Optical fiber communication system links performance enhancement for high-speed data transmission through short-reach applications

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Abstract: This paper clarified the optical fiber communication system links the performance signature for short-indoor applications. The electrical propagation delay time is investigated for copper links. The polystyrene optical link propagation delay time is also analyzed. The optical pulse broadening and the data transmission bit rates in the optical links are analyzed. The electrical/optical links performance is discussed with the variations of electrical/optical link variations and ambient temperature variations. The optical link performance efficiency has presented better performance than the electrical links, especially for short-indoor applications.

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1 Introduction

Any communication fiber system can be divided in to transmitter, channel, and receiver. The signals may be transferred over different media like air as in wireless communication or over physical medium such as cooper cable or optical fiber cable [1–14]. They are the most commonly used wired channels in electrical and optical communication system respectively [15–30]. According to the history of communication system, the credit for laying the foundations for today's optical communication systems is due to the world of Charles Kuen Kao, his work colleague George Hockham, and there team in 1966 [31–45]. The important question here, why has copper cables been replaced by optical fibers in most of the current communications systems. The name "soliton" being used in the sense of a solitary wave displaying panicle behavior. The existence of solitons in wave propagation in plasma has been known since the 1960s. Turning to optical communications, in 1973 Hasegawa and Tappert of Bell Laboratories proposed a method for creating the aforementioned "stable pulses that occur due to balancing of dispersion and nonlinearity" inside an optical fiber [46–60].

The details depend on some rather abstruse mathematics but for the proper pulse shape the two types of stretching offset each other [61–76]. This means that the shape of the pulse—how its intensity changes with time is not affected by chromatic dispersion Solitons can exist in places other than fibers—the first were waves spotted in nineteenth-century canals—but their only use in communications is for fiber-optic transmission. The reasons that the continuous need to increasing the number of subscribers, increasing the amount of information that be transferred [77–89], using different technologies in transmission, the emergence of new technologies need the transfer of a large amount of data and high-speed carrier media with minimum delay time, and the need for more capacity and bandwidth with minimum cost [90–111]. The simple form of the optical fiber cable consist of a thin core surrounded by a cladding material, which have a refractive index smaller than the core. There is also an outer protective layer surrounded the cladding. In the other side, the copper wire is a good conductive material for electricity at the room temperature [112–130].

2 Mathematical model analysis

As shown in Figure 1, the electrical links with C_L is the load capacitance, R_{on} is the ON transistor resistance, $R_{int.}$ is the internal resistance and $C_{int.}$ is the internal capacitance. The propagation time delay of the electrical links and the simplified equation can be modeled by [9–12]:

$$T_{P(EL)} = R_{int.}C_{int.} + 2.3\,(R_{on}C_{int.} + R_{on}C_L + R_{int.}C_L) \quad (1)$$

$$T_{P(EL)} = 2.3\,(R_{on} + R_{int.})\,C_{int.} \quad (2)$$

The internal electrical link resistance is given by the following formula [9, 10, 12].

$$R_{int.} = \rho\,\frac{L_E}{H\,W} \quad (3)$$

where ρ is the electrical link resistivity, L_E is the electrical link length, H is the electrical link thickness, and W is the electrical link width. The fitting relation between resistivity and temperature is expressed by [10, 12]:

$$\rho = \rho_0 - 0.00543 \times 10^{-7}\,T + 0.1235 \times 10^{-7}\,T^2 \quad (4)$$

where ρ_O is the electrical resistivity at room temperature (T_O). The electrical link capacitance is estimated by [9, 11, 12]:

$$C_{int.} = \varepsilon_{ox}\left[\frac{1.15\,W}{t_{ox}} + 2.28\left(\frac{H}{t_{ox}}\right)^{0.222}\right]L_E \quad (5)$$

where t_{ox} is dielectric oxide thickness, and ε_{ox} is the silicon dioxide permittivity. Optical links can be shown in Figure 2, where $R_{int.}$ and $C_{int.}$ tend to be zero, and the propagation delay time for the optical links [9, 11, 12]:

$$T_{P(OL)} = 2.3\,R_{on}C_L + t_{laser} + t_{int.} + t_{rec.} \quad (6)$$

where C_L is the input capacitance of the laser diode, t_{laser} is the delay time through the laser diode, $t_{int.}$ is the propagation delay along the optical fiber interconnect, and $t_{rec.}$ is the receiver delay time.

The internal delay time through fiber optic medium can be estimated by [9, 10, 12]:

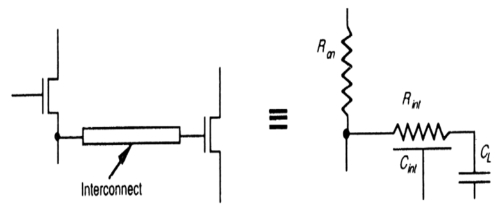

Figure 1: Electrical link circuit schematic view.

