Design of novel Sigma Shifted Matrix code family with adaptive transmitter-receiver architecture in OCDMA

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Department of Electronics & Communication Engineering with specialization in Communication Systems Engineering by the A P J Abdul Kalam Technological University

by

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CERTIFICATE

Certified that this thesis titled ***“Design of novel Sigma Shifted Matrix code family with adaptive transmitter-receiver architecture*** *is a bonafide record of the work done by* ***SHERIN SUSAN THOMAS*** *(Reg.No.TKM20ECCS12) under my supervision, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electronics and Communication Engineering with specialization in Communication Systems by the A P J Abdul Kalam Technological University.*

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Sherin Susan Thomas

ABSTRACT

Multiple Access Techniques are unavoidable part in a communication system.Among that optical code division multiple access (OCDMA) technique's support for asynchronous communication with comparatively high secrecy and Quality of service has made it an attractive technology for multiple-access optical networks. In OCDMA,the coding scheme that acts as the foundation for the system's operation is the main approach to satisfy user expectations. Each code in the OCDMA system is specifically created to prevent interference from multiple access. Sigma Shifted Matrix code is a novel spectral amplitude coding (SAC) technique that is developed.For the SSM coding scheme design, two methods are suggested. The identity and upper shift matrices are combined in the first method to create the SSM1 coding matrix. The second method implements the composition of an additional SSM matrix termed SSMs by assembling a single entry, lower, and upper shift matrix. To further improve the performance of the suggested setup, Then we are creating another code sequence which is called Modified Sigma shifted Matrix (MSSM) by bit wise ANDing of SSMI and SSM2. Combining these matrices results in variable SSM code families,which, depending on the number of users and the code weights chosen,and can offer additional flexibility. A concept for an optical control module(encoder) is described to make the system as adaptable as possible. To switch between SSM families, this control module chooses the desired encoding-decoding method based on the intended application. In comparison to the formerly used SAC-OCDMA codes, simulation findings show that the optical code division multiple access system based on the proposed SSM code family has better transmission rates, lower bit error rates (BER), Good Quality factor and longer travel distances without any signal quality loss.

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Chapter 1

Introduction

The most efficient way several users to share a spectrum is through the use of multiple access. Sharing is crucial to increase overall capacity over a specific geographic area because the spectrum is restricted.This is made possible by allowing multiple users to use the available bandwidth at once.Multiple access will help for the efficient utilization of spectrum.But one thing we need to confirm that in multiple access approaches there is no crosstalk and collision. Different sorts of multiple access strategies exist depending on the type of channel.They are

- Frequency Division Multiple Access (FDMA) - This multiple access approach divides the frequency band and assigns various frequencies to various users. The FM radio is one such. Here, a number of users can transmit at once using various frequency channels.
- Wavelength Division Multiple Access(WDMA) - Using various wavelengths, Wavelength Division Multiple Access (WDM) multiplexes a number of optical carrier signals onto a single optical cable. Time Division Multiple Access(TDMA)- In a Time Division Multiple Access (TDMA) system, each user is only permitted to send data for a limited amount of time using a wide frequency range.As a result, many users can utilise the whole frequency range at different times.
- Code Division Multiple Access (CDMA) - CDMA allows different users to broadcast at the same time over the same frequency range, but with the aid of various codes that may be decoded to identify a particular user.The most secure multiple access method is this one.

Our system uses OCDMA which has many benefits, including the ability to effectively use the same bandwidth by a larger number of users.The interference between users can be decreased according to code word distribution.It is also possible to use fixed frequency spectrum effectively in practise.

Different users can tolerate high data rates on the same channel with varied services using code domain OCDMA as opposed to TDMA. In contrast to WDMA, where the number of wavelengths may not be adequate for big cardinality networks, OCDMA offers wide dimension for the multiple access system. The main benefit of OCDMA technology over other multiple access strategies is its capacity to accommodate several user-specific differentiated classes of QoS while also eradicating channel conflict.

Quality of service (QoS) is the measurement of a system's total performance.High Signal to Noise Ratio (SNR), flexible user addition and deletion from network, reduced line interference etc helps to maintain a good QOS.

OCDMA system uses a variety of orthogonal codes to meet the needs of various services. A few examples include the Random Diagonal Code, Dynamic Cyclic Shift Code, Prime Codes, Multi Diagonal Code, Modified Double Weight Code, Enhanced Double Weight Code, Walsh Hadamard Codes, etc. Finding a suitable coding scheme that diminishes the impact of multiple access interference and other disturbances is essential for the OCDMA system.

OCDMA system performance is affected by a number of variables, including the number of active users, data throughput, bit error rate (BER), and signal to noise ratio (SNR) etc. The previous mentioned codes show a number of restrictions in their qualities when taken into account. For Walsh Hadamard codes, the cross correlation is not the best . Additionally, interference from many accesses affects it. Prime codes have a high cross correlation and are overly lengthy.

When compared to other SAC-OCDMA codes that are currently in use, random diagonal code (RD) offers good code length. This RD code's disadvantage, however, is that it has variable cross correlation. Consequently, a code that is very effective and has good qualities is required. Additionally, this code must allow the prioritisation of services for various traffic classes and be able to provide QoS for classes (like video streaming) that demand high bit rates.

As a result, the sigma shift matrix (SSM) signature code is being introduced.

When compared to alternative QoS provisioning methods, the SSM code family can achieve better-differentiated QoS by increasing SSM code weight. SSM codes are proven to offer improved Q factor and SNR, which is highly desired. A control module is created using logic gates to select the quality of services or make the system flexible. The control module is designed with the help og different logic gates.

Chapter 2

Literature Review

[1] Code division multiple access strategies and foundational ideas are explained by Jawad A. Salehi et al. This study looks into the fibre optic code division multiple access system. Optical orthogonal codes (OOCs), a new family of codes (signature sequences), are introduced. The experiment described in this paper demonstrates how to employ these codes and achieve the desired auto- and cross-correlation characteristics. It will be determined whether there is at least one family of OOCs (a family of OOCs must contain at least two OOCs) for each of the three cases under consideration: chip synchronous, strong interference chip asynchronous, and weak interference chip asynchronous (also known as the ideal chip asynchronous). In the paper, the fundamentals of OOCs are taught through an example. It introduces the idea of optical disc patterns, a comparable method of describing OOC. And from this, the probability density function is derived. According to the study, we must create sequences that meet the following two criteria: Each sequence can easily differentiate itself from a shifted version of itself, and each sequence can easily recognise every other sequence in the collection (potentially in shifted form).

[2] Hassan Yousif Ahmed et al. proposed a Diagonal Eigenvalue Unity (DEU) code. A Diagonal Eigenvalue Unity (DEU) code was proposed by Hassan Yousif Ahmed and others. Data rate, fibre length, and channel spacing are all optimised using DEU code to lower BER without the usage of dispersion compensating devices. DEU code was created using straightforward algebraic methods based on the Jordan block matrix. Based on the code weight ”W” and the number of users ”N,” four sets of DEU codes are created for the combinations ”even, even,” ”odd, odd,” and ”even,

even." The OCDMA system's DEU code performance and optimization are analysed. When the DEU code target parameters are reached for a large data rate (greater than 2.5 Gb/s), the BER can be greatly improved even without the use of dispersion compensated devices. It has been demonstrated that there is a trade-off between the restricted dispersion effects and the MAI when compensatory dispersion devices are not used in the system. This code has a wide range of benefits, such as quick and simple code creation, a straightforward encoder/decoder architecture, support for all n-th natural numbers, a maximum cross-correlation of 1, and good SNR. Chromatic dispersion is proven to have a detrimental effect on system performance for short fibre length and high data rate systems that cannot be ignored. The optimum performance in terms of channel spacing happens at a spacing bandwidth between 0.8 (100 GHz) and 1.2 nm. In the simulation, roughly 30 active users can be supported for error-free transmission at 10 Gb/s with data rate detection; however, the number of users might be tripled by using optical DEU code to remove the MAI. The analysis shows that the MAI noise has been successfully reduced.

[3] Hilal Adnan Fadhil et al.proposed a random diagonal (RD) code for spectral amplitude coding OCDMA.One of the key characteristics of this code is that phase intensity induced noise (PIIN) is reduced because the cross-correlation at the data segment is always zero. Any value higher than three may be used as the weight for the RD code. By categorising the code sequence into two groups—the code segment and the data segment—the design of this new code can be carried out. It is suggested to build a matrix with three and five users.

Simply repeat each row on both matrices to display an increase of users while also increasing the length of the code words. RD coding system performance is examined utilising a direct detection method. Results have shown that the new detection method outperforms the conventional complementary subtraction method in terms of performance. Because fewer filters are employed in the detection process, the cost and complexity of the entire system can be lowered. Using a direct detection strategy, RD codes can be implemented with only one pair of decoders and detectors needed, as opposed to two pairs in complementary subtraction techniques. The configuration of the proposed RD system with four users and spectral direct detection technique is described. Additionally, there is no subtraction procedure involved. The tests were conducted using single-mode optical fibre and the ITU-T G.652 standard at a rate of 10 Gb/s across a distance of 20 km (SMF).

To as closely replicate the real environment as feasible, all attenuation (i.e., 0.25 dB/km), dispersion, and nonlinear effects were active and set in accordance with standard industry norms. By referencing the bit-error-rate, the system's performance was evaluated (BER). The RD code with 20 active users was successful in achieving the maximum allowable BER of 109. When Psr ¿ 25 dBm, or a considerable effective received power, the RD approach performs significantly better. The relationship between number of users , fiberlength, effective power with BER is plotted.

These codes can be created quickly and are small in length. The modified double weight code (MDW), which avoids chip (the high bit) overlapping in the sequences, gave rise to the ZCC code family. Different mapping strategies were discussed in order to enhance the number of users and length. The BIBD method is utilised in the creation of a new ZCC code. A family of binary sequences with length C and a fixed Hamming weight w is known as the ZCC (C, w) code. Such codes are used in optical code division multiple access using spectral amplitude coding (SAC-OCDMA). The size of the constructing ZCC codes is C N w+1, where C is any prime number and N is the number of users. Compared to other construction methods, the suggested one is less challenging.

[4] Hassan Yousif Ahmed et al. propose a new algorithm for generating fixed right shifting (2D-FRS) code sequences, This is based on an OCDMA system that is spectral and spatially incoherent. With the minimum cross-correlation, the 1D-FRS code is used to build the proposed 2D-FRS algorithm (MCC). The 2D-FRS codes increase the system cardinality and provide the ability to eliminate MCC and the phase-induced intensity noise that goes along with it (PIIN). Additionally, the suggested technique enables the transmission of data by several users using various code sequences with the least amount of chance of interference. The Gaussian approximation is used to analyze the performance of the proposed 2D-FRS OCDMA system by investigating noise sources at photodiodes (PDs)

Due to division operation during the MCC elimination process at the balanced detectors, it is demonstrated that PD-1 and PD-3 have smaller contributions in terms of noise power compared to PD-0 and PD-2. The suggested system is validated by simulation results with a reasonable bit error rate (BER) of . In comparison to previously published approaches like Diagonal Eigenvalue Unity (DEU) and Two-Dimensional Diluted Perfect Difference codes, it is found that the 2-D FRS OCDMA system can accommodate a greater number of users in deterministic and stochastic ways (2D-DPD codes). At the BER of 10 -9, the 2D-FRS cardinality outperformed the 2D-DPD and 2D-DEU by 71.21 and 9.09, respectively. In comparison to published codes, the 2-D FRS meets the optical transmission criteria at a data rate of 622 Mbits/s with the lowest effective transmitted source power (Psr), of 27.5 dBm.

