

## Radio over Fiber Performance Evaluation in Optical Communication System Utilizing FBG under Different DCF Schemes for DPSK Format

Hussein Ahmed Mahmood and Riyadh Khlf Ahmed  
Department of Communication Engineering, College of Engineering,  
University of Diyala, Baqubah, Iraq

**Abstract:** Radio over Fiber (RoF) is one of the efficient technology in modern communication system by combination the facilities of optical communication capacity and the mobility of wireless networks. ROF technique provides many advantages in addition to the conventional wireless communication system such as high signal quality, low cost and high reliability. In this research, radio over fiber transmission for 100 km-long optical fiber operated at 1 Gb/sec data rate and modulated under efficient DPSK modulation technique is employed. The performance of the transmission system is evaluated using OptiSystem Version-10 in terms of max. Q-factor, min. bit error rate, eye height, threshold and decision inst. The performance of the system is improved by utilizing fiber bragg grating under dispersion compensation fiber scheme. According to our results, the set up utilizing DCF with FBG scheme has the better performance as compared to other schemes where Q factor, BER, eye height, threshold and decision inst. are 23.5971,  $1.999 \times 10^{-123}$ ,  $1.986 \times 10^{-005}$ ,  $2.217 \times 10^{-005}$ , 0.446, respectively.

**Key words:** RoF, Q-factor, BER, fiber, DPSK modulation, schemes, grating

---

### INTRODUCTION

Recently, the increasing demand to send the large amount of information from the source to the destination over long haul optical communication with high bit rate, fast internet for multimedia applications and broad band wireless access has resulted to propose Radio over Fiber (RoF) technology (Charbonnier *et al.*, 2007). The idea of RoF can be introduced as analog modulation system. The modulation is achieved by modulating the intensity of the laser source with radio frequency. The integration of optical fiber and wireless networks is efficient solution for modern broad band telecommunication.

The fast growth of mobile communication systems is a consequence to ease of the installation as compared to the fixed communication systems (Pena-Lopez, 2002). The use of RoF technology according to the concept of central/control station is to minimize the required base band and signal processing in both base station and remote antenna units. Basically, the RoF centralizes the RF signal processing (modulation, frequency up-conversion and multiplexing) functions in unique shared position and then to use the

optical fiber facilities which provides low sign allors about 0.2 dB/kmin C band (1550 nm) wavelength to split the RF signals to here mote antenna units.

RoF is analogue modulation, so, the system will be suffered from many limitations such as noise, distortion and dispersion in both transmitter side and detection of light in receiver side. The two limitations noise and distortion play the keys to limit noise figure and dynamic range in ROF technology (Al-Raweshidy, 2002). RoF technology was proposed and implemented using Intensity Modulation with Direct Detection (IM-DD) transmission system (Zibar *et al.*, 2010; Sambaraju *et al.*, 2010). Wave division multiplexing is technique used to multiplex many optical signals with different wavelengths of the laser source over single optical fiber (Pham *et al.*, 2008). Dispersion is the most restriction factor in optical link, so, the cancellation is achieved using dispersion compensation fiber (Ahmed, 2017).

Since, the differential phase shift keying is a special form of phase modulation and does not need reference oscillator, the phase of the modulated signal is shifted according to the previous signal element. Wave in range of THz frequency provides some features according to the

broadband width available (Pleros *et al.*, 2009). Different modulation formats have been designed and simulated for different wide band multimedia applications (Kathpal and Garg, 2016). The combination technology of microwave and optical links are employed and have enhanced the performance evaluation of the overall communication system (Vyas and Agrawal, 2012). The presentation of employing different energy of a heterogeneous network to provide the access of broadband communication system (Yadav and Jaiswal, 2014). The brief introduction, applications, some technologies and limitation of the RoF technology was discussed by Pooja *et al.* (2015).

## MATERIALS AND METHODS

**Differential Phase Shift Keying (DPSK):** DPSK has many advantages over conventional On-Off-Keying (OOK) modulation format. DPSK is less effect to dispersion and nonlinear effects. In addition, the essential advantage of this version of digital modulation that it is can be detected at a balanced receiver which gains OSNR sensitivity improvements of up to 3 dB (Gnauck and Winzer, 2005).

