Development of an Efficient Indoor Optical System using Different Wavelet Transforms

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Abstract

For an effective communication system whether indoor or outdoor, the most important concern is minimum noise. In this paper, an efficient noise reduction technique is presented using various wavelet transform techniques for indoor optical wireless communication system (IOWC). In IOWC system, Fluorescent Light Interference (FLI) is main source of noise. Here, in this paper three methods are used to reduce the effect of noise from a digital signal. These are Discrete Wavelet Transform (DWT), Stationary Wavelet transform (SWT) and Discrete Wavelet transform-Stationary Wavelet Transform (DWT-SWT). Through sub band coding in DWT the signal is decomposed into lower sub bands of high and low frequency respectively of unequal size; while in SWT the decomposed signal have sub bands of equal size. In DWT-SWT the high frequency components of both DWT and SWT are added. Using Pulse Position Modulation, the comparison between these three techniques is described here to enhance the overall performance of the IOWC system.

Keywords: DWT, SWT, DWT-SWT, PPM

1 Introduction

From pre-historic period, Light has been used as a major source of communication. For sending data, the very first system communication system without wire came into existence in early 19s. For communication in indoor environment, Infra-Red (IR) frequencies were used in different modes like direct, in direct, diffused and tracked [1]. Since optical communication is having number of applications and it is used in various regions not only for wireless but also for wired for exchanging information from one point to another.

1.1 Indoor Optical Wireless Communication Ease of Use

In Optical wireless communication, using infra-red frequency, it becomes too easy to link the computer based home appliances. Through this frequency even fast access is also made possible for various electronics and computer based machines. Though, IR systems also have few limitations for example they cannot cross via a wall and also FLI & background noise also exist with these systems [2]. Due to which the overall performance of the system affects a lot. Here, in this paper, a comparison is made between three wavelet transform techniques, which help in enhancing the performance of Indoor Optical Wireless System. These three techniques are Discrete Wavelet Transform (DWT), Stationary Wavelet Transform (SWT) and DWT-SWT which is a combination of previous techniques. An indoor optical wireless communication system is proposed here, which works on Pulse Position Modulation. First, confirm that you have the correct template for your paper size. This template has been tailored for output on the A4 paper size. If you are using US letter-sized paper, please close this file and download the Microsoft Word, Letter file.

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1.2 Signal Transformation Techniques

For computing frequency in any digital system, Fourier transform was a very common method. Although, this method was very simple but it also had a major drawback. Through this method only for fixed duration of time and frequency can be measured. To overcome the drawback wavelet transform techniques come into existence which is used to analyse the low frequency and high frequency components, or the transient behaviour of the signal. In this paper, three wavelet techniques used for indoor optical system are explained below:

1.3 DWT (Discrete Wavelet Transform):

The discrete wavelet transform has an immense number of utilizations in science, designing, arithmetic and software engineering. Most strikingly, it is utilized for signal coding, to express a discrete signal in a more repetitive structure, frequently as a preconditioning for data compression. Denoising is also a very useful application of DWT for easy and fast removal of noisy components from the original signal. The more or less denoising of a signal depends upon the number of highest coefficients of the discrete wavelet transform spectrum. An analysis of signal by DWT is done at various frequency bands, by decomposing the signal into an uneven approximation and detail information through different resolutions. Two components i.e. scaling and wavelet function are associated with LPF and HPF respectively in DWT. Since the signal is having p/2 as highest frequency instead of p, hence half of the samples can be eliminated after the filtering process as per Nyquist's rule. Therefore, in the first level of decomposition the signal is subsampled into two halves given in [3] as

$$y_{high}[k] = \sum_n x[n].g[2k-n] \quad (1)$$

$$y_{low}[k] = \sum_n x[n].h[2k-n] \quad (2)$$

Equation 1 and 2 are the outputs of HPF and LPF after subsampling by 2.

