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IMPROVING RADIO SYSTEMS EFFICIENCY VIA EMPLOYING SCRO-SOA (SQUARED COSINE ROLL OFF FILTER-SEMICONDUCTOR OPTICAL AMPLIFIER TECHNOLOGY) IN DWDM-ROF SYSTEM

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Abstract

The increasing demand on the internet trafficking exerts too much pressure to meet the demands of video streaming and mobile communication. Accordingly, this demand results in providing high bandwidth that increases the use of cells on the network. However, the current networks do not meet the requirements of the necessary data rate. Therefore, the Dense Wavelength Division Multiplexing (DWDM) network and the Radio over Fiber (RoF) technology are the ideal solution for providing the necessary data rate needed in the current networks. The DWDM will increase both of the transmission distance and the data rate. Nonetheless, the DWDM network will be compromised especially by the Non-linear effects. This study is intended to propose a system to find solutions for the issues of increasing the data rate and for reducing the nonlinear effects. There are number of technologies that could be adopted to fix such issues, which include; Optical Phase Conjugation (OPC), Semiconductor Optical Amplifier (SOA), and Digital Signal Processing (DSP). Notwithstanding, DSP-128 QAM-SCRO (Squared Cosine Roll off) filter has been used in this study. Then its performance was compared with the performance of the Semiconductor Optical Amplifier (SOA) to establish which one of these two is optimal to increase the data rate and to eliminate the nonlinear effects. The performance of the proposed system has been evaluated in terms of the Error Vector Magnitude (EVM), Bit Error Rate (BER), Q Factor and Eye-Diagram. The EVM has been measured in the proposed system prior to employing the DSP-128 QAM-SCRO technology, and it has reached the value 22.5%. However, when the EVM has been measured after employing the DSP-128 QAM-SCRO technology, it has reached the value 8.5%. Similarly, the values of BER and Q factor have been found to be acceptable and in accordance with ITU-T. Finally, the proposed system has been simulated via the software Optisystem 17.

Keywords: Cross phase modulation, Dense wavelength division multiplexing, Four wave mixing, Optical phase conjugation, Radio over fiber, Self-phase modulation.

1. Introduction

The accelerating growth in internet traffic currently is the ultimate challenge for radio access networks (RANs). The optical fiber technology has been widely spread in the last decades due to their ability for carrying high data rate for long distances with relatively low attenuation. Also, the optical fiber networks have various features in comparison to the traditional networks, RANs. The optical fiber networks are less affected by noise. They are not affected by the radio interference, and they are considered as totally isolated medium [1]. Several technologies have been developed to provide bandwidth for Tera per second in the optical fiber networks such the DWDM. Therefore, mobile network operators (MNOs) prefer to merge optical with radio technologies (Wi-Fi) to provide services for the end users with high data rate for long transmission distances [2]. And the combination of the Wi-Fi, the wireless, with optical fiber, wire, resulting the technology of the radio over fiber. It is considered as future solution for providing effective bandwidth in terms of cost and maintenance [3].

The DWDM of multiple density technology is used for the vert short distances between channels. Usually, their bandwidth is of 0.1- 0.8 nm; therefore, DWDM has the possibility to connect tens of optical channels utilizing one fiber. This possibility increases the connectivity of the optical fibers [4]. The ease of using DWDM networks is due to the opportunity of utilizing very narrow spectrum known as the DFB. The DWDM has two features: first, the width of transmission spectrum, the mm-wave which facilitates channel distancing; second, and the number of the wavelengths is significant which results in increasing the number of stations in the telecommunication networks [5]. Moreover, in the optical networks, there has to be a unique wavelength for each base station (BS) which can be retrieved and used in the main transmission [6, 7].

2. Background and Related Works

Considerable research has been conducted investigating the topic at hand from different angles. For example, in Patnaik and Sahu [8], researchers extensively discussed one nonlinear effect, namely the FWD on a DWDM-RoF system of 32-channel 40 GBS. In this study, researchers analysed the FWM effect on the inter-channel spacing, the level of input power, the area of the effective fiber as well as the types of modulation. It is crucial to point out that this study pioneered trials in minimizing the aforementioned effects. Therefore, this study suggested an optimization for setting up a DWDM system via employing the SPO technique. Mohammed [9] investigated possible schemes the enhancing wireless telecommunication systems of high data rates. For that purpose, the authors think that adopting a DWDM system would meet the demands of applications that require high data rate. In this paper, the researchers utilized certain amplifiers, EDFAs, and compensation technique namely the DCF in order to test the performance of the system when both the length of the optical fiber as well as the bit rates vary. The authors found out that the attenuation and dispersion are the most degrading effects for the system performance. Accordingly, the authors adopted the DCF technology for mitigating dispersion, and they utilized EDFAs to reduce attenuation and scattering

