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Impact Analysis of Cascaded EDFA in SMF based Optical Link

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***Abstract* - In this paper, an optical link based on cascaded EDFA has been designed. In addition, the conventional optical link utilizing single EDFA has been setup. The performance comparison of these two links has been carried out using fiber length, Q factor and Eye opening factor and Noise power. The above said optical links have been established for data transmission at the bit rate of 10Gbps with 150 km single mode fiber length.**

Keywords: EDFA, Optical Link.

I. INTRODUCTION

The fast-paced nature of today's technological advancements has led to an increased need for quick data transfer. Optical fiber communication allows data to be transmitted over great distances without significant signal attenuation. However, one of the biggest challenges in fiber communication is the reduction in signal quality over long distances. To address this issue, optical amplifiers are employed to restore the strength of the optical signals. These amplifiers function by amplifying light through a process called stimulated emission of photons.

The Erbium Doped Fiber Amplifier (EDFA) is a type of Optical Fiber Amplifier (OFA) that amplifies optical signals directly, without the need for optoelectronic or electro-optical conversion, thus maintaining both the speed and precision of data transmission. It serves as an optical device designed to counteract signal attenuation in fibers and components, thereby extending the optical transmission distance. The EDFA operates in both the C-band and L-band. The C-band, which spans wavelengths from 1530 nm to 1565 nm, is also referred to as the conventional band. This wavelength range is crucial for long-distance optical communication, as it experiences minimal optical signal attenuation. The L-band has a wavelength range from 1565 nm to 1625 nm and is known as the long-wavelength band. It is the second most critical wavelength band for long-distance optical communication, as the attenuation of optical signals is low in the L-band, following the C-band. EDFA allows for the amplification of multiple optical signals at the same time. It directly amplifies these signals prior to their transmission through optical fiber.

The combination of two cascaded EDFAs in optical network has attracted lot of attention in research domain. The dual-stage quadruple-pass technique enabled an EDFA to achieve a high gain of 62.56 dB and a low noise figure of 3.98 dB at a signal wavelength of 1550 nm [1]. A proposed dual-stage L-band EDFA offered a flat gain bandwidth over the L-band range of 1570 nm to 1605 nm [2]. A high gain and low noise figure were found to be achievable using a dual-stage L-band amplifier structure with a short EDF length [3]. A two-stage amplifier, featuring a 2 m Erbium-Zirconium co-doped fiber (Zr-EDF) and a 9 m silica-based Erbium-doped fiber (Si-EDF), optimized for C- and L-band operations, successfully achieved flat-gain and wideband operation in a double-pass parallel configuration [4].

The next article discusses how passive optical networks (PONs) should leverage technologies that enable multigigabit transmission speeds and distances of tens of kilometers—features that were previously exclusive to long-haul backbone networks [5]. The proposed Coherent Optical OFDM FSO communication link is evaluated at a 30 Gbps data rate using a cascaded EDFA [6]. A dual-stage EDFA with a narrow bandwidth has been proposed to reduce amplified spontaneous emission (ASE) noise in long-haul optical system [7].

this work, we have established optical links based on single EDFA and two cascaded EDFAs for high-speed data transmission over 150 km fiber length. The performance of these two optical links have been compared using parameters namely Q-factor, eye opening factor and noise power. All these investigations have been carried out on 1550nm wavelength range and an operating temperature range of 30°C to 85°C.

II. SIMULATION SETUP

The optical link is designed to transmit the data at bit rate of 20 Gbps with 150 km fiber length at 1550 nm wavelength by incorporating EDFA for amplification.

