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Performance Evaluation of 2D WxT Codes for OCDMA Systems in Noisy Environment

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***Abstract*—OCDMA is a multiple access technology for our next generation communication networks.The main issue of this paper is to devise a code set of good system performance. WxT -2D matrix codes for optical code-division multiple access (OCDMA) are of increasing interest because of their inherently high cardinality (code set size), high information spectral density (ISD), and ease of adapting WDM-like components for their implementation**

The basic idea of constructing a 2-D code is to assign temporal locations (time chips) of optical pulses to each spatial channel (or wavelength) in such a way that for any two distinct code words, there is a coincidence of optical pulses only at one spatial channel (or wavelength).Performance Analysis of 2D WxT Optical Orthogonal Codes for Incoherent Optical CDMA system for various system and code parameters is carried out under Noisy Environment.

Keywords-Optical Code Division Multiple Access, Optical Orthogonal Codes, Wavelength x Time two-dimensional optical orthogonal code (WxT 2-D OOC).

INTRODUCTION

For the OCDMA scheme to be more realistic, it is desired to devise an optical code that can accommodate a larger number of simultaneous users with a low error probability for a given code length.

In the last decades, various optical spreading sequences for OCDMA networks have been investigated and experimented. However, we only focus our attention on 2 D codes. By increasing the length of 1D code, the properties of the codes can be improved. But for a given chip width, the length of the code grows rapidly as the number of codes/weight of the code is increased and then the bit rate decreases. To overcome this problem 2 D codes have been reported. Moreover, the limit of 1-D optical codes is that out-of-phase autocorrelation cannot be zero because there are multiple optical pulses within one period. The lower limit of out-of-phase autocorrelation in the 1-D codes is 1, and to achieve it as in the OOC, code length increases rapidly as the number of users increases. To overcome the limit of the 1-D optical codes, 2-D approaches are proposed

In the 2-D optical codes, optical pulses are spread in both wavelength and time domains. By employing another dimension (wavelength), 2-D code with single pulse per row is achieved and the performance of the 2-D OCDMA system is much improved in comparison to the 1-D OCDMA system. Out-of-phase autocorrelation and cross-correlation of 2-D code families are equal to 0 and 1, respectively.

I. WXT 2 D CODE CONSTRUCTION

Codes which have

i) Reasonable weight to that a higher threshold value can be set at the receiver.

ii) low peak cross-correlation values to keep errors low, and

iii) low off-peak autocorrelation values for faster synchronization of transceivers.

Requirement of codes which have the above said characteristics along with good spectral efficiency and cardinality, motivated us to design WxT codes.

W/T codes reported so far can be constructed mainly into two types:

1) hybrid sequences: constructed by crossing one type of sequence with another and

2) matrix codes: conversion of 1-D sequences to 2-D sequences or the 2-D codes by construction

We have used the second method to generate 2 D WxT matrix code from 1-D prime codes by an optimum Golomb ruler.

The Fig. 1 depicts the optimum Golomb ruler D**(1,7)** of cardinality 1, weight 7, and length 26. Immediately below it is a table showing the ruler and three shifted versions, with filler zeroes to make up the code dimension (CD) of 32. The CD is determined as follows: The shifting of Golomb rulers described by Fig. 1 indicates that the result should be a matrix of dimensions r*C , where r*C>L. Here "r " is the number of rows, " C" is the number of columns, and "L" is the length of the Golomb ruler. There are then r*C-L possible shifts; thus the number of new matrices depends on the initial Golomb ruler length L as well as on the number of shifts permitted by the product r*C. The difference R*C-L should be equal to or greater than r-1 to assure that the matrix code set size is equal to the number of rows in the matrices.

