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A Comparative Study of the Effect of Analogue Pre-equalisers on VLC System Data Rates

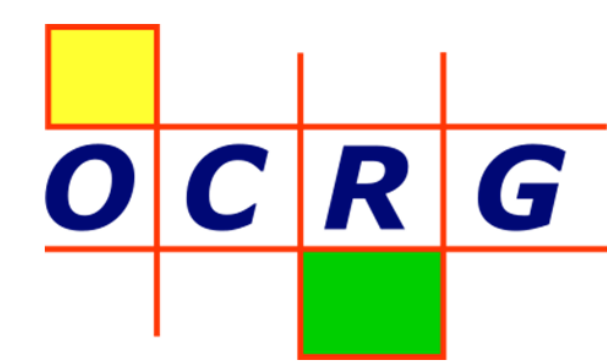
Xicong Li¹, Z. Ghassemlooy¹, S. Zvanovec², R. Perez-Jimenez³, P. A. Haigh⁴

¹Northumbria University, Newcastle upon Tyne, UK

²Czech Technical University in Prague, Prague, Czech Republic

³IDE TIC, University of Las Palmas de Gran Canaria, Spain

⁴Intelligent Sensing and Communications Group, Newcastle University, UK



Introduction

- The goal of this research is to investigate the fundamental principle behind the analogue pre-equaliser.
- Based on the principle, multi-carrier modulation with bit loading can outperform the VLC system with analog equalisers.