[5] S. A. Aljunid et al. A new code structure for spectral-amplitude-coding optical code-division multiple-access system based on doubleweight (DW) code families is proposed. The weight of the DW code is fixed as two. It is possible to create codes with more weights by utilising a mapping technique. A version of the DW code family with variable weights larger than two is called a modified double-weight (MDW) code

The newly suggested code exists for all natural numbers and has optimal cross-correlation features. then Hadamard and MFH codes are used to encrypt the system. The suggested code has many benefits, including simple encoder-decoder architecture, every natural number optimal cross-correlation , straightforward and efficient code building, and excellent SNR. One of the four MDW coded carriers running in simulation at 10 Gb/s over a communication-standard fibre demonstrates good transmission quality with a BER of 10 -12.

[6] Based on the 1-D PD code and the dilution method, Yeh et al. produced a brand-new 2-D spectral/spatial known as the 2-D diluted perfect difference (2-D DPD) code. Also given is the OCDMA system's architecture, which employs 2-D DPD codes. By inserting zeros in between each PD code's elements, the dilution approach is used. The number of zeros added between each pair of adjacent items determines how many groups are formed. A fixed in-phase cross-correlation of one for members of the same group and zero for members of other groups exists for each code sequence as a result.

The 2-D DPD codes' MAI cancellation characteristic minimises interference from other users. As a result, the 2-D DPD codes successfully lessened the impact of PIIN. The BER equation is theoretically derived for a receiver with PIN diodes or APD diodes in the analysis of the OCDMA system utilising this code. The system can accommodate a large number of simultaneous users at data speeds of 1Gbps and 2.5Gbps, which the authors demonstrated through numerical simulation to be superior to previous programmes. Better than dilution in the spectrum domain is dilution in the spatial domain.

By minimizing the effects of multiple access interference, the code improves quality of service (QoS). The power of two code-weight attributes in the MW-ZCC code provides improved support for the necessary service differentiation provisioning. Simulations have been used to examine how well this unique code performs. This investigation showed that the proposed OCDMA using MW-ZCC codes could support up to 32 simultaneous services over transmission distances up to 32 km in the presence of moderate atmospheric turbulence for a minimum allowable bit error rate of 10 -3, 10 -9, and 10-12 when supporting triple-play services (sensing, data communication, and video surveillance, respectively).

[7] The design of a 2-D temporal/spatial noncoherent OCDMA network based on matrix codes was reported by E. Park et al. with experimental findings. Delay lines and passive multimode fiber-optic couplers are used to implement the system. Based on pseudo-orthogonal matrix codes with a single pulse per row, a weight of four, and four users, this code is experimentally studied. The network design and the outcomes of the experiment are contrasted with those of an OCDMA network that employed temporal code. Because there are fewer couplers, there are no side lobes in the autocorrelation, and the coupler splitting is uniform, the authors were able to demonstrate that the suggested system had lower losses than temporal network losses. This allows for the use of shorter bit periods for a given piece of data.

In [8] A brand-new two-dimensional hybrid code based was proposed by Rima Matem et al. The 2D-ZCC/MD code is created by combining the 1D MD code with 1D ZCC code. The 2D ZCC/MD is built using the direct detection technique, as shown. There are two transmitters and two receivers in each pair, and the transmitter and receiver are connected by a star coupler. The incoming data will be encoded with the designated codeword and sent to the receiver via a star coupler. At the receiver, a single combiner will be used to decode the encoded data, and all codewords from various users will be correlated. There is no overlap in a spectrum, per the zero cross-correlation feature of the code 2D ZCC/MD.

[9] Nabiha Jellali et al. presented the two-dimensional dynamic cyclic shift codes, a new family of two-dimensional spectral/spatial codes (2D-DCS). The study describes the 2D-DCS codes' structure and characteristics. Its code length is brief, and its MAI is low. The cyclic shift mechanism and the Galois field are the foundations upon which the 1D-DCS code is built. Two sequence codes can be used to create the 2D-DCS code, which is produced from the 1D-DCS code. The proposed OCDMA network's system design includes M*N pairs of transmitters and receivers together with N star couplers. The EOM modulates the incoming data bits using the On-off keying format. We suggest using an optical receiver with MAI cancellation to pick up the transmitted data. N switches, two combiners, two balanced detectors, and a subtractor make up this receiver. User counts, effective transmitted power, data transmission rate, and source spectral width are investigated to characterise the code. Increases in N and decreases in M will improve system performance for a given code length. Spectral width and required transmission power are inversely proportional.

Sina Khaleghi and Mohammad Reza Pakravan [10]proposed an improved media access control (MAC) layer protocol that makes use of the physical layer's signalling method.benefits to offer different users varying degrees of quality. Users in the proposed network design are divided into two service classes, one with a greater degree of quality and the other with a lower level of quality.

Each class's users transmit at the same degree of power while being distinct from those of the other classes. Additionally, each user's MAC calculates the degree of channel interference and modifies the time of packet transmission to enhance network performance. Through simulation,It is shown that by combining appropriate power distribution to users and appropriate MAC algorithm parameters, different quality of service (QoS) metric levels on metrics like normalised throughput and packet error rate may be attained. This is accomplished by distributing the OCDMA network's resources among the users in each class. By establishing two factors linked to the normalised throughput of each class, we have studied the fairness issue in order to make the QoS provider technique more useful in data communication networks.

Chapter 3

Consruction of SSM code

The customized OCDMA transmitter and receiver is built using a unique coding system called SSM code.L, W, and C(where L is the code length, w is the code weight, and C is the cross correlation)between the code sequences, are the three parameters that describe SSM.The identity (I) and single-entry matrices(J), as well as the upper shift (Us) or lower shift (Ls) matrices, are used to create SSM codes.As a result, SSM1 and SSM2 can be produced with the same properties. The following equation can be used to generate SSM matrix code mathematically.

$$\begin{aligned} SSM &= \left[SSM^{ch+1}\,\mathrm{code} \right|_{K\times w} \\ &= \left\{ \sum_{m=0}^{W-2} Us_{i+m,j} \right\}_{K\times L} + I \times \overline{ch} + ch \times \{Ls + J\}_{k\times L} \end{aligned} \tag{3.1}$$

where ch is utilised to distinguish between SSM1 and SSM2, the total number of users served is expressed as K.When ch=0, the first term is ignored and the SSM code known as SSM1 (made using the Us and I matrices) is generated. If I is ignored, however, SSM2 is created.I, Ls, J, and Us are matrices,and the SSM code length "L" and can be represented as.

$$L = k(w-1) + 1 \tag{3.2}$$

SSM1 and SSM2 can be expressed as

$$\begin{aligned} SSM_I &= \lfloor SSM^1 \, \text{code} \rfloor_{K\times w} = f(I, Us) = \left\{ I + \sum_{m=0}^{W-2} Us_{i+m,j} \right\}_{K\times L} \\ SSM_s &= \lfloor SSM^2 \, \text{code} \rfloor_{K\times w} = g(J, Ls, Us) = \left\{ Ls + J + \sum_{m=0}^{W-2} Us_{i+m,j} \right\}_{K\times L} \end{aligned} \tag{3.3}$$

$$\begin{aligned} SSM &= \lfloor SSM^{0+1} \text{ code } \rfloor_{3\times 3} \\ &= \left\{ \sum_{m=0}^{3-2} U_{s_i+m,j} \right\}_{4\times 13} + I \times \overline{0} + 0 \times \{Ls + J\}_{3\times 7} \end{aligned} \tag{3.4}$$

$$thus$$

$$SSM = SSM^1 = Us_{i,j} + Us_{i+1,j} + I \tag{3.5}$$

Shift matrix: Us,which is called an upper shift matrix with "1s" only on the successive super diagonal and "0s" elsewhere. Additionally, Us is built with a diagonal matrix with dimension K × L, where K rows denote the number of subscribers and L columns denote the length of Us code sequences.

$$U_S = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \ldots & \\ 0 & 0 & 0 & \ddots & \\ 0 & 0 & 0 & \ddots & \\ \vdots & \vdots & \vdots & \cdots & 1 \\ 0 & 0 & 0 & \ldots & 0 \end{bmatrix} \tag{3.6}$$

Consider four subscribers as an example. If w = 4 and m = 0, then Usi,j can be expressed as

$$U_{s_{i,j}} = \begin{bmatrix} 0100000000000 \\ 0000100000000 \\ 0000000100000 \\ 0000000000100 \end{bmatrix} \tag{3.7}$$

The alternative sub-diagonal matrix Ls is alternatively referred to as a lower shift matrix. for 4 users and w = 4, Lsi,j can be written as:

$$Ls_{i,j} = \begin{bmatrix} 0000000000000 \\ 1000000000000 \\ 0100000000000 \\ 0010000000000 \end{bmatrix} \tag{3.8}$$

Identity matrix Identity matrix is designed with a K × L diagonal matrix.

$$\delta_{i,j} = \begin{cases} 0 & \text{if } i \neq j \\ 1 & \text{if } i = j \end{cases} \tag{3.9}$$

to conclude SSM1 can be written as,

SSM1 code for 4 subscribers and with weight 4 is given as

$$SSM^1 = I + Us_{i,j} + Us_{i+1,j} + Us_{i+2,j} \tag{3.10}$$

$$also$$

$$U_{S_{i+1,j}} = \begin{bmatrix} 0010000000000 \\ 0000010000000 \\ 0000000010000 \\ 0000000000010 \end{bmatrix} \tag{3.11}$$

$$U_{S_{i+2,j}} = \begin{bmatrix} 0001000000000 \\ 0000001000000 \\ 0000000001000 \\ 0000000000001 \end{bmatrix} \tag{3.12}$$

$$SSM^1 = \begin{bmatrix} \mathbf{1111000000000} \\ \mathbf{0100111000000} \\ 0010000111000 \\ 0001000000111 \end{bmatrix}_{4\times13} \tag{3.13}$$

Single – Entry matrix: A matrix with only one ”1” and all the other elements being ”0s” is called a single entry matrix. Designing the SSM2 code matrix, which may be expressed as

$$J^{00} = \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \ddots & \vdots \\ 0 & 0 & 0 & \ddots & \vdots \\ \vdots & \vdots & \vdots & \cdots & 0 \\ 0 & 0 & 0 & \cdots & 0 \end{bmatrix} \tag{3.14}$$

$$Hence$$

$$SSM^2 = J + LS + US_{i,j} + US_{i+1,j} + US_{i+2,j} \tag{3.15}$$

$$so$$

$$SSM^2 = \begin{bmatrix} 1111000000000 \\ 1000111000000 \\ 0100000111000 \\ 0010000000111 \end{bmatrix}_{4\times13} \tag{3.16}$$

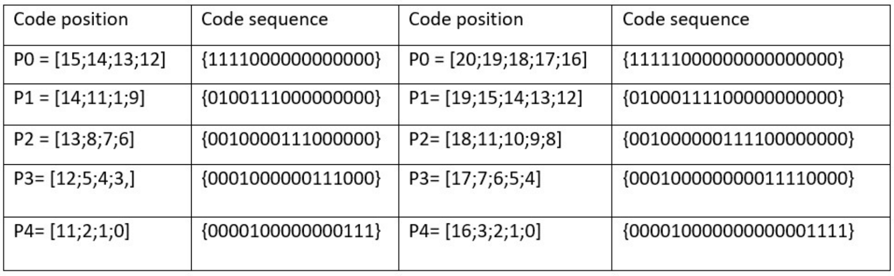
SSM1 and SSM2 share the same code structure, with the exception that the major diagonal's elements are shifted to the left.The proposed code, MSSM (Modified Sigma Shift Matrix).MSSM is produced by bitwise ANDing SSM1 and SSM2 together.The creation of MSSM code is described by the following equation.

