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Design of Voice Communication System Based on Visible Light

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Abstract

The visible light communication is a combination of LED lighting and wireless communication technology. In which, the LED visible light voice communication system is proposed due to the disadvantage of low security and weak ability to against interference in traditional wireless voice communication systems. It combines RS code with PSK modulation and uses CREE-XPE-Q5 white light LED and the SI-PIN photodiode respectively as transmitter and receiver to communicate. The experiment has realized the rate of 300K within 1m distance with single 1W LED and validates that the system without the noise interference has a good effect on real-time voice transmission.

Keywords: Visible light communication; Voice communication; RS code; PSK modulation; Communication distance; Transmission rate.

1. Introduction

With the development of electronic products and progress of technology, more and more new products are widely developed and researched in certain fields, these new products not only guarantee reliability and stability, but also greatly facilitate our lives, such as voice communication systems.

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The common voice communication system transmit voice information by wire or wireless , they have a lot of limitations ,wired transmission length is limited, poor mobility, complex connection, can not meeting the changing market environment , Wireless infrared, Bluetooth, WiFi and other transmission technology using radio waves or radio frequency modulation technology are susceptible to interference and poor stability, resulting in signal distortion or continuous sound can not accurately heard, the voice signal of transmission and transmission confidentiality is poor. Visible light communication technology uses the visible light as an information carrier and not uses optical fiber or radio waves as transmission medium. There is a wireless transmitter where there is a light; besides, light signal can be blocked by obstacles, leading to good confidentiality [1-4]. Compared to RF radio communication, visible light communication has many advantages, such as wide frequency band, high security, no electromagnetic radiation and no spectrum interference, etc [5-7]. Processing of collected voice signals and conversion speed of optical data directly affect the effect of the voice output [8]. So, a LED visible light communication system with simple circuit, reasonable design, simple operation and effective use is needed. It can effectively solve the problems of low conversion rate, poor maneuverability, low precision and low accuracy in the existing voice transmission circuit of the visible light communication.

In this paper, a voice communication system based on a single white LED is designed to solve the problems. The innovation of the system is RS code combined with PSK modulation different from the traditional OOK modulation method which can realize the real-time voice transmission and error correction function.

2. Communications Systems Introduction

Figure 1 shows the visible light voice transmission prototype, including light source, visible light transmitter module, photoelectric detector and visible light receiver module. Voice signal is changed into the signal easy to transmission in the optical carrier through modulation and code, and then white light LED driver modulation circuit transforms the electrical signals into light signals, which is transmitted through atmospheric channel in the form of beam emission. At the receiving terminal, the photoelectric detector receives the optical signals and converts them into electrical signals, then those signals are restored to original voice after decoding and demodulation.

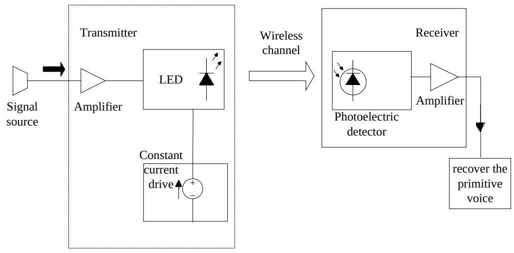

Figure 1: Visible light voice transmission prototype

3. Design of visible light transmitter

Figure 2 shows framework of transmitter, the voice signal is transmitted in the form of light after voice acquisition, amplification, A/D conversion, encoding and driven by the rive circuit of the white LED.

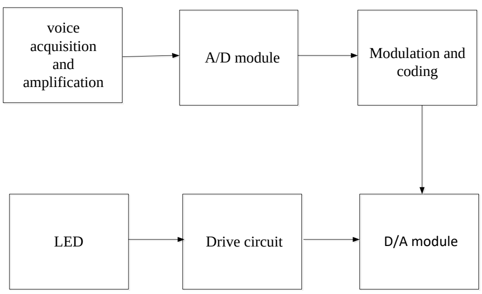

Figure 2: Framework of transmitter

3.1 Selection of light source

Visible light communication uses high- power LED for high speed communication as well as general illumination. The modulation bandwidth of LED determines the transmission rate and the channel capacity of communication system. Here we choose CREE-XPE-Q5 white LED as a light source, measure the variation curve of the light intensity with the distance of the light source under normal operating current (Figure3), and show curves of the relationship between light intensity and forward voltage at different distances (Figure4). As can be seen from the figure, the light intensity decreased with the increase of distance, while the light intensity will increase rapidly as soon as LED forward voltage exceeds the turn-on voltage, this relationship is consistent with the LED's volt ampere characteristic curve.

