Multivalued Multiplexing Method for LED-Based High-Speed Wireless Nets Using Visible Light

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ABSTRACT

A novel LED-based multiplexing transmission method with multivalued modulation can be used for high-speed optical wireless LANs (local area networks) via visible light medium.

Keywords*:* Optical multivalued multiplexing transmission, wireless visible-light nets, LED-based communications

1. INTRODUCTION

As a transmission medium for wireless data communications, visible light has been taking a great attention, and the LED is an advancing visible-light source because it not only can be employed as the illuminator, but also can be modulated to carry signal [1, 2]. In order to realize a high-speed and large-capacity network for optical wireless communications, multi-path dispersion of optical signals such as the WDM (wavelength division multiplexing), the SDM (space division multiplexing), or the TDM (time division multiplexing) should be considered [3-5].

In this paper, we propose a method of multiplexing transmission using visible-light LEDs to achieve a high-speed optical wireless network with 100Mbps. In addition, in order to ensure middle-range (less than 10m) transmission quality and the affinity with popular Ethernet networks, the multivalued method of MLT-3 (multi-level transmit) encoding is used to modulate the visible light wave to transmit data. These make an LED-based wireless LNA (local area network) is possible.

2. PRINCPLE OF METHOD

There are two important problems are considered when using the LED illuminator as a physical channel to data transmission in our method. One is how to achieve high speed of 100Mbps, and the other is to ensure middle-rang transmission quality and the affinity with the wire LAN.

First, to realize high-speed transmission, we have chosen a two-wavelength (blue and green) white LED (OPLL-50WH20) as the transmission source. Because no fluorescent material in this LED, so it has higher optical response speed and transmission frequency characteristic. Figure 1 shows a measurement result for the frequency response characteristic of the two-wavelength white LED. The abscissa is the transmission frequency and the ordinate is the averaged values of the frequency response. We can see that the –3dB frequency is about 30MHz, this value is about 1 order higher than in the others LEDs, which have the fluorescent material. In addition, in order to achieve the speed of 100Mbps, the optical filter is used to divide the two wavelengths in the white LED to operate the WDM.

Next, to ensure the transmission quality and the affinity with the wire LAN, the MLT-3 method is used to encode the modulation signal. The MLT-3 encoding uses three voltage levels and its cycles through the voltage levels -1, 0, +1, and 0, as shown in Fig. 2. MLT-3 has a coding efficiency of 1 bit/baud, however it requires four transitions (baud) to complete a full cycle (from low-to-middle, middle-to-high, high-to-middle, middle-to-low). Thus, the maximum fundamental frequency is reduced to one fourth of the baud rate. This makes signal transmission more amenable to copper wires for the long range, hence it is used for the 100BASE-TX wire LAN communications.

Fig. 1 The frequency response characteristic of the two-wavelength white LED.

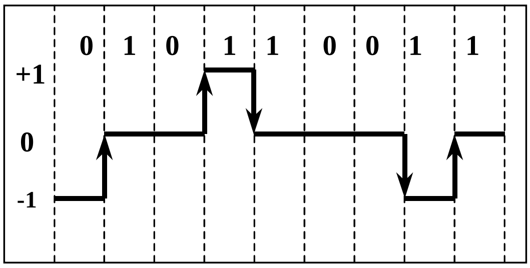


Fig. 2 An example of the MLT-3 encoding.

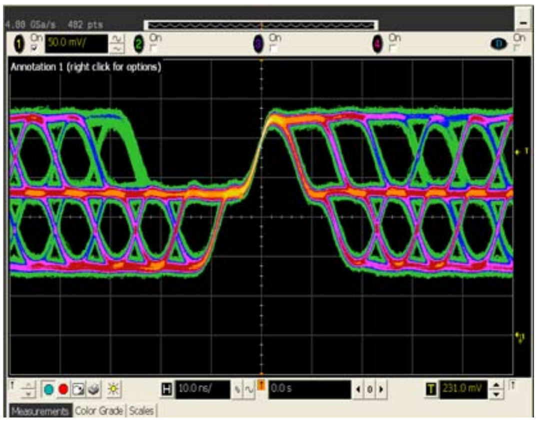
In our method, the visible light from the white LED is modulated by the MLT-3 codes, which are outputs from an Ethernet HUB chip on the control board of the white LED.

