TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 19, No. 2, April 2021, pp. 380~389
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v19i2.16871

High speed modulated wavelength division optical fiber transmission systems performance signature

Aadel M. Alatwi[1], Ahmed Nabih Zaki Rashed[2], Ismail A. Abd El-Aziz[3]
[1]Faculty of Engineering, Tabuk University, Tabuk, Saudi Arabia
[2]Faculty of Electrical Engineering, Menoufia University, Egypt
[3]Benha Faculty of Engineering, Benha University, Egypt

Article Info

Article history:

Received Jun 3, 2020
Revised Oct 28, 2020
Accepted Nov 11, 2020

Keywords:

OQPSK
OQPSKPM
PM
WDM-RoF

ABSTRACT

This study presents modulated-wavelength division radio signals over fiber with mixed modulation techniques in the transmitter stage. Hybrid optical sources are used to achieve optimal performance and enhancement for an optical fiber communication network. The proposed modulation techniques work at a frequency of 250 GHz. Optical quadrature phase shift keying (OQPSK) and phase modulation (PM) techniques were merged to create OQPSKPM. This was in addition to the minimum shift keying (MSK) modulation scheme that was applied in the proposed model. The modulated wavelength division multiplexing design to four subscribers was examined with a single mode optical fiber at a 1550 nm wavelength. The proposed and previous simulation models were executed, investigated and measured on important operating parameter quantities that expressed the behavior of the optical fiber network in detail, like maximum quality factor, minimum bit error rate, and output power. The obtained simulation results demonstrated the priority of the proposed simulation model.

Corresponding Author:

Ahmed Nabih Zaki Rashed
Electronics and Electrical Communications Engineering Department
Faculty of Electronic Engineering, Menouf, Menoufia University
Gamal Abd El-Nasir, Qism Shebeen El-Kom, Shibin el Kom, Menofia Governorate, Egypt
Email : ahmed_733@yahoo.com

1. INTRODUCTION

Yunhao Z., *et al.* [1] have noted radio over fiber (RoF) systems that have deployed passive optical network architecture wavelength-division multiplexing (WDM) with self-interference cancellation, with the most importance results recognized at 240 Mbps with interference cancellation of 32 dB. In addition, it has applied both the orthogonal frequency division multiplexing (OFDM) modulation technique and 16-QAM (quadrature amplitude modulation) not only for an uplink at 390.63 Mbps but also for a downlink at 468.75 Mbps. However, Beilei Wu, *et al.* [2] have presented a RoF communication system concerned with transmitting a colorless upstream that depended on a modulation technique described correction of an orthogonal phase that can be recognized as a rotation of a polarization rotator plus a Mach-Zehnder modulator (MZM); it was used in a central office where it was applied at 800-Mbps (OFDM) downstream for a signal at 58 Gbps, and at 800 Mbps (OFDM) upstream for a signal at 1 Gbps. [3] presented a RoF communication system using different modulation techniques, such as QAM, differential phase-shift keying (DPSK), and phase-shift keying (PSK). For example, it performed modulation at 5.28 Gbps by using 16-QAM signals.

Nevertheless, the study [4, 5-9] presented a RoF communication system that was an experimental implementation that depended on division multiplexing for polarization to have the ability of increasing both efficiency and capacity. It used a mix of both OFDM and pulse-duration modulation (PDM). The system architecture was executed with both modulation techniques at 200 Mbps to realizing an aggregation bit rate of 1.2 Gbps. However, a RoF system at 75–110 GHz, depending on an external optical modulator (EOM), for realizing several Gbps bit rates has been introduced in [5, 10-18]. The aim of this study was not only to enhance the transmission behavior with using two modulation techniques, QAM and OFDM, at 40 Gbps but also to achieve a higher spectral efficiency. The important recognized results were achieved with a distance of transmission reaching 50 km and a bit error rate (BER) reduction of $3.8\text{x}10^{-3}$. Nevertheless, they have presented a RoF communication system at 35-GHz that depends on a colorless laser diode (CLD) with an orthogonal polarization pair wavelength. Hence, the CLD provided one of a pair of wavelength modes with orthogonal polarizations, and the QAM and OFDM modulation techniques were applied. The obtained results achieved a transmission distance of 25 km at 24 Gbps (using 64-QAM and OFDM) and a BER reduction of 3.7×10^{-3} [6, 19-27]. A bidirectional transmission and massive multi-input multi-output (MIMO) RoF communication system has also been investigated. The optical upstream was recognized from the central office to the remote antenna unit through a core (inner) for the coreless fulfillment. An advanced 2×2 MIMO-based OFDM/optical quadrature amplitude modulation (OQAM) channel estimation algorithm was optimally designed to equalize the hybrid optical and wireless MIMO channels. The study demonstrated the bidirectional transmission of 4.46 Gbps over 20 km by the 2×2 MIMO-OFDM/16-OQAM technique [7, 28-31]. J. Wang, et al., presented a digital mobile front haul (MFH) architecture with a sigma-delta (σ-ơ) pulse modulation technique interface instead of conventional common public radio interface [8]. However, 2-bit (σ) or 1-bit (ơ) technique modulations have been executed on signals then sent by 4-pulse amplitude modulation (PAM), and it realized a transmission distance of 25 km with 10 gigabaud. The most important results have been achieved in increasing capacity, a reduction of error vector magnitude (EVM) of less than 5%, and a BER reduction evaluated at 3×10^{-5}.

