Effect of Timing Jitter on Performance of OCDMA Communication System

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ABSTRACT

This Paper focuses on the effect on BER, Eye Height and Q-factor for four user OCDMA system with varying jitter. Performance of this system has been evaluated in terms of bit error rate, eye height and Q-factor with jitter varying from 0 pico-seconds to 0.7 pico-seconds in steps of 0.1 pico-seconds. Simulations were carried out from the simulator available from Gigasoft, OPTIWAVE.

***Keywords* -** BER, Eye Height, Jitter, OCDMA, Optiwave, Q-Factor

I. INTRODUCTION

Optical Code Division Multiple Access (OCDMA) is one of the most important technologies that support many simultaneous users in shared media, and increases optical fibers transmission capacity. OCDMA provides full asynchronous communication, enhanced security and soft variations of the system properties to the number of users. In these days, CDMA has been widely used in the field of wireless communication, especially, in the third generation wireless communication systems. Prucnal in 1986 proposed to realize the fiber-optic LAN by using optical signal processing, and used prime codes to carry out the experiment of electronic encoding and fiber-optic delay line decoding, verifying the feasibility to implement incoherent OCDMA system by encoding in the time domain [1]. In 1988, Weiner, Heritage and Salehi demonstrated how to spread the femto-second optical pulse into pico second-duration pseudo noise bursts. The spread frequency was achieved by encoding the light spectrum into pseudo random binary phase and then by decoding the spectrum phase encoded to recover the original pulse [2]. The adoption of incoherent optical signal processing in CDMA LAN faces limitation of the absence of complementary elements which hinder the design of optical code sequences that are fully orthogonal to each other. Coherent optical processing is able to overcome the limitation [3]. In 2002, Keshavarzian and Salehi for the first time analyzed the performance of serial-search algorithm for OCDMA system using optical orthogonal codes (OOC). They have considered all the major sources of noise that impact the performance of the system such as shot noise, dark current and multi-access interference (MAI) [4]. OCDMA technology can build all the passive optical-access networks, LAN and WAN. The combination of OCDMA with WDM or/and TDM can enhance signal multiplexing and label switching through the combination of OCDMA with WDM or/and IP over WAN, so that we can improve transmission capacity and switching capacity of network, the flexibility of network can be enhanced and the performance of the communication network can be heightened [10]. As the result of intensive research on OCDMA in the past 20 years, many OCDMA systems have been proposed. Classifying them in terms of the nature of the superposition of the optical signal, they can be divided into coherent OCDMA systems and incoherent OCDMA systems. The coherent OCDMA system is one which makes use of the coherent property of light and implements bipolar encoding of the optical signal, i.e., encoding of the phase of optical signals, with the phase of light detected at the receiving terminals. The signal is added as the superposition of light signal amplitudes. This kind of OCDMA system uses ultrashort broadband light pulse sources [3]. The incoherent OCDMA system is one which employs the presence of light signal or absence of light signal to represent the binary “1” and “0” respectively, which is unipolar encoding, where the light signals are detected with the square-law devices at the receiving terminals [7]. The signal is added as the superposition of light powers. This kind of OCDMA system uses incoherent light sources, such as amplified spontaneous emission (ASE), light-emitting diode (LED), etc [6]. Because of the advantages of OCDMA, it can support multimedia including voice, video, data, including IP traffic, video-on-demand, streaming media, interactive applications, etc. And according to user’s requirement and diffrent services it also offers many kinds of QoS and differential degrees of security. It overcomes the shortcomings of asymmetric uplink and downlink in current access networks and supports FTTH of the peer-to-peer traffic [8].

