Visible Light Communication Using a Solar-Panel Receiver

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ABSTRACT

In this paper, a solar panel utilized as a photodetector with simultaneous energy harvesting is proposed in visible light communication (VLC). The solar cell is a self-styled passive device, which can convert optical signals into electrical signals. The generated energy can potentially be used to power user terminals or at least to prolong operation time. This work is an important step towards the future local area networks and vehicle to vehicle communication. In our proposed VLC system, a 3-W blue LED is as the light source and a low-cost solar panel is acted as the detector. A communication with a data rate of 15.03 Mbit/s and a bit error rate of 1.6883× 10^{-3} is successfully achieved using 16-quadrature amplitude modulation (16-QAM) orthogonal frequency division multiplexing (OFDM) technology over a 2-m air channel.

Keywords: *Solar panel, Energy harvesting, VLC, OFDM*

1. INTRODUCTION

In recent years, the commercial, industrial and scientific communities show an increasing interest towards wireless communication technologies. However, the present networks are not able to fully satisfy this traffic demands [1, 2]. Therefore, a novel wireless communication technology is strongly required to overcome the existing gap [3]. The visible light communication (VLC) technology is an alternative to the existing radio frequency (RF) based wireless communication [4, 5]. VLC is an optical wireless technology using visible bands (380-780nm), which employs the visible light source as a signal transmitter, the air as the transmission medium, and the appropriate photodiode as a signal receiving component [5-7]. VLC is an innovative and proficient optical wireless technology for short-range transmissions [2, 4, 6]. VLC is advantageous from various prosperous factors and is progressively getting more attractive for local area networks (LAN) and vehicle to vehicle communication (V2V) [4, 7], as shown in Fig. 1.

Light-emitting diodes (LEDs) are the most inspiring choice for the future illumination and data transmission because of high power efficiency and harmless to human eyes [1, 6]. Moreover, radio frequency (RF) holds several drawbacks of a limited spectrum bandwidth and poor security [2, 5]. In this paper, we propose a novel visible light communication system with a passive photodetector, which is implemented by using off-the-shelf and common commercial 25 mm x 30 mm silicon solar panel. The solar panel is used for energy harvesting and optical signal detection [4, 5]. Avalanche photodiodes (APDs) and positive-intrinsic-negative (PIN) detectors are commonly used in VLC system for high speed and linear photodetection [2]. The above mentioned photodetectors require an external power supply to operate [6, 7]. To overcome the disadvantage of external power supply the proposed application based on the idea that information and energy can be transmitted simultaneously over the communication channel if a solar panel is used as the optical receiver. [3, 5, 7].

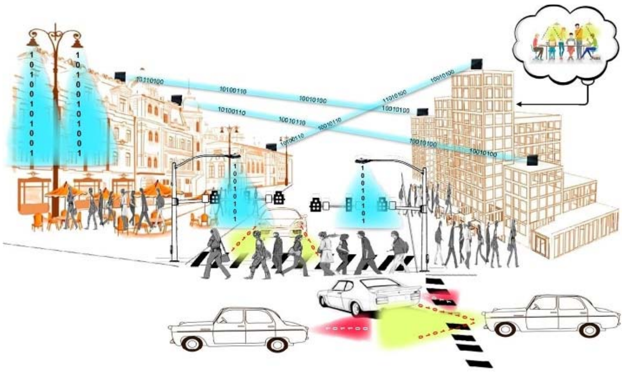

Fig. 1. The possible future application scenario.

Moreover, we propose and experimentally demonstrate a VLC system by using an off-the-shelf and common commercial 25mm x 30mm silicon solar panel as the receiver and 3-W blue LED as the transmitter [1, 4]. Orthogonal frequency division multiplexing (OFDM) together with 16-quadrature amplitude modulation (16-QAM) is implemented, and we successfully achieve a data rate of 15.03 Mbit/s with a bit error rate of 1.6883×10^{-3} via a 2-m air channel.

2. EXPERIMENTAL SETUP

Figure 2 shows the experimental setup of the proposed VLC system using a 3-W blue LED at the transmitter side and a solar panel at the receiver side. Note that the solar panel can directly convert the optical signal to an electrical signal, without the need of an external power supply 16-QAM OFDM signals generated by Matlab were loaded into an arbitrary waveform generator (Tektronix AWG

70002A) via a LAN. The output signals from the AWG were amplified by an amplifier (AMP, Mini-Circuits ZHL-6A+) with a maximum gain of 25 dB and bandwidth

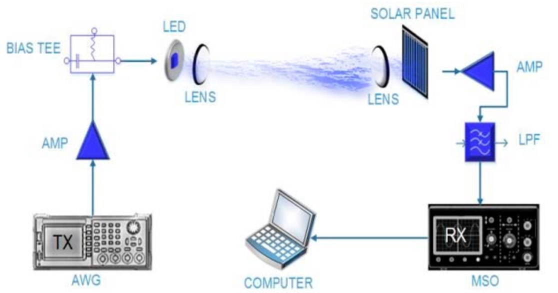

Fig. 2. Experimental setup of the proposed VLC system using a 3-W blue LED at the transmitter side and a solar panel at the receiver side.

