

# Development of Low-cost OCDMA Encoder based on Arrayed Waveguide Gratings (AWGs) and Optical Switches

Mohammad Syuhaimi Ab-Rahman, Boon Chuan Ng, Norshilawati Mohamad Ibrahim, and Sahbudin Shaari

**Abstract**—This paper describes the development of a 16-ports optical code division multiple access (OCDMA) encoder prototype based on Arrayed Waveguide Grating (AWG) and optical switches. It is potentially to provide a high security for data transmission due to all data will be transmitted in binary code form. The output signals from AWG are coded with a binary code that given to an optical switch before it signal modulate with the carrier and transmitted to the receiver. The 16-ports encoder used 16 double pole double throw (DPDT) toggle switches to control the polarization of voltage source from +5 V to -5 V for 16 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, uniformity, and optical signal-noise-ratio (OSNR) for the developed prototype are <12 dB, 9.77 dB, <1.63dB, and  $\geq 20$  dB.

**Keywords**— AWG, encoder, OCDMA, optical switch.

## I. 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.

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Interest in OCDMA has been steadily growing during 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 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 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 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 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].

## II. AWG-BASED OCDMA ENCODER

The 16-ports AWG-based OCDMA encoder prototype that developed in this work is consists of 1 input port and 16 output ports for AWG demultiplexer (demux) and multiplexer (mux) with back-to-back (serial) connection, as shown in Fig. 1. An adaptor device is used to convert the alternating current (AC) from the power supply to direct current (DC) and reduce the power supply from 240 V AC to 12 V DC. In the circuit design, a 12 V battery is used to replace the adaptor device. Due to the optical switch only function with a maximum input voltage at 5 V, a voltage regulator circuit is designed to reduce the voltage output from adaptor device (12 V) to 5 V for 16 different optical switches as indicated in Fig. 2.

The encoder is using 16 DPDT toggle switches to control the polarization of voltage source for 16 different optical switches. The optical switch will automatically change (opposite) the polarization of voltage source from +5 V to -5 V. Output voltage (5 V) from voltage regulator circuit is distributed to 16 different DPDT switches evenly to activate 16 optical switches. The output voltage is 5 V when the switch 1 in Fig. 2 is push up, and alters to -5 V when the switch 2 is push down.

Each optical switch is connected to an input and two output representation links (Link 1 and 2). There are 8 pins of the optical switch responsible for controlling the polarization of voltage source. Among that, pin 1 and pin 8 are controlling the optical path exchange. When -5 V is provided to the optical switch, the input link is connected to link 1. On the other hand, the input link is connected to link 2 if +5 V is provided to the optical switch. The parameters of optical switch such energy switching, dissipation insertion, reflection losses, crosstalk, and switching time, play an important role in the optical switching.

## III. CHARACTERISTICS OF AWG-BASED OCDMA ENCODER

Two methods are being used to study the specifications of the 16-ports AWG-based OCDMA encoder: linearity test and continuous signal test.

### A. Linearity Test

The linearity adjustment among two AWGs should proceed in designing an OCDMA encoder to assess counter their linearity's impact, although both AWGs' specifications are similar. The linearity test is conducted to compare the waveforms between the transmission signals and receiving signals according to their specifications before characterizing the encoder. This test is important for identifying a failure or damaged AWG. The broadband laser source with mean wavelength 1550 nm is supply to 16-ports demux and 16-ports mux before connected to analyze the spectrums in optical spectrum analyzer (OSA) (see Fig. 1). The spectrum display for the OCDMA encoder prototype with AWG back-to-back connection is indicated in Fig. 3.

### B. Continuous Signal Test

The parameters of the OCDMA encoder such as insertion loss, OSNR, uniformity, and crosstalk are measured through a continuous signal test to increase service reliability and efficiency of coding to make sure any information or data are correctly delivered. The instruments and measurement equipments such broadband source, tunable light source (TLS), and OSA are used in the experiment as summarized in Fig. 4 with the help of the block diagram. The output signals from demux port are coded in binary form, either '1' or '0'. When +5 V is given, the optical switch will give '1' and '0' is given to -5 V. The coding is based on the voltage polarity control of voltage regulator circuit. All the output signals will be combined by mux and then analyzed in OSA to observe the spectrums' specifications.