The time resolution is now half the total samples and defines the full signal now after first decomposition. Due to the reduction of the uncertainty in the frequency by half, the frequency resolution gets doubles after this process. The above procedure of sub band coding is explained in figure 1 below:

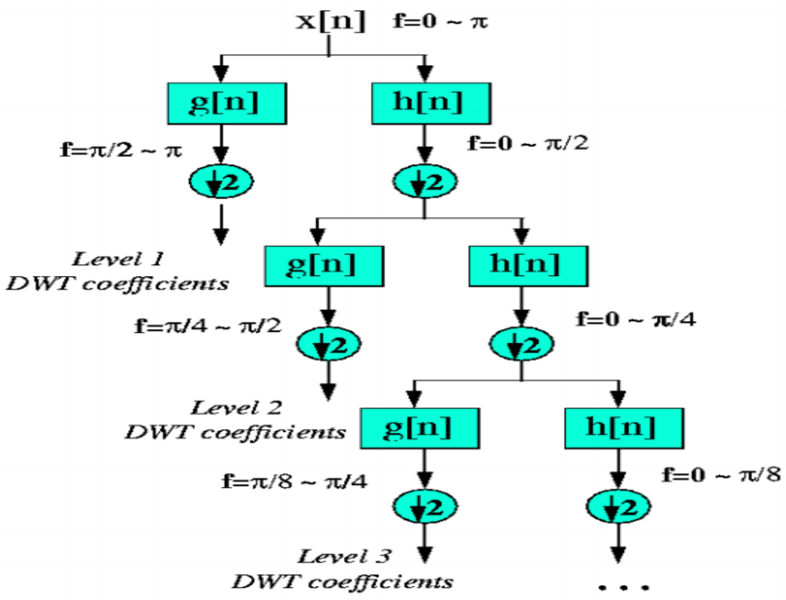

Figure 1 Discrete Wavelet Transform

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1.4 SWT (Stationary Wavelet Transform)

The well-known wavelet transform method i.e. DWT had certain limitations and to overcome those problems, the another wavelet transform method was designed by Mallat[4] named Stationary Wavelet Transform. The DWT is a method which is a non-time invariant. It means that with DWT the translated version of any signal was not same when extension of periodic signal was done. Hence by eliminating the down samplers and up samplers of DWT, Translation-in variance can be achieved. A 3 level SWT filter bank is given in figure 2. In SWT the obtained coefficients are of equal size.

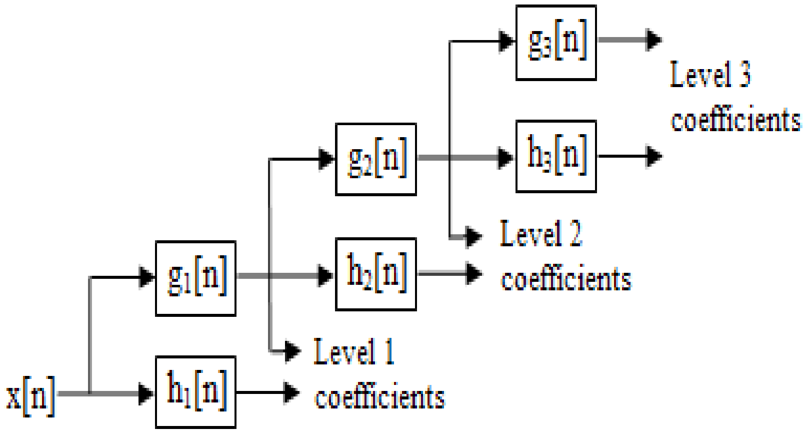

Figure 2. A 3 level SWT filter bank [8]

1.5 DWT-SWT

Discrete wavelet transform gives good time resolution only for high frequencies and only for low frequencies it showed good frequency resolution. So in order to achieve better resolution at both the levels, the high level frequencies components of discrete wavelet transform are added to similar components of stationary wavelet transform. For this arrangement, only the discrete wavelet transform is interpolated by a factor of 2 so that both transform will have same size samples. This method is named as DWT-SWT, in which sub bands of both the transform techniques are merged as to get better output. After this merging, the inverse wavelet transform is applied on this combined signal in order generate to generate a high resolution output. This DWT-SWT is shown if figure 3 below.

Figure 3 Discrete Wavelet Transform – Stationary Wavelet Transform

1.6 System Design:

In this section, the designing of the proposed system based on Stationary Wavelet transform, is described. The proposed system is manifest as: a PPM generator is used as input device, which generate a PPM signal, which it is mixed with the channel noise i.e. AWGN noise. At the receiver side, after filtering the received data using receiver filter, denoising based on wavelet transform and artificial neural network is applied. The wavelet transform used for the proposed system is Discrete Wavelet transform, Stationary Wavelet transform and combination of DWT and SWT. Finally, the threshold is applied to the output of ANN to achieve the desired output.

2 Results and Discussions:

In this section of the paper, the performance of the proposed system is specified and verified with the existing technique. Various characterizations used to show the performance of the proposed system are: the change in BER vs SNR, efficiency and NOPR.

