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Performance Evaluation of Optical Combinatorial Code For Potentially Increasing Number of Users

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***Abstract*— In this paper the performance evaluation has been done for combinatorial code for different system and code parameters under noisy optical channel conditions for potentially increasing number of users for optical code division multiple access system. It has been observed that code weight and effective power from each user are two main factors to decide the system performance.**
Keywords- Optical Code division Multiple Access (OCDMA), Optical Orthogonal Code (OOC), Phase Induced Intensity Noise(PIIN),Signal to Noise Ratio(SNR),Bit error Rate(BER).

I. INTRODUCTION

The technical challenge to today's communication network systems is for more information carrying capacity since the volume of information produced increases rapidly. Between the years 2000-2006 the volume of generated data grew from 3 billion to 160 billion Gigabytes. With the substantial growth in data traffic, the need for higher capacity optical systems increases.
The process of optical to electrical and electrical to optical conversion in fiber-optic-based optical networks for signal processing does not allow users to exploit the full potential of single mode optical fiber's bandwidth because of the limited speed of electronic signal processors. Optical components offer much higher speeds for optical signal processing than their electrical counterparts. Therefore, a desirable feature for next generation all-optical networks is their ability to perform signal-processing functions in optical domain whenever required.
Optical Code Division Multiplexing Access (OCDMA) is one class of such promising technology that takes advantage of excess bandwidth in single mode optical fiber to map low information rate into high rate optical sequences followed by optical transmitter to obtain random, asynchronous access without centralized control among users [1]. The optical CDMA has attracted much attention for various LAN applications due to its advantageous features like Simple, random and simultaneous access protocol, suitability for multimedia applications, security, no need of strict timing and wavelength control, utilization of bandwidth, immunity to various noises etc. [2].
A typical Optical CDMA communication network in star configuration is as shown in Fig.1.Users communicate by superimposing their message bits upon their unique address sequences, which they transmit asynchronously over a common channel.

Discrimination between them is achieved by assigning minimally interfering spread sequences to each user, selected from a family of so called optical orthogonal codes (OOC's). Depending upon the code dispreading procedure at the receiver OCDMA systems can be classified as Incoherent and Coherent OCDMA systems. Coherent OCDMA systems need complex receiver structures to perform code dispreading correctly. This requires vital choice of optical components and more complex circuitry than incoherent OCDMA systems. Incoherent OCDMA systems are comparatively simple and are based on Intensity modulated direct detection schemes for receiving data. It makes data dispreading simpler and cost effective [3].

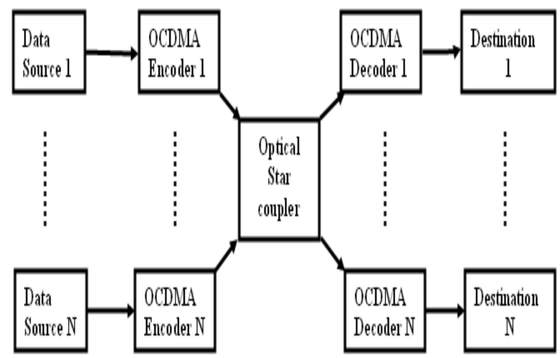

Fig 1. Optical CDMA communication network in star configuration with "N" Transmitters/ Receivers.

II. OPTICAL COMBINATORIAL CODE

The key to an effective CDMA system is the choice of efficient address code sequences with excellent autocorrelation and cross correlation properties for encoding and decoding of the source bits. An optical orthogonal code (OOC) is a family of (0, 1) sequence with good auto and cross correlation properties. The auto correlation amplitude must be very high and in phase cross correlation amplitude between two sequences must remain as low as possible [1]. The high value of auto correlation amplitude facilitates the detection of the desired signal under noisy conditions and low cross correlation amplitude helps in reducing interference from other users. Extensive research has been made to find out the suitable optical orthogonal codes for non-coherent optical CDMA systems.
Recently Hassan Yousif Ahmed et. al. had proposed combinatorial code based on the combination of specific vectors with combinatorial theories[5]. Simplicity of code construction, flexibility of choosing the number of users and weights, make our proposed system strong candidate for future networks. This paper analyzes zero vector combinatorial codes for spectral amplitude coding based optical CDMA system. An investigation of detrimental effects on OCDMA is presented, showing the effect of effective power from each user, code weight, various noises like shot noise, thermal noise and Phase induced intensity noise (PIIN) on bit error rate. The simulated performance

of intensity modulation technique is presented using 80 MHz electrical bandwidth at 1550 nm.
The performance evaluation has been done for these codes using MATLAB 7.1 in terms of BER as a function of different code and system parameters. Each of the simulation plots shown in this paper were produced using MATLAB simulation script

III. SYSTEM PERFORMANCE ANALYSIS

Spectral Amplitude Coded Optical CDMA system is limited by interference between incoherent sources. The novel Fiber Bragg Grating (FBG) based balanced detection scheme is used for here multi user interference (MUI) cancellation. This balanced detection scheme is helpful to eliminate multi user interference completely. The signal to noise ratio (SNR) and bit error rate (BER) performance for incoherent SAC optical CDMA has been investigated for zero in phase based o cross correlated optical orthogonal code using a method suggested in [4].

