Performance of SMD-LED Array for Visible Light Communications

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***Abstract*— In this work it is described a communication link with white light generated by an array of SMD-LEDs as the transmitter. A single phototransistor is used in the receiver. Effects of diffused light, color-temperature of lighting LEDs and field-of-view are investigated. Optical link tests were performed up to 2m distance in the OOK-NRZ pseudo-random digital modulation format.**

***Keywords*— IoT, Phototransistor, VLC, White LED.**

I. Introduction

From the turn to the 21st century, the evolution of telecommunications triggered the growth of equipment belonging to the Internet of Things (IoT) in favor of greater ease, productivity, and practicality in everyday life. Thus, the massification of devices and sensors that are connected to a network has begun. As a result, there was an increase in demand for bandwidth and, considering the variety and quantity of interconnected devices and equipment, there was also a need to ensure security in these communications. In this context, it is interesting to explore the Visible Light Communications (VLC) technology and its domestic applications in the IoT scenario [1].

In this paper, VLC experiments up to 2m range are described in order to verify the usefulness and sensitivity of SMD-LEDs-array as a white light transmitter. A single phototransistor was used as a receiver. Effects of light diffusion, color-temperature of the white LEDs and field-of-view are also addressed.

II. Experimental

The experimental setup is composed by one of the three white SMD-LED 5730 arrays with 6 LEDs each placed up to 2 meters from a single NTE 3032 silicon NPN phototransistor with 15μs@100Ω rise/fall time. The light color-temperature of the arrays here used were: cool (6000K), neutral (4000K) and warm (2700K). Each white LED present an optical analog band of ~2 MHz@-3dB. The SMD-arrays are driven by a simple circuit based on the 2N2222A transistor. The operating voltage is 3.0-3.6V for a current of 150mA. In order to evaluate the link in a realistic VLC situation, in front of the array was placed a bulb to diffuse the white light. Figure 1 shows the pictures of one of the LED-array without and with a light diffusing bulb.

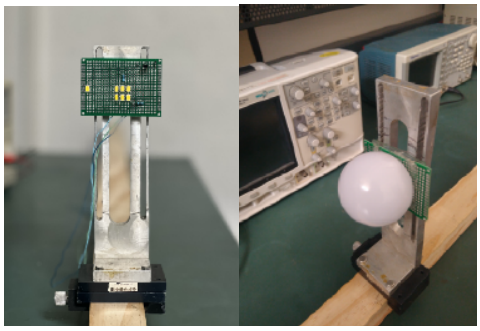

Fig. 1. One of the LEDs-array (left) without and (right) with a light diffusing bulb.

III. Results and discussions

To verify the effects of the color-temperature of the LED and simultaneously the light diffusing bulb on the link performance, the output voltage signal from the phototransistor was analyzed varying the distance between the array and the optical detector with 5 cm step. Figure 2 shows the peak-to-peak amplitude A_{out}(V) versus the distance d(cm), parameterized by the color-temperature, without and with the use of the light diffusing bulb.

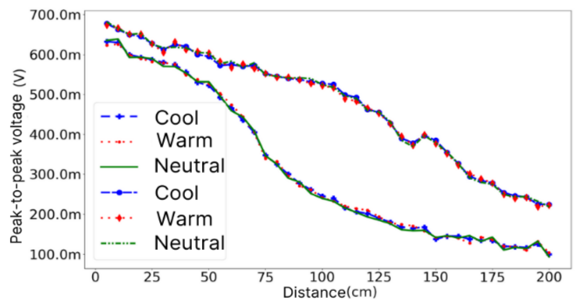

Fig. 2. Plots of A_{out}(V) x d(cm), parameterized with the color-temperature, without and with the diffusing bulb (m = millivolt).

Although each white LED has its own color-temperature and therefore electromagnetic spectrum, the output signal on the phototransistor remains the same demonstrating that the performance of the link does not depend on the color-temperature. However, as is expected the use of the diffusing bulb reduces the output voltage for all distances up to 2m thus shortening the link range.

The first experiments (see Fig.2) were made with direct line-of-sight. Nevertheless, in practice the optical beam may be not aligned with the receiver front-end. Figure 3 shows the peak-to-peak amplitude A_{out}(V) versus the LoS (Line-of-Sight)

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elevation angle in steps of 5º by placing the LEDs-array and the phototransistor distanced of ~ 1m each other.

From Figure 3, the optical FoV for -3dB can be achieved as to be 2x(~ 64º) ~ 128º, close to the 120º viewing angle of the LEDs-array without the diffusing bulb as disclosed by the manufacturer. The use of the bulb flattens the angular response of the transmitter thus increasing the FoV to be now 180º. At the angle around 60º the response of the diffused light becomes to be higher than with LoS thus resulting in a “gain”.

