BER Analysis and Mitigation of Four-Wave Mixing effect in Radio over Fiber System

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Abstract: Comparative analysis of wavelength division multiplexing (WDM) techniques in Radio over fiber system at different bit rates (1Gbps, 2Gbps, 5Gbps, 10Gbps and 15Gbps) have been investigated in this paper. A high-quality factor (Q-factor) with low Bit Error Rate have been reported. Erbium doped fiber amplifier (EDFA) and dispersion compensating fiber (DCF) have been used to mitigate the different attenuation and dispersion in the optical fiber. An increase in channel spacing have shown a better result in the reduction of the nonlinear effects such as Four wave Mixing (FWM). Simulated results have been analyzed and different received power, Optical signal to noise ratio (OSNR) and Eye diagram have been reported.

***Index Terms* – Radio over fiber, Wavelength Division Multiplexing, Bit Error rate, Four Wave Mixing, OSNR.**

I. INTRODUCTION

In this recent year, there is a significant demand of data rate thought wired and wireless network [1]. These causes an increasing traffic congestion in the mobile communication network. In order to meet the demand such as high-speed broadband wireless access and high capacity solution like microcellular have been proposed. In this system high capacity communication with high speed can be improve through frequency reuse technique offer by the large number of small cells. The limitations of this systems are its requirement of a huge number of base stations (BSs) to cover the whole area. Moreover, channel control techniques and handoff procedure among BSs is becoming more complicated. In order to overcome the huge data traffic that will be present in the future communication technology such as fifth generation (5G) technology, a new architecture in which all complicated processing which were performed at BS will be done at a control station (CS) [2-3]. A new high-speed communication has been proposed in which the radio signals is transmitted through an optical fiber. This new access network is known as Radio over fiber [4]. The optical fiber used in RoF technology present a very low attenuation and immunity to electromagnetic interference. Hence the transmission of information over a long distance is possible. Moreover, it enhances the mobility of the wireless networks [5-6]. In the basic architecture of the RoF network, all the necessary equipment for the conversion of electrical signal into optical signal and vice-versa are present. In optical communication links the operating wavelength are either 1310nm or 1550nm which are second and third optical windows respectively. At these operating wavelengths, the attenuation is very low therefore data rate transmission is high. At the transmitter side, a direct or external modulation is used to modulate the incoming radio frequency signal. From the central station (CS) to the base station (BS), the incoming radio frequency modulates the optical source gives as output a wavelength which amplitude varies with the variation of laser DC biasing current. After the generated optical wavelengths are coupled into wavelength division multiplexing (WDM) and the obtained signals are carried by the optical fiber to the base station. The optical detector at the base station detect and convert the received multi wavelength signal back into the original radio frequency signal. Finally, the radio frequency signal is transmitted to the mobile unit via the base station antenna. The basic diagram of RoF is shown in Fig. 1. It is to be noted that the objective of implementing WDM systems is to increase the number of wavelengths transmitted through a single optical fiber. WDM technique is employed for multiple data transmission and also for an efficient utilization of bandwidth [7-8]. The variation of the refractive index in core of the optical fiber with the optical intensity leads to nonlinear phenomena in RoF technology. These nonlinear phenomena can be arranged into two categories. In the first category, the impairments are caused by the interaction of the propagating field intensity with the refractive index of the fiber. The nonlinear phenomena present in this category are self-phase modulation (SPM), cross-phase modulation (XPM) and four wave mixing (FWM). All the impairments cause by stimulated scattering mechanisms such as simulated Brillouin scattering (SBS) and simulated Raman scattering (SRS) are classed in the second category [9]. These nonlinearity phenomena lead to signal broadening [10], attenuation and undesirable signal modulation which therefore reduce the transmission capability in the long-haul optical communication system. In contrast to the single optical channel, the nonlinear effects are more stringent in WDM system [11]. FWM nonlinear effect occurs mostly in WDM system. It is the interaction between two or more wavelengths to generate more wavelengths due to scattering of the incident photon on the fiber [12-14]. Moreover, it is an important parameter determines the performance of an optical transmission system. These phenomena become very important over a long-haul optical communication. To minimize the FWM effects that cause the cause the crosstalk a statistical analysis has been described in [15]. Further optimization techniques have proposed based on the channel spacing, channel power and fiber area. Monika et al. have proposed different input channels with various parameters of channel spacing [16]. Moreover, four waves mixing and the chromatic dispersion are inversely proportional. Therefore, it is great importance to find a method that can meet these two challenges. In order to reduce the losses experience by the optical network due to nonlinearity and dispersion, the introduction of an optical amplifier is required. The commonly used optical amplifier is the Erbium doped feedback amplifier (EDFA) [17-19]. EDFA increase the power that raises the incoming signal to a desired level in the optical communication system. To study the performance of an optical communication system, parameters like quality factor (Q-factor) and bit error rate (BER) are very important [20]. To transmit an information over a long distance, it is important to have a low BER and high Q-factor.

