QAM based high power LED visible light communication system

Xing Mou, Xiaohan Sun and Tianyuan Liu

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Xing Mou, Xiaohan Sun *, Tianyuan Liu
Chien-shiung Wu College
National Research Center for Optical Sensing/Communication Integrated Networking
Southeast University, Nanjing 210096, China

Abstract
The wireless communication is facing challenge with the growth of information volume. Visible Light Communication (VLC) system based on LED shows potential to solve this problem. It has the advantages of extending the communication's capacity and saving energy as it is an eco-friendly lighting resource. But it also has some congenital defects. In this paper a QAM based VLC system with high power LED is implemented. This work demonstrates the realizability of adding communication function on existing LED illumination system.

Keywords: Visible light communication, High power LED, QAM

1 Introduction

Recent emerging techniques lead to an increasing demand for the overall traffic volume in wireless-communication. But the traditional systems have faced the challenge of the limited radio frequency band[1], also they are restrained in some special areas like hospitals and airplanes[2]. Developing a new communication system is in urge demand. LIFI is a kind of visible light communication, which uses a new eco-friendly resource LED as the emitter. It has the capacity of using higher frequency in electromagnetic spectrum. Besides, LIFI can also provide another advantages, such as high security, electromagnetic interference (EMI) free, license-free[3] and in the same time maintain illumination function, which can eliminate the use of extra power. However, unlike the laser, the conventional photo-communication source, the universial LED has the bigger time constant ($\tau = RC$) and it restricts the modulation speed. Although, there are researches about using group-III nitrides to make high-speed LED for higher communication volume, it suffers from the sharp decrease of quantum efficiency with increasing injection current, which is hard for maintaining the illumination function and extending the communication distance[4][5].

In this paper, a quadrature amplitude modulator (QAM) based visible light communication (VLC) system with high power LED is implemented. This LED is universal used and has the advantages of low cost and high power. It means it can be popularized in our daily life to achieve not only illumination function but also communication function. In the demonstration, we use QAM to modulate the data, and it can break through the limitation of LED's modulation speed.

2 QAM scheme

As the analyses of LED visible light communication system shows above, the bandwidth of information channel is limited by the modulated speed of LED. In order to expand the communication volume, we use QAM to modulate signal. Amplitude modulator (AM) is easier in designing circuit than the other similar modulation factors and widely used in many signal processing areas that can modulate signal to high frequency to make transmitting easier. QAM combines the quadrature modulation and amplitude modulation, and it can double the effective bandwidth. The system shows in Fig. 1. A modulator circuit and a demodulator circuit is implemented before the emitting circuit and after the receiving circuit, respectively.
In the demonstration, we process a 100Mbits/s data stream produced by FPGA. The data is deserialized into two streams in FPGA. It is aimed at fitting the passband of the actual information channel. The following comparators called TLV3501 are used to improve the load capacity and reshape the waveform of the digital signal. Then they are modulated with quadrature carrier signals respectively. Two band pass filters (BPF) are implemented to keep only a part of waveform. Then the remaining are added again. Also, we build an impedance matching network before emitting circuit to improve the transmitting quality. After receiving circuit, the demodulation process is showed in Fig. 1. b. The first BPF is used to reduce noise. And the signal is coherent demodulated by the same carrier signals. Then the following filters cut down the extra high frequency signal. They are recovered again in FPGA after reshaped by comparators.

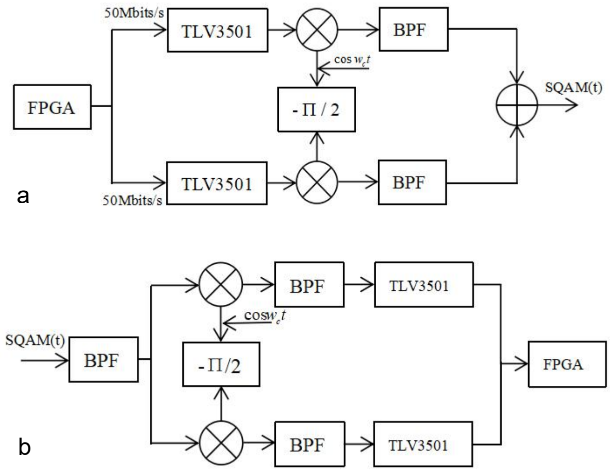


Fig. 1. The diagrams of (a) modulator and (b) demodulator

The concrete modulation scheme is showed in Fig. 2. A data stream of 50Mbits/s has power concentrates on the frequency from 0Hz to 50MHz. After multiplied with carrier signal of 60MHz, the frequency band is moved higher. Then only keep low side band (LSB) by low passing filter. And as the carrier signals are orthometric, these two modulated signals can be added without interference.

