The error rate analysis for MPPM

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Abstract. Multiple pulse position modulation is one of many modulation techniques that are appropriate for optical communication systems. In this paper, a brief description of MPPM is introduced. More importantly, the error rate performance of MPPM is discussed as the main topic. It is investigated in both theoretical part by mathematical models and experimental part by MATLAB tool and some other techniques. It can be found that the error rate performance of MPPM can be affected by several factors such as signal to noise ratio (SNR), the figure of chips in each symbol, the operating bit rate level and the number of optical pulses. Besides, let LPPM compared with MPPM, MPPM has higher error rate in ideal circumstances. However, there are still limitations in this paper, only preliminary works were done to analyze the MPPM error rate. Therefore, further progress can be made in this topic and other facets of MPPM can also be researched to reach an achievement.

Keywords: MPP, SNR, MPPM.

1. Introduction

As a digital communication technique, Multiple Pulse Position Modulation(MPPM), which is a kind of Pulse Position Modulation(PPM), is commonly used in optical communication systems. MPPM modulation is to map N-bit binary bits into PPM signals which are composed of M information time slots according to a set of guidelines, in which at least 2 of the M information time slots of each PPM signal have signal optical pulses, while there are no signal optical pulses in other information time slots.

Since MPPM encodes multiple bits of information instead of 1 bit as PPM does, it can improve the band-utilization efficiency. In 1989, H.Sugiyama and K.Nosu first put forward that by increasing the signal pulse and changing the pulse position to achieve the goal that transmit more information with less bandwidth[1]. In 1993, T.Ohtsuki, I.Sasas and S.Mori proposed that MPPM can have a higher transmission rate and efficiency by combining RS code overlap. However, there were still some drawbacks[2]. While in 2003, K.M.Simon and A.V.Vilnrotter focused on comparing the peak and average power limitations effects on the error performance of LPPM(Single Pulse Position Modulation) and MPPM. The results indicated that MPPM has better resilience[3]. In 2004, H.Park and R.J.Barry discovered that the utilization ratio of MPPM constellation point can be as high has 94% by combining the irregular MPPM with network coding which has higher coding gain. However, the location of the constellation points can be optimized because there were still some problems between the constellation points[4]. Jump to 2009, Xu.F, A.M.Khalighi tried to combine SCPPM with 2-16 MPPM which had better error correction performance to achieve the Serial Concatenated Multi-Pulse Pulse Modulation(SCMPPM) method. Nevertheless, the 2-16 MPPM chosen in the project only transmit 4-bit information for each constellation point, leaving up to 87% of the constellation points unused[5]. In 2011, T.Ying and Liu.W proposed a new method for SCMPPM by substituting 2-16 MPPM with 2-12 MPPM. Although it worked in a certain degree, the position of the constellation points can still be improved[6]. In the same year, Azzam.N, Moustafa .H and AboulSeoud A.K compared the error rate performance between the PPM and MPPM. They dropped the conclusion that though MPPM can have higher efficiency, PPM generally has better error performances. Next year, H.Selmy, M.H.Shalaby and Z.Kawasaki provided a new way of MPPM by continuously changing the number of signal pulses in the MPPM symbol to increase the channel capacity[7]. In 2016, Y.Wang, et al presented the same research. Both didn't consider the difficulty that the receiver can hardly determine the number and location of signal optical pulses by counting

the photons. Therefore, it was unsuitable for Poisson Channel[8]. T.T.Nguyen,et al in 2012 and J.Y.Wang in 2015 published the average mutual information formula when the constellation points of MPPM followed discrete and continuous distributions. While there were still some limitations, the cost maybe unaffordable when the modulation order got higher[9][10]. In addition, in recent years, research on MPPM mostly focused on the hybrid modulation techniques like BPSK-MPPM[11] which have higher transmission rate and more complex demodulation technology.

In this paper, an analysis focusing on the error rate of the MPPM will be discussed. Based on some mathematical models, the operating principle of MPPM and error rate results will be displayed by equations. While by Matlab tool and some other techniques, various figures can show how do factors like SNR affect the error rate performance of MPPM.

2. Principle

As mentioned above, according to a set of criteria, MPPM modulation maps N-bit binary bits into PPM signals made up of M information time slots, where at least 2 of the M information time slots in each PPM signal have signal optical pulses and the remaining information time slots do not. Difference can simply be discovered that two of the M information time slots in each PPM signal have signal optical pulses, while in LPPM only one contains optical pulses. Besides, with the same modulation order, the types of symbol in MPPM is far more than the ones in LPPM. With a fixed time, MPPM can transmit more information with higher power efficiency. However, the drawback of MPPM is that the encoding and the decoding parts are far more complex. In addition, because the types of symbol in MPPM are not always an integer power of two and among the different symbols, they are not completely orthogonal. Problems like constellation point redundancy occur often. Therefore, the number of the redundant constellation points and their locations which will directly affect the communication systems, is really essential.