In this work an optical communication system that can be used in RoF technology has been designed. The system consists of a multiplexing of four different channel over a single optical fiber using WDM. A Comparative analysis of the Q-factor and BER has been investigated with different input bit rate. Secondly on a tabulated form the different value of optical signal to noise ratio (OSNR) and the Eye height for four different channels has been reported. Finally, a comparison between the different output of the WDM analyzer and their Eye diagram for different channel spacing has been reported.

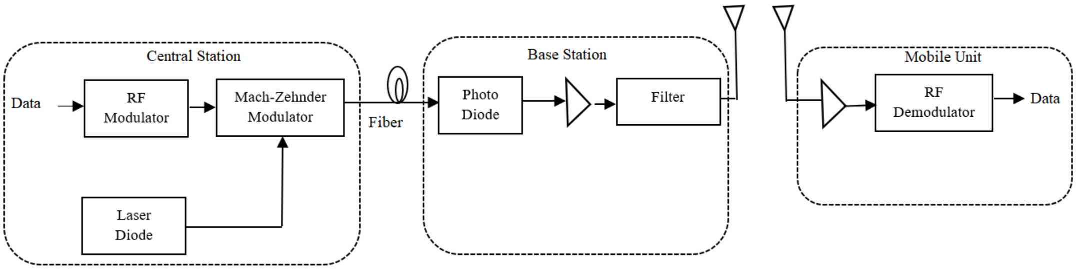
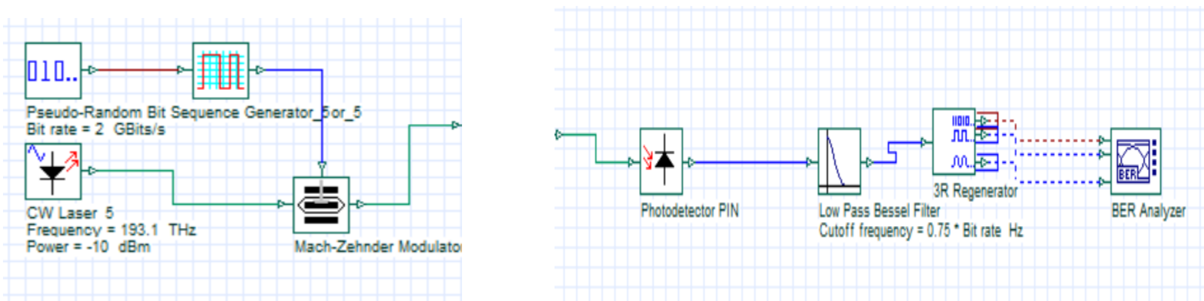