It has been assumed that multi user interference (MUI) is mainly due to thermal noise, shot noise and phase induced intensity noise (PIIN). The effect of dark current for photodiodes is negligible and therefore has been neglected here**.** The parameters used in our analysis are listed in Table I.

TABLE I. SYSTEM PARAMETERS

parameter	***value***	***unit***
Line width of Source	3.75	THz
Operating Wavelength	1550	nm
PD quantum efficiency	0.6	--
Rx. Noise Temperature	300	K
Load Resistance	1030	Ohm
Data Rate	155	Mbps
Electrical bandwidth	80	MHz
Line width of Source	3.75	THz

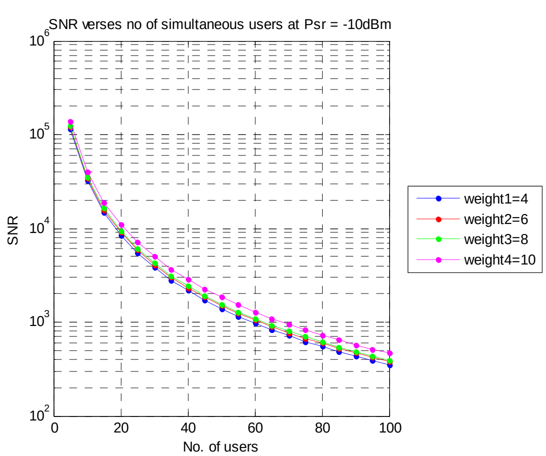

Fig. 2: SNR verses no. of simultaneous users, psr= -10dBm

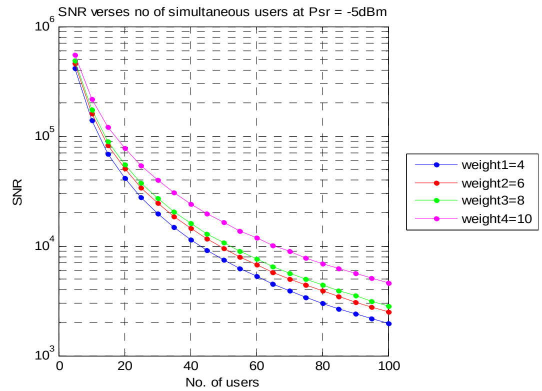

Fig. 3: SNR verses no. of simultaneous users, psr= -5dBm

Fig.2 & Fig. 3 are showing the effect of simultaneous users for given code weight on signal to noise ratio. It is very clear from the figure that signal to noise ratio is very high for lesser number of user and decrease drastically with an increase in number of users. Four different values have taken into consideration i. e w=4, w= 6, w= 8 and w=10 for different values of effective power. It is clear from the figure that code weight is an important parameter to decide the performance of optical CDMA as it improves the signal to noise ratio by increasing code weight from w=4 to w=20. This is also due to the fact that code weight is basically representing number of 1's in code sequence. More is the number of 1's in sequence more will be the auto correlation peak and by suitably selecting threshold value noise can be reduced significantly and signal to noise ratio of the system can be improved.

The BER is the likelihood of a bit misinterpretation at receiver of any kind of communication system while transmission in noisy channel. For the system taken into consideration here, i. e. spectral encoded incoherent optical code division multiple access system, BER depends upon several factors like, code weight, code length, effective power from each user, number of users simultaneously accessing the optical channel and data rates from users. For a typical optical CDMA system the minimum acceptable BER is 10^{-9}.

