Designing a 40 Gbps Radio Over Fiber system based upon EDFA and SOA amplifiers and using WDM-PDM multiplexing techniques

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Abstract: Amplifiers are backbone of modern communication system They boost the transmitted signal and provide the signal with significant increase in strength along the communication path. In optical communication system the amplification of optical signal is done by optical amplifiers such as EDFA and SOA. In the present work a Radio over fiber (RoF) system is realized having four channels. The system utilized wavelength division multiplexing and polarization division multiplexing to transmit multiple signals simultaneously. Furthermore, a combination of EDFA and SOA is used as optical amplifiers. The system and observations are made using Opti system software which is a simulation software specifically designed for an optical system's evaluation.

Keywords: Bit error rate (BER), Erbium Doped Fiber Amplifier (EDFA), Eye diagram, Radio over fiber (RoF) systems, Signal to noise ratio (SNR), Semiconductor Optical Amplifiers (SOA), Wavelength Division Multiplexing (WDM).

1. Introduction

An optical system can be used to transmit radio frequency signal by using an optical fiber system. Such systems are known as Radio over fiber (RoF) systems [1]. Now a RoF system performance and bandwidth can further be enhanced by using a multiplexing technique such as Wavelength division multiplexing (WDM) and polarization division multiplexing (PDM) [2]. Attenuation of signal significantly affects the performance of any communication system. To overcome attenuation and increase the transmission range of any system, amplifiers are used.

Amplifiers are necessary tools for transmission of signal since long distance transmission has started. Amplifiers play a huge role by providing necessary boost to the signal along the transmission channel against signal attenuation. Optical amplifiers provide the necessary amplification to optical signal without having the need for converting the optical signal to electrical form. Optical amplifiers include EDFA amplifiers, SOA amplifiers and Raman amplifiers.

EDFA amplifiers amplifies signals in C and L bands [3]. EDFA utilizes stimulated emission for amplifying the incoming optical signal. A pump laser at 980nm or 1480nm is used for this purpose [4]. In EDFA amplifiers, an optical fiber is doped with Erbium ions. The pump laser excites the erbium ions to higher energy levels and when a weakened optical signal passes through the erbium doped fiber, the erbium ions drop to lower energy level releasing photons and thereby amplifying the signal [4]. EDFA is also affected by Amplified Spontaneous Emission (ASE) noise which can significantly affect the gain and noise figure of the optical system [5].

Semiconductor Optical amplifiers (SOA) have wider bandwidth coverage as compared to EDFA [6], [7]. SOA work in the range from 1310 to 1550 nm [6]. An SOA can be constructed using elements such as In, Ga, As and Al or their combination such as InP and InGa [6]. Like all optical amplifiers, SOA also uses stimulated emission for amplification. SOA working is similar to a laser but without the oscillations in the cavity. The oscillations needs to be suppressed by using an anti-reflection coating [8].

EDFA and SOA are known to provide higher gains along with low noise figure [9]. EDFA and SOA amplifier can together be used in an optical communication channel to form an hybrid combination of optical amplifiers to exploit the advantages of both optical amplifiers. Optical amplifiers offer advantage to an optical system as they can boost an incoming optical signal without first converting it to electrical form [9].

2. System Description

The optical system designed consist of a receiver section, channel and a transmitter section. The transmitter part is shown in figure 1. The transmitter side consists of four channel which are wavelength multiplexed using 2 x 1 WDM multiplexer and polarization division multiplexed using a polarization controller. The four channels are composed of a pseudo random bit generator which generates the binary sequence which is transmitted. Then the binary bits are changed to NRZ form using a NRZ pulse generator. After this an MZ modulator is used to modulate the output of NZ pulse generator with a CW laser. Next another MZ modulator is used to modulate a Radio frequency signal. This process is repeated for all four channels. The four channels start from 1350nm to 1351.5 nm with spacing of 0.5 nm.