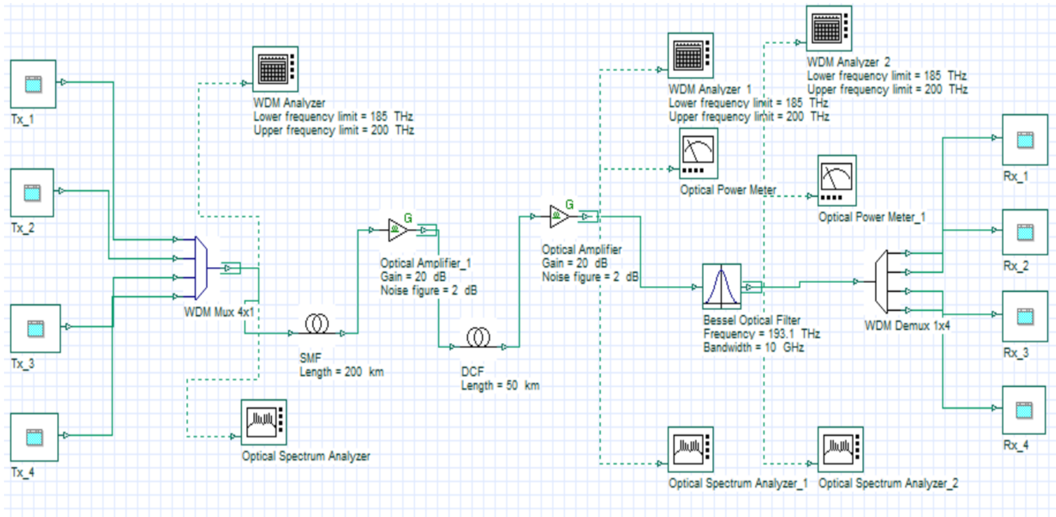
Fig.1: Basic architecture of Radio over Fiber System

II. System Architecture

Optisystem version 7 has been used to design the propose architecture. Parameters to analyze the performance have been tabulated in Table 1. The layout model is shown in Fig. 2(c). The proposed system consists of optical transmitter, transmission medium and receiver. The transmitter in Fig. 2(a) consists of Pseudo random bit sequence (PRBS) which contains the data to be transmitted. non return to zero electrical signal, often abbreviated as NRZ. It encodes the data received from PRBS generator. Continuous wave laser is used as light source. Mach-Zehnder modulator (MZM) is used to interfere between two light waves with the same frequencies. But, the two waves propagate with different phases. Moreover, intensity of light source also varies. It varies from the laser or source, as per the output of the NRZ pulse generator. The modulated optical signal from the transmitter for four different wavelengths (λ_1 = 1550.91nm, λ_2 = 1551.51nm, λ_3 = 1552.72nm, λ_4 = 1553.12nm) are combined by WDM to rise the system capacity. The output signal of WDM is transmitted through first through a single mode fiber (SMF). SMF can carry high data rate signal over a long distance in controversy to multimode fiber (MMF). An optical amplifier and Dispersion Compensating Fiber (DCF) are then used to amplify and compensate the attenuation and loss caused by the nonlinear effect and the dispersion. The optical amplifier used is the Erbium Doped Fiber Amplifier (EDFA) and it is put between and at the end of SMF and DCF. In order to get a higher signal to noise ratio and lower bit error rate, a pre-amplifier must be placed just at the entry of the optical receiver. The receivers in Fig. 2(b) is composed of a PIN photo detector to detect the signal after demultiplexing, then convert electrical signal pass through a Low Pass Bessel filter to remove some higher frequency component the generated noise by the link. The signal then passes through a 3R-regenerator then the performance of the receiver is measured by the BER analyzer which is directly connected to the 3R-regenerator. Performance like Q-factor and log of BER has been reported at bit rate of 1Gbps, 2Gbps, 5Gbps, 10Gbps and 15Gbps. Component like Optical Analyzer, WDM Analyzer, Optical Power Meter are used to observe the OSNR of the four different wavelengths and to visualized the effect of nonlinearity in optical fiber.



(a) (b)



(c)

Fig. 2: (a)Transmitter (b) Receiver (c) Architecture of the proposed system

Table 1:Simulation parameters used in this system.