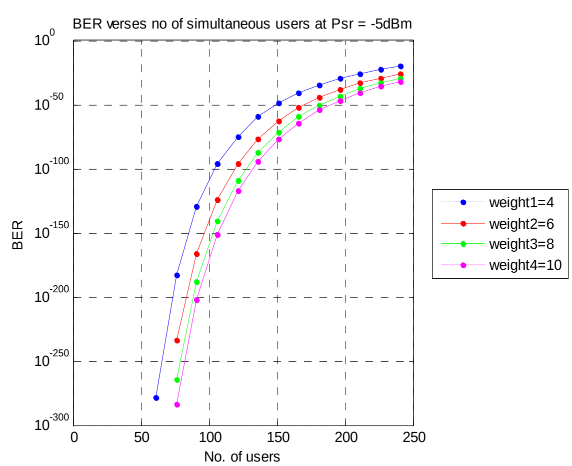

Fig. 4: BER verses no. of simultaneous users at Psr= -5 dB

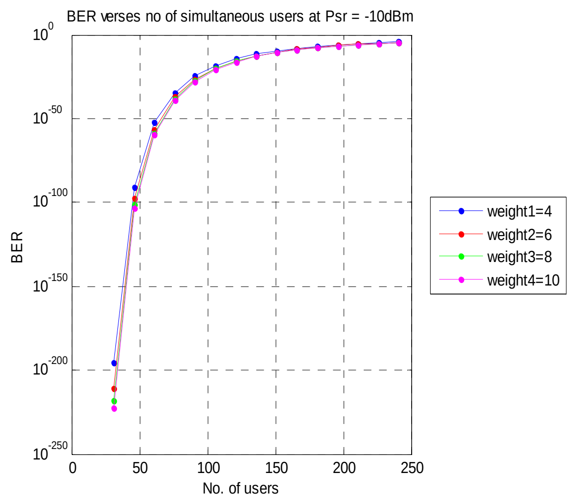

Fig. 5: BER verses no. of simultaneous users at Psr= -10 dBm

Fig. 4 & Fig.5 are showing the effect of code weight on bit error rate for increasing number of users when effective power from each user is changing. It is clear from the figure that BER is far lesser than 10-9 for 100 numbers of simultaneous users even if we increase the code weight from 4 to 8 and so on. It is also clear from these figures that better response can be obtained by increasing the effective power from each user. For example by increasing the effective power of user (at receiver) from -10 dBm to -5 dBm, the drastic improvement in bit error rate could be seen.

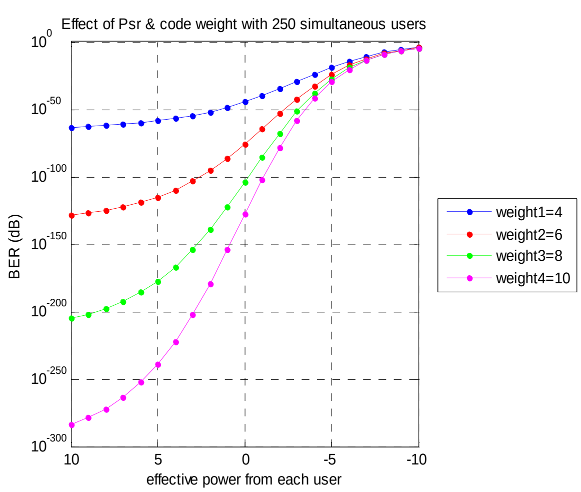

Fig. 6: Effect of Psr & code weight

From Fig.6,the effect of code weight is observed over range of effective power. It is quite clear from these graphs that when more number of users is trying to access the optical channel with significant effective power received at receiver the bit error rate is reduced significantly. This constraint can be used effectively hard limiter is the requirement for particular application for which these codes are employed whereas if the smallest power received from each user is worth detection for specific application (i.e. the case with soft limiting) bit error rate is comparatively high.

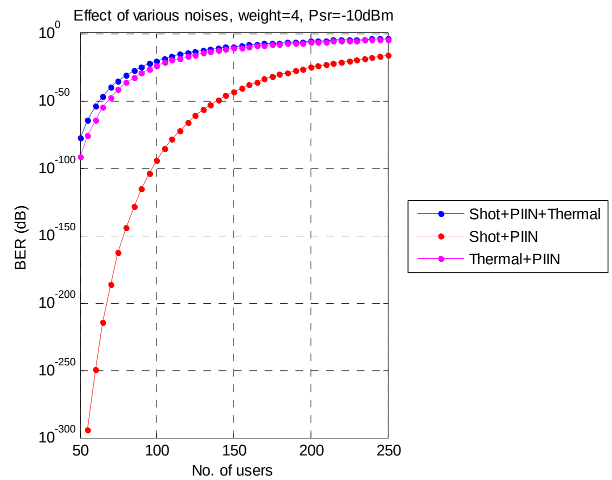

Fig. 7: Effect of various noises on BER, Psr=-10dBm

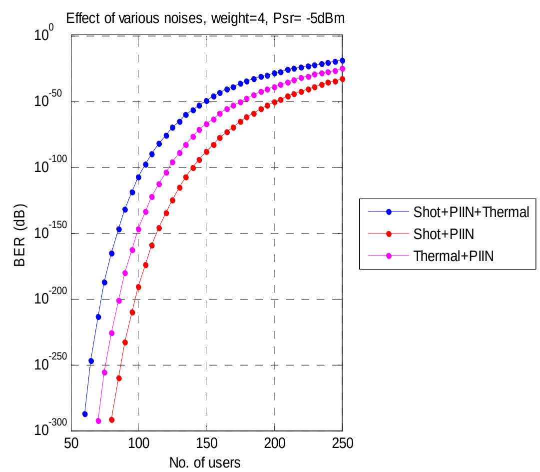

Fig. 8: Effect of various noises on BER, Psr=-5dBm

From fig. 7 & fig. 8, it is clear 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 system performance. However, when effective power from each user is low, the effect of intensity noise becomes small in comparison with other two types of noises. The reason behind this is, when each user try to access the optical channel with strong intensity signal at receiver, contribute towards interference and these interfering signals with higher intensity at receiver cause signal to noise ratio to reduce drastically. As a result bit error rate boost high. It can also be concluded from these graphs that thermal noise is much more influential than shot noise on the system performance.

IV. CONCLUSION

Based on the simulation results conclusion may be drawn that signal to noise ratio is very high when less number of users are trying to access the optical channel simultaneously. Code weight doesn't influence the system performance much as long as the effective power from each user is fixed and less.

It may also be concluded that 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.

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