

Investigation on the nonlinear effect of a Gb/s visible light communication system utilizing DFT-S OFDM modulation

Can Wang^{1,a}, Meng Shi^{2,b}, Yiguang Wang^{3,c} and Nan Chi^{4,d}

^{1,2,3,4} Department of Communication of science and engineering, Fudan University, Shanghai, 200433, China

^a13307130503@fudan.edu.cn, ^b13307130529@fudan.edu.cn, ^c12110720015@fudan.edu.cn, ^dnanchi@fudan.edu.cn

Keywords: *subcarrier numbers, dft-s ofdm.*

Abstract.

Visible light communication is a hot topic of wireless communication area which has drawn more attention to be researched. *Dft-s ofdm* is a main modulation method used in *long term evolution (lte)* in wireless communication, which is able to reduce the nonlinear limitation in client amplifier. Modulating directly by transmitter led in *vlc* will cause a strong linear effect which is harmful. As a result, this paper is aimed to do a research to study the anti-linear ability of *dft-s ofdm*. The study shows that *dft-s ofdm* is helpful in reducing linear effect and *papr*. It also shows the simulation and experiment results to make sure the system can work safely and precisely in a certain situation. We make a conclusion that less number of subcarriers can help to lower *papr* and *bit error ratio (ber)*.

Introduction

With the development of wireless communication technology, visible light communication which can improve performance in speed and other aspects catches people's eyes and become popular in communication area. *Vlc* is effective and feasible so that lots of researchers are busy doing experiments with the purpose of improvement of higher speed and lower bit error ratio. Such as *cap*, *ofdm*, *bit loading ofdm*, these are all applied in higher data transmission rate. *Ofdm* becomes an attractive modulation format for optical communications recently for its high spectrum efficiency, flexible coding scheme and obvious tolerance to *intersymbol interference*. But it is limited by *papr*. By our research, it suggested that *papr* can be controlled by some factors and several approaches can be adopted to reduce *papr*. As far as we know, there are measures such as *clipping*, *pts*, *slm*, *coding*, *companding*, *active constellation*, *tone reservation* which can reduce *papr* in wireless communication system. Lots of researchers considered a large quantities of methods to find out the relationship between these factors and reduction of *papr*. Few of these experiments pay more attention to the effect of subcarrier number. This paper provides a special view to show it. Recently, there is a method of using *dft* to finish frequency domain signal extensions to reduce *papr*. It has a nice characteristics on *papr* reduction which is similar to single-carrier signal's feature. What's more, simple algorithm is a highlight for the uplink requirements. This technique is named *dft-s ofdm*.

The paper is organized as follows. In the next section, main ideas and theories are given. Then, the *matlab simulation* for different numbers of subcarrier based on interleaving is presented. After that, next part presents the setup and experiment result. The experiment is aim to illustrate the efficiency of the different number of subcarriers. Finally, we conclude our paper.

Theory and Discussions

Before we learn about the detail of *dft-s ofdm*, *papr* and *ccdf* are presented as followed. The *ofdm* signal is composed of multiple independent subcarrier signal. This is different with the single carrier communication system. When the signal of subcarrier are in the same phase addition, the obtained synthetic signal may bring a high *papr*. We need a method named *ccdf* to measure the *papr* distribution. The *complementary cumulative probability distribution function (ccdf)* curve shows

how much time the signal spends at or above a given power level. The power level is expressed in *db* relative to the average power. The percentage of time the signal spends at or above each line defines the probability for that particular power level. A *ccdf* curve is a plot of relative power levels versus probability.

Dft-s ofdm is made up of these procedures approximately. Firstly, the time domain signal is divided into *k* blocks. Then they are converted into the frequency domain signal by *dft* respectively. Secondly, signal sequences from each block *dft* transform is allocated to each subcarrier. In this paper, the allocated method is interleaved allocation distribution. Each in turn from the choice of a symbol *dft* output sequences with different block is mapped to a set of consecutive subcarriers, until the completion of the distribution. As far as we know, *dft-s* method is a linear process, as a result, the *dft-s ofdm* can reduce the *papr* effectively.

