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Performance Investigation of CO-OFDM WDM-RoF Network with different Modulation Techniques and Dispersion Compensation using FBG

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ABSTRACT: The innovation of novel schemes of optical amplification, modulation format, or fiber design are required for fiber capacity of Tb/s poses new challenges. The convergence system of Coherent detection-OFDM WDM-RoF network which can improves the spectral efficiency of the wireless access system and also support the seamless integration between air and optical transmission is to be proposed. The performance of the system in terms of BER, Q-factor, OSNR, fiber length, and receiving constellation is evaluated. Dispersion management and modulation formats have been studied for 8 Channel-WDM optical communication system with per channel bit rate of 1Tbit/s. Q-factor for 4-QAM = 81 is 3 times greater than DPSK and 2 times greater than 8-QAM using FBG. By comparing results of 4-QAM, 8-QAM and DPSK, it is found that 4-QAM performs better in terms of fiber length, OSNR, Q-factor and BER.

KEYWORDS: Coherent detectionOrthogonal frequency division multiplexing; Wavelength Division Multiplexing; Radio over fiber; Modulation Techniques; Fiber Bragg Grating; Coherent receiving

I. INTRODUCTION

OFDM is a method of encoding digital data transmission on various carrier frequencies. For instance, OFDM technique works on splitting a radio spectrum into several sub-channels at the base station in the mobile communication systems.RoF refers to a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access. Although radio transmission over fiber serves as multiple purposes in CATV networks and satellite base stations, the term RoF is usually applied where there is wireless access.In addition, the WDM is a multiplexing technique for fiberoptic system to multiplex a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e. colours) of laser light to carry different signals.

In relation to OFDM, WDM and RoF network many studies had been conducted to transform something that can improves the efficiency on high speed and low cost networks[1] [2]. In terms of efficiency and speed of data transmission all the researchers need to face great challenges on designing a network that can meet the above criteria for the needs of consumers. Therefore, the understanding of each component in the network is in urgent great demand such as OFDM, WDM and RoF.Many researches and works were done in the field of using multicarrier transmission technique especially OFDM for transmitting and receiving data through optical link in RoF network [3]. Meanwhile, this work is based on modeling and analyzing the performance of the CO-OFDM for WDM-RoF system to utilized applications based on WLAN IEEE 802.11 b/g standard (2.4 GHz) and is simulated using commercial software, Optisystem 10.0 [4].

