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Design of Wireless Optical Access System using LED

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ABSTRACT

This paper develops a prototype to demonstrate a full-duplex wireless visible light communication (VLC) system based on Universal Serial Bus (USB) port. Combing with a USB 2.0 port on one board, it can achieve up to 2 Mbps bit rates error free, which is mainly limited to the USB bridge circuit, between two computers for data transmission, such as text, audio and video. Hyper Terminal and self-written software are used to allow setting the transmission data rate, control bits, check bits and achieve real-time transmission between any two mobile devices with a USB port. The work is based on the research of VLC local access network. This paper also shows the experimental results and the relationship between system transmission eye diagram and bit rate.

Keywords: Visible Light Communications; Visible Light Access Networking; USB Interface; Real-time Transmission; Full-duplex

1. Introduction

Looking into the future, traditional home and office illumination tools will soon be substituted by the lower energy consuming, longer lifetime and health harmless LED devices. Meanwhile, the very fast changing capability in the output power makes LED devices possible to transmit a large amount of data at high speeds in the visible range, which is an added advantage of LED besides its illumination purpose. Visible light communication (VLC) using white LEDs has aroused global attention. At present, many famous research institutions and universities, such as the Visible Light Communications Consortium (VLCC) [1-2], the European OMEGA project [3], the Wireless World Research Forum (WWRF) [4] and so on, have dedicated much to area. And it has witnessed increasing interest in the research community with a forthcoming IEEE standard [5]. High speed transmission rate [6,8], channel characteristics [9,10], modulation and demodulation methods [11-13], etc [14,15] are the main focuses of research.

USB is a universal standard of external bus to specify the connection and communication through computer and peripheral electronic devices. USB port as the interface to PC with its popularity and support to hot plugging. VLC with a variety of practical applications in short-range transmission scenarios is promised to enter into people's daily life. The channel between two computers via VLC has been shown in [16-19], where RS-232 protocol or RS-485 protocol is used to connect visible light module with a PC. Design of an integrated optical receiver using USB interface is introduced in [20]. The data rate and transmission distance can surely be improved by increasing the number of LEDs and adopting modulation schemes. An application scenario for the developed system is indoor short distance wireless transmission where LED with communication function is enveloped as a desk lamp and when turned on, data stream flows wirelessly in both ways.

In this paper, a full-duplex access system using white LED based on USB port with 2 Mbps data rate is designed as a basic visible light access network. Hyper Terminal and self-written software are used to achieve the transmission of data and real-time audio transmission between two PCs. The rest of this paper is organized as follows. Section 2 gives the system design and system characteristics. In section 3, the testing and results of transmission link is discussed. Finally, Section 4 concludes the paper.

2. System Design and System Characteristics

2.1. System Design

A CH340 is used to connect USB interface for realizing the conversion of signal from differential to TTL, or inverse. USB signal after conversion has a 4V peak-to-peak voltage value. A voltage follower then plays the role of buffer to amplify the signal current to an adequate level, driving LED for lighting. A high power white LED of 1W and with the beam angel 120° is used as optical transmission source. OOK NRZ data for Intensity modulation (IM) and direct detection (DD) scheme is chosen for the widely reception in VLC research. The circuit design of transmitter is given as **Figure 1**.

The receiver employs a commercially available Si PIN (Hamamatsu S6968) photodiode for optical to electrical conversion with 150 mm^2 effective active area, 14mm active area size and 35° half angle. The received optical signal is sent to a low pass filter followed by a custom amplifier for recovery. A decision circuit (LT1715) is used as a single threshold voltage comparator to achieve the signal decision with a reference voltage level to obtain the original signal. The TTL signal after decision is sent to CH340 to achieve the conversion from TTL signal to USB serial signal. The whole circuit of receiver design is given in **Figure 2**. It needs to be noted that the transceiver module is composed of a transmitter and a receiver to realize a full-duplex wireless communication. Transceiver design is shown in **Figure 3**.

