Design of Optical Star Coupler for 3D OCDMA system

Shilpa Jindal[1], Neena Gupta[2]
Department of Electronics and Electrical Communication Engineering
PEC University of Technology Sector 12, Chandigarh, India
[1]Ji_shilpa@yahoo.co.in

Abstract- 3D OCDMA coding schemes have been proposed recently supporting more subscribers than conventional 2D & 1D techniques. This is achieved by employing or taking the relaxation with the third degree of freedom i.e. employing temporal, spectral and spatial domains. The objective of this work is to design a star coupler for 3 Dimensional encoding based on Mathematical Models A and B as proposed earlier by the authors. Optical star coupler uses multiplexer and demultiplexers for OCDMA system. The modeling work is carried out using Rsoft's optsim simulator. Though star coupler is an important component that will be used in huge optical communication systems supporting many simultaneous users for data transfer Star coupler thus designed will be used in 3D OCDMA System to evaluate the performance of the 3D system.

Keywords- OCDMA; Star Topology; Ring Topology; Bus Topology; Tree Topology; Mathematical Model A and Model B; Algebraic Congruent Operators; Optical multiplexer; Optical de Multiplexer.

I. INTRODUCTION

OCDMA due to its inbuilt features is the most suitable candidate for next generation networks, keeping in view the symmetry of data for both uplink and downlink. Most challenge features for OCDMA is the coding or the signature sequences. These sequences should have good auto correlation and cross correlation properties. Authors are working in this domain. Hence need was felt to design optical star coupler to simulate proposed 3D (increased spectral efficiency [10]) codeset in optsim simulator. This paper is organised as follows. Section 2 briefly discusses the Mathematical Models: Model A and Model B. In Section 3, OCDMA architecture is described having either of Tree, mesh, star, ring topology, further connectivity is based on applications and then the Design of Optical star coupler is elaborated.

II. MATHEMATICAL MODEL

3D OCDMA system is based on following mathematical models:

Model A: In Model A, Fig. 1, Optical Orthogonal Code is used to spread in time domain, any one scheme of algebraic congruent operator based on Table 1 is used for spreading in spectral domain and the same scheme is used for spreading in spatial domain. Model B: In Model B, Fig. 2, OOC code is used to spread in time domain, any one scheme of algebraic congruent operator based on Table 1 is used for spreading in spectral domain and the scheme other than used for spreading in spectral domain is used to spread in spatial domain. With a given prime number p $s_m(n,a,b)$, is used to represent a certain Algebraic congruent operator within Galois field GF(p), GF(p) ={0, 1, …, p-1}, where m is the index of sequences in family, while n points out the position of time slots in a sequence. Here, with a given operator $s_m(n,a,b)$ .four types of ACO (Algebraic Congruent Operator) are Linear Congruent Operator, Quadratic congruent Operator, Hyperbolic Congruent Operator and Cubic Congruent Operator. These operators are expressed in the following Table 1