Pre-equaliser design method

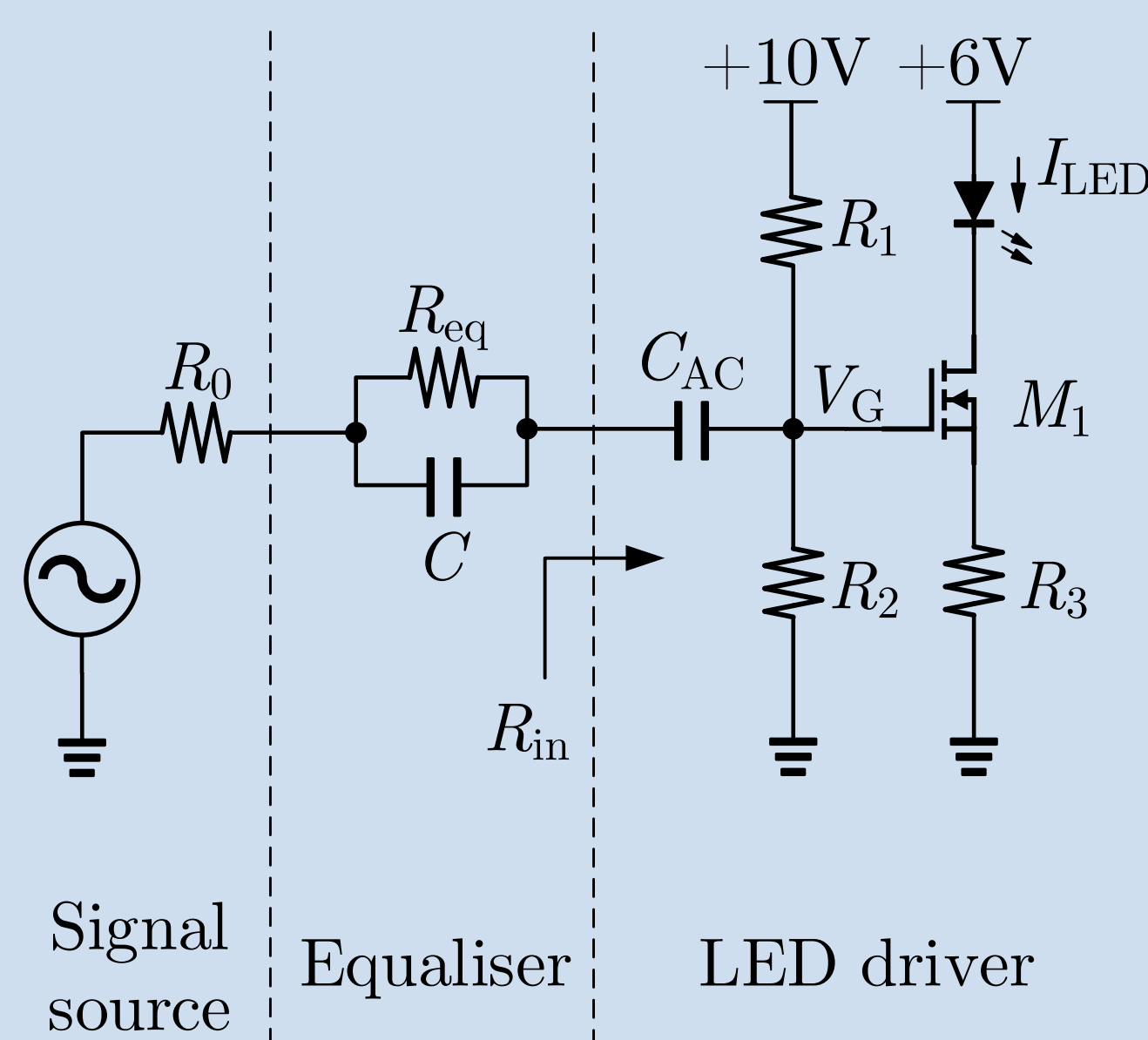


Figure 1: Driver and pre-equaliser for the LED.