Simulation Analysis

Several simulations through *matlab* have been presented to investigate the relationship between subcarrier number and *papr* reduction under visible light in the *ofdm* system.

As shown in Fig. 1 for *vlc* system based on *dft-s ofdm*, we figures out that subcarrier number is related to *papr* reduction. This simulation is under the condition: data number is equal to 1000, *qam* order is equal to 4 (64qam), set number is equal to 2, *dft-s* method is interleaved allocation. As can be seen from the picture, when carrier number is equal to 512, its line of *ccdf* is taller than any other line of different number of subcarrier. From what is shown in Fig. 1, we can safely draw a conclusion: Lower the number of subcarrier is, better the *papr* performance of system is.

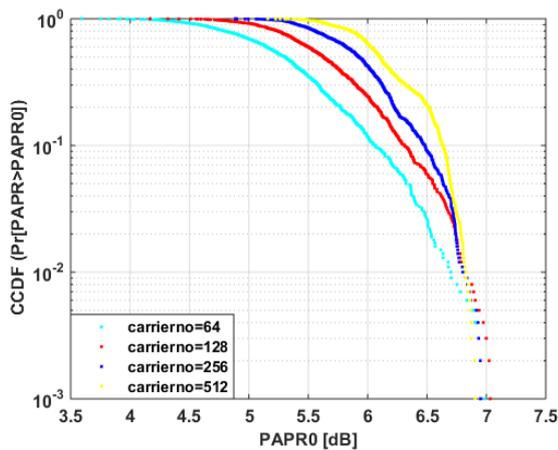


Fig. 1 *papr* performance of different subcarrier number in ideal *vlc* system.

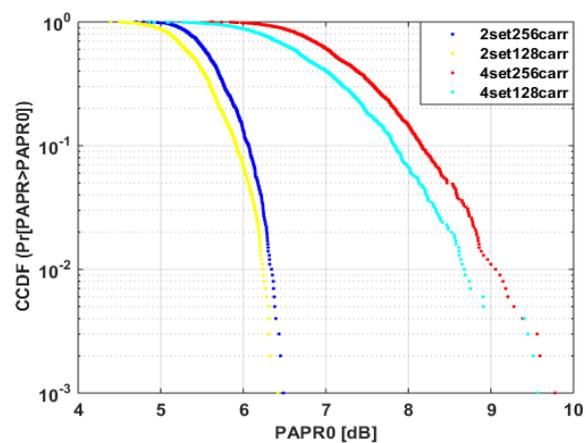


Fig. 2 *papr* performance of 128 and 256 subcarrier number in 2 and 4 sets

Furthermore, as shown in Fig. 2, this paper compares 128 and 256 carriers in 2 and 4 sets. From what is shown above, we can clearly find the subcarrier number play an important part in *papr* performance. The regulation is the same as of last simulation. Besides, performance of 2 sets is better than that of 4 sets.