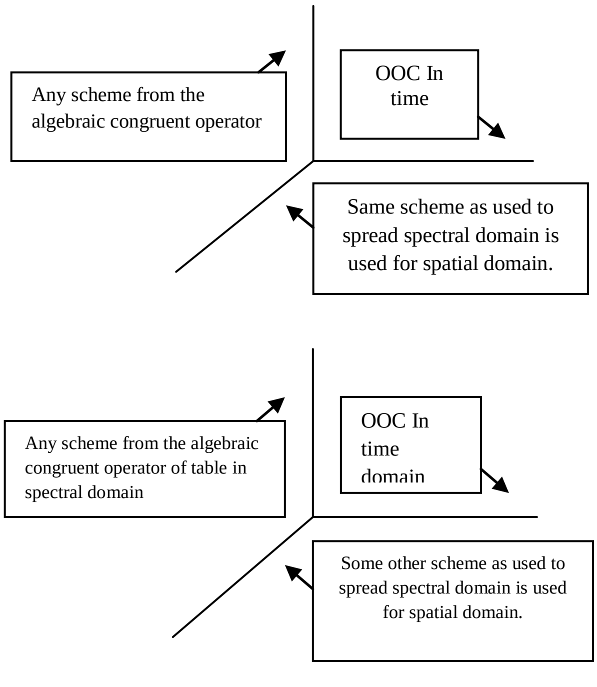

Fig. 1 Mathematical Model A and Model B

TABLE I ALGEBRAIC CONGRUENT OPERATOR FOR SPREADING IN TEMPORAL, SPECTRAL AND SPATIAL DOMAINS [5, 6, 9]

Algebraic Congruent operator	Formulae	
Linear Algebraic Congruent operator	$s_m(n,a,b)=\left[m.(n.a+b)\right]\left[(\bmod p)\right]$	a=1 and b=0

Quadratic Algebraic Congruent operator[7]	$s_m(n,a,b,c) = \left(m\left(an^2.+b.n+c\right)\right)(\bmod p)$	a= b=1/2 and c=0
Hyperbolic Algebraic Congruent operator[1,2,3,4]	$s_m(n) = \left((am/n)+b\right)(\bmod p)\right)$	a and b are constants whose value is a=1, b=0
Cubic Algebraic Congruent operator	$s_m(n,a,b) = \left(m\left(a+n\right)^3+b\right)(\bmod p)$	a= b=0

Table II Sequences of GF (3, 5, 7) using cubic congruent operator

m,n	0	1	2
0	0	0	0
1	0	1	2
2	0	2	1

m,n	0	1	2	3	4
0	0	0	0	0	0
1	0	1	3	2	4
2	0	2	1	4	3
3	0	3	4	1	2
4	0	4	2	3	1

m,n	0	1	2	3	4	5	6
0	0	0	0	0	0	0	0
1	0	1	1	6	1	6	6
2	0	2	2	5	2	5	5
3	0	3	3	4	3	4	4
4	0	4	4	3	4	3	3
5	0	5	5	2	5	2	2
6	0	6	6	1	6	1	1

Table 2 shows the sequences over GF (3), GF (5), GF (7) and put these possibilities for codeword from the Galois field GF(p), where p is the prime number the As per the formulae from the Table 1. In this paper three values of prime number p=3, 5 and 7 are considered for cubic algebraic congruent operator.

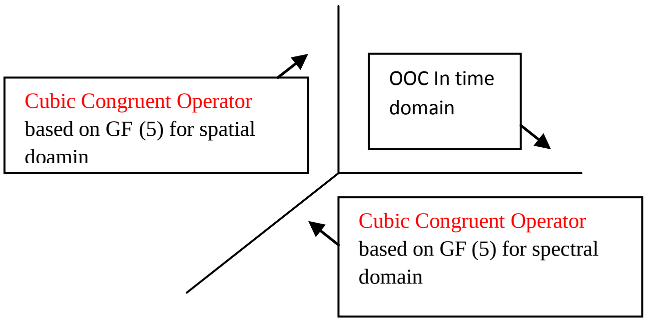

Fig. 2 Shows the Placement of 3D Code Based On GF (5) Model A

In Table 3 code sequences that are used in simulation are drawn based on cubic congruent operator of Model A specifying block 0, 1, 2 with sets 0, 1 and 2. Sequences used in simulation are 1101000 optical orthogonal codes for temporal domain and sequences from Table 3 for spectral and spatial domain. Fig. 2 shows the Placement of 3D Code Based on GF (5) with Model A.

