Organic solar cells as high-speed data detectors for visible light communication: supplementary material

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Practical implementations of VLC are realised using intensity modulation and directed detection (IM/DD). Therefore, a modulation signal has to be both real and non-negative. Because conventional orthogonal frequency division multiplexing (OFDM) generates a bipolar complex signal, Hermitian symmetry has to be imposed in the inverse fast Fourier transform (IFFT) during the signal generation process [1, 2]. In OFDM, a total of N_{fft} subcarriers are equally distributed within the bandwidth of $[-T_s/2; T_s/2]$ where T_s is the time-domain sampling period of the communication system. Some subcarriers can be left unmodulated in order to avoid interference or because of insufficient signal-to-noise ratio (SNR) levels in the corresponding frequency band. The average spectral efficiency of the modulation scheme can be calculated as:

$$\eta = \sum_{k=1}^{N_{\text{fft}}-1} \frac{\log_2 M_k}{N_{\text{fft}} + N_{\text{cp}}} \left[\frac{\text{bit}}{\text{s} \cdot \text{Hz}} \right], \quad (\text{S1})$$

where N_{fft} corresponds to the fast Fourier transform (FFT) size, M_k is the size of the M -ary quadrature amplitude modulation (M-QAM) constellation on subcarrier k , N_{cp} is the OFDM cyclic prefix length. The single-sided bandwidth of the communication system is:

$$B = \frac{1}{T_s} [\text{Hz}]. \quad (\text{S2})$$

Using the bandwidth and the spectral efficiency, the data-rate of the system is:

$$D = 2B\eta. \quad (\text{S3})$$

In this work, the FFT size has been set to $N_{\text{fft}} = 1024$, and the cyclic prefix length has been set to $N_{\text{cp}} = 10$.

In order to accommodate the bipolar OFDM signal within the active region of the laser diode (LD), a suitable direct current bias is applied. It sets a positive operating point for the device around which the bipolar signal can be realised [1, 2]. This modulation technique is referred to as direct-current-biased optical OFDM (DCO-OFDM). A typical time-domain OFDM signal is characterised by a high PAPR, which increases with the number of utilised subcarriers. The linear dynamic range of the LD is limited from below and from above due to the opto-electrical properties of the devices. As a result, the OFDM signal is clipped on both sides of its time-domain distribution. Simulation work and exhaustive experiments have shown that clipping levels at -3.2σ and 3.2σ , where σ is the standard deviation of the time-domain signal, are approximately optimal in the digital signal conditioning step. The standard deviation of the OFDM signal is:

$$\sigma^2 = \sum_{k=1}^{N_{\text{fft}}-1} \frac{E_{\text{bk}} \log_2 M_k}{N_{\text{fft}}}, \quad (\text{S4})$$

where E_{bk} is the energy per bit on subcarrier k . The pulse shaping and matched filtering operations are performed with a root-raised-cosine (RRC) filter with a roll-off factor of 0.1 and an oversampling ratio of 4. The sampling frequency of the arbitrary waveform generator (AWG) is fixed at $F_s = 80$ Ms/s, which results in a maximum achievable single-sided bandwidth of $B = 10$ MHz.

Channel estimation is performed with a pilot sequence that consists of random 4-QAM symbols with a uniform energy profile.

References

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