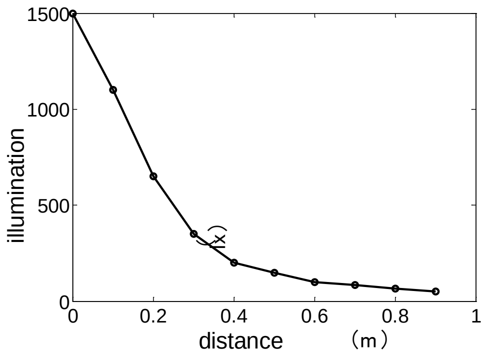

Figure 3: Variation of the light intensity with distance under normal operating current

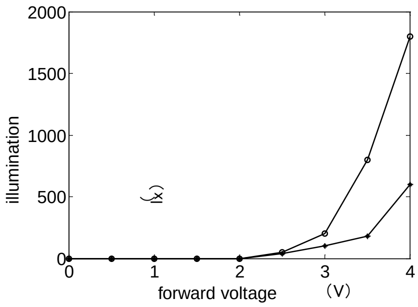

Figure 4: Relationship between light intensity and forward voltage at different distances

3.2 Acquisition and voice amplification processing section

Figure5 shows schematic of this part, this part is mainly composed of the audio operational amplifier RC4580, the first stage is a voltage follower composed of RC4580 for voice signal acquisition, the second stage is a in-phase proportion operational amplifier composed of RC4580 for voice signal collection.

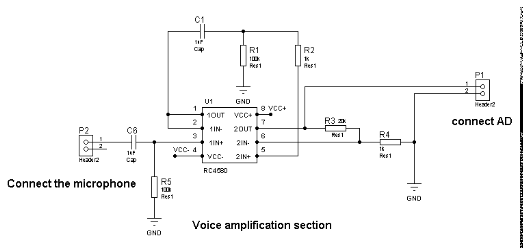

Figure 5: Voice acquisition and amplifying circuit

3.3 coding and modulation

RS code is a kind of Hexadecimal BCH code with strong error correcting capability. RS codes are especially suitable for the channel with burst errors, such as the fading channels of mobile communication networks [9]. This part are completed in FPGA, using (41, 4) RS encoding to improving the reliability of the system. Each encoding code word contains 37 message code word and 4 redundant code for error detection and correction. Digital baseband signal can change the sinusoidal carrier signal's amplitude, frequency, or phase through the modulator, generating amplitude shift keying(ASK), phase shift keying(PSK) and frequency shift keying(FSK) signals or changing some parameters of sine carrier signal to produce complex modulation signal. In this paper, the PSK modulation is adopted.

3.4 drive circuit

Figure7 shows the schematic diagram of the driving circuit, the constant current of 300mA is used to drive the LED luminescence. The constant current source circuit is composed of 3 NPN transistors in parallel, each of them provides 100 mA of output current. The modulation signal driving circuit is composed of a high speed drive chip BUF634, the output current of the modulation signal reaches 250 mA, and the modulation depth is 83.3%, so as to improve the transmission distance of the modulated signal.

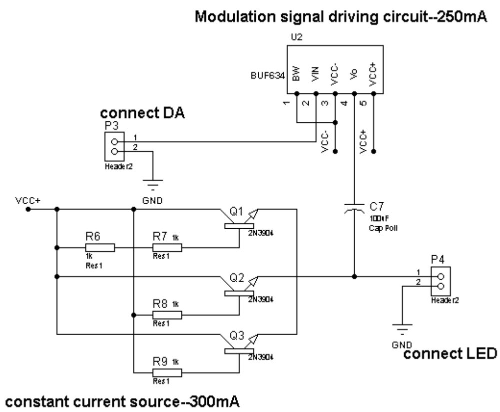

Figure 7: Drive circuit

4. Design of visible light receiver

Figure8 shows framework of receiver, PIN photoelectric diode receives the light intensity signal, restores the original speech signal through the signal conditioning circuit, and the AGC(Automatic Gain Control)circuit and then decoding and demodulation.

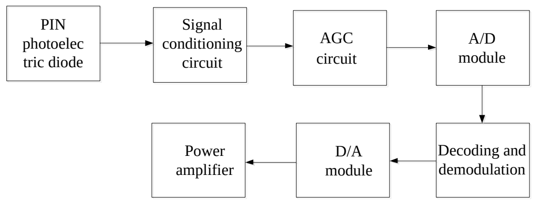

Figure 8: Framework of transmitter receiver

4.1 Circuit of receiver signal conditioning

Figure 9 shows the circuit of receiver signal conditioning, this part consists of two stages, the first stage is the cross resistance amplifier, which is used to convert the current signal from the PIN photodiode to the voltage signal, the output relationship: $Uo = I * R_2$. the diode biasing circuit provides a bias voltage to the photodiode. The width of the reverse bias voltage of the diode PN junction can be widened, and increases the response speed of the PIN, the low frequency signal may not be applied to the bias voltage, but the high frequency signal can be applied to the bias voltage [10]. The specific voltage determined by the size of the PIN datasheet. The second stage is a in-phase proportion operational amplifier, the magnification is $1 + R_3 / R_1 = 1.8$ fold.