The code sequences are placed by first considering time domain. In this the sequences are assigned as codes from optical orthogonal codes, here we have chosen 1101000 as code for time domain and for placing code sequences for spectral domain, the codes from operator based on algebraic coding theory i.e. cubic congruent operator explained in Table 2 are used with weight as 3 as three chips are present out of 7 in ooc code. These sequences based on GF (5) are assigned to spectal and spatial domains. For example Table 3 shows the list of codeword and the red colour code S0λ1 $S_2\lambda_0$ $S_1\lambda_2$ is assigned third row and 1, 2 and 3rd column of Table 2 for spatial domain and same but in shifted form as 1, 0, 2 for spectral domain. Similarly rest code words are generated

TABLE III NUMBER OF CODE WORDS

BLOCK 0		
SET 0	SET1	SET2
$S_0\lambda_0S_0\lambda_0S_0\lambda_0$	$S_0\lambda_0$ $S_1\lambda_1$ $S_3\lambda_2$	$S_0\lambda_0$ $S_2\lambda_2$ $S_1\lambda_1$
$S_1\lambda_0S_1\lambda_0S_1\lambda_0$	$S_1\lambda_0$ $S_3\lambda_1$ $S_0\lambda_2$	$S_1\lambda_0$ $S_0\lambda_2$ $S_2\lambda_1$
$S_3\lambda_0S_3\lambda_0S_3\lambda_0$	$S_3\lambda_0$ $S_0\lambda_1$ $S_1\lambda_2$	$S_2\lambda_0$ $S_1\lambda_2$ $S_0\lambda_1$
BLOCK 1		
SET 0	SET1	SET2
$S_0\lambda_1S_0\lambda_1S_0\lambda_1$	$S_0\lambda_1$ $S_1\lambda_3$ $S_3\lambda_0$	$S_0\lambda_1S_2\lambda_0$ $S_1\lambda_2$
$S_1\lambda_1S_1\lambda_1S_1\lambda_1$	$S_1\lambda_1$ $S_3\lambda_3$ $S_0\lambda_0$	$S_1\lambda_1$ $S_0\lambda_0S_2\lambda_2$
$S_3\lambda_1S_3\lambda_1S_3\lambda_1$	$S_3\lambda_1$ $S_0\lambda_3$ $S_1\lambda_0$	$S_2\lambda_1$ $S_1\lambda_0$ $S_0\lambda_2$
BLOCK 2		
SET 0	SET1	SET2
$S_0\lambda_3S_0\lambda_3S_0\lambda_3$	$S_0\lambda_3$ $S_1\lambda_0$ $S_3\lambda_1$	$S_0\lambda_2S_2\lambda_1$ $S_1\lambda_0$
$S_1\lambda_3S_1\lambda_3S_1\lambda_3$	$S_1\lambda_3$ $S_3\lambda_0$ $S_0\lambda_1$	$S_1\lambda_2$ $S_0\lambda_1$ $S_2\lambda_0$
$S_2\lambda_3S_2\lambda_3S_2\lambda_3$	$S_3\lambda_3$ $S_0\lambda_0$ $S_1\lambda_1$	$S_2\lambda_2$ $S_1\lambda_1$ $S_0\lambda_0$

III. OCDMA ARCHITECTURE: STAR COUPLER

There are various topologies for implementing OCDMA networks like Tree, mesh, star, ring e.t.c. It actually depends on the application area where one topology has edge over one another. For Example: An appropriate topology for local area network (LAN) is a star and, that for multimedia data distribution, a tree. Fig. 3 shows the configuration of star coupler connecting nodes: Node 1 to N. here each node is controlled centrally by star coupler and encodes in temporal and spectral domain. Optical star coupler encodes the incoming signal in spatial domain. Hence 3 D OCDMA encoding is performed for LAN.

