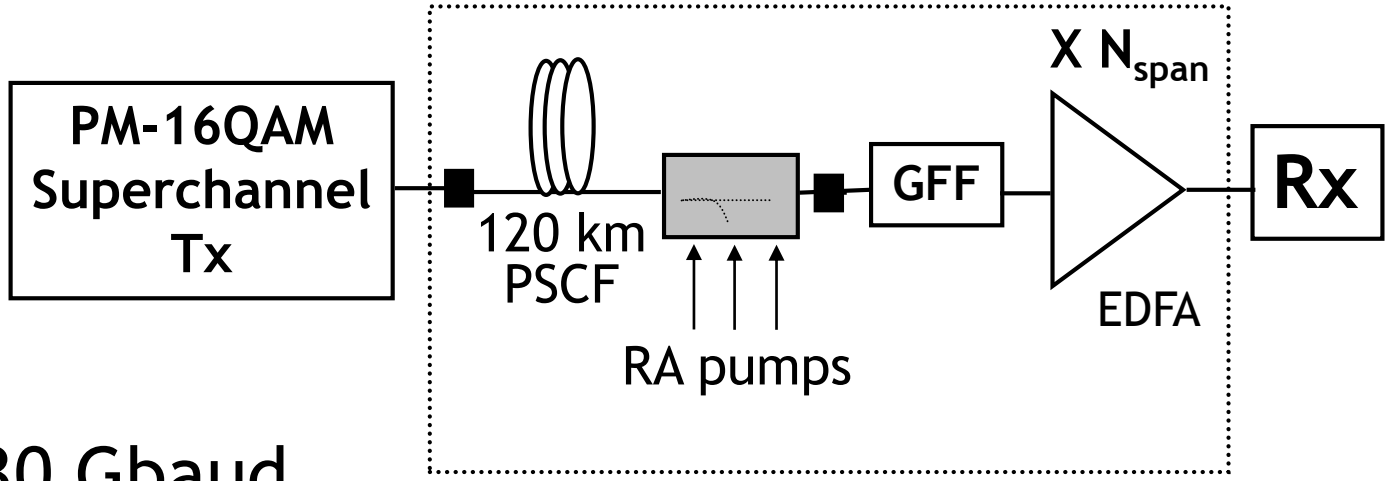
Flattened G_{RA} vs. P_{pump}



HFA equivalent noise figure F_{eq} vs. P_{pump}

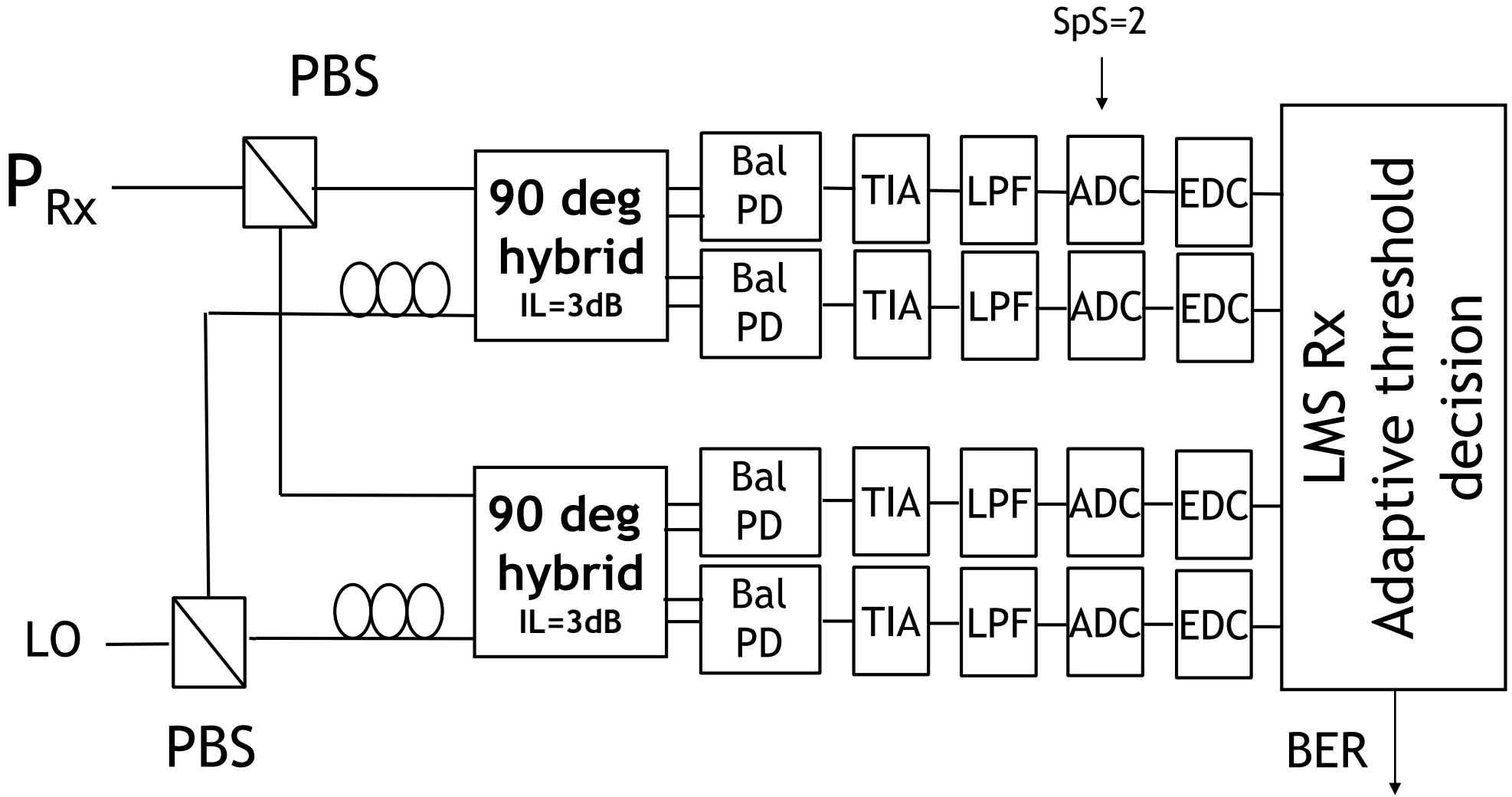


Link setup



- R_S = 30 Gbaud
- Δf = 33.3 GHz = 1.1 ·R_S
- 10 subcarriers (2 superchannels)
- P_{pump} = 0 -> 1600 mW (0 mW <-> EDFA only)
- Subcarrier power P_{TX} = -5 -> +5 dBm
- EDFA recovering residual loss (F_{EDFA}= 6 dB)

