Investigations on OCDMA System under Effect of Timing Jitter

Manmeet Kaur[1], Monika Aggarwal[2]

Student, M.tech Electronics and Communication section, Bhai Gurdas Instituite of Engg. & Technnology, Sangrur, India[1]

Associate Prof., M.tech Electronics and Communication section, Bhai Gurdas Instituite of Engineering & Technology, Sangrur, India[2]

Abstract: This paper focuses on the BER, Q-Factor, Eye Height for a four user OCDMA with varying jitter. Performance of the OCDMA communication system has been evaluated in terms of bit error rate, Q-factor and eye closure with jitter varying from 0 Unit-Interval to 0.7 Unit-Interval in steps of 0.1 Unit-Interval. Simulations were carried out using commercially available simulator from Gigasoft, OPTIWAVE.

Keywords: Bit Error Rate (BER), Jitter, Optical Code Division Multiple Access (OCDMA), Optiwave, Q-Factor (QF).

I. INTRODUCTION

Optical code division multiple access (OCDMA) has been recognized as one of the most important technologies for supporting many simultaneous users in shared media, and in some cases can increase the transmission capacity of an optical fiber. OCDMA has distinctive features that include possibility of full asynchronous communication, enhanced security and a soft variation of the system properties to the number of users. However, for improperly designed codes, the maximum number of simultaneous users and the performance of the system can be seriously limited by the crosstalk from other users. For this reason, various code families have been suggested, from the one-dimensional (1D) optical orthogonal code (OOC) to the recent two-dimensional (2D) codes [1]. In Code Division Multiple Access (CDMA) has been widely used as a multichannel access technology in wireless networks such as the cellular phone system for several years because of its resilience to multiuser interference and graceful degradation under heavy load. Its use on an optical link has been studied extensively [2]. However, several concerns have been expressed about the use of spread spectrum on an optical link However; several concerns have been expressed about the use of spread spectrum on an optical link due to low network throughput. The primary difference between wireless and optical CDMA is that optical fiber is intensity medium. A pulse of light is used to transmit a signal. Code-division multiple-access (CDMA) is a spread spectrum technique, which has been well researched and implemented in mobile radio communications employing electrical signal processing. In this approach each receiver on the network is assigned a unique 'address' sequence that is approximately orthogonal to the sequences assigned to all other receivers. Data bits to be transmitted are then modulated by the assigned sequence of the targeted receiver before being sent. The targeted receiver in turn detects the incoming data by correlating it to its own address sequence. It is possible for a number of users to simultaneously access the network as long as the total sum of the cross-correlations of the approximately orthogonal sequences to the targeted receiver is not excessive. In CDMA systems, the transmitted spectrum of CDMA signals is broader, than the spectrum of the original data. In order to accommodate many subscribers and a large number of simultaneous users, long sequences or large spreading factors are required. However, the available bandwidth in radio channels is normally strictly limited by regulatory authorities, hence; the use of long sequences is not possible. Although copper cables are not subject to this restriction, their bandwidth is generally insufficient for large networks. In contrast, single-mode optical fibers have enormous bandwidths and the limitations of radio and copper-cable CDMA systems are effectively eliminated. Therefore, in such optical systems, spreading factors can, in principle, be increased to very high values [3]. Hence, CDMA techniques can be implemented in fiber optic networks with a large number of users to provide ultra-fast communications and achieve very high throughput. As discussed earlier, the roots of OCDMA are found in spread spectrum communication techniques. Spread spectrum technology is based on the idea of spreading the spectrum of the narrow band message over a much wider frequency spectrum by means of digital codes. Due to the spreading, the transmitted signal arrives at the receiver as a noise like signal[11]. And message recovery is impossible unless the original code is known. The received signal is correlated by the authorized receiver with a local code, which is a replica of a transmission code.