II. BLOCK DIAGRAM OF OCDMA SYSTEM

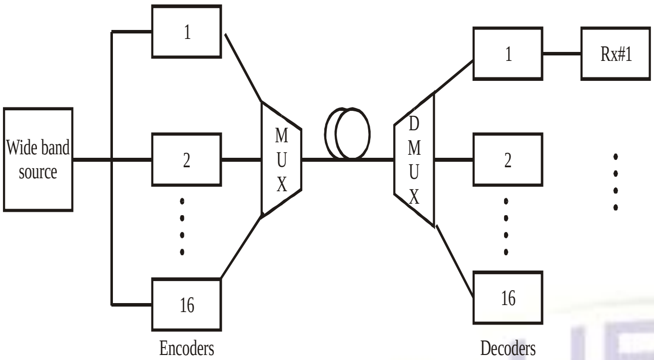

Figure 1: Conceptual diagram of OCDMA System

An OCDMA system can be described by data source for each user, which contains the data to be sent, followed by encoder and then a laser that maps the signal from electrical form to an optical pulse sequence. At the receiver end to extract the encoded data, optical correlator is used. As we know many subscribers transmit data simultaneously and each user has its own codeword, which is approximately orthogonal to all other codewords. The encoded data of all the users are then added chip by chip and the result, which is called superposition, and is sent over the channel. The individual receivers which consist of optical correlator recover the data from corresponding transmitter by continuously observing the superposition of all incoming pulse transmission. This is done by correlating the incoming signal and stored copies of that user unique sequence. If the incoming stream of optical pulses contains the unique sequence, then correlator will give a peak and presence of other users will be considered as noise. To detect only specific desired codeword the receiver performs a time correlation operation and due to de-correlation all other code words appears as noise. Each user operates independent with no knowledge of the other users [6].

III. PROPOSED SYSTEM

We have built the Four User OCDMA System in Optiwave software as shown in fig. 2 below. The model consists of many components which all contribute to the four user OCDMA system. Electrical jitter is introduced in the model so as to study its effect on the system. The system is capable of calculating the effect of jitter on bit error rate, eye height and Q-Factor. In our model we have taken two optical fibers i.e. Optical Fiber 1 and Optical Fiber 2 and we have changed the value of jitter from 0 pico-seconds to 0.7 pico-second in steps of 0.1 pico-seconds and calculated BER, eye height and Q-Factor at various lengths of 20 km, 30 km, 40 km and 50 km. The BER analyzer at the output is used to provide the output graphically. Each time the value of jitter is changed we read the values of BER, eye height and Q-factor from BER analyzer for each length and then plotted the graphs for both the fibers to see which one is better fiber.

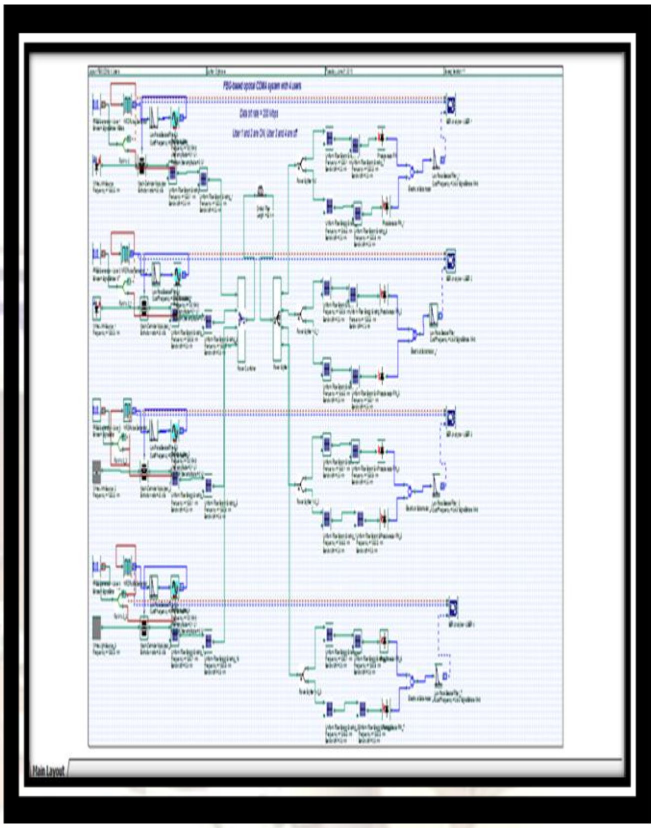

Figure 2: Snap Shot of Four User OCDMA System

IV. RESULTS AND DISCUSSIONS

Two Optical Fibers with following parameters have been taken to study the effect of timing jitter. They are:

Optical Fiber 1 with reference wavelength= 1550 nm, attenuation= 0.2 dB/km, dispersion= 16.75 ps/nm/km, dispersion slope= 0.075 ps/nm^2/km.