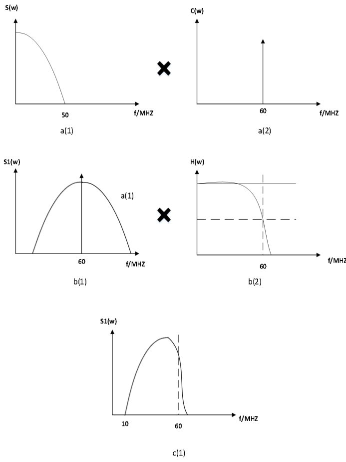


Fig. 2. The modulation process. (a) The baseband signal is modulated by carrier signal. (b) The QAM signal and the filter. (c) The receiving low side band signal.

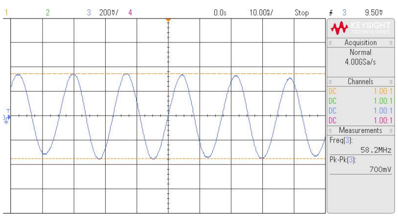
3 System test

We choose a high power LED as the optical source in the emitter, which has good linearity and easy-used. We design the pre-equalization circuit in order to fit the device. Firstly, we test the information channel, that is except the modulation part mentioned above. The test platform is show in Fig. 3. The emitting amplifying circuit including a low noise amplifier (LNA) and a high-power MOSFET to reduce the noise and in the same time provide enough drive capability. The receiving amplifying including a trans-impedance amplifier (TIA) in order to change the current signal received by PIN into voltage and a LNA to provide more gain. In order to reduce noise, there is a filter circuit after them.

Fig. 3. The test platform. The distance is from 1m to 6m.

We change the distance and the input signal frequency to get the response. The result shows in Fig. 4. The frequency response vary with different test distances. All of them perform fairly bad in low frequency below 10MHz, and become tremendously different above 40MHz. This result is similar with other research[5].

a.



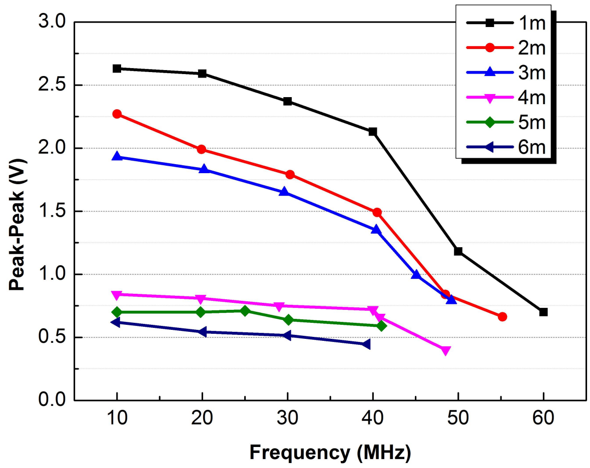


Fig. 4. (a) The example waveform shows on oscilloscope. (b) The frequency respond from different distance.

In order to get a flat and steady passband, we add a high pass filter circuit after the last amplifier. Finally, we achieve a steady information channel, which has the passband from 10MHz to 60MHz in the test distance of 1m. Furthermore, combining with the modulation circuit mentioned in Part II, we finally achieve a visible light communication system with the bandwidth of 100MHz.

4 Conclusions

This paper achieves a VLC system of 100Mbits/s. Unlike some researches[5][7], we use high power LED rather than specific GaN-based LED, and focus on signal modulation to double the communication volume. Although this kind of LED suffers from the modulation speed and its high power characteristic brings difficulty in design, it still has the great advantage of achieving VLC while maintaining illumination function at the same time. Furthermore, this modulation circuit can be easily added to existing illumination system and it has the capability of extending it to high-order QAM, so it has potential to extend the capacity further.

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