II. TIMING JITTER

The timing jitter is a problem in optical communication systems, which has been observed to have great impact on an optical link design for higher data rate. Timing jitter refers to the short term varations of significant instants of a digital signal from their ideal position in time here short term implies phase oscillation of frequency greater than or equal to 10hz.Timing jitter may lead to crosstalk and distortation of the orginal analog signal and is potential source of slips at the input port of the digital system.Jitter can cause undesirable effects in a OCDMA system and amount of tolerable jitter depends on the affected application. During the last two decades, two books were published with significant space dedicated to jitter analysis.[5], [6] During that time, most communication architectures operated at a data rate of less than 1 Gb/s. Jitter was not as serious then as it is today, when most leading communication links are running at rates of 1 to 10 Gb/s. The book by Trischitta & Varma[5] in 1989 was mostly focused on the accumulated jitter in a network system and jitter related to some specific components in an optical network at the time, including regenerators, retimers, and multiplexers. The book by Takasaki[6] in 1991 treated digital transmission design and jitter in the same context. The major point of Takasaki on jitter classification is that there are two types of jitter: random and systematic. However, it has no quantitative math model discussion on the jitter classification scheme. The discussion of jitter accumulation is largely based on the repeater component in a network. In the past 15 years, significant progress has been made in the field of understanding jitter, and related new theory, definition, analysis methods, and measurement tools. In particular, more rigorous definition of and theory about jitter and its associated jitter components have been developed (such as [4], [7], and [8], to name a few). Now jitter and noise component concepts have been widely accepted and adopted by many serial data communication standards.

III. SIMULATION OF FOUR USER OCDMA SYSTEM

Simulation set-up for four user OCDMA system has been developed using Optiwave tool. The tool is useful in analyzing nonlinear effects with respect to dispersion, noise, jitter etc. Performance of four user OCDMA system will be analyzed by using BER, Eye Height and Q-Factor parameters by using Optiwave tools like spectrum analyzer, scopes (electrical and optical) and signal analyzer.

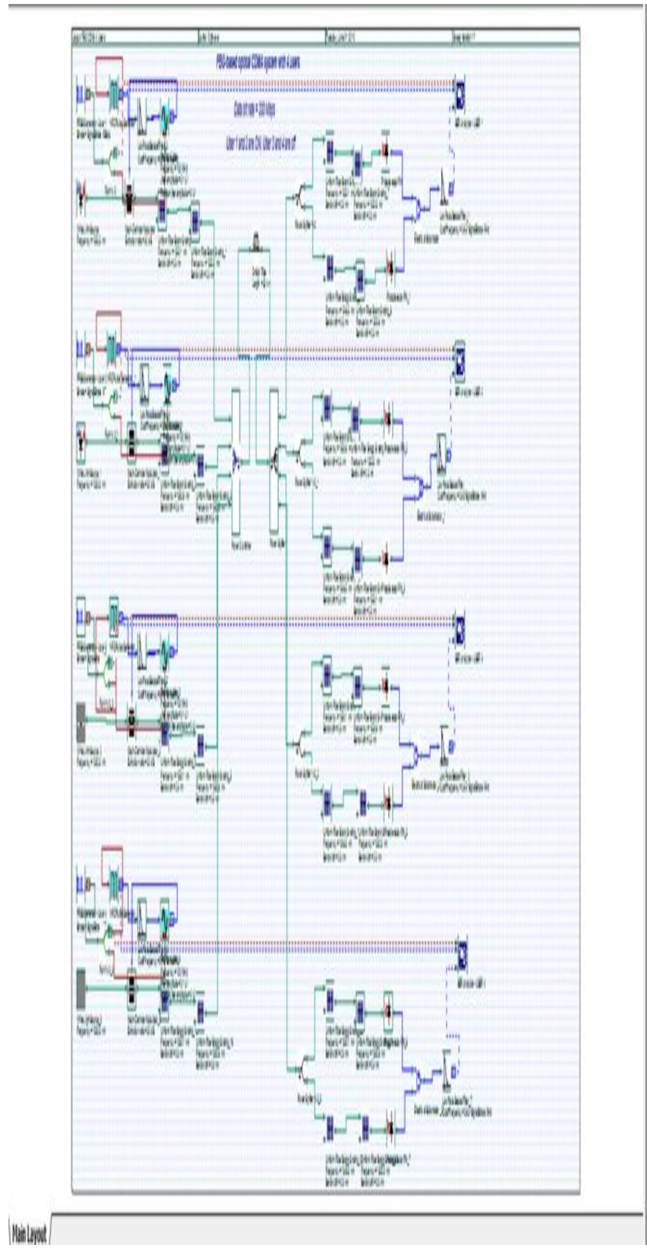

Fig.1: Screen shot of four user OCDMA system

IV. RESULTS AND DISCUSSIONS

Two optical fibers with following parameters have been taken to study the effect of timing jitter.

Optical Fiber 1 with reference wavelength=1550 nm, attenuation=0.2 dB/km, dispersion=16.67 ps/nm/km, dispersion slope=0.075 ps/nm^2/k, differential group delay=0.2 ps/km.