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II. RELATED WORK

In [5] the authors studied the system for quality factor (Q-factor) of thereceived data versus the optical launch power forthe both schemes after 320km transmission, withOSNR 23dB. It can be seen that the P-OSSBscheme has higher nonlinearity tolerance probablydue to the larger subcarriers spacing which couldsuppress the nonlinear effects like FWM and XPM etc. Simulationsin 320km SMF link show that P-OSSB OFDM has4.5 dB OSNR benefits comparing with Conventional-OSSB (C-OSSB) OFDM system in linear case, and strongercapability of combating the nonlinearity than C-OSSBOFDM system. In [6]authors proposed and experimentally demonstrated a novel OFDM modulated WDM-ROFsystem by employing a single SC multi-wavelength lightwave source based on photonic crystal fiber (PCF). Thisscheme also employs wavelength reuse scheme for power consumption. The wired andwireless applications for the downstream signal with four 40 GHz RoF channels by properly designed FBG are implemented. Both the 1Gb/s 16QAM-OFDM downstream signal and 1 Gb/s OOK upstream signal present goodperformance. The results show that the power penalty of the downstream wireless and wiredsignal at BER of 10^{-4} are 0.35 and 0.2 dB, respectively. The upstream signal at BER of 10^{-9} is less than 0.4dB after 20km SMF transmission. In [7]authors shown that the recent advances in FBG technology and Optical phase conjugator (OPC) now allow the realization of a high performance, high speed optical fibers with good in line dispersion compensation. The system performance is evaluated for a 10 Gb/s system using FBG and OPC for the in line dispersion compensation. The results demonstrate that the Q-factor increases by near about three times in FBG than in OPC by 18Db. Hence after dispersion compensation using FBG, the BER is 1×10^{-40}. In [8] authors demonstrated a schematicfor 10 Gb/s coherent 512-subcarrier 16-QAM OFDM system; however the input data for the OFDM modulator can have different modulation formats such as BPSK, QPSK, QAM, etc. Fiber dispersion is fully compensated by the DCF in each span. In [9] authors presented a novel cost-efficient architecture based on a hybrid mode locked laser capable to simultaneously generate WDMPON and RoF signals for 60 GHz applications and it does not require high bandwidth MZM. Simulation results reveal the potentiality of this architecture for 10 Gb/s PON signals and 5 Gb/s RoF signals up to 30 km employing OFDM modulation format with a BER below 10^{-3}. In [10]authors proposed a WDM-RoF-PON based on the improved OFDM format and optical coherent technology. With OFDM and coherent receiving technology, the access network achieves high bandwidth utility efficiency and excellent transporting properties. Using optical heterodyne, the network implements 60 GHz wireless access without adding a radio source. The performance of the system in terms of BER, coverage area, and receiving constellation is studied and a network with an excellent access property is to be obtained. The improvedRZ-OFDM, which has half the bandwidth of the RZ-OFDMsignal, has a maximum reach of 80 km defined by the assumed7% hard decision forward error correction (FEC)threshold, which is Q=8.5 dB, corresponding to BER=3.8×10^{-3}. In [11] authors gave an account of a WDM-OFDM-PON, using atunable mode bolted brush source for downstreamtransmission. The 10 brush tones are separated by 10GHz andmodulated by 12.75 Gb/s compatible SSB OFDM signal. Transmission over 50 km and 87 km of SSMF was successfully demonstrated.The average spectral efficiency of 1.12 and 1 bit/s/Hz wereobtained in conjunction with the use of low complexityelectronics. Relative to the back-to-back case the penaltiesafter transmission over 50km were 1dB at a BER of 3×10^{-3} this indicates improved efficiency intransmission. All channels after 87km transmission achievedperformance below the 20% FEC limit.

III. PROPOSED SYSTEM

A. *Design Considerations:*

- OFDM is a multicarrier transmission technique where a data stream is carried with many lower-rate subcarrier tones.
- The signal at all the eight channels is transmitted using single mode fiber after multiplexing to the CBS.
- At CBS each base signal is de-multiplexed using WDM de-multiplexer then the respective base station detects the signal using RoF receiver.
- The system has been modulated and simulated for different powers, bit rates and fiber lengths.
- CO-OFDM combines the advantages of ‘coherent detection’ and ‘OFDM modulation’ and possesses many merits that are critical for future high-speed fiber transmission systems.

B. *Description of the Proposed Network:*

(i) Basic model

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The optical device using FBG features high resilience to Chromatic Dispersion. The chromatic dispersion degrades the system BER and hence reduces the transmission distance. Therefore distance tests are performed to evaluate and compare the dispersion tolerance for the OFDM in WDM-RoF networks with and without using FBG.

