OPTIMIZATION OF AN OPTICAL WIRELESS COMMUNICATION SYSTEM

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Abstract
This paper presents a preliminary study aimed to optimize the signal characteristics of an optical indoor wireless communication system for telemedicine and mobile user applications. Specifically, detected signals associated with experimental geometries based on line-of-sight (LOS)-point-to-point-optical link and line-of-sight (LOS)-point-to-point-parallel to a surface-optical links are shown. In addition, applications of wavelet transform algorithms aimed to reduce the noise components associated with the detected signal are presented.

Keywords: Optical wireless, link geometries, wavelet algorithms, noise reduction.

I. INTRODUCTION

The use of an optical wireless system for indoor applications offers distinct advantages over the RF counterpart technology [1]-[3], [5]. The optical infrared wave energy can be contained within the room, thus eliminating interference generated by adjacent users, as well as introduces a degree of security. This unique property of the IR waves can be utilized effectively for monitoring and transmission of biomedical signals in healthcare institutions where EMI interference can be proved harmful for patients with implanted heart pacemakers as well as to biomedical sensitive electronic circuitry. Other potential optical wireless applications include indoor data networking and the delivery of broadband multimedia services to mobile users. Light emitting diodes (LED) are preferred over lasers as optical wireless transmitters, because they can produce substantial launch power and yet be Class 1 eye safe. However, indoor optical wireless communications are vulnerable to daylight, fluorescent and incandescent lighting as well as to multipath interference. In addition, there are problems associated with receiver bandwidth and speed limitations associated with large area photocathodes. As a remedy approach, improved optical wireless detection techniques based on transimpendance with bootstrapping have been developed aimed to reduce the noise and increase sensitivity, while reducing the effective capacitance of the photodiode [1]. Moreover, by placing a narrow filter over the photodiode, stray light interfering with the wanted signal tends to be reduced [6]. In addition, studies on the design of the optical wireless links consisting of imaging diversity receivers and eye-safe quasi-diffuse transmitters are in progress, which aim to improve detection characteristics [1]-[3]. Overall, digital transmission is preferred because the problems of managing the cumulative effects of noise and dispersion over long distances are less. ASK modulation is used in optical WLANS where light emitting diodes and photodetectors offers practical and inexpensive transmitter and noncoherent receiver implementations. It is an on-off intensity modulation. Using an LED as a transmitter for a binary PCM system, the input current would consist of a rectangular pulse of suitable pulse width to represent the binary 1, and no pulse (a pulse of amplitude zero) to represent the binary 0. In contrast, in this preliminary study, the transmitted light can be thought of as a carrier which is modulated by simply turning the LED on and off, by means of a 10 kHz rectangular pulsed wave. The photodetector can be thought of as a noncoherent envelope detector demodulating the transmitted signal by eliminating the optical carrier signal and detecting only the signal amplitude.

II. SIGNAL CONSIDERATIONS

For the purpose of studying the probability of error in binary decisions, the probability of error when a binary 1 is transmitted is

$$P(e\mid 1)=\frac{1}{2}erfc[\frac{(V_1-V_t)}{\sqrt{2}\sigma_1}] \qquad (1)$$

Similarly, for a binary 0, it is

$$P(e\mid 0)=\frac{1}{2}erfc[\frac{V_t}{\sqrt{2}\sigma_0}] \qquad (2)$$

Considering an ASK modulation system, a transmitted pulse of power P_1 is represented by a binary 1 and nothing transmitted for a binary 0. For the P_1 signal, the photocurrent is $I_{ph}=R_0P_1$, where R_0 is the detector responsivity in [A/W]. Assuming that shot noise is the only form of noise associated with the signal current, then

$$\frac{S}{N} = \frac{P_1}{2hfB} \quad (3)$$

If the signaling interval T=1/R, R=2B, and P1/hf=φ photons per second, then,

$$\frac{S}{N} = \phi T \text{ per bit} \quad (4)$$

For a given receiver power, wavelength, and bit rate, the average received energy in photons per bit can be calculated.