MSSM=

$$
\begin{aligned}
&= SSM^1 \otimes SSM^2 = \left\{ I + \sum_{m=0}^{W-2} Us_{i+m,j} \right\}_{k\times L} \\
&\quad \times \left\{ Ls + J + \sum_{m=0}^{W-2} Us_{i+m,j} \right\}_{k\times L} \\
&= I \times Ls + I \times J + I \times \sum_{m=0}^{W-2} U_{si+m,j} + Ls \times \sum_{m=0}^{W-2} U_{si+m,j} \\
&\quad + J \times \sum_{m=0}^{W-2} Us_{i+m,j} \times \sum_{m=0}^{W-2} Us_{i+m,j} \\
&= \sum_{m=0}^{W-2} Us_{i+m,j} \times \sum_{m=0}^{W-2} Us_{i+m,j} = \sum_{m=0}^{W-2} Us_{i+m,j}
\end{aligned}
$$

An example for two different SSM code sets with 5 users and weights of 4 and 5

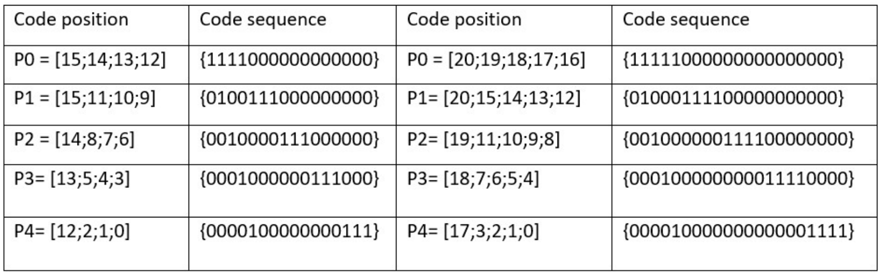
figure 3.1 shows SSM1 codes



Code position	Code sequence	Code position	Code sequence
P0 = [15;14;13;12]	{1111000000000000}	P0 = [20;19;18;17;16]	{11111000000000000000}
P1 = [14;11;1;9]	{0100111000000000}	P1= [19;15;14;13;12]	{01000111100000000000}
P2 = [13;8;7;6]	{0010000111000000}	P2= [18;11;10;9;8]	{001000000111100000000}
P3= [12;5;4;3,]	{0001000000111000}	P3= [17;7;6;5;4]	{000100000000011110000}
P4= [11;2;1;0]	{0000100000000111}	P4= [16;3;2;1;0]	{000010000000000001111}

Figure 3.1: SSM1 code sequences

Figure 3.2 shows SSM2 codes .It is found that both SSM1 and SSM2 having the same code structure with a diagonal is left shifted by one. MSSM code is shown in figure 3.3.MSSM is the result of AND oparation between SSM1 and SSM2.Code position and sequence for different weight is shown in the table.



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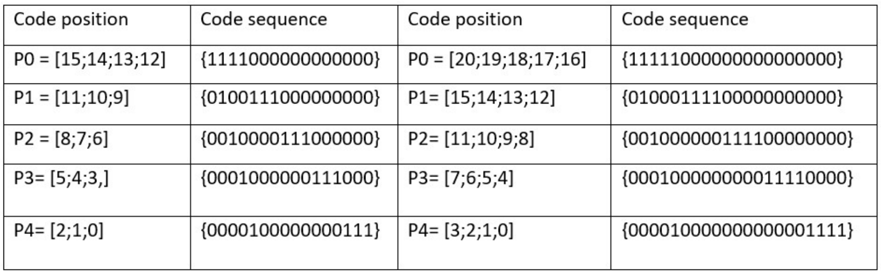
P3= [13;5;4;3]	{0001000000111000}	P3= [18;7;6;5;4]	{000100000000011110000}
P4= [12;2;1;0]	{0000100000000111}	P4= [17;3;2;1;0]	{000010000000000001111}

Figure 3.2: SSM2 code sequences



Code position	Code sequence	Code position	Code sequence
P0 = [15;14;13;12]	{1111000000000000}	P0 = [20;19;18;17;16]	{11111000000000000000}
P1 = [11;10;9]	{0100111000000000}	P1= [15;14;13;12]	{01000111100000000000}
P2 = [8;7;6]	{0010000111000000}	P2= [11;10;9;8]	{001000000111100000000}
P3= [5;4;3,]	{0001000000111000}	P3= [7;6;5;4]	{000100000000011110000}
P4= [2;1;0]	{0000100000000111}	P4= [3;2;1;0]	{000010000000000001111}

Figure 3.3: MSSM code sequences

Chapter 4

Proposed Model

4.1 OCDMA Transmitter-Receiver structure

The representation of a typical Optical Code Division Multiple Access system consist of several components such as a light source is there.When the information is in the form of an electrical signal,an optical encoder converts each bit into an optical sequence.The modulated signals are delivered through a typical single mode optical fibre with natural channel parameters.After that it is multiplexed in a WDM multiplexer or combined in a power combiner. A demultiplexer is used on the receiver side to transfer the data to various receivers.The optical data is converted to an electrical signal using a PIN photo diode detector,which is then sent through a low pass Gaussian filter to recover the data.To examine the received signal an eye diagram analyzer is connected at the end.

This section makes a design for a configurable transmitter-receiver structure based on SSM coding families.Three different encoding algorithms are used in the suggested design.Depending on whether the subscriber has chosen SSM1, SSM2, or MSSM as the encoding techniques are used.The SSM coding families can use simultaneously for K subscribers on the configurable transceiver design, which helps to improve QoS for desired applications.

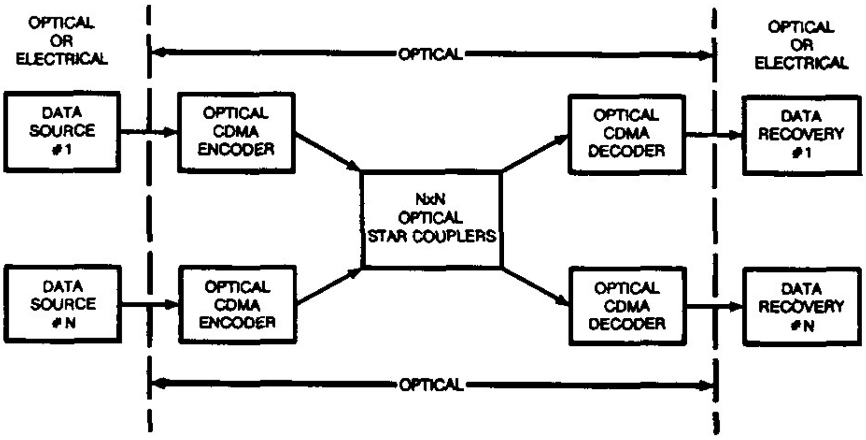


Figure 4.1: Basic block diagram of OCDMA system

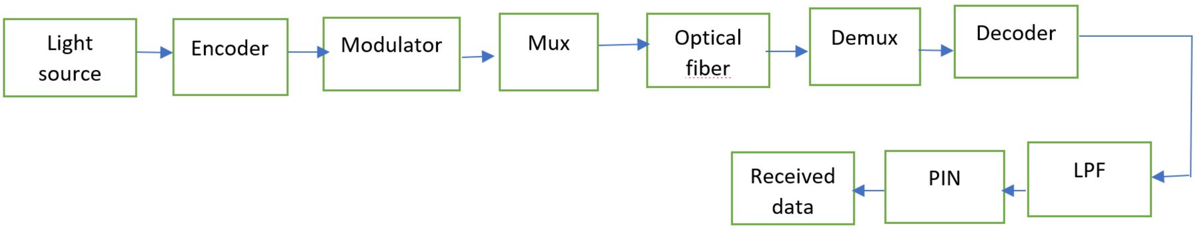


Figure 4.2: Block diagram of Proposed CDMA

4.2 OCDMA Control Module(Encoder)

The suggested transceiver model's new component is the control module.In order to carry out the necessary encoding scenario,it is incorporated to the transceiver architecture. The control module is managed by the class selection (CLS) and Ch signals.The transceiver's high- and low-quality services can be distinguished using CLS.When CLS is zero, MSSM performs the encoding function to ensure high-quality service. In any other case,the subscriber may employ SSM1 or SSM2. Because of this,if (CLS,ch) is (1,0) or (1,1) for the encoding process, SSM1 or SSM2 will be employed.

An optical Multiplexer(control module) is incorporated into the transceiver's architecture so that every users can select the suggested coding methods. With the help of the optical multiplexing, the user can select any service. The control module in the transceiver design is responsible for forwarding the correct wavelength. We can say that a single wavelength distinguishes MSSM from the other SSM families approaches. An illustration of the encoding-decoding procedure for three users is shown in the table 4.1 below.

S1	S2	S1.S2(MSSM)
0100111000	1000111000	0000111000
0010000111	0100000111	0000000111
0001000000111	0010000000111	0000000000111

Table 4.1: Encoding-decoding process for 3 users

From the table,if SSM1,SSM2,MSSM is used as the encoding technique, the equivalent wavelengths for a user are (2; 5; 6; 7), (1; 5; 6; 7), or (5; 6; 7). We can observe that, for a given person, all three encoding methods share the same wavelengths (5, 6, and 7), with the exception of one wavelength that differentiates SSM1, SSM2, and MSSM.Hence at the time we constructing the MUX For each user, the (w-1) wavelengths are passed straight to the modulator, and the remaining wavelength will come from the associated Mux to complete the modulation process. By using this it is possible combining all three encoding approaches into a single design.

The output of the mux is therefore ignored when MSSM is employed as the encoding technique since the weight is decreased to w-1.The Mux has three possible cases: MSSM, SSM1 or SSM2, thus we use the signals CLS and Ch to regulate the mux. Whereas CLS is used to signal that MSSM has been chosen as the encoding strategy and Ch distinguishes between SSM1 and SSM2.

The appropriate optical source for each user will produce (w+1)lamda. The remaining lamda (w and (w+1)) are then transmitted to the MUX inputs, and (w-1)lamda out of (w + 1) are forwarded to the modulator. As a result, the desired lamda is passed to the modulator by the associated MUX depending on CLS,ch. The modulator can then begin to modulate.

Table 4.2 summarizes the MUXs operations

- For a user if selection input is set as(0,0),output of the MUX will be first wavelenth. .