D (1,7) =

0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

M(i) from D (1,7)

	C1				C2				C3				C4				C5				C6				C7				C8			
	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4	r1	r2	r3	r4
M1=	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
M2=	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
M3=	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
M4=	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0

M1

	c1	c2	c3	c4	c5	c6	c7	c8
r1	0	0	1	0	0	0	0	0
r2	0	0	0	0	0	0	1	0
r3	1	0	0	0	0	0	0	0
r4					1			

M2

	c1	c2	c3	c4	c5	c6	c7	c8
r1	0	0	0	0	0	1	0	0
r2	0	0	1	0	0	0	0	0
r3	0	0	0	0	0	0	1	0
r4	1	0	0	0	0	0	0	0

M3

	c1	c2	c3	c4	c5	c6	c7	c8
r1	0	1	0	0	0	0	0	0
r2	0	0	0	0	0	1	0	0
r3	0	0	1	0	0	0	0	0
r4	0	0	0	0	0	0	1	0

M4

	c1	c2	c3	c4	c5	c6	c7	c8
r1	0	0	0	0	0	0	0	1
r2	0	1	0	0	0	0	0	0
r3	0	0	0	0	0	1	0	0
r4	0	0	1	0	0	0	0	0

Figure 1: Construction of WxT Code Matrix OOC.

During the design process, the dimension "r " is chosen first and it's usually taken to be a multiple of two (2,4,8,12,16,32) because of photonic component (e.g., coupler, ribbon fiber, or WDM multiplexer/demultiplexer) characteristics. Returning to the example of Fig. 1 (given L=26 and assuming r=4 and trials C=7,8) r*C = 4*7=28 gives M=28-26+1=3, while r*C = 4*8=32 gives M= 4 (plus three shifts that do not produce new OOC matrices due to the cyclic nature of the operation). Increasing the CD by increasing the number of columns does not increase M , and it reduces the spectral efficiency. Thus, r = 4,32 with , 32 is the optimum CD, maximizing both the matrix code set size and the corresponding spectral efficiency. It should be pointed out that the ruler-to-matrix transformation increases the cardinality (code set size) from one (1) to four (4).

II. Performance Evaluation 2 D WxT Optical Orthogonal Codes

The general system behavior employing a range of 2-D TW codes with different code properties is considered taking into account BN, MAI, shot, thermal, and relative intensity noise (RIN).

P_d and P_i are the instantaneous optical chip powers for data and interferers at the photodetector, respectively. ω_d, is the frequency of the intended data chip corresponding to wavelength λ., crosstalk level parameter ξ be defined as the ratio of the average optical intensity of the decoded signal of interferers' chips to the desired data, i.e., $\xi = P_i/P_d$. For unity responsivity, the signal-to-noise ratio (SNR) for "1" and "0" bits considering thermal noise, shot noise, RIN, MAI, and BN are then given

$$SNR \cong \frac{R^2 P_{sr}^2 / p^2}{q\Delta f R P_{sr}[k+(N-1)] + \frac{\Delta f R^2 P_{sr}^2 kN}{2v^2\Delta f_c}((N-1)+k*k) + \frac{4K_b T_n F_n \Delta f}{R_L}}$$

Using Gaussian approximation, the bit error rate (BER) can be expressed as

$$P_e = \frac{1}{2} erfc\left(\sqrt{SNR/8}\right)$$

Where

$$erfc(x) = \frac{2}{\sqrt{\Pi}} \int_x^{\infty} e^{-u^2}$$

Also SNR can be expresed as

$$SNR = \frac{(w \bullet P_d + k' \bullet \xi \bullet P_d)^2}{\sigma_{th}^2 + \sigma_{sh}^2 + \sigma_{RIN}^2 + \sigma_{\text{int-int}}^2}$$

where

$$\sigma_{th}^2 = (4 \bullet K_B \bullet T \bullet B_e)/R_L$$

$$\sigma_{sh}^2 = 2 \bullet q \bullet (s \cdot w \cdot P_e + k' \cdot \xi \cdot P_d) \bullet B_e$$

$$\sigma_{RIN}^2 = RIN \bullet (s \cdot w \cdot P_e + k' \cdot \xi \cdot P_d)^2 \bullet B_e$$

$$\sigma_{\text{int-int}}^2 = 2 \bullet P_d \bullet P_i \bullet k' = 2 \bullet \xi^2 \bullet P_d^2 \bullet k'$$