Differential Phase Shift Keying (DPSK) is the non-coherent type of BPSK which using two symbols 1 and 0 with single carrier signal. The main property of DPSK that synchronization between the receiver and the transmitter is eliminated by combining the two parts of transmitter operation:

- Differential encoding of the input data
- Phase shift keying of the sequential stream of data

The first bit of differential encoding is arbitrary bit which is regarded as reference bit. Hence, the arbitrary bit has symbol 1. The generation of DPSK is done according to the two rules. Firstly, the sending of symbol 1 leads to the phase of the DPSK will be unchanged. Secondly, the sending of the symbol 0 leads to the phase of the DPSK will be shifted by 180° (Haykin, 2013).

**Dispersion Compensation Fiber (DCF):** In spite of a set of optical fiber problems that limit the performance of the transmission system, the chromatic dispersion is most of restriction in the link. Dispersion is problem stills collection after stages of repeaters as a consequence electronic amplifiers failure to recover the original signal. Chromatic dispersion is compensated in the both domains

optical and electrical. Dispersion compensation fibers are the module to compensate the dispersion optically and the electrical dispersion compensation is achieved by employing signal processing. Equation 1 explain the relationship between the chromatic dispersion and the length of optical fiber.

$$D_1 L_{f_1} + D_2 L_{f_2} = 0 \quad (1)$$

Where:

$D_1$  and  $L_{f_1}$  = The positive group velocity dispersion and the length of Single Mode Fiber (SMF)

$D_2$  and  $L_{f_2}$  = The negative group velocity dispersion and the length of Dispersion Compensation Fiber (DCF)

**Fiber bragg grating:** Fiber bragg grating is a periodical perturbation of refractive index along the axis of the fiber. It is usually fabricated by phase mask method that is achieved by exposing the single mode fiber to intense optical interference pattern made with an ultraviolet 244 nm argon ion laser. A certain narrow band of the incident light is reflected by successive, coherent scattering on refractive index perturbations. Through strong interaction happens at incident light, the maximum reflected wavelength equal to wavelength ( $\lambda_{i_B}$ ) is determined by phase matching condition as shown in Eq. 2:

$$\lambda_{i_B} = 2n_{eff} \Lambda_i \quad (2)$$

Where:

$n_{eff}$  = Refractive index that has the effect of the guided mode in the fiber core

$\Lambda_i$  = The grating pitch

**Simulated details:** The system is simulated and evaluated using OptiSystem Version-10. The simulation setup consists of three parts the transmitter, transmission medium (SMF) and the receiver. The details of the proposed system are depicted in Fig. 1-4 and 8. The input data is represented as PRBS generator at bit rate of 1 GB/sec in the transmitter side. Then, the output signals of the two generators are connected to the two DPSK modulators. In the modulator, the electrical carrier frequencies are different one is 250 GHz and the other is 255 GHz. Each of the two output signal are connected to the Bessel filter. The cut off frequency of the BPBF is 10 GHz. Mach-Zender optical modulator is used for optical modulation. The CW laser of wavelength of