In the study conducted by Fang et al. [10], the authors investigated the possibility of improving the efficiency of combining the wireless with wire networks, specifically the RoF. However, the challenge is how to assign wavelengths to light paths when designing a DWDM system. And to solve this problem, the authors suggest utilizing algorithm BCO-RWA with modifications since algorithm BCO-RWA does not tune in the FWM effect. In a study conducted by Kaur et al. [11], they found out that the power of the FWM effect could be suppressed when a destructive interference is introduced between the two halves of the OPC, the first half and the second one. In a study carried out by Alipoor et al. [12], the researchers investigated the FWM effect on the performance of a DWDM-RoF system. They adopted ODSB, Optical Double Side Band, along with Mach–Zehnder modulator of dual drive for both external and direct modulations. Additionally, in a different study, the authors presented the authors presented an analysis for the performance of the proposed system in the presence of the FWM effect for various parameters including channel spacing, data rate, input power, optical amplifier gain, and finally fiber length [13, 14].

3. Description of the proposed system DWDM-RoF

Figure 1 illustrates the structure of DWDM-PON-RoF network for the proposed system. It is an optical system which consists of three parts: the Optical Line Network (OLT), Optical Network Unit (ONU), and Optical Distribution Network (ODN). The linear and nonlinear distortions will be exerted on the system such as attenuation, polarization mode dispersion (PMD), and dispersion as linear effects in addition to the nonlinear ones such as the SPM, XPM, and FWM.

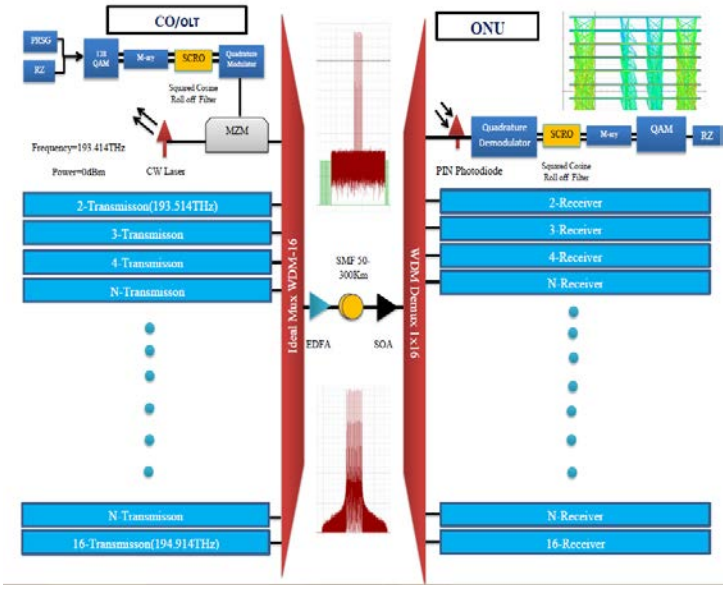


Fig. 1. The proposed DWDM- RoF architecture system.

The proposed system operates in accordance with the digital signal processing (DSP) technology. The OLT contains the Transmission X (TX) as in Fig. 2. Considering numerical solutions (EDFA). As illustrated in Fig. 3. QAM, the M-ray detectors, pulse generator RZ, and finally, the Quadrature Demodulator as illustrated in Fig. 4.