Optical Fiber 2 with reference wavelength=1550 nm, attenuation=0.0002 dB/km, dispersion=8.37 ps/nm/km, dispersion slope=0.037 ps/nm^2/k, differential group delay=0.002 ps/km.

TABLE 1: Variation of BER with Jitter for different fibers with different lengths

Jitter (UI)	Bit Error Rate (BER)							
	20 Km		30 Km		40 Km		50 Km	
	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2
0	2.34E-24	1.17E-25	4.40E-17	1.26E-44	3.90E-08	3.11E-16	0.000134	4.20E-45
0.1	7.38E-27	1.83E-026	4.64E-13	8.26E-18	4.14E-08	1.08E-15	0.000298	1.57E-25
0.2	2.38E-38	8.49E-68	2.16E-09	1.05E-18	2.99E-08	1.92E-41	0.000119	1.39E-49
0.3	7.43E-26	2.46E-26	1.47E-13	1.25E-19	1.99E-07	5.13E-06	1.04E-06	2.48E-22
0.4	8.06E-18	1.22E-48	4.82E-12	1.17E-27	3.67E-08	5.84E-19	0.00036	4.58E-37
0.5	3.01E-43	4.85E-23	4.42E-15	3.69E-55	4.52E-10	5.61E-19	0.009669	3.06E-15
0.6	2.74E-28	4.55E-34	1.45E-12	5.86E-22	3.38E-09	3.83E-21	0.000187	6.78E-15
0.7	4.42E-02	2.21E-02	1.00E+00	6.29E-03	1.00E+00	2.80E-03	1	1.62E-02