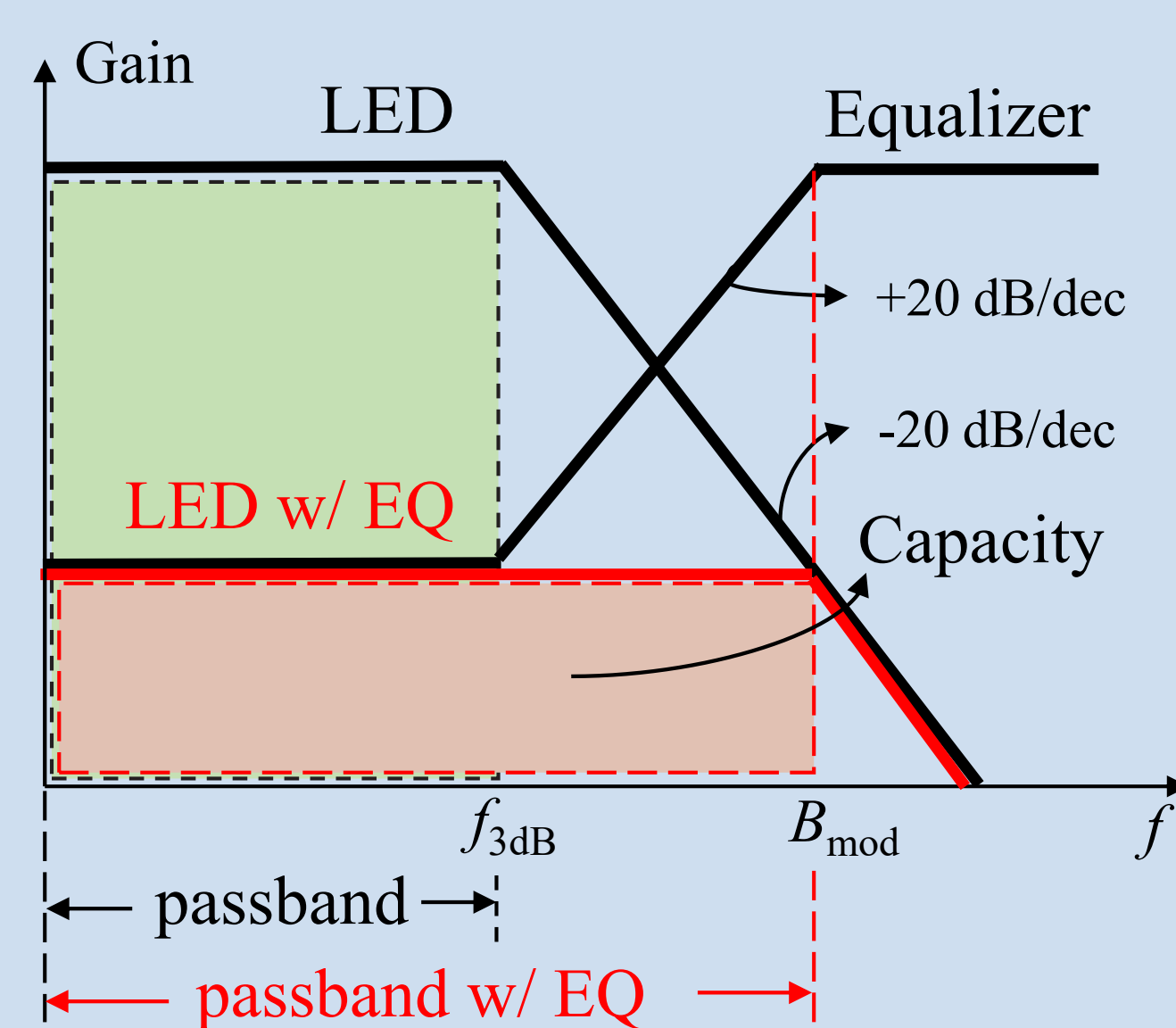


Figure 2: Frequency response of the LED and the equaliser.

The EQ design has to satisfy this condition:

$$\omega_{LED} = 2\pi f_{3dB} = \frac{1}{R_{eq}C}$$

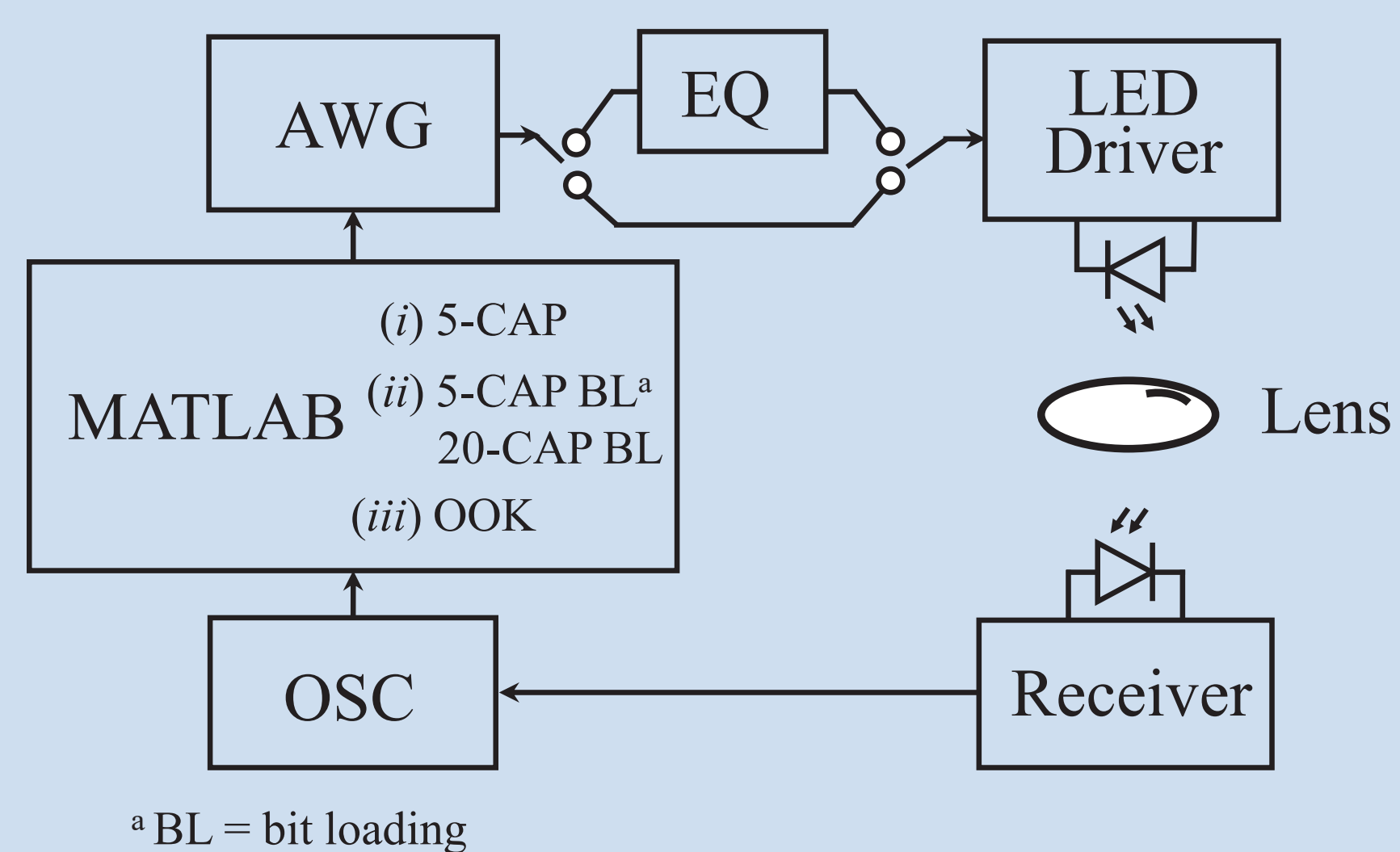


Figure 3: System block diagram

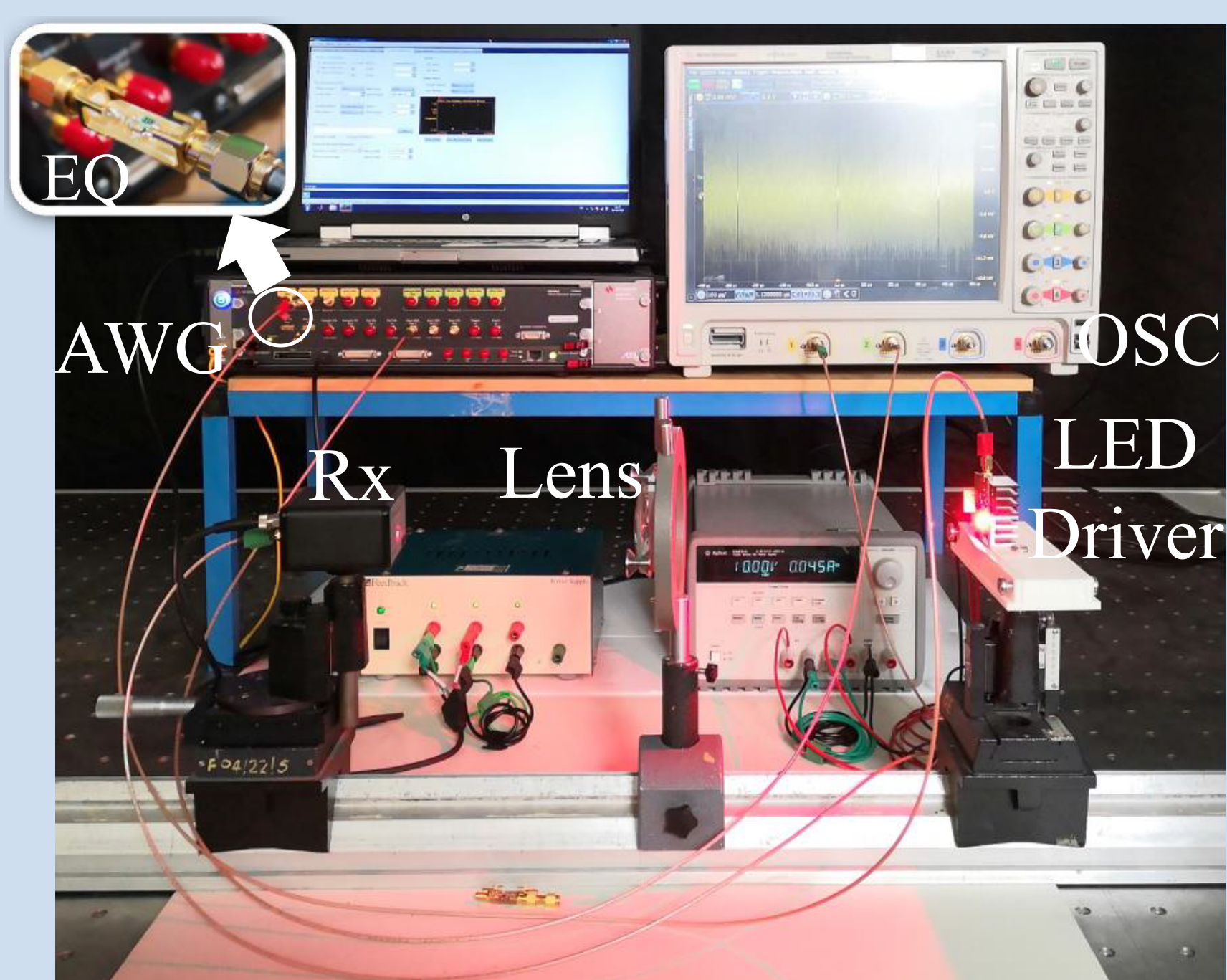


Figure 4: Measurement setup

Analogue pre-equaliser design examples

Type	Value	DC SNR loss		System bandwidth with EQ	
		designed ^[1]	measured	designed	measured
EQ1	111 Ω//200 pF	6.5 dB	6 dB	15 MHz	18 MHz
EQ2	240 Ω//82 pF	10.6 dB	11 dB	27 MHz	26 MHz
EQ3	510 Ω//42 pF	15.7 dB	15 dB	45 MHz	45 MHz

^[1]The DC SNR loss is calculated by $20 \log \frac{1}{2} - 20 \log \left(\frac{R_0}{2R_0 + R_{eq}} \right)$.