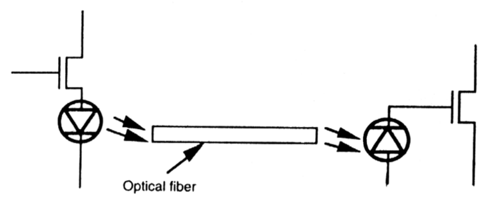

Figure 2: Schematic view of the optical link configuration.

$$t_{int.} = \frac{n\,L_O}{c} \quad (7)$$

where L_O is the optical link length and n is the optic link refractive index and is given by [9, 10, 12]:

$$n = \sqrt{\frac{B_1\lambda^2}{\lambda^2 - B_2^2} + \frac{B_3\lambda^2}{\lambda^2 - B_4^2} + \frac{B_5\,\lambda^2}{\lambda^2 - B_6^2}} \quad (8)$$

For the polystyrene optical link, coefficients are expressed by the following formulas [9, 10, 12]:

$$B_1 = 0.2652, B_2 = 0.004321\,(T/T_O), B_3 = 1.876 \quad (9)$$

$$B_4 = 0.976542(T/T_O), B_5 = 0.41987, \quad B_6 = 73.654\,(T/T_O) \quad (10)$$

The optical pulse broadening in the optical links is expressed by [12]:

$$\Delta\tau_{(OL)} = T_{P(OL)}\,\Delta\lambda\,L \quad (11)$$

where $\Delta\lambda$ is the pulse width of the laser diode. The data rate transmission through the optical link is [12–14]:

$$B_{R(OL)} = \frac{0.7}{\Delta\tau_{(OL)}} \quad (12)$$

$$D_r\,(EL) = \frac{0.7}{T_{P(EL)}} \quad (13)$$

3 Results and performance analysis

One of the most important metrics for the performance of a link is the bit rate, which indicates the reliability of the link.

This reliability ties closely with the data rate as excessive errors may force a link to operate at a lower data rate. The errors are due to noise on the signal that is transmitted and the noise in the receiving circuits as well as the noise introduced by the channel. We have discussed the obtained results of the performance parameters for optical/electrical links depend upon the operating parameters such as light wavelength (λ) = 1300 nm, Room temperature (T_0) = 300 K, 300 K ≤ ambient temperature (T) ≤ 400 K, 1 m ≤ optical/electrical link length ($L_{E/O}$) ≤ 10 m, electrical link width (W) = 0.5 m, electrical link width (H) = 0.7 m, dielectric oxide thickness (t_{ox}) = 0.65 mm, silicon dioxide permittivity (ε_{ox}) = 3.4514 × 10^{-5} pF/mm, copper resistivity (ρ_0) = 1.68 × 10^{-6} Ω mm, ON transistor resistance (R_{on}) = 10 kΩ, load capacitance (C_L) = 1 pF, laser propagation delay time (t_{laser}) = 1 ps, receiver propagation delay time ($t_{rec.}$) = 1 ps, the pulse width of the laser diode ($\Delta\lambda$) = 0.1 nm.

Figure 3 shows the propagation delay time increases as electrical/optical links increase at temperature (T = 300 K). The propagation delay time increases he electrical/optical link length. The time delay for the electrical reach of 1 m is 3 ns and the optical link length of 1 m is 0.5 ns at room temperature. As well as the propagation delay time for the electrical link length of 5.5 m is 25 ns and the optical reach of 5.5 m is 4 ns at room temperature. In addition to the propagation delay, time for the electrical reach of 10 m is 200 ns and the optical reach of 10 m is 32 ns at room temperature.

Figure 4 clarifies the propagation delay time with respect to electrical/optical links at ambient temperature (T = 350 K). The time delay increases as the electrical/optical reach increases. The time delay for the electrical link length of 1 m is 6 ns and optical link length of 1 m is 1 ns at ambient temperature of 350 K. As well as the propagation delay time for the electrical link length of 5.5 m is 50 ns and optical link length of 5.5 m is 8 ns at ambient temperature of 350 K. In addition to the propagation delay, time for the electrical reach of 10 m is 400 ns and the optical reach of 10 m is 64 ns at an ambient temperature of 350 K.

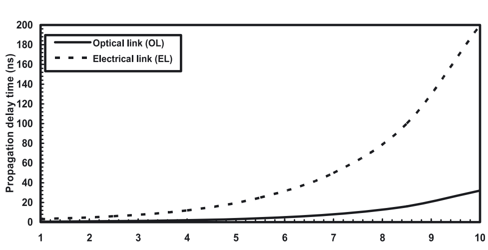

Figure 3: Propagation delay time with respect to electrical/optical links at room temperature (T = 300 K).

Figure 5 illustrates the propagation delay time with respect to electrical/optical links at ambient temperature (T = 400 K). The time delay increases as the electrical/optical link length increases. The time delay for the electrical link length of 1 m is 12 ns and optical link length of 1 m is 2 ns at ambient temperature of 400 K. As well as the propagation delay time for the electrical link length of 5.5 m is 100 ns and optical link length of 5.5 m is 16 ns at ambient temperature of 400 K. In addition to the propagation delay, time for the electrical reach of 10 m is 800 ns and the optical reach of 10 m is 128 ns at an ambient temperature of 400 K.

Figure 6 illustrates the data rate transmission variations with ambient temperature at electrical/optical links length (L = 2.5 m). The data rate transmission decreases as the ambient temperatures increase. The transmission rate for the optical link is 20 Gb/s at the optical length of 2.5 m, the data rate transmission for the electrical link is 0.7 Gb/s

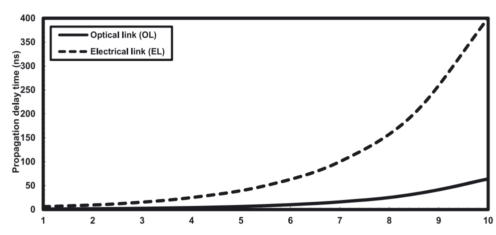

Figure 4: Propagation delay time with respect to electrical/optical links at ambient temperature (T = 350 K).