Experimental Setup and Result

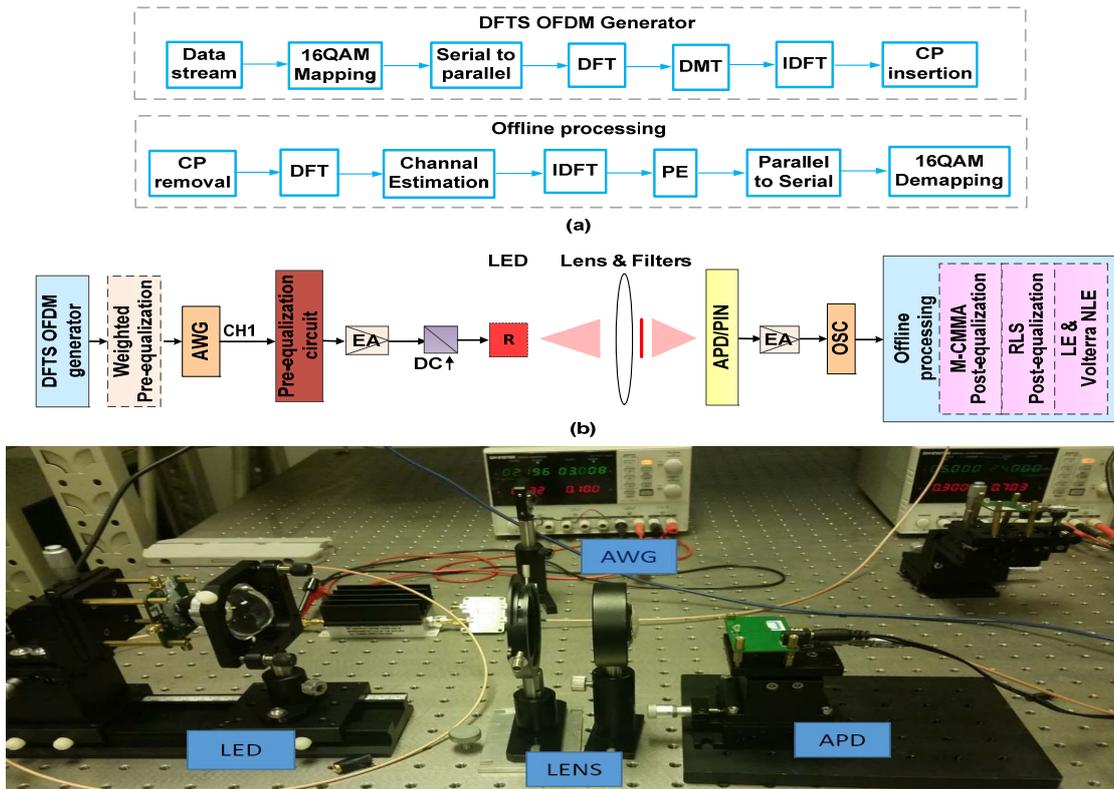


Fig. 3(a) (b) Experimental setup of DFT-S OFDM signal transmission

In order to illustrate the feasibility and effectiveness of different number of subcarriers, we construct a whole series of experimental facility. Fig. 3 indicates the experimental setup of *dft-s ofdm* signal transmission. The signal is generated off-line by *matlab* program and mapped to 64-qam constellation. The *dft-s ofdm* baseband signal is constructed with 128 or 256 subcarriers. When the subcarrier number is equal to 128, current is varied from 80mA to 120mA, voltage is changed from 0.5V to 1.2V. While subcarrier number is equal to 256, the operation is the same. The *ber* is recorded to figure out the regulation. At the same time, we keep four constellation diagrams to find out whether 128 subcarriers or 256 subcarriers is helpful to get a lower *ber* in transmission.

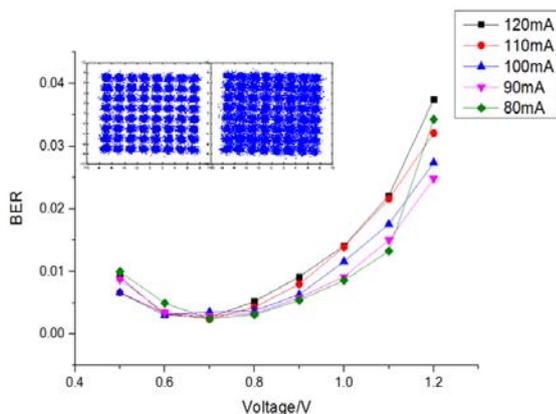


Fig. 4(a) 128 carriers and two constellation diagrams (best and worst)

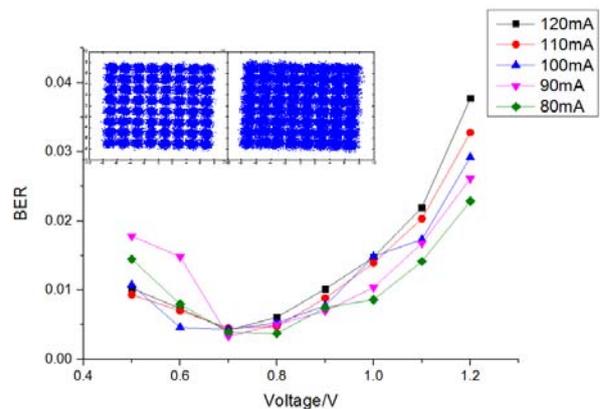


Fig. 4(b) 256 carriers and two constellation diagrams (best and worst)