Transmitter Parmeters	**Value**
PRBS Bit Rate	1Gbps to 15 Gbps
CW Laser Power	-10dBm
CW Laser Frequency	193.1THz to 193.4THz
Channel Spacing	25GHz to 100GHz
CW Laser Line width	10MHz
MZM Extinction Ratio	30dB
SMF Parameters	**Value**
Length	2t0 200km
Attenuation	0.2dB/km
Dispersion	16.75ps/nm-km
Dispersion Slope	0.075
Effective Area	80μ*m*2
EDFA Parameters	**Value**
Gain	20dB
Power	80dBm
Noise Figure	2dB
DCF Parameters	**Value**
Length	20km
Attenuation	0.005dB/km
Dispersion	-83.75ps/nm-km
Dispersion Slope	0.075
Effective Area	80μ*m*2
Receiver Parameters	**Value**
PIN Responsitivity	1A/W
Dark Current	10nA
Thermal Noise	10-21W/Hz
Low Pass Bessel Filter cut off frequency	0:75*Bit Rate Hz
Low Pass Bessel Filter Insertion Loss	0dB
Low Pass Bessel Filter Order	4

III. Result and Discussion

Quality factor of the receive signal at different link length and different bit rate is plotted in Fig. 3. The total link length is 250 km. The different bit rate consider are 1Gbps, 2Gbps, 5Gbps, 10Gbps and 15Gbps. At a bit rate of 10Gbps and optimum Q-factor of 9 has been obtained for the link range of 100km. At lower bit rate of 1Gbps a better-quality factor of about 20 has been observed for the same link distance.

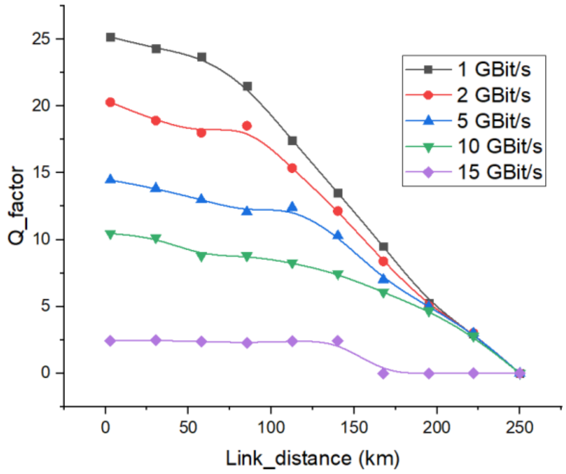


Fig. 3: Q factor of received signal with respect to link length at different bit rate

Fig.4 represent the log of BER at different link length and at different bit rate. It conforms that our design system can support bit rate of 10Gbps up to a link of 150 km