"K_B" is Boltzman's constant, "T" is the absolute temperature in degree kelvin, "R_L" is the receiver load resistance, "B_e" is the receiver electrical bandwidth, and "q" is the electron charge. RIN is the RIN parameter (decibel per hertz). k' and k'' are the so-called signal-interferer beat and interferer-interferer beat parameters, respectively; their values are dependent on the distribution of wavelengths in the code family. k represents the total number of interferers' pulses that overlap ("hit") the active wavelengths in the desired codeword, while k is the sum of the combinational values of hits that have occurred at each wavelength of the desired codeword.

III. Analysis & Results

The spectral amplitude coding based optical CDMA system has been analyzed for Golomb ruler based 2 D WxT matrix optical orthogonal codes. The performance evaluation has been done for these codes using MATLAB 7.5 in terms of SNR and BER as a function of different code and system parameters.

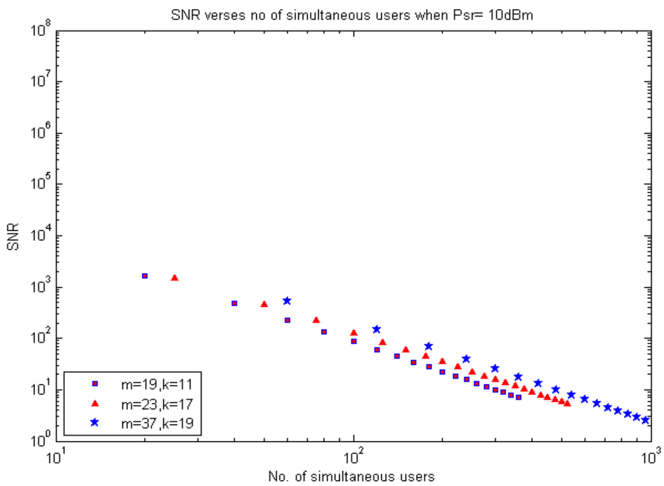


Figure 2: SNR versus number of simultaneous users at effective power P_{sr}= -10dB for different values of m and k .

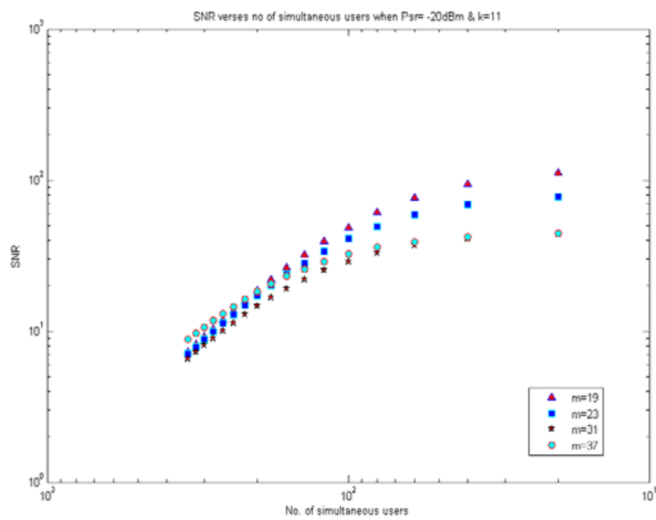


Figure 3: SNR versus number of simultaneous users at an effective power P_{sr}= -20 dB from each user for different values of different values of code parameter m when code weight k is fixed to 11.