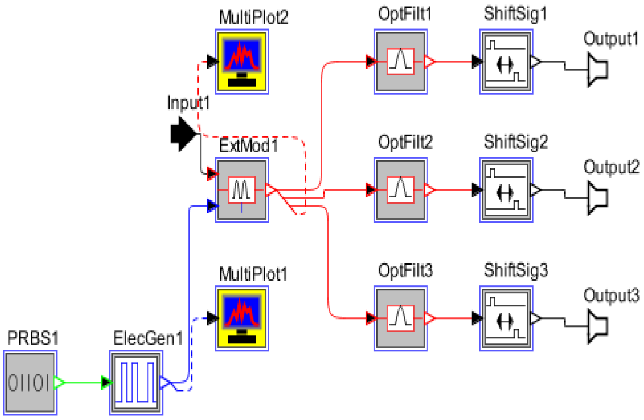

Fig. 3 Star Topology for OCDMA systems

Based on the Star topology, Fig. 5 shows the snapshot of 3D OCDMA System captured in Rsoft's optsim. It consists of following components from software's library. Three mode locked lasers, optical multiplexer, encoder (encoding in temporal and spectral domain) optical star coupler (proposed design), decoder, optical attenuator, receiver, BER, Eye Diagram, Plotter and Fig. 4 shows the internal architecture of encoder and decoder utilizing PRBS, electrical signal generator, external modulator, optical filter, time delay components.