Data rate comparison between equaliser and bit loading

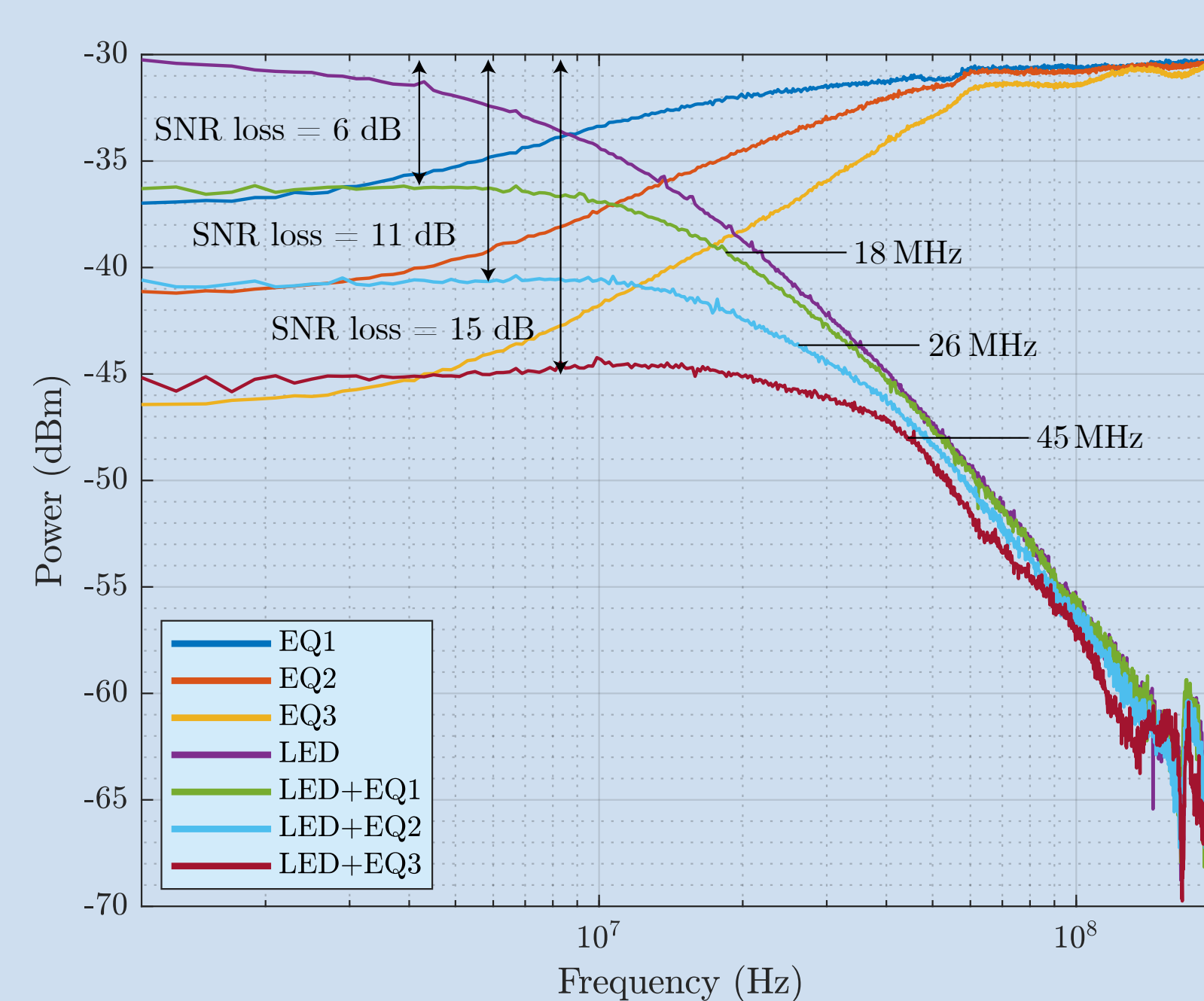


Figure 5: Frequency response of the red LED (raw bandwidth 7.5 MHz) with EQs

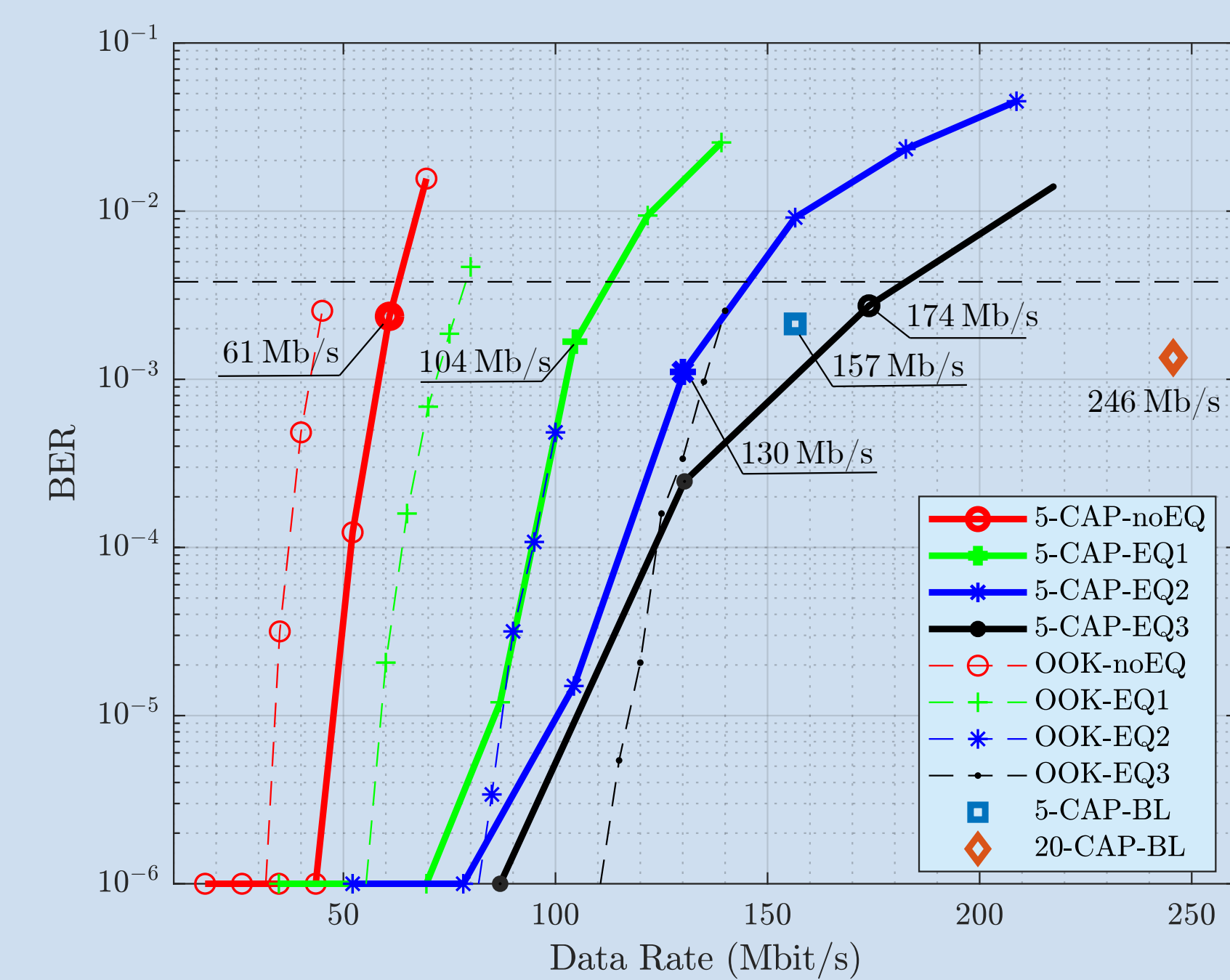


Figure 6: BER vs. the data rate for *m*-CAP and OOK

SNR or BW: easier to understand in the frequency domain!