3. Discussion

3.1. Develop the relationships between SNR and Error rate of MPPM

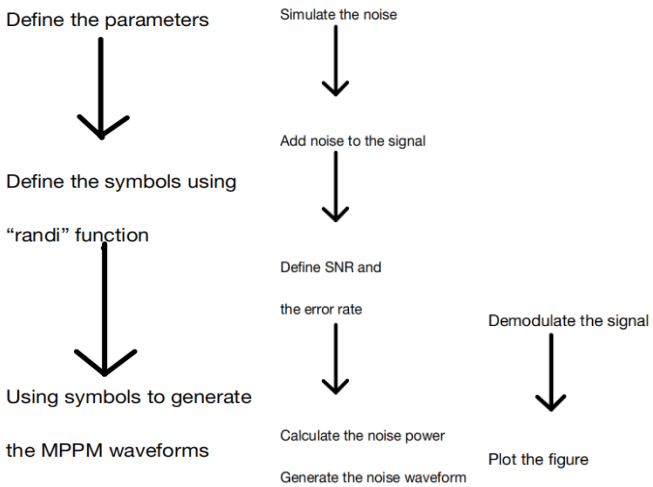


Figure 1. Coding ideas

In this part, by using Matlab tool, Figure 1 displays the relationships between SNR and the error performance of MPPM should be obtained. Defining the parameters is the first step. Here, define number of symbols, which is represented by the letter M, equals to 4. Define number of symbol periods, represented by the letter N, which is equals to 1000. Define the number of pulses per symbol, which letter L represents, equals to 4. After that, as shown in the Figure 3, generate the random symbols using Matlab's built-in function. At last, based on the random symbols, generate the MPPM waveform.

In the second step, first according to the characteristic of the noise in the reality, simulate the noise in the Matlab tool. Then add noise to the signal. To do this, define vectors SNR and error rate in the code. Then calculate the noise power and generate the noise waveform. Finally, demodulate the signal and simply just plot the figures. The result is as follows in Figure 2.

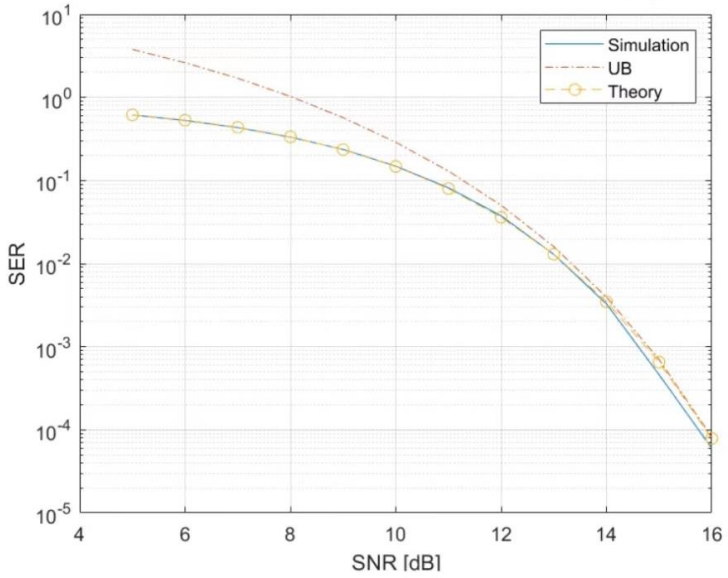


Figure 2. Error Rate vs SNR

It is apparent that gradually as SNR increases, the error rate dwindles. Yet generally speaking, the error rate of MPPM should normally decrease as the SNR rises. Having a greater SNR makes it easier to discern between distinct pulse positions and lowers the likelihood of decoding errors because the received signal is stronger in relation to the noise.

However, the correlation between SNR and error rate is not constant and depends on the particular modulation scheme employed. For instance, some MPPM schemes may be less robust at low SNR but have higher error rates at high SNR due to problems with inter-symbol interference or other factors. This is because detecting and decoding the pulse positions in a noisy channel is more difficult.

Finally, simulation or analysis can be used to discover the precise link between SNR and error rate for a given MPPM scheme, taking into consideration of the modulation parameters, channel characteristics, and other variables that may have an impact on performance.

3.2. Discuss the effect of the quantity of chips in each symbol and operating bit rates on Error rate

To discuss how these factors affect error rate, other factors like number of optical pulses and SNR should be fixed. The error performance for the MPPM method is shown in Figure 4 at various operating bit rate levels(Rb) as well as the number of chips per symbol (n) along with a constant SNR of 10 dB. Here the number of optical pulses w equals to 2.