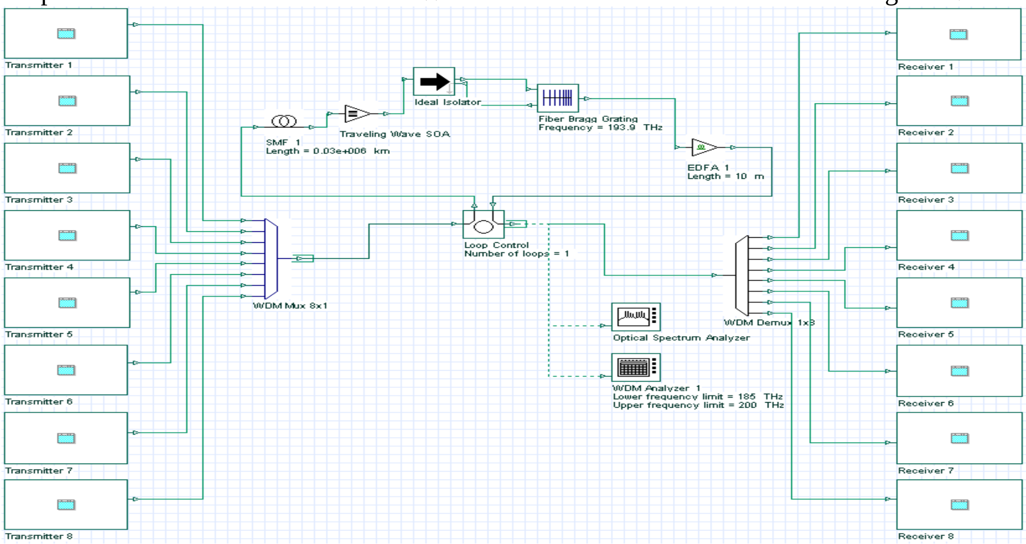

Fig. 1.Simulation setupof CO-OFDM WDM-RoF Network.

Besides eliminating complex and inefficient conversion and electronic amplification stages, the EDFA allows the transmission of signals that employ WDM. This increases the realizable bandwidth relative to conventional repeaters still further. Additionally, EDFA offers a number of advantages such as high gain, low noise figure, negligible coupling loss, high stability and compact size. In WDM-RoF system the transmission takes place between Remote Antenna Unit (RAUs) to the central base station (CBS). In this thesis work eight channels are multiplexed to form the WDM-RoF system. It means for the RoF transmitter each RAU can work at a single wavelength. All the eight channels are transmitted using single mode fiber after multiplexing to the CBS. At CBS each base signal is de-multiplexed using WDM de-multiplexer. Then the respective base station detects the signal using RoF receiver. The system has been modulated and simulated for different powers, bit rates and fiber lengths. The various subsystems for transmitter and receiver modules are also discussed.

(ii) Transmitter

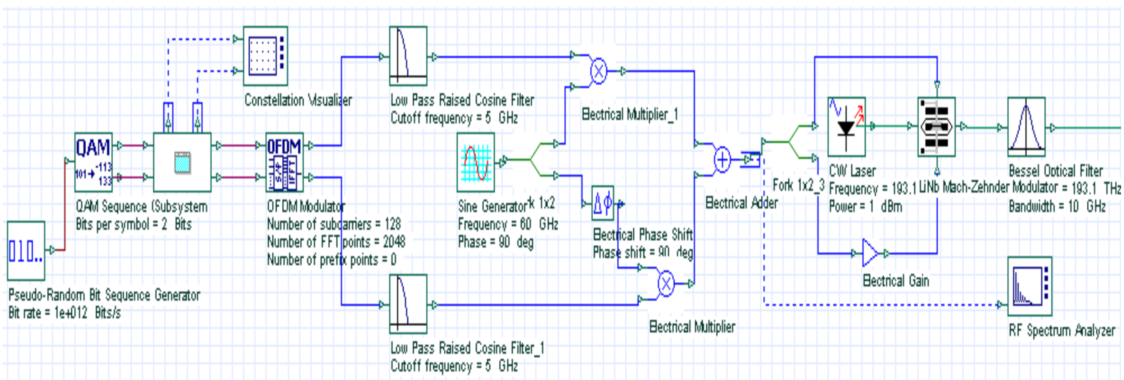

Fig. 2.Structure of CO-OFDM WDM-RoF network for Transmitter and RTO up-conversion.