The current work clarifies various modulation techniques that are used to enhance high-modulated RoF communication systems. Hybrid optical sources were used to achieve optimal performance and enhancement for optical fiber communication networks. These modulation schemes were mixed in the aptly named optical quadrature phase-shift keying phase modulation (OQPSKPM). In addition, a minimum shift keying (MSK) modulation scheme was applied in the proposed model. The proposed and previous simulation models were executed, investigated, and measured on important operating parameter quantities that expressed the behavior of the optical fiber network in details like the maximum quality factor, the minimum bit error rate, and the received power levels.

2. RESEARCH METHOD

The configuration of a modulated WDM-RoF subsystem transmitter model simulation involves several elements is shown in Figure 1. First, a serial sequence sample has to generated. Then, it is electrically modulated by one of the novel mixing techniques. These modulation schemes are OQPSK, OQPSKPM, in addition to the MSK technique. The modulated signals are combined and filtered before the optical modulation process. Then, this is carried out by a hybrid of vertical-cavity surface-emitting (VCSEL) lasers and LiNb (lithium niobate) MZM. Then, the optical signals are propagated through single-mode optical fiber. However, these optical signals are wavelength multiplexed or combined by a wavelength-division multiplexer (digital switch) that has multiple inputs and a single output [6]. The channel bandwidth is 40 Gb/s, and the channel frequency spacing is 50 GHz in the proposed simulation. Figure 2 illustrates the transmitter construction of the proposed model of the WDM-RoF communication system.

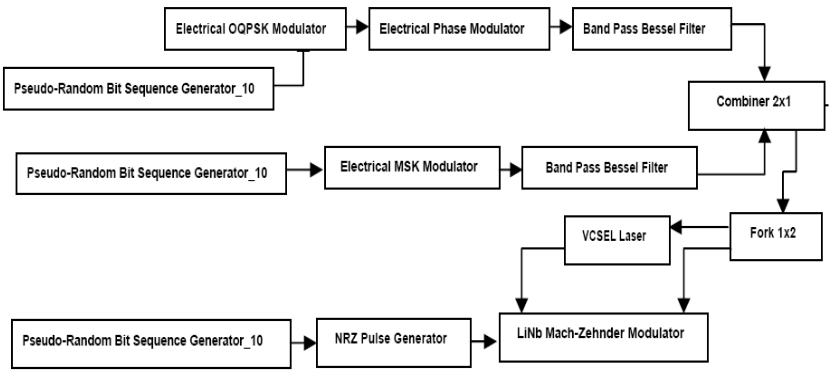

Figure 1. Modulated WDM transmitter subsystem unit

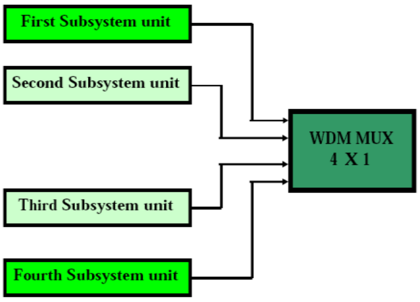

Figure 2. Proposed modulated WDM transmitter model

The single mode fiber cable losses have been compensated by using an erbium-doped fiber amplifier (EDFA), which has been widely applied [7]. After completion of the transition process of the optical signals through an optical fiber, it is fitted by a Bessel optical filter before the conversion process. Hence, the optical signals are converted into an electrical form at the receiver end, and this is carried out by an avalanche photodiode (APD). The construction of the proposed modulated WDM-RoF receiver system simulation has been demonstrated as shown in Figure 3, where the demultiplexer (DEMUX) is the component that selects one of several input optical signals and forwards the selected signal into a multiple-line [8-15]. The essential function of the demultiplexer is to separate the combined or multiplexed optical signals, however, both a multiplexer (MUX) and DEMUX are joined here in one component. They function synchronously to realize the proper information or data transmission [16-27].