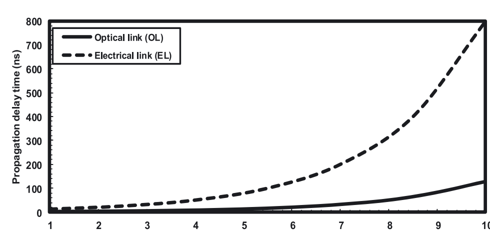

Figure 5: Propagation delay time with respect to electrical/optical links at ambient temperature (T = 400 K).

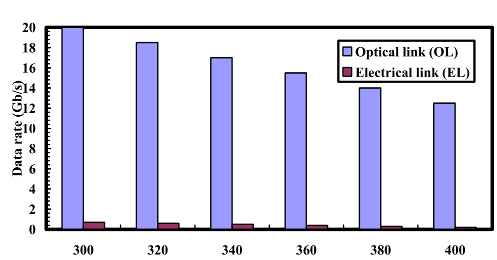

Figure 6: Transmission rate variations versus temperature at electrical/optical links length (L = 2.5 m).

at the electrical length of 2.5 m at room temperature. Moreover, the data rate transmission for the optical link is 16.5 Gb/s at the optical length of 2.5 m, the data rate transmission for the electrical link is 0.45 Gb/s at the electrical length of 2.5 m at a temperature of 350 K. The transmission rate for the optical link is 12.5 Gb/s at the optical length of 2.5 m, the data rate transmission for the electrical link is 0.2 Gb/s at the electrical length of 2.5 m at an ambient temperature of 400 K.

Figure 7 shows the transmission rate with temperature at the electrical/optical links length (L = 6.5 m). The data rate transmission decreases as ambient temperatures increase. The transmission rate for the optical link is 12 Gb/s at the optical length of 6.5 m, the data rate transmission for the electrical link is 0.2 Gb/s at the electrical length of 6.5 m at room temperature. Moreover, the data rate transmission for the optical link is 10.5 Gb/s at the optical length of 6.5 m, the transmission rate for the electrical link is 0.16 Gb/s at an electrical length of 6.5 m at an temperature of 350 K. Transmission rate for the optical link is 7 Gb/s at the optical length of 6.5 m, the data rate transmission for the electrical link is 0.1 Gb/s at the electrical length of 6.5 m at an ambient temperature of 400 K.

Figure 8 indicates the transmission rate with temperature at electrical/optical links length (L = 10 m). The data rate transmission decreases with the increase of the ambient temperatures.

The transmission rate for the optical link is 5 Gb/s at the optical reach of 10 m, the transmission rate for the electrical link is 0.1 Gb/s at the electrical length of 10 m at room temperature. Moreover, the transmission rate for the optical link is 3.8 Gb/s at the optical reach of 10 m, the transmission rate for the electrical link is 0.085 Gb/s at the electrical length of 10 m at a temperature of 350 K. The transmission rate for the optical link is 2.5 Gb/s at the optical length of 10 m, the data rate transmission for the electrical link is 0.075 Gb/s at the electrical length of 10 m at an ambient temperature of 400 K.

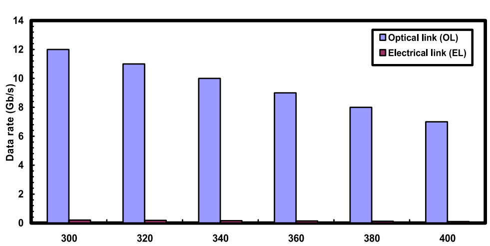

Figure 7: Transmission rate in relation to temperature at electrical/optical links length (L = 6.5 m).

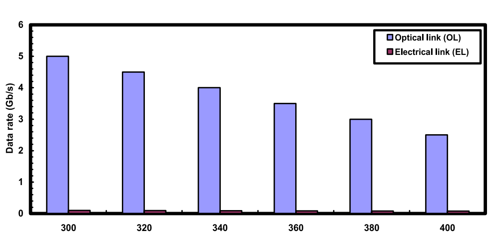

Figure 8: Transmission rate against temperature at electrical/optical links length (L = 10 m).

4 Conclusions

The optical and electrical system links performance are investigated for short-range applications. The propagation delay time and the transmission data rates variations for both electrical/optical links are discussed. The obtained results are assured that the optical links are better performance than the electrical links. The lower optical/electrical links length, the lower the propagation delay time, and consequently the higher data rate transmission through these links under the control of ambient temperature variations.

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References

1. Rashed ANZ. Performance signature and optical signal processing of high speed electro-optic modulators. Opt Commun 2013;294:49–58.
2. Rashed ANZ, Metwae'e M. Maximization of repeater spacing in ultra wide-wavelength-division multiplexing optical communication systems based on multi pumped laser diodes. J Russ Laser Res 2013;34:255–61.
3. Rashed ANZ, Saad AE-FA. Different electro-optical modulators for high transmission-data rates and signal-quality enhancement. J Russ Laser Res 2013;34:336–45.
4. Rashed ANZ, Mohamed AE-NA, Mostafa S, Abd El-Samie FE. Performance evaluation of SAC-OCDMA system in free space optics and optical fiber system based on different types of codes. Wireless Pers Commun 2017;96:2843–61.