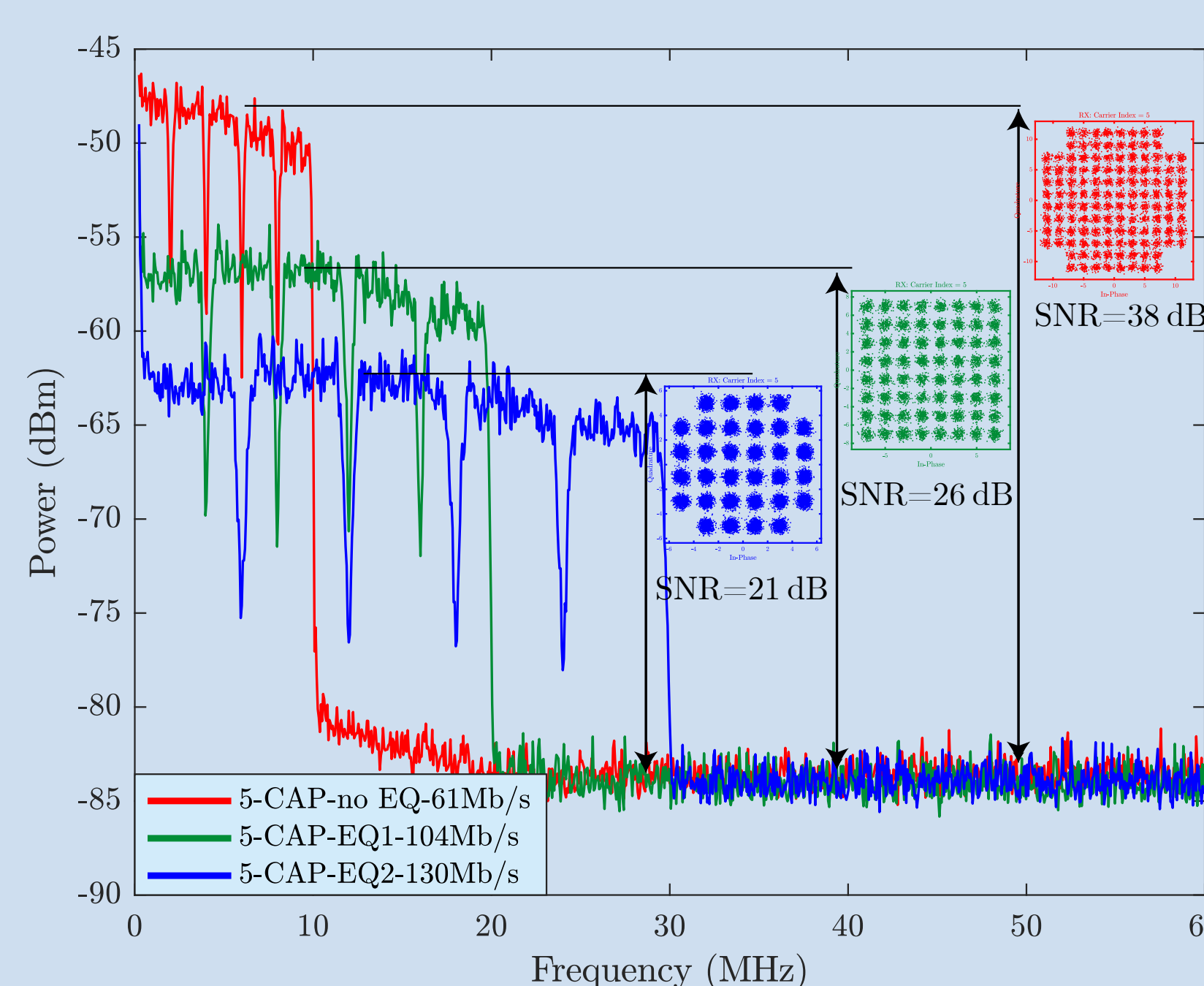


Figure 7: Measured spectrum of the received signal for 5-CAP with no EQ, EQ1 and EQ2 (1 GHz receiver Newport 1601 used)