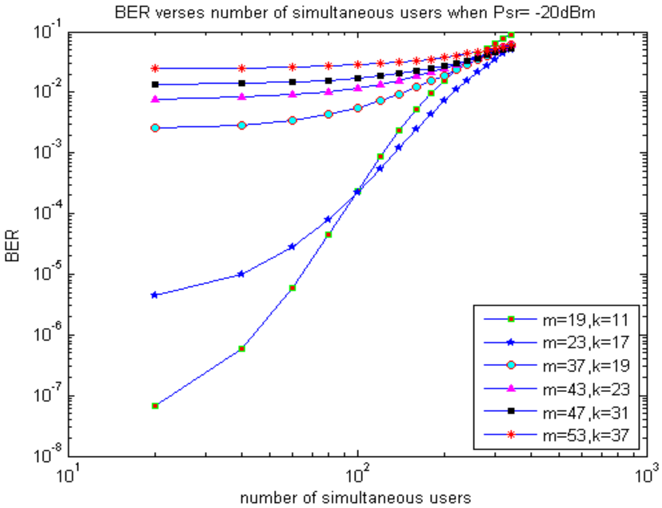


Figure 4: BER versus number of simultaneous users for an effective power P_{sr} = -20 dB for different code parameters m and k

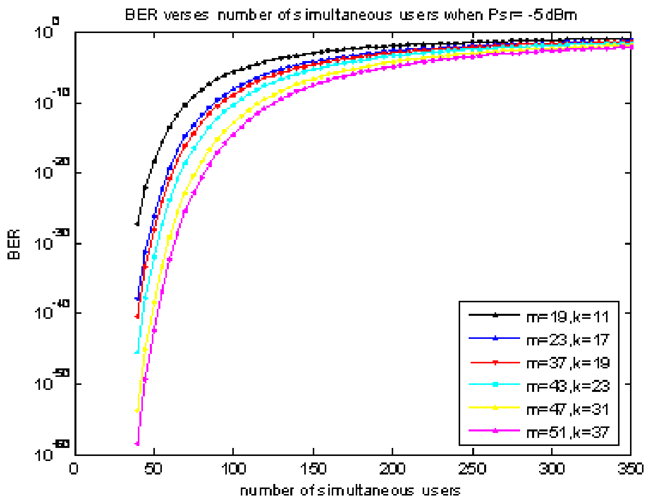


Figure 5: BER versus number of simultaneous users for an effective power P_{sr} = -5 dB for different code parameters m and k.

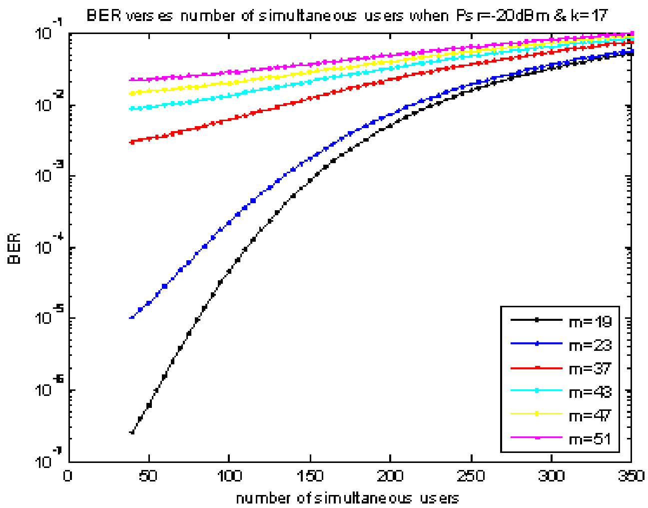
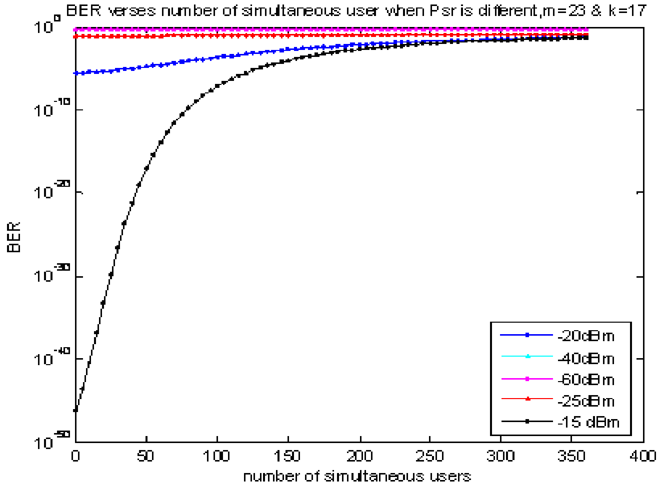