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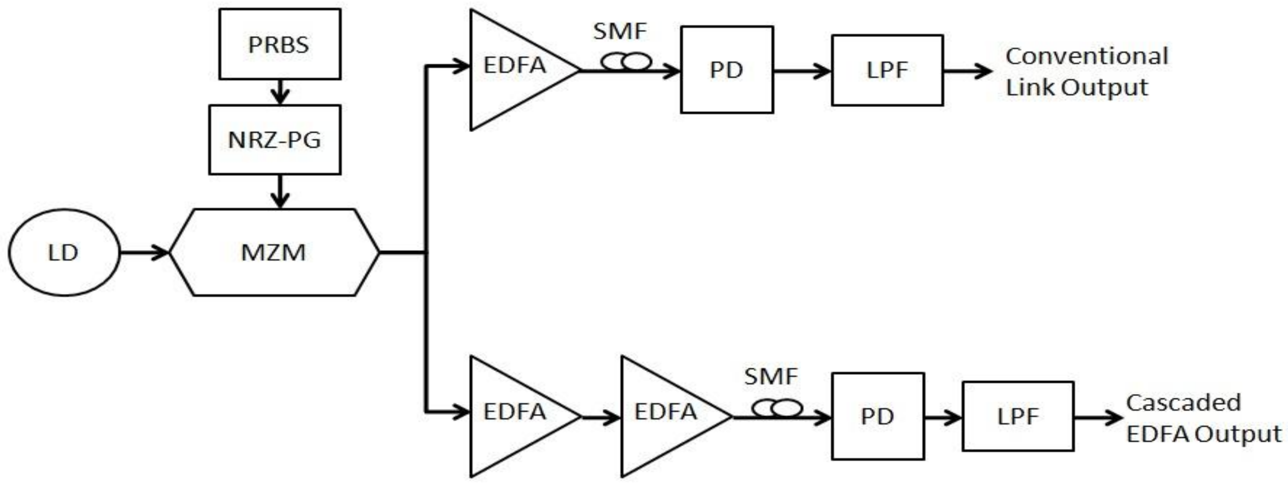

Figure 1: Block diagram of Single EDFA and Cascaded EDFA based optical link; PRBS: Psudo random bit sequence generator; NRZ-PG: Non return to zero-pulse generator; OC: Optical combiner; PD: photodetector; LPF: Lowpass filter

Figure 1 represents the simplified block diagram of the optical link that consists of single EDFA based conventional link and cascaded EDFA based link. Pseudo Random Bit Sequence (PRBS) generator produces digital data and it is encoded by pulse generator in Non-Return Zero (NRZ) format. The encoded data is superimposed on optical signal generated by continuous wave laser. The Mach Zehnder modulator is employed for modulation of optical carrier in accordance with encoded NRZ data. The output signal of MZM is further processed through two different links. The first link involves single EDFA with 12.8 dB gain for amplification of optical signal while the other link used two cascaded EDFA with 4 dB and 3 dB gain respectively for amplification. In Channel Section, a single mode optical fiber of length 150 km is employed. The output of EDFA is received by separate PIN photodiode in receiver section. The optical signal detection is performed by PIN diode and its output is applied to the low pass Bessel filter which then passes the low frequency signals and rejects the high frequency signals. The processed outputs of both the links are compared in terms of fiber length, Q factor and Eye opening factor and Noise power. The simulation setup shown in figure has been simulated using Optisystem software.

