

# Placement of dynamic reconfigurable optical add/drop multiplexer using dynamic channel equalizer in an optical communication system

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In this paper, we investigate the effect of crosstalk of Dynamic Reconfigurable Optical Add/Drop Multiplexer based on Dynamic Channel Equalizer obtained at 40×10Gbps with 100GHz channel spacing. The influence of increase in length of fiber has been investigated to evaluate the performance of optical communication system. The dynamic power transient with dynamic channel equalizer is also studied which equalizes the power variations with a single ROADM. It is found that the signal can be transmitted with acceptable optical output power (-40dBm) using dynamic ROADM based on Dynamic channel equalizer up to maximum transmission distance of 220 km at 15dB crosstalk.

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## 1. Introduction

In optical network system, it is necessary to add or drop different wavelengths and optical add/drop multiplexer (OADM) is one of the key components to enable greater connectivity and flexibility of the network [1, 2]. The reconfigurable optical Add Drop Multiplexer (ROADM) is a practical approach to remotely controlling which wavelengths are added/dropped, or passed through a node [3]. However, as the number of wavelengths increases, placing additional signal sources at each node causes network cost and power consumption to become impractical [4]. A ROADM enables multiple wavelengths carrying data to be added and/or dropped from a transmission optical fiber port without the need to convert the optical signals to electronic signals and again back to optical signals. The main advantages of using ROADMs in optical networks are the ability to dynamically allocate the available network bandwidth to individual users while not affecting the traffic, and to equalize the power levels of the different wavelength channels processed through every ROADM. In particular, the optical “add-drop” network based on ROADM is useful for migrating or upgrading existing optical networks. ROADM can be defined as an optical module capable of adding/dropping or passing through (express) any or all wavelengths present in the DWDM signal. ROADM offers pay-as-you-grow capability and flexibility on the provisioning of wavelengths regardless of how the network changes [5]. There are two general types of ROADMs, two-degree and multi degree, where the degree refers to the numbers of DWDM fibers entering and exiting the ROADM node.

A two-degree ROADM is like a location on a highway with off and on ramps to drop off and accept local traffic. It terminates an incoming DWDM fiber, drops specified wavelengths, and in most cases blocks these wavelengths from propagating further, adds local wavelengths, equalizes the combined traffic of passed-through and added wavelengths, and provides an exit for this traffic toward the next ROADM node. A multidegree ROADM is like an interchange where highways meet. It is used for interconnecting DWDM rings or for mesh networking. It accepts and rearranges wavelengths from the multiple fibers entering and leaving the multidegree node, as well as adding and dropping local wavelength traffic [6]. A network containing ROADM nodes with different add/drop capabilities shows different flexibilities in establishing a light path. Wei Hong et al. [7] presented a two-way hitless reconfigurable optical add/drop multiplexer (ROADM) and an Optical Cross Connect (OXC) structures based on microring resonators (MRRs). The OXC was simulated by the transfer matrix compound with Finite-Different Time-Domain method, and the results show that optical signals can be carried out to any destination in this structure. The two-way hitless ROADM was suited for two-way network and the OXC can be used as core node in mesh network. J. M. Tang et al. [8] investigated the wavelength-routing capability of ROADMs of various categories in dynamic optical networks. A theoretical routing power model was developed, taking into account ROADM architectures and dynamic traffic. Yong cheng Li et al. [9] evaluated the impact of the colorless, directionless, and contentionless (CDC) features of reconfigurable optical add/drop

multiplexers on wavelength division multiplexing optical transport networks (OTNs). Under the assumption of fixed shortest path routing, he developed analytical models for evaluating the impacts of the CDC features. Next, allowing for adaptive light path route selection, he proposed three light path routing and add/drop port selection strategies.

The investigation presented in [5] restricted to 32 channels and bit rate of 2.48 Gbps. We have extended the work to 40 channels and bit rate to 10 Gbps with improvement in optical transmission distance in terms of output optical power using single ROADM based on Dynamic channel Equalizer by varying the crosstalk.