Optical Fiber 2 is ITU-T recommended G.657 A1 single mode optical fiber with reference wavelength= 1550 nm, attenuation= 0.16 dB/km, dispersion= 15.50 ps/nm/km, dispersion slope= 0.060 ps/nm^2/km

Table 1: Variation of BER with jitter for different fibers with different lengths

Jitter (ps)	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	4.73E-35	4.40E-17	6.58E-14	3.90E-08	1.03E-11	0.000134	4.92E-09
0.1	7.38E-27	7.41E-27	4.64E-13	6.07E-18	4.14E-08	2.55E-14	0.00298	7.42E-06
0.2	2.38E-38	1.05E-40	2.16E-09	2.84E-18	2.99E-08	4.41E-13	0.00119	2.89E-08
0.3	7.43E-26	3.53E-21	1.47E-13	1.40E-20	1.99E-07	6.02E-22	1.04E-06	2.03E-09
0.4	8.06E-18	1.39E-35	4.82E-12	3.07E-15	3.67E-08	2.31E-13	0.0036	2.86E-13
0.5	3.01E-43	7.39E-16	4.42E-15	1.60E-16	4.52E-10	1.37E-12	0.009669	4.94E-09
0.6	2.74E-28	1.07E-13	1.45E-12	8.12E-17	3.38E-09	4.02E-12	0.00187	8.55E-07
0.7	4.42E-02	2.88E-02	1.00E+00	5.58E-02	1.00E+00	1.23E-02	1	1.00E+00

