The Proposal of OCDMA Encoder Based on Optical Cross Add and Drop Multiplexer (OXADM) - Device Characteristic

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Summary
This paper proposes the development of N-ports optical code division multiple access (OCDMA) encoder prototype based on OXADM device. It is potentially to provide a high security for data transmission due to data transmitted in binary code form. The output signals from OXADM are coded with a binary code that is given to an optical switch before the signal is modulated with the carrier and transmitted to the receiver. The N-ports encoder used N double pole double throw (DPDT) toggle switches to control the polarization of voltage source from +5 V to -5 V for N optical switches. When +5 V is given, the optical switch will give code '1' and vice versa. The experimental results showed the insertion loss, crosstalk, return loss, and optical signal-noise-ratio (OSNR) for the developed prototype at <6 dB, 60dB, 40 dB, and ≥20 dB.

Key words:
OXADM, OCDMA, encoder, characteristics, crosstalk, return loss, OSNR

1. Introduction

Owing to the maturity of optical components and electronic circuits, optical fiber links have become practical for access networks [1]. Passive optical network (PON) is one of the most promising solutions for fiber-to-the-home (FTTH) since it breaks through the economic barrier of traditional point-to-point (P2P) solutions. PON has been standardized for FTTH solutions and is currently being deployed in the field by network service providers worldwide [2-4]. The PON is based on some multiplexing technologies, including time division multiplexing (TDM), wavelength division multiplexing (WDM), hybrid TDM/WDM, code division multiplexing (CDM), and optical code division multiplexing (OCDM) for access networks have been proposed.

Interest in OCDMA has been steadily growing in recent decades [5]. That trend is accelerating due to fiber penetration in the first mile and the establishment of PON technology as a pragmatic solution for residential access [6]. OCDMA is one promising technique for the next-generation broadband access network with the following advantages: asynchronous access capability, accurate time of arrival measurements, flexibility of user allocation, ability to support variable bit rate, busty traffic and security against unauthorized users. OCDMA is a very attractive multi-access technique that can be used for local area network (LAN) and the first one mile [7]. Moreover, the OCDMA method is preferable for multiplexing in the optical domain because it uses broad bandwidths in optical devices for the electrical CDMA method and the electrical-to-optical (E/O) conversion [8].

OCDM is a multiplexing procedure by which each communication channel is distinguished by a specific optical code rather than a wavelength or time-slot. An encoding operation optically transforms each data bit before transmission. At the receiver, the reverse decoding operation is required to recover the original data. The encoding and decoding operations alone constitute optical coding. OCDMA is the use of OCDM technology to arbitrate channel access among multiple network nodes in a distributed fashion [9].

There are many different kinds of OCDMA encoder/decoders that use optical delay lines or optical switches with optical orthogonal code (OOC) for the time domain; fiber Bragg grating (FBG) or AWGs and OOCs for the optical frequency domain, and FBGs or AWGs for optical wavelength-hopping/time spreading (TS) [8]. AWG-based encoder/decoder has the unique capability of simultaneously processing multiple time-spreading optical codes (OCs) with a single device, which makes it a potential cost-effective device to be used in the central office of OCDMA network to reduce the number of encoder/decoders. The AWG-based encoder/decoder also has a very high power contrast ratio (PCR) (15~20 dB) between auto- and cross-correlation signals, which means the interference value could be significantly reduced (up to 20 dB) with the short OC [10].

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2. OCDMA Encoder

Figure 1 displays the architecture of the OXADM used as a decoder in the OCDMA communication system. OCDMA is a revelutionary data transmission architecture in the new millenia which utilizes coded spectrum as an optical signal carrier. In Figure 1, the architecture adds a new element, the interleaver device, before the original OXADM architecture. The interleaver will divide all signals into two main groupings before entering the OXADM input terminal. A desired doded spectrum will then be generated by a microcontroller as it enters the terminal. The imput signal are matched with the spectrum code in order to have a similar signal with the code as it exits the device. This device used in the system will be primarily focused on indentification of received coded signals. Photodetector on the receiver's side will then accept the signal to be deciphered. Other than that, the OXADM is able to route the signal to be either sent to output A, or output B. With this distinguish feature, it is able to decode a single signal to two seperate stations. In addition, this decoder can also function as a variable encoder. The different forms of output spectrum codes is being controlled by switches P, Q, R and S.