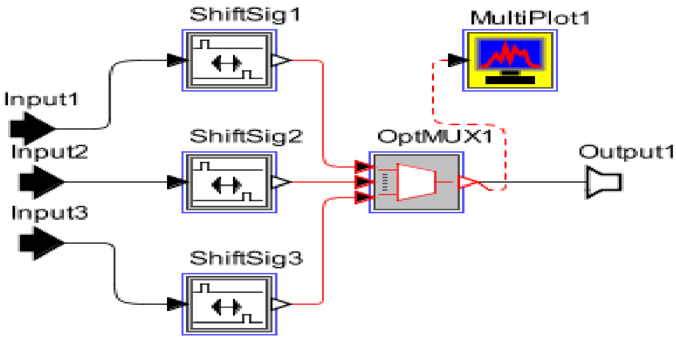

Fig. 4 OCDMA Encoder and Decoder

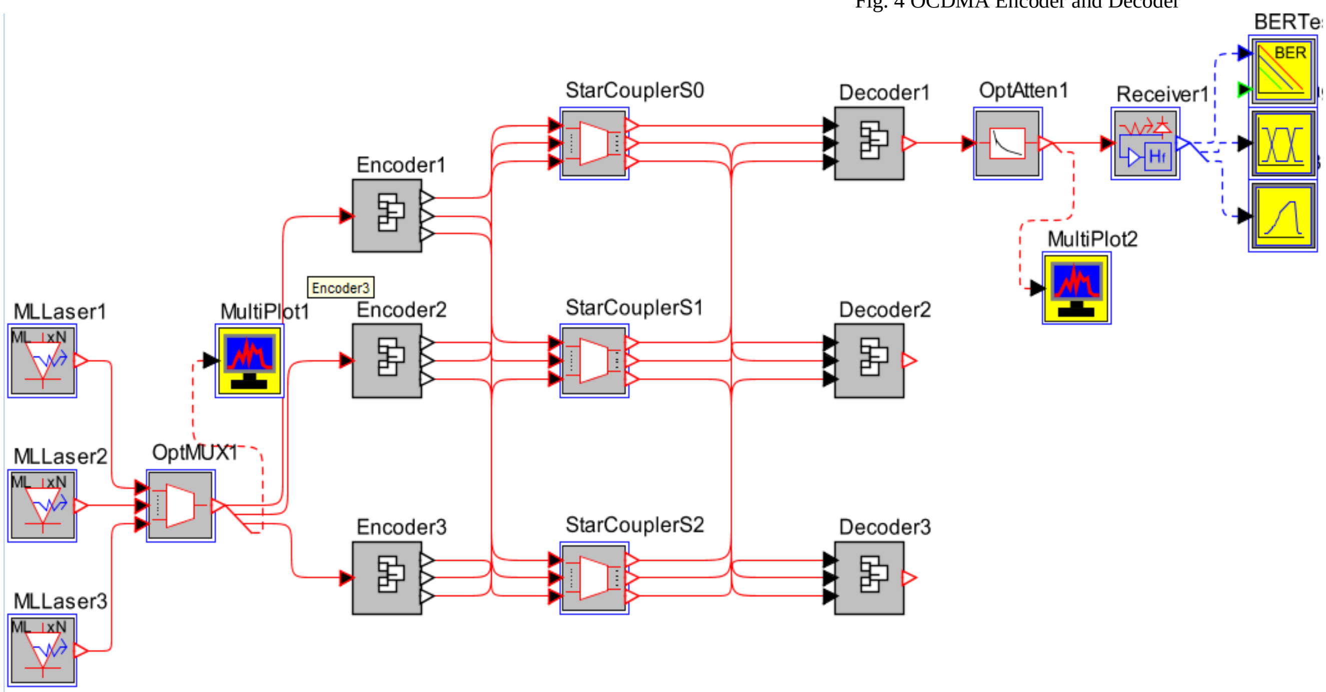

Fig. 5 3D OCDMA snapshot in Rsoft's optsim[8]

Optical star coupler: optical star coupler is constructed using Optical multiplexer and Optical De Multiplexer in following configuration. Where Optical multiplexer (Nx1 MUX) represents an optical WDM. It accepts multiple optical signals at its input ports and produces a WDM optical signal at its output port that includes all the input WDM optical signals. And Optical De Multiplexer (1xN DEMUX) represents an optical WDM de multiplexer. It accepts a WDM optical signal at its input port and produces N single channel optical signals at its output ports, one channel per port. Fig 6, 7 shows the design of Optical Star Coupler where inputs and outputs are shown as lines. Other method of designing optical star coupler would be by cascading 2*2 optical couplers as per the requirement of the system.

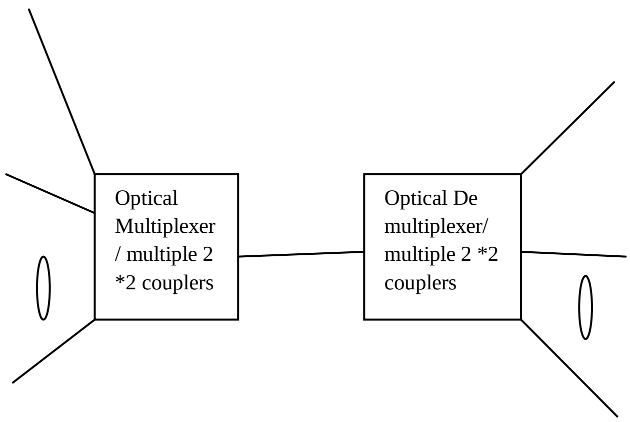

Fig. 6 Optical star coupler design

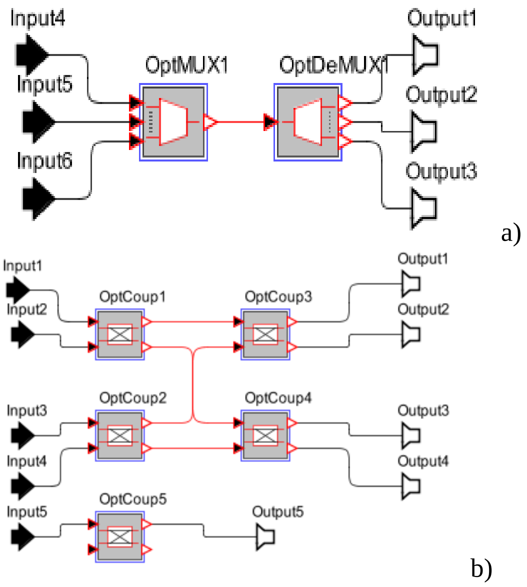

Fig. 7 Schematic star coupler in optsim

a) with Mux and De Mux b) with Five 2*2 optical coupler

IV. RESULTS AND CONCLUSION

In this section, the results are discussed while simulating OCDMA system using newly designed optical star coupler. Following Figures 8 through 11 shows the inputs like signal graph w.r.t. time and input wavelength spectrum along with Fig. 10 and 11 shows the output signal magnitude and the auto correlation graph.