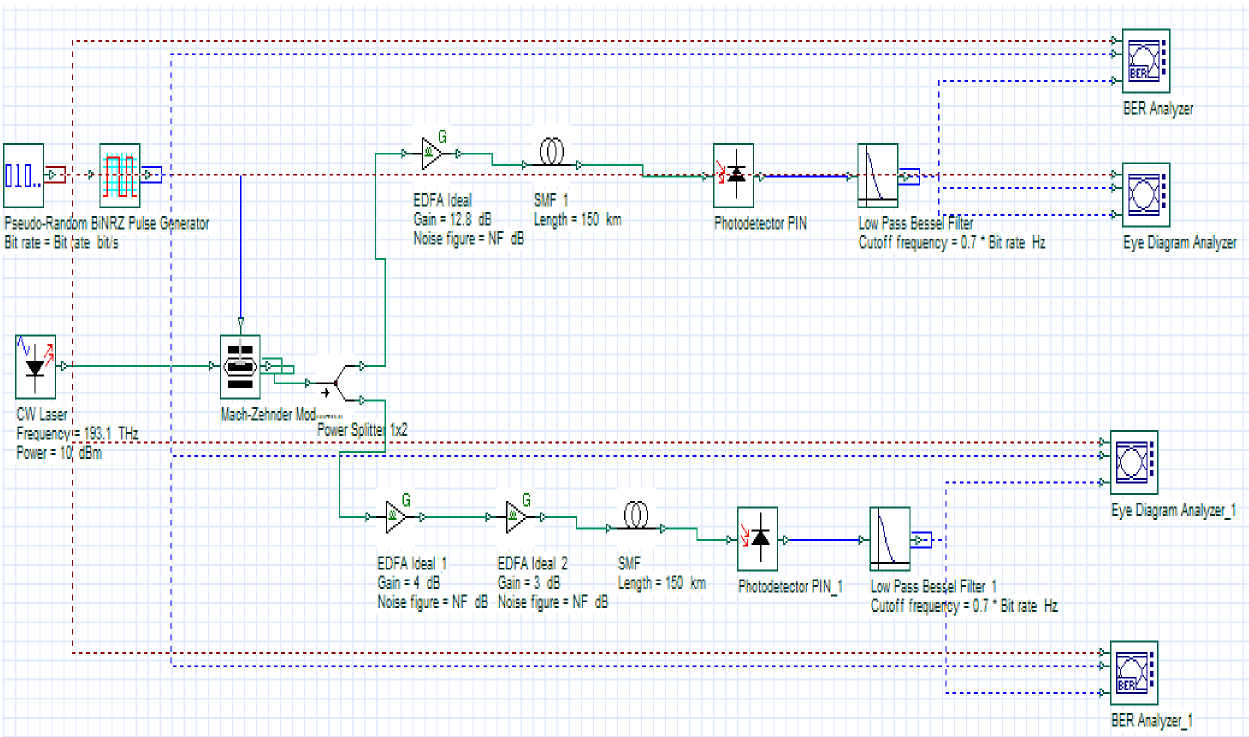

Figure 2: Simulation set up for proposed link

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Table1: Simulation Parameters involved in system design

Parameter	Value		Parameter	Value
Laser Frequency	193.1 THz		SMF chromatic dispersion	17 ps/nm km
Laser beam Power	0 dBm		SMF loss	0.2 dB/km
Data Rate	10 Gbps		PD Dark current	10 nA
SMF length	150 km		PD Responsivity	1 A/W

III. RESULTS AND DISCUSSION

The model shown has been simulated and the varous outputs are observed. The outputs were taken from conventional link with single EDFA and cascaded EDFA based link. The results obtained from both the link were compared. The figures 3, 4 and 5 display how the performance parameters Q factor, eye opening factor and noise power vary with the variation in fiber length. The figure 3 reveals how Q factor is impacted as the fiber length is increased. The cascaded EDFA link shows improved Q factor as compared to that of single EDFA link. The value of Q factor at 125 km fiber length are measured equal to 55 and 40 for cascaded EDFA link and single EDFA link respectively. The figure 4 depicts how eye opening factor changes as the fiber length is increased. The eye opening factor goes on decreasing with increased fiber length. The cascaded EDFA based link shows better eye opening factor as compared to conventional link. The figure 5 presents relation between noise power and fiber length. It can be seen clearly that cascaded EDFA link has less noise power at various fiber lengths as compared to noise power of single EDFA based optical link.