3. EVALUATIONS OF CHARACTERISTICS

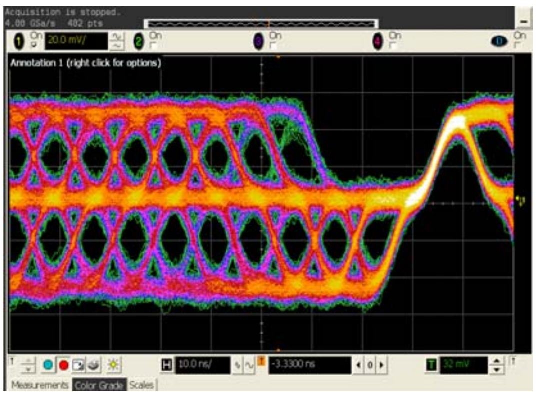
In order to evaluate the communication quality of proposed multivalued multiplexing method, we have used an evaluation software of throughput analysis. Evaluation results indication that when the distance between the LED transmitter and the APD (avalanche photodiode) receiver is less than 5m, about 90Mbps throughput can be obtained.

On the other hand, when data are transmitted along a physical path, especially in a higher frequency, receiving signals may suffer waveform distortion by crosstalk noise or jitter, which eventually causes intersymbol interference resulting the attenuation of communication quality. A useful and insightful graphical illustration of the degradation of signals is the use of an eye pattern plot. An eye diagram consists of many overlaid traces of small sections of a signal. If the data symbols are random and independent, the plot visually summarizes all possible transient waveforms. Hence, the wider the eye opening, the greater the noise immunity.

The eye pattern of MLT-3 signal for modulation waveform of the LED transmitter is shown in Fig. 3(a), and Fig. 3(b) shows the detected eye pattern on the receiving side. We can see the eyes are clearly open, and this result indicates that the MLT-3 encoding can be used effectively for optical wireless LAN.



(a)



(b)

Fig. 3 Eye diagrams of MLT-3 signal for: (a) transmitted waveform of the white LED, and (b) received signal waveform of the APD.

Because the LED not only is a transmitter, but also is employed as an illuminator, so we measured simultaneously its transmission and luminance characteristic are plotted in Fig. 4. The abscissa is the rotation angles of the LED transmitter, and the ordinate at left is the transmission distance and at right is the illumination luminance. We can see in the range of 0˚-60˚, the transmission distance of the LED is larger than 1m, and in the range of 0˚-45˚, its luminance is higher than 15lx.

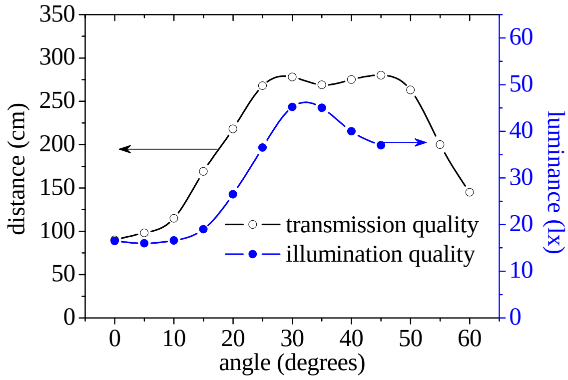


Fig. 4. Transmission and illumination quality of the white LED.

4. CONCLUSIONS

We have proposed an optical multiplexing transmission method with multivalued MLT-3 modulation for LED-based visible-light wireless net. By using this multivalued multiplexing method, data throughput of about 100Mbps has been achieved. The communication distance should be increased by using a good radiator to the white LED for further study.

ACKNOWLEDGMENTS

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