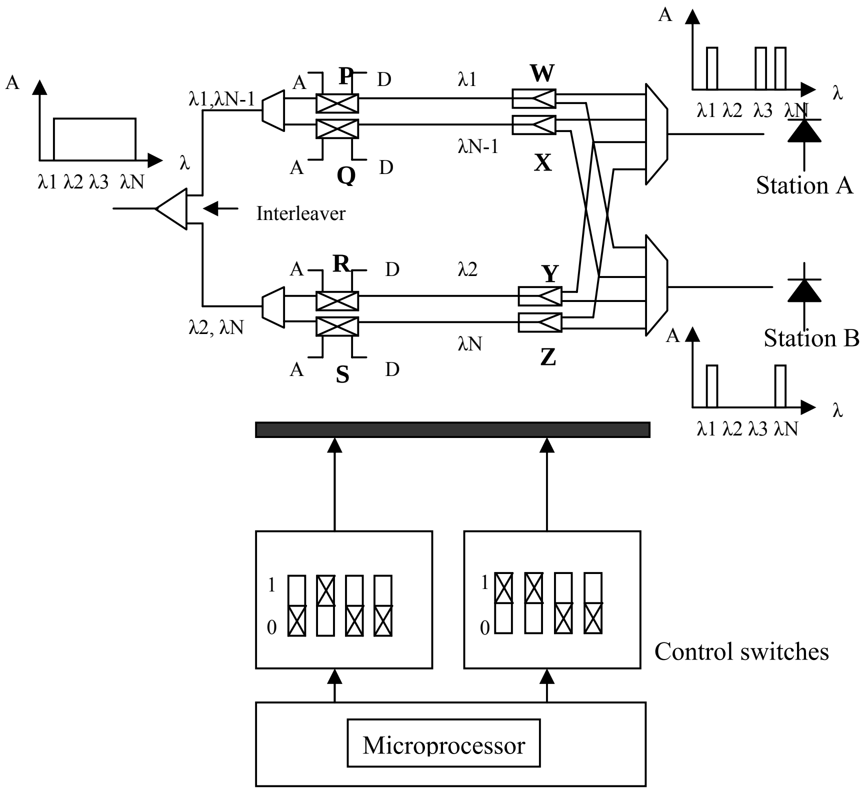


Figure 1 Architecture of a variable decoder that utilizes the OXADM as a code identification system in OCDMA. application

3. Device test

3.1. Crosstalk

Two parameters have been studied experimentally to ensure the interference of uninterested signal is minimized. Figure 2 shows the experimental set up to measure the crosstalk and two ports of OXADM and the results have been redrawn in Figure 3 and 4 respectively. A crosstalk value is bigger than 60 dB means the interested wavelength is in safety mode and the transmitted data can be interpreted at any receiver end.

