Design of a four channel Radio over Fiber Optical system using EDFA amplifiers and WDM PDM techniques

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Abstract: Attenuation of a signal as it traverses through any channel results in severe reduction in signal strength thereby limiting the performance of a communication system. Similarly, any optical signal traversing through optical fiber suffers attenuation which causes signal strength to worsen and thus amplifiers are required to give boost to the signal. In this work a Radio over fiber system is considered having four channels with WDM-PDM multiplexing technique and EDFA amplifier is used to rejuvenate the signal strength. The work below is conducted in Opti System software which is explicitly designed for optical communication systems. Different parameters such as bit error rate (BER), optical signal to noise ratio (OSNR), signal power, quality factor and eye diagram are considered to assess the performance of the system.

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

1. Introduction

Transmission through optical fiber has provided for signal to travel at much faster rate than previously possible through electrical transmission cable. This strength of optical communication can also be applied in transmission of radio frequency signal by using radio over fiber (RoF) technology [1]. In RoF, a RF signal is transmitted through an optical fiber cable [1].

Optical systems can be enhanced by increasing bit rate by using different multiplexing techniques such as WDM and PDM [2]. Furthermore, optical amplifiers can be employed during the transmission path to compensate for attenuated signal strength and restore it to optimal level. Optical amplifiers increase the strength of a weak incoming optical signal without having the need to convert the optical signal into electrical signal first [3].

EDFA amplifiers can be used in the transmission path to counterbalance the effect of attenuation. EDFA amplifiers allow large dynamic range for long distance communication [4]. In EDFA, a pump laser is multiplexed with the incoming input optical signal needed to be amplified by using an optical device known as coupler. The pump laser wavelength is either 980 nm or 1450 nm to achieve amplification in 1550 nm range [5]. The main principle behind amplification in EDFA is stimulated emission of photons [6]. The substances that are used for construction of EDFA include glass materials such as SiO and Erbium ions [7]. EDFA is relevant for amplification in C- band and L- band for optical transmission [7]. EDFA offers a number of advantages which includes small noise figure and significant signal amplification in 1500 nm to 1600 nm range [8].

2. System Description

A four channel Radio over Fiber optical system is designed here. The system's performance is enhanced by employing multiple multiplexing techniques such as WDM and PDM and applying EDFA amplifier to reduce the effect of attenuation on the optical signal.

The transmitter section is shown in Figure 1. The transmitter is a quad channel, and each channel includes a 10Gbps pseudo-random bit generator that generates the input bit sequence. This sequence is then encoded into a non-return-to-zero (NRZ) format using an NRZ pulse generator. The encoded signal is subsequently modulated by a Mach-Zehnder (MZ) modulator, which uses a continuous-wave (CW) laser to imprint the signal onto an optical carrier. The laser sources operate within a wavelength range of 1550 nm to 1551.5 nm, with 0.5 nm spacing between them. The signals from the first two channels are combined using a 2x1 wavelength division multiplexing (WDM) multiplexer, while another 2x1 WDM multiplexer processes the remaining two channels. These multiplexed outputs then pass through polarization controllers, which adjust the azimuth parameter to create two orthogonal signals. Finally, the outputs from both polarization controllers are merged using another 2x1 WDM multiplexer before being transmitted.

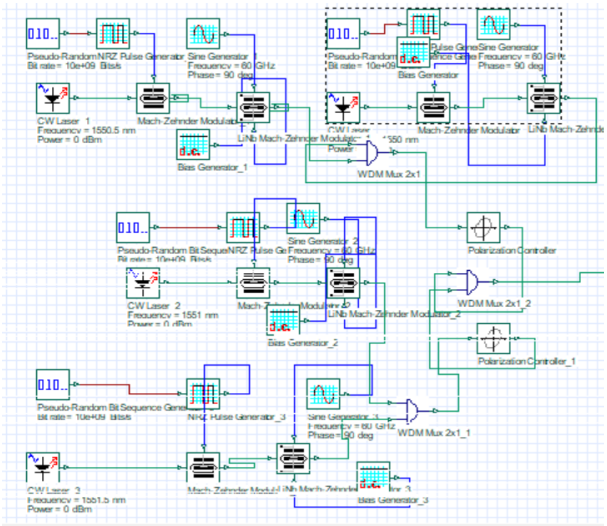

Figure 1: Transmitter section.

The channel consists of an optical fiber of varying length from 15 Km to 60 Km. Further the channel consists of an EDFA as pre-amplifier and a second EDFA as post amplifier which are five metres in length. The channel is shown in Figure 2.

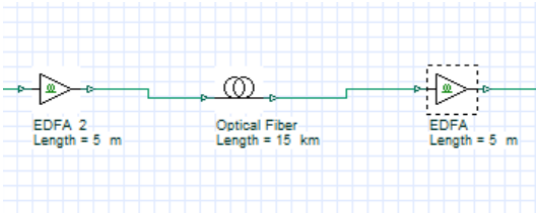

Figure 2: The Channel.

At receiver a polarization splitter first separates the received signal based on its state of polarization. The separated signals are then demultiplexed using two 1x2 WDM demultiplexers, which extract the individual optical channels. Next, a PIN photodiode detects the optical signals and converts them into electrical signals. The output signal is then refined by passing it through a Gaussian optical filter. Finally, a BER analyser evaluates the quality of the received signal. The receiver section is shown in Figure 3.