2.1 SNR vs BER:

The ratio of signal power to noise power was used to compare the level of desired signal to the level of background noise. The values are calculated for the proposed system using PPM with DWT –SWT, SWT and DWT transforms techniques. The comparison between these methods is given in table 1. The table described the comparison of wavelet techniques for PPM method by varying the symbol length from 4 to 16. The outcomes of the table described that for a particular value of SNR the value of BER decreased when the value of symbol length increased. The value of BER also decreased when the value of SNR was increased for PPM-4, 8, 16.

From the table it can be seen that at SNR of 5.5 dB, the value of BER was maximum for PPM-4 with DWT and is minimum when DWT-SWT was applied with PPM-16. Similarly at SNR of 25dB, the BER obtained for DWT, SWT and DWT-SWT declined in the order 16>8>4, means maximum for L=4 then for 8 and 16. Therefore, it can be illustrated that with the increment in the value of SNR the values BER goes down for all the methods such that maximum for DWT-SWT and least for DWT and following the order such that more for 16, then for 8 and minimum for L=4.

Table 1: Comparison of SNR/BER for DWT & SWT using PPM

S.NO.	**SNR(dB)**	**BER(10^-3)**								
		DWT			**SWT**			**DWT - SWT**		
		4	**8**	**16**	**4**	**8**	**16**	**4**	**8**	**16**
1	5.5	0.1767	0.1733	0.1683	0.1725	0.1683	0.1675	0.1675	0.1658	0.1658
2	8.5	0.0975	0.096	0.096	0.096	0.096	0.0955	0.096	0.094	0.0905
3	10	0.085	0.0783	0.0779	0.0838	0.0825	0.0817	0.0725	0.0714	0.0700
4	16	0.0539	0.0532	0.0517	0.052	0.0518	0.0512	0.0473	0.0473	0.0465
5	19	0.0466	0.0448	0.0433	0.0464	0.0454	0.0427	0.0425	0.0423	0.0413
6	25	0.0328	0.0314	0.0309	0.0322	0.0303	0.0278	0.0319	0.0309	0.0278
7	28	0.0291	0.029	0.0286	0.027	0.0268	0.0256	0.0263	0.0254	0.0249

2.2 Efficiency:

By using Shannon's theorem from signal to noise ratio, the spectral efficiency for the proposed system was calculated. Through spectral efficiency the utilization of the spectrum can be determined so as to determine the performance of the system. The spectral efficiency computed in bits/Hz through SNR is described in table 2 for PPM methods with three different wavelet schemes. From the table it can be seen that for PPM it is maximum for DWT-SWT and least for DWT.

Table 2: Spectral Efficiency for DWT, SWT and DWT-SWT

Spectral Efficiency in bits//Hz	PPM-4	PPM-8	PPM-16
DWT	2.251	2.605	2.767
SWT	2.698	2.807	3.042
DWT-SWT	3.358	3.528	3.634

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It is 2.251bits/s/Hz for PPM-4 with DWT, 2.698 bits/s/Hz for SWT and 3.358 bits/s/Hz for DWT-SWT. For PPM-8 it is obtained 2.605 bits/s/Hz with DWT, 2.807 bits/s/Hz for SWT and maximum with DWT-SWT i.e. 3.528 bits/s/Hz. Similarly, it is 2.767 bits/Hz for PPM-16 using DWT, 3.042 bits/s/Hz with SWT and 3.634 bits/s/Hz with DWT-SWT.

The graphical representation of efficiency for PPM is shown in figure 4. From this figure it can be illustrated that it is obtained maximum for DWT-SWT method then for SWT and least for DWT. Hence it can be concluded that the maximum spectrum has been utilized using DWT-SWT wavelet transform technique for pulse position modulation with symbol length of 16.

2.3 NOPR vs Data Rate:

The optical power requirement using proposed system was calculated with respect to data rate for the proposed wavelet transform techniques. For plotting the results threedifferent cases considered were without interference, with interference and with proposed technique.