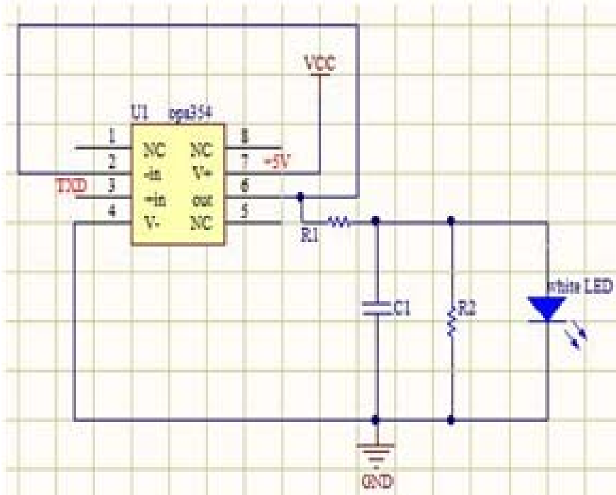

Figure 1. Transmitter circuit diagram.

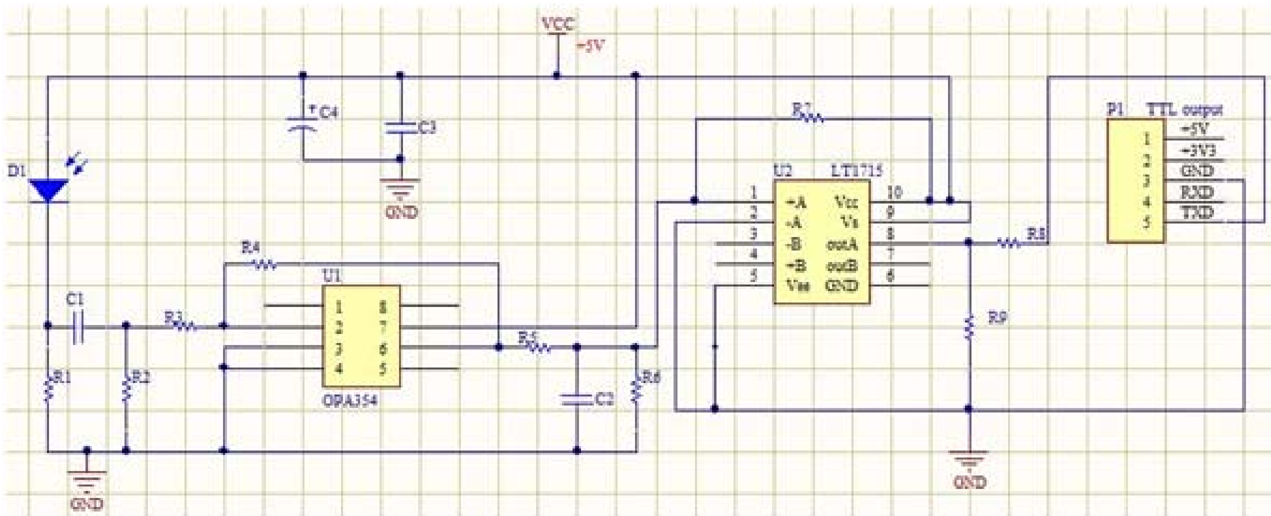

Figure 2. Receiver circuit diagram.

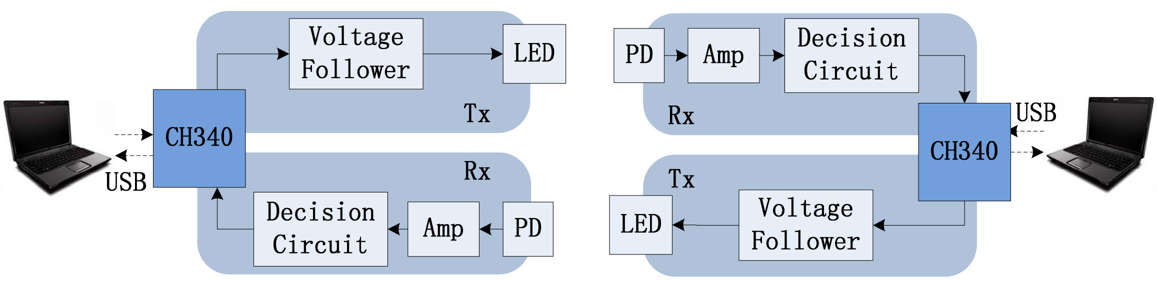

Figure 3. Transceiver block diagram.