5. Rashed ANZ, Tabbour MSF. Suitable optical fiber communication channel for optical nonlinearity signal processing in high optical data rate systems. Wireless Pers Commun 2017;97:397–416.
6. Rashed ANZ, Tabour MSF, El-Meadawy S. Optimum flat gain with optical amplification technique based on both gain flattening filters and fiber bragg grating methods. J Nanoelectron Optoelectron 2018;13:665–76.
7. Mohamed SE-DN, Mohamed AE-NA, Abd El-Samie FE, Rashed ANZ. Performance enhancement of IM/DD optical wireless systems. Photonic Netw Commun 2018;36:114–27.
8. Rashed ANZ, Tabbour MSF. The trade off between different modulation schemes for maximum long reach high data transmission capacity optical orthogonal frequency division multiplexing (OOFDM)". Wireless Pers Commun 2018;101: 325–37.
9. Rashed ANZ, Abdel Kader HM, Al-Awamry AA, Abd El-Aziz IA. Transmission performance simulation study evaluation for high speed radio over fiber communication systems. Wireless Pers Commun 2018;103:1765–79.
10. Rashed ANZ, Tabbour MSF. Best candidate integrated technology for low noise, high speed, and wide bandwidth based transimpedance amplifiers in optical computing systems and optical fiber applications. Int J Commun Syst 2018;31: e3801.
11. Rashed ANZ, Tabbour MSF, El-assar M. 20 Gb/s hybrid CWDM/ DWDM for extended reach fiber to the home network applications. Proc Natl Acad Sci India Sect A Phys Sci 2019;89: 653–62.
12. Boopathi CS, Vinoth Kumar K, Sheebarani S, Selvakumar K, Rashed ANZ, Yupapin P. Design of human blood sensor using symmetric dual core photonic crystal fiber. Results Phys 2018; 11:964–5.
13. Vigneswaran D, Mani Rajan MS, Aly MH, Rashed ANZ. Few-mode ring core fiber characteristics: temperature impact. Photonic Netw Commun 2019;37:131–8.
14. Praveen Chakkravarthy S, Arthi V, Karthikumar S, Rashed ANZ, Yupapin P, Amiri IS. Ultra high transmission capacity based on optical first order soliton propagation systems. Results Phys 2019;12:512–3.
15. Rashed ANZ, Vinoth Kumar K, Prithi S, Maheswar R, Tabbour MSF. Transmittivity/reflectivity, bandwidth, and ripple factor level measurement for different refractive index fiber grating shape profiles. J Opt Commun 2019. https://doi.org/10.1515/joc-2018-0233 [Epub ahead of print].
16. Rashed ANZ, Vinoth Kumar K, Venkatesh Kumar P, Mohamed AE–NA, Tabbour MS, El-Assar M. DWDM channel spacing effects on the signal quality for DWDM/CWDM FTTx network. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0012 [Epub ahead of print].
17. Rashed ANZ, Tabbour MSF, Vijayakumari P. Numerical analysis of optical properties using octagonal shaped photonic crystal fiber. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0013 [Epub ahead of print].
18. Rashed ANZ, Satheesh Kumar S, Tabbour MSF, Sundararajan TVP, Maheswar R. Different graded refractive index fiber profiles design for the control of losses and dispersion effects. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0036 [Epub ahead of print].
19. Rashed ANZ. Comparison between NRZ/RZ modulation techniques for upgrading long haul optical wireless communication systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0038 [Epub ahead of print].
20. Rashed ANZ, Vinoth Kumar K, Tabbour MSF, Sundararajan TVP. Nonlinear characteristics of semiconductor optical amplifiers for optical switching control realization of logic gates. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0027 [Epub ahead of print].
21. Ahmed K, Kumar Paula B, Vasudevan B, Rashed ANZ, Maheswar R, Amiri IS, et al. Design of D-shaped elliptical core photonic crystal fiber for blood plasma cell sensing application. Results Phys 2019;12:2021–5.
22. Ramana TV, Pandian A, Ellammal C, Jarin T, Rashed ANZ, Sampathkumar A. Numerical analysis of circularly polarized modes in coreless photonic crystal fiber. Results Phys 2019;13: 102140.
23. Rashed ANZ, Mohammed AE-NA, Zaky WF, Amiri IS, Yupapin P. The switching of optoelectronics to full optical computing operations based on nonlinear metamaterials. Results Phys 2019;13:102152.
24. Ranathive S, Vinoth Kumar K, Rashed ANZ, Tabbour MSF, Sundararajan TVP. Performance signature of optical fiber communications dispersion compensation techniques for the control of dispersion management. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0021 [Epub ahead of print].
25. Amiri IS, Rashed ANZ, Yupapin P. Interaction between optical sources and optical modulators for high-speed optical communication networks. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0041 [Epub ahead of print].
26. Amiri IS, Rashed ANZ, Yupapin P. Effects of order super Gaussian pulses on the performance of high data rate optical fiber channel in the presence of self phase modulation. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0039 [Epub ahead of print].
27. Amiri IS, Rashed ANZ, Yupapin P. Mathematical model analysis of dispersion and loss in photonic crystal fibers. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0052 [Epub ahead of print].
28. Amiri IS, Rashed ANZ, Yupapin P. Basic functions of fiber bragg grating effects on the optical fiber systems performance efficiency. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0042 [Epub ahead of print].
29. Amiri IS, Rashed ANZ, Mohammed AE-NA, Aboelazm MB, Yupapin P. Nonlinear effects with semiconductor optical amplifiers. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0053 [Epub ahead of print].
30. Amiri IS, Rashed ANZ, Yupapin P. High-speed light sources in high-speed optical passive local area communication networks. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0070 [Epub ahead of print].
31. Rashed ANZ, Tabbour MSF, Natarajan K. Performance enhancement of overall LEO/MEO intersatellite optical wireless communication systems. Int J Satell Commun Netw 2020;38: 31–40.
32. Amiri IS, Rashed ANZ, Mohammed AEA, El-Din ES, Yupapin P. Spatial continuous wave laser and spatiotemporal VCSEL for high-speed long haul optical wireless communication channels. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0061 [Epub ahead of print].
33. Amiri IS, Rashed ANZ, Yupapin P. Average power model of optical Raman amplifiers based on frequency spacing and

