MZI based Modified Trinary Number System

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Abstract

To successfully be able to achieve higher data rates, advanced optical networks will require all optical ultra fast signal processing such as wavelength conversion, optical logic and arithmetic processing, etc. So, one efficient conversion scheme is essential to convert one number system to another. Modified Trinary Number (MTN) has already taken a significant role towards carry and borrows free arithmetic operations. In this paper, we proposed Mach-Zehnder Interferometer (MZI) based tree-net architecture is used for the conversion scheme from binary number to modified trinary number in all-optical domain.

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1. Introduction

In the information age, the relentless demand for networks of higher capacities at lower costs. Optical communication technology has developed rapidly to achieve larger transmission capacity and longer transmission distance. For that such data rates can be achieved if the data remain in the optical domain eliminating the need to convert the optical signals [1]. To achieve the parallelism of optics a suitable number system and an efficient encoding scheme for handling the data are very much essential. Binary number is one of the best representing number system in almost all types of existing electronic computers but “carry” is generate by the binary numbers. So, such computers are not suitable for parallel arithmetic computing. The fundamental exposures to the parallelism in arithmetic’s are “carry” and “borrow” free arithmetic operation. So, to get carry-borrow free arithmetic operations various signed digit number systems have been described such as MSD (modified signed-digit), MMSD (mixed modified signed-digit), TSD (trinary signed digit), NTSD (non-recoded trinary signed digit) and negabinary signed-digit number system [2-10]. In initial stage of digital optical computing MSD and MMSD based techniques guided the “carry” and “borrow” free parallel operation in optics. Binary arithmetic operations can be successfully performed by using MSD numbers and it can easily be extended to the optical purview. The technique of arithmetic operations uses both barred and unbarred numbers to maintain the parallel processing capability.
Among different topologies, monolithically integrated MZI switches represent the most promising solution due to their compact size, thermal stability and low power. The present work is an attempt for an efficient circuit realization of conversion from binary data to modified trinary number (MTN) in all-optical domain. Semiconductor optical amplifier (SOA) based Mach-Zehnder interferometer (MZI) can play a significant role in this field of ultra fast all optical signal processing. Here simulation has been done with Mathcad-7 and results are also reported.

2. Modified ternary number

It is very important to substitute data which are generally in binary form into signed digit numbers. MMSD representation satisfied the requirement of fully parallel addition and subtraction and also the unique representation for the zero value. In MMSD number system, the numbers (decimal and binary) are represented not only by zero and positive numbers but also by barred numbers. A barred number indicates a number with negative value but with the same radix.

For parallel conversion from binary to MMSD the steps are following:

Step-1: If the least significant bit (LSB) of a binary number is 0s, they are deleted. This step is bypassed if it is 1.
Step-2: Now the obtained results of step-1 are complemented bit wise.
Step-3: All 1’s in the result of step-2 are replaced by \( \overline{1} \). Also, a 1 is inserted to the left of the most significant bit (MSB).
Step-4: \( \overline{1} \) is added with the result of step-3. \( \overline{1} \) added with either 1 or 0 and result is 0 or \( \overline{0} \).
Step-5: If LSB is 1 of the binary number, then the result of step-4 is the MMSD form of that particular binary number. If there are 0s in the least significant position of the binary number then the 0s that were deleted during step-1 are placed to the right hand side to give converted result.

MTN is a particular type of MMSD number. So, a binary number when expressed in MTN system takes 1 as its most significant digit (except for 0 MTN) where all other digits are either 0 or \( \overline{1} \). Table 1 shows the three input binary number and its corresponding MTN form.

As for example:

| Binary number | 0 1 0 | as | Binary Number | Corresponding Modified Trinary Number |
|---------------|------|----|---------------|---------------------------------------|
| Step-1        | 0 1  |    | A  B  C  A_3  A_2  A_1  A_0 | 0 0 0 0 0 0 0 0                        |
| Step-2        | 1 0  |    | 0 0 1 1 1 1 1 1 | 0 0 0 0 1 1 1                         |
| Step-3        | 1 1  |    | 0 1 1 1 1 1 1 1 | 0 0 0 0 1 1 1                         |
| Step-4        | 1 1  |    | 1 0 1 1 1 0 0 1 | 0 0 0 0 1 1 1                         |
| Step-5 (MMSD) | 1 1  |    | 1 1 0 1 1 0 0 1 | 0 0 0 0 1 1 1                         |

Shown in Fig 1(a), is a very powerful optical device to realize ultra fast all-optical switching [11]. In this switch a semiconductor amplifier (SOA) is inserted in each arm of a MZI. The pulsed signal at the wavelength \( \lambda_1 \) enters to the upper arm through coupler C2 such that most power passes through upper arm.
At the same time, the incoming signal pulse at the wavelength $\lambda_2$ enters port-1, is split equally by this coupler C1 and propagates simultaneously in the two arms.