2.2. System Characteristic

All the system power supply is supported by the 5V DC from USB port. The driver of CH340 must be firstly installed on PC before being connected to a transceiver module. After transmission rate being set and Com port being selected in Hyper Terminal, which is a communication tool available in computer's self-carried enclosures, PC treats the transceiver module as a visual serial port via which all types of the data can be transmitted, such as text, audio, video and so on. Another application example is developed using Visual C#. Program is created to achieve real time audio transmission between two transceiver-settled computers. The input voice from microphone or music of wave waveform type is captured by one computer, and then audio data is sent to the selected Com port and transmitted by our transceiver module. After a light of sight channel, the opposite transceiver module interfaced on the second PC received the bit streams and played it real time. The physical map of the system model is shown in **Figure 4**. The transmission between two computers using Hyper Terminal is shown in **Figure 5**.

3. Testing and Results

With the VLC system described above, performance of the transceiver module is measured. On one hand, we studied the eye pattern of the TTL signal before decision circuit versus data rate, and the relationship between data rate and eye diagram is investigated. On the other hand, the text transmission using program based on Visual C# is also given. The system is tested using the configuration shown in **Figure 6**, as the arbitrary waveform generator and oscilloscope instead of PCs.

Figure 7 presents the eye diagrams for the receiver arbitrary OOK NRZ data (PN23) at speeds of 1 Mbps and 2 Mbps after optical signal conversation. The eye diagrams of the signal receive without amplify and filtering are clear, thus show error free performance. The eye diagrams indicate that the signal can be correct recovered after decision circuit.

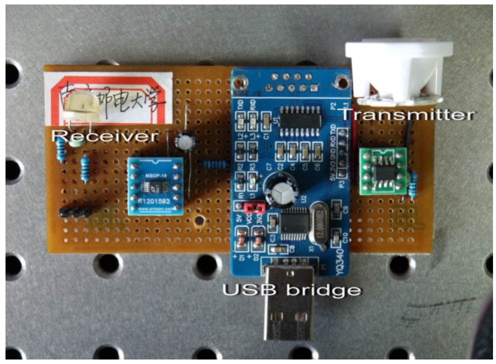

Figure 4. Physical map of system design.

Figure 5. Prototype of the full-duplex system.

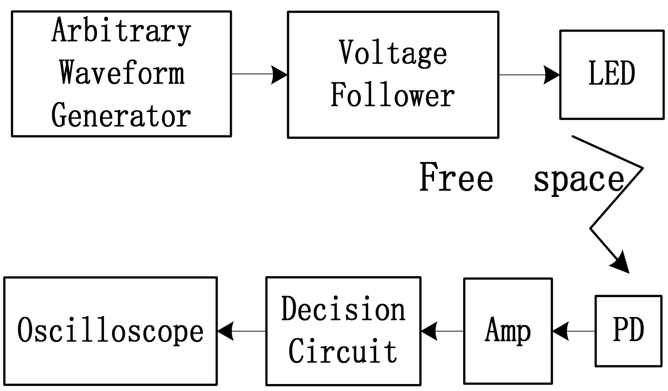

Figure 6. Testing block diagram.

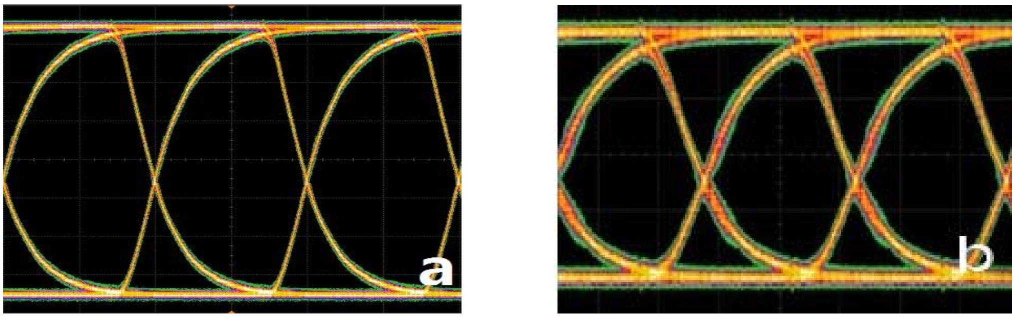

Figure 7. Eye diagram waveforms after direct detection without filtering and being amplified at (a) 1 Mbit/s data rate, (b) 2 Mbit/s data rate.