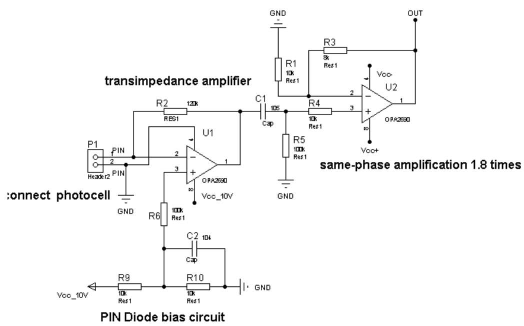

Figure 9: Circuit of receiver signal conditioning

4.2 AGC circuit

Figure9 shows AGC circuit, this part mainly consists of AD603, which includes the gain controlled amplifier circuit and the voltage-control forming circuit. The amplification of the gain controlled amplifier is changed by the control voltage Uc. The voltage-control forming circuit mainly has the rectification and the filter circuit, producing the control voltage Uc. Input signals are changed into output signals by amplified, and then after rectification devices signals become a single direction, then they will be filtered to a relatively smooth DC.

Controlling gain by controlling the amplification device operating point or the attenuation network attenuation coefficients.

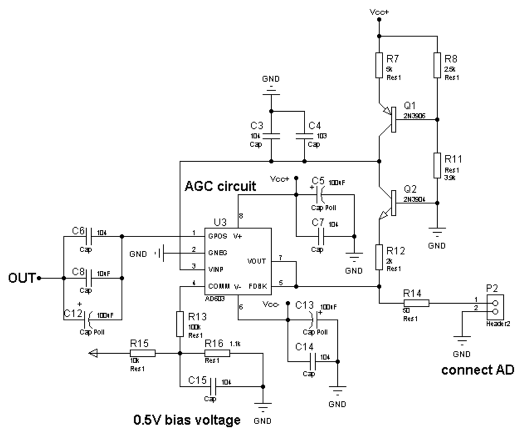

Figure 10: AGC circuit

4.3 decoding and demodulation

The same with the coding and modulation, this part is mainly completed on FPGA. Decoding module uses (41,4) RS code, in order to verify the validity of the output of the decoder module, we modify the second information code word "02H" to "04H" and send it to the decoder module to simulate the output of the decoder. The results show that the output of the RS decoding module is the correct result. Coherent demodulation method is usually used in demodulation of PSK signal. In coherent demodulation, synchronization information is important to decision symbols and codes, so a series of 1us all "0" is used as the frame synchronization at the transmitter of the start, while the transmitter symbol rate is fixed at 300 KHz.

5. Analysis of the test results

In order to verify the effect of visible light communication system to voice transmission, FPGA internal generate data in a form of fixed bit stream, and through the receiver circuit processing, the message will be restored with a serials of port to display, so the experiment could be repeated several times. Figure11 shows the maximum transmission distance and frequency curve at maximum error-free case. Figure12 shows the curve of experimental error rate comparison. It can be seen from the figure that the maximum transmission distance is 0.7 m when the frequency reaches 1000 KHZ. The combination of PSK modulation with RS code used in the experimental system has the advantage than the OOK modulation and PSK modulation in bit error rate performance. With the increase of transmission power of LED, the bit error rate decreases gradually. When the transmit power is greater than 18 mW, the BER performance is improved obviously, which is consistent with the theoretical analysis.

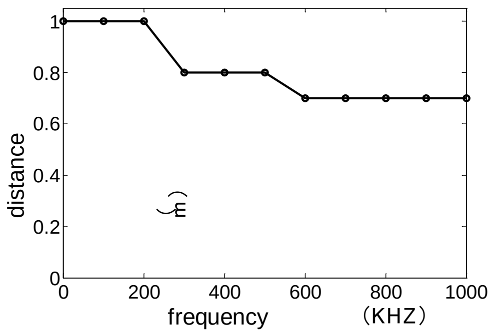

Figure 11: Maximum transmission distance and frequency

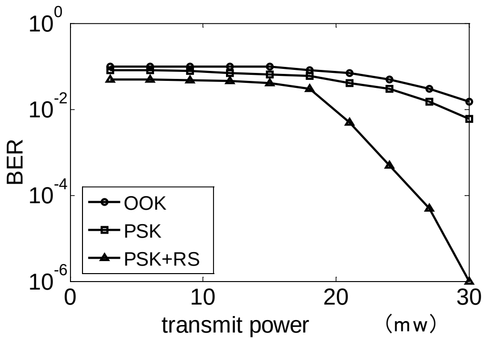

Figure 12: Comparison of experimental error rate curves

6. Conclusion

In this paper, a voice communication system based on visible light is designed by using the combination of RS coding and PSK modulation. When communication distance of the system is 1 m, the maximum transmission rate is 300 kbit/s. RS coding can correct the errors in the channel in real time, which can improve the reliability of the system. PSK modulation enhances the anti-interference ability of the system. The system has strong real-time performance, high reliability and low energy consumption. But there still are some limitations, the communication distance is much more shorter and the transmission rate is much slower comparing with wireless radio systems; and also The information cannot be transmitted across the barrier in this system.

7. Recommendations

To improving the transmission rate, we can use the blue light filtering, pre equalization technology, post equalization technology, wavelength division multiplexing, optical MIMO technology, which has a certain reference value for real-time video transmission.

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Author Biographies

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Rinmin Guo, born in Henan Chine, in 1992. And graduated from Tianjin polytechnic University in 2016,earning his Bachelor Degree of Engineering, and going on his study training in the same school.