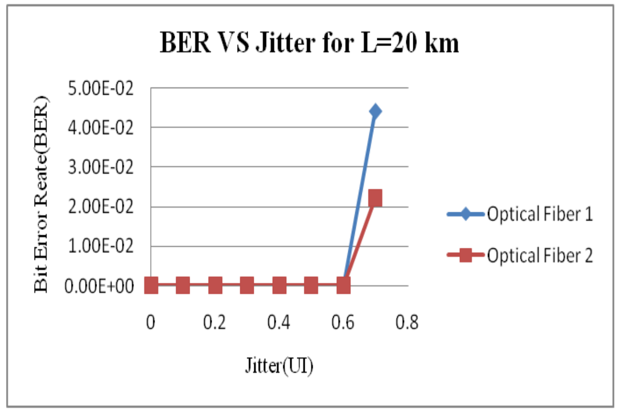

Fig 2: Variation of BER with Jitter for L=20 km

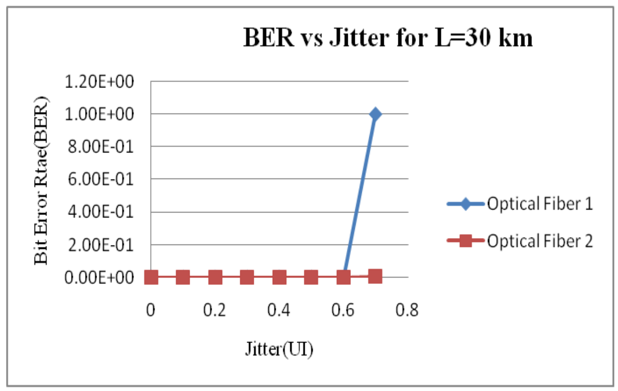

Fig 3: Variation of BER with Jitter for L=30 km

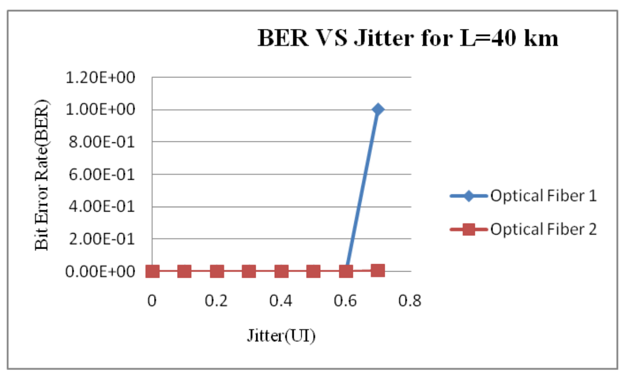

Fig 4: Variation of BER with Jitter for L=40 km

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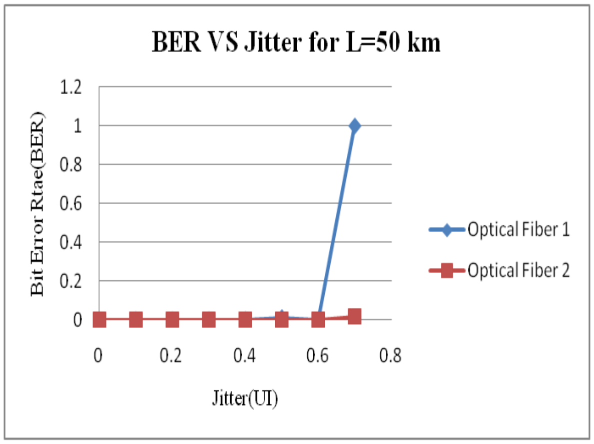

Fig 5: Variation of BER with Jitter for L=50 km

From Figures 2-5 and Table 1 as the value of jitter is increased from 0 unit-interval to 0.7 unit-interval, the value of BER varies from 2.34E-24 to 4.42E-02 and 1.17E-25 to 2.21E-02 for L=20 km, from 4.40E-17 to 1.00E+00 and 1.26E-44 to 6.29E-03 for L=30 km, from 3.90E-08 to 1.00E+00 and 3.11E-16 to 2.80E-03 for L=40 km and from 0.000134 to 1 and 4.20E-45 to 1.62E-02 for L=50 km for Optical Fiber 1 and Optical Fiber 2 respectively.

TABLE 2: Variation of Q-Factor with Jitter for different fibers with different lengths

Jitter (UI)	Q-Factor							
	20 Km		30 Km		40 Km		50 Km	
	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2
0	10.11	10.39	8.31	13.96	5.37	8.07	3.62	14.03
0.1	10.65	10.56	7.12	8.49	5.36	7.91	3.42	10.37
0.2	12.89	17.35	5.86	8.73	5.41	13.43	3.67	14.75
0.3	10.44	10.54	7.29	8.97	5.06	8.27	4.74	9.63
0.4	8.50	14.60	6.79	10.82	5.38	8.81	3.37	12.66
0.5	13.73	9.79	7.74	15.59	6.12	8.80	3.07	7.79
0.6	10.96	12.10	6.97	9.53	5.79	9.34	3.55	7.68
0.7	1.67	2.00	0	2.49	0	2.75	0	2.12