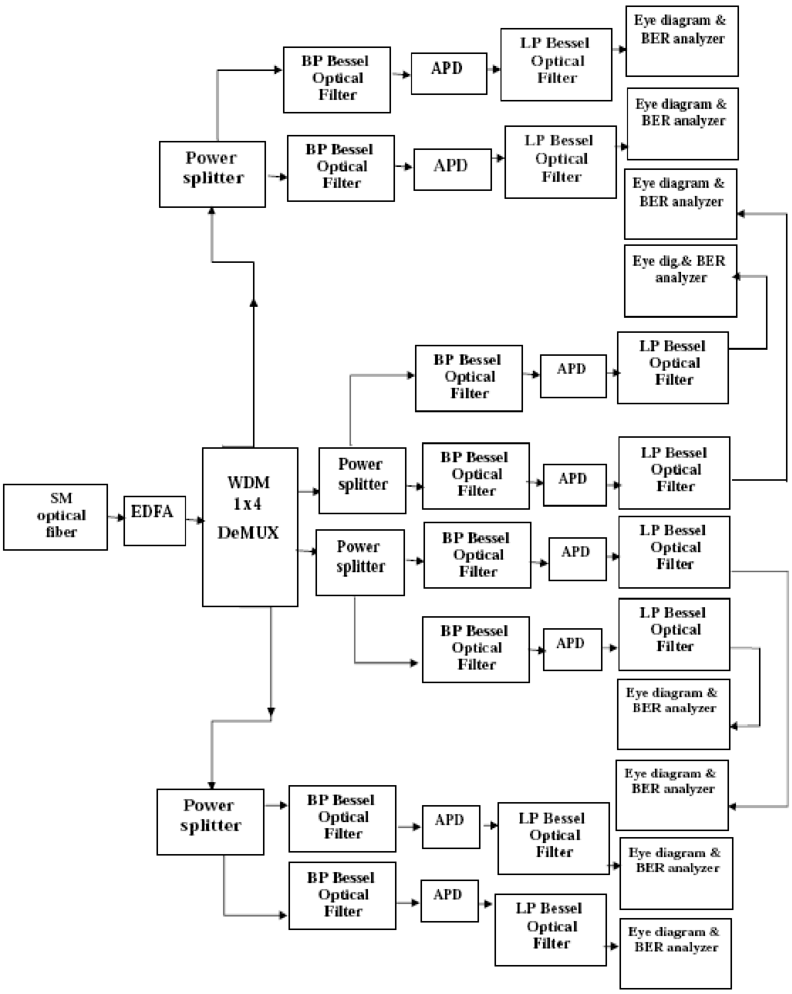

Figure 3. Modulated-wavelength division-multiplexing receiver of the proposed model WDM-rof simulation communication system

3. RESULTS AND ANALYSIS

The proposed simulation model was developed for a modulated wavelength division transmission system with an OQPSKPM technique at the transmitter end-stage. Performance was measured by a number of parameters. Most of the parameters express behavior that can be measured at the receiver end like the maximum quality factor. This parameter indicates the ability of the system to produce reasonable output and enhance the signal quality. In addition, the quality factor (QF) measures the quality of the transmitted signal, and the BER is the percentage of bits that have error related to the total number of received bits in a transmission. Moreover, comparisons were made between this model and the previous proposed simulation model approaches in terms of the maximum quality factor, minimum BER, and received power. These performance parameters were controlled and adapted by the performance behavior development of the WDM-RoF network, depending on the simulation parameters listed in Table 1.

Table 1. Simulation parameter list in proposed model

Parameter	Value	unit
Wavelength	1550	nm
Data rates	10-150	Gb/s
System Temperature	20	ºC
Propagation length	10 -130	km

Figure 4 illustrates the variations of the maximum QF regarding the extension length of the single mode (SM) cable. As the fiber length is extended, the maximum QF is reduced. The proposed model is based on OQPSKPM with MSK modulation techniques introduced at higher values of the maximum QF parameter compared to the previous model. The variation of minimum BER regarding data rates is clear from Figure 5. When the data rate increases, the minimum BER increases. However, the BER has minimal increasing values in the proposed OQPSKPM technique when compared to the previous model.

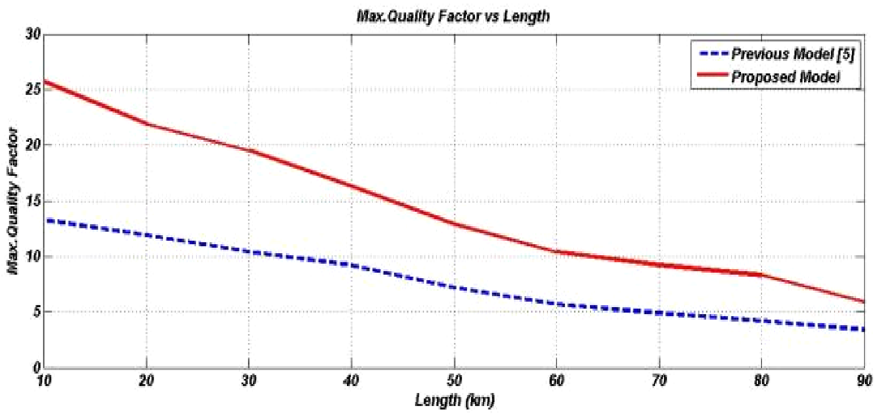

Figure 4. Max. QF versus length for the proposed and previous models of the WDM-RoF system at 10 Gb/s

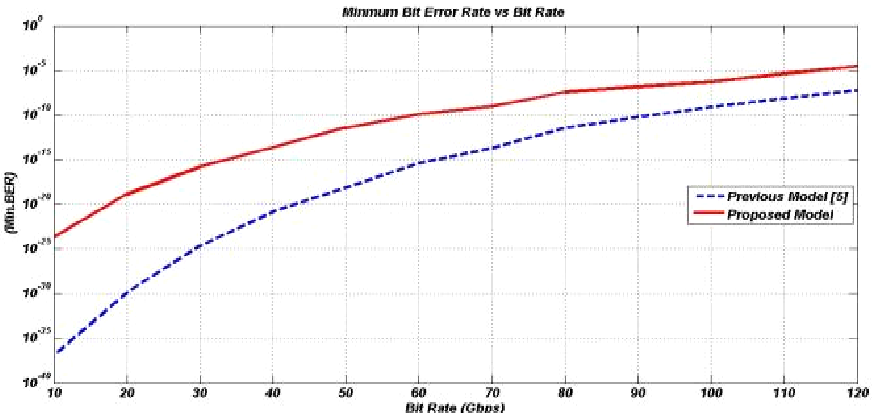

Figure 5. Min. BER versus bit rate for the proposed and previous models of the WDM-RoF system at L=20 km

Figure 6 clarifies the description of the received power behavior related to the number of subscribers for both the proposed and previous models of the WDM-RoF communication networks. With a rising subscriber number (N), the received power decreases. However, received power reduction for the proposed WDM-RoF communication network based on the OQPSKPM with MSK technique is minimal when compared with the previous model. Figure 7 demonstrates the received power versus the data rate for both the proposed and previous WDM-ROF communication network simulation models. Increasing the bit rate decreased the received power. The proposed model was based on applying a mix of OQPSK and PM, or OQPSKPM, in the transmitter of the WDM-RoF communication network simulation model better than in the previous model. Hence, the proposed simulation model has optimized the decreasing received power.