Each optical switch has 2 delay ports and each port is connected to an optical fiber line with specified range. The wavelengths from demux will be modulated with the binary code '1' in optical switches when voltage supply + 5 V are given. Then, the signals will move to the delay port (from port D1 to port D2) and returned to mux to deciphered and finally analyze in OSA. However, when voltage supply - 5 V are given, the signals still move to the delay port even though they don't modulate with the binary code. The characterization will be carried out based on the coding. Each output signals from demux are given a different binary code and analyzed in OSA. The parameters of uniformity and crosstalk can be identifying through the spectrums display. Fig. 5 shows the spectrum display for 8-ports OCDMA encoder in OSA when broadband source is given with the binary code 11111111.

### C. Parameters of AWG-based OCDMA Encoder

Three parameters of the AWG-based OCDMA encoder: uniformity, crosstalk, and insertion loss, are measured in this work. Uniformity is the different values of optical power between the maximum peak power,  $P_1$ , and minimum peak power,  $P_2$ . The uniformity measurement for 8-ports AWG-based OCDMA encoder is shown in Fig. 6. Crosstalk is measured the degree of isolation between the input at one port and the optical power scattered or reflected back into the other input port (see Fig. 7); while the insertion loss refers to the loss for a particular port-to-port path.

## IV. CONCLUSION

We have proposed an OCDMA encoder optical access network using binary coded AWGs and optical switches. The experimental results showed insertion loss, cross-talk, uniformity, and OSNR are <12 dB, 9.77 dB, <1.63dB, and  $\geq 20$  dB. In future research activity, we aim to increase the number of ports to be 32 or 64, greater signals can be coded and delivered. A microprocessor system will develop to replace the DPDT toggle switch for controlling the polarization of voltage source for optical switches.