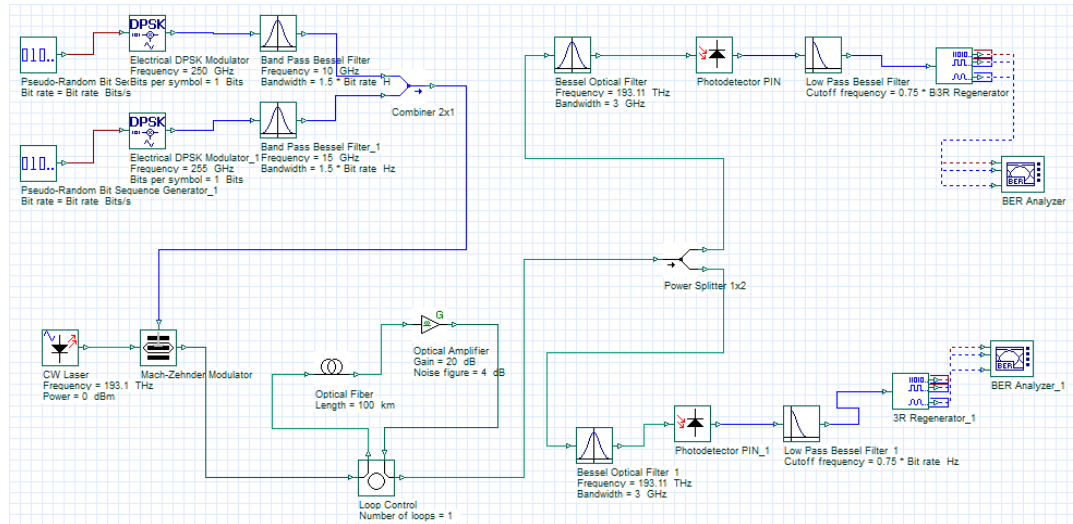


Fig. 1: The setup of 100 km radio over fiber under DPSK modulation format

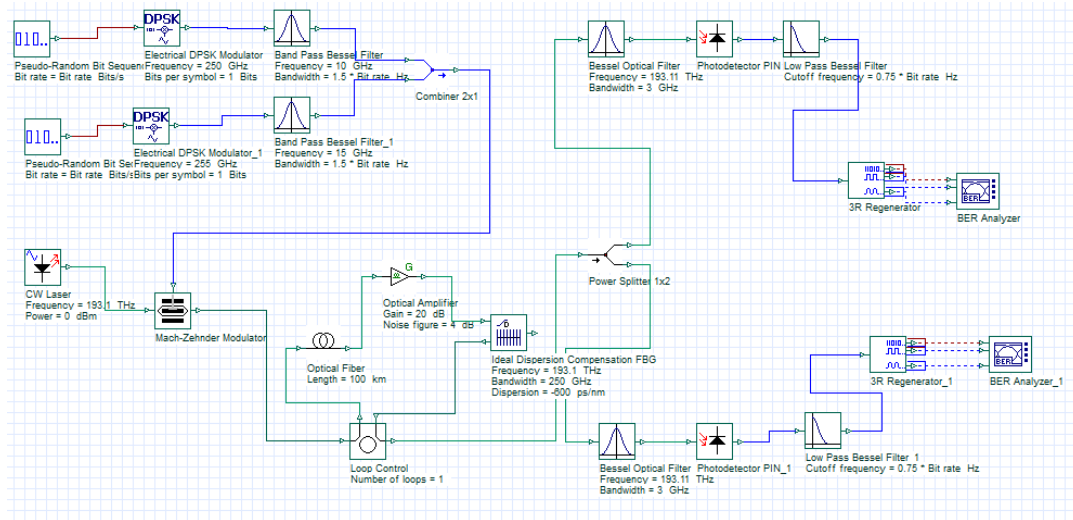


Fig. 2: The setup of 100 km radio over fiber under DPSK modulation format with FBG

1550 nm has power of 0 dbm is modulated with the posted signal of the two combined filtered signal. The feature of the MZ-modulator is high bit rate operation which is compatible with our application. At 100 km SMF, the modulated signal is amplified using erbium doped amplifier and dispersion compensated using DCF with cascade to FBG.

At the receiver, the amplified dispersion compensated signal is connected to the splitter (1\*2). The two signals are fed two OBPFs. The functions of the Fig. 2 filters are filtering the upper sideband signal. Each of the filtered signals are posted signal is fed to the Optical Band Pass Filter (OBPF) to filter

the upper side band of optical signal which is then applied to PIN photo-detector. The functions of the detectors are converting the optical signal to electrical signal. LPF is used to attenuate the high frequency harmonics. The cut off frequency of the filter is calculated by multiplying 0.75 by symbol rate. BER analyzer and eye diagram are used to monitor the performance evaluation of the proposed system. In this system, the laser regards the carrier and the radio Fig. 3 frequency regards as subcarrier. Table 1-3 show the simulation parameters, fiber parameters and ideal FBG parameter, respectively.