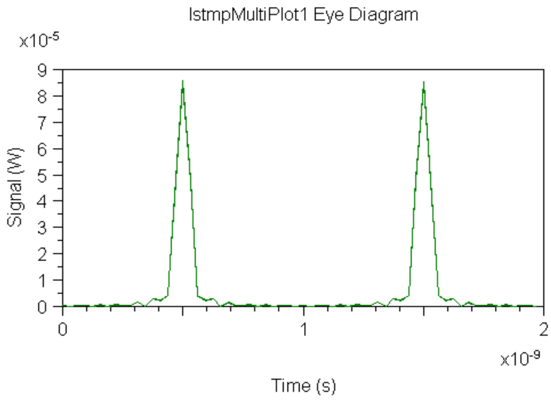

Fig. 8 Input signal graph w.r.t. time

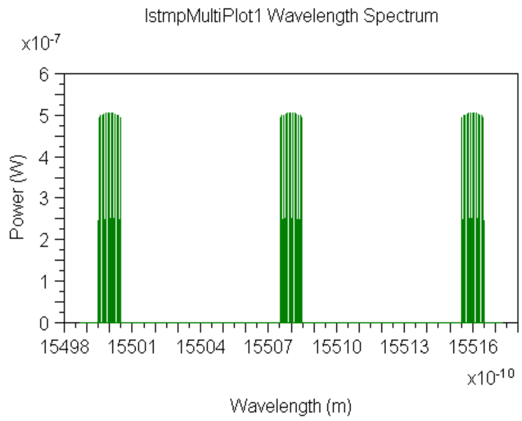

Fig. 9 Wavelength spectrum

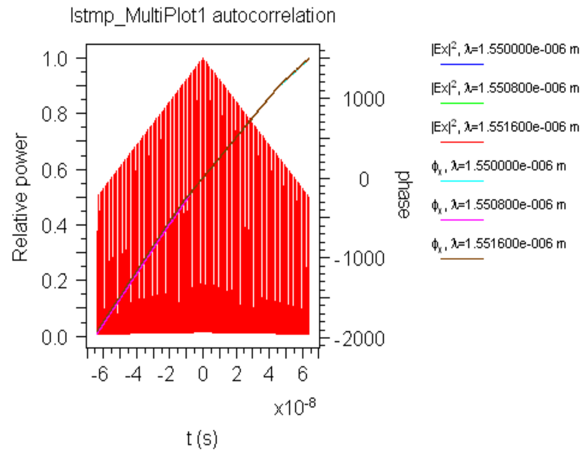

Fig 10: Auto correlation function

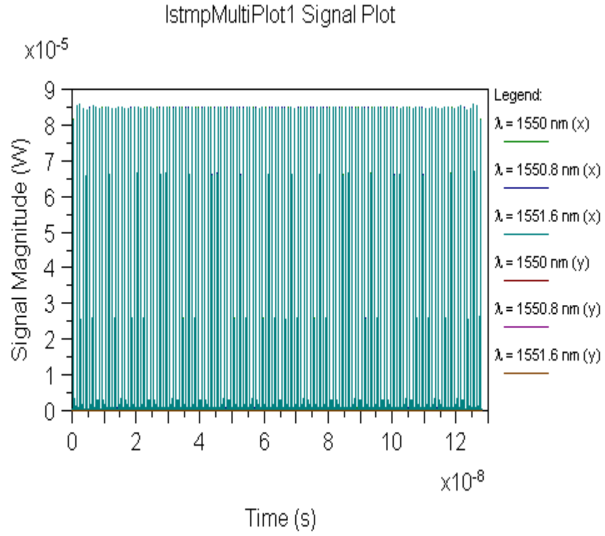

Fig. 11 Input signal graph w.r.t. time

In this paper, we have proposed and successfully designed an optical star coupler using multiplexer and demultiplexers for OCDMA system. The modeling work is carried out using Rsoft's optsim simulator. Optical star coupler thus generated is used in implementing and evaluating the performance of 3 Dimensional OCDMA codes based on Mathematical Models A and B.