CLS	ch	O $\mathrm{MUX}_{\mathrm{i-TX}}$	user choice
1	x	0	MSSM
0	0	λ_{i}	SSM1
0	1	λ_{i-1}	SSM2

Table 4.2: Mux oparations

- If the selection input is set to (1,X) output of MUX will be 0. Consequently, Hence MSSM can be selected for encoding.
- The output of the MUX will be second wavelength when the selection input set to (0,1)

Every user has ’w’ wavelengths and the remaining is assigned by designed control module(encoder) according to user’s choice. Table 4.3 represents a scenario of three users selecting SSM1,MSSM, SSM2 respectively

The user can select SSM1, SSM2,or MSSM to decode the associated data at the receiver side (CLS,ch). Y is the output of MUXs, and it is supplied, together with the received signal (SSM1, SSM2), to an OR bitwise operation. The output of OR is always encoded as a direct detection scheme, then the user’s data is extracted using PIN photodiode and Low pass filter..

The three possible cases can be expressed as

- If we are giving the selection input CLS as 1,we can say the output data will be in the form of MSSM encoding.
- When we are providing the selection input CLS as ’0’and ch as ’0’ output will be in the form of SSM1 encoding.
- When the selection inputs CLS as’0’ and ch is given as ’1’ output will be in the form of SSM2 encoding.

4.3 Design of logic circuit of control module

We are developing a control module to make the transceiver adaptable. Logic gates are used to create it. Figure depicts how the logic gates are arranged to obtain the desired output signal. The Boolean expression for the designed multiplexer with inputs and data select lines such as CLS and ch is expressed as

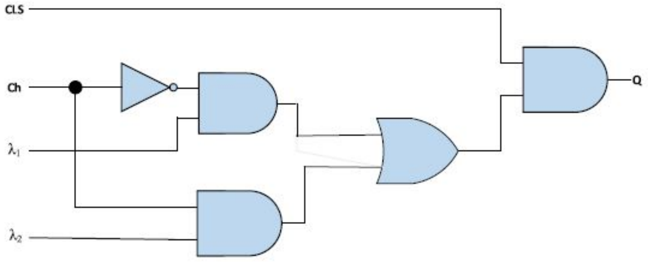


Figure 4.3: Control module for recovery of the intended wavelength.

$$Qi = CIS\left(\overline{Ch}\cdot\lambda_i + Ch\cdot\lambda_{i+1}\right)$$

The designed system is implemented using optisystem software.All gates are implemented using semiconductor optical amplifiers.

Figure consist of NOT gates,AND gates and an OR gate.ch value is given to the AND gate.for one Gate it is given directly and in other a NOT gate is used to make the inverse are given as other input.Outputs of both AND gats are given to a OR gate.finally output of OR gate along with CLS is given to an AND gate.

4.4 Implementation of all optical logic gates using MZI-SOA structure

In order to implement various logic functions, optical amplifiers (SOAs) are highly desirable nonlinear components.As a result of their substantial increase and large refractive index change.We consider the nonlinear behaviour of the SOA,which is advantageous for constructing an optical gate but is a drawback as a linear amplifier.

SOAs are set up in inter-ferometric arrangements to produce Gates with higher performance.By utilising the correlation between the carrier density and the refractive index in the SOAs, the optical input signal in these gates controls the phase difference between the interferometer arms through the use of cross-phase modulation (XPM).

These interferometric, reliable, SOA-based configurations are compact.Signal regeneration is an attractive characteristic of such devices. Mach-Zehnder interferometers have been used to build optical logic gates in numerous applications (MZI).

The MZI arrangement allows for AND, OR and NOT operations to be performed at speeds of up to 10 Gbit/s. The SOA is a particularly attractive device for application in optical networks because of so-called nonlinear phenomena, XPM(Cross phase modulation) and XGM(Cross gain modulation),which have been studied.

- Cross Gain Modulation (XGM): The XGM effects are implemented by changing the SOA gain in accordance with the input power. When the input signal's power is raised, the SOA's carrier density is depleted,which reduces the SOA's amplification gain.Because the dynamic processes that take place in the SOA carrier density occur at speeds of the order of picoseconds, it is possible to use this variation on the gain with bit-to-bit fluctuations in the input signal strength.
- Cross phase modulation(XPM):The XPM's principle of operation is this latter effect.The refractive index changes as a result of the variation in carrier density,which modulates the continuous wave's phase.Utilizing the MZI setup, this phase modulation can be changed into an intensity modulation.

4.4.1 Design of MZI-SOA based AND gate

Boolean AND gate operation becomes a good choice in optical signal processing.It gives logic “1” only when the two input signals under comparison are logic “1”.In other cases, the output is logic “0”.The AND gate only gives a “1” at the output in the event that both inputs are “1”.

The data signal enters through port 1 and 2.A zero level signal must be ensured through in port 3.An optical pulse will produced at the output if both data signals are ’1’.The AND operation is similar to do a XOR between data a and signal with zero level.

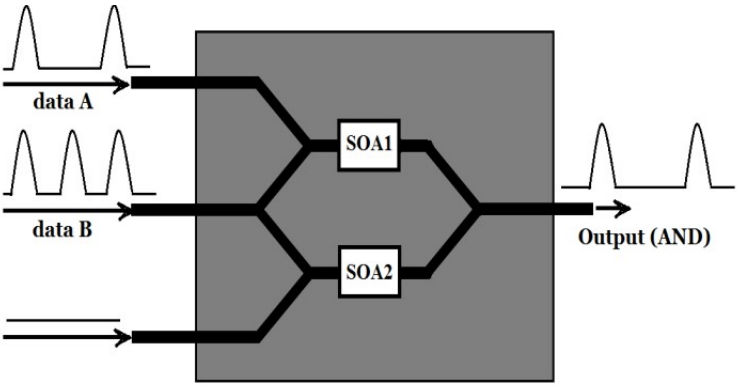


Figure 4.4: AND Gate using MZI-SOA.

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Table 4.3: Truth Table of AND gate

4.4.2 Implementation of MZI-SOA based OR gate

The truth table for OR gate is shown in Table. When both the inputs are zero, the result of OR gate is logic “0”. When any one of the input is one, then the result of OR gate is logic “1”.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Table 4.4: Truth Table of OR gate

The block diagram of OR gate based on MZI-SOA is shown in figure 4.8.

In an OR gate when both the inputs are zeros,gain of the SOA placed upper arm of Mach zehnder interferometric arrangement remains constant compared to gain of SOA in the lower arm.Due to destructive interference the output of OR gate become logic ’0’.SOA outputs are coupled at the output through a coupler.If any inputs is ’1’ SOA in the uper arm of MZI arrangement changes its gain and there is a phase shift happends which is known as cross phase modulation.This phase shift increases the

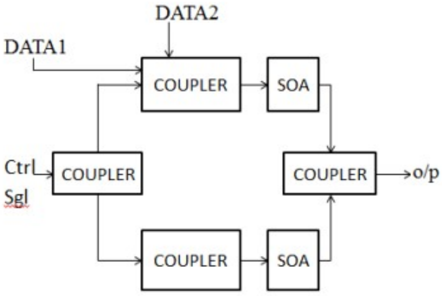


Figure 4.5: OR Gate using MZI-SOA.

output power.Due to this effect output signal become logic '1'.

4.4.3 NOT gate based on SOA-MZI

Table displays the truth table for the NOT gate. When the input is one for a NOT gate, the output will be logic "0." The output will be logic "1" if the input is zero.

The table presented in figure 4.9 depicts the truth table for NOT operation.

A	Y
0	1
1	0

Table 4.5: Truth Table of NOT gate

Block diagram of The NOT gate based on MZI-SOA is displayed. There are two inputs.When it comes to practical implementation One port can be used to connect a user-defined bit sequence generator, and the second input can be used to connect a CW laser.

For not gate whatever signal we provided at the input the reverse will get the output.Figure 4.6 shows the block diagram of NOT gate using MZI-SOA.

Figure 4.6: NOT gate using MZI-SOA.

Chapter 5

Software Tool

Optisyatem is an innovative, powerful and flexible design tool that is continually expanding.With OptiSystem, users can construct various circuit diagrams of designed system and can done the simulation process.version 19 is using here.Different types of components,transmission channels,visualizers are available in it.Users can place the components appropriately and construct the system. Software interface of optisystem is shown below.

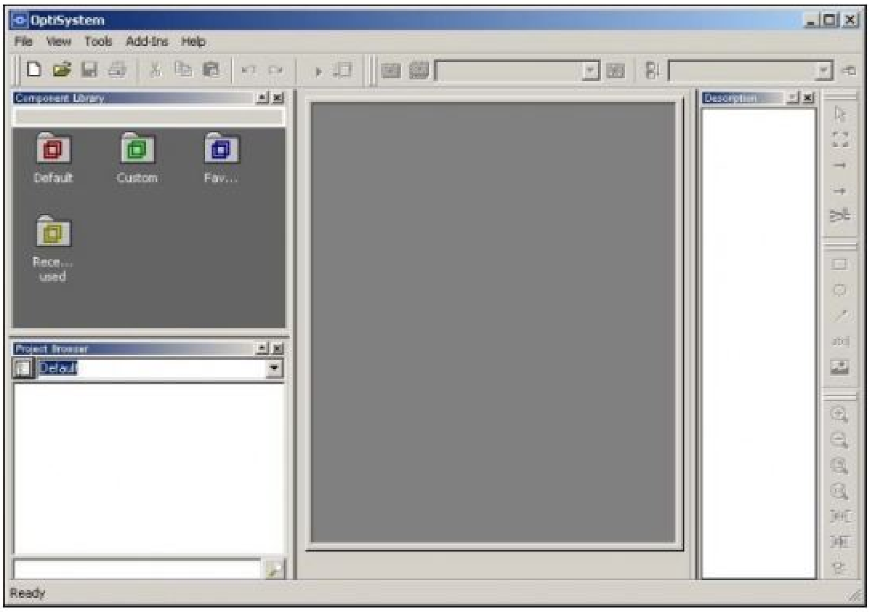


Figure 5.1: Software interface.

Benifits of optisystem

- Optisystem Provides information about designed system's performance.

- We can change the components parameters to enhance the efficiency.
- Integration with Mathlab is possible
- Drag and drop of components,duplication,deletion and providing connection between components are very easy.
- Automated parameter optimization and sweeping
- Wide component library and user can customize them according to the application.

Chapter 6

Simulation and Results

6.1 Implementation of SSM coding Family in OCDMA system

SSM codes are generated and designed a OCDMA system by using this family of SSM codes.The designed circuit is shown in figure.