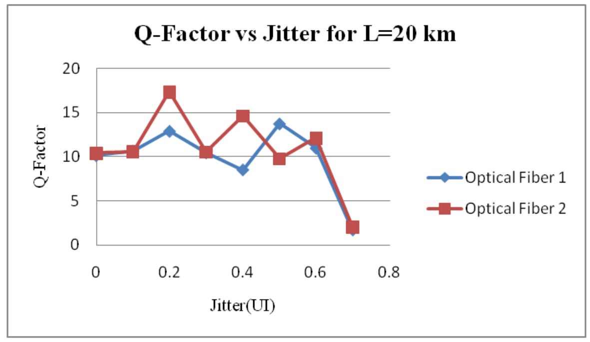

Fig 6: Variation of Q-Factor with jitter for L=20 km

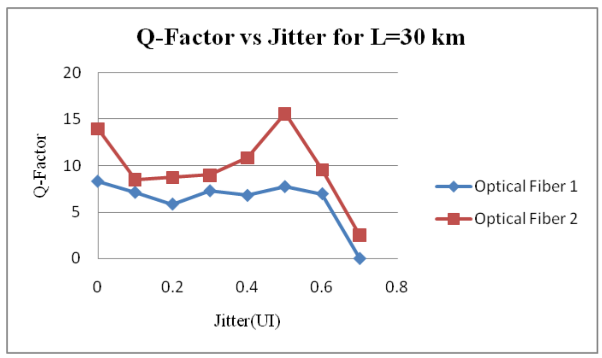

Fig 7: Variation of Q-Factor with Jitter for L=30 km

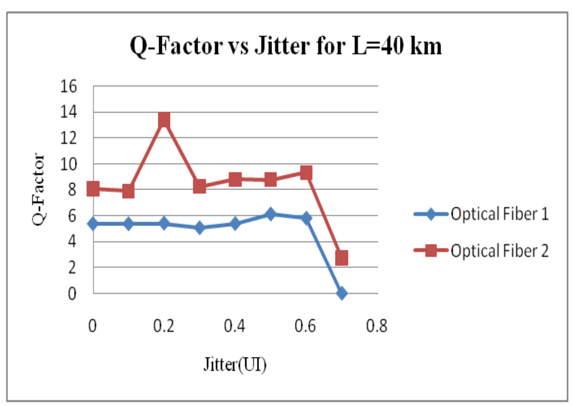

Fig 8: Variation of Q-Factor with Jitter for L=40 km

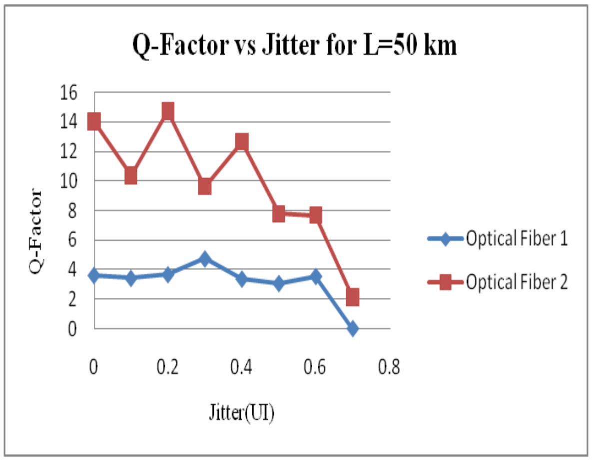

Fig 9: Variation of Q-Factor with Jitter for L=50 km

From Figures 6-9 and Table 2 as the value of jitter is 0 unit-interval to 0.7 unit-interval, the value of Q-Factor varies from 10.11dB to 1.67dB and 10.39dB to 2.00dB for L=20 km, from 8.31dB to 0dB and 13.96dB to 2.49dB for L=30 km, from 5.37dB to 0dB and 8.07dB to 2.75dB for L=40 km and from 3.62dB to 0dB and 14.03dB to 2.12dB for L=50 km for Optical Fiber 1 and Optical Fiber 2 respectively.

TABLE 3: Variation of Eye Height with Jitter for different fibers with different lengths

Eye Height								
Jitter (UI)	20 Km		30 Km		40 Km		50 Km	
	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2	Optical Fiber 1	Optical Fiber 2
0	2.07E-06	5.23E-06	1.12E-06	5.62E-06	4.96E-07	4.62E-06	1.25E-07	5.74E-06
0.1	2.09E-06	5.03E-06	1.08E-06	4.62E-06	5.17E-07	4.48E-06	7.25E-08	5.21E-06
0.2	2.13E-06	6.01E-06	8.85E-06	4.64E-06	5.02E-07	5.55E-06	1.24E-07	5.51E-06
0.3	2.09E-06	5.21E-06	1.03E-06	5.00E-19	4.61E-07	4.54E-06	2.95E-07	4.93E-06
0.4	1.82E	5.58E	9.83E	5.24E	5.10E	4.63E	7.93E	5.24E

	-06	-06	-06	-06	-07	-06	-08	-06
0.5	2.17E-06	4.89E-06	1.08E-06	5.62E-06	5.88E-07	4.97E-06	1.45E-08	4.47E-06
0.6	2.01E-06	5.23E-06	1.08E-06	4.87E-06	5.26E-07	4.59E-06	9.49E-08	4.36E-06
0.7	-3.50E-06	-5.47E-07	0.00E+00	-2.12E-07	0.00E+00	-9.69E-08	0.00E+00	-4.46E-06