amplifier section stage optimization. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0081 [Epub ahead of print].
34. Amiri IS, Houssien FMAM, Rashed ANZ, Mohammed AE-NA. Temperature effects on characteristics and performance of near-infrared wide bandwidth for different avalanche photodiodes structures. Results Phys 2019;14:102399.
35. Amiri IS, Rashed ANZ. Simulative study of simple ring resonator-based brewster plate for power system operation stability. Indones J Electr Eng Comput Sci 2019;16:1070–6.
36. Amiri IS, Rashed ANZ. Different photonic crystal fibers configurations with the key solutions for the optimization of data rates transmission. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0100 [Epub ahead of print].
37. Amiri IS, Rashed ANZ, Ramya KC, Vinoth Kumar K, Maheswar R. 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. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0156 [Epub ahead of print].
38. Amiri IS, Houssien FMAM, Rashed ANZ, Mohammed AE-NA. Optical networks performance optimization based on hybrid configurations of optical fiber amplifiers and optical receivers. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0153 [Epub ahead of print].
39. Amiri IS, Rashed ANZ, Sarker K, Paul BK, Ahmed K. Chirped large mode area photonic crystal modal fibers and its resonance modes based on finite element technique. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0146 [Epub ahead of print].
40. Amiri IS, Houssien FMAM, Rashed ANZ, Mohammed AE-NA. Comparative simulation of thermal noise effects for photodetectors on performance of long-haul DWDM optical networks. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0152 [Epub ahead of print].
41. Amiri IS, Rashed ANZ, Mohammed AEA, Aboelazm MB. Single wide band traveling wave semiconductor optical amplifiers for all optical bidirectional wavelength conversion. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0168 [Epub ahead of print].
42. Amiri IS, Rashed ANZ, Mohammed AE-NA, Zaky WF. Influence of loading, regeneration and recalling elements processes on the system behavior of all optical data bus line system random access memory. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0163 [Epub ahead of print].
43. Malathy S, Vinoth Kumar K, Rashed ANZ, Vigneswaran D, Eeldien ES. Upgrading superior operation performance efficiency of submarine transceiver optical communication systems toward multi tera bit per second. Comput Commun 2019;146:192–200.
44. Amiri IS, Rashed ANZ. Numerical investigation of V shaped three elements resonator for optical closed loop system. Indones J Electr Eng Comput Sci 2019;16:1392–7.
45. Rashed ANZ, Tabbour MSF. The engagement of hybrid dispersion compensation schemes performance signature for ultra wide bandwidth and ultra long haul optical transmission systems. Wireless Pers Commun 2019;76:1265–77.
46. Rashed ANZ, Tabbour MSF, El-Meadawy S, Anwar T, Sarlan A, Yupapin P, et al. The effect of using different materials on erbium-doped fiber amplifiers for indoor applications. Results Phys 2019;15:102650.
47. Amiri IS, Rashed ANZ. Power enhancement of the U-shape cavity microring resonator through gap and material characterizations. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0108 [Epub ahead of print].
48. Amiri IS, Kuppusamy PG, Rashed ANZ, Jayarajan P, Thiyagupriyadharsan MR, Yupapin P. The engagement of hybrid ultra high space division multiplexing with maximum time division multiplexing techniques for high-speed single-mode fiber cable systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0205 [Epub ahead of print].
49. Amiri IS, Rashed ANZ, Jahan S, Paul BK, Ahmed K. Polar polarization mode and average radical flux intensity measurements based on all optical spatial communication systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0159 [Epub ahead of print].
50. Sivaranjani S, Sampathkumar A, Rashed ANZ, Sundararajan TVP, Amiri IS. Performance evaluation of bidirectional wavelength division multiple access broadband optical passive elastic networks operation efficiency. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0175 [Epub ahead of print].
51. Amiri IS, Rashed ANZ, Yupapin P. High-speed transmission circuits signaling in optical communication systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0197 [Epub ahead of print].
52. Amiri IS, Rashed ANZ, Jahan S, Paul BK, Ahmed K, Yupapin P. Technical specifications of the submarine fiber optic channel bandwidth/capacity in optical fiber transmission systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0226 [Epub ahead of print].
53. Amiri IS, Rashed ANZ. Signal processing criteria based on electro-optic filters for fiber optic access transceiver systems. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0116 [Epub ahead of print].
54. Amiri IS, Rashed ANZ, Yupapin P. Pump laser automatic signal control for erbium-doped fiber amplifier gain, noise figure, and output spectral power. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0203 [Epub ahead of print].
55. Amiri IS, Rashed ANZ, Parvez AHMS, Paul BK, Ahmed K. Performance enhancement of fiber optic and optical wireless communication channels by using forward error correction codes. J Opt Commun 2019. https://doi.org/10.1515/joc-2019-0191 [Epub ahead of print].
56. Amiri IS, Rashed ANZ, Yupapin P. Z Shaped like resonator with crystal in the presence of flat mirror based standing wave ratio for optical antenna systems. Indones J Electr Eng Comput Sci 2020;17:1405–9.
57. Amiri IS, Rashed ANZ, Yupapin P. Influence of device to device interconnection elements on the system behavior and stability. Indones J Electr Eng Comput Sci 2020;18:843–7.
58. Eid MMA, Amiri IS, Rashed ANZ, Yupapin P. Dental lasers applications in visible wavelength operational band. Indones J Electr Eng Comput Sci 2020;18:890–5.
59. Amiri IS, Rashed ANZ, Yupapin P. Comparative simulation study of multi stage hybrid all optical fiber amplifiers in optical communications. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0132 [Epub ahead of print].
60. Amiri IS, Rashed ANZ, Kader HMA, Al-Awamry AA, Abd El-Aziz IA, Yupapin P, et al. Optical communication transmission systems improvement based on chromatic and polarization mode dispersion compensation simulation management. Optik 2020;207:1–19.