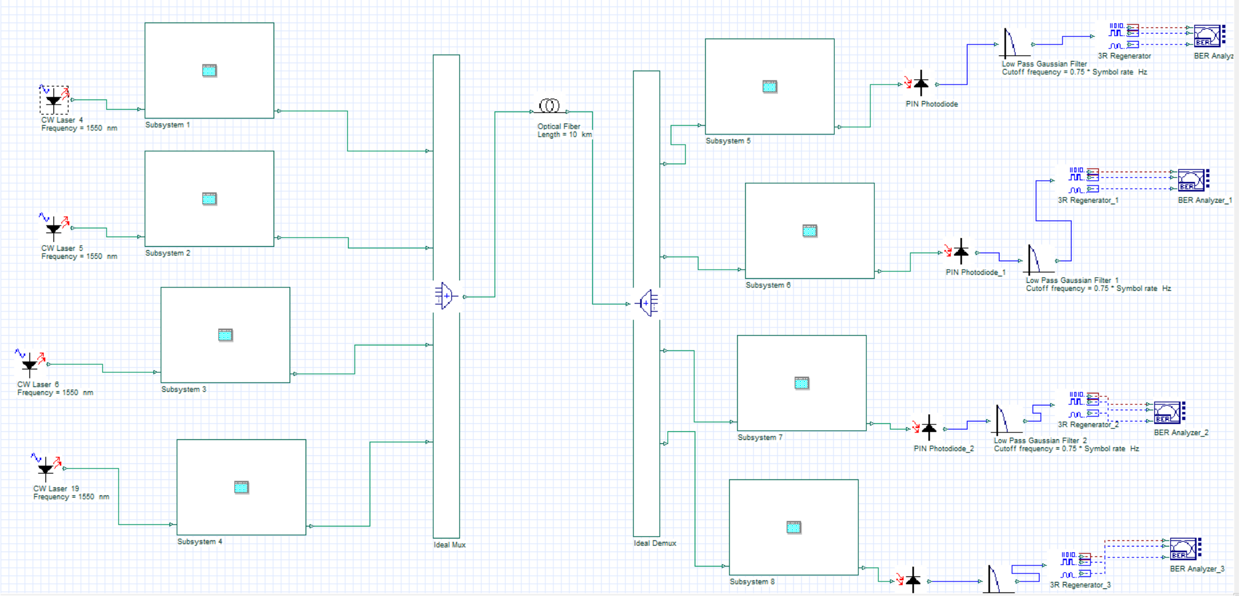


Figure 6.1: CDMA using Sigma Shifted Matrix codes.

As an optical source a contennous wave laser is used in the encoder side.By using an user defined bit sequence generator, orthogonal codes for different users are given as input and are encoded to the equivalent non return to zero (NRZ) signals.The encoder and decoder along with the modulator is shown as a subsystem. In the designed circuit SSM1,SSM2,and MSSM codes are given.The data is modulated using a Mach-Zehnder modulator.

The multiplexed signals are delivered across a common single mode optical cable after being multiplexed in a WDM multiplexer. A demultiplexer is employed on the receiver side to send the data to four corresponding receivers.A PIN photo detector is used for electrical to optical conversion.A low pass Gaussian filter is used to recover the data. The end is attached to an BER analyzer, which will examine the signal that was received.

The parameters used for the design is given in the table

SI.NO	parameters	value
1	Line encoding	NRZ
2	Effective sourse power	0 to -10 dBm
3	Number of users	2-10
4	operating wavelength	1550 nm
5	length of fiber	25-100 km
6	Data rate	622Mbps - 1.5 Gbps
7	Recieved power	o to -35dBm
8	attenuation of fiber	0.25 dB/km
9	Dispersion	16.7 ps/nm/km
11	Filter cut off frequency	0.75*Bit Rate

Table 6.1: OCDMA Design parameters

6.2 Implementation of logic gates using MZI SOA

The control module,which select the encoding technique must be designed utilising various logic gates. Mach zehnder Interferometric SOA is used to implement AND, OR, and NOT gates. The elements utilised in the creation of optical gates are

- Optical Gaussian Pulse Generator: It generates a series of optical Gaussian pulse.
- Optical Time Domain Visualizer: The modulated optical signal is shown in time-domain using this.

- Optical Power Meter: It measures the power of the optical signal passed through the optical cable.
- X-Coupler: It is used for either combing or splitting the optical signal.
- SOA: Semiconductor Optical Amplifier.
- Optical Receiver:The optical signal is transformed into an electrical signal using it.
- NRZ Pulse Generator: It is utilised to produce the series of coded non-return to zero pulses. which are coded by a digital signal.
- Low-Pass Gaussian Filter: It is a filter that has impulse response look like a Gaussian function.
- Time domain Visualizer: It displays the electrical signal in time domain.

Parameters of SOA used for the design of gates are shown in table

Parameters	Value
Input power of pump signal	0.3 mw
Input power of probe signal	0.25 mw
frequncy of pump signal	1550nm
frequency of probe signal	1540 nm
Injection current	0.15 A
optical confinement factor	0.3

Table 6.2: Parameters of SOA

6.2.1 AND Gate

Design of AND gate using MZI-SOA is shown in figure 6.2

In this design we generated two data signals.The MZI-SOA is used to generate AND gate. Two sequences are generated which are having same wavelength and same optical power. These two data signals are generated with the help of optical Gaussian pulse generator.A continuous wave is generated with a wavelenth of 1540 nm.

The SOA-MZI ports receive these signals in order to perform an AND operation. For filtering, a Gaussian optical filter is employed. The AND operation between the

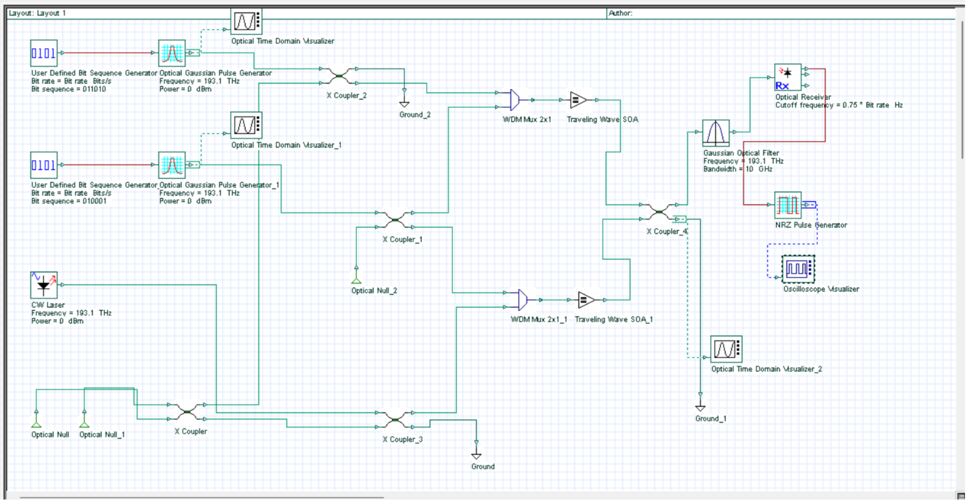
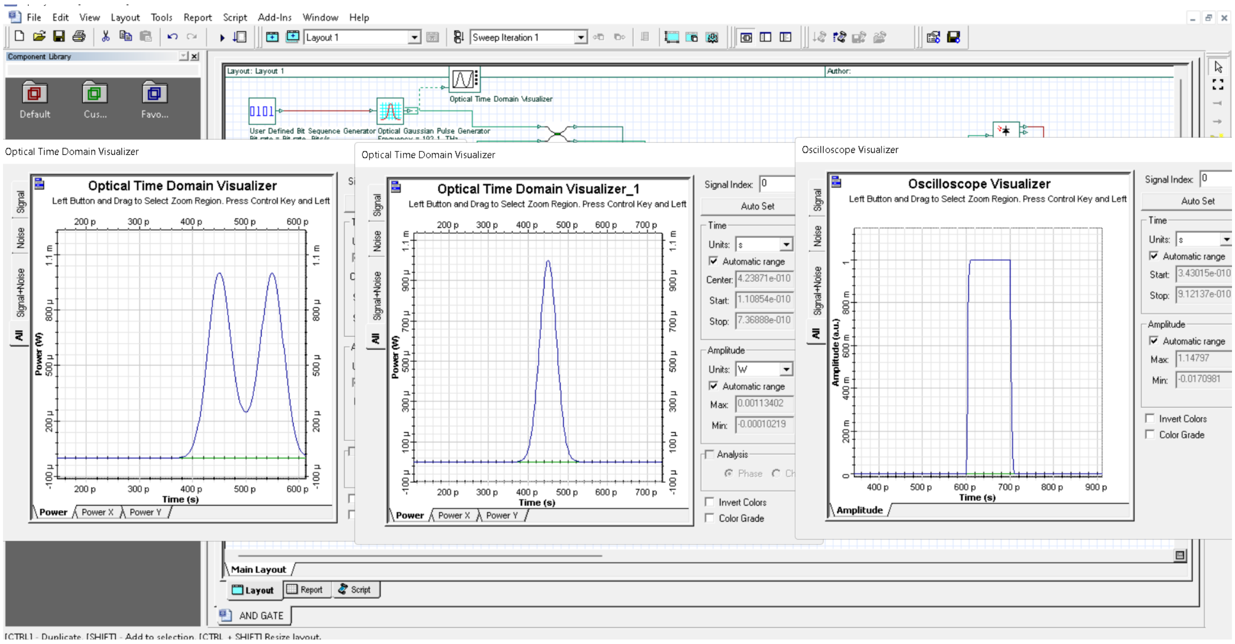


Figure 6.2: AND gate using MZI-SOA.

two data signals applied at ports of the SOA-MZI configuration produces this output signal. The semiconductor optical amplifier is regarded as a crucial part of the design. It can be viewed as an extremely appealing nonlinear component for implementing various logic gates. Because of its nonlinear behaviour as an amplifier, SOA is a good option in this situation.The simulation result of AND gate is shown in figure 6.3



Optical Time Domain Visualizer_1:

Signal Index: 0
Time
Units: s
☑ Automatic range
Center: 4.23871e-010
Start: 1.10854e-010
Stop: 7.36888e-010
Amplitude
Units: W
☑ Automatic range
Max: 0.00113402
Min: -0.00010219
☐ Analysis
☐ Invert Colors
☐ Color Grade

Oscilloscope Visualizer:

Signal Index: 0
Time
Units: s
☑ Automatic range
Start: 3.43015e-010
Stop: 9.12137e-010
Amplitude
☑ Automatic range
Max: 1.14797
Min: -0.0170981
☐ Invert Colors
☐ Color Grade

Figure 6.3: Simulation result of designed AND gate circuit.

6.2.2 OR Gate

Two sequences are offered for OR operation in the same manner as we did for AND gate implementation. The optical Gaussian pulse generator is once again used to create the two data signals in this instance. The OR operation between the two applied data signals produced this resultant signal.Design of OR gate using MZI-SOA is shown in figure 6.4. The simulation result by giving two input data sequence and the corresponding output after the OR operation is shown in figure 6.5.

