밴드패스 광 필터를 이용한 VLC 채널의 고휘도 RGB LED 잡음 제거 모델에 관한 연구

A Study on Noise Cancellation Model in VLC Channel caused by High Luminance of RGB LED, Using Band-Pass Optical Filters

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요 약

LED조명의 강점을 토대로 LED조명이 보급되고 있으며, 다양한 정부정책이 시행되고 있다. 조명을 활용한 무선통신 기술인 VLC 연구가 활발히 이루어지고 있으며, 많은 연구를 통해서 고속 데이터 전송기와 같은 일반적인 LED 광원을 사용할 수 있다는 것이 증명되었다. 그러나 여전히 주요 문제 중 하나로 라디오 방송의 잡음과 유사한 빛의 간섭문제가 있다. 이에 본 논문에서는 스펙트럼 분리형 VLC 채널을 위한 광 필터를 사용하여 주변 조명의 간섭을 제거하기 위한 모델을 제안하였다. 제안한 모델의 검증을 위하여 다양한 고휘도 RGB LED 모듈을 활용하여 비교분석을 진행하였으며, 추가로 실생활에 적용되어 활용 중인 고휘도 LED 조명을 활용한 실험을 통한 적용성을 검증하였다.

핵심어 : 간섭 제거, 광 스펙트럼, 광 필터, VLC 채널, 고휘도 LED

ABSTRACT

LED lighting is spreading on the strength of LED lighting, and various government policies are being implemented. VLC research which is a wireless communication technology using lighting has been actively conducted, and it has been proven through many studies that a general LED light source such as a high-speed data transmitter can be used. But from now on, one of the main problems is the noise from side lights, which can be compared to the noise of radio broadcasts. So in this paper, we proposed a noise canceling model to remove the interference of ambient light by using an optical filter for a detachable VLC channel. In order to verify the proposed model, various high brightness RGB LED modules were used for comparative analysis. In addition, the applicability was verified through experiments using High Luminance LED lighting which is applied in real life.

Key words : Noise Cancellation, Optical Spectrum, Optical Filter, VLC Channel, High Luminance LED

Ⅰ. Introduction

Demands of time and life rhythms making people to aspire higher speed of connect. But the limitation of radio spectrum puts constraints on the increasing demand for finding alternate broadcasting range. Not so long time ago humanity re-opened possibility of using visible light spectrum in data communication systems. Different applications and systems were invented since Harald Haas showed his first high speed emitting lamp. LiFi technologies is inaccessible to use in cases when transmitting light radiation is much lower by illumination level than other light sources. Also there is still no exact technics to separate different types of VLC sources in one local area.

The problem of obtaining of VLC signal under a condition of high luminescence intensity of other artificial light sources, especially in the case if different types of LEDs are used in the lighting infrastructure, nowadays is still not solved. This paper is devoted to separation of low intensity light VLC channel in case of high influence of "noise" from other illumination sources.

Ⅱ. Related Work

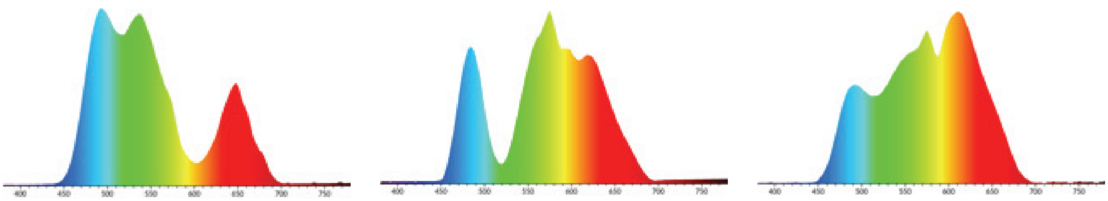
Some authors are investigating the relationships between the colors comprising the lighting source for a range of lighting states, the spectral separation of communication channels and describes the design of an optical filtering approach to maximize signal to noise ratio while minimizing crosstalk at the receiver. But most of the simulation results based on a three colored VLC system are discussed using orthogonal frequency division multiplexing for each color, without separating mixed light of different types of LED case(Butala et al., 2014). Others are experimenting with RGB LED based systems which can potentially to perform multi-wavelength on transmission side, with equalized receiver based on broadband optical filters. To show an effective approach for RGB based LEDs VLC system to receive multiple wavelengths transmitted from RGB-based LEDs simultaneously since the entire system transmission rate will be enhanced compared with the use of a single wavelength transmission. But also this researches are based only one type of LED – RGB one(Chou et al., 2015). However, many researchers are trying to cover different types of light sources used in everyday life, and analyze the possibility of using.