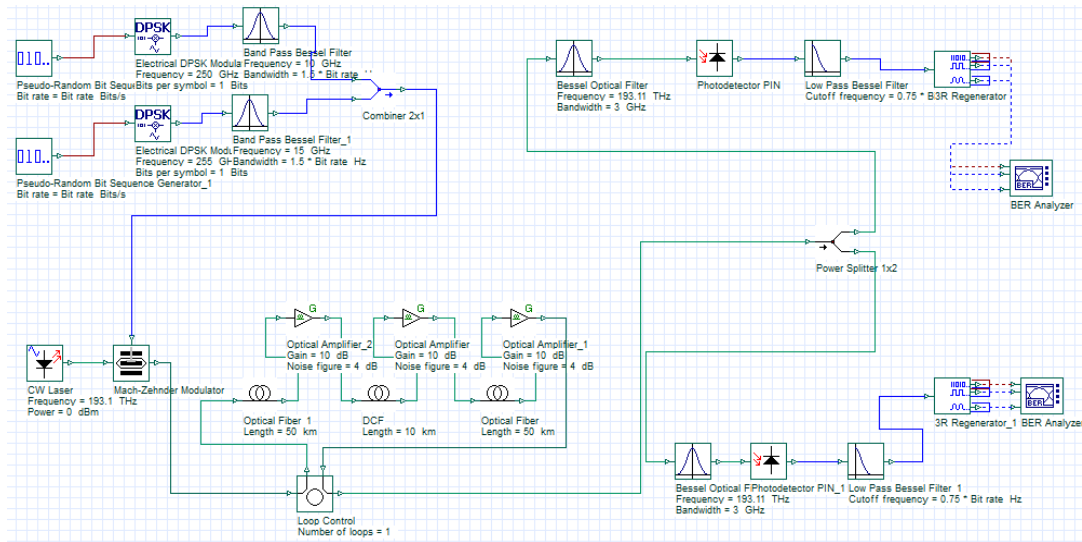


Fig. 3: The setup of 100 km radio over fiber under DPSK modulation format with DCF

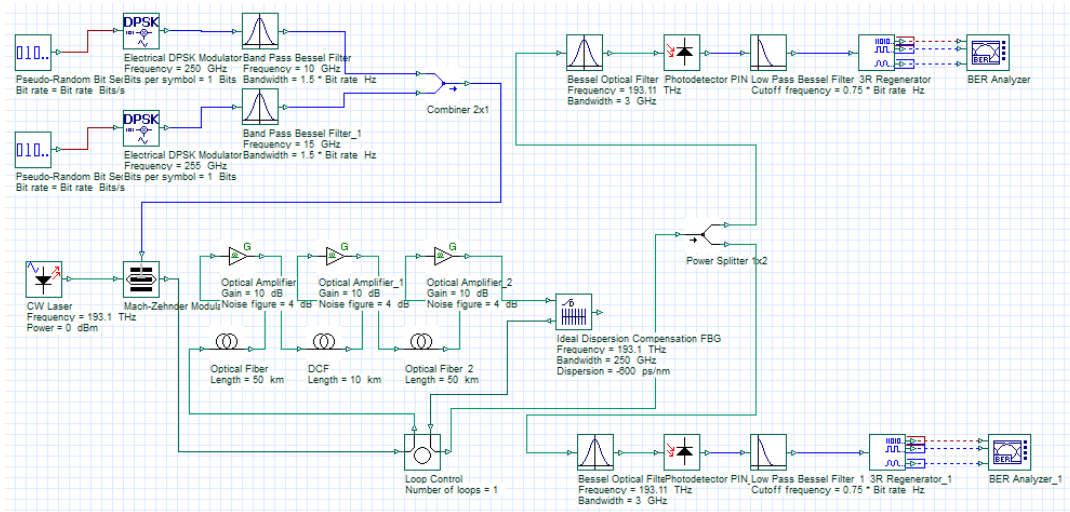


Fig. 4: The setup of 100 km radio over fiber under DPSK modulation format with combination of DCF and FBG

Table 1: Simulation parameters

Parameters	Values
Bit rate	1 Gbps
Sequence length	64
Samples/bit	256
Central frequency	193.1 THz

Table 2: Fiber parameters

Parameters	Single Mode Fiber (SMF)	Dispersion
Length ( km)	100	10
Dispersion (ps/nm/km)	17	-170
Dispersion slope (ps/nm <sup>2</sup> /km)	0.075	-0.3
Attenuation	0.2	0.6
First order dispersion coefficient (ps <sup>2</sup> /km)	-20	-20

Table 3: Ideal dispersion compensation FBG parameters

Parameters	Values
Frequency (THz)	193.1
Bandwidth	250
Dispersion	-600

## RESULTS AND DISCUSSION

Figure 1 shows the proposed setup of 100 km-long, 1 GB/sec bit rate, radio over fiber under DPSK format. Figure 2 shows the proposed system involving FBG scheme. Figure 3 shows the proposed system involving DCF. Figure 4 shows the proposed setup involving DCF in cascade with FBG.