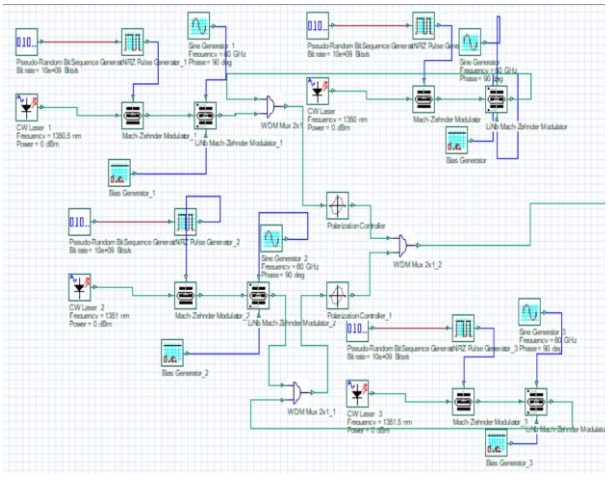

Figure 1: Transmitter Section

The channel is shown in Figure 2. The channel is composed of an optical fiber, a booster amplifier which is an EDFA amplifier and a preamplifier which is used at the receiver. An SOA amplifier is used as a preamplifier.

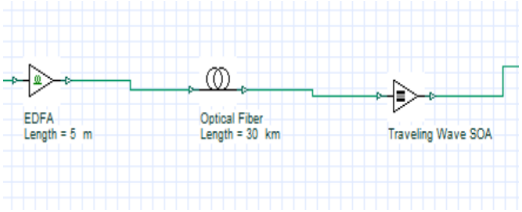

Figure 2: The Channel

At the receiver side, firstly a polarization splitter is used to separate the polarized signals, the two WDM multiplexers are used to distinguish the four channels from multiplexed signals. Each four separated signals consist of a Gaussian optical filter which has central frequency as channel frequency which is 1350 nm, 1350.5nm, 1351nm and 1351.5 nm. Then a PIN photodetector is used to convert received optical signal into electrical signals. A BER analyser is used to analyse the received signal. The receiver is shown in Figure 3.

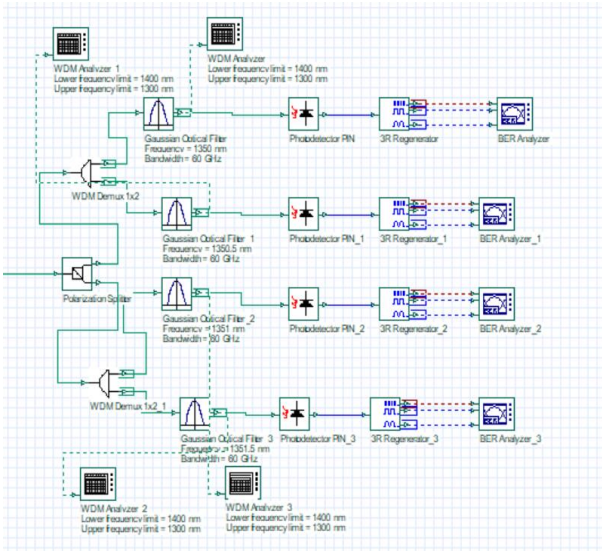

Figure 3: Receiver Section.

3. Results and Discussions

The results were obtained using BER analyser and WDM analysers. The variation of received optical power, OSNR, BER and Q-factor can be viewed in table 1. From table 1 it can be observed that as fiber length is increased from 15 Km to 60 Km, the above mentioned performance metrics deteriorates.