Receiver structure

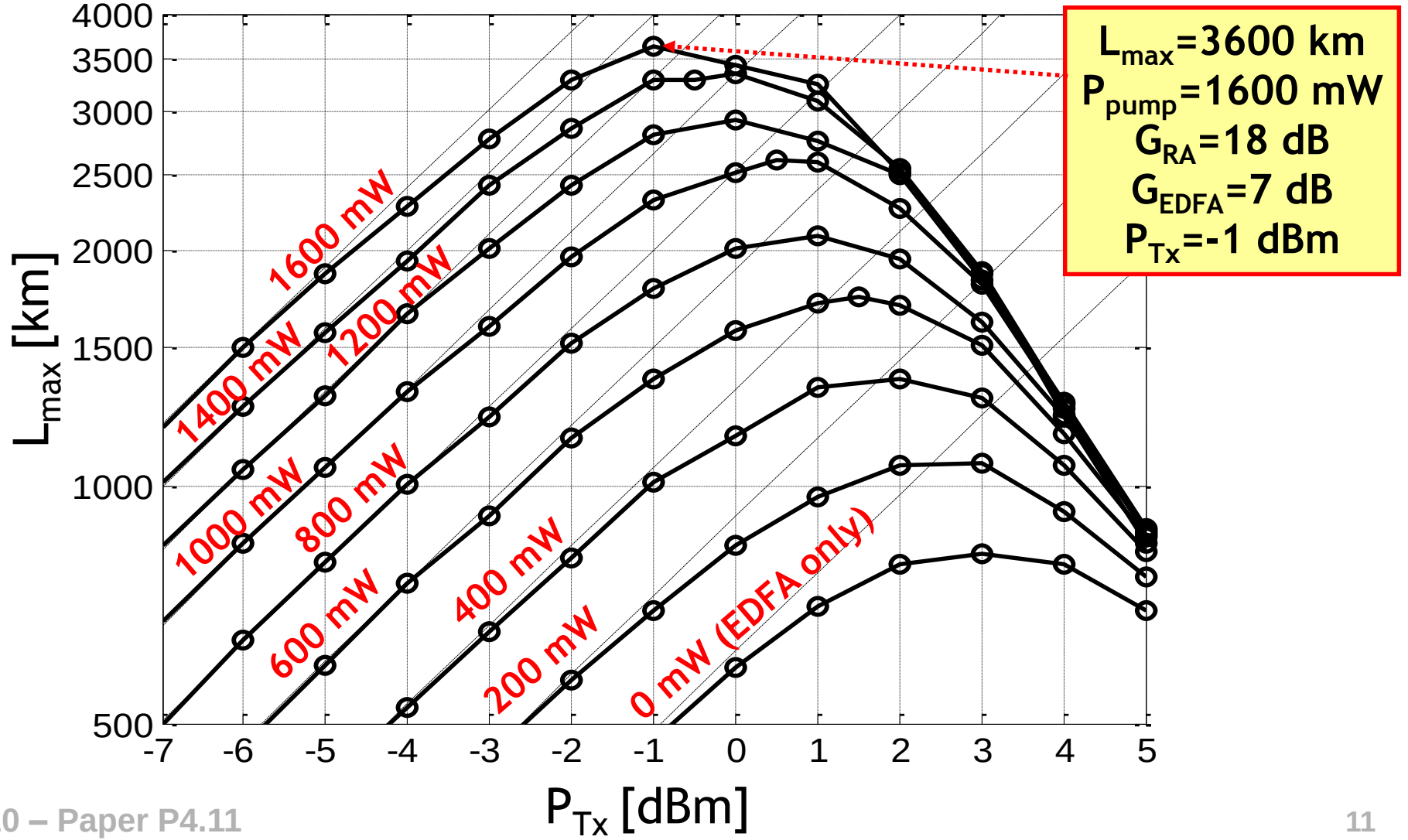


Simulation data

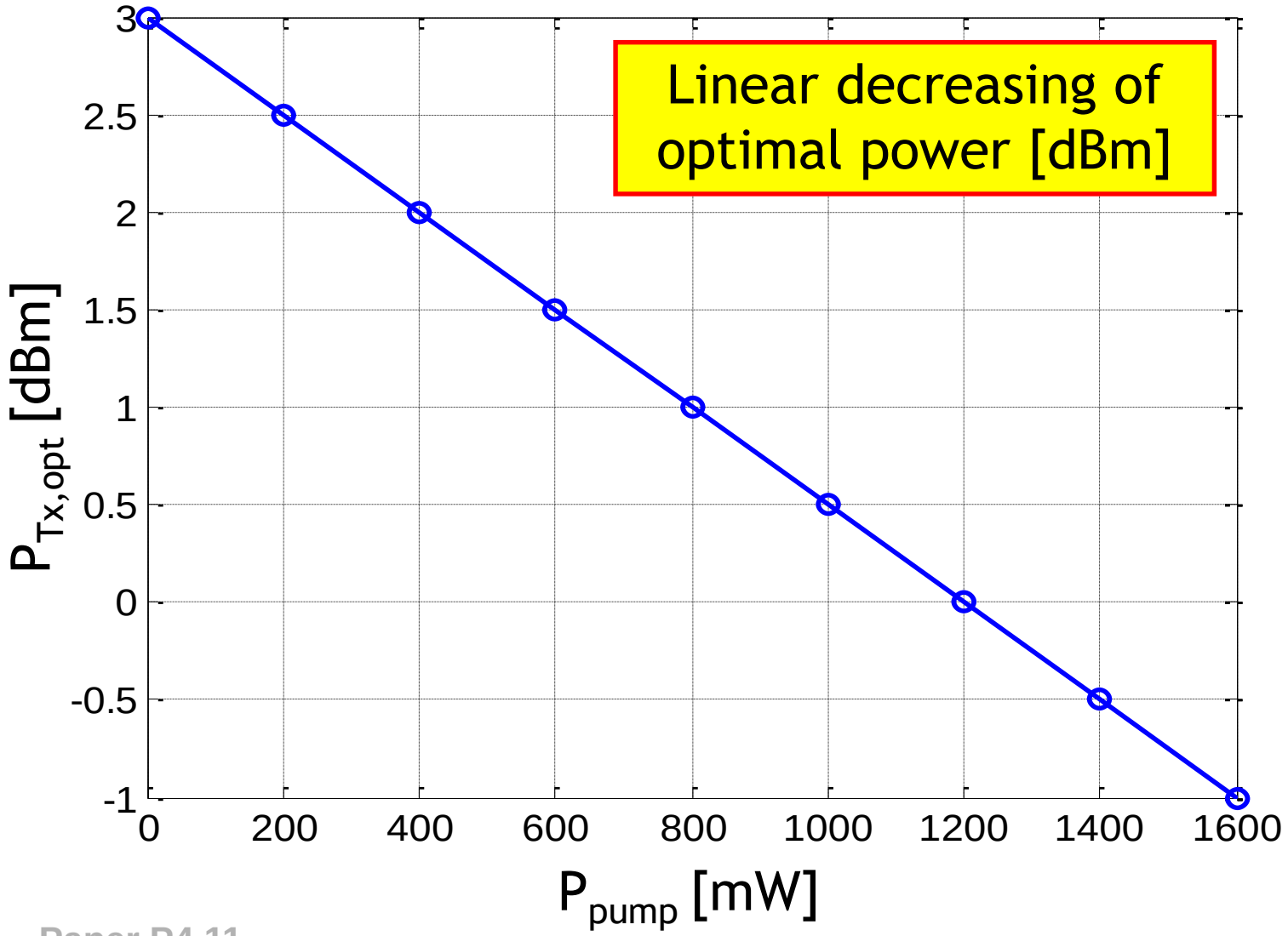
- Different PRBS for each tributary in every subcarrier
- PRBS degree: 16
- Simulated symbols: 65536 $\Leftrightarrow$ 524288 bits per subcarrier
- Target BER = 10^{-2}
- PSCF data
  - α = 0.185 dB/km (including splice losses)
  - D = 20.6 ps/nm/km
  - γ = 0.81 1/W/km