From RoF point of view, the data signals at RAU are RF signals. Therefore, base station can be modeled as a source of information in the form of zeros and ones which are modulated using Radio Frequency carrier signal. To increase the spectral efficiency of the system OFDM modulation technique is used. The signal is modulated using 60 GHz RF

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carrier. The eight CW Laser diodes used have an operating frequency of 193.1THz, 193.2 THz, 193.3 THz, 193.4 THz, 193.5 THz, 193.6 THz, 193.7 THz and 193.8 THz respectively.The CW laser diode has output power is zero. The output of CW laser diode is modulated using MZM which is driven by electrical signal generator (OFDM Modulator) having a fixed frequency of 60 GHz. The extinction ratio of the input is always 1 dB for all the data rates. Fig 2 shows the transmitter used for system**.**

(iii) Receiver

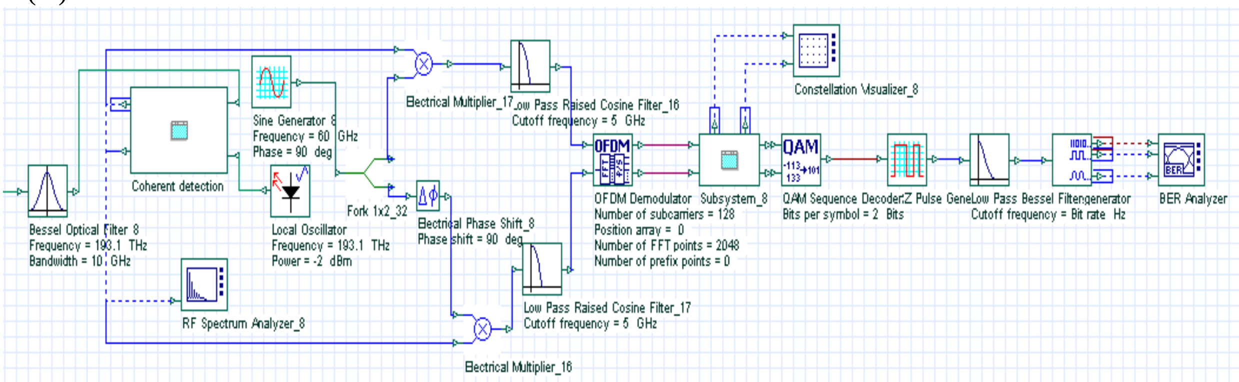

Fig. 3.Simulation setup for OTR down-converter and OFDM receiver.

Every reflected channel in these subsystems is connected to a Bessel Optical filter. For CO-OFDM WDM-RoF network, each base station detects signal using a RoF receiver. After passing through Bessel Optical filter, it is connected to the PIN Photo Detector, in order to convert the optical signals back into electrical pulses form. The detected electrical output is passed through a Low Pass Raised Cosine filter having a cut off frequency of 5 GHz. This signal is then demodulated using an OFDM demodulator circuit. Because of the analog nature of transmission, even for digital data, optical signals undergo degradation as they travel through optical fiber due to dispersion, loss, crosstalk, and nonlinearities associated with fiber and optical components. These signals require regeneration periodically. There are 1R Regeneration, 2R Regeneration and 3R Regeneration. Using 3R Regeneration in this design will assure Amplification, Reshaping and Re-timing (signal size increases, limited to give distinct "0" and "1" levels, and the signal's timing information is restored). The simulation setup of CO-OFDM WDM-RoF receiver is shown in Fig 3.The simulation setup demonstrates a 1 Tb/s coherent 4-QAM OFDM system; however the input data for the OFDM modulator can have different modulation formats such as 4-QAM, 8-QAM, DPSK, etc. In this paper, eight channels are multiplexed to form the WDM- RoF system.

(iv) Coherent Detection

Coherent optical OFDM (CO-OFDM) uses D/A at the transmitter and also unique pilot subcarrier based channel and phase estimation, and extremely convenient way is offered by it to achieve high spectral efficiency transmission through higher order modulation.The use of coherent detection over the un-coded direct detection counterpart can offer the potential of up to 24 dB improvement.