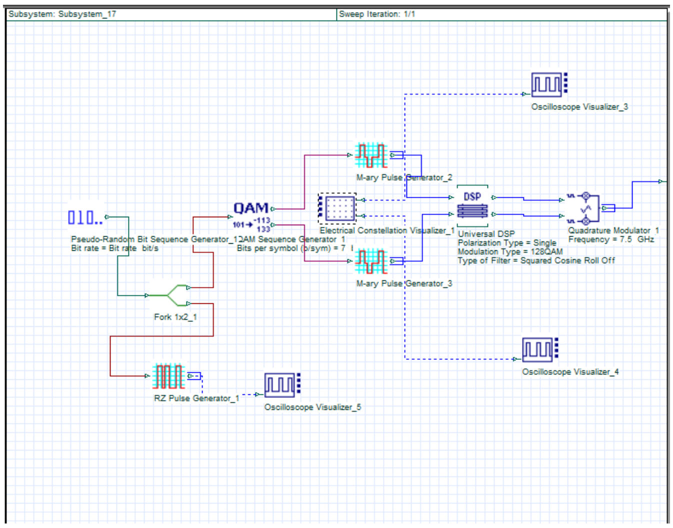


Fig. 2. Transmission (OLT).

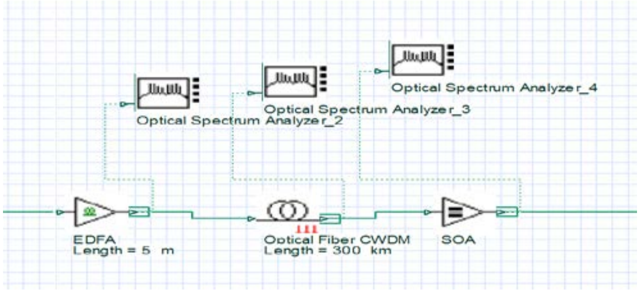


Fig. 3. Optical distributed network (ODN).

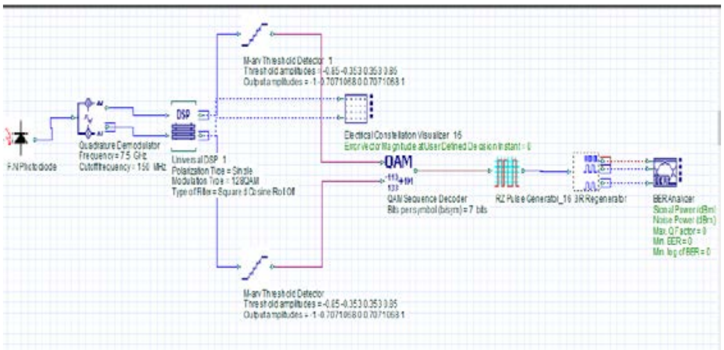
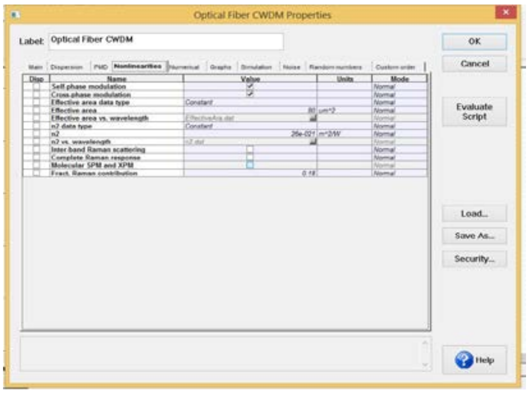


Fig. 4. Receiver (ONU).

4. Results and Discussion

For that purpose, the density of wavelength has been measured through transmission distance from 50-300 km, where the wavelengths are uplinked with 300 Gpbs under presence the nonlinear effects as illustrated in Fig. 5. The form of the light spectrum is shown in Fig. 6 when using SOA technology due to transmitting wavelengths that range from 193.414 THz to 194.914 THz.



Label: Optical Fiber CWDM

Disp	Name	Value	Units	Mode
☐	Self phase modulation	☑		Normal
☐	Cross phase modulation	☑		Normal
☐	Effective area data type	Constant		Normal
☐	Effective area	80	um^2	Normal
☐	Effective area vs. wavelength	EffectiveArea.dat		Normal
☐	n2 data type	Constant		Normal
☐	n2	26e-021	m^2/W	Normal
☐	n2 vs. wavelength	n2.dat		Normal
☐	Inter band Raman scattering	☐		Normal
☐	Complete Raman response	☐		Normal
☐	Molecular SPM and XPM	☐		Normal
☐	Fract. Raman contribution	0.18		Normal

Fig. 5. SPM, XPM , FWM parameters.