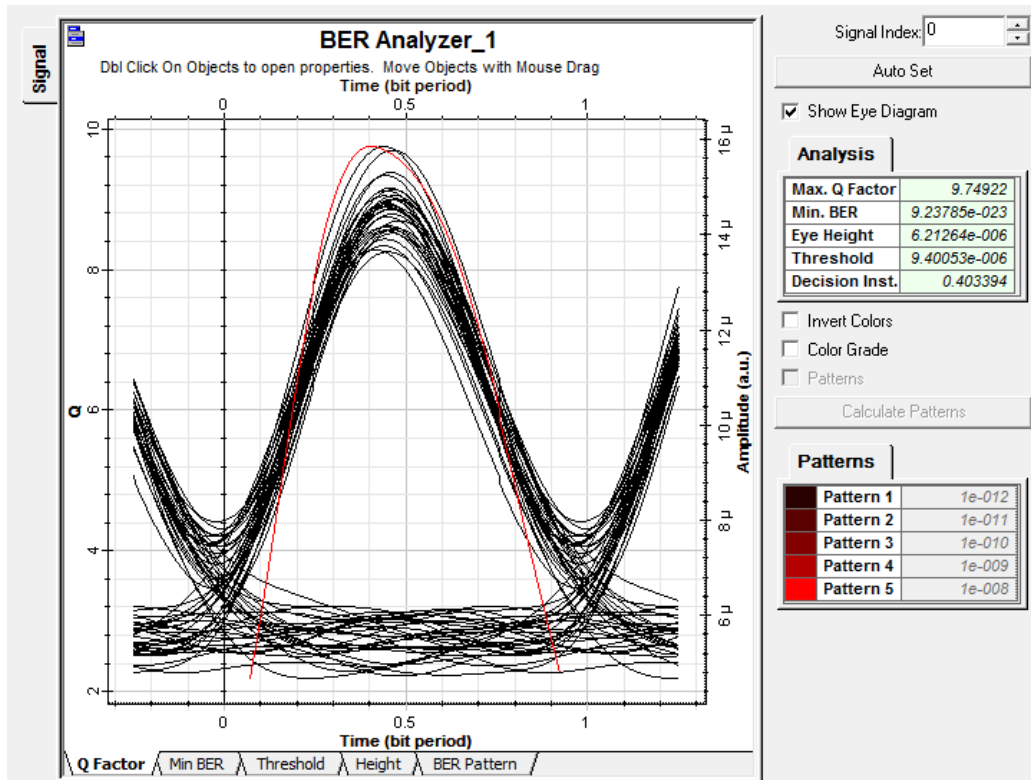


Fig. 5: The performance of 100 km radio over fiber under DPSK modulation format

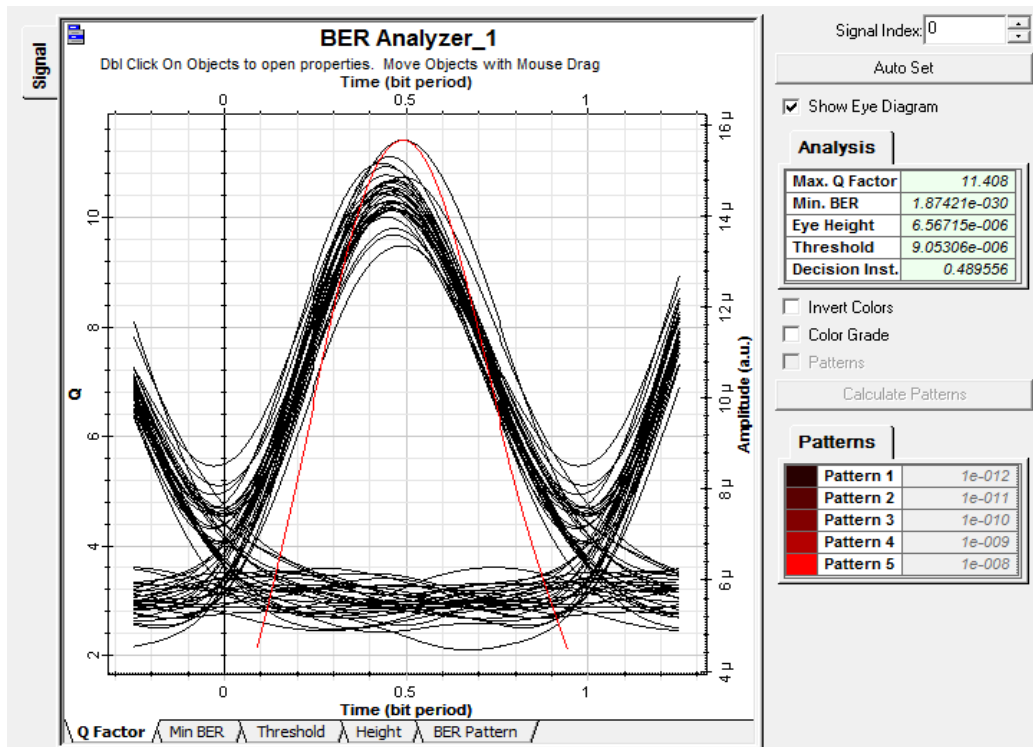