![Diagram](image)

**Fig. 1.** (a) MZI-based optical switch; (b) Schematic diagram of SOA based MZI optical switch

Now, it is clear that in the absence of control signal ($\lambda_1$), the incoming signal ($\lambda_2$) exits through cross-port (lower channel) of MZI as shown in Fig 1 (a). In this case no light is present in the bar-port (upper channel). But in the presence of control signal, the incoming signal exits through bar port of MZI as shown in Fig 1(a). In this case no light is present in the cross port. In the absence of incoming signal, bar-port and cross-port receives no light as the filter blocks the control signal. Schematic block diagram of MZI is shown in Fig 1(b).

### 3. MZI based three Input Tree Architecture

Seven MZI based optical switches $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$ and $S_7$ are used to describe three input (A, B and C) tree architecture. Here eight output terminals are T-1, T-2, T-3, T-4, T-5, T-6, T-7 and T-8. The pictorial representation of this is shown in Fig 2. When the signal is present in any terminal then the terminal is in 1 state and when it is absent the terminal is in 0 states. All the output in several cases is shown in Table 2.
Table 2. State of different output terminals in several combinations of input signal A, B and C

| Input | Output at different terminals |
|-------|-----------------------------|
| A     | B   | C   | T-1 | T-2 | T-3 | T-4 | T-5 | T-6 | T-7 | T-8 |
| 0     | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 0     | 0   | 1   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 0   |
| 0     | 1   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   |
| 0     | 1   | 1   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   |
| 1     | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0   |
| 1     | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   |
| 1     | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | 0   |
| 1     | 1   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   |

Fig. 2. Optical tree architecture with MZI based optical switch

4. Conversion of binary to MTN with the help of all-optical MZI based tree-net architecture

By using the above tree architecture we can convert the binary number to its MTN form very easily. A special interconnection system (basically a reverse tree structure) is needed for this purpose. This interconnection can be easily done with the help of beam splitters or mirror-beam splitters combination. The character of the used beam splitters are not polarizing. For all polarization it only reflect (and transmit) 50 % of the incident light. When the light beam incident on the upper surface of the beam splitter it suffers transmission only but when falls on the lower surface of the beam splitter it suffers both transmission and reflection. The optical circuit is shown in Fig 3. Here the control signals (A, B and C) are taken as binary input. The output obtained in the form of a polarized light. When it is perpendicular to the plane of the paper (•) indicates 1 and parallel to the plane of the paper (↑) indicates 1 and no light signifies 0 state. Here, the input light beams are expected to be an un-polarized one. The MTN output (A3 A2 A1 A0) is obtained through respective polarizer as shown in Fig 3. A0 will receive light from T-8, T-6, T-4 and T-2 terminals, A1 will receive light from combination of T-7 and T-6 and T-3 and T-2 terminals, from combination of T-5 and T-4 and T-3 and T-2 terminals light will reaches at A2, A3 will receive light from combination of T-2, T-3, T-4, T-5, T-6, T-7 and T-8 terminals.
For example, if we take the binary number 110 as the input (that means A=1, B=1 and C=0) then T-7 receives light from constant light source. Hence, in the final output A₀ and A₂ will get no light but the polarized light (•) perpendicular to the plane of paper will appear in A₁ and the polarized light (tı) parallel to the plane of paper will appear in A₃. Therefore, A₁ A₂ A₃ A₀ will give the output as 10 1 0. This is MTN equivalent of binary 110. In this way we can get the conversion of other numbers.

5. Simulation and performance Evaluation

Simulation is done in Mathcad-7 and is shown in Fig 4. The power of the input pulse is taken A=1.13 dBm, B=2.26dBm and C=1.13 dBm. Here we use 50:50 beam splitters.

6. Concluding remarks
In this paper, MZI based MTN circuit has been proposed and described. Simulations are done. The process is all-optical in nature and bears the inherent advantages of tree structure. The scheme can easily and successfully be extended and designed for higher number scheme. This can be done by proper incorporation of MZI based optical switches, vertical and horizontal extension of the tree and by suitable branch selection.

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