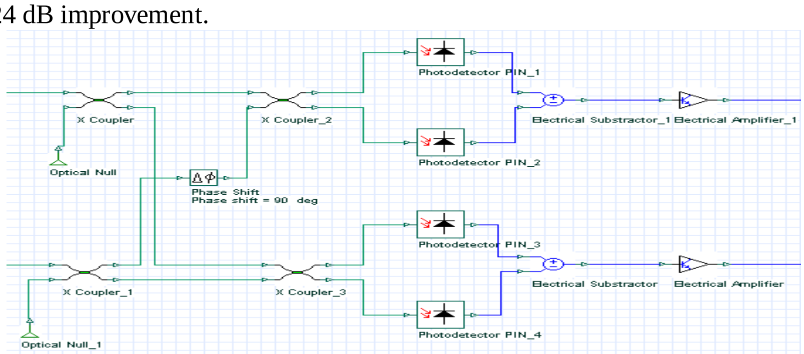

Fig. 4.Simulation setup for coherent detection.

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IV. Simulation Results

(a) 4-QAM (b) 8-QAM (c) DPSK

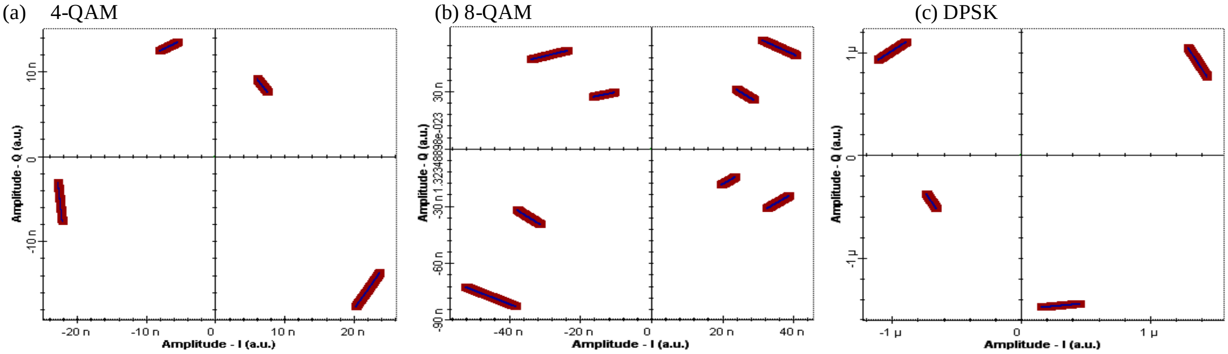

Fig. 5. Constellation diagrams of (a) 4-QAM, (b) 8-QAM and (c) DPSK using FBG.

From simulation results, the constrained and uniform distribution of the signal elements in constellation diagram shows the good reception at the receiver as shown in Fig. 5. The optical filter also depresses the noise of the fiber: dispersion and nonlinear interference. There is an amplified and modulated signal is received at the receiver side.

(a) 4-QAM (b) 8-QAM (c) DPSK

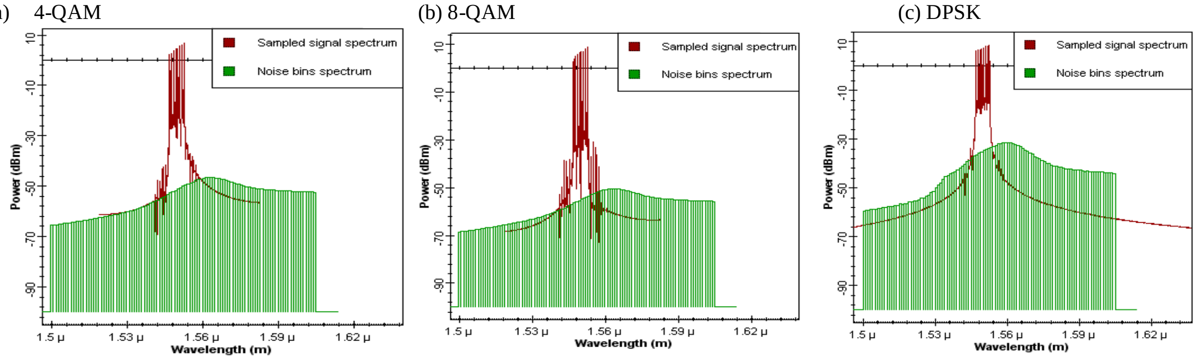

Fig. 6. Optical Analyzer outputof (a) 4-QAM, (b) 8-QAM and (c) DPSK using FBG.