Figure 8 illustrates the maximum QF in relation to the number of subscribers (N) for the proposed and previous simulation models of the WDM-ROF communication network at data rates of 10 Gb/s and L = 20Km. The increase in subscriber number (N) causes a decrease in maximum QF. Moreover, it was noticed that the decrement in the maximum QF for the proposed simulation model was the lowest. So, the maximum QF was granted in terms of procedure priority for the proposed simulation model case.

Figure 9 elucidates the minimum BER variation against the SM length with the development of the newly proposed OQPSKPM in the WDM-RoF transmitter communication system simulation model. The extension of the SM fiber length was met with an increase in the minimum BER. Moreover, it was noticed that the proposed OQPSKPM model behavior was optimized. Thus, the minimum BER parameter supports a preference for the proposed OQPSKPM simulation dependence model than others that depend on OQPSK and FM modulation techniques individually. Figure 10 clarifies the maximum QF changes regarding the bit rate with developing the novel mixed OQPSKPM in the proposed WDM-RoF communication network simulation model.

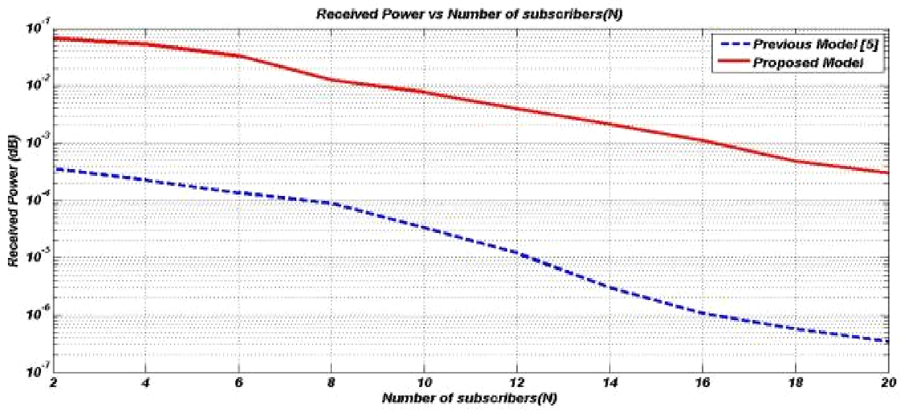

Figure 6. Received power versus number of subscribers (n) for the proposed and previous models of the WDM-RoF system with 10 Gb/s and L= 20 km

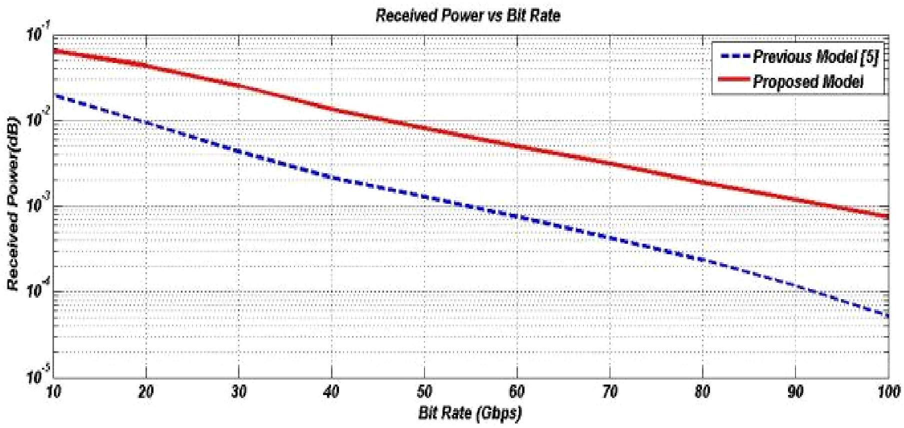

Figure 7. Received power versus data rates for the proposed and previous models of the WDM-RoF at L= 20 km

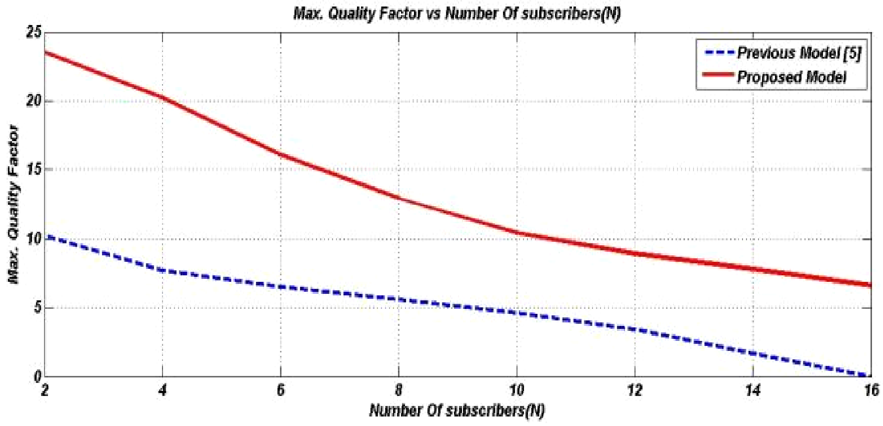

Figure 8. Max. QF with subscriber number for both proposed and previous models of the WDM-RoF system at 10 Gb/s and L=20 km