Finally, the link was tested by optically sending a 16 bits pseudo-random binary sequence. The signal is an OOK-NRZ in the clock frequency of 10kHz. Figure 4(a) shows the measured oscilloscope traces by placing the generator and oscilloscope in back-to-back (B2B) setup. Figures 4(b) and (c) show the measurements performed in 25cm steps in the range of 2m and without and with the diffusing bulb, respectively.

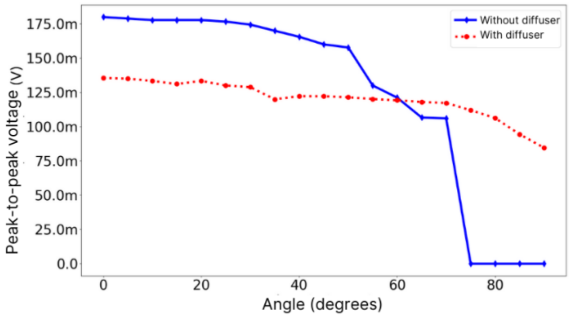
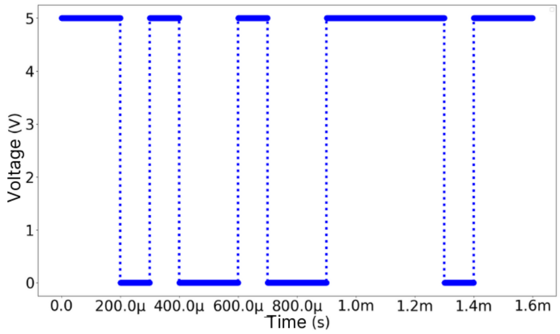
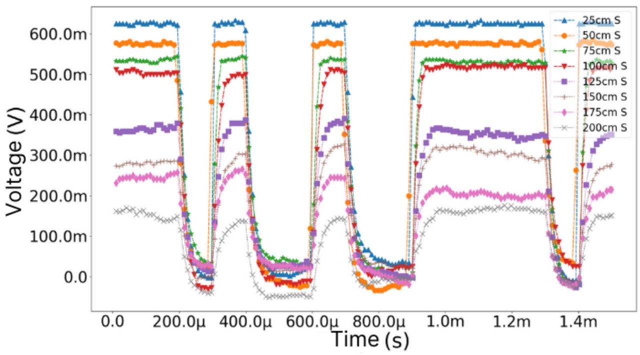


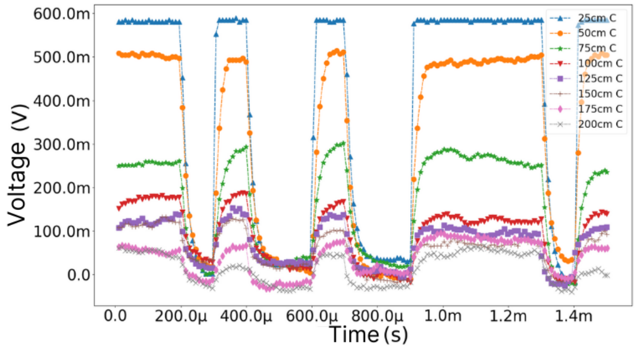
Fig. 3. Plots of A_{out}(V) x angle (degree) without and with the diffusing bulb (m = millivolt).



(a)



(b)



(c)

Fig. 4. Oscilloscope traces of the pseudo-random OOK-NRZ digital modulation (a) originally generated, (b) without and (c) with the diffusing bulb (m = millivolt).

As expected, it was observed an attenuation in the amplitude of the B2B compared with the link signal from 5 V_{pp} to ~ 0.6 V_{pp} whatever with or without diffusion. The measurements also showed that up to 50cm distance the amplitudes without and with diffusion does not differ significantly. For at least up to ~100cm distance with the link in LoS, the amplitude does not drop significantly when compared with 25cm. With the use of the diffusing bulb, the signal format was only maintained up to ~ 50cm. It can be observed that the rise-time of the waveforms is degraded as the power arriving at the phototransistor decreases.

A low-cost phototransistor in principle working without additional amplification may be used as a simple receiver for low-bandwidth IoT devices. To keep the high sensitivity (and low-bandwidth) of the link, none optical filtering is needed to perform to transmit the blue light which carrier faster modulation [2].

IV. Conclusions

It was demonstrated that the use of different color-temperature white LEDs does not affect the received signal. The use of a diffusing bulb in the transmitter reduces the power arriving at the receiver but it can flatten the angular response of the link thus increasing the FoV from 128º to 180º. Such characteristics are typical of domestic LED lamps. Under a qualitative point-of-view, even at 2m distance using light diffusion at 90º angle, the output OOK-NZR digital modulation in 10kHz clock seems to be recoverable. As a further research, measurement of Bit Error Rate (BER) and tests with others digital modulation formats is scheduled to be done.

References

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