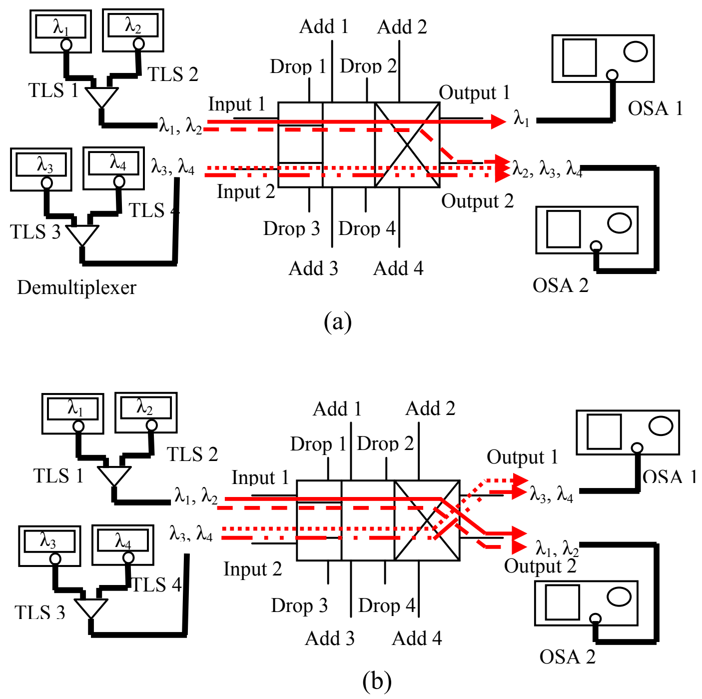


Figure 2. Crosstalk measurement set up. (a) Configuration 1 (b) Configuration 2

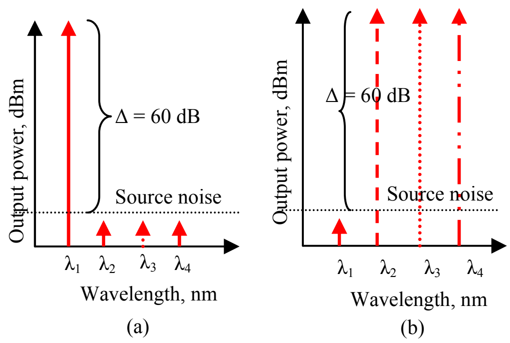


Figure 3. Redrawing of measured output signal for configuration 1. (a) Output 1 (b) Output 2

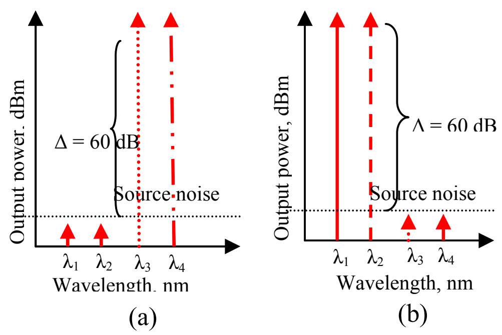


Figure 4. Redrawing of measured output signal for configuration 2. (a) Output 1 (b) Output 2

3.2. Return loss

The other parameter that should be considered for bi-directional device is return loss. Return loss is the disturbance of uninterested signal against the direction of interested signal. This can be explained using Figure 5. The return loss is measured by using the set up in Figure 2 (adding circulator in front of device and the reflection was measured by optical spectrum analyzer (OSA)) and the result is shown in Figure 5 (redrawn). The value is 40 dB which is higher than minimum safety value. Both experimental values have clear indications that the OXADM optical switch has a good value of crosstalk and return loss.

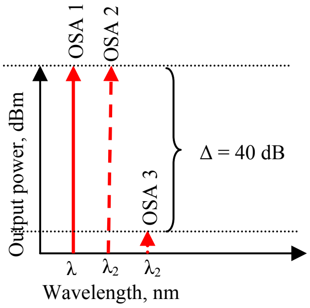


Figure 5. Redrawing of measured signal at every output port for return loss measurement

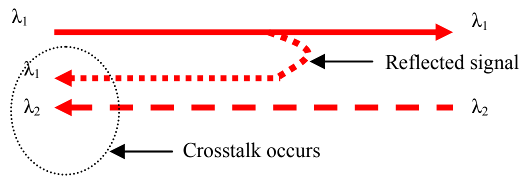


Figure 6. Return loss is a reflected leakage signal which contributes to crosstalk phenomena in bi-directional device

3.3. Insertion Loss

Figure 7 represents the maximum distance allowed in point-to-point configuration using two OXADM with the attenuation varied from 10 dB to 20 dB. The study is important to determine the exact maximum distance that can be achieved with the real OXADM attenuation. The test is under ideal condition (α = 0 dB) using Optisystem simulator indicates the operational loss is under 0.052 dB. Under this condition, the maximum length that can be achieved by OXADM with the losses values is 94 km. But when the loss of every element build OXADM (Il = 6 dB) is considered, the maximum length can be achieved in point to point configuration (using two OXADMs) is 71 km without regeneration and Figure 8 verifies on this with the equation below. The experimental data is also collected to study the maximum output power that can be achieved at a certain distance in point-to-point configuration (Figure 13). Here, the output power in measured by varying the input power at different length of fiber. The results are compared with simulation to ensure the synchronization of correctness. At 50.4 km, the output power is 31 dB after considering the losses of OXADM. The sensitivity of the detection is about – 35 dBm, meaning that the length of fiber can be extended.