61. Samanta D, Sivaram M, Rashed ANZ, Boopathi CS, Amiri IS, Yupapin P. Distributed feedback laser (DFB) for signal power amplitude level improvement in long spectral band. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0252 [Epub ahead of print].
62. Amiri IS, Rashed ANZ, Yupapin P. Analytical model analysis of reflection/transmission characteristics of long-period fiber bragg grating (LPFBG) by using coupled mode theory. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0187 [Epub ahead of print].
63. Amiri IS, Rashed ANZ, Rahman Z, Paul BK, Ahmed K. Conventional/Phase shift dual drive mach–zehnder modulation measured type based radio over fiber systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0312 [Epub ahead of print].
64. Alatwi AM, Rashed ANZ, El-Eraki AM, Amiri IS. Best candidate routing algorithms integrated with minimum processing time and low blocking probability for modern parallel computing systems. Indones J Electr Eng Comput Sci 2020;19:847–54.
65. El-Hageen HM, Alatwi AM, Rashed ANZ. Silicon-Germanium dioxide and aluminum indium gallium arsenide-based acoustic optic modulators. Open Eng 2020;10:506–11.
66. El-Hageen HM, Alatwi AM, Rashed ANZ. RZ line coding scheme with direct laser modulation for upgrading optical transmission systems. Open Eng 2020;10:546–51.
67. Alatwi AM, Rashed ANZ, El-Gammal EM. Wavelength division multiplexing techniques based on multi transceiver in low earth orbit intersatellite systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0171 [Epub ahead of print].
68. El-Hageen HM, Kuppusamy PG, Alatwi AM, Sivaram M, Yasar ZA, Rashed ANZ. Different modulation schemes for direct and external modulators based on various laser sources. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0029 [Epub ahead of print].
69. El-Hageen HM, Alatwi AM, Rashed ANZ. High-speed signal processing and wide band optical semiconductor amplifier in the optical communication systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0070 [Epub ahead of print].
70. El-Hageen HM, Alatwi AM, Rashed ANZ. Laser measured rate equations with various transmission coders for optimum of data transmission error rates. Indones J Electr Eng Comput Sci 2020; 20:1406–12.
71. Eid MMA, Ahasan Habib M, Shamim Anower M, Rashed ANZ. Highly sensitive nonlinear photonic crystal fiber based sensor for chemical sensing applications. Microsyst Technol 2020;55: 134–45.
72. Eid MMA, Rashed ANZ, Shafkat A, Ahmed K. Fabry Perot laser properties with high pump lasers for upgrading fiber optic transceiver systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0146 [Epub ahead of print].
73. Eid MMA, Rashed ANZ, Hosen MS, Paul BK, Ahmed K. Spatial optical transceiver system–based key solution for high data rates in measured index multimode optical fibers for indoor applications. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0117 [Epub ahead of print].
74. Eid MMA, Rashed ANZ, El-Meadawy S, Ahmed K. Simulation study of signal gain optimization based on hybrid composition techniques for high speed optically dense multiplexed systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0150 [Epub ahead of print].
75. Alatwi AM, Rashed ANZ. Hybrid CPFSK/OQPSK modulation transmission techniques' performance efficiency with RZ line coding–based fiber systems in passive optical networks. Indones J Electr Eng Comput Sci 2021;21:263–70.
76. Alatwi AM, Rashed ANZ. An analytical method with numerical results to be used in the design of optical slab waveguides for optical communication system applications. Indones J Electr Eng Comput Sci 2021;21:278–86.
77. Alatwi AM, Rashed ANZ. Conventional doped silica/fluoride glass fibers for low loss and minimum dispersion effects. Indones J Electr Eng Comput Sci 2021;21:287–95.
78. El-Hageen HM, Alatwi AM, Rashed ANZ. Spatial optical transmitter based on on/off keying line coding modulation scheme for optimum performance of telecommunication systems. Indones J Electr Eng Comput Sci 2021;21:305–12.
79. Eid MMA, Rashed ANZ, Kurmendra. High speed optical switching gain based EDFA model with 30 Gb/s NRZ modulation code in optical systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0223 [Epub ahead of print].
80. Eid MMA, Rashed ANZ, Amiri IS. Fast speed switching response and high modulation signal processing bandwidth through LiNbO3 electro-optic modulators. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0012 [Epub ahead of print].
81. Eid MMA, Houssien FMAM, Rashed ANZ, Mohammed AE-NA. Performance enhancement of transceiver system based inter satellite optical wireless channel (IS-OWC) for ultra long distances. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0216 [Epub ahead of print].
82. Eid MMA, Rashed ANZ, El-din ES. Simulation performance signature evolution of optical inter satellite links based booster EDFA and receiver preamplifiers. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0190 [Epub ahead of print].
83. Eid MMA, Rashed ANZ, El-gammal EM. Influence of dense wavelength division multiplexing (DWDM) technique on the low earth orbit intersatellite systems performance. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0188 [Epub ahead of print].
84. Eid MMA, Rashed ANZ, Al-Mamun Bulbul A, Podder E. Mono rectangular core photonic crystal fiber (MRC-PCF) for skin and blood cancer detection. Plasmonics 2021;16:717–27.
85. Eid MMA, Seliem AS, Rashed ANZ, Mohammed AE-NA, Ali MY, Abaza SS. High speed pulse generators with electro-optic modulators based on different bit sequence for the digital fiber optic communication links. Indones J Electr Eng Comput Sci 2021;21:957–967.
86. Eid MMA, Seliem AS, Rashed ANZ, Mohammed AE-NA, Ali MY, Abaza SS. The key management of direct/external modulation semiconductor laser response systems for relative intensity noise control. Indones J Electr Eng Comput Sci 2021;21:968–77.
87. Eid MMA, Seliem AS, Rashed ANZ, Mohammed AE-NA, MohamedAli Y, Abaza SS. Duobinary modulation/predistortion techniques effects on high bit rate radio over fiber systems. Indones J Electr Eng Comput Sci 2021;21:978–86.
88. Alatwi AM, Rashed ANZ. A pulse amplitude modulation scheme based on in-line semiconductor optical amplifiers (SOAs) for optical soliton systems. Indones J Electr Eng Comput Sci 2021; 21:1014–21.
89. Eid MMA, Rashed ANZ, El-Meadawy S, Habib MA. Best selected optical fibers with wavelength multiplexing techniques for

