Dual Amplitude-Width Pulse Interval Modulation for Optical Wireless Communications

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Abstract

In this paper, a new modified digital pulse interval modulation called Dual Amplitude-Width Pulse Interval Modulation (DAWPIM) is presented, on the basis of Pulse Amplitude Modulation (PAM) and Pulse Width Modulation (PWM), and its properties are presented. After introducing symbol structure, data rate improvement, average normalized power requirement and bandwidth efficiency are studied. The proposed concept showed to be well suited to use in Optical Wireless Communications links by virtue of its increased data rate, high spectral efficiency and the absence of receiver synchronization problems.

We present theoretical expressions of spectral efficiency, power requirements, and the data rate improvement normalized to PPM, and we present comparison results to DPIM and the hybrid PAM-DPIM.

Keywords: DAWPIM, DPIM, hybrid modulation, performance analysis, WOC.

1. Introduction

Wireless Optical Communication (WOC), also called Free Space Optic (FSO), refers to the transmission of modulated visible or infrared beams through the free space (atmosphere) to transmit data between two ends, over several kilometers as long as there is a clear line of sight (LOS) between the transmitter and the receiver.

The choice of modulation scheme is one of the most important factors in realizing a high performance wireless optical communication system at a reasonable cost and acceptable complexity, and because of the complexity and expensiveness of coherent modulation techniques like phase or frequency modulation [1] current WOC systems typically use Intensity Modulation and Direct Detection (IM/DD) [2] for its simple implementation and low cost. There is various modulation schemes compatible with IM/DD such as PPM and DPIM. Selecting the most appropriate modulation scheme will depend on a number of system criteria. For optical wireless systems, the main criteria are power requirements, bandwidth efficiencies, data rate and complexity.

Multi-level modulation techniques such as PAM are powerful in terms of spectral efficiency. On the other hand, higher average power efficiency can be achieved by Pulse Time Modulation schemes "PTM" in which a range of time dependent features of a pulse may be used to convey information. These PTM techniques fall into two categories, namely isochronous and Anisochronous. Isochronous schemes encode data by varying the position or width of a pulse, but the overall symbol structure remains constant such as PPM, in contrast, Anisochronous schemes have no fixed symbol structure [3]. Among the anisochronous modulations, DPIM (Digital Pulse Interval Modulation) has been combined with PAM (Pulse Amplitude Modulation) in DAPIM "Dual-Amplitude Pulse Interval Modulation" [4] to achieve more efficiency in term of bandwidth, and to improve the data rate.

In order to more improve the data rate, and the spectral efficiency, we propose and analysis in this paper a new concept of modulation on the basis of DAPIM and PWM, called DAWPIM "Dual Amplitude-Width Pulse Interval Modulation", as a new potential alternative to the existing DPIM modulation.

2. Pulse Position Modulation "PPM"

Among the isochronous schemes, PPM has been used widely in optical communication systems, and has been adopted by the IEEE 802.11 working group for the infrared physical layer standard [5]. In PPM information is transmitted as follows: at the transmitter side the encoder maps blocks of b consecutive bits for each block into a single PPM symbol by placing a single laser pulse into one of $M = 2^b$ time slots. On the other end, the receiver detects the encoded PPM symbols by determining which one of the M slots contains the pulse, and performs the inverse mapping operation in order to recover the transmitted bit stream. The average power requirement for PPM is given by [6]:

$$\frac{P_{PPM}}{P_{OOK}} = \sqrt{\frac{2}{M \log_2 M}} \qquad (1)$$