Performance Comparison of Advanced Modulation Formats for Low-bandwidth optics-based 50-Gb/s/λ PON at O-band

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Abstract

A comprehensive comparison of PAM-4, CAP-16QAM and DMT-16QAM modulations is simulated in 50-Gb/s/λ PON based on bandwidth-limited optics at O-band. The power budget, thermal noise performance and DSP complexity are discussed. The results show that over 29 dB power budget at 3.8×10^{-3} threshold can be achieved.

Introduction

Considering the limited bandwidth of low-cost optics, advanced modulation formats with spectral efficiency and advanced digital signal processing (DSP) are researched in order to reduce the baud-rate of the signal. The performance of multi-level pulse amplitude modulation (PAM), carrier-less amplitude and phase modulation (CAP) and discrete multi-tone (DMT) modulation formats for 50G PON at O-band using 10G-class optics and simple DSP has been simulated and compared in order to reduce the CAPEX and OPEX for both the network operators and the customers.

Simulation Setup

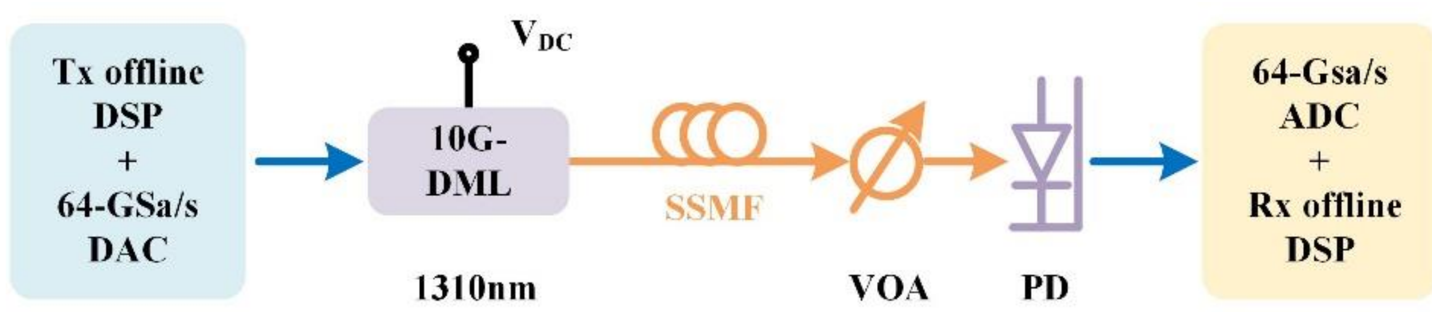

Fig. 1. Simulation setup for 50-Gb/s/λ PON system based on bandwidth-limited optics at O-band

The 50 Gb/s signals with different modulations are generated and performed offline by MATLAB and uploaded into a 64 GSa/s DAC with a resolution of 8 bits, and then filtered by a 4th order Bessel low pass filter (LPF) with a 3 dB bandwidth of 10 GHz in order to simulate the bandwidth limitation of the transmitter.

The output of the LPF is directly modulated by a directly modulated laser (DML) with a power output of 17.68 dBm at the central wavelength of 1310 nm. The modulated optical signal transmits 20 km standard single-mode fiber (SSMF) with an average loss of 0.35 dB/km. At receiver side, a variable optical attenuator (VOA) is placed after SSMF to adjust the received optical power for sensitivity measurement. A photodiode (PD) is used for signal detection. An electric 4th order Bessel LPF with a 3 dB bandwidth of 15 GHz is placed after PD in order to simulate the bandwidth limitation of the receiver. After LPF, the detected signal is processed by a 64GSa/s ADC for offline DSP.

Simulation Results

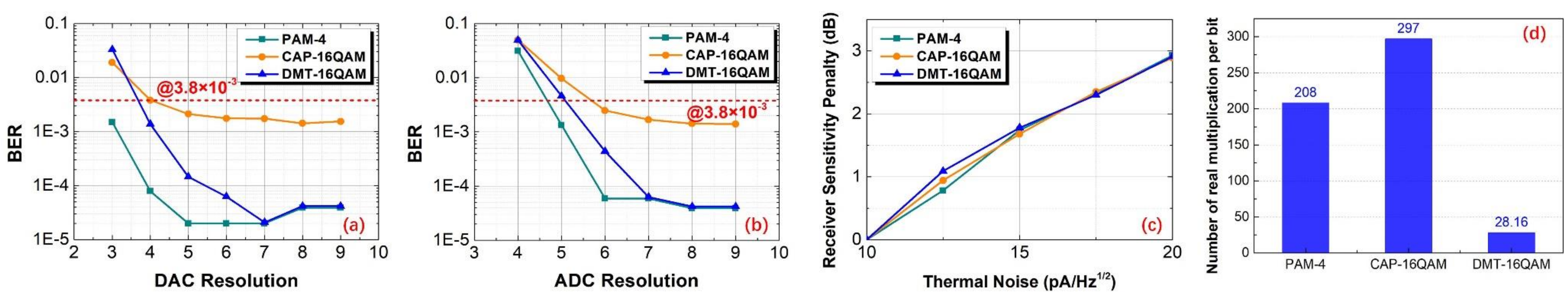

Fig. 2. (a) BER versus DAC resolution; (b) BER versus ADC resolution; (c) Receiver sensitivity penalty versus thermal noise; (d) Computational complexity of three modulation formats