minimum bit error rates. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0239 [Epub ahead of print].
90. Alatwi AM, Rashed ANZ, Abd El-Aziz IA. High speed modulated wavelength division optical fiber transmission systems performance signature. TELKOMNIKA Telecommun Comput Electron Control 2021;19:380–9.
91. Eid MMA, Rashed ANZ, El-gammal EM, Delwar TS, Ryu JY. The influence of electrical filters with sequence generators on optical ISL performance evolution with suitable data rates. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0257 [Epub ahead of print].
92. Alatwi AM, Rashed ANZ, Parvez AHMS, Paul BK, Ahmed K. Beam divergence and operating wavelength bands effects on free space optics communication channels in local access networks. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0276 [Epub ahead of print].
93. Shafkat A, Rashed ANZ, El-Hageen HM, Alatwi AM. The effects of adding different adhesive layers with a microstructure fiber sensor based on surface plasmon resonance: a numerical study. Plasmonics 2021;55:167–78.
94. Eid MMA, Rashed ANZ. Fiber optic propagation problems and signal bandwidth measurements under high temperature and high dopant germanium ratios. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0278 [Epub ahead of print].
95. Eid MMA, Rashed ANZ. Simulative and analytical methods of bidirectional EDFA amplifiers in optical communication links in the optimum case. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0193 [Epub ahead of print].
96. Eid MMA, Shehata E, Rashed ANZ. Cascaded stages of parametric optical fiber amplifiers with Raman fiber amplifiers for upgrading of telecommunication networks through optical wireless communication channel. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0279 [Epub ahead of print].
97. Eid MMA, Mohammed AE-NA, Rashed ANZ. Simulative study on the cascaded stages of traveling wave semiconductor optical amplifiers based multiplexing schemes for fiber optic systems improvement. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0281 [Epub ahead of print].
98. Parvin T, Ahmed K, Alatwi AM, Rashed ANZ. Differential optical absorption spectroscopy based refractive index sensor for cancer cell detection. Opt Rev 2021;67:564–73.
99. Eid MMA, Said SM, Rashed ANZ. Gain/noise figure spectra of average power model Raman optical amplifiers in coarse wavelength multiplexed systems. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0289 [Epub ahead of print].
100. Eid MMA, Rashed ANZ, Ahammad MS, Paul BK, Ahmed K. The effects of Tx./Rx. pointing errors on the performance efficiency of local area optical wireless communication networks. J Opt Commun 2020. https://doi.org/10.1515/joc-2019-0256 [Epub ahead of print].
101. Eid MMA, Abd El-Hamid HS, Rashed ANZ. High-speed fiber system capacity with bidirectional Er-Yb CDFs based on differential phase shift keying (DPSK) modulation technique. J Opt Commun 2020. https://doi.org/10.1515/joc-2021-0001 [Epub ahead of print].
102. Eid MMA, Ibrahim A, Rashed ANZ. In line and post erbium-doped fiber amplifiers with ideal dispersion compensation fiber Bragg grating for upgrading optical access networks. J Opt Commun 2020. https://doi.org/10.1515/joc-2020-0306 [Epub ahead of print].
103. Tahhan SR, Taha RM. Mercedes Benz logo based plasmon resonance PCF sensor. Sens Bio-Sens Res 2022;35:100468.
104. Tahhan SR, Atieh A, Hasan M, Hall T. Characterization and experimental verification of actively mode-locked erbium doped fiber laser utilizing ring cavity. TM - Tech Mess 2020;87: 535–41.
105. Tahhan SR, Abass AK, Ali MH. Characteristics of chirped fiber bragg grating dispersion compensator utilizing two apodization profiles. J Commun 2018;13:108–13.
106. Tahhan SR, Atieh A, Ali MH, Hasan M, Abass AK, Hall T. Characteristics of actively mode-locked erbium doped fiber laser utilizing ring cavity. In: 2019 IEEE Jordan international joint conference on electrical engineering and information technology (JEEIT). Amman, Jordan; 2019:840–4 pp.
107. Fadil EA, Abass AK, Tahhan SR. Secure WDM-free space optical communication system based optical chaotic. Opt Quant Electron 2022;54:477.
108. Tahhan SR, Mohammed MF, Moosa AA, Atieh A. WDM ROF OFDM/QAM system for wireless PON. In: 2021 IEEE jordan international joint conference on electrical engineering and information technology (JEEIT). Amman, Jordan; 2021:164–9 pp.
109. Tahhan SR, Ghazai AJ, Alwan IM, Ali MH. Investigation of the characteristics of high-resistivity silica based hybrid porous core photonic crystal fiber for terahertz wave guidance. Dig J Nanomater Biostruct 2019;14:831–41.
110. Singh M, Malhotra J. Performance comparison of different modulation schemes in high-speed MDM based radio over FSO transmission link under the effect of atmospheric turbulence using aperture averaging. Wireless Pers Commun 2020;111: 825–42.
111. Singh M, Malhotra J. Modeling and performance analysis of 400 gbps CO-ofdm based inter-satellite optical wireless communication (IsOWC) system incorporating polarization division multiplexing with enhanced detection. Wireless Pers Commun 2020;111:495–511.
112. Singh M, Malhotra J. Performance comparison of 2×20 gbps-40 GHz OFDM based RoFSO transmission link incorporating MDM of hermite Gaussian modes using different modulation schemes. Wireless Pers Commun 2020;110:699–711.
113. Singh M, Malhotra J. Performance investigation of high-speed FSO transmission system under the influence of different atmospheric conditions incorporating 3-D orthogonal modulation scheme. Opt Quant Electron 2019;51:285.
114. Singh M, Malhotra J. 4×20 Gbit/s-40 GHz OFDM based Radio over FSO transmission link incorporating hybrid wavelength division multiplexing-mode division multiplexing of LG and HG modes with enhanced detection. Optoelectron Adv Mater Rapid Commun 2020;14:233–43.
115. Singh M, Malhotra J. 40 Gbit/s-80 GHz hybrid MDM-OFDM-Multibeam based RoFSO transmission link under the effect of adverse weather conditions with enhanced detection. Optoelectron Adv Mater Rapid Commun 2019;14:146–53.
116. Al-Khaffaf DAJ, Rashid Hujijo HS. High data rate optical wireless communication system using millimeter wave and optical phase modulation. ARPN J Eng Appl Sci 2018;13:9086–92.
117. Al-Khaffaf DAJ, Alshimaysawe IA. Miniaturised tri-band microstrip patch antenna design for radio and millimetre waves of 5G devices. Indones J Electr Eng Comput Sci 2021;21: 1594–601.