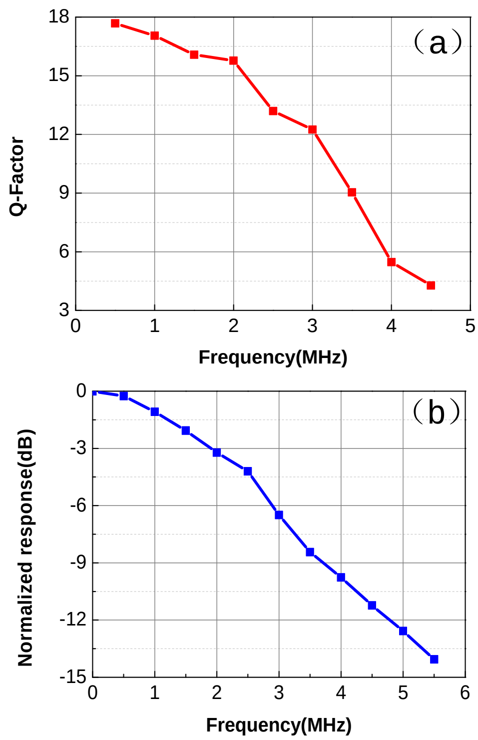

Figure 8. (a) Eye diagram Q-factor Vs data rate, (b) frequency response curves of the whit light LED.

We obtained the Q-factor of eye diagram at different transmission rates and estimated the BER from Q-factor. All BERs are below 10^{-6} when data rate goes up to 4.5 Mbit/s. The curve of Q-factor vs data rate is showed in **Figure 8(a)**. We can find that the BER performance is mainly restricted to 3 dB bandwidth of the white LED emitter, where the normalized response is shown in **Figure 8(b)**.

In this experiment, the system of VLC was demonstrated for applying to data transmission because the concept of VLC can be used in marine, automotive, underwater, home network and other scenarios. The green waveforms stand for the transmission signal and the yellow waveforms come from the receiver after decision circuit, as **Figure 9** shown. It is clear that no bit error

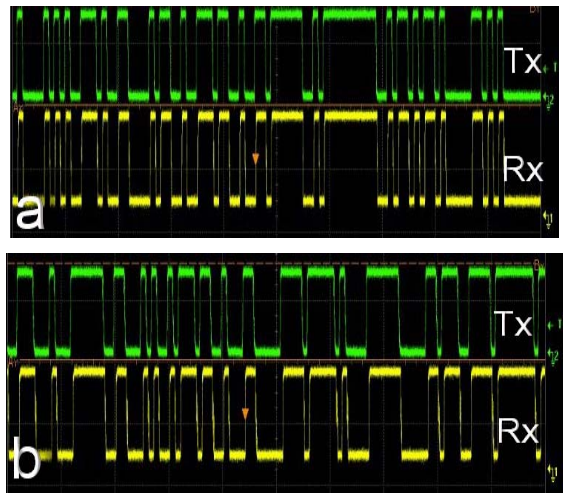

Figure 9. Captured data waveforms after decision circuit at (a) 1 Mbit/s data rate, (b) 2 Mbit/s data rate.

occurs after visible light transmission through the system and the decision circuit can correctly complete the signal decision.

4. Conclusions and Future Work

We developed a full-duplex optical wireless system prototype to achieve the transmission between two computers using white light LED. The upper limit transmission rate is 2 Mbit/s, which is restricted to USB bridge circuit CH340. The obtained Q-factor of eye diagram at different transmission rates and estimated the BER from Q-factor. All BERs are below 10-6 when data rate goes up to 4.5 Mbit/s. The higher USB bridge circuit, the more optimizing circuit designs, efficient coding method, advanced modulation techniques and mechanism for correcting errors will be considered to improvement the transmission system in our future work.

5. Acknowledgements

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