The received output at the Optical Analyzers shows the comparison between Dispersion Compensated system and without Dispersion Compensated system for channel distortions. In case of Dispersion Compensated system using FBG, the effect of noise (which is shown by green colour) is less as compare to without Dispersion Compensated system. Also 4-QAM performs better at fiber distance 220 km than 8-QAM and DPSK as shown in Fig. 6.

(a) 4-QAM (b) 8-QAM (c) DPSK

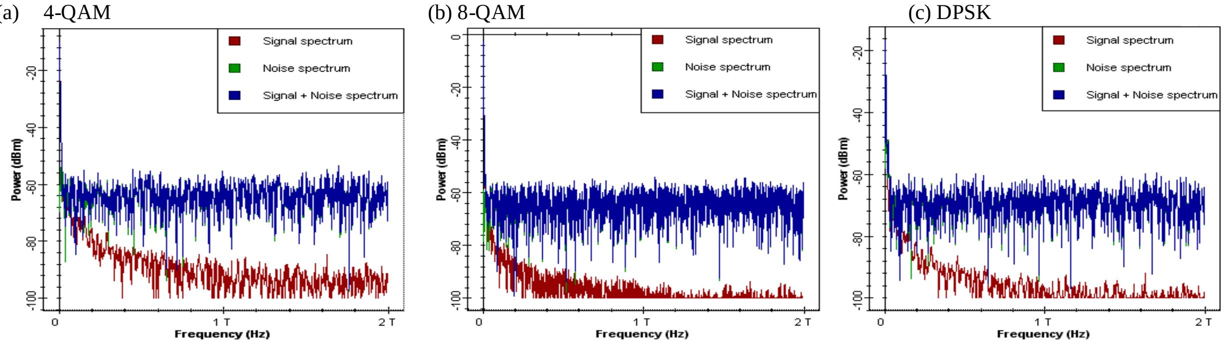

Fig. 7.RF Spectrum of (a) 4-QAM, (b) 8-QAM and (c) DPSK using FBG.

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The RF spectrum for the in phase component and the generated optical OFDM spectrum after I/Q modulation.It is clear from the spectrum shown in Fig. 7 that the signal power is reduced at the receiver side which in turn adds to the spectral efficiency of the system.

(a) 4-QAM (b) 8-QAM (c) DPSK

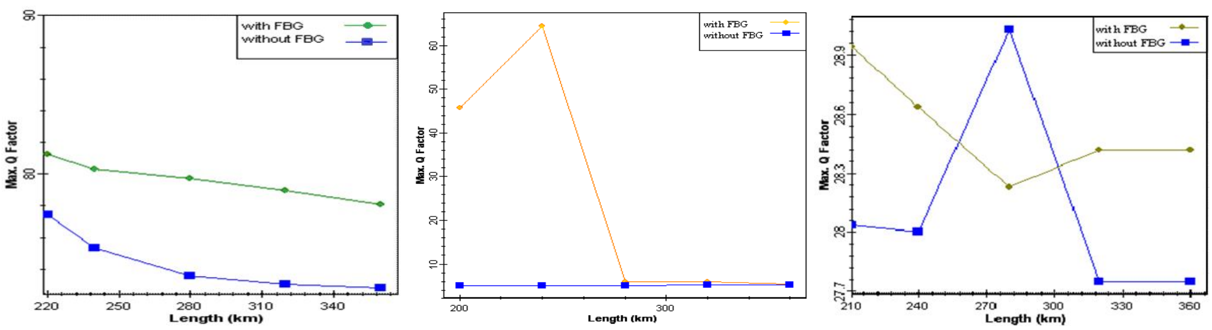

Fig. 8.Q-Factor graphs of (a) 4-QAM, (b) 8-QAM and (c) DPSK.