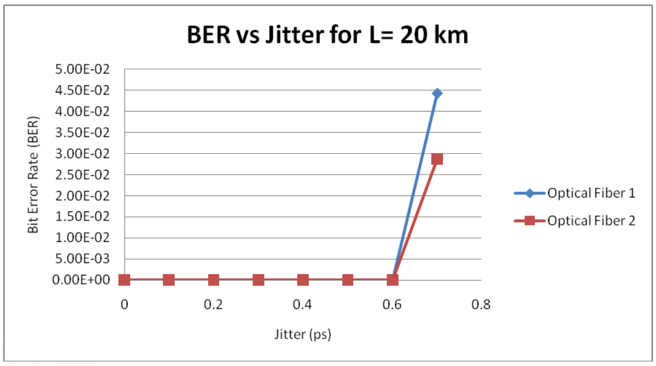

Figure 3: Variation of BER with Jitter for L= 20 km

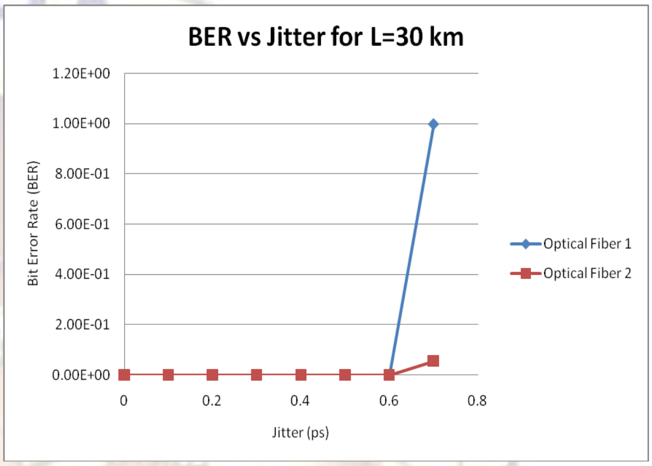

Figure 4: Variation of BER with Jitter for L= 30 km

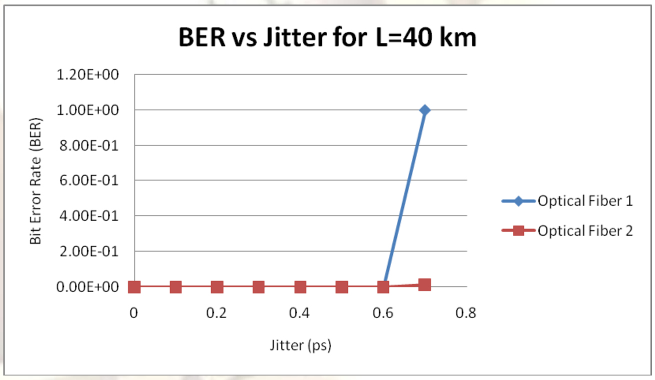

Figure 5: Variation of BER with Jitter for L= 40 km

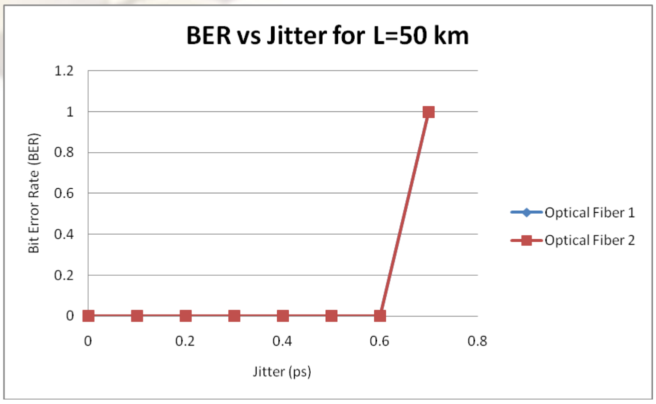

Figure 6: Variation of BER with Jitter for L= 50 km

From Figures 3-6 and Table 1 as the value of jitter is increased from 0 pico-seconds to 0.7 pico-seconds, the valur of BER varies from 2.34E-24 to 4.42E-02 and 4.73E-35 to 2.88E-02 for L= 20 km, from 4.40E-17 to 1.00E+00 and 6.58E-14 to 5.58E-02 for L= 30 km, from 3.90E-08 to 1.00E+00 and 1.03E-11 to 1.23E-02 for L= 40 km and from 0.000134 to 1 and 4.92E-09 to 1.00E+00 for Optical Fiber 1 and Optical Fiber 2 respectively.

Table 2: Variation of Q-Factor with jitter for different fibers with different lengths

Jitter (ps)	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	12.28	8.31	7.39	5.37	6.70	3.62	5.69
0.1	10.65	10.65	7.12	8.55	5.36	7.52	3.42	4.31
0.2	12.89	13.30	5.86	8.63	5.41	7.14	3.67	5.42
0.3	10.44	9.35	7.29	9.22	5.06	9.55	4.74	5.87
0.4	8.50	12.39	6.79	7.79	5.38	7.23	3.37	7.20
0.5	13.73	7.96	7.74	8.15	6.12	6.98	3.07	5.73
0.6	10.96	7.32	6.97	8.24	5.79	6.83	3.55	4.77
0.7	1.67	1.89	0	1.57	0	2.21	0	0