But when the loss of every element build OXADM is considered, the maximum length can be achieved in point to point configuration (using two OXADMs) is 71 km without regeneration and Figure 9 verifies on this with the equation below

$$y = -3.9151x + 94.434 \quad [1]$$

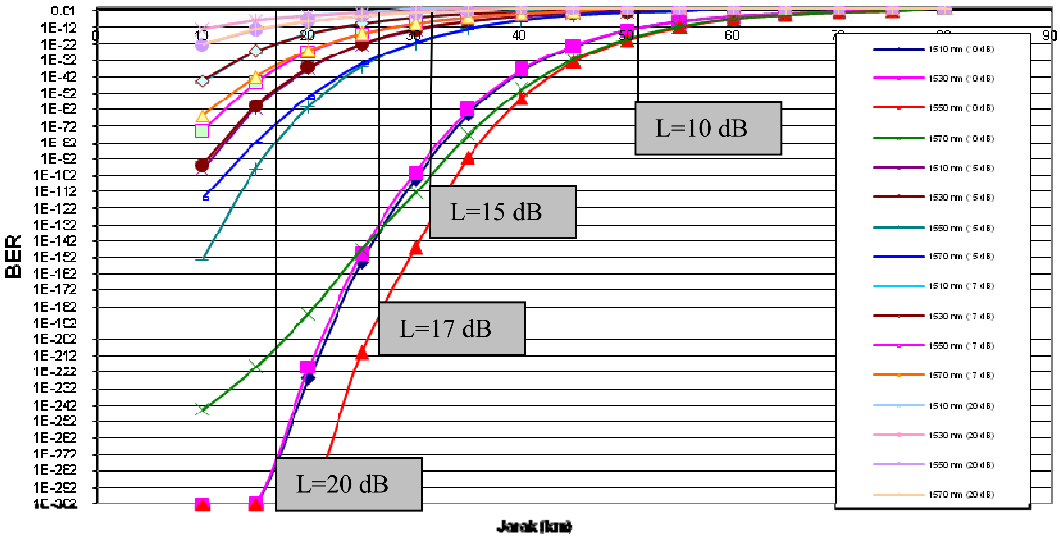


Figure 7. The maximum distance allowed at different attenuation of OXADM (10 dB to 20 dB) in point-to-point OXADM configuration at 2.5 Gbps