III. EXPERIMENTAL RESULTS AND DISCUSSION

In this study, an 850 nm LED transmitter array and Thorlab's PDA55 variable gain photodetector, with a spectral response between 400-1100 nm, have been utilized. Specifically, the photodetector integrates a large active area (13 mm^2) silicon PIN diode and a low noise transimpedance amplifier (1.5 x 10^4-1.5 x 10^6 V/A gain). A transimpedance design offers a compromise between bandwidth and noise, both of which are affected by the photodiode capacitance. The detector system provides a noise equivalent figure (NEP) of 4 x 10-12 W/√Hz at 960 nm, 40 dB gain, and a broadband noise of approximately 0.3 mV RMS. The photodetector includes a removable 1" optic mount for attaching optical filter or lenses. By placing a narrowband infrared filter over the photodiode, the level of stray light (mainly ambient light) relative to the wanted beam was significantly reduced. The following experimental geometries were studied: a) line-of-sight (LOS)-point-to-point-optical link geometry, and b) line-of-sight-point-to-point- parallel to surface-optical link geometry. The thresholding method of wavelet transform [4] was applied in order to reduce noise components associated with signal. Specifically, Haar wavelet was used in denoising the detected signals, as it is very efficient for 1-d signals. In Fig 1 and 2, unfiltered detected optical signals obtained under the two different optical link geometries are shown. In Fig 3 and 4 filtered detected optical signals obtained under the two different optical link geometries are shown. Finally, in Fig 5 and 6, filtered noise components associated with the detected signal under the two different optical link geometries are shown.

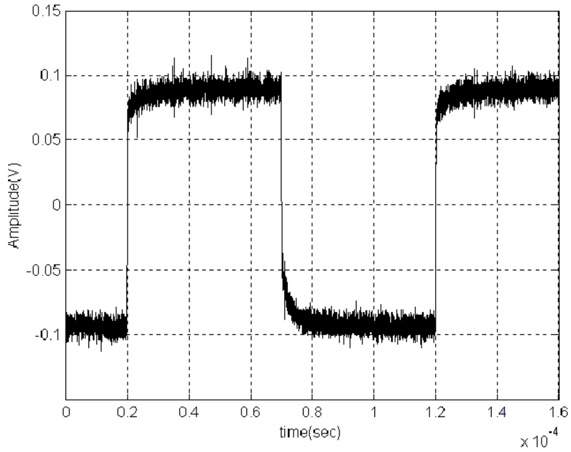

Fig. 1 Unfiltered detected signal under line-of-sight (LOS) point-to-point optical link geometry

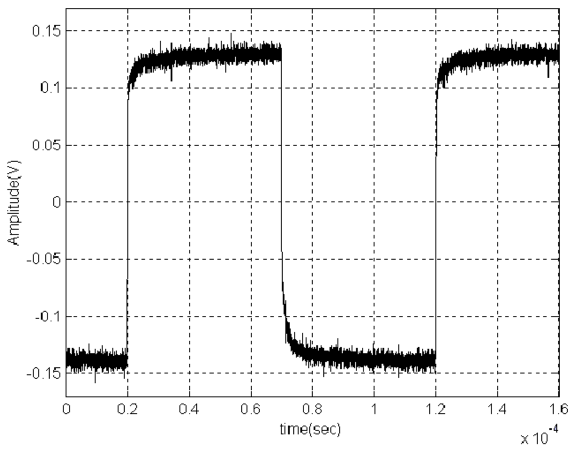

Fig. 2 Unfiltered detected signal under line-of-sight (LOS) point-to-point - parallel to a surface- optical link geometry

IV. CONCLUSION

In this paper, detected signal characteristics under different indoor optical link geometries have been presented. By processing the detected signals with wavelet transform algorithms, significant reduction of the noise components associated with the signal has been achieved

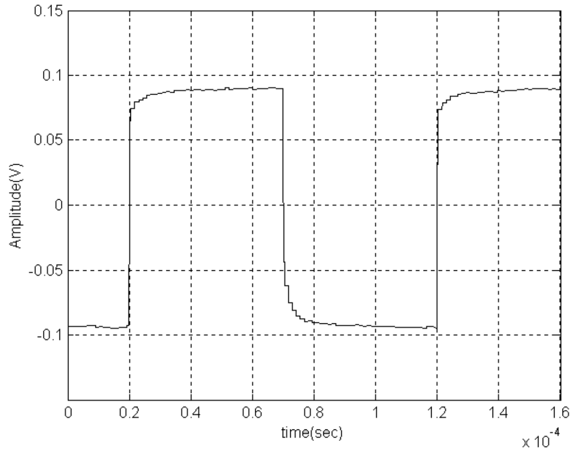

Fig. 3 Filtered detected signal through wavelet transform under line-of-sight (LOS)-point-to-point-optical link geometry