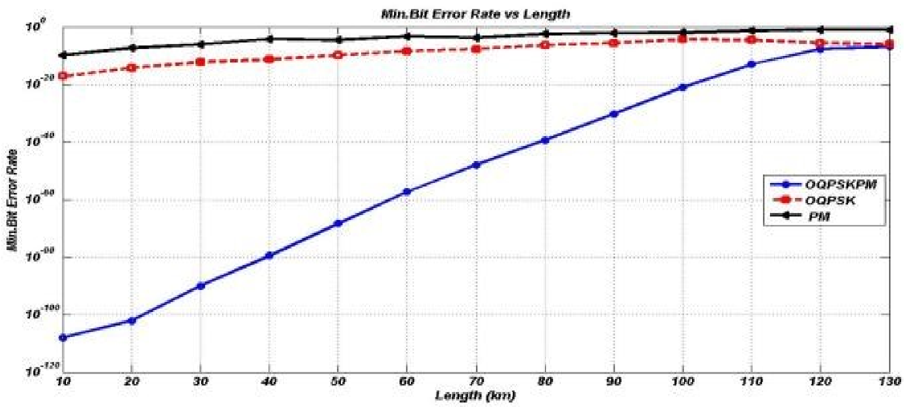

Figure 9. Min. BER against length depending on the OQPSKPM technique of the proposed WDM-RoF model at 10 Gb/s

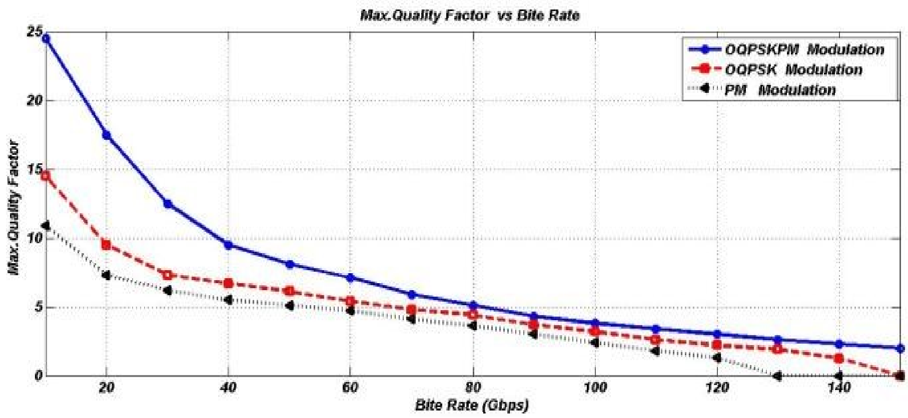

Figure 10. Max. QF versus bit rates depending on the OQPSKPM of the proposed WDM-RoF model at L=20 km

The increase in data rates causes a decrease in maximum QF. Moreover, the maximum QF was observed to be best for the proposed modulation simulation model. So, the maximum QF grantee priority for the proposed simulation model depended on the novel OQPSKPM in comparison with the OQPSK and PM individually. Figure 11 demonstrates the variation of maximum QF distinction regarding the SM fiber length with using the novel mixed OQPSKPM in the proposed WDM-RoF communication system simulation model. As the SM fiber was extended, the maximum QF was reduced. Moreover, the decreasing maximum QF was noticed to still be the best for the OQPSKPM simulation model case.

So, the maximum QF parameter supports a preference for the OQPSKPM simulation model in comparison with the simulation model that depended on the OQPSK and PM, individually. Figure 12 indicates the received power variation regarding the SM cable fiber length when applying the novel hybrid OQPSKPM in the proposed WDM-RoF communication system simulation model. With an extension in the SM cable fiber length, the received power begins decaying. However, the proposed hybrid OQPSKPM technique grants higher values of received power than the original OQPSK and PM individually.

Figure 13 illustrates the minimum BER variation regarding the data rates with the development of the mixed OQPSKPM in the proposed WDM-RoF communication system simulation model. Increasing the bit rate causes an increase in the minimum bit error rate. However, the increasing BER was lowest in the simulation model that depended on the OQPSKPM as observed. So, the lowest variation of the minimum BER showed a preference for the proposed model OQPSKPM dependence.

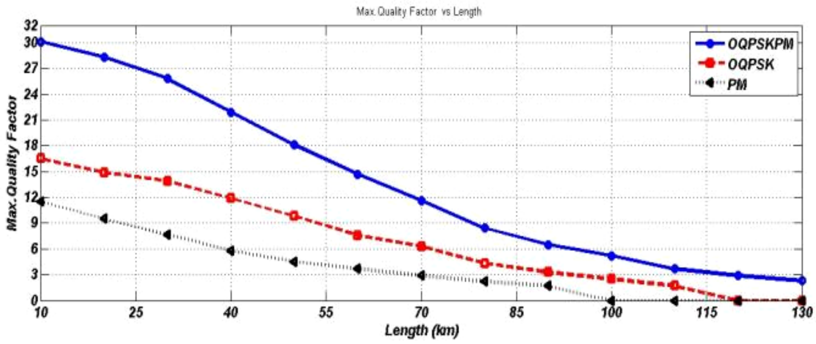

Figure 11. Max. QF against length depending on the OQPSKPM of the proposed WDM-RoF model at 10 Gb/s