According to Figure 3, MPPM symbol error probability increases when the operating bit rates increase when w and SNR is at certain values. For the same Rb, SNR, and w, those MPPM using large n have a lower error performance than those using a small n. The maximum value of error performance, appears as error probability of symbols in this simulation case study is 0.341, 0.269, and 0.215, respectively, with Rb equals to 155Mbps, w equals to 2 and P/N0 equals to 10.

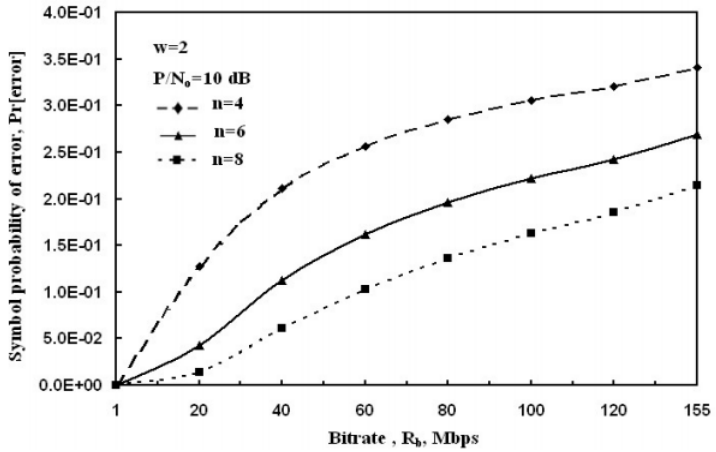


Figure 3. Error performance for MPPM with certain operational bit rate and quantity of chips in each symbol[16].

According to former calculations, implementing an Multiple Pulse Position Modulation with plenty of n and few w results in a acceptable error performance throughout a wide range of operational bandwidths. Here, further researches can be done to discuss the mixed effect of changing SNR and the number of chips in each symbol. Let operating bit rate stay constant. At the same time, vary SNR as well as n. In Figure 8, the symbol probability of error for the MPPM method is shown for the same w as in the previous simulation with many levels of SNR and n.

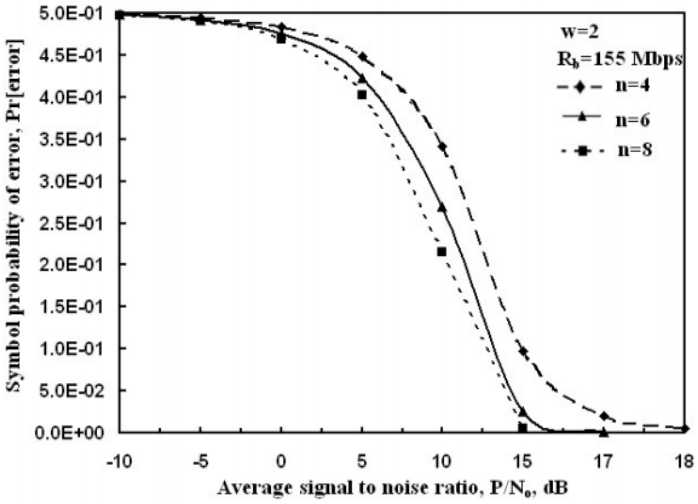


Figure 4. Error performance for MPPM with varying SNR values and the quantity of chips in each symbol.

From Figure 4, it can be shown that for MPPM, when w equals to 2, which stands for the situations of low optical pulses, the symbol probability of error decreases as the SNR increases. With the identical levels of operational bit rate and w, the Multiple Pulse Position Modulation scheme which uses big n uses less cost to produce the identical likelihood of mistake than the one which uses low n. What's more, according to simulation data, the MPPM scheme for n equals to 4, n equals to 6 and n equals to 8 requires SNR of 19.423 dB, 17.594 dB, and 16.498 dB, correspondingly, in order to reach specific error performance which is known as 10-4 symbol error rate probability. In all prior situations, the maximum level of symbol likelihood of mistake was 0.498 when SNR equals to 10dB.

Then, change w=2 to w=4, and discuss the same factors again. First, discuss how the mixed factor ,SNR and n, affect the error rate.