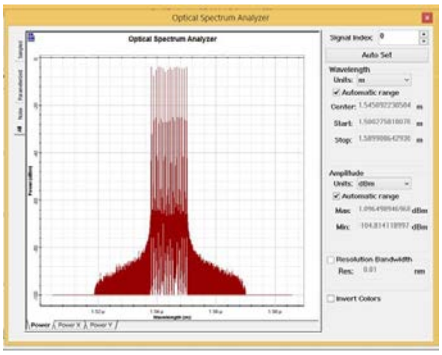
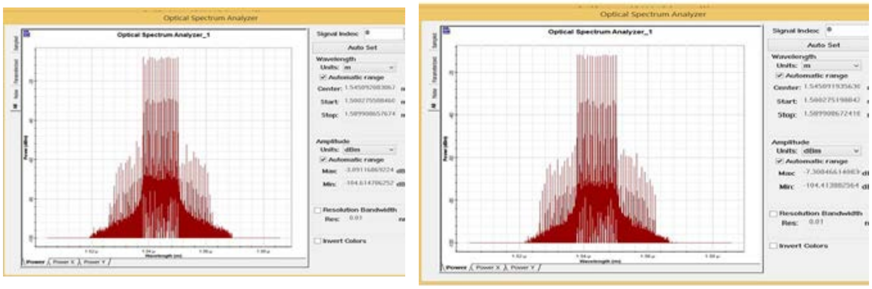


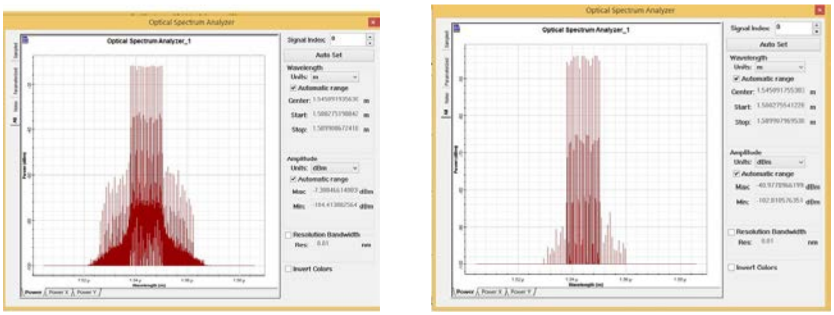
Fig. 6. Input signals frequency spectrum.

Transmission distances where the form of the spectrum frequency are shown Figs. 7(a) to 7(d) show that the second order harmonic will have greatest impact on the performance of the system. Representation, the Eye-Diagram at 300 km as illustrated in Fig. 8.



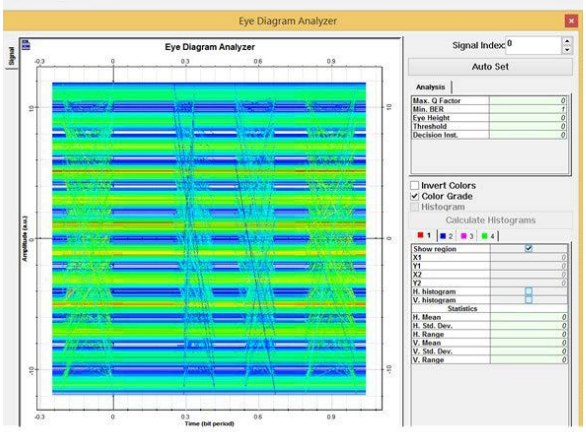
(a) Output signal frequency spectrum.

(b) Output signal frequency spectrum



(c) Output signal frequency spectrum. **(d) Output signal frequency spectrum**

Fig. 7. Output signal frequency spectrum.



Signal Index: 0

Analysis

Max. Q Factor	0
Min. BER	1
Eye Height	0
Threshold	0
Decision Inst.	0

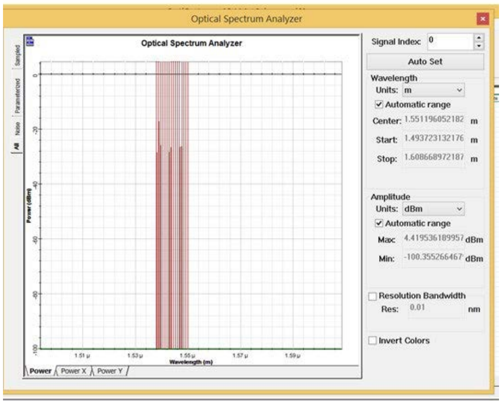
☐ Invert Colors
☑ Color Grade
☐ Histogram

🟥 1 | 🟦 2 | 🟪 3 | 🟩 4

Show region	☑
X1	0
Y1	0
X2	0
Y2	0
H. histogram	☐
V. histogram	☐
Statistics	
H. Mean	0
H. Std. Dev.	0
H. Range	0
V. Mean	0
V. Std. Dev.	0
V. Range	0

Fig. 8. Eye-diagram in presence of the nonlinear effects.

