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

Xicong Li[1], Z. Ghassemlooy[1], S. Zvanovec[2], R. Perez-Jimenez[3], P. A. Haigh[4]

[1] *Northumbria University, Newcastle upon Tyne, UK*

[2] *Czech Technical University in Prague, Prague, Czech Republic*

[3] *IDeTIC, University of Las Palmas de Gran Canaria, Spain*

[4] *Intelligent 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

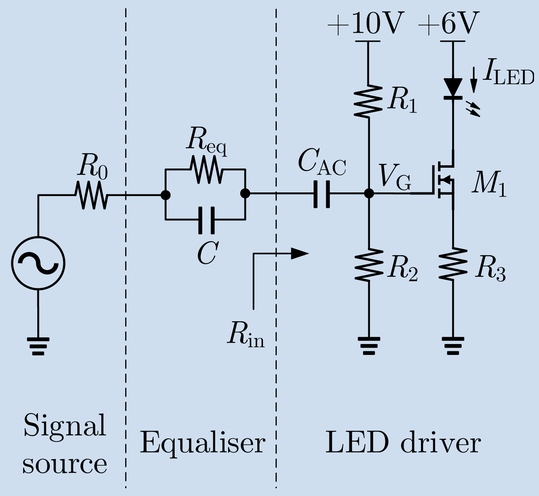

Figure 1: Driver and pre-equaliser for the LED.

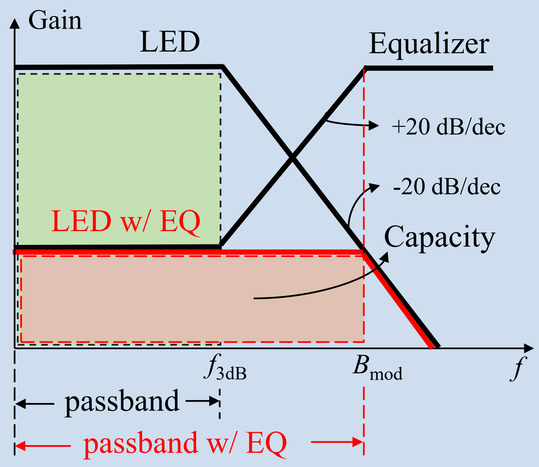

Figure 2: Frequency response of the LED and the equaliser.

The EQ design has to satisfy this condition:

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

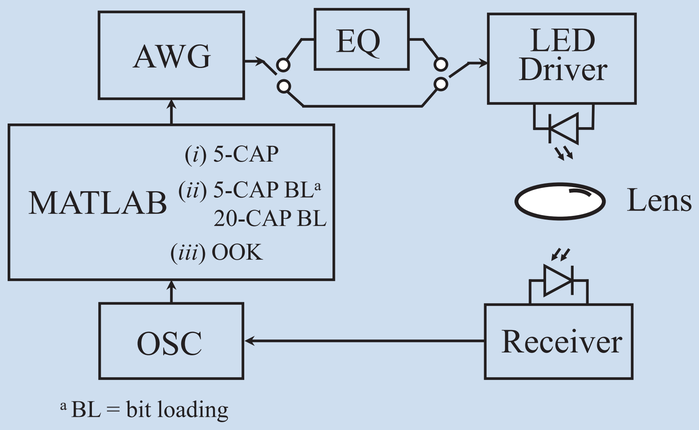

Figure 3: System block diagram

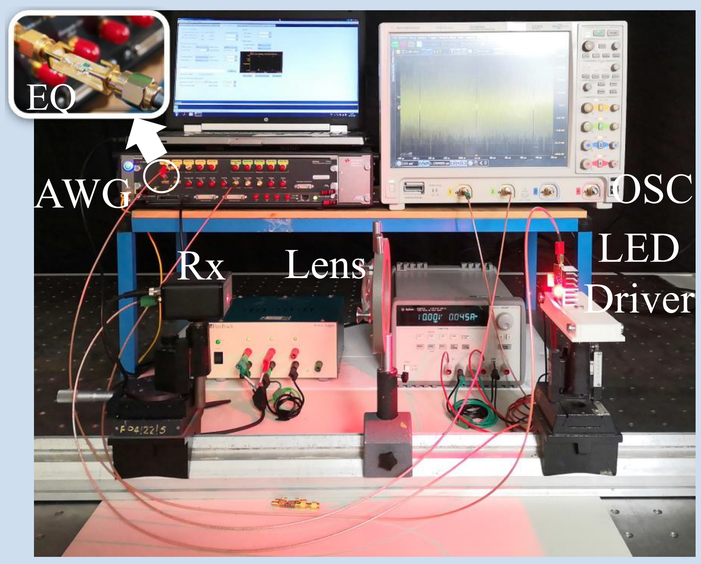

Figure 4: Measurement setup

Analogue pre-equaliser design examples

Type	Value	DC SNR loss designed[1]	DC SNR loss measured	System bandwidth with EQ designed	System bandwidth with EQ 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 $20\log\frac{1}{2} - 20\log\left(\frac{R_0}{2R_0+R_{\mathrm{eq}}}\right)$.