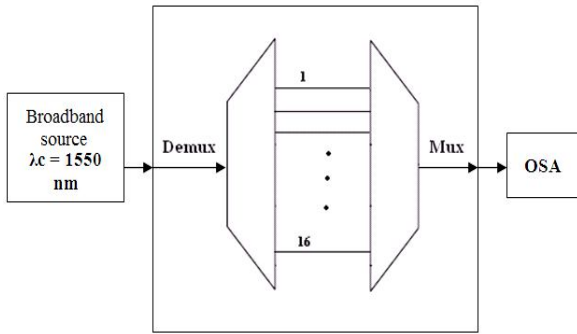


Fig. 1 Block diagram of linearity test for AWG with back-to-back connection

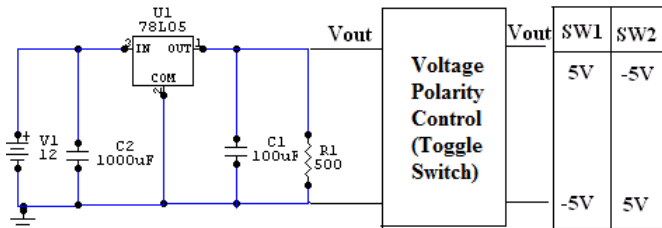


Fig. 2 The voltage regulator circuit and voltage polarity control

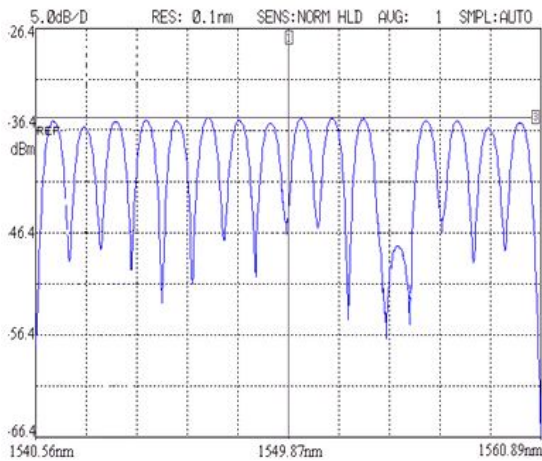


Fig. 3 The spectrum display for AWG back-to-back connection

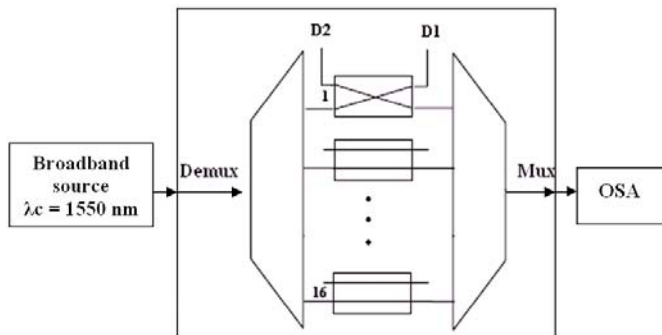


Fig. 4 Block diagram of continuous signal testing for OCDMA encoder

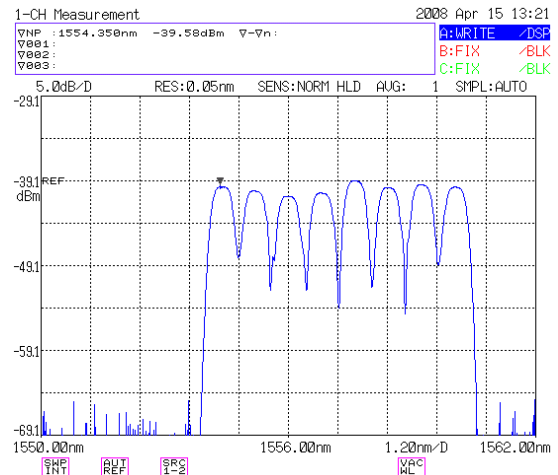


Fig. 5 Spectrum display for 8-ports OCDMA encoder

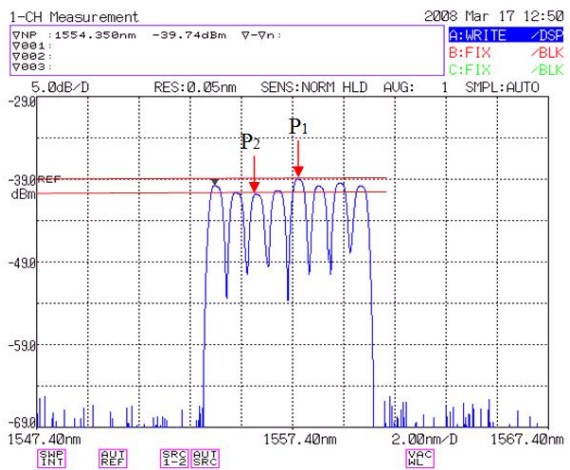


Fig. 6 The uniformity measurement for 8-ports AWG-based OCDMA encoder. Uniformity = Maximum peak power,  $P_1$  - Minimum peak power,  $P_2 = (-37.28) - (-38.91) = 1.63$  dB

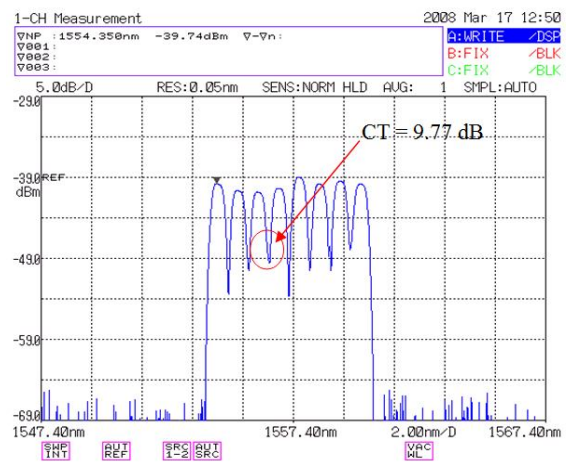


Fig. 7 The crosstalk measurement for 8-ports AWG-based OCDMA encoder. The crosstalk value for the OCDMA encoder is 9.77 dB

APPENDIX

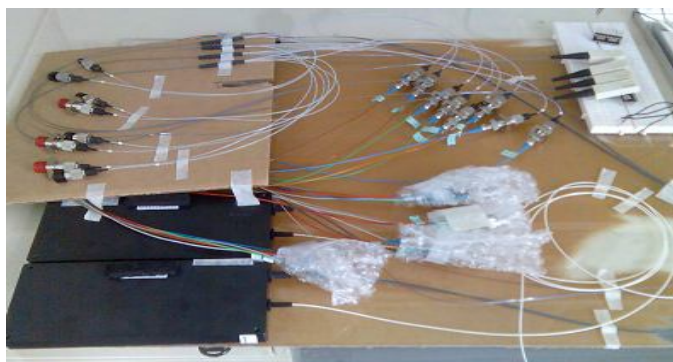


Fig. 8 Photographic view of AWG-based OCDMA encode prototype before chasing



Fig. 9 Photographic view of the developed AWG-based OCDMA encode prototype (Front view)



Fig. 10 Photographic view of the developed AWG-based OCDMA encode prototype (Back view)

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