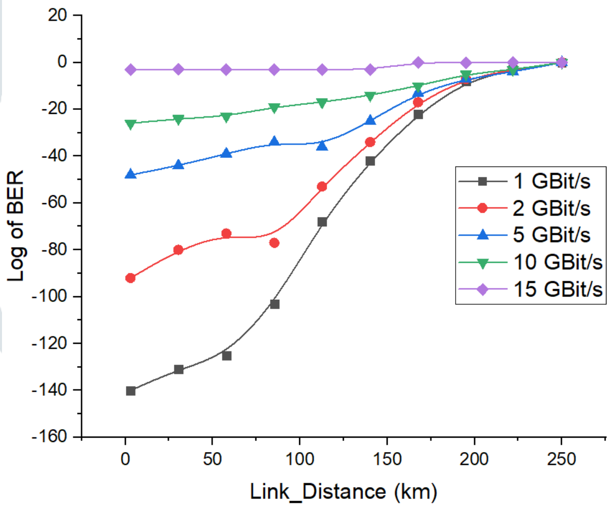


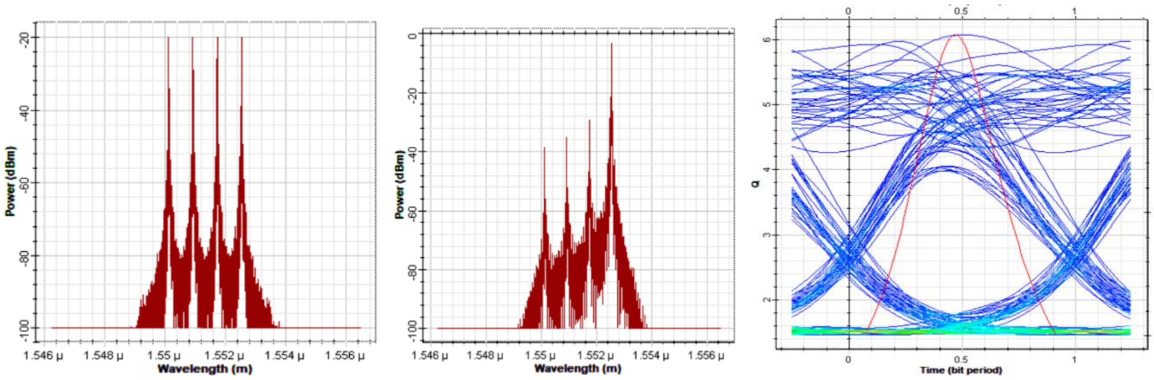
Fig. 4: Log of BER of received signal with respect to link length at different bit

From Table 2 it can be observed that the Eye height decrease with the increase of the value of the wavelength. The highest value is 0.752842 at a wavelength λ_1 =1550.91 nm, which imply that the effect of inter symbol interference is low at this wavelength. Therefore, when choosing the bandwidth for amplification this region can be considered. A higher value of more than 40dB has of OSNR has also been obtained for the four different channels.

Table. 2: Amplified WDM system output

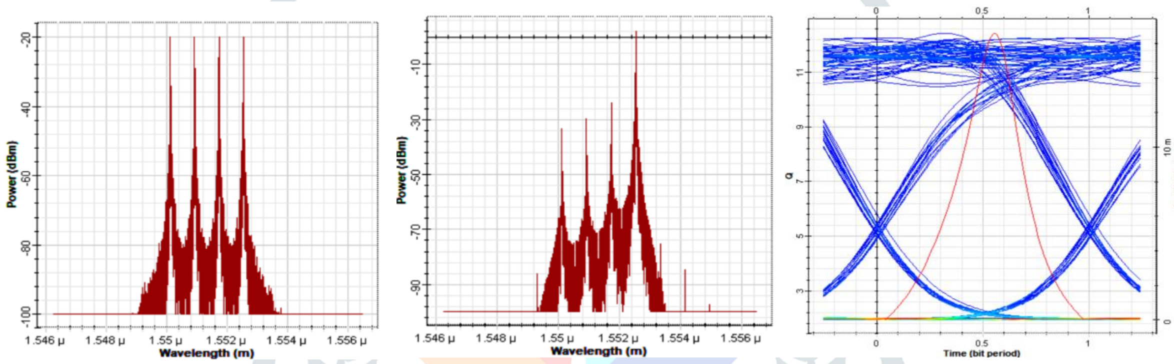
Wavelength(nm)	Output power(dBm)	OSNR (dB)	Eye height(km)
λ_1 = 1550.91	26.52	44.50	0.752842
λ_2 = 1551.51	0.608	41.97	0.229061
λ_3 = 1552.72	-5.4	42.55	0.0312259
λ_4 = 1553.12	-8.97	43.27	0.006905

To reduce the effect of FWM in the designed radio over fiber system, channel spacing method has been investigated. For simulation we have used four different channels spacing which are 25GHz, 50GHz, 75GHz and 100GHz at a bit rate of 5Gbps over the fiber length of 250 km. The obtained result of optical spectrum analyzer at the input and output of the fiber and the Eye diagram for these different channels spacing are shown in Fig. 5, Fig. 6, Fig. 7 and Fig. 8 respectively. From these results we can observed that an increase in the channel spacing lead to a wider eye opening which therefore produce higher quality factor and less error in the data transmission.