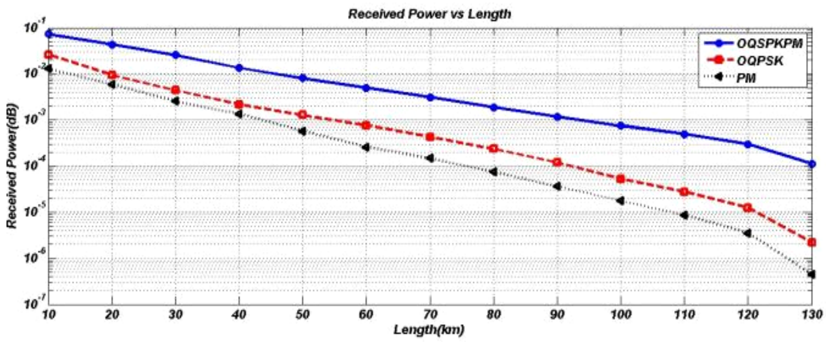

Figure 12. Received power against length with OQPSKPM technique of the proposed WDM-RoF at 10 Gb/s

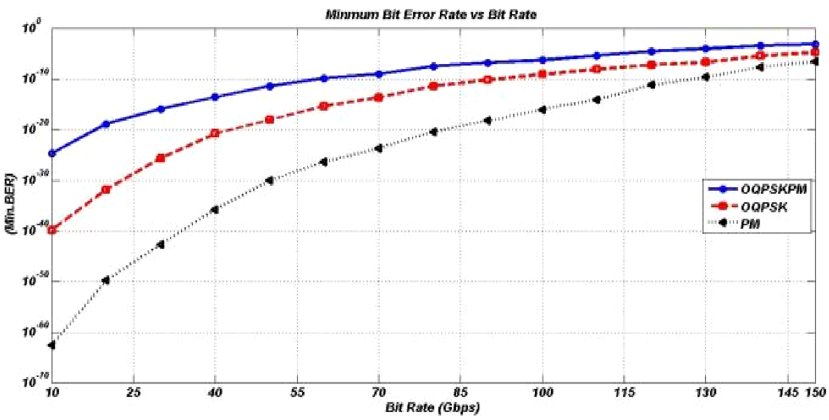

Figure 13. Min. BER with bit rate for OQPSKPM of the proposed WDM ROF Model at L=20 km

Figure 14 illustrates the maximum QF variation against the subscriber number (N) with the development of the mixed OQPSKPM in the WDM-RoF system. The increase in the subscriber number (N) resulted in a decreasing maximum QF. Moreover, the reduction in the maximum QF for the novel mixed OQPSKPM in the proposed model was the lowest. So, the maximum QF parameter permits a priority proposed simulation model to depend on the OQPSKPM in comparison with the individual OQPSK and PM dependence model. Figure 15 clarified that the received power changed regarding the bit rate with the development of the hybrid OQPSKPM in the WDM-RoF system. With the increasing of the bit rate, there was decreasing in the values of the received power. Moreover, the lowest decreasing of the received power level was the case of the OQPSKPM technique. Thus, the lowest variation of the received power level grants a preference for the proposed simulation model that depended on the novel OQPSKPM technique in comparison with the model which depended on the OQPSK and PM individually.

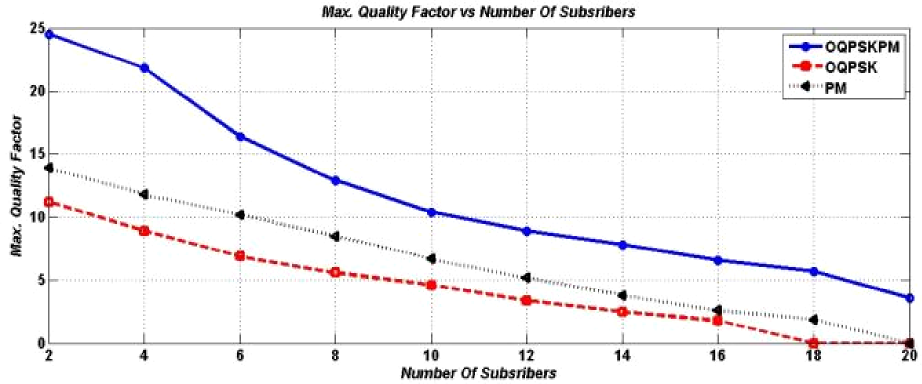

Figure 14. Max. QF against the subscriber number for OQPSKPM of the proposed WDM-RoF model at L=20 km and 10 Gb/s

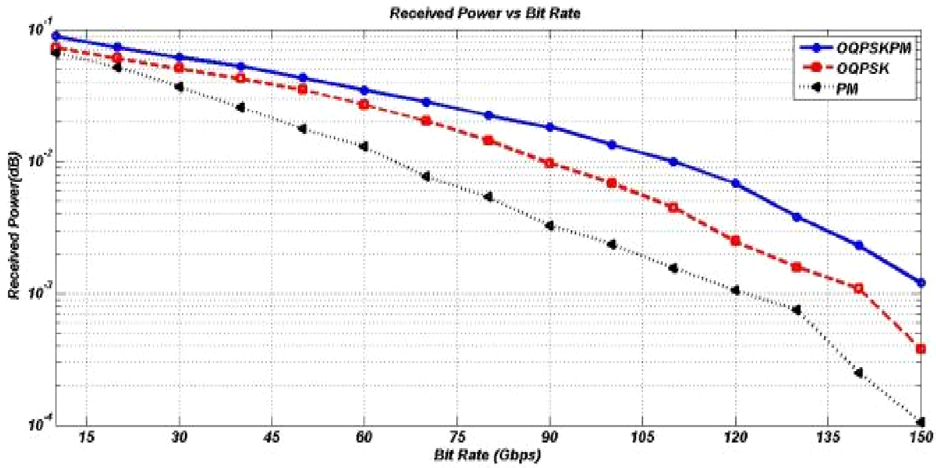

Figure 15. Received power with bit rate for OQPSKPM of the proposed WDM ROF model at L=20 km

From Figure 16, the received power variation in relation to the number of subscribers (N) while using the new mixed OQPSKPM in the WDM-RoF system was clear. The rising in subscriber number reduced the received power. While the reduction in the received power was noticed in the novel mixed OQPSKPM dependence simulation model to be lower than the ordinary modulation, OQPSK and PM, simulation model. Thus, the received power parameter allowed priority for the proposed simulation model which depended on the novel OQPSKPM technique in comparison with the model depending on OQPSK and PM individually. The optimized parameter values for the proposed modulation scheme based on the WDM-RoF system are listed in Table 2.