Fig. 6: The performance of 100 km radio over fiber under DPSK modulation format with FBG

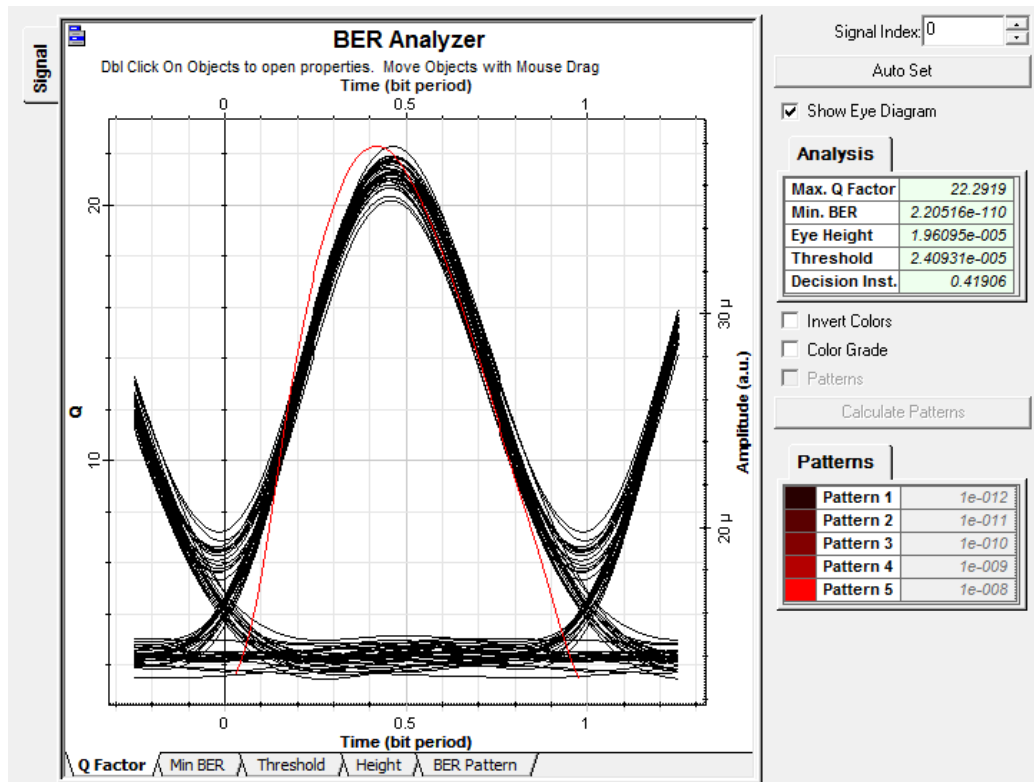


Fig. 7: The performance of 100 km radio over fiber under DPSK modulation format with DCF