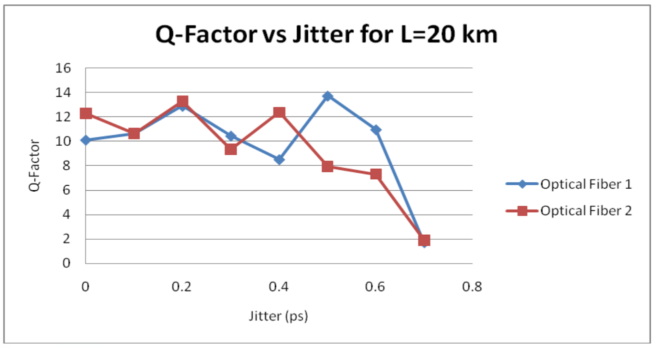

Figure 7: Variation of Q-Factor with Jitter for L= 20 km

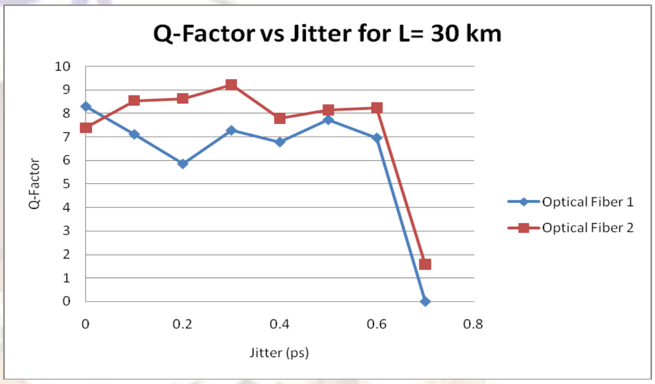

Figure 8: Variation of Q-Factor with Jitter for L= 30 km

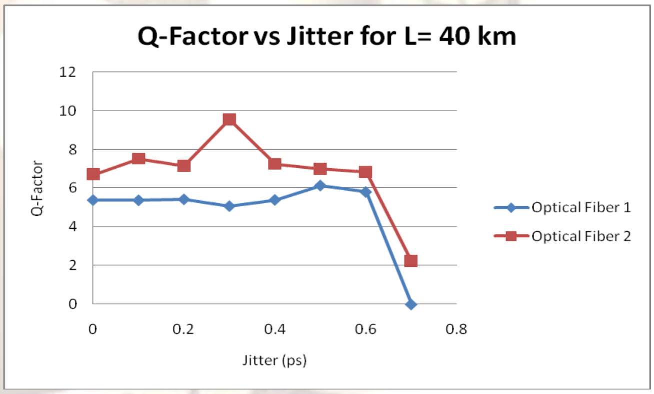

Figure 9: Variation of Q-Factor with Jitter for L= 40 km

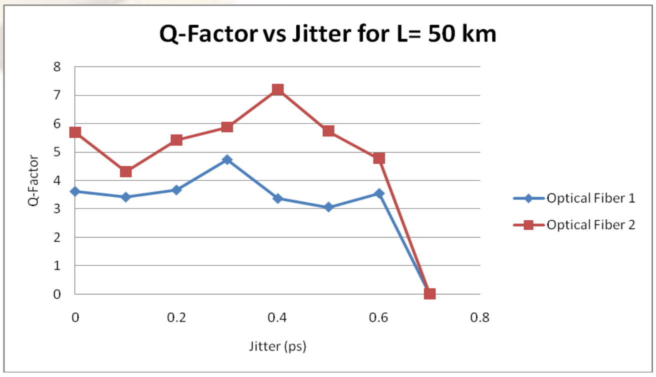

Figure 10: Variation of Q-Factor with Jitter for L= 50 km

From Figures 7-10 and Table 2 it has been concluded that as the value of jitter is varied from 0 pico-seconds to 0.7 pico-seconds, the value of Q-Factor varies from 10.11 to 1.67 and 12.28 to 1.89 for L= 20 km, from 8.31 to 0 and 7.39 to 1.57 for L= 30 km, from 5.37 to 0 and 6.70 to 2.21 for L= 40 km and from 3.62 to 0 and 5.69 to 0 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

Jitter (ps)	Eye Height							
	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	2.64E-06	1.12E-06	1.43E-06	4.96E-07	9.29E-07	1.25E-07	5.12E-07
0.1	2.09E-06	2.54E-06	1.08E-06	1.52E-06	5.17E-07	1.00E-06	7.25E-08	3.37E-07
0.2	2.13E-06	2.60E-06	8.85E-06	1.58E-06	5.02E-07	9.31E-07	1.24E-07	5.01E-07
0.3	2.09E-06	2.31E-06	1.03E-06	1.59E-06	4.61E-07	1.13E-06	2.95E-07	5.52E-07
0.4	1.82E-06	2.52E-06	9.83E-06	1.42E-06	5.10E-07	9.92E-07	7.93E-08	6.18E-07
0.5	2.17E-06	2.22E-06	1.08E-06	1.58E-06	5.88E-07	8.56E-07	1.45E-08	4.79E-07
0.6	2.01E-06	2.03E-06	1.08E-06	1.46E-06	5.26E-07	9.10E-07	9.49E-08	3.83E-07
0.7	-3.50E-06	-2.91E-07	0.00E+00	-3.07E-07	0.00E+00	-1.40E-07	0.00E+00	0.00E+00