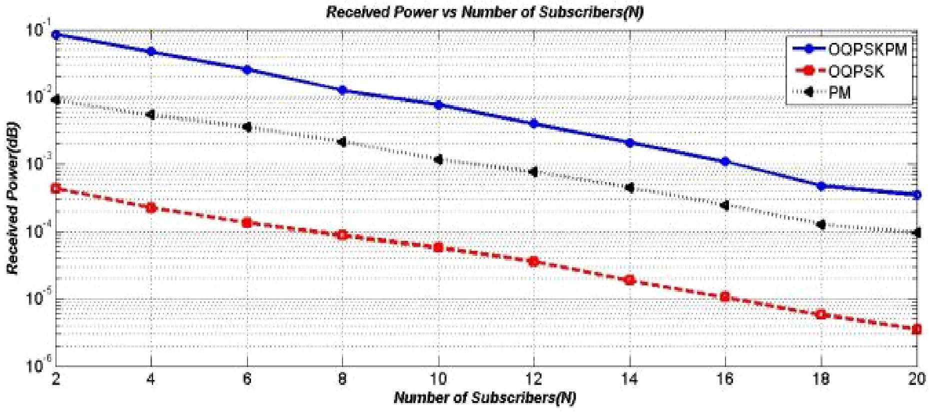

Figure 16. The received power against subscriber number (N) depending on the OQPSKPM of the proposed WDM-RoF system simulation model at L=20 km and 10 Gb/s

Table 2. Optimized parameter values for the proposed simulation model based on the WDM-RoF system

Parameter	Operating parameters conditions [L=20 km, Bit rate =10 Gb/s, wavelength (λ)=1550 nm]		
	OQPSK	PM	OQPSKPM
Max. Q factor	17.3	13.8	30.2
Min. BER	$39.7x\ 10^{-16}$	$45.7x\ 10^{-13}$	43.610^{-20}
Received power (µW)	457.5	542.2	886.5

4. CONCLUSION

The modulated-wavelength division-multiplexing radio over fiber communication system was executed with single-mode optical fiber at a wavelength of 1550 nm. The merged advanced modulation (OQPSKPM) techniques granted enhanced behavior for the proposed WDM-RoF communication system simulation model more than the ordinary modulation dependence basic simulation model. In addition, the validation and verification for the operating parameters have been carried out and the optimized values have been obtained. The maximum quality factor value reached 30.2, the bit error rate parameter decayed to $43.6x10^{-20}$, and the received power was recognized at 886.5 µW. In addition, the optimized transmission length was extended to 130 km, and the bit rate reached 150 Gb/s.

REFERENCES

[1] Y. Zhang, *et al.*, "Self-interference cancellation using dual-drive Mach-Zehnder modulator for in-band fullduplex radio-over-fiber system," *Optical Society of America, Optics Express*, vol. 23, no. 26, pp. 1-9, 2015.
[2] B. Wu, *et al.*, "Multi-service RoF links with colorless upstream transmission based on orthogonal phase correlated modulation," *Optical Society of America, Optics Express*, vol. 23, no. 14, 2015.
[3] A. Sharma, S. Rana, "Comprehensive study of radio over fiber with different modulation techniques-a review," *International Journal of Computer Applications*, vol. 170, no.4, pp. 22-23, 2017.
[4] M. Morant, *et al.*, "Polarization division multiplexing of OFDM radio-over-fiber signals in passive optical networks," *Hindawi Publishing Corporation, Advances in Optical Technologies*, vol. 21, pp. 1-5, 2014.
[5] S. E. Alavi, *et al.*, "W-Band OFDM for radio-over-fiber direct-detection link enabled by frequency nonupling optical up-conversion," *IEEE Photonics Journal*, vol. 6, no. 6, pp. 1-12, 2014.
[6] H. Y. Wang, *et al.*, "Remote beating of parallel or orthogonally polarized dual-wavelength optical carriers for 5G millimeter-wave radio-over-fiber link," *Optics Express*, vol. 24, no. 16, 2016.
[7] J. He, B. Li, *et al.*, "Experimental demonstration of bidirectional OFDM/OQAM-MIMO signal over a multicore fiber system," *IEEE Photonics Journal*, vol. 8, no. 5, pp. 1-10, 2016.
[8] J. Wang, *et al.*, "Digital mobile front haul based on delta–sigma modulation for 32 LTE carrier aggregation and FBMC signals," *Optical Society of America journal*, vol. 9, no. 2, pp. a233-a239, 2017.
[9] X. Fernando and A. Sesay, "Adaptive asymmetric linearization of radio over fiber links for wireless access," *IEEE Transactions on Vehicular Technology*, vol. 51, no. 6, pp. 1576-1586, 2002.
[10] A. Mishra, P. Mishra, "Optical communication with time division multiplexing (OTDM) and hybrid WDM/OTDM PON," *International Journal of Science and Research (IJSR)*, vol. 3, no. 12, pp. 1681-1683, Dec. 2014.
[11] B. Wu, *et al.*, "Polarization-insensitive remote access unit for radio-over-fiber mobile fronthaul system by reusing polarization orthogonal light waves," *IEEE Photonics Journal*, vol. 8, no. 1, pp. 1-9, 2016.