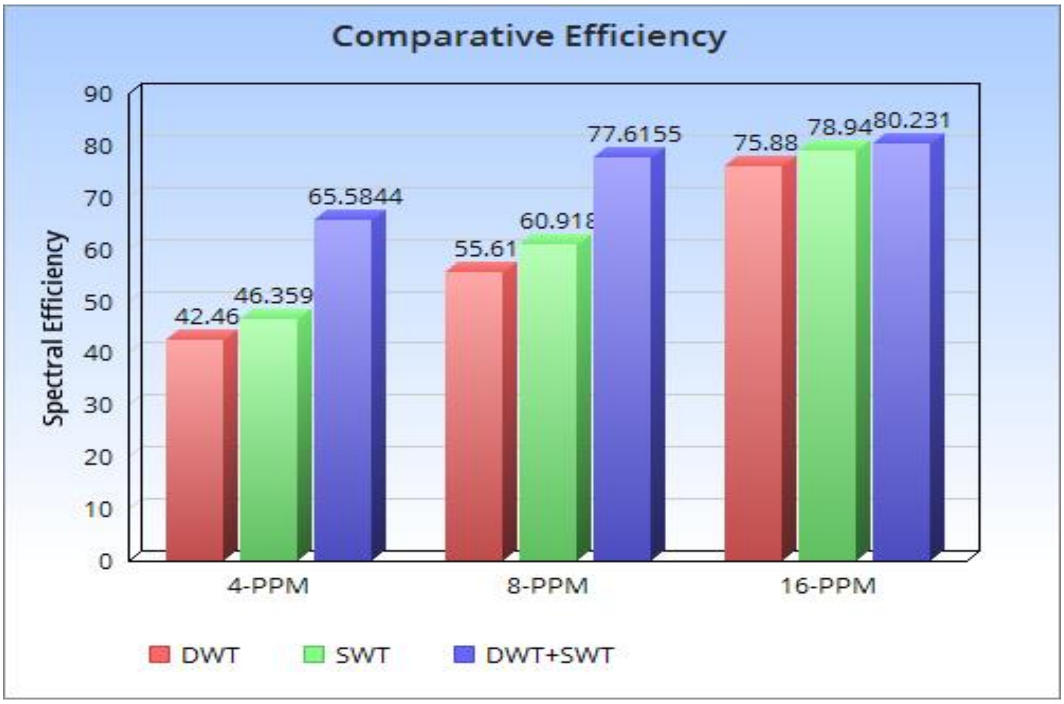

Figure 4 Efficiency for DWT, SWT & DWT-SWT with PPM

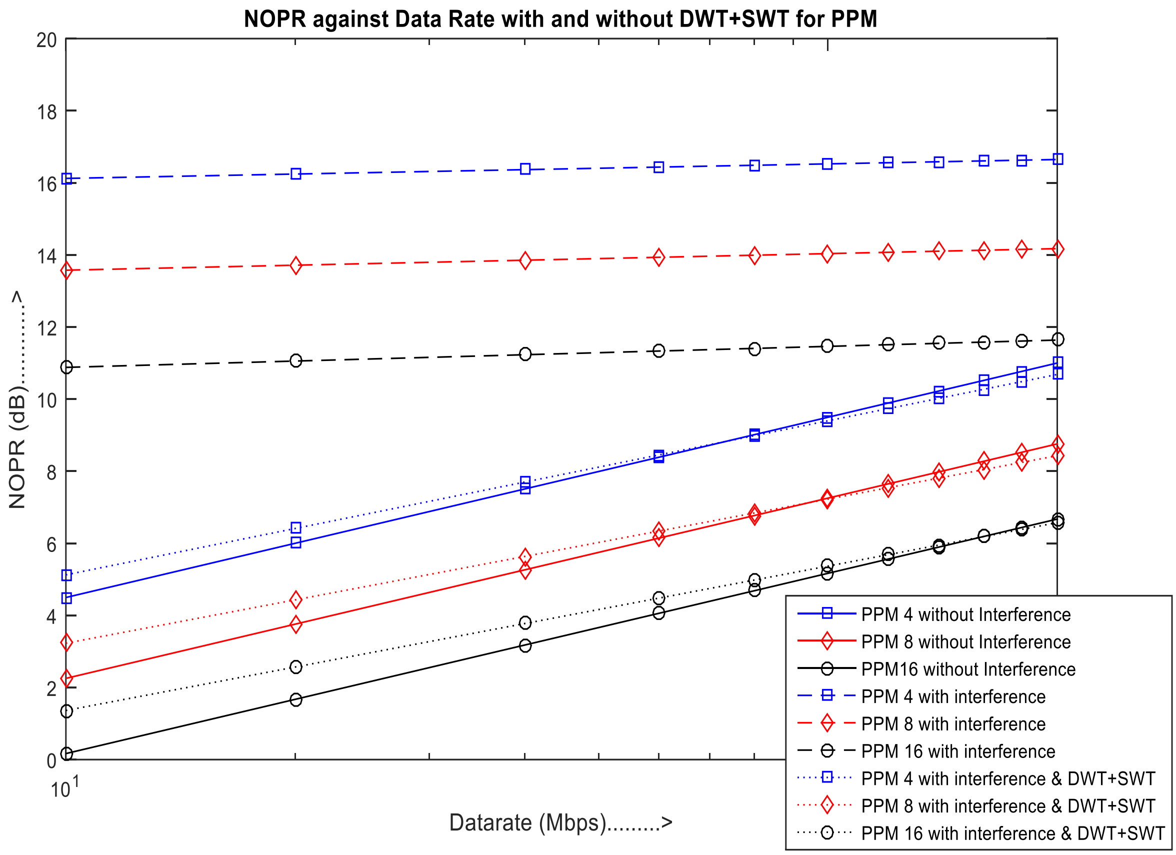

Figure 5 NOPR vs Data Rate for PPM

For PPM method, the relation of NOPR and data rate for DWT and SWT was described in previous publication. For DWT-SWT technique, the relation between power requirement and data rate for PPM-L is shown in figure 5.

On applying the proposed wavelet technique, the NOPR reduced to an approximate more than 10 dB for PPM-L and the curves showed the linear relation with data rate. Henceforth, with DWT-SWT, the interference and power requirement was reduced such that it was more for PPM-16 and least for PPM-4. Figure 6 represents the values of NOPR when data rate is increased to Gbps.