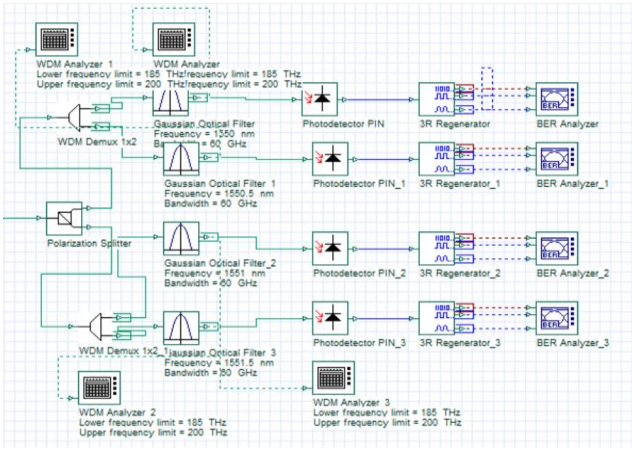

Figure 3: The receiver section.

3. Results and discussions

The variation of received power, OSNR, BER and Q-factor for the received optical signal can be viewed in Table 1 which were found using BER analyser. It is clearly visible from the table that as the distance of the optical fiber cable used to transmit the light signal between the transmitter and receiver is increased the various above said parameter values deteriorates. These performance parameter values are shown in table 1 for varying distance from 15 Km to 60 Km.

Fiber length	Channel	Received Power(dBm)	Optical Signal to noise ratio(dbm)	BER	Q-factor
15 Km	1550 nm	11.95	40.29	2.27×10^{-54}	15.46
	1550.5 nm	13.26	41.60	6.58×10^{-53}	15.24
	1551 nm	12.38	40.42	2.15×10^{-48}	14.54
	1551.5 nm	13.62	41.66	1.13×10^{-51}	15.05
30 Km	1550 nm	11.30	40.29	8.46×10^{-52}	15.08
	1550.5 nm	12.57	41.56	2.05×10^{-63}	16.75
	1551 nm	11.68	40.41	4.06×10^{-44}	13.86
	1551.5 nm	12.89	41.63	1.97×10^{-47}	14.40
45 Km	1550 nm	10.92	40.28	4.41×10^{-41}	13.36
	1550.5 nm	12.17	41.52	3.30×10^{-49}	14.68
	1551 nm	11.26	40.40	4.23×10^{-33}	11.91
	1551.5 nm	12.45	41.59	1.04×10^{-42}	13.63
60 Km	1550 nm	10.71	40.25	2.06×10^{-29}	11.18
	1550.5 nm	11.93	41.46	1.73×10^{-24}	10.12
	1551 nm	11.00	40.37	6.24×10^{-20}	9.04
	1551.5 nm	12.16	41.54	1.09×10^{-29}	11.24

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

The eye diagram for the four channels can be viewed from figure 4 and figure 5 for the distances of 15 Km and 60 Km. It can be clearly seen that the eye diagram worsens for 60 Km fiber length when compared to fiber length of 15 Km.

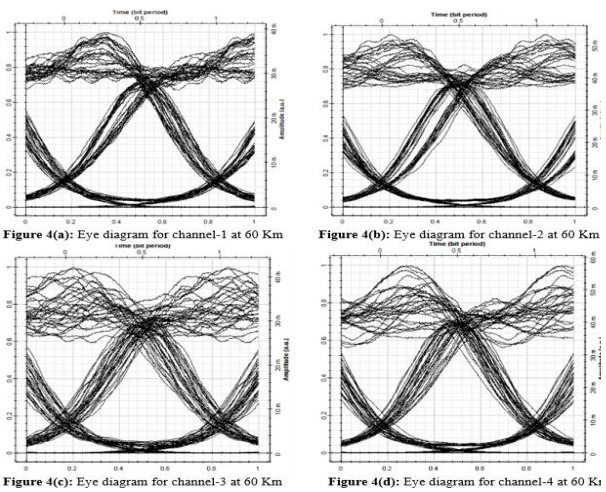

Figure 4: Eye diagram at optical fiber length of 60 Km

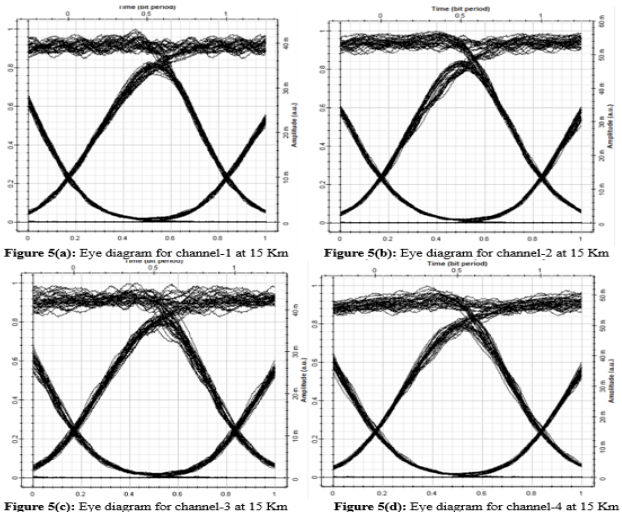

Figure 5: Eye diagram at optical fiber length of 15 Km.

4. Conclusions

Here a four channel Radio over Fiber system is realised using multiple multiplexing techniques and erbium doped fiber amplifiers (EDFA) are used for providing amplification during transmission against factor of attenuation. The received signal power at 15 Km for channel 1 is 11.95 dBm, for channel 2 received power is 13.26 dBm, for channel 3 received power is 12.38, for channel 4 received power is 13.62 dBm. The received optical power and quality factor progressively reduces as the distance between transmitter and receiver is increased.

The bit error rate also increases as fiber length increases. The various performance parameters deteriorates as distance increases between transmitter and receiver. The system shows robust performance for fiber length of 60 Km distance.

5. References

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