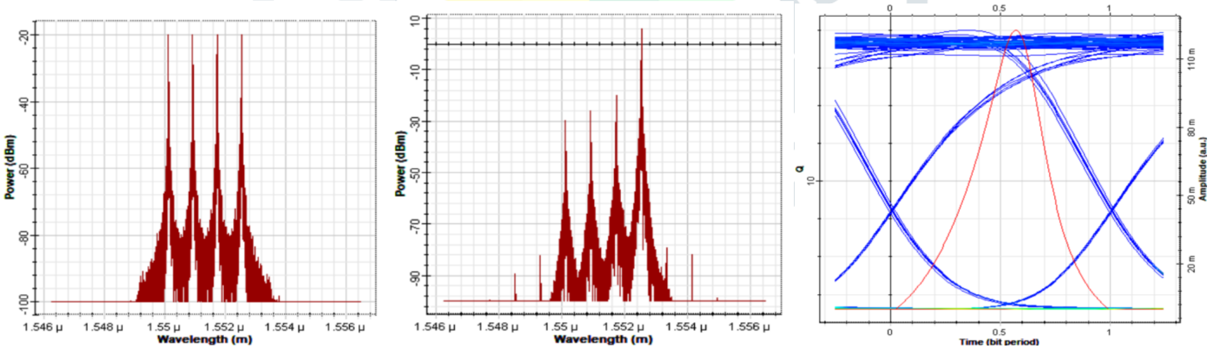
(a) (b) (c)

Fig. 5: Optical Spectrum at the (a) Input of SMF, (b) Output of Filter (c) Eye Diagram at 25GHz Channel Spacing.



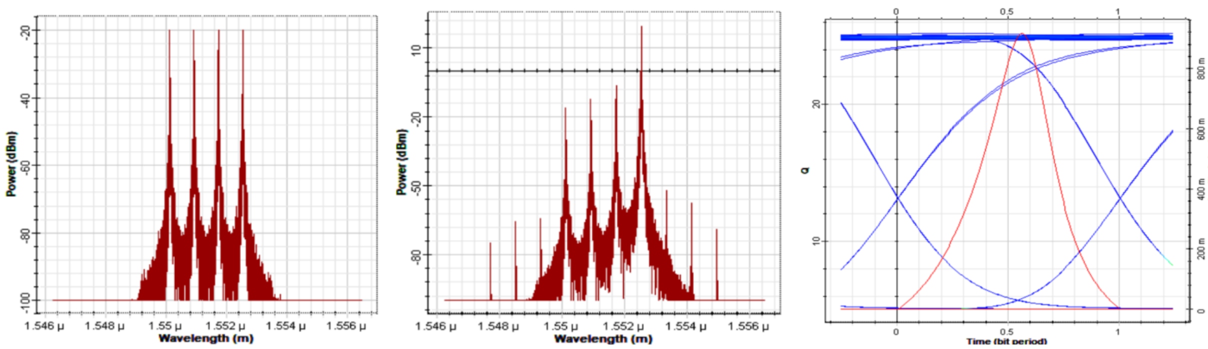
(a) (b) (c)

Fig. 6: Optical Spectrum at the (a) Input of SMF, (b) Output of Filter (c) Eye Diagram at 50GHz Channel Spacing.



(a) (b) (c)

Fig. 7: Optical Spectrum at the (a) Input of SMF, (b) Output of Filter (c) Eye Diagram at 75GHz Channel Spacing.



(a) (b) (c)

Fig. 8: Optical Spectrum at the (a) Input of SMF, (b) Output of Filter (c) Eye Diagram at 100GHz Channel Spacing.

IV. CONCLUSION

In this paper, long haul optical fiber communication system has been investigated for its use in Radio of Fiber (RoF) technology. Higher value of Q-factor of around 20 has been obtained at a bit rate of 1Gbps over 250km of link length. OSNR value for the four different wavelength is greater than 40dB therefore the Inter Symbol Interference (ISI) in the design system is very low. Also, channel spacing of 100GHz have reported much wider eye opening as compared to the other channel spacing. Hence it can reduce the Four Wave Mixing (FWM) in the investigated WDM system of different channel.

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