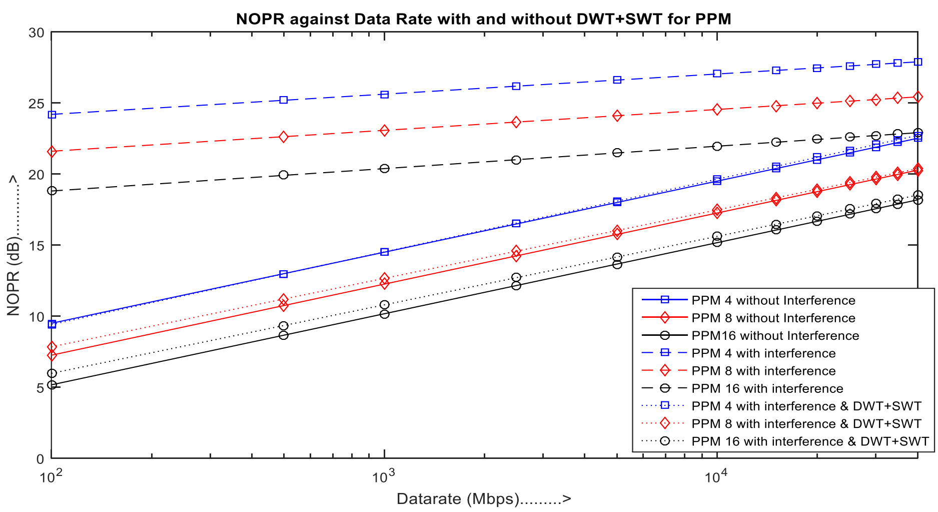

Figure 6 NOPR vs Increased Data Rate for PPM

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As can be seen from the figure, there is a rapid increase in NOPR with increase in data rate. It is increased approximately to 11dB and has a variation of around 4 dB. With proposed method, the interference is reduced and varied linearly with data rate. So it can be said that with pulse position modulation, interference is reduced but with increase in data rate, the power requirement increased as compared with low data rate.