The paper is organized into four sections. Section 1 presents the introduction. Section 2 presents the system set-up and the description of its components. Section 3 includes the discussion of the results for the network. Section 4 presents the conclusion about the feasibility of the system.

## 2. System set up

The simulation set up consists of three stages i.e. transmitter, Reconfigurable optical add drop multiplexer and receiver. The transmitter section consists of 5 bands each of which consists of 8 channels resulting in 40 channels as shown in Fig. 1. 40 channels with different centre frequencies are fed through the multiplexers to the input port of ROADM. The band represents a laser array which consists of user defined number of on-off keying transmitters. Band spacing and channel spacing of Transmitter is 1THz and 100GHz. Band1 has centre frequency ranging from 193.1 to 193.8THz. Each transmitter is composed of data source, NRZ rectangular driver, laser source and optical amplitude modulator. Data source generates a binary sequence of data stream which is customized by baud rate, sequence type. The output from the driver and laser source is passed to the optical amplitude modulator. Modulation driver here generates data format of the type NRZ rectangular with a signal dynamics i.e. low level -2.5 and high level +2.5. The single mode fiber with a dispersion of 16 ps/nm/km is used to transmit the optical signal. The power controlled amplifiers are used which have a maximum gain of 20dB and noise figure of 4dB at the input and add port of the ROADM. The ROADM (Reconfigurable optical add drop multiplexer) adds and drops the group of wavelengths (band) dynamically. The response time of ROADM is  $3 \times 10^{-4}$  sec and crosstalk varying from 15dB to 35dB. The signal duration of ROADM is equal to time step.

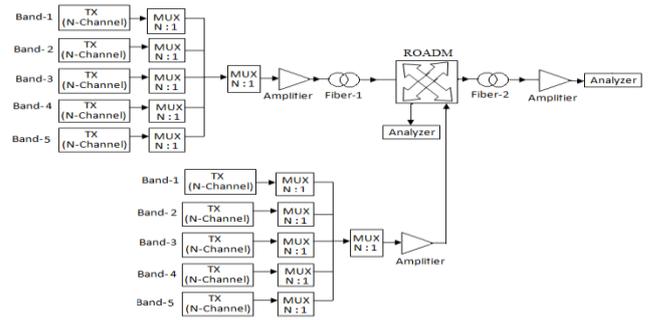


Fig. 1. Proposed multiband system setup with ROADM.

The ROADM model includes a DCE (Dynamic channel equalizer) with maximum attenuation 10dB, power threshold  $1 \times 10^{-6}$  W, integral gain 1.5 and integration time  $4 \times 10^{-4}$  sec. All three parts (add, drop & VOA-array) as shown in Fig. 2 are modeled on the per channel level, taking into account crosstalk & finite switching time. The Dynamic channel equalizer (DCE) is a VOA-array with proportional integral (PI) Controller. A common control interface is developed for the Dynamic ROADM architecture that provides the control over the  $2 \times 2$  switches and VOAs placed within the reconfigurable add module. With the help of VOAs; it is possible to develop a dynamic power-balancing system that will equalize the power levels between different express- and add-channels. Separation of Mux/Demux and switching functions enable to study both per-band (group of channels) or per channel ROADM-functionality using the same switch matrix model. The signal duration parameter enables to use this module in both the multi iterative simulations with sampled blocks & in power transient analysis using parameterized signals & special interactive simulation (sweep). The amplifier after the ROADM is saturable type amplifier with gain 20dB, saturation power  $10^{-3}$ W and noise Fig. 4dB. The final results in terms of optical output power are obtained on the analyzer.

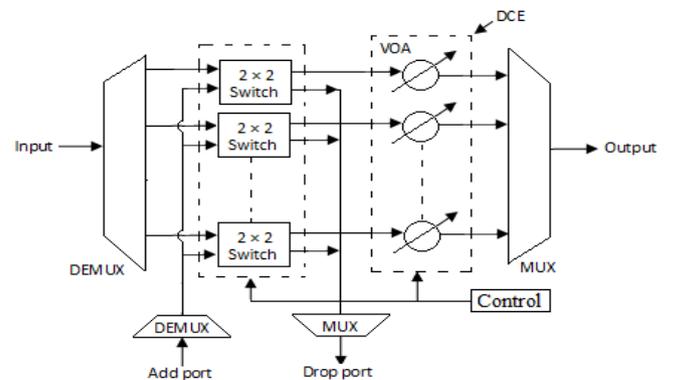


Fig. 2. Architecture of ROADM using Dynamic Channel Equalizer.

