Under-sampled Frequency Shift On-Off Keying for Low-SNR Optical Links

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1. Introduction

Recently, camera communication (CamCom) has emerged as a viable candidate for realizing complementary communication technology in driver assistance applications related to intelligent transportation systems (ITS). Under-sampling based CamCom links have been proposed before [1-2]. However, they impose restrictions on the minimum signal-to-noise ratio (SNR) requirement of the transmitter due to receiver sampling at fast shutter speeds. Moreover, they do not consider the variable frame rate phenomenon of the camera, which can drastically affect the bit error rate (BER) performance of the system.

In this work, we propose and implement a novel modulation scheme that not only supports low-SNR transmitters but also minimizes the effect of variable frame rate on the BER of the system.

2. System Architecture

We propose a 90^0 phase offset under-sampled frequency shift on-off keying (90^0-UFSOOK) modulation scheme. Data bit ‘1’ and data bit ‘0’ are represented by 20-ms 90^0 phase-shifted waveforms of 125-Hz and 1-KHz, respectively, as shown in Fig. 1. The receiver samples at 50 fps (PAL standard) with a shutter speed of 1/250. The selected shutter speed corresponds to the minimum possible value that can sample a flicker-free optical pulse with maximum intensity deviation. This allows more light to enter the image sensor, resultantly increasing the communication distance of low-SNR transmitters. The perceived intensity of data bit ‘0’, as represented by the 1-KHz waveform, at the receiver end will be 50%, regardless of the induced sampling time variation due to the variable frame rate. The intensity of data bit ‘1’ will fluctuate between the minimum and maximum brightness level as a function of the current position of the sampling window.

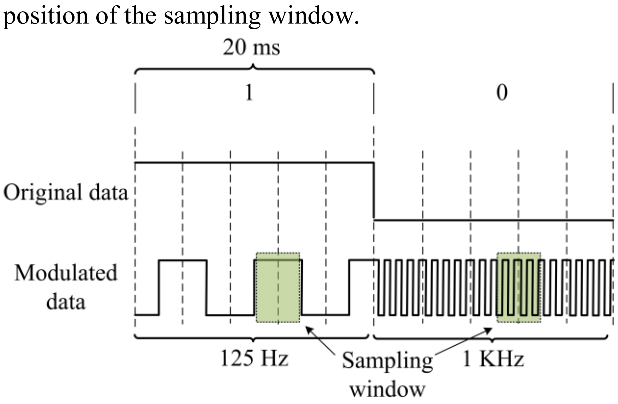

Figure 1: Proposed 90^0-UFSOOK modulation waveform

Decoding is performed by adaptively deciding a minimum and maximum threshold value which is a function of the transmitter intensity, receiver focal length, aperture configuration and communication distance.

3. Experimental Results

The transmitter is implemented using a 3x3 high brightness LED array modulated through a field programmable gate array (FPGA). A pseudo-noise (PN) data sequence is generated and sent over the free space optical link. The receiver end comprises a Nikon D3200 camera. The experimental setup and results are illustrated in Fig. 2.

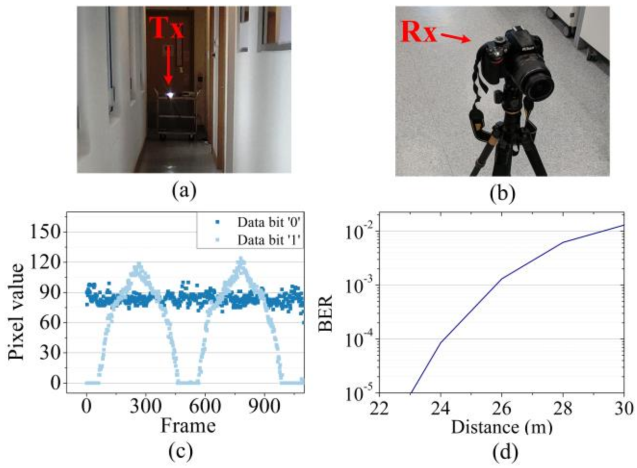

Figure 2: (a) Transmitter. (b) Receiver. (c) Experimental results. (d) BER vs Distance.

4. Conclusion

The proposed transceiver architecture has increased the communication distance of low-SNR transmitters three-folds when compared with previous works, while maintaining robustness against the variable frame rate.

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