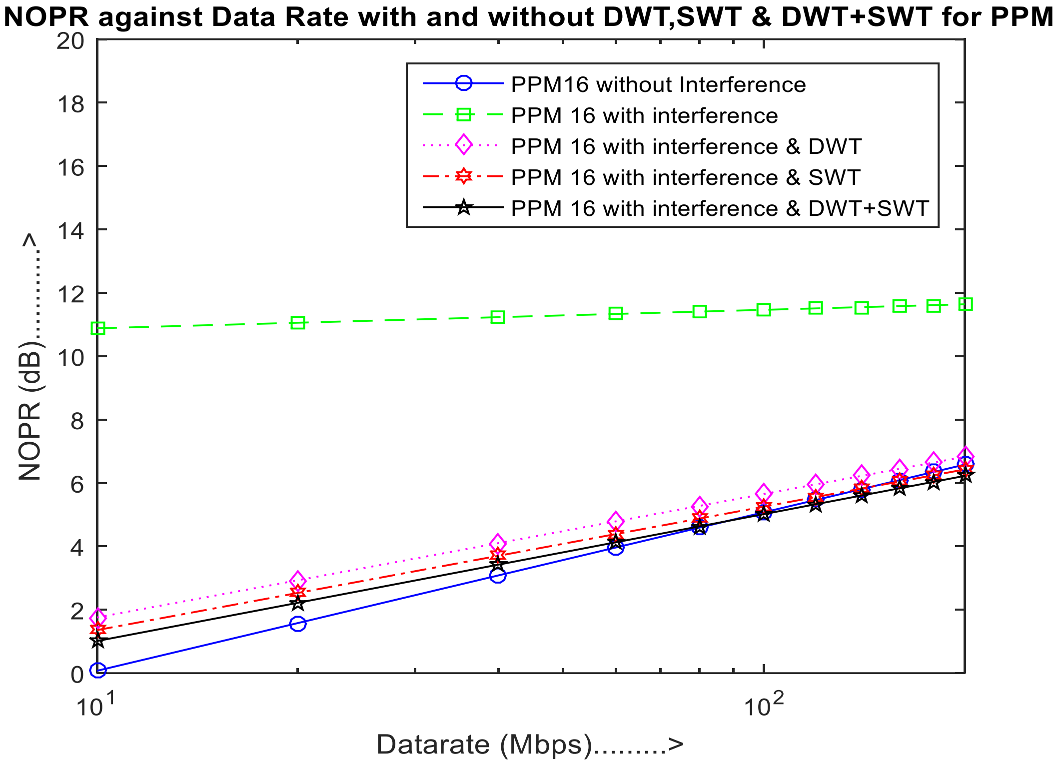

Figure 7 Comparison between NOPR vs Data rate

The comparison between three wavelet techniques for PPM-16 is given in figure 7. It can be illustrated from the figure that with DWT-SWT method the value of NOPR obtained was minimum when compared with SWT and DWT. Even the curve coincide the curve with no interference.Figure 8 represents the values of NOPR when data rate was increased to Gbps. With PPM-16 the value of NOPR is reduced for more than 14dB. Also the curves try to approach the linear curve which represents the NOPR without interference. Hence, PPM-16 showed marketable performance with decreased NOPR and interference.

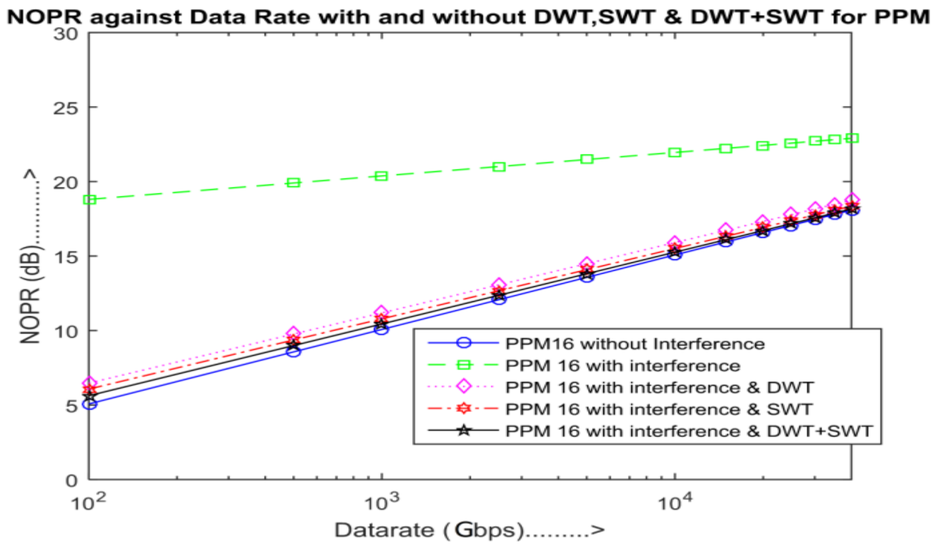

Figure 8 Comparison between NOPR vs Data rate

3 Conclusion

The results are computed using discrete wavelet transform, stationary wavelet transform and combination of DWT-SWT transform method for PPM modulation technique. Through SNR/ BER, efficiency and NOPR the performance of the system was computed for PPM and comparison was made between three wavelet transform techniques. Results obtained from DWT-SWT were improved as compared to those obtained from SWT and DWT in terms of efficiency, NOPR and SNR/BER.

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