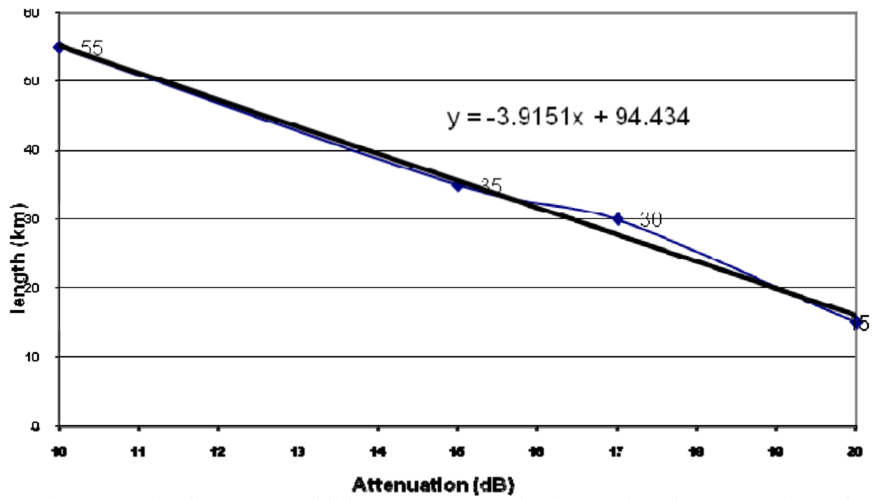
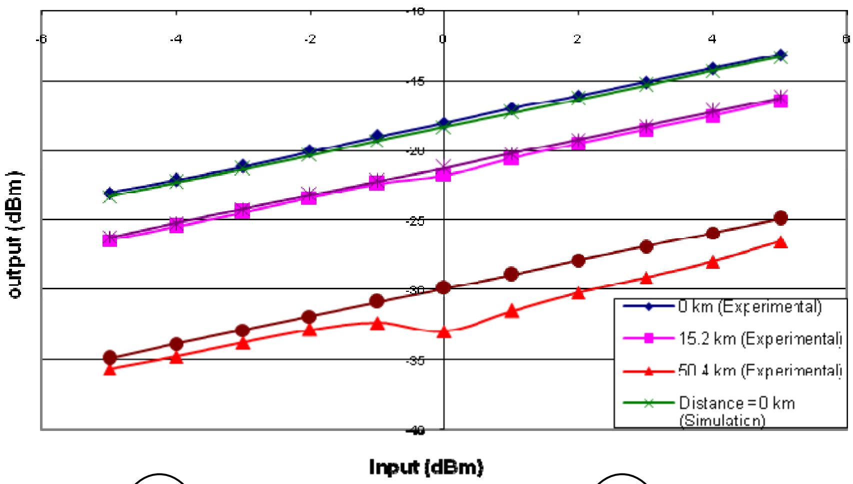


Figure 8. The decrement of kilometers occurs by increasing the attenuation of OXADM which represent the device losses



y = 0.9994x - 18.061 (0 km – Experimental)
y = 0.9945x - 21.467 (15.2 km – Experimental)
y = 0.8457x - 31.604 (50.4 km – Experimental)

y = x - 18.295 (0 km – Simulation)
y = 0.9998x - 21.199 (15.2 km – Simulation)
y = 0.9995x - 29.889 (50.4 km –Simulation)

The output power measured at 0 dBm input power

Figure 9. Comparison between the simulation and experimental result for output versus input power in point-to-point configuration

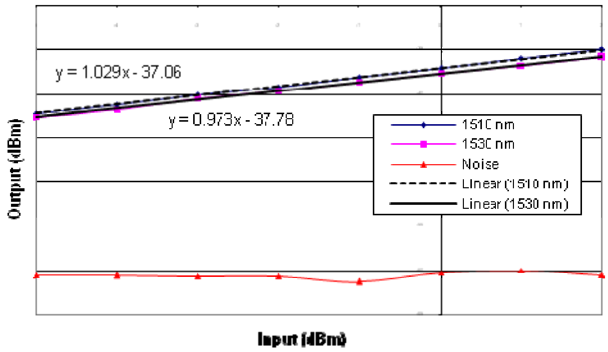
3.4. Optical Signal-noise-ratio (OSNR)

The OXADM device is characterized by using two tunable light sources (TLSs) and two OSAs. The designed 4-channel OXADM device is expected to have maximum operational loss of 0.6 dB for each channel when the device components are in ideal condition. The maximum insertion loss when considering the component loss at every channel is 6 dB. The testing is carried out for every single function of OXADM. The function includes bypass, path exchange and accumulation.

In the single operating wavelength test (wavelength is 1510 nm), the results show the OSNR value for bypass function is 20 dB (as Figure 2a) and path exchange is also 20 dB. Each measurement result are indicated in Figure 10 and Figure 11. The path splitting function is also applied and the result is shown in Figure 12 with OSNR > 24 dB. For backwards operation as depicted in Figure 13, the OSNR values for cross-connecting function are bigger than 22 dB. This can be defined that the level of signal is 20 dB higher than noise level for all single functions of OXADM optical switch. The 20 dB reference indicates the acceptable value for the signal to noise ratio in data communication.