Data rate comparison between equaliser and bit loading

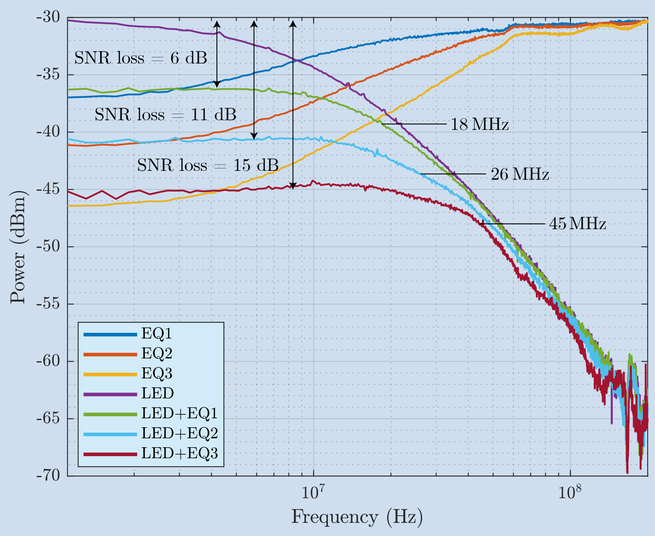

Figure 5: Frequence response of the red LED (raw bandwidth 7.5 MHz) with EQs

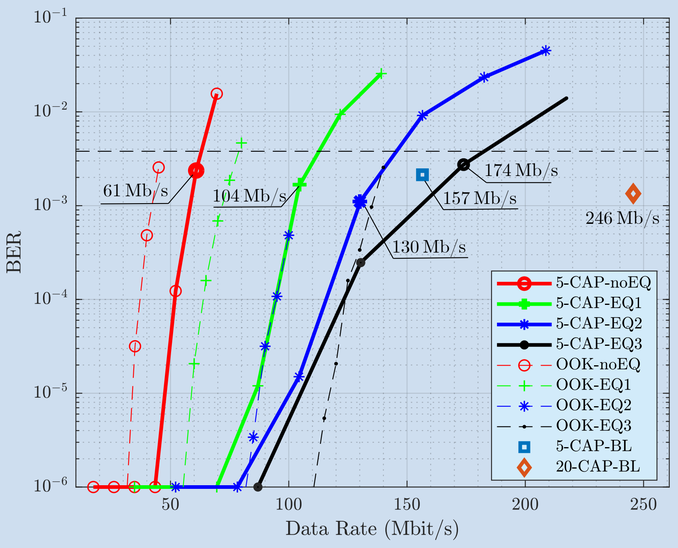

Figure 6: BER vs. the data rate for m-CAP and OOK

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

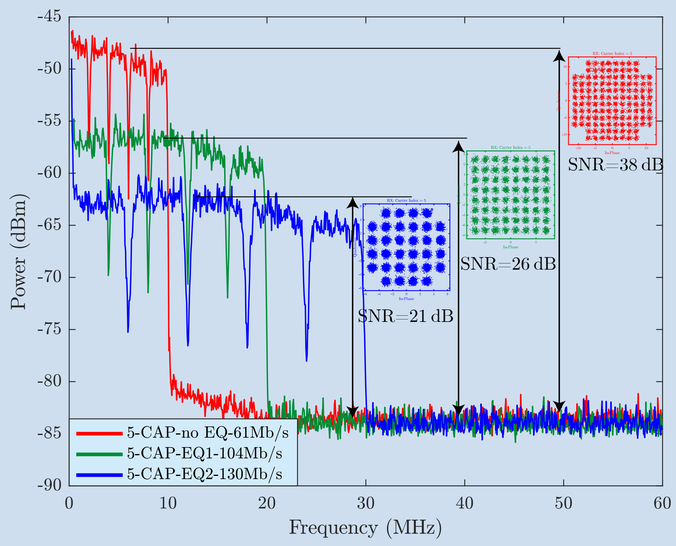

Figure 7: Measured spectrum of the received signal for 5-CAP with no EQ, EQ1 and EQ2 (1 GHz receiver Newport 1601 used)

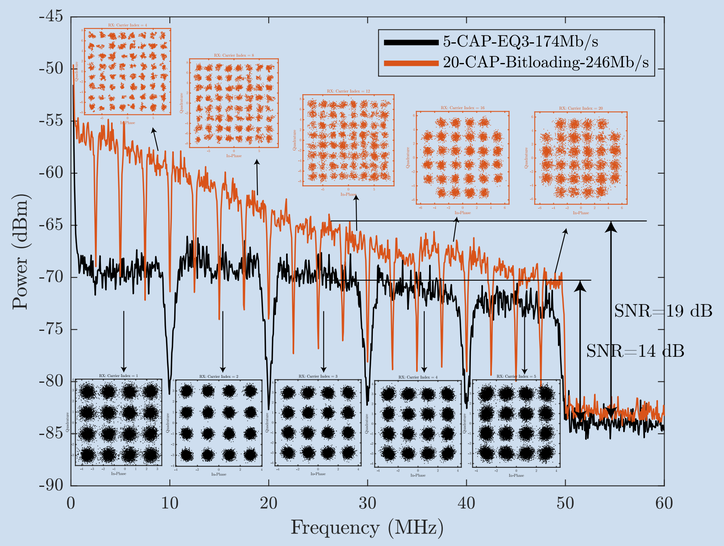

Figure 8: Measured spectrum of the received signal for 5-CAP with EQ3, and 20-CAP with bit loading using the raw LED

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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