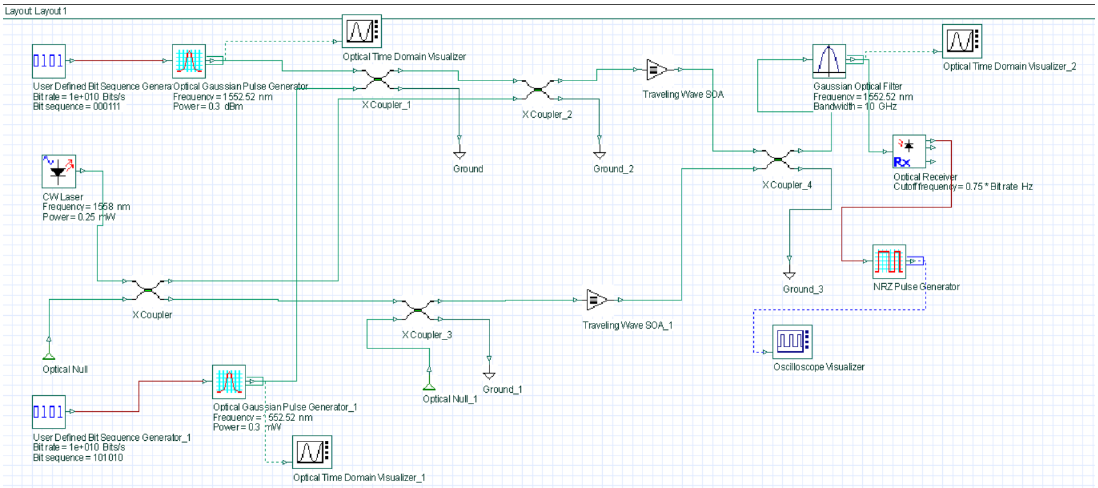
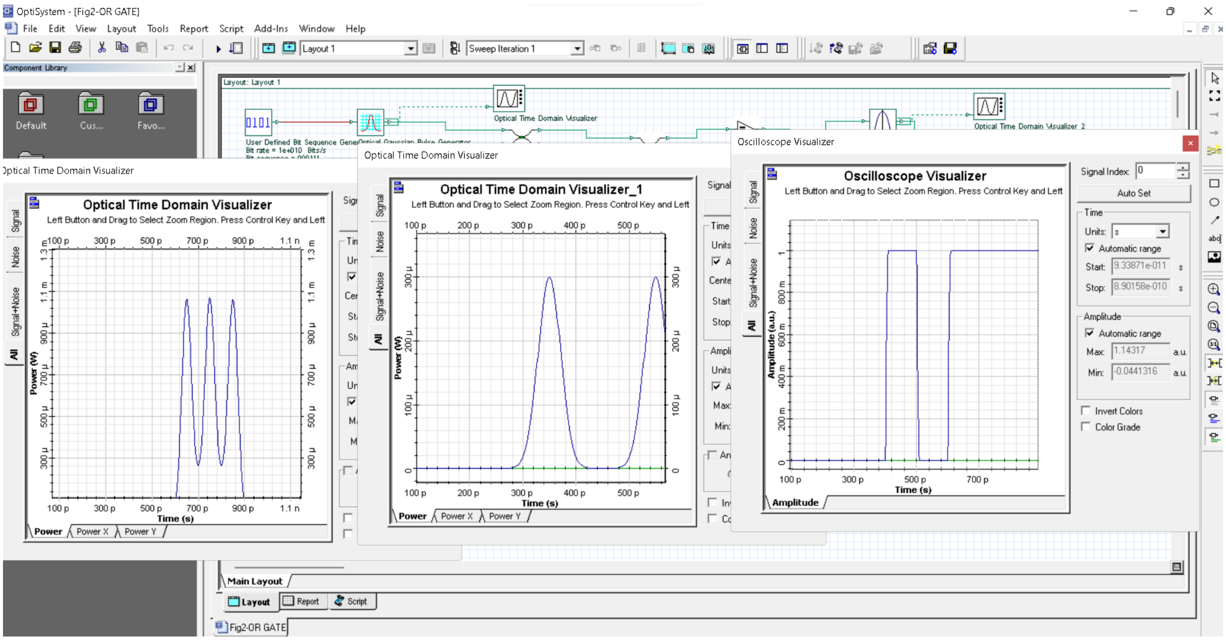


Figure 6.4: OR gate using MZI-SOA.



Signal Index: 0

Auto Set

Time

Units: s

☑ Automatic range

Start: 9.33871e-011 s

Stop: 8.90158e-010 s

Amplitude

☑ Automatic range

Max: 1.14317 a.u.

Min: -0.0441316 a.u.

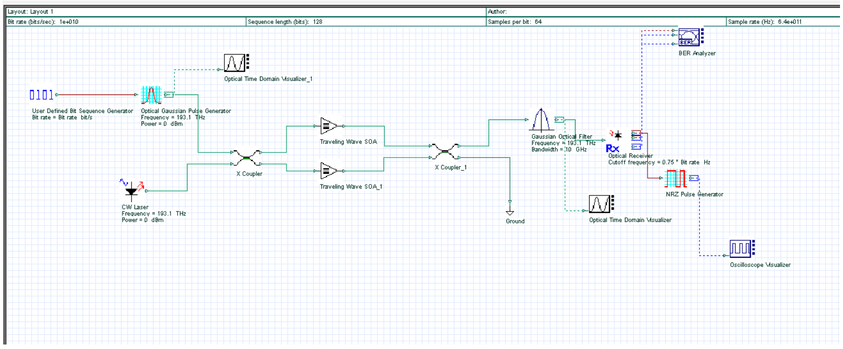
☐ Invert Colors

☐ Color Grade

Figure 6.5: simulation result of OR gate using MZI-SOA.

6.2.3 NOT Gate

In the case of Not gate an input is given and we will get the reverse at the output.The design of NOT gate using SOA is shown in figure 6.6.Simulation result is shown in figure 6.7.


Layout: Layout 1
Author:
Bit rate (bits/sec): 1e+010
Sequence length (bits): 128
Samples per bit: 64
Sample rate (Hz): 6.4e+011

User Defined Bit Sequence Generator
Bit rate = Bit rate bit/s

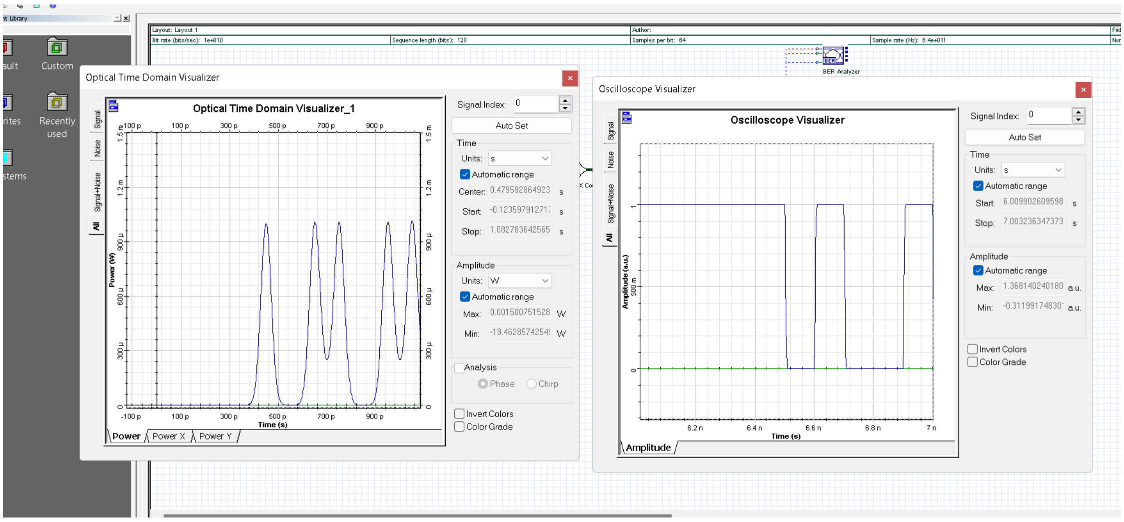
Optical Gaussian Pulse Generator
Frequency = 193.1 THz
Power = 0 dBm

CW Laser
Frequency = 193.1 THz
Power = 0 dBm

Gaussian Optical Filter
Frequency = 193.1 THz
Bandwidth = 10 GHz

Optical Receiver
Cutoff frequency = 0.75 * Bit rate Hz

Figure 6.6: Not gate using MZI-SOA.


Layout: Layout 1
Author:
Bit rate (bits/sec): 1e+010
Sequence length (bits): 128
Samples per bit: 64
Sample rate (Hz): 6.4e+011

Optical Time Domain Visualizer
Signal Index: 0
Time
Units: s
☑ Automatic range
Center: 0.479592864923 s
Start: -0.12359791271 s
Stop: 1.082783642565 s
Amplitude
Units: W
☑ Automatic range
Max: 0.001500751528 W
Min: -18.46285742545 W
☐ Analysis
○ Phase ○ Chirp
☐ Invert Colors
☐ Color Grade

Oscilloscope Visualizer
Signal Index: 0
Time
Units: s
☑ Automatic range
Start: 6.009902609598 s
Stop: 7.003236347373 s
Amplitude
☑ Automatic range
Max: 1.368140240180 a.u.
Min: -0.31199174830 a.u.
☐ Invert Colors
☐ Color Grade

Figure 6.7: NOT gate simulation result using MZI-SOA.

All this gates are combined together to form the control module.This is shown in the figure 6.8. Now, each circuit of AND, OR, and NOT gates has been divided into subsystems, and a control module has been constructed, as seen in figure 6.9. An oscilloscope is provided at receiving end to see the bit sequence coming from the desired user.Recovery of desired wavelength is possible by maintaining CLS and ch.This is shown in figure 6.10.This part make the system adaptive.Because by providing the value for CLS and ch the encoding techniques such as SSM1,SSM2 and MSSM can be selected.