Figure 6: BER versus number of simultaneous users for effective power of -20 dBm for fixed code weight k=17.



t**Figure 7: BER versus number of simultaneous users for different values of effective power when code parameters m and k are 23 and 17 respectively.**

Fig. 2 and Fig 3 is showing the relationship between signal to noise ration (SNR) and number of simultaneous users at different values of code parameters m and k for Golomb based WxT OOC. Each curve ends at the point where number of users becomes equal to m^2. It is clear from figures the SNR decreases as the number of users' increases. Increase in effective power from each user helps to improve SNR significantly. More effective power from each user contributes in making detection process easier.

Fig. 4 and 5 are showing variations in bit error rate (BER) as a function of simultaneous users for different values of m and k at P_{sr} -20dB, -5dB, respectively. The BER performance degrades as the number of simultaneous users' increases. At minimum acceptable bit error rate (BER) of 10^9, system can accommodate 135 users with each having effective power of -10dB.The increase in code length by designing codes with large values of m and k causes intensity of optical pulse to spread over longer time and therefore instantaneous intensity contained by optical pulses reduces. This reduction in instantaneous intensity results decrease in the probability of false detection. But, this further increases hardware complexity. On reducing effective power from each user, bit error rate increases. For example, bit error rate for m=53 and k=37 at P_{sr} = -5 dB is10^{-38} increases to 10^{-7} for the same code parameter with P_{sr}= -20dB.

Fig.6 and 7 are showing variations in BER with respect to the number of simultaneous users for different values of effective power $P_{sr.}$ for fixed number of users with P_{sr} > -20dBm, system performance improves drastically. For example, with 20 simultaneous users with m=53 and k=37 bit error rate for P_{sr}=-20dBm reduced to 10^{-2} to 10^{-10} with P_{sr}=-15dBm for same values of m and k. it can be also be observed that more number of users can be accommodated with lesser bit error probability by increasing effective power from each users.

The increase in code weight causes increase in the transmitting signal power which further helps in reducing multiple user interference and therefore improvement in bit error probability.

The next few graphs are showing the effect of various noises when code matrix is employed to spectral encoded incoherent optical code division multiple access system