### 3. Results and discussions

To illustrate the performance of ROADM, received output power is recorded at first band obtained at  $40 \times 10$  Gbps with 100 GHz channel spacing. The received optical power vs. transmission distance before amplifier without DCE at different crosstalk's is shown in Fig. 3. It is observed that the received optical output power decreases with increase in transmission distance. It is also evident that the reachable distance in case of 15dB and 35dB crosstalk is 120 km and 40 km respectively with optical output power of  $-39$ dBm. For 25dB crosstalk the reachable distance is 60 Km with acceptable optical output power of  $-37$  dBm. As crosstalk of ROADM increases, the transmission distance decreases. Fig. 4 reveals that after amplifier without Dynamic channel Equalizer, the maximum reachable distance at 15dB, 25 dB and 35dB crosstalk is 200 km, 140 km, 60 km with acceptable optical output power of  $-37.8$ dBm,  $-38.5$ dBm and  $-38$ dBm.

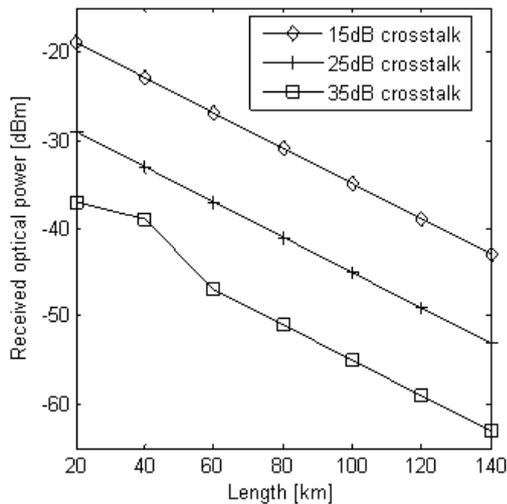


Fig. 3. Received optical power vs. transmission distance before amplifier without DCE.

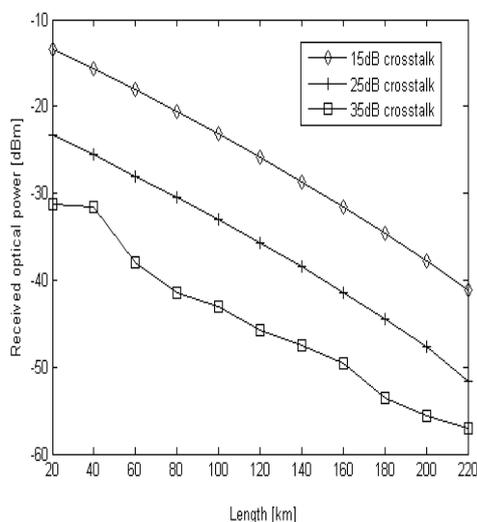


Fig. 4. Received optical power vs. transmission distance after amplifier without DCE.

Fig. 5 shows the received optical power vs. transmission distance before amplifier with Dynamic channel Equalizer at different crosstalks. The maximum reachable distance before amplifier with DCE at 15dB, 25 dB and 35dB crosstalk are 140 km, 80 km and 60 km with acceptable optical output power of  $-39.02$ dBm,  $-37.90$  dBm and  $-39.70$  dBm respectively. As shown in Fig. 6, the optical signals coming out of the DCE based ROADM is strong enough to travel maximum reachable distance after amplifier at 15dB, 25dB and 35dB crosstalk are 220 km, 160 km and 100 km with acceptable optical output power of  $-39.5$ dBm,  $-38$  dBm and  $-37.6$  dBm.