In case of modern city life RGB LEDs are commonly used as advertisement lighting, however common illumination street lights are using Blue-Yellow phosphor LED. Li-Fi technology is planned to be used in modern cities in simple street light systems, as well interference problems are still not solved for real world applications yet. Some authors are propose how to detect RGB LED light, excluding Blue-Yellow phosphor LED(Song et al., 2017). But in real world RGB LED is recently just a side "noise" light. This paper proposed the noise canceling model to remove the interference of ambient light by using an optical filter for a detachable VLC channel. The goal of proposed system is for multichannel VLC forming based on using optical wavelength filtration, even in condition of high level of light noise from different types of LED. The proposed model adopts a simple optical filter module of 600nm band for noise removal in the 600nm wavelength band.

Ⅲ. Analysis and Theoretical Purpose

With development of technologies requirement of society to energy efficient, environmentally friendly and cheap lighting devices increased. And solid state lighting sources become dominant on the world market. However there are two mostly accepted LED types. The one is Blue-Yellow phosphor LED, and the other is RGB LED. Both of this LEDs are giving “white light” through mixing main radiating colors. Comparing of technical characteristics of both of this LED shows that spectrum of radiated wavelength are different, even if both LED has same illumination level of white light. However a mix of just 3 basic colors of RGB LED allows human eye to sense the rainbow specter even without radiating of full visible specter (Lin, 2016). For example, in case of RGB LED it is possible to radiate yellow color by using combinations of green and red, but in fact it will be just a “surrogate” of yellow color, with no radiation of wavelength in range of “pure” yellow. But at the same time “pure” yellow wavelength is possible to get from the Blue-yellow phosphor LED. We proposing that different color wavelength could be used at the same time, without making a noise to each other in case of possibility to extract needed wavelength. And this factor allows organizing VLC data channel receiving, in case of high level of illumination of third-party light sources.

The supposition and realize if it is possible to determine the differences in specter radiation were checked on a spectrometer. Spectrogram results of 3 light sources were compared as shown in <Fig. 1>.



(a) RGB WS2812 (b) Epistar 1W high power LED (c) SW COB LED LC1216

<Fig. 1> RGB LED spectrogram

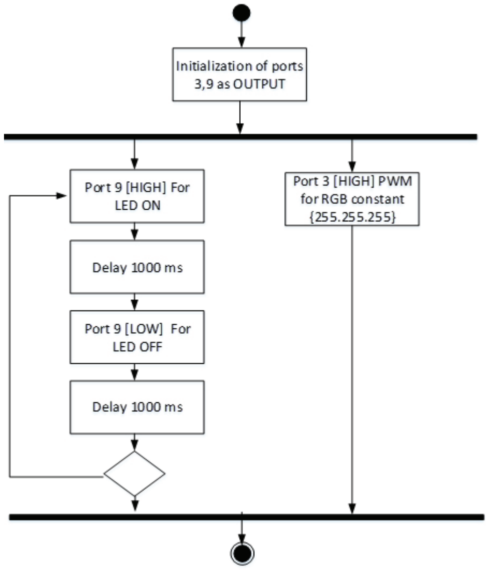
The visual comparison of these 3 spectrograms clearly shows the differences in wavelengths radiating between LED light source types. Spectrogram of RGB LED source has a big gap around 600nm wavelength. This wavelength gap is the target of filtering in current hypothesis. So In this paper, By Using 600nm wavelength channel modeling, we proposed noise cancellation.

Ⅳ. High Luminance RGB LED Noise Cancellation Model in VLC Channel Using 600nm Band-Pass Optical Filters

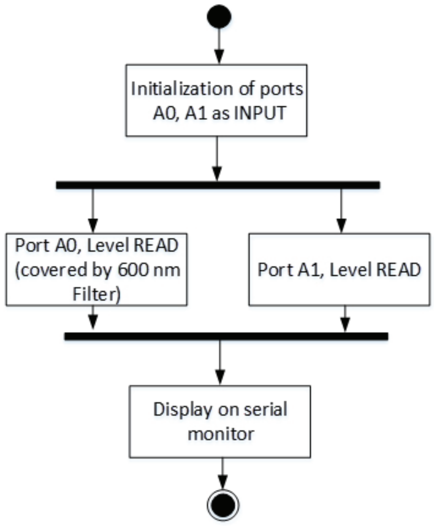
In this section, the operation structure and implementation of the proposed system for eliminating the high-intensity RGB LED interference is proceeded.