ACKNOWLEDGEMENT

We Acknowledge the Optical Communication Lab at Department of Electronics Electrical and Communication Engineering, PEC University of Technology, Sector 12, Chandigarh were this work has been carried out.

REFERENCES

[1] Maric, S.V, 1992: A Class of Frequency Hop Codes with Nearly Ideal characteristics for Use in Multiple-Access Spread-Spectrum Communications and Radar and Sonar Systems, IEEE Transaction Communications, Volume**:** 40, Issue: 9, **Page:** 1442–1447.

[2] Wronski, L.D.; Hossain, R.; Albicki, 1996: Extended Hyperbolic Congruential Frequency Hop Code: Generation And Bounds For Cross- And Auto-Ambiguity Function,

IEEE Transactions on Communications, Volume: 44 , Issue: 3 Digital Object Identifier: 10.1109/26.486324 , Page(s): 301 - 305.

[3] Hossain, R. Wronski, L. Albicki, A. D., 1994, Signal Generation for Extended Hyperbolic Congruential Frequency Hop codes , IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing, **Volume:** 41 , Issue: 1 **Page:** 33-39.

[4] Menghui Zheng, Albicki, A., 1995: A Modified Hyperbolic Congruential Frequency Hop Codes for Asynchronous Event Signaling, Published Computers and Communications, **Page(s):** 666 - 670.

[5] Tao Pu, Yu Quan Li, and Shu Wen Yang, 2003: Research of Algebra Congruent Codes Used in Two-Dimensional OCDMA System, Journal of Light wave Technology, Vol. 21, NO. 11.

[6] S. Jindal, N. Gupta, 2010: A New Family of 3D Code Design Using Algebraic Congruent Operator for OCDMA Systems, International Journal of Electronics & Telecommunication and Instrumentation Engineering (IJETIE) ISSN 0974- 4975, Volume 3, Pg. 51-58. 2010.

[7] S. V. Maric´, Z. I. Kostic´, and E. L. Titlebaum, 1993:A New Family of Optical Code Sequences for Use in Spread-Spectrum Fiber Optic Local Area Networks, *IEEE Trans. Commun.*, Vol. 41, pp. 1217–1221.

[8] Rsoft's Opt Sim Models Reference Volume II Block Mode.

[9] S Jindal, N Gupta "Exploration of Three Dimensional Codes Based On Model A and Model B Using Algebraic Congruent Operator in OCDMA System" International Journal of Mobile & Adhoc Network, Vol. 2, Issue 3, August 2012. Pg. 345-351. ISSN (Online) 2231–6825, ISSN (Print) 2249-202X.

[10] S. Jindal, N. Gupta, "Comparison of Spectral Efficiency of CDMA Communication System" International Journal of Communication Engineering ISSN No. 0975-6094 Volume 2, Number1, January-June 2010, pp. 29-32.

BIOGRAPHY

Shilpa Jindal received B.Tech in Electronics and Communication Engineering in 2003 (Hons.) by securing second position in Punjab Technical University, Jallandhar and Silver Medal thereof. Then she completed M.E. in 2008 from PEC University of Technology (Deemed University), Chandigarh, India. Her current areas of interest are Communication Engineering, Optical Communication, Optical Networks, and Wireless Communication. She regularly contributes in various Journals, Magazines, and Conferences. She can be contacted at ji_shilpa@yahoo.co.in.

Dr Neena Gupta is working as Associate Professor at PEC University of Technology in Electronics and Electrical Communication Engineering Department. Her areas of interest are Communication, Optical/ Mobile, Wireless Communication, Digital Electronics. She is a member of IEEE. She is in the committee of Reviewer in national and international Journals. She regularly contributes in various Journals, Magazines, and Conferences.