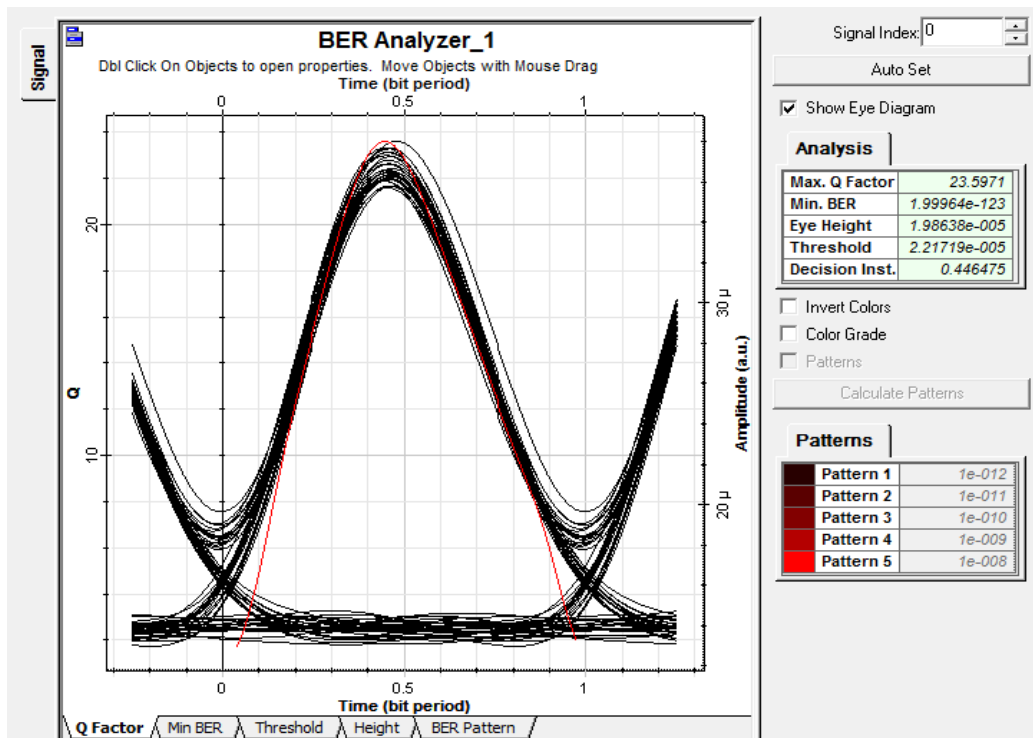


Fig. 8: The performance of 100 km radio over fiber under DPSK modulation format with combination of DCF and FBG

Table 4: Performance analysis for 100 km radio over fiber

100 km channel	Q factor	BER	Eye height	Threshold	Decision inst
DPSK	9.74922	$9.23785e^{-023}$	$6.21264e^{-006}$	$9.40053e^{-006}$	0.403394
DPSK with FBG	11.408	$1.87421e^{-030}$	$6.56715e^{-006}$	$9.05306e^{-006}$	0.489556
DPSK with DCF	22.2919	$2.20516e^{-110}$	$1.96095e^{-005}$	$2.40931e^{-005}$	0.41906
DPSK with combination FBG and DCF	23.5971	$1.99964e^{-123}$	$1.98638e^{-005}$	$2.21719e^{-005}$	0.446475

In addition to that, Fig. 5-8 indicate the max. Q-factor, min. BER, eye height, threshold and decision inst. analysis of the radio over fiber system using eye diagram under DPSK format for 100 km-long optical fiber for each system. In Table 4, the performance analysis of each system using eye-diagram is listed to show the better performance. The results report that the set up which contains the combination of DCF with FBG is the better performance as compared to other schemes where Q, BER, eye height, threshold and decision inst. are 23.5971,  $1.999 \times 10^{-123}$ ,  $1.986 \times 10^{-005}$ ,  $2.217 \times 10^{-005}$ , 0.446, respectively. From our results, it is clear that dispersion compensation fibers reduce the dispersion as much possible extend. Compensation of dispersion based on DCF with cascade FBG is helpful in reducing the dispersion and more efficient in increasing quality factor that comes from this technique of DPSK modulation for radio over fiber system.