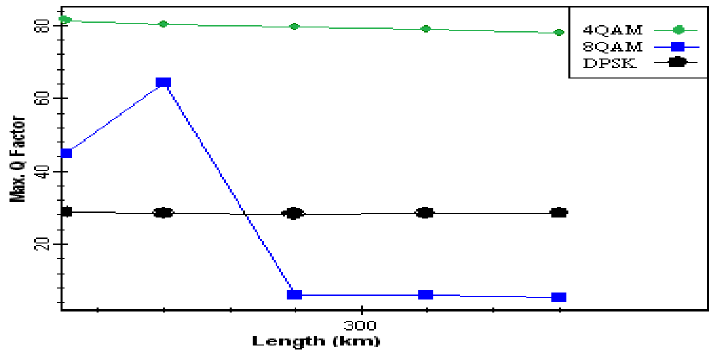

Fig.9.Comparison graph for Q-factor of 4-QAM, 8-QAM and DPSK using FBG.

This also implies that CO-OFDM with 4-QAM could enable much longer reach than 8-QAM and DPSK. CO-OFDM WDM-RoF network using 4-QAM has better performance at 220 km fiber length using FBG as shown in Fig. 8 and Fig. 9. Q-factor for 4-QAM is 3 times greater than DPSK and 2 times greater than 8-QAM using FBG. From the graphs it is also observed that the Q-factor for OFDM in WDM-RoF system with dispersion compensation using FBG falls below 6 for 8QAM near 360 km distance. This distance is approximately 2 times of reach of OFDM in WDM-RoF system not integrated with FBG. So, FBG provides enhanced transmission reach for network. This increase in transmission distance also interpreted that efficiency of the system is also improved which is major requirement of the present communication system. Table 1 shows the comparative simulation results of the system.

Table 1. Simulation results comparison for different modulation techniques.

Parameters	**4-QAM**	**8-QAM**	**DPSK**
Fiber length	220 km	200 km	210 km
OFDM Subcarriers	128	128	128
OFDM - FFT points	2048	2048	2048
Q Factor with FBG	81	41	28.94
Q Factor without FBG	78	5	28.03
BER with FBG	0	$1.016*10^{-87}$	$1.799*10^{-184}$
BER without FBG	0	$1.737*10^{-32}$	$1.016*10^{-173}$
OSNR with FBG	60 - 63 dB	52 - 55 dB	54 - 58 dB

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OSNR without FBG	17 - 18 dB	9 dB	17 - 18 dB
Signal Power with FBG	7 to 12 dBm	7 to 12 dBm	1 to 4 dBm
Signal Power without FBG	-5 to -7 dBm	-5 to -6 dBm	-5 to -7 dBm
Noise Power with FBG	-50 to -53 dBm	-43 to -45 dBm	-53 to -55 dBm
Noise Power without FBG	-23 to -24 dBm	-15 to -16 dBm	-23 to -24 dBm

V. CONCLUSION AND FUTURE WORK

The simulation results showed that for proposedhigh-speed circuit design of CO-OFDM transceiver, bandwidth requirement is greatly reduced, which is extremely attractive where electrical signal bandwidth dictates the cost. The work presented in this paper has shown that the problems of dispersion and BER are minimized by using FBG dispersion compensation technique. Hopefully, the benefits of the advanced modulation formats demonstrated in this work will be sufficient to overcome the drawbacks of extra transmitter and receiver complexity.Also to migrate from conventional 4-QAM to higher QAM only requires a software modification without any optical hardware change, provided that the DAC resolution is sufficient in CO-OFDM systems.As the channel rate approaches above 1 Tb/s, the achievable capacity per fiber may become abottleneck. How to overcome the bottleneck is expected to be an important andinteresting research topic.

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BIOGRAPHY

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