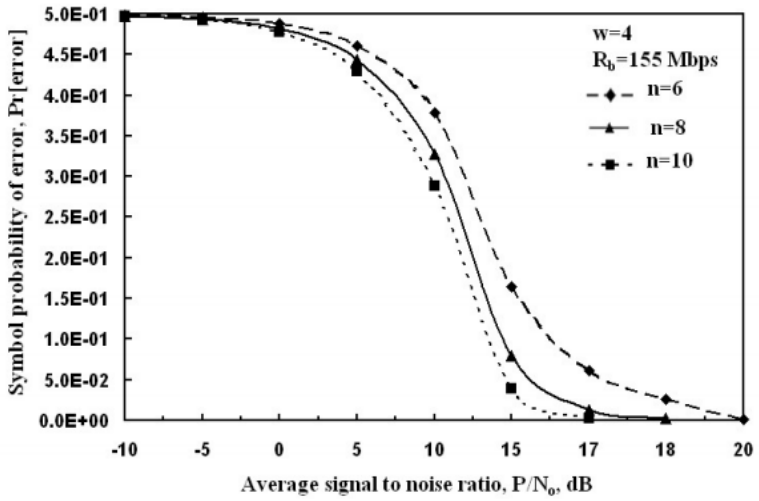


Figure 5. Error performance for MPPM with varying SNR values and quantity of chips in each symbol.

Figure 5 shows the error performance for the Multiple Pulse Position Modulation scheme for large number of w, which is equals to 4. With various values of SNR and n. There are no big differences between Figure 9 and Figure 8. While according to simulation studies, the MPPM scheme needs SNR respectively to achieve certain values like 18 dB, 19 dB, and 20 dB in order to obtain the same specific error performance as mentioned above when w equals to 4. Here the operating bit rate is the same as above so it is unworthy to discuss. In all prior examples, the maximum level of symbol probability of mistake was 0.498 and it was reached when SNR equals to -10dB.

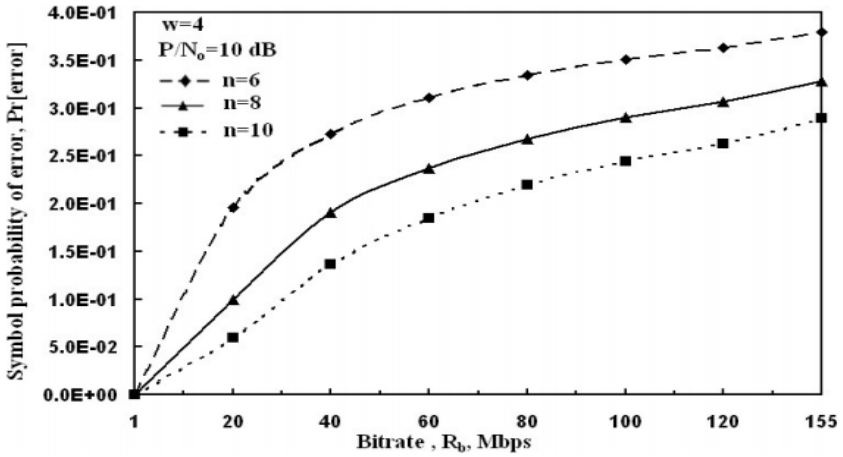


Figure 6. Error performance for MPPM with varying operational bit rate and quantity of chips in each symbol.

With a constant SNR of 10 dB and multiple values of operational bit rate and n, Figure 6 shows the error performance for the MPPM system when w equals to 4. According to Figure 6, the maximum value of the error probabilities of symbol is, respectively, 0.379, 0.328, and 0.289 with Rb=155Mbps, SNR=10dB. Both situations (i.e., w equals to 2 and w equals to 4) exhibit appealing performances for the MPPM scheme with an ideal channel and no ISI requirement. First, it makes sense that symbol error probability would drop as the SNR increased. Second, a large-n MPPM scheme uses less SNR than a low-n MPPM scheme to reach the same probability of error at the identical Rb as well as w. Finally, MPPM symbol error probability increases as Rb increases with fixed SNR and w. Furthermore, given the same Rb, SNR, and w, the MPPM scheme that uses large number n can reach a better error rate performance than the strategy that uses small n. Symbol chance of error is unaffected by n or w at low SNR (i.e., -10dB), and all scenarios attain unsatisfactory error under constant value of bit rate.

3.3. Maintaining the Integrity of the Specifications

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4. Conclusion

For conclusion, as a subset of Pulse Position Modulation, MPPM is frequently employed in optical communication systems as a digital communication technology. It can be affected by various factors such as SNR, quantity of chips in each symbol, operational bit rate levels, and quantity of optical pulses. Generally, with other factors unchanging, As SNR and n increasing, the error rate will decrease. While when SNR and number of chips are fixed, the error rate will increase with increasing levels of operational bit rate.

MPPM scheme can be used in lots of realms in reality. Therefore analyzing its error rate performance under different situations is essential. However, this report's results were mostly investigated in ideal situations with no ISI or other distortion, so further researches can be done to reach more applicable results.

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