

A Space-frequency Power Allocation Algorithm for MIMO OWC Systems over Low-Pass Channels

Citation for published version (APA):

Bitencourt Cunha, T., Fan, W. X., Deng, X., & Linnartz, J. P. (2020). *A Space-frequency Power Allocation Algorithm for MIMO OWC Systems over Low-Pass Channels*. Abstract from 1st Optical Wireless Communication Conference, OWCC 2020.

Document status and date:

Published: 05/10/2020

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

A Space-frequency Power Allocation Algorithm for MIMO OWC Systems over Low-Pass Channels

T. E. Bitencourt Cunha¹, W. Fan², X. Deng^{1,2} and J. -P. M. G. Linnartz^{1,3}

¹Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

²South China Normal University, Guangzhou 510006, China

³Signify (Philips Lighting) Research, 5656 AE Eindhoven, The Netherlands

{t.e.bitencourt.cunha, x.deng, J.P.linnartz}@tue.nl, wxfan@m.scnu.edu.cn, j.p.linnartz@signify.com

In the last two decades, an unprecedented spread of communication systems has been witnessed. While at the beginning these systems were only able to support a small number of devices with limited data services, they have now matured to high speed networks that are densely populated. Society is increasingly connected, with different types of applications running on, by now Billions of devices, and this trend drives the use of communication systems. The growth is so fast that the Radio Frequency (RF) spectrum is already overcrowded. In future, it is expected that many applications will require speeds far beyond a Gbit/s. In order to achieve this capacity and, at the same time, to off load the pressure on RF systems, higher spectral bands and optical frequencies are currently being explored.

Exploring higher frequencies in the electromagnetic spectrum, optical wireless communication (OWC) systems have recently gained great interest [1,2]. Due its many advantages, such as low cost, high energy efficiency, and minimal heat generation, LEDs are commonly used for illumination and are strong candidates to drive data transmission in OWC systems [2-4]. However, the modulation bandwidth of this source is limited and there is still the need to increase data throughput [4,5]. An alternative is to deploy multiple LEDs in a Multiple Input Multiple Output (MIMO) scheme [2-6]. MIMO is a well-known technology which explores the additional spatial dimension in order to provide a degree-of-freedom gain. By transmitting multiple data-streams over the light channel in a Spatial Multiplexing (SM) scheme from multiple spatially separated locations, Distributed-MIMO technology offers higher data throughput without the need of additional power or bandwidth. An important additional advantage of MIMO in OWC systems is that communication still works even when one line-of-sight link is blocked. In further boosting the bits rate, the low-pass frequency response of the LEDs poses further limitations. The low-pass behaviour of this source was pointed out in [6-9], but its impact on the performance of LED-based MIMO OWC systems still not fully addressed.

To compensate the low-pass effect, Orthogonal Frequency Division Multiplexing (OFDM) is often used. OFDM is a robust and effective technology commonly used in RF systems to suppress inter-symbol interference (ISI) and to convert a frequency-selective fading

channel into multiple parallel flat-fading, i.e., non-dispersive channels. In an OFDM scheme the spectrum bandwidth is divided into a set of orthogonal subcarriers in order to support high data rates through parallel transmission. By using OFDM, power loading strategies can be used to appropriately distribute power over the subcarriers in order to reduce the performance degradation caused by the low-pass effect of the LEDs [8].

Different power loading strategies are proposed to allocate power resources in the frequency domain, mainly the uniform loading and the optimized waterfilling loading [6-8]. In this paper, we consider the transmission mode of an indoor LED-based MIMO OWC system with SM and OFDM. We present an analytical model for the channel and we derive expressions for the achievable rate of the system considering common low-pass channel frequency responses: Gaussian, exponential and first-order [6-9]. Based on an indoor LED-based MIMO OWC setup, we investigate through analytical and simulation results the system performance for different power loading strategies. Through simulation results, we point out that the resource allocation optimization only in the frequency domain may not be satisfactory and we propose a new algorithm that considers both spatial and frequency domains to load power over the MIMO channels and OFDM subcarriers. With the singular value decomposition (SVD) applied to the channel frequency response matrix, the proposed space-frequency power allocation algorithm allocates more power to subchannels with larger gains considering all subchannels available for transmission in space and frequency domains.

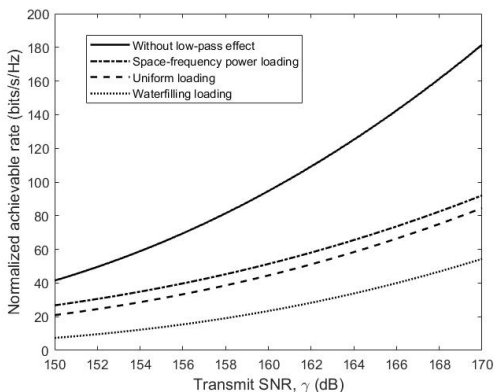


Fig. 1. Normalized achievable rate to the corresponding link budget of a 4x4 LED-based MIMO OWC system considering the exponential low-pass channel.

References

- [1] Haas, Harald. "LiFi is a Paradigm-Shifting 5G Technology". *Reviews in Physics*, 3, pp.26-31, 2018.
- [2] P. W. Berenguer, D. Schulz, J. K. Fischer and V. Jungnickel, "Distributed 8x6 MIMO Experiments for Optical Wireless Communications," *2017 European Conference on Optical Communication (ECOC)*, Gothenburg, 2017.
- [3] T. Fath and H. Haas, "Performance Comparison of MIMO Techniques for Optical Wireless Communications in Indoor Environments," in *IEEE Transactions on Communications*, vol. 61, no. 2, pp. 733-742, February 2013.
- [4] J. Song, L. Wei and H. Zhang, "Deflected field-of-views receiver for indoor MIMO visible light communications," *2017 International Conference on Infocom Technologies and Unmanned Systems (Trends and Future Directions) (ICTUS)*, Dubai, 2017, pp. 11-17.

- [5] P. M. Butala, H. Elgala and T. D. C. Little, "SVD-VLC: A novel capacity maximizing VLC MIMO system architecture under illumination constraints," *2013 IEEE Globecom Workshops (GC Wkshps)*, Atlanta, GA, 2013, pp. 1087-1092.
- [6] S. Mardani, X. Deng and J. Linnartz, "Efficiency of Power Loading Strategies for Visible Light Communication," *2018 IEEE Globecom Workshops (GC Wkshps)*, Abu Dhabi, United Arab Emirates, pp. 1-6, 2018.
- [7] S. Mardani and J. P. Linnartz, "Capacity of the First-Order Low-Pass Channel with Power Constraint," in *Proceedings of the 2018 Symposium on Information Theory and Signal Processing in the Benelux, Enschede*, pp. 149–153, 2018.
- [8] S. Mardanikorani, X. Deng and J. P. M. G. Linnartz, "Sub-Carrier Loading Strategies for DCO-OFDM LED Communication," in *IEEE Transactions on Communications*, vol. 68, no. 2, pp. 1101-1117, 2020.
- [9] M. Wolf, S. A. Cheema, M. A. Khalighi and S. Long, "Transmission schemes for visible light communications in multipath environments," *2015 17th International Conference on Transparent Optical Networks (ICTON)*, Budapest, pp. 1-7, 2015.