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Simulation and Analysis of Power Spectral Density for Digital Pulse Interval Modulation

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***Abstract*---In free space optical communication the signal power is changing with the bandwidth therefore PSD curves are very important in the link design. The power spectral density(PSD) of intensity modulation scheme i.e. Digital Pulse Interval Modulation (DPIM) has been presented. Results which are generated by simulations of an experimental system are presented. Which shows that DPIM has higher transmission capacity compared with digital pulse position modulation (DPPM) and is less complex to implement.**

Keywords---Pulse Position Modulation, Power Spectral Density, Digital Pulse Interval Modulation, On-Off Keying.

I. INTRODUCTION

The DPIM improves the power efficiency as well as the bandwidth efficiency or the throughput by removing all the empty slots that follow a pulse in a PPM symbol. The average number of slots per symbol in DPIM LDPIM L is almost half that of PPM. This provides the possibility for improving the data throughput or bandwidth efficiency [1]. A block of M = log2L input bits is mapped to one of L distinct DPPM waveforms defined as

$$x(t)_{DPPM} = P_p \sum_{k=-\infty}^{\infty} c_k p(t - kT_s) \tag{1}$$

where ck ∈ {0, 1} and Pp is the peak transmitted power, p(t) is a unit-amplitude rectangular pulse shape with one time slot duration. The bandwidth requirement, spectral and error analysis of the DPPM is the same as that of the DPIM. Although every DPIM symbol ends with a pulse, thus displaying an inherent symbol synchronization capability at the receiver, a single slot error not only affects the corresponding symbol but also subsequent symbols, thus resulting in multiple symbol errors [2]. There are two scenarios: (i) false alarm error—a pulse is detected in an empty slot following the pulse at the end of a symbol, thus resulting in the next symbol
being demodulated in error, and (ii) erasure error—noise causing a pulse to be received as an empty slot, thus resulting in two symbols becoming one with the transmitted symbol being deleted and the next symbol being demodulated in error. Note that if error slots result in a run of empty slots longer than (L − 1) slots, then the error is detected, otherwise it is not detected.

II. POWER SPECTRAL DENSITY

The general formula for the PSD of a digital signal is given by [1]

$$S(f) = S_c(f) + S_d(f) \tag{2}$$

$$S_c(f) = \frac{|P(f)|^2}{T_p} \sum_{k=-\infty}^{\infty} \left[R(k) - m_a^2\right] e^{-2\pi k f T_p} \tag{3}$$

$$S_d(f) = \left(\frac{m_a |P(f)|}{T_p}\right)^2 \sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_p}\right) \tag{4}$$

are the continuous and discrete parts of the PSD, respectively. $P(f)$ is the Fourier transform of the pulse shape, T_p is the pulse duration, $R(k)$ is the autocorrelation function and m_a is the mean value of the signal. In the following, we have considered a non-return to zero rectangular pulse shape and its Fourier transform is given by $P(f) = T_p \, sinc(fT_p)$. Since $sinc(fT_p)$ for all $f = n / T_p$ except at $n = 0$,, (3) can be written as

$$S_d(f) = m_a^2 \, sinc^2(fT_p)\delta(f) \qquad (5)$$

It is simply a delta function at $f = 0$. In the following analysis, we have considered only the

continuous part. In the continuous part as given by (2), $R(k)$ is given by [1][3]

$$R(k) \equiv \overline{a_n a_{n+k}} = \sum_{i=1}^{I} (a_n + a_{n+k})_i \, P_i \qquad (6)$$

III. PSD of DPIM

Every DPIM symbol has a pulse followed by empty slots, the number of which determines the transmitted symbol [4] . (i) Evaluation of m_a: The symbol lengths vary from 1 to M. Hence, we consider the average length of the symbol to find $p(1), p(0)$ and m_a. The average length of a DPIM symbol is given by

$$L_{avg} = \frac{M+1}{2} \qquad (7)$$

The mean value of the signal is given by

$$m_a = \frac{A_m}{L_{avg}} = \frac{2A_m}{M+1} \qquad (8)$$

(ii) Evaluation of $R(k)$: The probabilities of bits '1'and '0'are given by

$$p(1) = \frac{1}{L_{avg}} = \frac{2}{M+1} \qquad (9)$$

$$p(0) = 1 - p(1) = \frac{L_{avg} - 1}{L_{avg}} = \frac{M-1}{M+1} \qquad (10)$$

Since all symbols are considered equiprobable

$$p(S_i) = \frac{1}{M}, \, i = 1 to M \qquad (11)$$

where $p(S_i)$ is the probability of occurrence of a DPIM symbol [5] [6].

IV. RESULTS & DISCUSSION

The PSD of are plotted for L = 4, 8, 16 and 32, as shown in Figure 1. All curves were plotted for the same average optical power, using rectangular shaped pulses occupying the full slot duration. The power axis is normalized to the average electrical power multiplied by the bit duration and the frequency axis is normalized to the bit rate *R*b. The discrete terms at DC are not shown Unlike PSD of PPM (Figure 1), DPIM has a DC content, although the power content at low frequencies is relatively small compared with OOK. Hence, DPIM will be more susceptible to the effects of baseline wander compared with PPM. Furthermore, if the areas under the curves are compared, for a given average optical power, the increase in detected electrical power as L increases is easily observed Comparing the two DPIM schemes, for any given L, DPIM(NGB) has a slightly higher DC power component compared with DPIM(1GS), again suggesting a greater susceptibility to baseline wander By observing the null positions, the slightly higher bandwidth requirement of DPIM(1GS) compared with DPIM(NGB) is also evident. Furthermore, if the areas under the curves are compared, for a given average optical power, the increase in detected electrical power as L increases is easily observed .

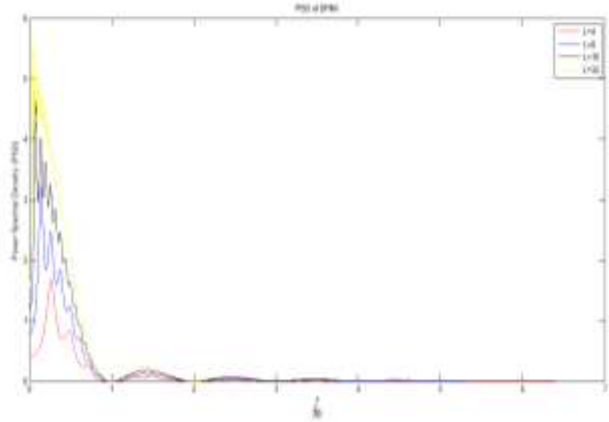

Fig. 1 PSD of DPIM for L = 4, 8, 16 and 32.

V. CONCLUSION

The bandwidth is not a primary concern in some applications. In multipath FSO links, bandwidth is of major concern. Also, because of the atmospheric turbulence induced pulse spreading, the available channel bandwidth decreases. Hence, it is important to know the bandwidth requirement of the modulation schemes used the bandwidth requirement of system using DAPIM is the minimum. The PSD curves are very important in the link design which provide the information of the signal power is changing with the bandwidth are presented in the paper.

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