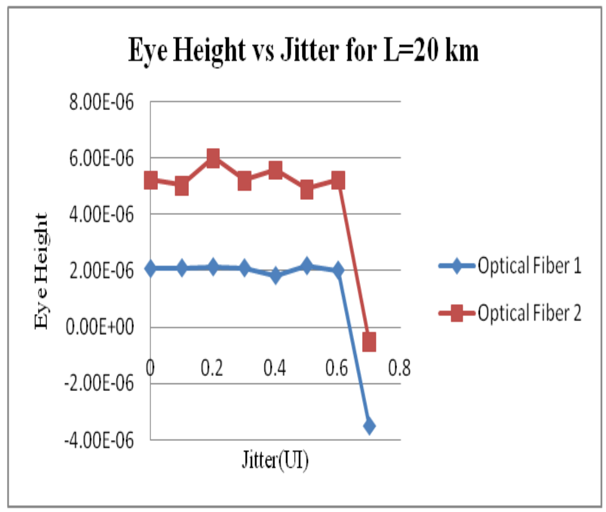

Fig 10: Variation of Eye Height with Jitter for L=20 km

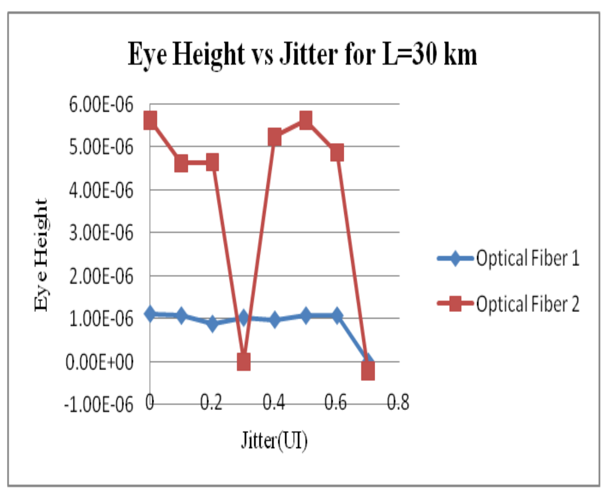

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Fig 11: Variation of Eye Height with Jitter for L=30 km

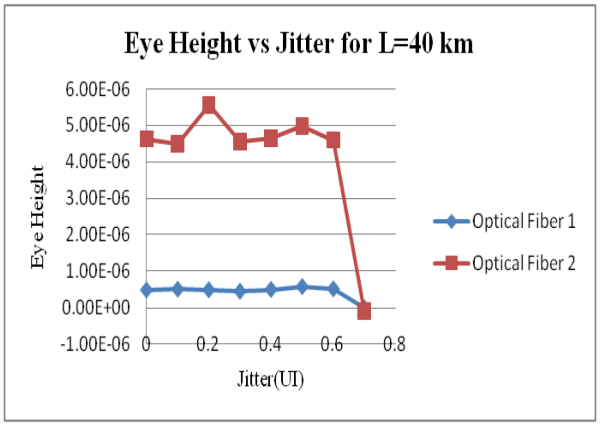

Fig 12: Variation of Eye Height with Jitter for L=40 km

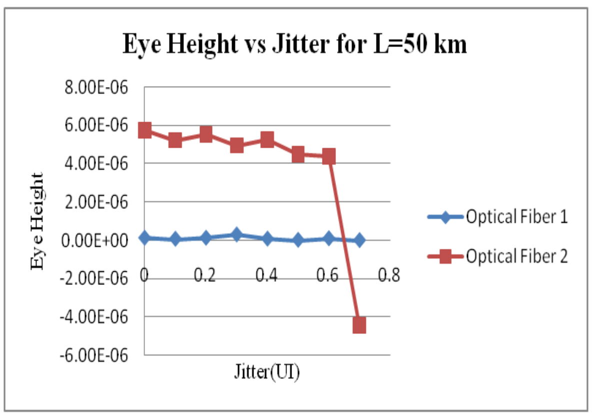

Fig 13: Variation of Eye Height with Jitter for L=50 km

From Figures 10-13 and Table 3 it can be concluded that as the value of jitter is increased from 0 unit-interval to 0.7 unit-interval, the value of Eye Height varies from 2.07E-06 to -3.50E-06 and 5.23E to -5.47E-07 for L=20 km, from 1.12E-06 to 0 and 5.62E-06 to -2.12E-07 for L=30 km, from 4.96E-07 to 0 and 4.62E-06 to -9.69E-08 for L=40 km and from 1.25E-07 to 0 and 5.74E-06 to -4.46E-06 for L=50 km for Optical Fiber 1and Optical Fiber 2 respectively. Thus from comparison of the overall performance of both the fibers, it can be concluded that although in some cases Optical Fiber 1 show better results but overall Optical Fiber 2 shows more consistent performance.

V. CONCLUSION

With advantages like ability to increase the transmission capacity of an optical fiber optical code division multiple access (OCDMA) has been recognized as one of the most important technologies for supporting many simultaneous users in shared media. Jitter is an important factor, which degrades the overall performance of OCDMA system. In this paper performance of the OCDMA communication system has been evaluated by jitter varying from 0 unit-interval to 0.7 unit-interval in steps of 0.1 unit-intervals. From simulation results it has been concluded that although in some cases Optical Fiber 1 show better results but overall Optical Fiber 2 shows more consistent performance.

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