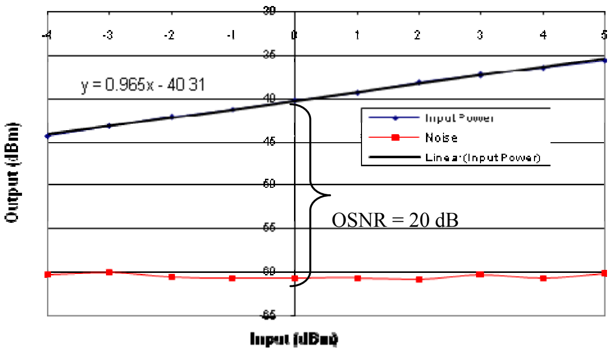
4. Conclusion

We have proposed the development of a N-port optical code division multiple access (OCDMA) encoder prototype based on OXADM device. OXADM is the multifunctional that was used to increase the survivability, flexibility of node migration, multifunctional switch that was reported in our previous publication. It has the potential to provide a high security for data transmission due to data transmitted in binary code form. The output signals from OXADM are coded with a binary code that is given to an optical switch before the signal is modulated with the carrier and transmitted to the receiver. The N-ports encoder used N double pole double throw (DPDT) toggle switches to control the polarization of voltage source from +5 V to -5 V for N optical switches. When +5 V is given, the optical switch will give code ‘1’ and vice versa. In this paper we highlighted on device characteristics. The experimental results showed the insertion loss, crosstalk, return loss, and optical signal-noise-ratio (OSNR) for the developed prototype are <6 dB, 60dB, 40 dB, and ≥20 dB. The test under ideal condition (α = 0 dB) using Optisystem simulator indicates that the operational loss is less under the 0.052 dB. Under ideal (IL< 1 dB) condition, the maximum length that can be achieved by OXADM with the losses values is 94 km. But when the loss of every element build OXADM is considered (IL = 6 dB), the maximum length can be achieved in point to point configuration (using two OXADMs) is 71 km without regeneration.



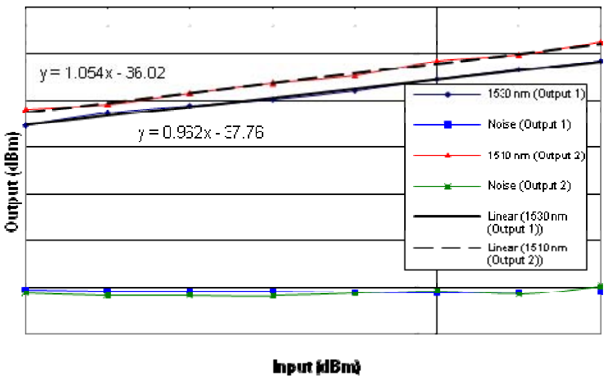
OSNR 1510 nm = 23.547 dB
OSNR 1530 nm = 22.83 dB

Figure 10. The measured output power at two operating wavelength for bypass operation



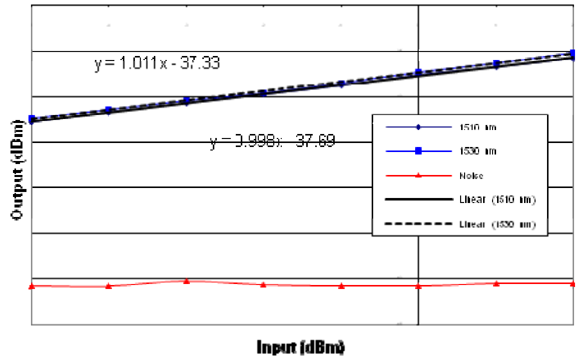
OSNR 1510 nm = 20 dB
(Path change)

Figure 11. The measured output power for path exchange operation (cross-connecting)



OSNR 1530 nm = 22.78 dB
(Bypass)
OSNR 1510 nm = 24.506 dB
(Path change)

Figure 12. The measured output power two operating wavelength for path splitting operation (multiplexing/accumulation function in reverse mode)



OSNR 1510 nm = 22.943 dB
(Path change)
OSNR 1530 nm = 23.301 dB
(Path change)

Figure 13. The measured output power at two operating wavelength for path exchange operation (cross-connecting)

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