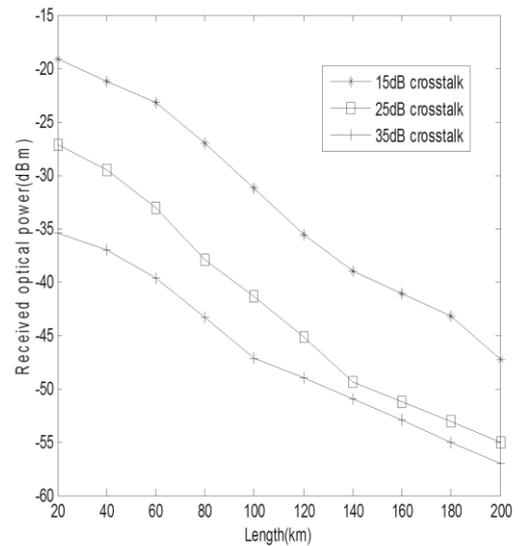


Fig. 5. Received optical power vs. transmission distance before amplifier with DCE.

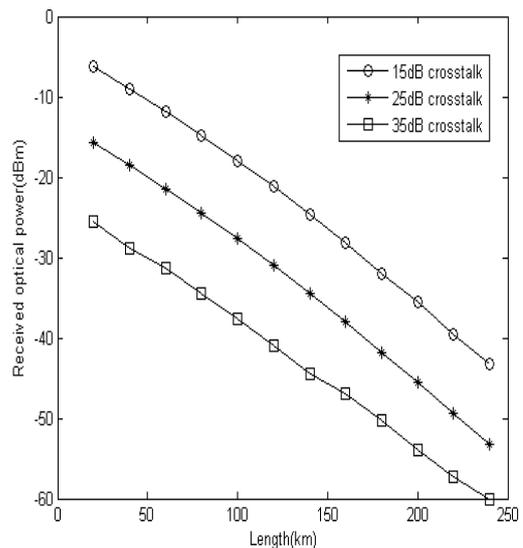


Fig. 6. Received optical power vs. transmission distance after amplifier with DCE.

Fig. 7 shows the dynamic transient power response using single ROADM which dynamically add and drop the multiple wavelengths due to which significant mismatch in the optical power levels and also signal to noise ratio among the multiple channels occur. Hence to avoid such anomalies, Dynamic channel Equalizer is used to maintain equal power levels among different channels. It is also observed from the response that there are less power variations among the channels using a single ROADM which yields to improvement in performance of the system, since utilization of multiple ROADM's leads to maximum power variations as reported in [10].

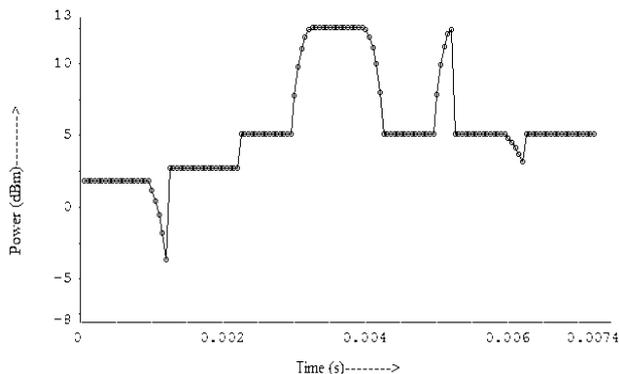


Fig. 7. Dynamic transient power response.

#### 4. Conclusion

The performance of Dynamic Reconfigurable Optical Add/Drop Multiplexer based on Dynamic Channel Equalizer is obtained for  $40 \times 10$  Gbps with 100GHz channel spacing. The effect of crosstalk has been investigated to evaluate the performance of optical communication system in terms of received optical power. The Dynamic Channel Equalizer is used to maintain equal power levels among different channels. It is also observed that the maximum transmission distance covered with

DCE is 220 km after the amplifier and 140 km before the amplifier at minimum crosstalk (15dB) respectively. However at maximum crosstalk (35dB), the transmission distance covered upto 100 km after the amplifier and 60 km before the amplifier.

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