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Experimental Demonstration of Vehicular Visible Light Communications

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Introduction

- Given LED-based exterior vehicle lighting, VLC has emerged as a natural candidate for V2V connectivity in 6G and subsequent networks.
- VLC offers high-speed communication with inherent security due to its line-of-sight nature.
- In this study, we detail a real-time FPGA-based VLC system for vehicular connectivity, utilizing the Zynq-7000 series SoC board and a 26 W LED headlight module.

System Design and Implementation

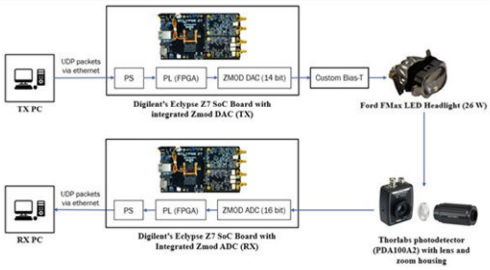

Fig. 1. System block diagram

- Data from TX PC is transmitted as UDP packets via ethernet to the Eclypse Z7 SoC development board, where it is modulated with on-off keying (OOK) modulation using VHDL programming.
- After modulation, the data is passed to the built-in 14-bit 100 Msps Zmod DAC module.
- The output of the DAC module is directed to the AC input port of a custom-design bias-T which is built in-house specifically for driving high-power vehicular LEDs and is capable to support DC currents of up to 12-A with a 3-dB bandwidth of approximately 11 MHz.
- The output of the Bias-T is connected to the 26-W Ford Fmax low-beam headlight LED module used as VLC transmitter.

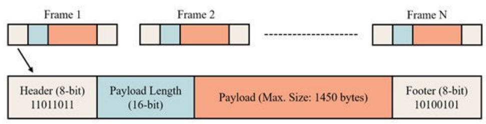

Fig. 2. Frame Structure

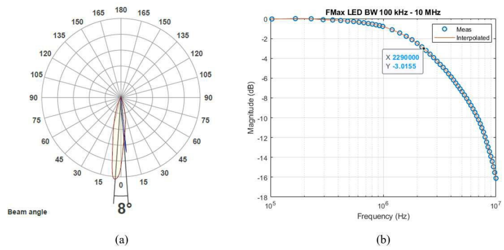

Fig. 3. (a) 26-W Ford Fmax LED radiation pattern (b) LED's inherent 3-dB bandwidth

- On the RX side, the optical intensity is captured by a Thorlabs' PDA100A2 PIN adjustable-gain photodetector module.
- A 25.4 mm diameter bi-convex lens is positioned in front of the photodetector using a zoom housing to enhance the received optical power and achieve a longer communication distance.
- The output of the photodetector is transferred to the 16-bit Zmod ADC module integrated with the Eclypse board. The received signal is then detected and demodulated by the receiver FPGA, converted back to the UDP format and dispatched to the receiver PC via Ethernet.

Experimental Setup

- The low-beam headlight LED module was mounted in front of the transmitter vehicle while the Thorlabs' PDA100A2 photodetector along with zoom housing and lens were mounted at the rear of the receiver vehicle.
- All experiments were performed in broad daylight during similar times of the day in the late afternoon, with similar ambient lighting and clear weather conditions.

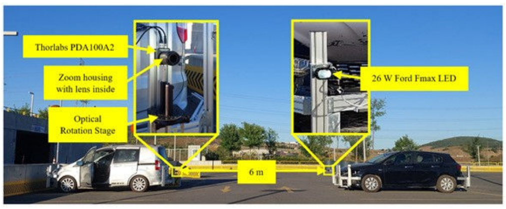

Fig. 4. Transmitter and receiver vehicles placed at a 6 m distance for measurements

Results

- For data-rate, BER, and packet loss ratio measurements, 10,000 packets were transmitted, each being 1450 bytes in size (116 million bits).

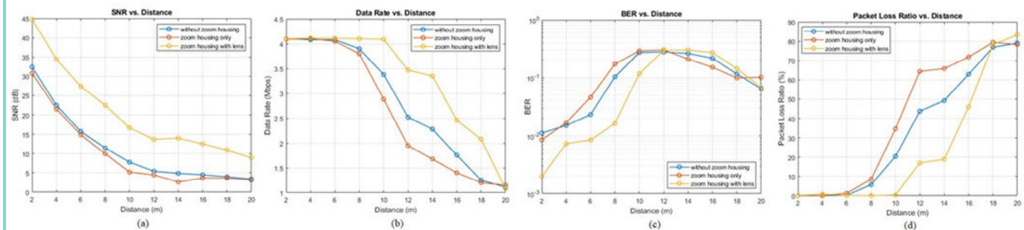

Fig. 5. (a) SNR vs. distance, (b) data-rate vs. distance, (c) BER vs. distance, (d) packet loss ratio vs. distance

- It is observed that the receiver's performance is negatively affected when only zoom housing is utilized, while it improves notably when combined with the lens.
- In this study, only line-of-sight (LOS) scenario was considered. NLOS scenario will also be considered in future studies.

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