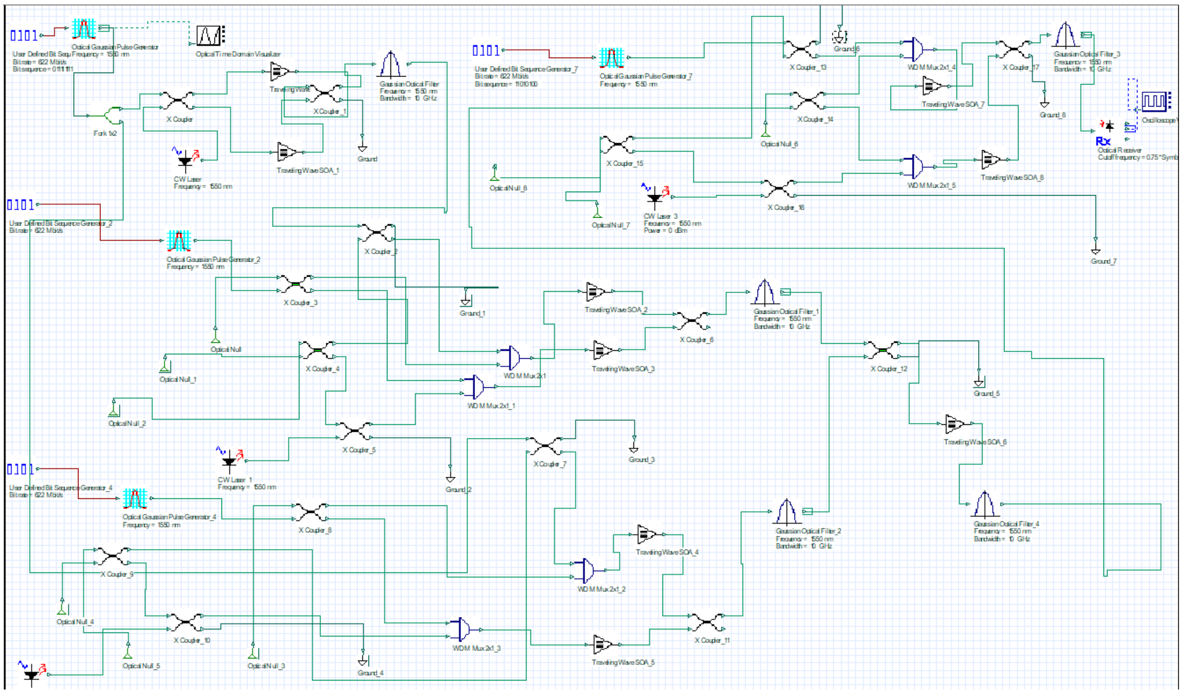


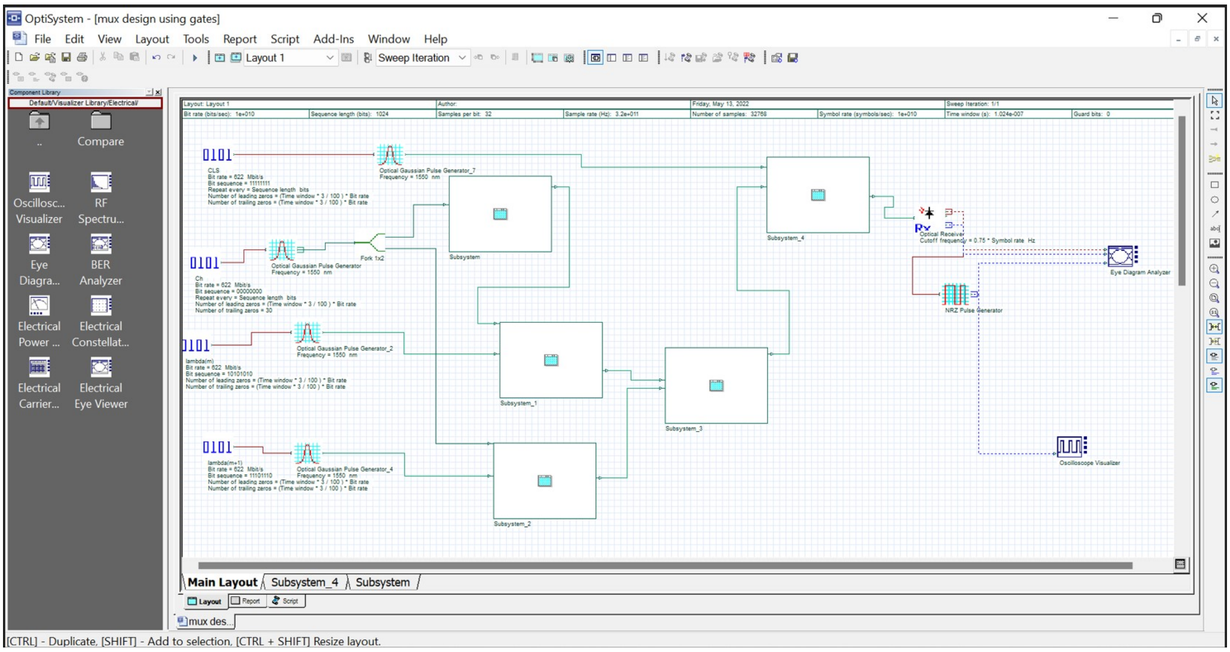
Figure 6.8: Combination of gates using MZI-SOA.

Recovery of the desired wavelength is demonstrated by recovery of a specific bit sequence assigned at input.This is shown in figure 6.10

The CLS and ch values are used to choose the required encoding method. As an illustration of how the SSM2 approach is used, the values of CLS and ch are made 0000 and 1111 respectively. Similar to this, first bit sequence at the input is set to 1010, while lambda second bit sequence is set to 1110. 8-bit sequence length data at 622 Mbps is used for the simulation.One is encoded using SSM1 and other is encoded using SSM2.By maintaining the value of CLS and ch,the desired signal will get at the output.

It is possible to see that the suggested configuration can deliver the needed performance while recovering the desired signal spectrum. As a result, achieving the requisite QoS is easy.

According to the design in figure 6.1 ,the encoder designed and the generated SSM codes are given to the system.The obtained eyediagrams are analysed.



Layout: Layout 1
Author:
Friday, May 13, 2022
Sweep Iteration: 1/1
Bit rate (bits/sec): 1e+010
Sequence length (bits): 1024
Samples per bit: 32
Sample rate (Hz): 3.2e+011
Number of samples: 32768
Symbol rate (symbols/sec): 1e+010
Time window (s): 1.024e-007
Guard bits: 0

CLS
Bit rate = 622 Mbit/s
Bit sequence = 11111111
Repeat every = Sequence length bits
Number of leading zeros = (Time window * 3 / 100) * Bit rate
Number of trailing zeros = (Time window * 3 / 100) * Bit rate

Optical Gaussian Pulse Generator_7
Frequency = 1550 nm

Ch
Bit rate = 622 Mbit/s
Bit sequence = 00000000
Repeat every = Sequence length bits
Number of leading zeros = (Time window * 3 / 100) * Bit rate
Number of trailing zeros = 30

Optical Gaussian Pulse Generator
Frequency = 1550 nm

lambda(m)
Bit rate = 622 Mbit/s
Bit sequence = 10101010
Number of leading zeros = (Time window * 3 / 100) * Bit rate
Number of trailing zeros = (Time window * 3 / 100) * Bit rate

Optical Gaussian Pulse Generator_2
Frequency = 1550 nm

lambda(m+1)
Bit rate = 622 Mbit/s
Bit sequence = 11101110
Number of leading zeros = (Time window * 3 / 100) * Bit rate
Number of trailing zeros = (Time window * 3 / 100) * Bit rate

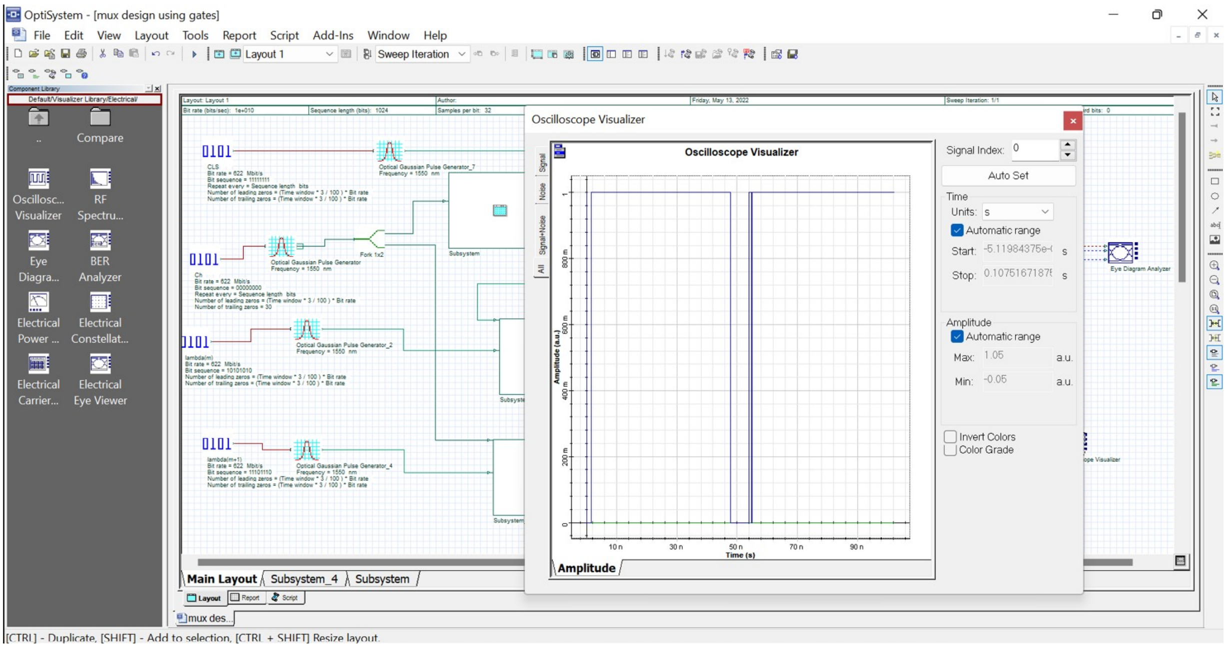
Optical Gaussian Pulse Generator_4
Frequency = 1550 nm

Optical Receiver
Cutoff frequency = 0.75 * Symbol rate Hz

[CTRL] - Duplicate, [SHIFT] - Add to selection, [CTRL + SHIFT] Resize layout.

Figure 6.9: Control module using gates.

An optical fibre is given between the transmitted receiver systems. BER and eye diagram characteristics are used to accomplish the simulation analysis.Eye diagram indicates the quality of signals in data transmission.Viewing an eye diagram help us to find the interference,cross talk,signal loss.Bigger the eye opening better will be the signal to noise ratio.The eye diagram obtained that was produced with good quality. Figure 6.12,6.13,6.14 are the eye diagram of SSM1,SSM2,MSSM respectively. The Bit Error Rate(BER) is defined as the total number of received bits in a stream of data over a communication channel that is affected by noise,interference,distortion etc.Our Aim is to design a OCDMA scheme that should have reduced BER.Next parameter we are considering is Q Factor.Q Factor is defined as the ratio of energy stored in the system to the energy lost in one cycle.By using Sigma Shifted Matrix code families we obtained better output signals with high Q factor,reduced BER with wide eye opening.It has been found that BER rises as data rate increases. The developed system is proven the system function well at higher data rates. For proving the efficiency we can compare the sigma shift matrix code with other orthogonal codes.



Signal Index: 0

Time

Units: s

☑ Automatic range

Start: -5.11984375e-(s

Stop: 0.10751671876 s

Amplitude

☑ Automatic range

Max: 1.05 a.u.

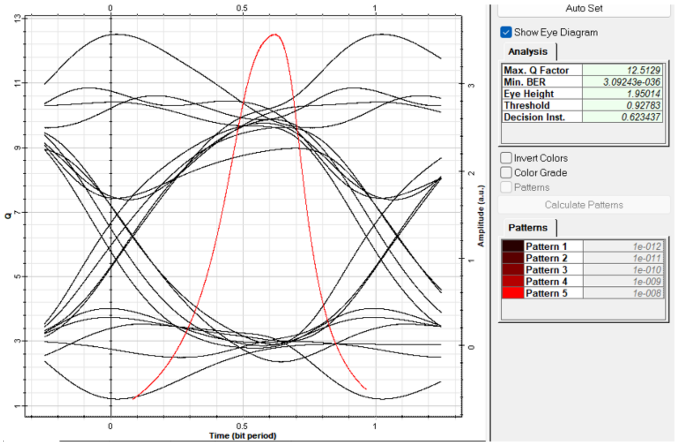
Min: -0.05 a.u.

☐ Invert Colors

☐ Color Grade

[CTRL] - Duplicate, [SHIFT] - Add to selection, [CTRL + SHIFT] Resize layout.

Figure 6.10: Recovery of desired input.