Light spectrum for both of the input and output will be as illustrated in Fig. 9. Accordingly, the second order harmonic has been reduced considerably as shown in Figs. 10(a) to 10(d). Representation, the Eye-Diagram at 300 km as illustrated in Fig. 11.



Signal Index: 0

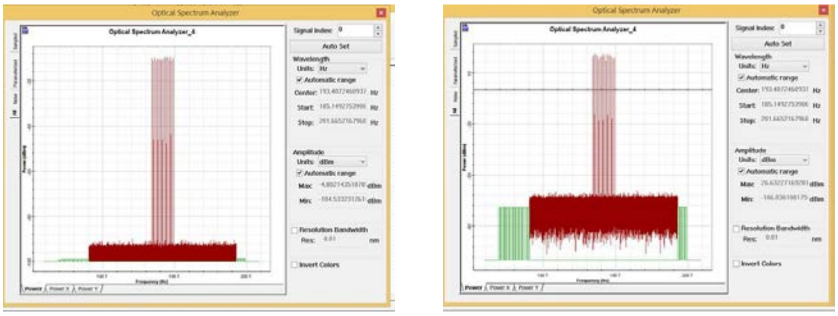
Wavelength
Units: m
☑ Automatic range
Center: 1.551196052182 m
Start: 1.493723132176 m
Stop: 1.608668972187 m

Amplitude
Units: dBm
☑ Automatic range
Max: 4.419536189957 dBm
Min: -100.355266467 dBm

☐ Resolution Bandwidth
Res: 0.01 nm

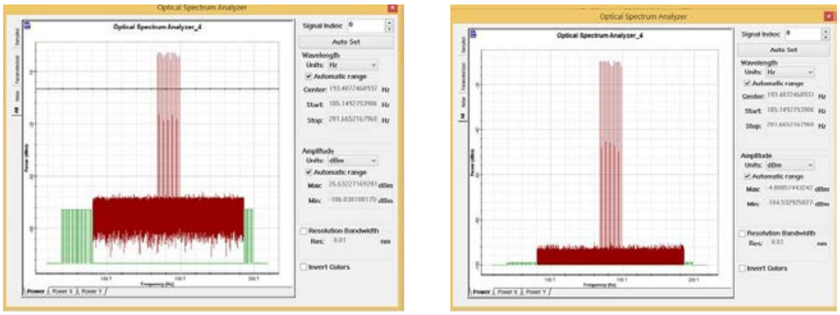
☐ Invert Colors

Fig. 9. Input signals frequency spectrum with QAM-SCRO.



(a) Output signal frequency spectrum.

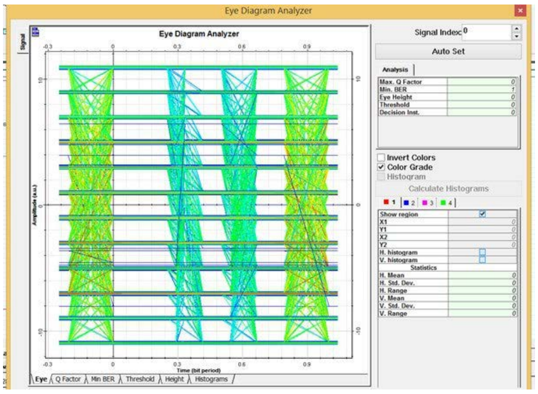
(b) Output signal frequency spectrum.



(c) Output signal frequency spectrum.

(d) Output signal frequency spectrum.

Fig. 10. Output signal frequency spectrum.



Signal Index: 0

Max. Q Factor	0
Min. BER	1
Eye Height	0
Threshold	0
Decision Inst.	0

☐ Invert Colors
☑ Color Grade
☐ Histogram

Show region	☑
X1	0
Y1	0
X2	0
Y2	0
H. histogram	☐
V. histogram	☐
Statistics	
H. Mean	0
H. Std. Dev.	0
H. Range	0
V. Mean	0
V. Std. Dev.	0
V. Range	0

Fig. 11. Eye-diagram in presence of the nonlinear effects.