[12] B. Singh, D. Singh "Performance evaluation of RoF system by using SAMZM and DAMZM in external modulation," *International Journal of Current Engineering and Technology*, vol. 4, no.3, pp. 2135-2136, Jun. 2014.
[13] H. Pakarzadeh, *et al.*, "Propagation of telecommunication pulses in photonics nanowires: A comparative physics study," *Results in Physics*, vol. 13, Jun. 2019.
[14] H. Pakarzadeh, *et al.*, "Designing a photonic crystal fiber for an ultra-broadband parametric amplification in telecommunication region," *Journal of Nonlinear Optical Physics & Materials*, vol. 25, no. 02, 2016.
[15] H. Pakarzadeh, *et al.*, "Two-pump fiber optical parametric amplifiers: Beyond the 6-wave model," *Optical Fiber Technology*, vol. 45, pp. 223-230, 2018, doi: https://doi.org/10.1016/j.yofte.2018.07.015.
[16] IS Amiri, *et al.*, "Basic functions of fiber bragg grating effects on the optical fiber systems performance efficiency," *Journal of Optical Communications*, Apr. 2019, doi: https://doi.org/10.1515/joc-2019-0042.
[17] Ahmed Nabih Zaki Rashed, *et al.*, "Nonlinear effects with semiconductor optical amplifiers," *Journal of Optical Communications*, Apr. 2019, doi: https://doi.org/10.1515/joc-2019-0053.
[18] IS Amiri, *et al.*, "High-speed light sources in high-speed optical passive local area communication networks," *Journal of Optical Communications*, Apr. 2019, doi: https://doi.org/10.1515/joc-2019-0070.
[19] IS Amiri, *et al.*, "Spatial continuous wave laser and spatiotemporal VCSEL for high-speed long haul optical wireless communication channels," *Journal of Optical Communications*, Apr. 2019, doi: https://doi.org/10.1515/joc-2019-0061.
[20] Ahmed Nabih Zaki Rashed, *et al.*, "Average power model of optical raman amplifiers based on frequency spacing and amplifier section stage optimization," *Journal of Optical Communications*, May 2019, doi: https://doi.org/10.1515/joc-2019-0081.
[21] IS Amiri, *et al.*, "Temperature effects on characteristics and performance of near-infrared wide bandwidth for different avalanche photodiodes structures," *Results in Physics*, vol. 14, Sep. 2019, doi: https://doi.org/10.1016/j.rinp.2019.102399.
[22] IS Amiri, Ahmed Nabih Zaki Rashed, "Different photonic crystal fibers configurations with the key solutions for the optimization of data rates transmission," *Journal of Optical Communications*, Jul. 2019, doi: https://doi.org/10.1515/joc-2019-0100.
[23] Ahmed Nabih Zaki Rashed, *et al.*, "The physical parameters of EDFA and SOA optical amplifiers and bit sequence variations based optical pulse generators impact on the performance of soliton transmission systems," *Journal of Optical Communications*, Jul. 2019, doi: https://doi.org/10.1515/joc-2019-0156.
[24] IS Amiri, *et al.*, "Optical networks performance optimization based on hybrid configurations of optical fiber amplifiers and optical receivers," *Journal of Optical Communications*, Jul. 2019, doi: https://doi.org/10.1515/joc-2019-0153.
[25] IS Amiri, *et al.*, "Comparative simulation of thermal noise effects for photodetectors on performance of long-haul DWDM optical networks," *Journal of Optical Communications*, Aug. 2019, doi: https://doi.org/10.1515/joc-2019-0152.
[26] Ahmed Nabih Zaki Rashed, *et al.*, "Single wide band traveling wave semiconductor optical amplifiers for all optical bidirectional wavelength conversion," *Journal of Optical Communications*, Aug. 2019, doi: https://doi.org/10.1515/joc-2019-0168.
[27] IS Amiri, *et al.*, "Comparative simulation study of multi stage hybrid all optical fiber amplifiers in optical communications," *Journal of Optical Communications*, Feb. 2020, doi: https://doi.org/10.1515/joc-2019-0132.
[28] IS Amiri, *et al.*, "Optical communication transmission systems improvement based on chromatic and polarization mode dispersion compensation simulation management," *Optik Journal*, vol. 207, Apr. 2020, doi: https://doi.org/10.1016/j.ijleo.2019.163853.
[29] Ahmed Nabih Zaki Rashed, *et al.*, "Distributed feedback laser (DFB) for signal power amplitude level improvement in long spectral band," *Journal of Optical Communications*, Apr. 2020, doi: https://doi.org/10.1515/joc-2019-0252.
[30] IS Amiri, *et al.*, "Analytical model analysis of reflection/transmission characteristics of long-period fiber bragg grating (LPFBG) by using coupled mode theory," *Journal of Optical Communications*, Apr. 2020, doi: https://doi.org/10.1515/joc-2019-0187.
[31] IS Amiri, *et al.*, "Conventional/phase shift dual drive mach–zehnder modulation measured type-based radio over fiber systems," *Journal of Optical Communications*, Apr. 2020, doi: https://doi.org/10.1515/joc-2019-0312.