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Performance of color-independent OFDM visible light communication based on color space

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ABSTRACT

In this paper, we propose an orthogonal frequency division multiplexing (OFDM)-based visible light communication (VLC) system that can be color independent by using a color-space-based modulation. Along with all of the promising advantages of OFDM, the proposed system will be applicable for all colors in the visible range. Through the simulation results, we show that the proposed OFDM-VLC system is robust to intersymbol interference (ISI) and a large peak-to-average power ratio (PAPR), and is also color independent.

1. Introduction

Presently, the optical wireless communication (OWC) technology is being considered as a strong candidate for ubiquitous, high-speed wireless communication applications [1,2]. Through the extensive use of light-emitting diodes (LEDs) over the course of the last few years and the anticipated development of a widespread LED lighting and signaling infrastructure, visible light communication (VLC) has become the mainstream in the current OWC fields [1,2]. VLC can be applied to a short-range communication system using visible light and a solid-state light (SSL) source, such that the system can serve the dual purposes of communication together with illumination. A VLC system utilizes all of the notable advantages of visible light since it has aesthetically pleasing, an unregulated huge bandwidth with no electromagnetic interference, no known health risks, security, and ubiquitous nature (can be used in RF-prohibited areas such as aircraft, space shuttles, and hospitals). Hence, by using visible light for data transmission, many problems related to radio and infrared communications are avoided. In addition to the advantages over RF- and IR-based communications, LEDs are more advantageous than other light sources because of their faster switching time, higher efficiency, smaller size, higher directivity, longer lifetime, and cheaper transmitter components as compared to expensive RF units. Therefore, with all the advantages of visible light and LEDs, VLC systems are an attractive, alternative technology for indoor wireless communications [3,4].

A number of modulation schemes have been considered for VLC systems, which include variable on-off keying (VOOK), variable pulse position modulation (VPPM), multiple PPM (MPPM), pulse dual slope modulation (PDSM), orthogonal frequency division multiplexing (OFDM), and subcarrier modulation [5–10]. Among them, thus far, OFDM is found to be the most advantageous for VLC systems and OFDM for VLC was first introduced in [11]. Parallel data transmission by orthogonal subcarriers offers overall high data rates (i.e., rates similar to conventional single carrier modulation schemes), high bandwidth efficiency, and reduced complexity in equalizers. Owing to its long symbol duration, OFDM is inherently very robust against multipath induced intersymbol interference (ISI), which is a major concern in indoor OWC. OFDM has a relatively large peak-to-average power ratio (PAPR), which brings a reduced power efficiency of RF power amplifier.

As a means of color-space-based modulation, color-shift keying (CSK) and generalized color modulation (GCM) have been proposed thus far [12,13]. While CSK is currently applicable for only white visible light, GCM is a color-independent modulation scheme that can be used for communication under varying target color conditions. Furthermore, GCM can provide flicker-free operation, dimming control, and the ability to function irrespective of the number of LEDs at the transmitter or photo detectors (PDs) at the receiver [13–15].

Most of the previous research on OFDM-based VLC has utilized only white light (LEDs) and did not consider the color issue of

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visible light [9,10]. Therefore, no systematic way of coping with the color changing conditions of visible light has been suggested thus far. However, the color of visible light is a vital issue for a VLC system, and VLC should be compatible with all colors in the visible range. Although the possibility of color-independent OFDM-based VLC was introduced in [16], the simulation was not concrete and main results were not included there. In this paper, we propose a color-independent OFDM-VLC system in a complete form. Therefore, our proposed OFDM-VLC system will be applicable for all visible colors.

The remainder of this paper is organized as follows. In Section 2, our proposed system model for the OFDM-VLC is introduced and explained in detail. The simulation results are presented and discussed in Section 3. Finally, Section 4 presents the conclusions of the paper.