Fiber length	Channel	Received Power(dBm)	Optical Signal to noise ratio(dbm)	BER	Q-factor
15 Km	1350	-2.20	80.19	1.03×10^{-38}	12.94
	1350.5	-4.23	79.08	1.89×10^{-33}	11.98
	1351	-2.26	80.32	3.26×10^{-40}	13.20
	1351.5	-4.25	79.14	9.82×10^{-35}	12.21
30 Km	1350	-2.31	80.20	2.80×10^{-31}	11.55
	1350.5	-4.35	79.12	1.15×10^{-28}	11.03
	1351	-2.28	80.33	7.18×10^{-33}	11.86
	1351.5	-4.37	79.13	1.53×10^{-26}	10.58
45 Km	1350	-2.40	79.18	7.71×10^{-27}	10.64
	1350.5	-4.44	76.66	1.34×10^{-22}	9.69
	1351	-2.37	80.34	1.39×10^{-24}	10.15
	1351.5	-4.46	79.10	1.06×10^{-22}	9.71
60 Km	1350	-2.48	78.23	7.50×10^{-19}	8.95
	1350.5	-4.50	72.16	5.62×10^{-18}	8.54
	1351	-2.44	78.39	2.86×10^{-20}	9.13
	1351.5	-4.54	76.40	4.38×10^{-18}	8.57

Table1: Variation for Received power, SNR, BER and Q- factor with distance.

The eye diagram for all four channels can be viewed from figure 4 and figure 5 for 15 Km and 60 Km distance for all four channels. The eye diagram also deteriorates for all four channels as fiber length is increased.

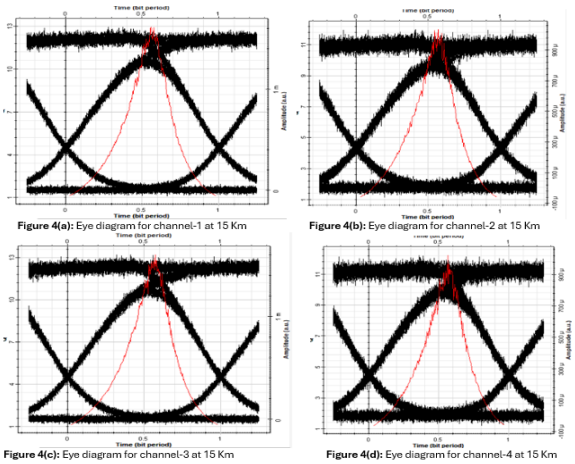

Figure 4: Eye diagram at optical fiber length of 15 Km.

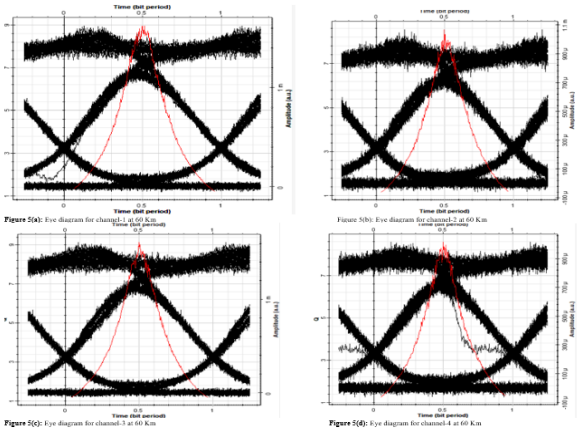

Figure 5: Eye diagram at optical fiber length of 60 Km.

4. Conclusion

A Radio over fiber system is designed here with EDFA amplifier as booster amplifier and SOA amplifier as preamplifier. The BER and Q factor were found using BER analyser. BER and Q factor at 15 Km distance for channel 1 is found as 1.03×10^{-38} and 12.94, for channel 2 BER and Q factor is found as 1.89×10^{-33} and 11.98, for channel 3 BER and Q factor is found as 3.26×10^{-40} and 13.20 and finally for channel 4 BER and Q factor is found as 9.82×10^{-35} and 12.21. As distance is increased gradually to 60 Km, it is found that both parameters Q factor and BER reduces but the values found are acceptable for successful signal transmission.

The eye diagram for all four channel was also observed for 15 Km distance and 60 Km distance. The eye diagram was found to worsen from 15 Km to 60 Km for all four channels.

5. References

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