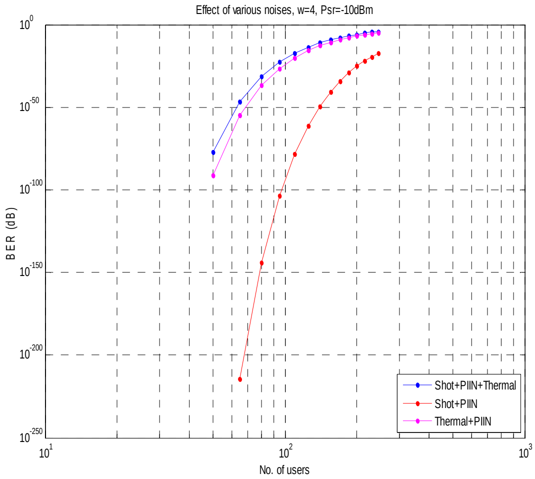


Fig 8: Effect of shot, thermal and PIIN noise with code weight 4 & Psr= -10dBm

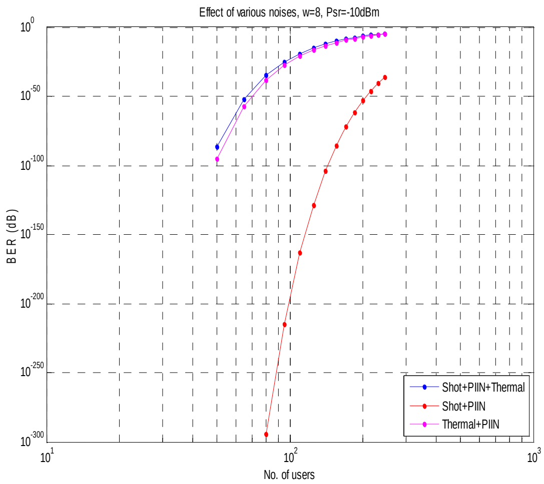


Fig 9: Effect of shot, thermal and PIIN noise with code weight 8 & Psr= -10dBm

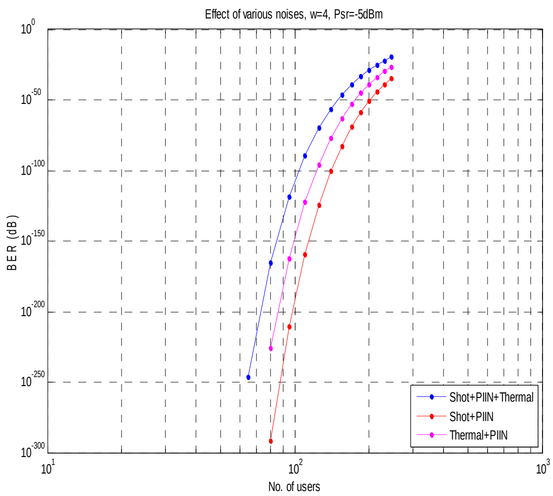


Fig 10: Effect of shot, thermal and PIIN noise with code weight 4 & Psr= -5dBm

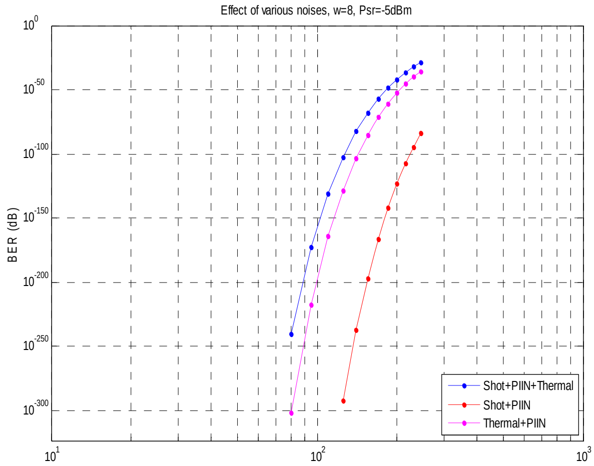


Fig 11: Effect of shot, thermal and PIIN noise with code weight 8 & Psr= -5dBm

From Figure 8 and 9 in comparison with Figure 10 and 11 it is clear that when effective power from each user is not very large, irrespective of the code weight, effect of shot noise is very small. Thermal noise is bit high in comparison with shot noise. Therefore, proper cooling arrangements must be done for optical system set up especially for the laser and its driver circuitry to avoid the excessive heating and therfore to reduce the thermal noise.

It is also very clear from these graphs that when effective power from each user is large, both shot noise and thermal noise are negligibly small compared with the intensity noise, which becomes the main limitation factor of the syetm performance. However, when effective power from each user is low, the effect of intensity noise becomes minimum, and , hence, the thermal noise becomes the main factor that limits the system performance. It can also be concluded from these graphs that thermal noise is much more influential than shot noise on the system performance.

IV. Conclusion

The analysis has been done for various code parameter and system parameters like code weight, code length, auto and cross correlation properties of the code, effective user power, number of simultaneous users and for variable data rate. In addition to these above stated parameters different noises like shot noise, Phase Induced Intensity noise (PIIN) and thermal noise. It has been observed for Golomb's 2 D WxT OOC that an increase in effective power from each user helps to improve SNR significantly. It is clear from simulated results that using small values of code weight significant reduction can be made in optical power losses and hardware complexity. Moreover, as the code parameters (m and k) increases SNR improves This comes from the fact that code weight helps in detection process which increase SNR. It is clear that BER can be improved by increasing code weight only while keeping rest of the parameters constant. For example with m=53 bit error rate improves from 10^{-8} to 10^{-13} as code weight increases from 7 to 37 for 50 simultaneous users.