From what we can see above, *ber* of 256 subcarriers is much bigger than that of 128 subcarriers. Also, comparing the constellation diagrams in those pictures is easy to show that subcarrier number is a significant factor to reduce *papr* in *vlc* system. In addition, when *rf* voltage varies from about 0.7V to 0.8V, the system is fit for all current. The bottom circle in the picture below is the best situation area.

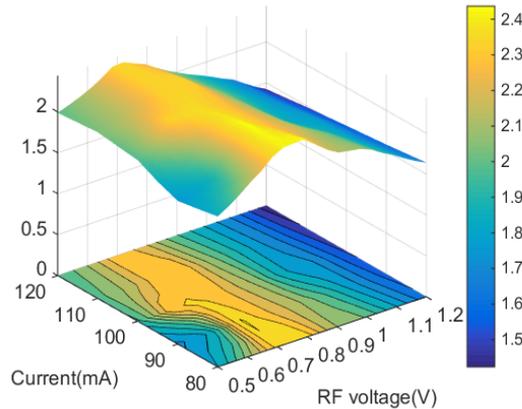


Fig. 4(c).The 3d contour maps of *dft-s ofdm* (256 carriers and 128 carriers)

Conclusions

In this paper, for the first time, we explored *dft-s ofdm* modulation method in high-speed *vlc* system and achieve a gbit/s 64qam signal transmission using interleaving with different subcarriers in *dft-s ofdm*. The experimental results show that the bit error rate (*ber*) for an overall 1.2gb/s 64qam signal over 40 cm transmission can be under the 7% *forward error correction (fec)* limit of 3.8×10^{-3} . The major advantage of this method is that it can solve high *papr* issues. Comparing a few of numbers of subcarriers of *dft-s ofdm*, the smaller one has efficiency advantage to lower *papr*, reduce *ber* and improve the performance. What's more, different number of sets, *qam* modulation order, real working condition, and other else all have multi effects on the system's performance. From all of our researches, *dft-s ofdm* will be of great advantage in the high-speed *vlc* system. Further study will be focused on higher transmission speed, lower *ber*, and safety.

Acknowledgements

This work was financially supported by the national "863" program of china (no.2015AA016904) and the cast foundation project.

References

- [1] Y. Fang, L. Tao and N. Chi, "Interleaved subcarrier allocation for DFT-spread OFDM to reduce PAPR", 17th Opto-Electronics and Communications Conference Technical Digest (OECC 2012), Busan, Korea, July 2012
- [2] Nan Chi, Yiguang Wang, Yuanquan Wang, et al. Ultra-high-speed single red-green-blue light-emitting diode-based visible light communication system utilizing advanced modulation formats [J]. Chinese Optics Letters, 2014, 12(1): 010605.
- [3] L. Tao, Jianjun Yu, Q. Yang, M. Luo, Z. He, Y. Shao, J. Zhang, N. Chi, "Spectrally efficient localized carrier distribution scheme for multiple-user DFT-S OFDM RoF PON wireless access systems", Optics Express, Vol. 20, No. 28, pp. 29665-29672 (2012).
- [4] Li Tao, Ze Dong, Jianjun Yu, Nan Chi, Junwen Zhang, Xinying Li, Yufeng Shao, G. K. Chang, "Experimental demonstration of 48-Gb/s PDM-QPSK radio-over-fiber system over 40-GHz mm-wave MIMO wireless transmission", [J] Photonics Technology Letters, 24(24), pp. 2276-2279 (2012). (SCI)
- [5] J.Y. Shi, X.X. Huang, Y.G. Wang, L. Tao, N. Chi, "Improved Performance of a high speed 2×2 MIMO VLC network Based on EGCSTBC," ECOC, 2015