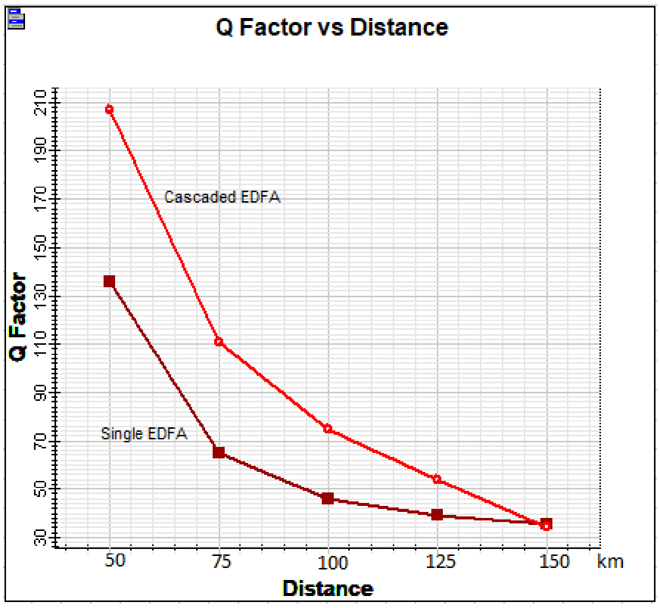

Figure 3: Q factor vs Distance

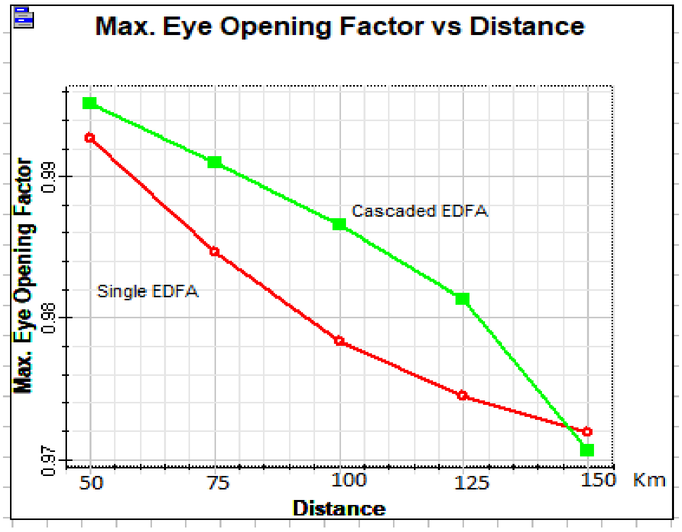

Figure 4: Eye Opening Factor vs Distance

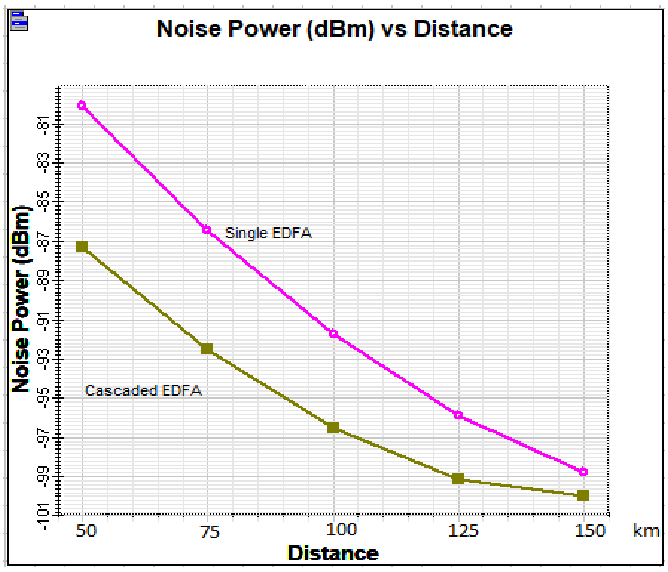

Figure 5: Noise Power vs Distance

IV. CONCLUSION

The performance of an optical link based on cascaded EDFA has been compared with performance of conventional optical link based on single EDFA. The performance comparison of these two links has been carried out using parameters namely fiber length, Q factor, eye opening factor and noise power. It was observed that Q factor and eye

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opening factor decrease with the increase in fiber length. The noise power decreases as the transmission distance is increased. The cascaded EDFA based optical link shows better performance parameters including Q factor, eye opening factor and noise power when compared to conventional link. The optical links have been established for data transmission at the bit rate of 10Gbps with 150 km SMF length.

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