☑ Show Eye Diagram

Analysis	
Max. Q Factor	12.5129
Min. BER	3.09243e-036
Eye Height	1.95014
Threshold	0.92783
Decision Inst.	0.623437

☐ Invert Colors

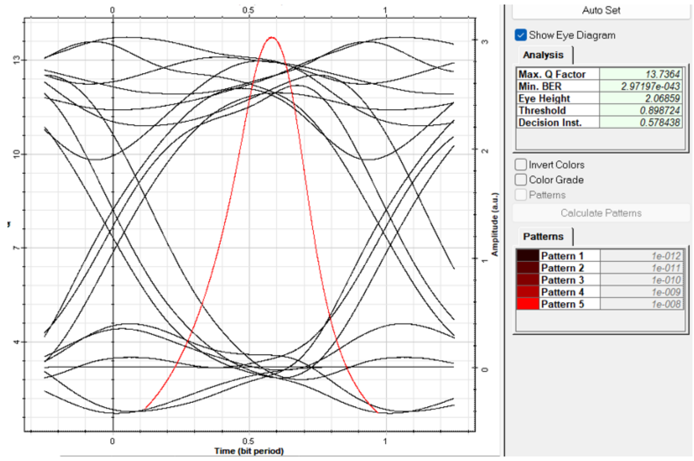
☐ Color Grade

☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Figure 6.11: Eye diagram of CDMA with control module and using SSM1 Code.

The comparison table indicate that the proposes SSM code family is highly efficient with reduced BER,high Quality factor and wide eye opening.SSM1 having a Q factor of 12.5129,SSM2 having a Quality factor of SSM2 and MSSM having a Q factor of 14.0978.From the results we can see MSSM have very high Q factor which is two times higher than that of other codes.Considering the eyeopening,higher the eye opening higher will be the signal to noise ratio.Here using SSM code family we got higher eye opening which shows it is having high efficiency.



☑ Show Eye Diagram

Analysis

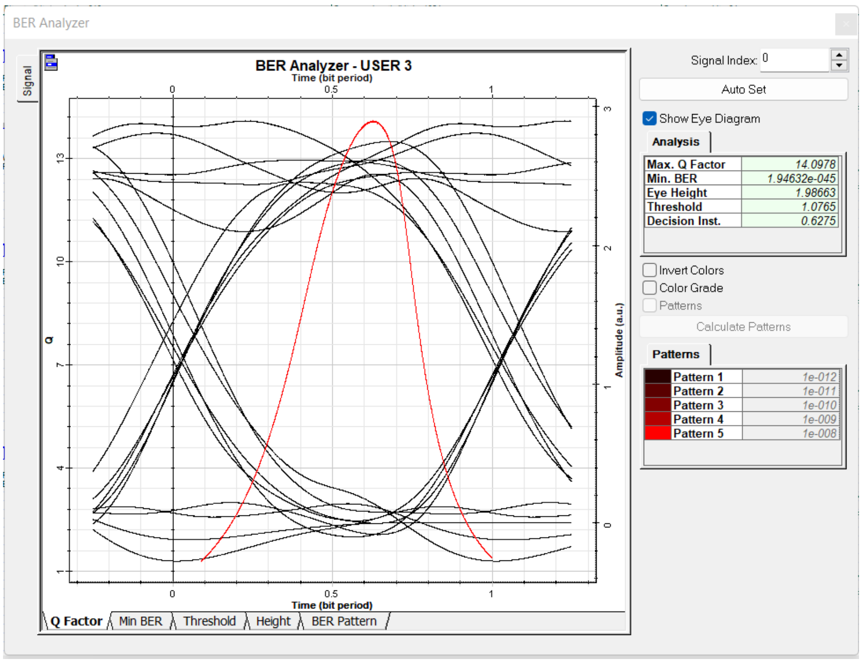
Max. Q Factor	13.7364
Min. BER	2.97197e-043
Eye Height	2.06859
Threshold	0.898724
Decision Inst.	0.578438

☐ Invert Colors
☐ Color Grade
☐ Patterns

Patterns

🟥	Pattern 1	1e-012
🟥	Pattern 2	1e-011
🟥	Pattern 3	1e-010
🟥	Pattern 4	1e-009
🟥	Pattern 5	1e-008

Figure 6.12: Eye diagram of CDMA with control module and using SSM2 Code.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	14.0978
Min. BER	1.94632e-045
Eye Height	1.98663
Threshold	1.0765
Decision Inst.	0.6275

☐ Invert Colors
☐ Color Grade
☐ Patterns

Patterns

🟥	Pattern 1	1e-012
🟥	Pattern 2	1e-011
🟥	Pattern 3	1e-010
🟥	Pattern 4	1e-009
🟥	Pattern 5	1e-008

Figure 6.13: Eye diagram of CDMA with control module and using MSSM Code.

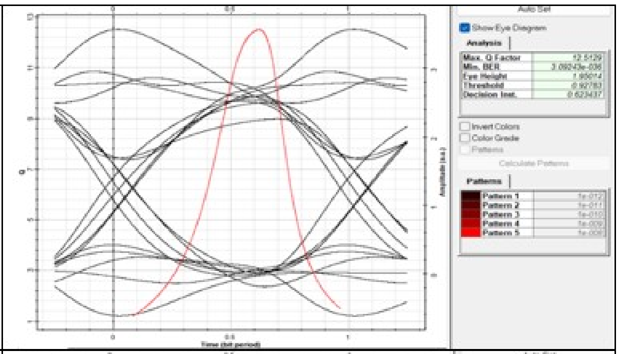
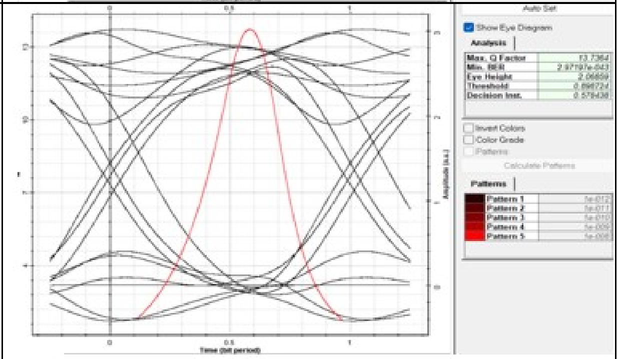
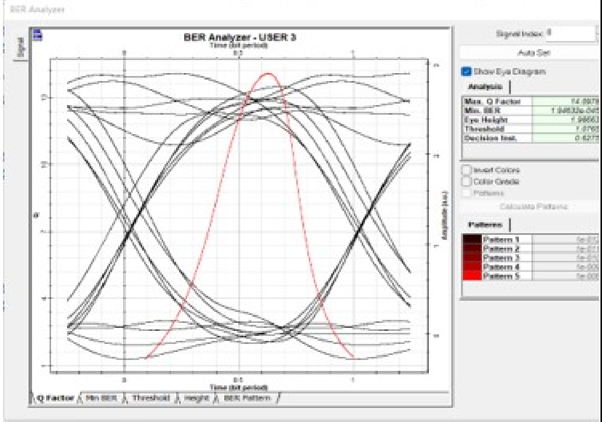
SSM1 Code	Q Factor:12.5129 BER:10^{-36} Eye Height :1.95	
SSM2 Code	Q Factor:13.7364 BER:$1O^{-43}$ Eye Height :2.06	
MSSM Code	Q Factor:14.0978 BER-10^{-45} Eye Height :1.98	

Figure 6.14: Q factor,BER and eye height of SSM code family

Chapter 7

Conclusion

For the SAC OCDMA system, a configurable transmitter-receiver design has been developed to accommodate varied QoS. In the adjustable transceiver architecture with multiple circumstances,orthogonal codes from the SSM code families are used to carry out the encoding-decoding procedure. These families have a number of benefits over the existing families, such as flexible encoder/decoder structure designs, maximum cross correlation, flexibility to choose any weight, high degree of cardinality, capacity to create different code sets, and simplicity of code construction.

The suggested transceiver architecture separates users into two service classes, one offering services of a high quality than the other. A design for an control module is also illustrated. The control module designed selects the preferred encoding-decoding technique according on the required application to transition between SSM families. A systematic approach is also developed to control the behaviour of the adaptive transceiver. Using the modelling application Optisystem 19, a verification test for the proposed configurable transceiver is conducted and is found successful.Parameters such as QOS and BER are analysed to prove the efficiency of designed system.

References

[1] Jawad A Salehi, code division multiple-access techniques in optical fiber networks-parts: fundamental principles, IEEE transactions on communications, vol. 37, no. 8, august 1989

[2] Hassan Yousif Ahmed, K.S. Nisar, Diagonal Eigenvalue Unity (DEU) code for spectral amplitude coding-optical code division multiple access, Opt. Fiber Technol.19 (2013) 335–347.

[3] Hilal Adnan Fadhil, S.A. Aljunid, R.B. Ahmad, Performance of random diagonal code for OCDMA systems using new spectral direct detection technique, Opt. Fiber Technol. 15 (2019) 283–289.

[4] Hassan Yousif Ahmed, Medien Zeghid, Numerical method for constructing fixed right shift (FRS) Code for SAC-OCDMA systems, Int. J. Adv. Comp. Sci. Applications (IJACSA) 8 (2017) 245–252

[5] S.A. Aljunid, M. Ismail, A.R. Ramil, A new family of optical code sequence for spectral-amplitude-coding optical CDMA systems, IEEE Photon. Technol. Lett. 16 (2004) 2383–2385.

[6] B. C. Yeh, C. H. Lin, C. L. Yang, and J. Wu, “Noncoherent Spectral/Spatial OCDMA System Using 2-D Diluted Perfect Difference Codes”, J. Lightw. Technol., vol. 27, no. 13, pp. 2420-2432, Jul. 2009.

[7] Eugene Park Antonio J. Mendez, and Elsa M. Garmire, ” Temporal/ Spatial Optical CDMA Networks-Design, Demonstration, and Comparison with Temporal Networks. IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 4, NO. 10, OCTOBER 1992.

[8] Rima. Mathem, S. A. Aljunaid, M. N Junitha, C. B. M Rashidi, Israa. Shihab Ahmed, “a novel two-dimensional spectral/spatial hybrid code for optical code division multiple access systems”Theorotical and Applied Information Technology 97(3):704-713.

[9] Nabiha Jellali, Monia Najjar, Moez Ferchichi, Houria Rezig,Development of new two-dimensional spectral/spatial code based on dynamic cyclic shift code for OCDMA system,Optical Fiber Technology, Volume 36,2017

[10] S. Khaleghi and M. R. Pakravan, “Quality of service provisioning in optical CDMA packet networks,” J. Opt. Commun. Netw., vol. 2, no. 5, pp. 283-292, 2010.

[11] S. Seyedzadeh, G.A. Mahdiraji, R.K. Sahbudin, A.F. Abas, S.B. Anas, Experimental demonstration of variable weight SAC-OCDMA system for QoS differentiation, Opt. Fiber Technol. 20 (5) (2014 Oct 1) 495–500.

[12] C.B.M. Rashidi, S.A. Aljunid, F. Ghani, H.A. Fadhil, M.S. Anuar, New design of flexible cross correlation (FCC) code for SAC-OCDMA system, Procedia Eng. 53 (2013) 420–427.

[13] C.-C. Yang and J.-F. Huang, “Two-dimensional M-matrices coding in spatial/frequency optical CDMA networks,” IEEE Photon. Technol. Lett., vol. 15, no. 1, pp. 168–170, Jan. 2003.

[14] Wei Z. H., Shalaby M., and Shiraz H. G., New code families for fiber-Bragg-grating-based spectral-amplitude-coding optical CDMA systems. IEEE Photonic Technology Letters, 13 (2001) 890-892

[15] Wei Z, Shalaby H. M. H, and Ghafouri Shiraz H., Modified quadratic congruence codes for fiber Bragg-grating based spectral-amplitude coding optical CDMA system. Journal of Light wave Technology, 19 (2001) 1274-1281.