### CONCLUSION

An efficient RoF system based on dispersion compensation fiber under DPSK modulation format is designed and simulated. The parameters max. Q-factor, min. BER, Eye height, threshold and decision inst. analysis are evaluated and compared for various dispersion compensation fiber techniques. OptiSystem Version-10 Software is used to evaluate the performance of RoF transmission link in terms of max. Q-factor, min. BER, eye height, threshold and decision inst. analysis. The results indicate that the proposed systems could operate better performance when the proposed system based on DPSK modulation scheme with combination of DCF and FBG. Since, it has higher Q factor and low BER. In addition, the results reveal that the systems have great potential in modern applications such as future wide band multimedia. We conclude that the proposed system is a flexible and low cost. However, our systems enable multiple functionalities which are required to help wireless access. Additionally, the system can be studied, analyzed and evaluated for various systems by changing the distance or the bit rate. Other efficient modulation for RoF system can be suggested for the future research.

### REFERENCES

- Al-Raweshidy, H., 2002. Radio Over Fibre Technology for the Next Generation. In: Radio over fiber technologies for Mobile Communications Networks, Al-Raweshidy, H. and S. Komaki, (Eds.). Artech House, Inc, Norwood, Massachusetts, USA., ISBN:1-58053-148-2, pp: 183-214.
- Charbonnier, B., H.L. Bras, P. Urvoas, Q.T. N'Guyen and M. Huchard *et al.*, 2007. Upcoming perspectives and future challenges for RoF. Proceedings of the IEEE International Conference on Microwave Photonics, October 3-5, 2007, IEEE, Victoria, British Columbia, Canada, ISBN:978-1-4244-1167-2, pp: 21-23.
- Gnauck, A.H. and P.J. Winzer, 2005. Optical phase-shift-keyed transmission. J. Lightwave Technol., 23: 115-130.
- Haykin, S., 2013. Digital Communication Systems. John Wiley and Sons, Hoboken, New Jersey, USA., ISBN:9780471647355, Pages: 800.
- Kathpal, N. and A.K. Garg, 2016. Performance analysis of RoF system employed efficient modulation techniques based on BER and Q-factor. Intl. J. Innov. Res. Comput. Commun. Eng., 4: 176-182.
- Mahmood, H.A., 2017. Performance evaluation of high data rate optical communication system utilizing FBG compensated dispersion schemes under different modulation techniques. Perform. Eval., 10: 94-106.
- Pena-Lopez, I., 2002. World telecommunication development report 2002: reinventing telecoms. Master Thesis, International Telecommunication Union, Geneva, Switzerland.
- Pham, T.T., H.S. Kim, Y.Y. Won and S.K. Han, 2008. Bidirectional 1.25-Gbps WDM-PON with broadcasting function using a fabry-perot laser diode and RSOA. J. Opt. Soc. Korea, 12: 359-363.
- Pleros, N., K. Vysokinos, K. Tsagkaris and N.D. Tselikas, 2009. A 60 GHz radio-over-fiber network architecture for seamless communication with high mobility. J. Lightw. Technol., 27: 1957-1967.
- Pooja, M., S. Saroj and B. Manisha, 2015. Advantages and limitations of radio over fiber system. Intl. J. Comput. Sci. Mob. Comput., 4: 506-511.

- Sambaraju, R., J. Herrera, J. Marti, U. Westergren and D. Zibar *et al.*, 2010. Up to 40 Gb/s wireless signal generation and demodulation in 75-110 GHz band using photonic techniques. Proceedings of the IEEE Conference on Microwave Photonics (MWP'10), October 5-9, 2010, IEEE, Montreal, Quebec, Canada, ISBN:978-1-4244-7824-8, pp: 1-4.
- Vyas, A.K. and N. Agrawal, 2012. Radio over fiber: Future technology of communication. Int. J. Emerg. Trends Technol. Comput. Sci., 1: 233-237.
- Yadav, V. and A.K. Jaiswal, 2014. Radio over fiber technology. IOSR. J. Electr. Commun. Eng., 9: 83-87.
- Zibar, D., R. Sambaraju, R. Alemany, A. Caballero and J. Herrera *et al.*, 2010. Radio-frequency transparent demodulation for broadband hybrid wireless-optical links. IEEE. Photonics Technol. Lett., 22: 784-786.