It is also clear from the simulated results that system performance degrades radically as we accommodate more number of users.

An increase in the effective power from each user doesn't help much to overcome the effect of phase induced intensity noise. it is clear that effect of noises become more severe as the number of subscribers increase. When P_{sr} is large, both the shot noise and thermal noises are negligibly small compared with the intensity noise, which is the main limitation factor of the system performance.

The effective power from each user and the sequence code weight are two very important factors which contribute to phase induced intensity noise (PIIN) the tradeoff must be set before hand for transmitting and receiving parties for the optical CDMA to work effectively. With higher code weight and effective power > -5dB advantages as it increases the value of auto correlation peak when transmitter and receiver are properly synchronized and therefore reduction in bit error rate. when effective power from each user is not very large, irrespective of the code weight, effect of shot noise is very small. Thermal noise is bit high in comparison with shot noise. Therefore, proper cooling arrangements must be done for optical system set up especially for the laser and its driver circuitry to avoid the excessive heating and therfore to reduce the thermal noise.When effective power from each user is large, both shot noise and thermal noise are negligibly small compared with the intensity noise, which becomes the main limitation factor of the syetm performance. However, when effective power from each user is low, the effect of intensity noise becomes minimum, and , hence, the thermal noise becomes the main factor that limits the system performance.

REFERENCES

[1]. Gurjit Kaur, “Performance Comparison of W/T Matrix with Variable Code Parameters for OCDMA System,” ICTON 2008

[2] Taher M. Bazan, David Harle Performance Analysis of 2-D Time-Wavelength OCDMA Systems With Coherent Light Sources: Code Design Considerations Journal Of Lightwave Technology, Vol. 24, No. 10, October 2006.

[3] Sun Shurong, Hongxi Yin, Ziyu Wang, and Anshi Xu “A New Family of 2-D Optical Orthogonal Codes and Analysis of Its Performance in Optical CDMA Access Networks,” Journal Of Lightwave Technology, Vol. 24, No. 4, April 2006.

[4] Djafar K. Mynbaev, Lowell L. Scheiner, “Fiber optic communications technology”, Pearson Education, India, 2003.

[5] Antonio J. Mendez, Robert M. Gagliardi, Vincent J. Hernandez, Corey V. Bennett and William J. Lennon “Design and Performance Analysis of Matrix Codes for Optical CDMA” Journal Of Lightwave Technology, Vol. 21, No. 11, Nov 2003

[6] W.C. Kwong and G.C.Yang, “Construction of 2 N prime sequence codes for optical code division multiple access, IEE proc. Commun., vol. 142, No. 3, pp. 141-150, 1995

[7] H. M. H. Shalaby,” Performance analysis of optical Synchronous CDMA communication systems with PPM signaling,” IEEE trans. Commun., vol. 43, pp. 624-34, Feb-apr.1995.

[8] Z. Kostic and E. L. Titlebaum, “ The design and performance analysis for several new classes of codes for optical synchronous CDMA and for arbitrary- medium time hopping synchronous CDMA communication systems, IEEE Trans. On commun., vol. 42, no. 8, pp. 2608-17, 1994.

[9] Azizoglu M, Salehi J A and Li Y, “Optical CDMA via temporal codes,” IEEE Trans. Commun. Vol.40, pp. 1162–70, 1992.

[10] W.C. Kwong, P.A. Perrier and P.R. Prucnal, “Performance comparison of asynchronous and synchronous code-division multiple-access techniques for fibre-optical local area networks,” IEEE Trans. Commun.,vol.39, pp. 1625–34, Nov. 1991.