2. OFDM-VLC system model

The proposed OFDM-VLC system model is shown in Fig. 1; this system contains two main blocks: (a) the transmitter and (b) the receiver. We combined the OFDM and GCM schemes together in the implementation of a color-independent VLC system using OFDM. The operation of the entire OFDM-VLC block system is described as below:

2.1. Transmitter blocks

The transmitter mainly consists of a channel coder, a color-space-based modulator, and an OFDM modulator. Several of the

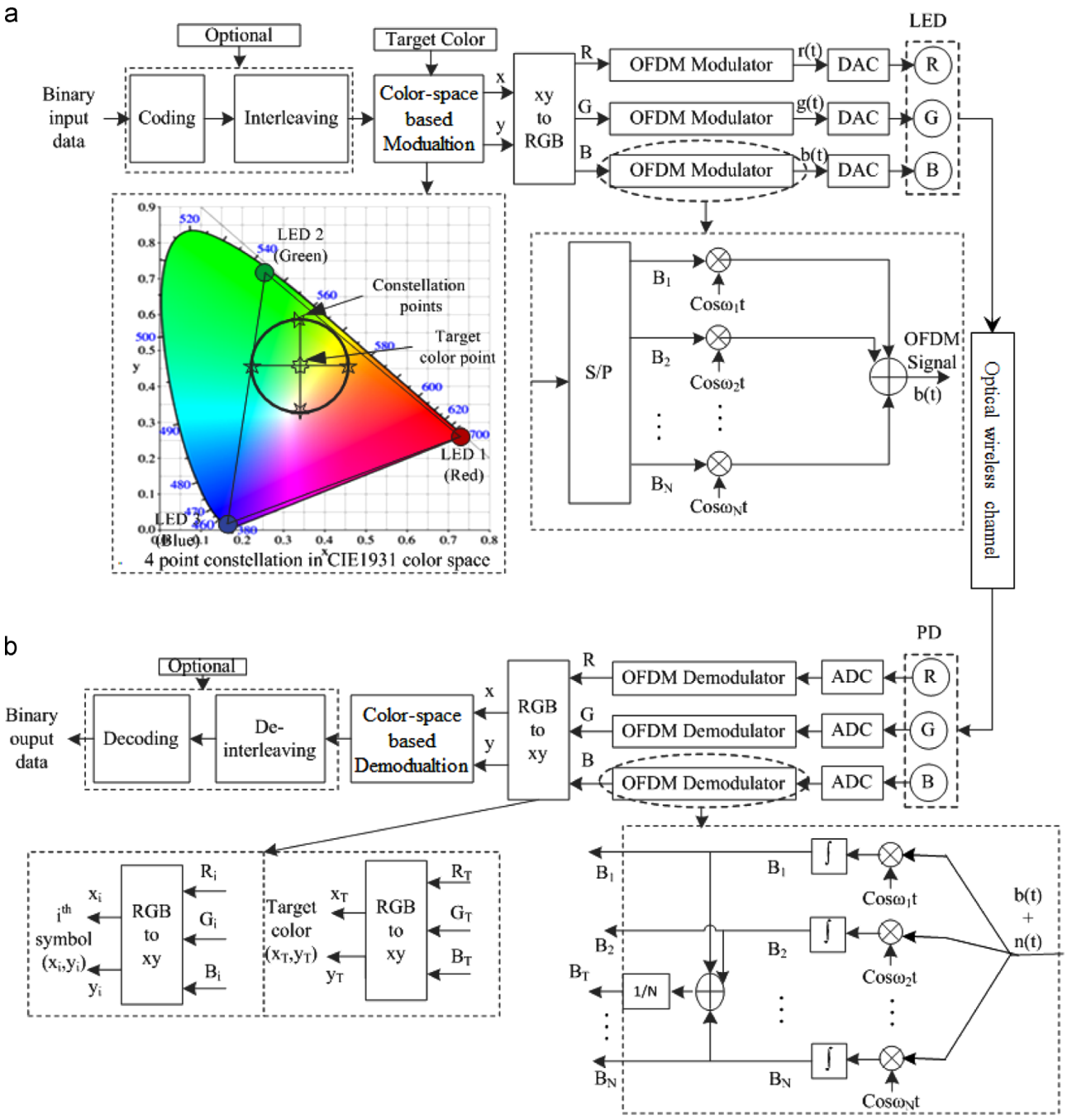

Fig. 1. Complete system model for the OFDM-VLC system. (a) Transmittar and (b) Receiver.