1. The Proposed Model Activity Diagram

The transmitter and receiver activity diagram is shown in Figure 2. Receiver code was simplified by as much as it was possible.



(a) Transmitter activity diagram



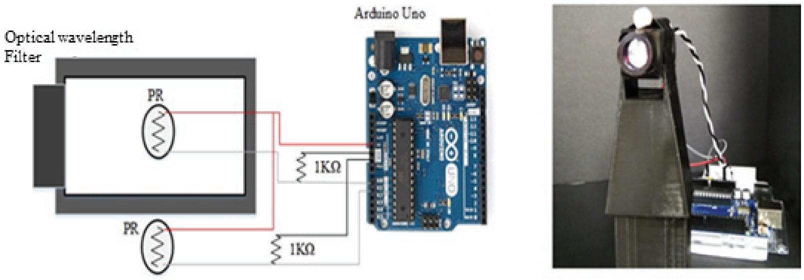
(b) Receiver activity diagram

<Fig. 2> Activity diagrams

The transmitter is designed to check the ON/OFF state of the lighting according to the surrounding lighting conditions by controlling the ON/OFF of the LED every one second. The receiver uses the photo resistors equipped with the 600nm band-pass optical filter, It is designed to recognize the brightness and to check the ON/OFF state of the lighting based on the brightness and output it through the serial monitor.

2. The Proposed Model Implementation

For the experiment of the proposed model, “Edmund optics” brand 400-700nm band-pass filters, with optical density 4 and Full Width-Half Max 10nm was used. To measure level of passing of the wavelength through filter was created a photo resistor based, device, controlled by Arduino Uno. This device playing a role of a receiver. On <Fig. 3>, connection scheme and common view of installed receiver are displayed. The results of metering were gain using simple Arduino code in the measuring range from 0 to 1023. All measures were made for all three pre-analyzed light sources with same conditions as spectrogram capturing. High level of illumination dropping was noted after filter passing. Main reason of illumination dropping is in all other spectral components cutting. However up to 25% of light is dispersing on the surface of the filter leans, and also here the influence of the constructive features of the lens, minimum transmission $\geq$85% by datasheets. The metering results were collected to the Table 1 and they partially prove our spectrogram pre-results.



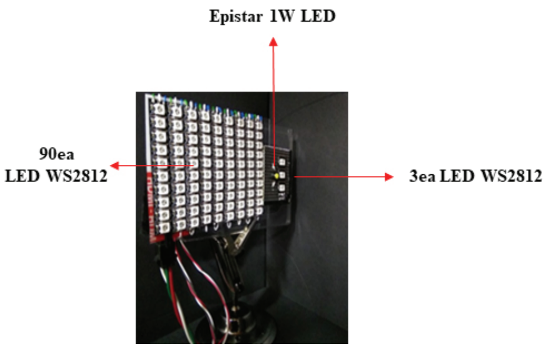
<Fig. 3> Optical wavelength filter

Main reason of illumination dropping is in all other spectral components cutting. However up to 25% of light is dispersing on the surface of the filter leans, and also here the influence of the constructive features of the lens, minimum transmission ≥85% by datasheets. The metering results were collected to the <Table 1> and they partially prove our spectrogram pre-results.

<Table 1> Optical filters using metering results

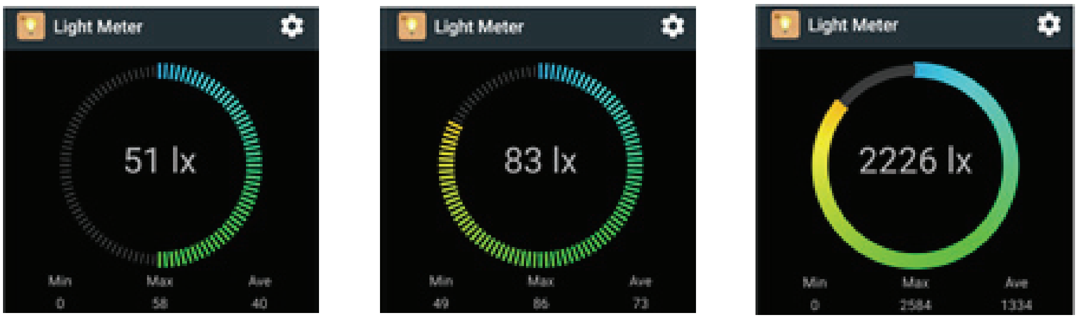
Model	Filter wavelength						
	700	650	600	550	500	450	400
Epistar 1W High Power LED	60	180	250	340	60	160	0
RGB WS2812	0	120	16	95	20	98	0
12V	320	600	550	400	320	450	0