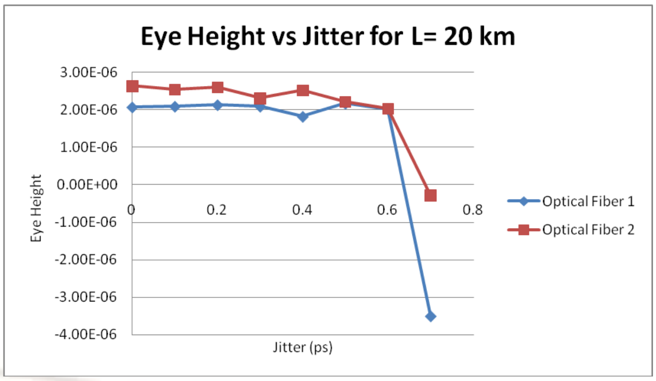

Figure 11: Variation of Eye Height with Jitter for L = 20 km

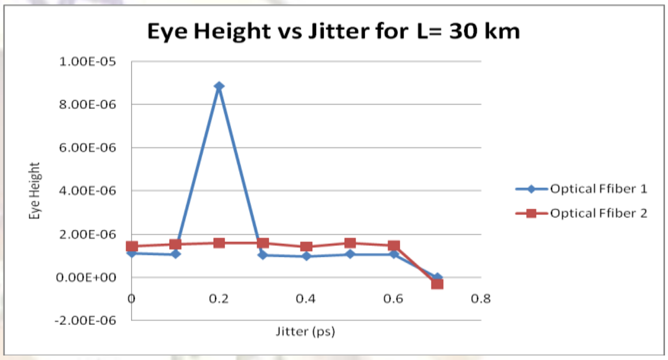

Figure 12: Variation of Eye Height with Jitter for L= 30 km

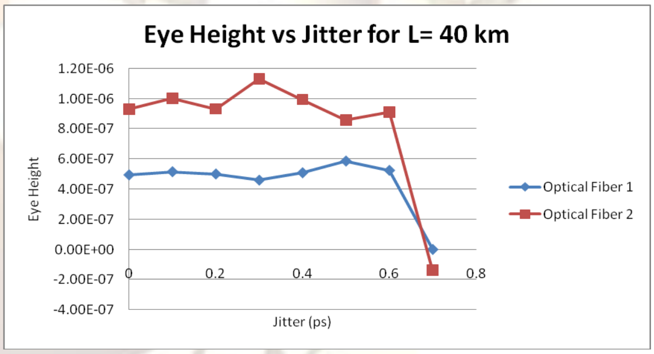

Figure 13: Variation of Eye Height with Jitter for L= 40 km

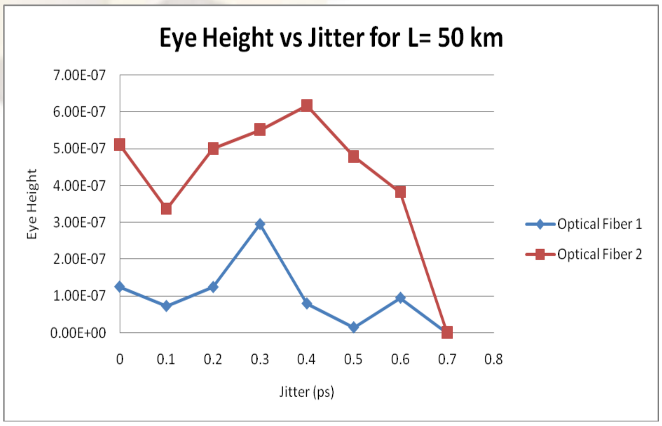

Figure 14: Variation of Eye Height with Jitter for L= 50 km

Form Figures 11-14 and Table 3 it has been concluded that as the value of jitter is increased 0 pico-seconds to 0.7 pico-seconds, the value of Eye Height varies from 2.07E-06 to -3.50E-06 and 2.64E-06 to -2.91E-07 for L= 20 km, from 1.12E-06 to 0.00E+00 and 1.43E-06 to -3.07E-07 for L= 30 km, from 4.96E-07 to 0.00E+00 and 9.29E-07 to -1.40E-07 for L= 40 km and from 1.23E-07 to 0.00E+00 and 5.12E-07 to 0.00E+00 for L= 50 km for Optical Fiber 1 and Optical Fiber 2 respectively.

V. CONCLUSION

Optical Code Division Multiple Access (OCDMA) has been recognized as one of the most important technologies for supporting many simultaneous users in shared media, because of its advantage to increase the transmission capacity of an Optical Fiber. OCDMA as it can work in asynchronous environment and each user is assigned a unique optical code which is orthogonal to all other code words used by different users, is very popular technology today. Jitter which distorts the optical pulse is an important factor, which degrades the overall performance of OCDMA system. In this thesis performance of the OCDMA communication system has been evaluated by varying the value of jitter from 0 pico-seconds to 0.7 pico-seconds in steps of 0.1 pico-seconds, at different lengths of 20 km, 30 km, 40 km and 50 km for both the Optical Fiber 1 and Optical Fiber 2. The fiber which has minimum BER, maximum Q-Factor and maximum Eye Height is considered to be the better fiber. So from the simulation results we conclude that Optical Fiber 2 has Bit Error Rate less than Optical Fiber 1, Q-Factor high than Optical Fiber 1 and also Eye Height higher than Optical Fiber 1. So from our results, we can conclude that Optical Fiber 2 is better than Optical Fiber 1.

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