As we can see, 4-bit DAC resolution and 6-bit ADC resolution are enough to achieve below 3.8×10-3 threshold after 20km SSMF transmission and there is error floor when both resolutions increase for three modulation formats. It can be seen that PAM-4 has better tolerance at low thermal noise. Besides, PAM-4 and CAP-16QAM have similar computational complexity. DMT-16QAM offers lower complexity than the other two formats.

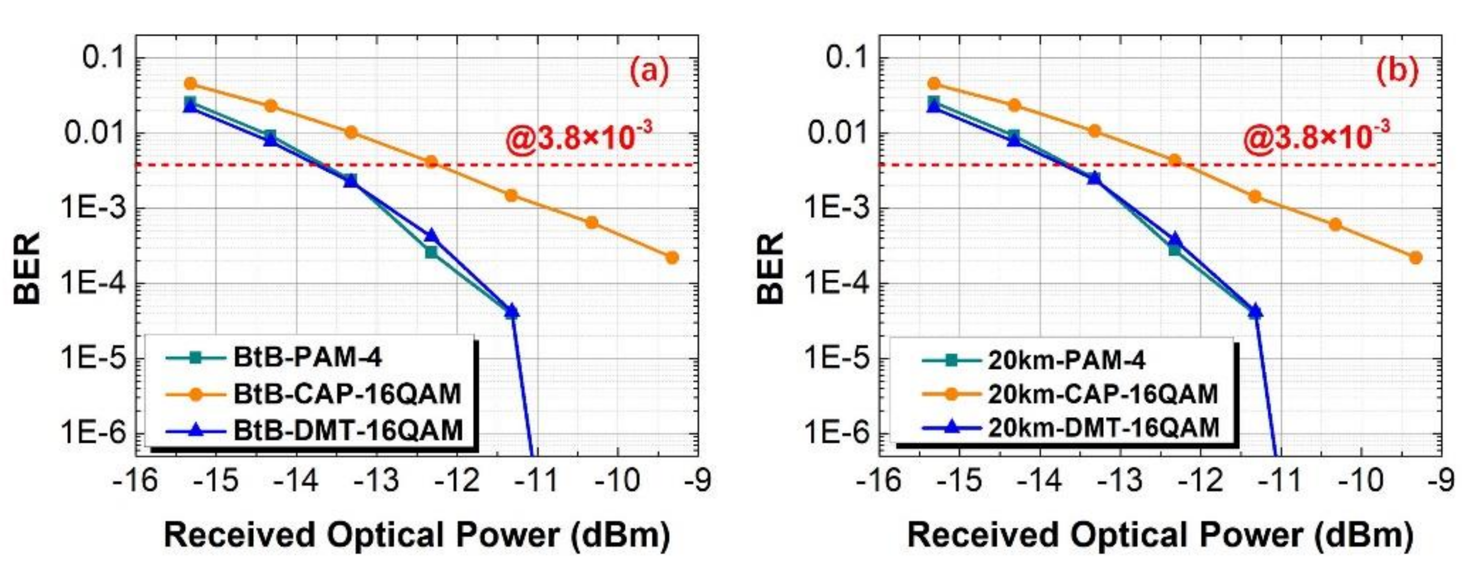

Fig. 3. BER versus ROP for 50-Gb/s/λ PON with different formats: (a) BtB; (b) 20 km.

Modulation Formats	Launched Power/dBm	Sensitivity @3.8×10^{-3}/dBm	Power budget @3.8×10^{-3}/dB
PAM-4	17.68	-13.6	31.28
CAP-16QAM		-12.2	29.88
DMT-16QAM		-13.7	31.38

TABLE I. SUMMARY OF RECEIVER SENSITIVITY AND POWER BUDGET FOR THREE MODULATION FORMATS AT HD-FEC THRESHOLD

The receiver power for PAM-4, CAP-16QAM and DMT-16QAM after 20km SSMF transmission at HD-FEC (3.8×10^{-3}) threshold are -13.6 dBm, -12.2 dBm and -13.7 dBm, respectively. The performances of all modulation formats have around 0.1 dB penalty in sensitivity after 20 km fiber transmission compared to BtB case. Over 29 dB power budget can be achieved for all modulations at BER threshold of 3.8×10^{-3}. DMT- 16QAM has the largest power budget.

Conclusion

PAM-4 has the best thermal noise tolerance performance and DMT-16QAM has the largest power budget. The results show that over 29 dB power budget at HD-FEC threshold can be achieved. DMT-16QAM offers much lower computational complexity than PAM-4 and CAP-16QAM.

Funding

Key Research and Development Program of Jiangsu Province (BE2020012).

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