118. Al-Khaffaf DAJ, Alsahlany AM. A cloud VLC access point design for 5G and beyond. Opt Quant Electron 2021;53:472–81.
119. Rashed ANZ. High reliability optical interconnections for short range applications in high speed optical communication systems. J Opt Laser Technol 2013;48:302–8.
120. Rashed ANZ. High performance photonic devices for multiplexing/demultiplexing applications in multi band operating regions. J Comput Theor Nanosci 2012;9:522–31.
121. Rashed ANZ, Sharshar HA. Analysis of transmission line feed method for transparent conductor oxide materials based optical microstrip patch antennas design. OAMRC 2012;6:980–7.
122. Rashed ANZ, Metwae'e MA. Operation performance characteristics of vertical cavity surface emitting lasers (VCSELs) under high thermal neutrons irradiated fields. J Russ Laser Res 2013;34:1–8.
123. Rashed ANZ. Optical fiber communication cables systems performance under harmful gamma irradiation and thermal environment effects. IET Commun 2013;7:448–55.
124. Rashed ANZ, El-halawany MME. Transmission characteristics evaluation under bad weather conditions in optical wireless links with different optical transmission windows. Wireless Pers Commun 2013;71:1577–95.
125. Rashed ANZ, Sharshar H. Performance evaluation of short range underwater optical wireless communications for different ocean water types. Wireless Pers Commun 2013;72:693–708.
126. Daher MG, Jaroszewicz Z, Zyoud SH, Panda A, Ahammad SKH, Abd-Elnaby M, et al. Design of a novel detector based on photonic crystal nanostructure for ultra high performance detection of cells with diabetes. Opt Quant Electron 2022;54:701.
127. Smirani LK, Rashed ANZ, Ahammad SKH, Hossain MA, Daher MG, Fahmy E. Conventional/linear/Lorentzian material gain semiconductor optical amplifiers performance signature with four wave mixing (FWM) nonlinearity in optical fiber communication systems. J Opt Commun 2022. https://doi.org/10.1515/joc-2022-0147 [Epub ahead of print].
128. Smirani LK, Kumari M, Ahammad SKH, Hossain MA, Daher MG, Rashed ANZ, et al. Signal quality enhancement in multiplexed communication systems based on the simulation model of the optimum technical specifications of Raman fiber optical amplifiers. J Opt Commun 2022. https://doi.org/10.1515/joc-2022-0129 [Epub ahead of print].
129. Smirani LK, Ahammad SKH, Daher MG, Hossain MA, Rashed ANZ, Aabdelhamid HS. Optical transceiver communication systems performance evaluation based on nonlinear cross gain modulation effects. J Opt Commun 2022. https://doi.org/10.1515/joc-2022-0134 [Epub ahead of print].
130. Smirani LK, Abd El-Aziz IA, Ahammad SKH, Hossain MA, Daher MG, Rashed ANZ. Low loss flexibility and high efficiency of radio per fiber system for modern wireless communication system. J Opt Commun 2022. https://doi.org/10.1515/joc-2022-0145 [Epub ahead of print].