Figure 12 shows the relationship between the BER and the wavelength for significant reduction in the nonlinear effects where the values of the BER and Q factor are 10.40 and 1.32E-10 respectively as illustrated in Figs. 13 and 14. As shown in Fig. 15 the EVM value is 22.5 when using the SAO technology at the distance of 300 km.

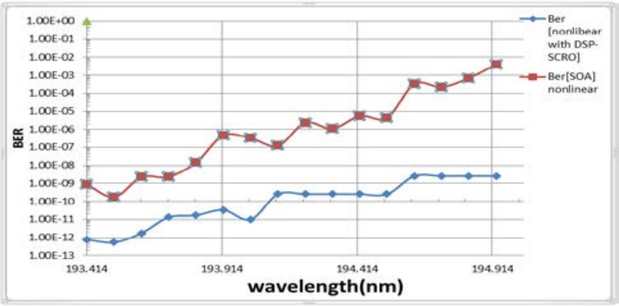


Fig. 12. BER to Wavelength in the presence of the nonlinear effects.

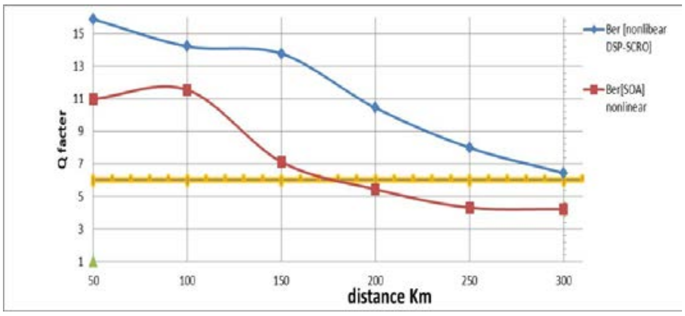


Fig. 13. Q factor to distance in the presence of the nonlinear effects.

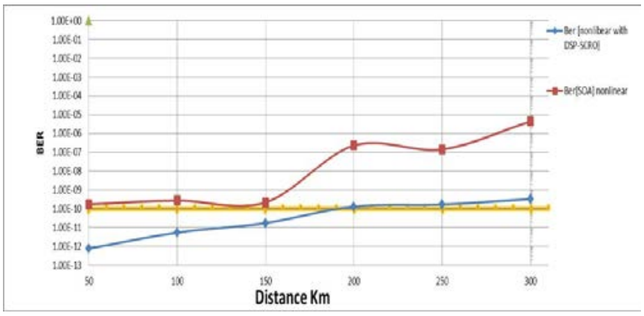


Fig. 14. BER to distance in the presence of the nonlinear effects.

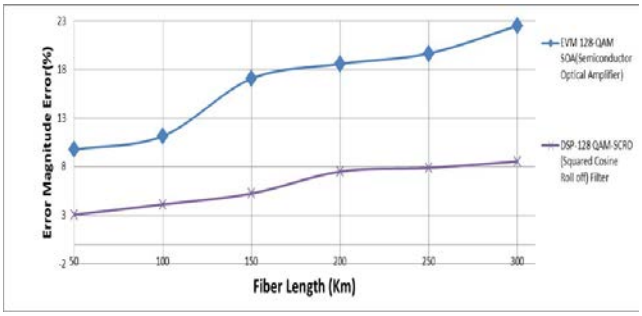


Fig. 15. Comparison of EVM to distance.

5. Conclusion

To sum up the discussion presented above, the following remarks can be drawn. Essentially, the DSP-128 QAM-SCRO (Squared Cosine Roll off) Filter is considered one of the best technologies which has been tested in the optical communication systems for the DWDM-PON-RoF. It is considered the best technology for achieving the optimal values for both of the Q factor and the BER at the distance of 300 km. Further, when employing the DSP-128 QAM-SCRO (Squared Cosine Roll off) in the proposed system, the performance of the system has enhanced significantly by measuring the EVM in the system where it was reduced from 22.5 to 8.5. Conversely, when using the SOA technology, the EVM was never reduced at the distance of 300 km. Furthermore, the DSP-128 QAM-SCRO (Squared Cosine Roll off) Filter aids in mitigating the nonlinear effects, namely the SPM, XPM, and FWM.

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