from 0.0025 to 500 MHz. The amplified baseband OFDM signals were used to drive a blue LED via a bias-tee (ZFBT-4R2GW+). A pair of focusing lens were deployed after the LED and before the solar panel. The generated optical signals transmitted through a 2-m air channel. At the receiver side, the optical OFDM signals were received by an off-the-shelf and common commercial silicon solar panel as shown in Fig. 3. The detected baseband OFDM signal was amplified by another AMP (Mini-Circuits ZHL-6A+) with a maximum gain of 25 dB and bandwidth from 0.0025 to 500 MHz. The amplified OFDM signals passed through a 98-MHz low-pass filter (LPF) (SLP-100+) to block the high-frequency signals. Mixed signal oscilloscope (MSO, Tektronix MSO 71254C) with a sampling rate of 1.25 GSamples/s was used to capture the received signal waveforms. At last, captured signals were transmitted to the computer via a LAN for further signal demodulation and evaluation offline.

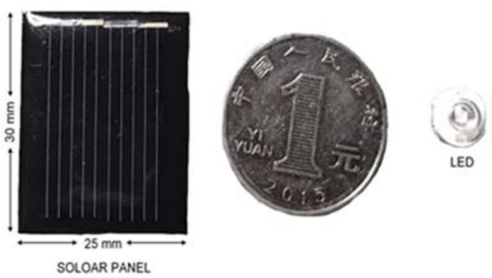

Fig. 3. A solar panel and a blue LED with a 1-yuan RMB coin as a reference.

3. RESULTS AND DISCUSSION

We have achieved a bit rate of 15.03 Mbit/s, a BER of 1.6883×10^{-3} and a peak-to-peak voltage (Vpp) of 126.9 mV, respectively. The measured BERs and error vector magnitudes (EVMs) of the 16-QAM OFDM signal at different subcarriers over a 2-m air channel are shown in Fig. 4 and Fig. 5, respectively. Higher BERs in the high-frequency region were mainly caused by the bandwidth limitation of the system.

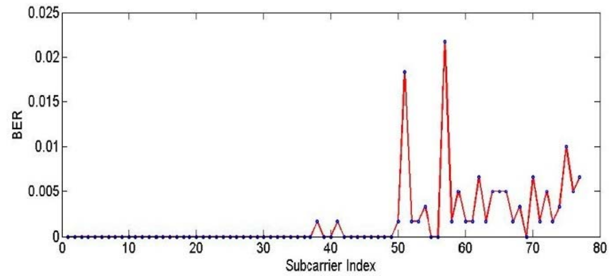

Fig. 4. Measured BERs of the 16-QAM OFDM signal at different subcarriers over a 2-m air channel.

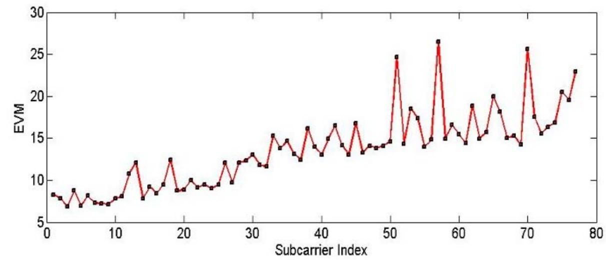

Fig. 5. Measured EVMs of the 16-QAM OFDM signal at different subcarriers over a 2-m air channel.

The captured spectrum of the received 16-QAM OFDM signal after transmitting through a 2-m air channel is presented in Fig. 6. The corresponding constellation map is shown in Fig. 7, which is well converged.

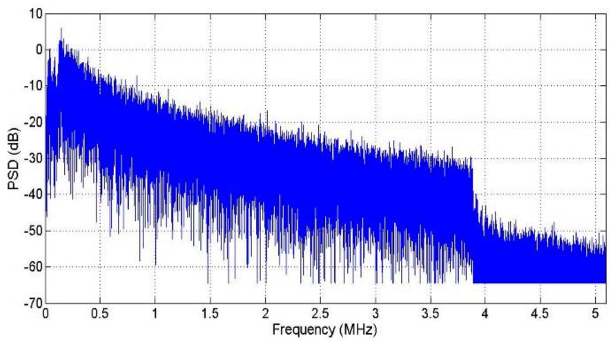

Fig. 6. Captured spectrum of the received 16-QAM OFDM signal over the 2-m air channel.

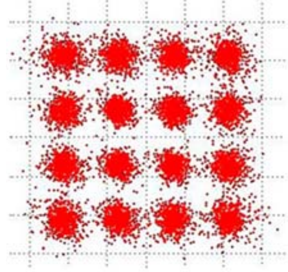

Fig. 7. Constellation map of the 16-QAM OFDM signal over the 2-m air channel.

4. CONCLUSION

In this paper, we prove the feasibility of optical wireless communication using a low-cost and off-the-shelf solar

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panel as a passive receiver. Adopting the proposed system can be advantageous for certain applications. It is an economical and eco-friendly scheme to solve the RF spectrum crisis and power supply issues for future communication systems. The use of a solar panel with high photoelectric conversion efficiency as the detector instead of a conventional photo detector can further simplify the receiver circuitry by removing the need for a transimpedance amplifier.

5. ACKNOWLEDGMENTS

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