To improve results of experiment, 12V LED should be excluded, as the illumination level of this light source much more higher comparing others. Thus the required light source for further experiment is “Epistar” 1W High Power LED. And it will be used as the main VLC transmitter. Considering direct relationship of illumination level and its influence on the VLC receiver photo resistors, the maquette with mix of light sources was made as shown in <Fig. 4>. This maquette consist 2 types of LED, i.e. RGB WS2812 LED and 1W High Power LED (Epistar). One part of the maquette consist full-color RGB patch of 90 LED chips WS2812 which is imitating a typical street advertisement signage.



<Fig. 4> Transmitter maquette

By using free android based application called “Light Meter” the level of illumination was measured. Measures are made with no attenuation or filtering from the distance of receiver. The results of measures are showed on Figure 5 Difference between the illumination level of one Epistar 1W LED, 3ea RGB WS2812 and 10x9 RGB WS2812 Patch is clear.



(a) Epistar 1W LED (b) 3ea RGB WS2812 (c) 90ea RGB WS2812 patch

<Fig. 5> Transmitter illumination level

Illumination of all LED sources turned on at once is equal 2393. In view of the apparent difference in illumination, measurement errors can be neglected. Experimental activities include same measures conducted with photo resistors, one of which was uncovered and second was covered by 600nm filter. Thus the difference of illumination between LED on the maquette are 51 lx for “1w Epistar” LED comparing to about 2300 lx of all 90 One a WS2812 LED. This means almost 45 times more for WS2812. Results of experiment showed that it is possible to receive light signal of blue-yellow phosphor LED through filter even if the illumination of other (RGB) source light is much higher.

3. The Experiment

In this paper, experiments were conducted in indoor and outdoor to verify the proposed model. First, the experiment was carried out indoors, During experiment for transmitting side simple code which turn on and turn of the 3V Epistar LED light with frequency 1000ms was used and other LEDs were constantly turned on “White” light with the highest illumination level. With using no wavelength filter receiver device could not detect simple data transmitting from 1W Epistar High Power LED, in time when even just 3 RGB WS2812 are constantly turned on.

<Table 2> Indoor test environment

Type	Name	Model
Transmitter	LEDs	Epistar 1W LED
	Noise	90ea LED WS2812
	Microcontroller	Arduino Uno
Light intensity meter	Lux Calculator	Xiaomi redmi note 4x and “Light Meter” app.
Receiver	Microcontroller	Arduino Uno
	Sensor	LDR
	600nm Band-Pass Optical Filter	Edmund optics

The results of indoor experiments prove that even in case of influence of “noise” from high level illumination from RGB LED sources, getting stable data from Blue-Yellow LED is possible, in case of adding optical filter.

In addition, We proceeded to experiment outdoors. The illumination level of typical street light is demonstrated on a <Fig. 6>. A height of the street light is 4 meters.

<Fig. 6> The result of outdoor experiment

The illumination of street light was detected by created measuring device, Receiver was able to detect all incoming light. Device was held on a normal height – on the level of chest of 178 cm height person. As it was expected the results was fully positive.

3. The Experimental Result Analysis

It is expected that the VLC channel environment can be constructed based on the wavelength depending on the characteristics of the LED. The result of the experiment, confirmed that the data transmitted from the yellow-phosphor LED, which is common used in street lights, can be acquired normally even in the case of an “noise side light” based on RGB LED has much more high illumination level.

Ⅴ. Conclusion

In this paper, we proposed a model that can eliminate the interference of ambient light by applying band-pass optical filter to the problem that noise is generated due to the influence of ambient light in VLC environment using LED lighting. In order to verify the proposed model, we analyze the characteristics of the LED and implement the theoretical verification and actual transmitter and receiver that it is possible to effectively remove the noise in the 600nm band using the characteristics of the LED. Operating with the possibility of filtering wavelength create an opportunities of channel separation on a same light source with different form factor and construction of LED chip. It is expected that this paper will be used as a good research feed for VLC channel allocation in the future as various studies on VLC communication are under way.

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