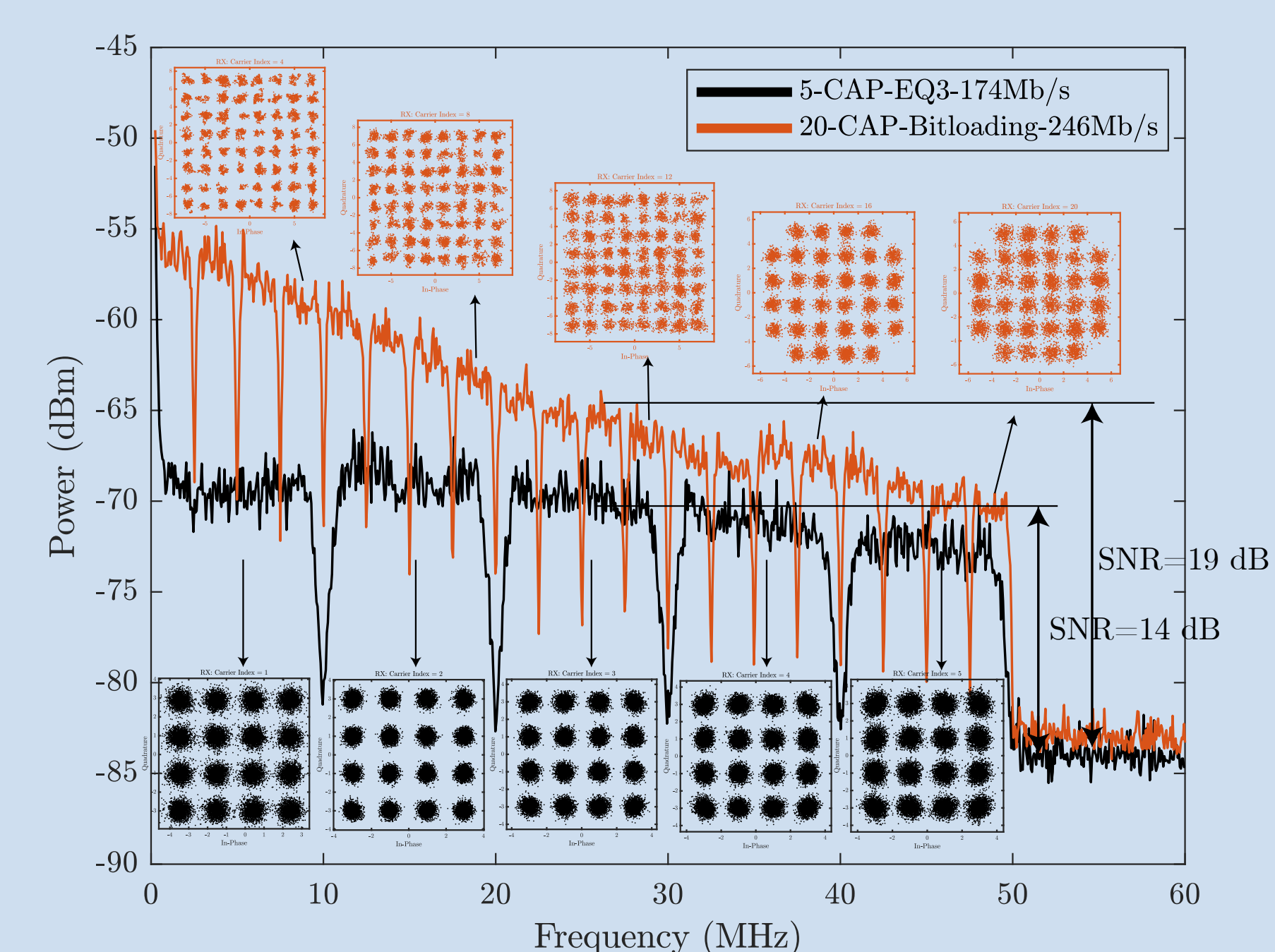


Figure 8: Measured spectrum of the received signal for 5-CAP with EQ3, and 20-CAP with bit loading using the raw LED

Conclusion

- The pre-equaliser based system can increase the data rate by extending the normalised 3-dB bandwidth at the cost of SNR penalties;
- However, VLC with multi-carrier modulation and bit-loading offered higher data rates because of no SNR penalties and higher spectrum efficiency;
- We experimentally demonstrated that for VLC with equalisers the data rate increased from 61 to 174 Mb/s when the equalised bandwidth was extended from 7.5 MHz to 48 MHz. In comparison to equalised VLC systems, the raw LED based VLC system achieved a data rate of 246 Mb/s by using 20-CAP with bit loading.

Acknowledgements

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