200 Mb/s visible optical wireless transmission based on NRZ–OOK modulation of phosphorescent white LED and a pre-emphasis circuit

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We present a high-speed visible light communication (VLC) link that uses a commercially available phosphorescent white light-emitting diode (LED). Such devices have few megahertz bandwidth due to the slow response of phosphorescent component, which severely limit the transmission data rate of VLC system. We propose a simple pre-emphasis circuit. With blue-filtering and the pre-emphasis circuit, the bandwidth of VLC system can be enhanced from 3 to 77.6 MHz, which allows non-return-to-zero on-off-keying (NRZ–OOK) data transmission up to 200 Mb/s with the bit error ratio of 5.3 × 10⁻⁷ which is below 10⁻⁶. The VLC link operates at the room illumination level of ~1000 lx at 1.1 m range using a single 1 W white LED.

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White light-emitting diodes (LEDs) are considered to be a promising candidate for future indoor lighting. These lighting sources have the ability of simultaneous illumination and data transmission. The advantages of visible light communication (VLC) include low cost, high security, non-interference with radio frequency bands, and so on. VLC is becoming an emerging technology for high speed and short-range optical wireless communication that stimulates worldwide research and global standardization efforts.

One way to improve the VLC system transmission data rate is to enhance the bandwidth of VLC system. Commercially available phosphorescent LEDs are attractive for general illumination as well as communication because of its higher efficiency and lower complexity. The modulation bandwidths of such devices are in lower megahertz range (typically 3–5 MHz) due to the long response time of the yellow phosphor. There are a number of approaches to improve bandwidth of VLC link, including the use of a blue filter at the receiver to filter out the slow yellow component, multiple-resonant pre-equalization, and post-equalization of the receiver. With pre-equalization, the bandwidth of VLC system is 45 MHz and transmission data rate is up to 80 Mb/s. Fujimoto et al. showed a pre-emphasis circuit and a VLC link using a single RGB-type white LED in which its data rate could reach 477 Mb/s with only red LED modulated and green and blue LEDs OFF state at the distance of 40 cm. And as the distance was increased to 1.6 m, only 100 Mb/s could be achieved. The operating speed of RGB-type white LEDs is higher than that of the phosphorescent white LEDs, because the RGB-type LED has no low-speed phosphor layer. However, the phosphor-based white LEDs are more attractive for general illumination due to their lower complexity when compared with RGB-type LEDs. Another way to improve the transmission data rate of VLC system is using advanced modulation format. By using spectrally efficient modulation techniques such as orthogonal frequency-division multiplexing (OFDM), discrete multi-tone modulation, multiple input–multiple output-OFDM, and wavelength division multiplexing, 513 Mb/s, 1.1 Gb/s, 3.4 Gb/s, and 3.75 Gb/s VLC systems have been demonstrated.

We propose a simple pre-emphasis circuit and demonstrate a high-speed VLC link using a commercially available phosphorescent white LED. With blue-filtering and the pre-emphasis circuit, a bandwidth of 77.6 MHz has been achieved in our VLC system, which allows non-return-to-zero on-off-keying (NRZ–OOK) data transmission up to 200 Mb/s with the bit error ratio (BER) below 10⁻⁶. We confirm that 200 Mb/s is the highest data rate based on pre-emphasis technology and NRZ–OOK modulation of phosphorescent white LED. The VLC link operates at the room illumination level of ~1000 lx at 1.1 m range using a single 1 W white LED.

Figure 1 shows a simple VLC pre-emphasis circuit. We use a wideband and current feedback amplifier (OPA695). The amplifier is used to amplify the signal and enhance the modulation index of LED. The circuit contains a passive equalizer (PEQ) that comprises a capacitor $C_i$ in parallel with a resistor $R_i$ and a load resistor $R_C$.

The transfer function of pre-emphasis circuit is expressed by