L_{max}@BER=10^{-2} vs. P_{Tx} at different P_{pump}

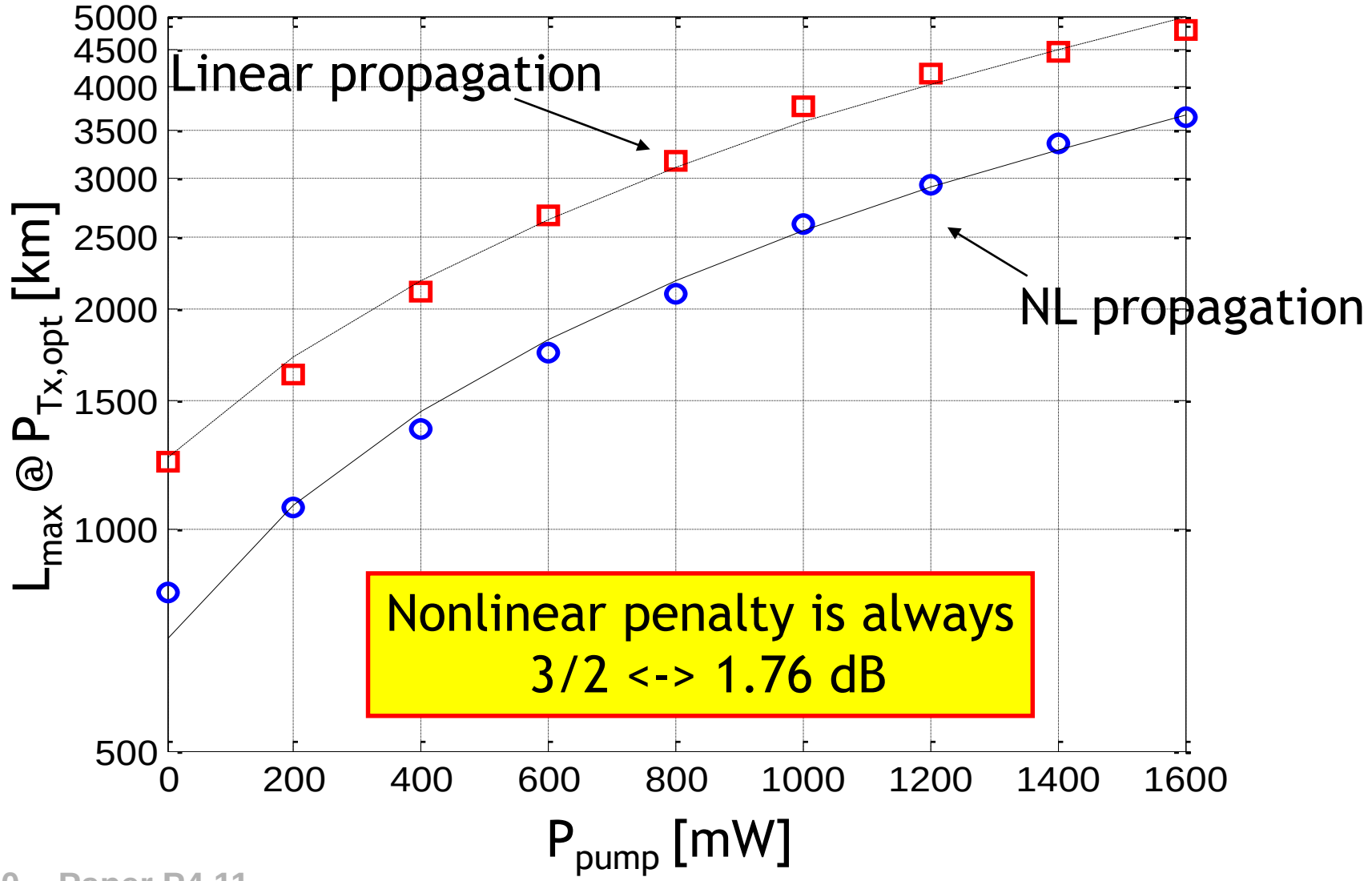
P_{pump} = 0 -> 1600 mW



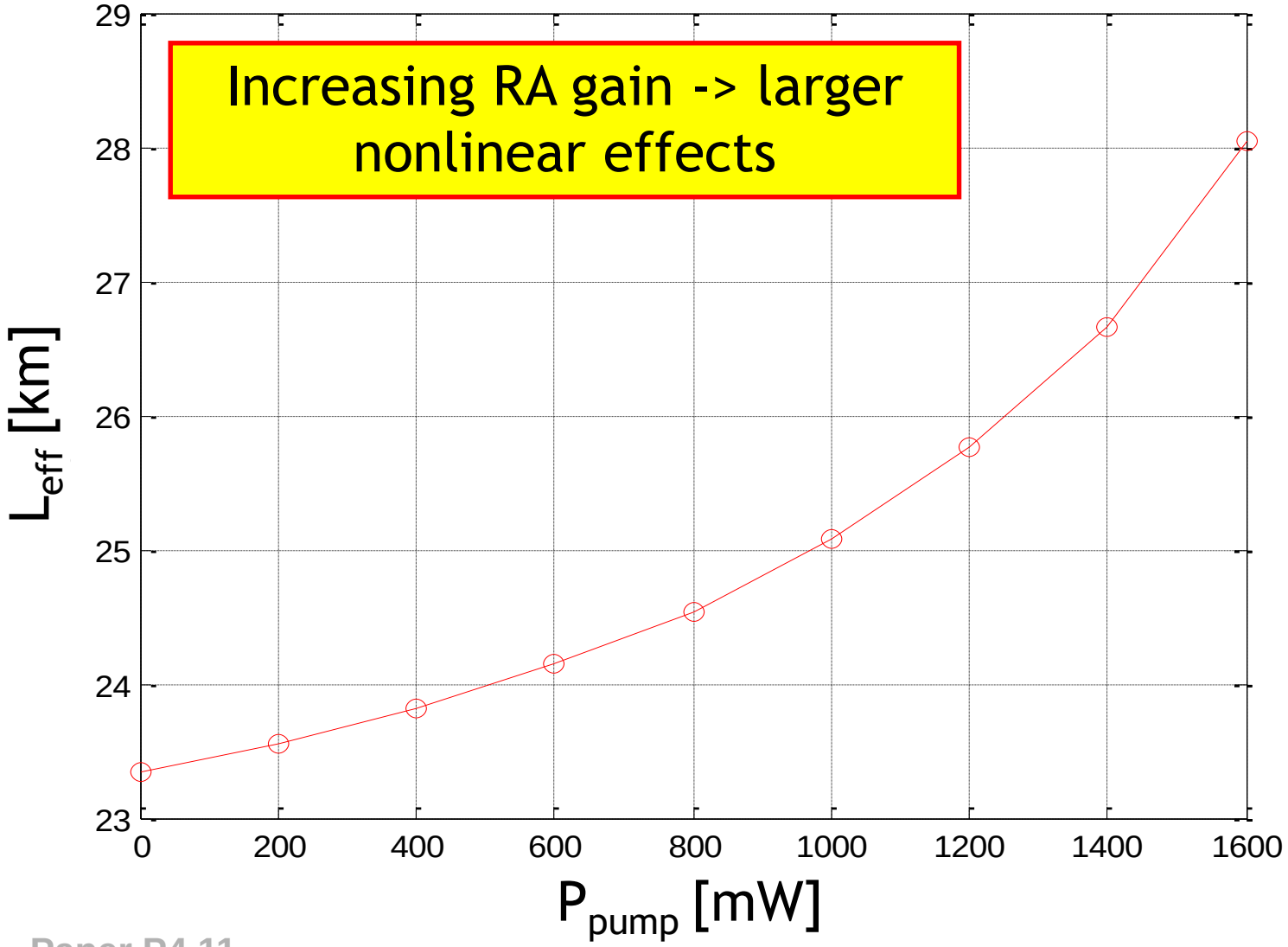
Optimal P_{Tx} vs. P_{pump}



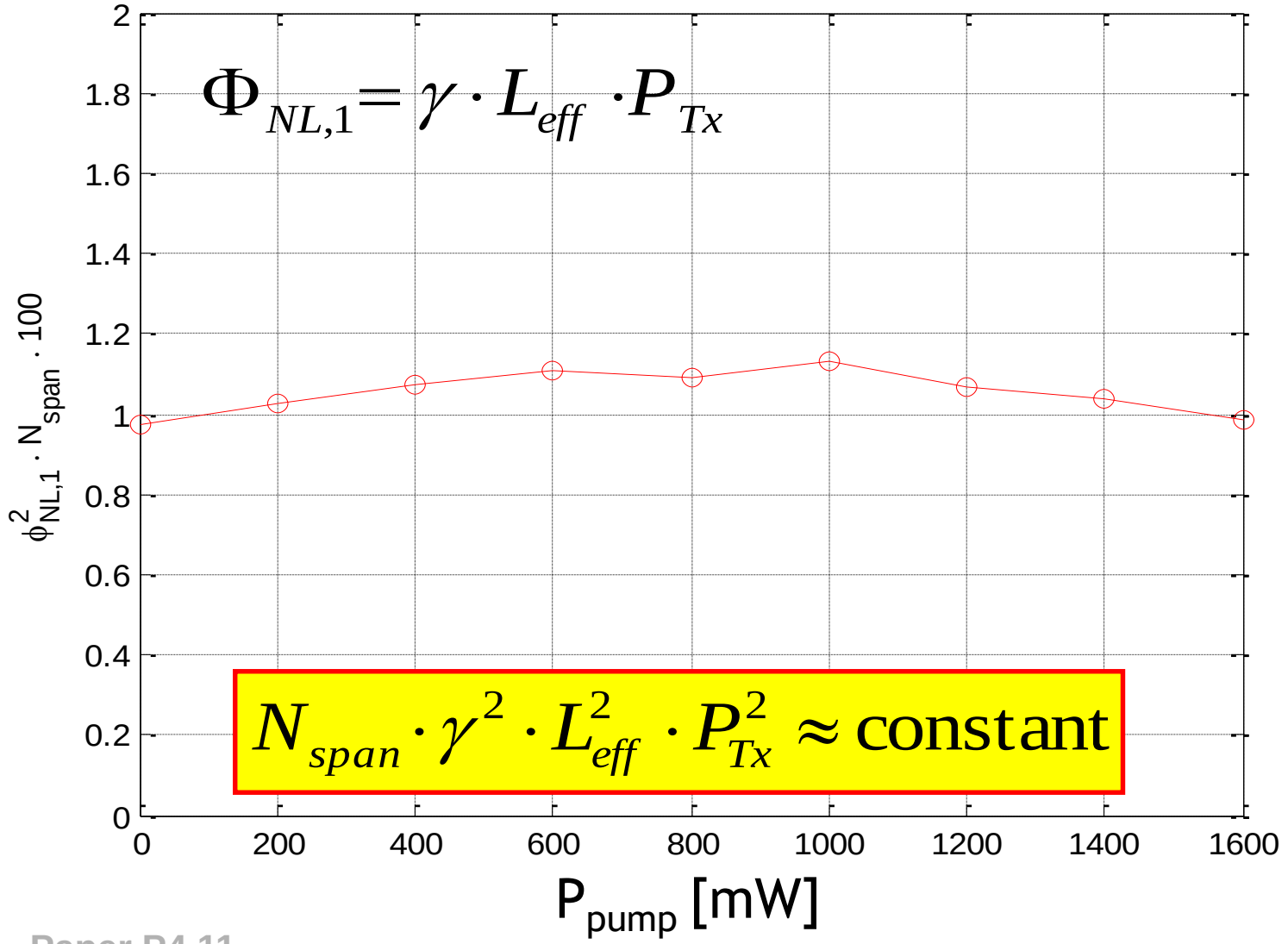
L_{max}@BER=10^{-2} @ $P_{Tx.opt}$ vs. P_{pump}



L_{eff} vs. P_{pump}



The invariant *nonlinear weight*



Conclusions

- Use of Raman amplification and PSCF enables PM-16QAM Superchannels with net **spectral efficiency of 6 bit/s/Hz** to reach **3600 km** with BER=10^{-2}
- Increasing pump power: more gain, less noise and larger nonlinear effects
  - Larger max reach
  - Optimal transmitted power [dBm] linearly decreases
  - There exists an invariant *nonlinear weight* linearly proportional to the number of spans and to the square of transmitted power