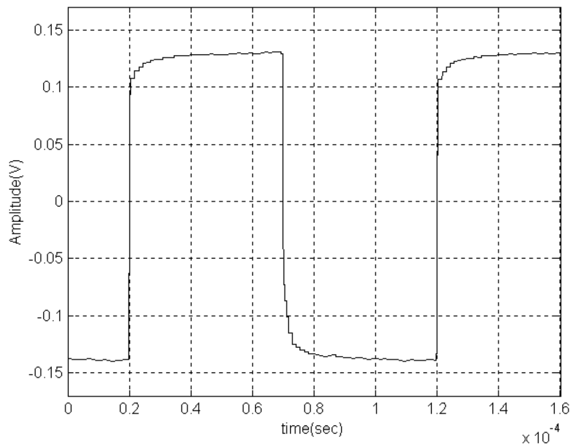

Fig. 4 Filtered detected signal through wavelet transform under line-of-sight (LOS) point-to-point -parallel to a surface optical link geometry

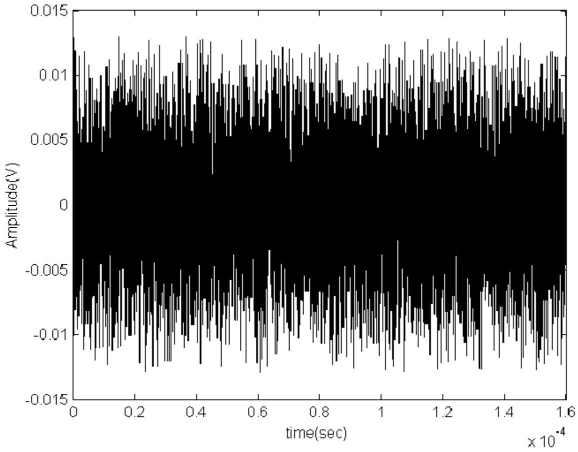

Fig. 5 Removed noise under line-of-sight (LOS)-point-to-point-optical link geometry

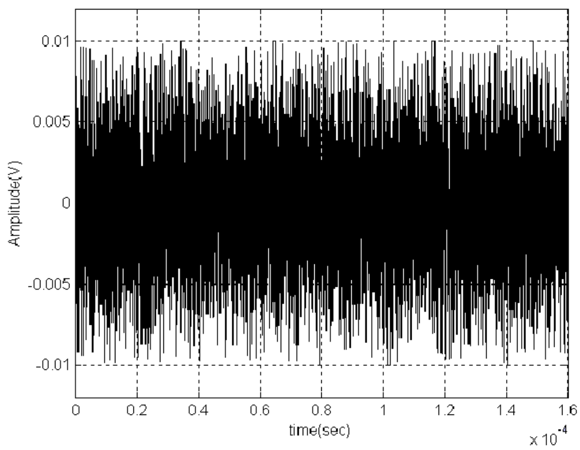

Fig. 6 Removed noise under line-of-sight (LOS) point-to-point -parallel to a surface- optical link geometry

V. REFERENCES

[1] J.M. Kahn, and J.R. Berry, "Wireless Infrared Communications", Proc. IEEE, pp. 265-298, 1997.

[2] A. Moreira, R. Valadas, and A. Duarte,"Optical Interference Produced by Artificial Light", ACM Wireless Networks J., vol.3., pp. 131-140, 1997.

[3] J.M. Elmirghani, and R.A. Cryan, "New PPM-CDMA Hybrid for Indoor Diffused Infrared Channels", Elect. Lett., vol. 30, no. 20, pp. 1646-1647, 1994.

[4] J.S. Walker, "Wavelets and their Scientific Applications", CRC Press, 1999.

[5] J.R. Barry, "Wireless Infrared Communication", Boston, Klwster, 1994.

[6] A.C. Boucouvalas, "Indoor Ambient Light Noise and its Effect on Wireless Optical Links", IEE Proc. Optoelect., vol. 143, no. 6, pp. 334-338, 1996.