

Hybrid CPFSK/OQPSK modulation transmission techniques' performance efficiency with RZ line coding based fiber systems in passive optical networks

Aadel M. Alatwi¹, Ahmed Nabih Zaki Rashed²

¹Electrical Engineering Department, Faculty of Engineering, University of Tabuk, Tabuk, Saudi Arabia

²Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia University, Egypt

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ABSTRACT

This study shows hybrid continuous-phase frequency shift keying (CPFSK)/optical quadrature-phase shift keying (OQPSK) modulation transmission techniques' performance efficiency with return-to-zero (RZ) line coding scheme based fiber systems in passive optical networks. Max. Q factor/min. bit error rate variations versus modulation frequency and fiber length are studied in detail for various bits/symbol, based on hybrid proposed modulation transmission techniques. Also, optical power and received electrical power variations are simulated with fiber-length variations at a specified modulation frequency of 300GHz. Max. Q Factor, min. BER, max. signal power, and min. noise power variations are based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency of 500GHz through a fiber length of 30km.

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Corresponding Author:

Ahmed Nabih Zaki Rashed
Faculty of Electronic Engineering
Menoufia University
Menouf 32951, Menouf, Egypt
E-mail: ahmed_733@yahoo.com

1. INTRODUCTION

Equalization can significantly help increase the overall communication bandwidth over copper channels with a severe frequency-dependent loss [1-5]. As the communication distance grows while the bandwidth requirement keeps scaling [6-8], equalized channels exceed the power envelope and become inadequate for delivering the required data in a power-efficient manner [9-13]. The optical transmitter and receiver electronics' power consumption and area can limit the number of possible on-chip interconnections. An example of such limitation is board-to-board communication in data centers and high-performance computers [14-19]. A promising solution to this IO bandwidth requirement is the use of optical signaling [20-23].

The primary motivation for such a radical input/output architecture modification as optical signaling is the magnitude of potential bandwidth that occurs with an optical channel. In conventional optical data transmission, data is transmitted by modulating the high-frequency optical carrier signal's optical intensity or amplitude. In order to achieve high fidelity over the most common optical channels that is, optical fiber high-speed optical communication systems typically use infrared light from source lasers with wavelengths ranging from 850nm to 1.550nm [24-34].

2. MODEL DESCRIPTION AND RESEARCH METHOD

Figure 1 shows the basic simulation model for the proposed model. The electrical modulators namely, electrical CPFSK/OQPSK are combined together to modulate the user-defined data generators' two stream bits sequences. CPFSK is employed with different bits per symbol: 8 bits/symbol, 16 bits/symbol, and 16 bits/symbol, respectively. The carrier signal is generated from a directly modulated laser measured with a frequency of 193.1 THz, a power of 10 mW, and an extinction ratio of 10 dB. Data sequences' stream bits are encoded with an RZ coding line. The modulated electrical signal with the modulated carrier signal is injected into LiNbO₃ electro-optic modulators.

The modulated electro-optic signal is injected into a fiber cable with a length of 30 km. An optical power meter is used to show the total power through the fiber cable. Signal power levels versus time/wavelength are shown using optical time domain/optical spectrum analyzers. The Bessel light filter is used to filter the modulated light signal from the ripples, which are then converted to the electrical signal form through APD photo-detectors. The low-pass Bessel filter is used to show the modulated electrical signal from the noise (unwanted signals with high frequencies). The signal is modified (retiming, reshaping), and the max. Q factor and min. data error rate can be calculated through eye diagram analyzers.

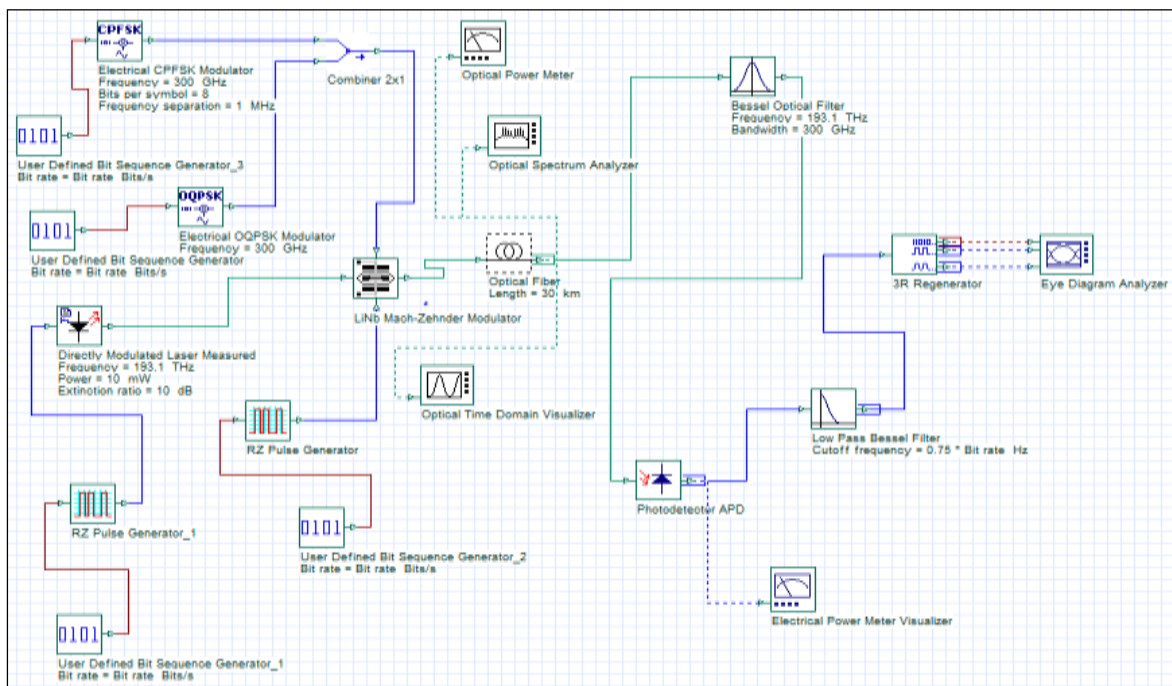


Figure 1. Proposed simulation model description

3. PERFORMANCE ANALYSIS WITH DISCUSSIONS

The optical power and received electrical power variations are simulated with fiber length variations at a specified modulation frequency of 300GHz. Max. Q Factor, min. BER, max. signal power, and min. noise power variations are based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency of 500GHz through a fiber length 30km. All the results are assured, depending upon the variables in Table 1.

Figure 2 shows the max. Q Factor variations based on hybrid modulation techniques for CPFSK/OQPSK of 16 and 32 bits/symbol with modulation frequency variations through a fiber length of 30km. The max. Q factor is 18.12 with CPFSK/OQPSK of 16 bits/symbol and 24.65 with CPFSK/OQPSK of 32 bits/symbol at a modulation frequency of 300MHz. Moreover, the max. Q factor is 24.12 with CPFSK/OQPSK of 16 bits/symbol and 22.14 with CPFSK/OQPSK of 32 bits/symbol at a modulation frequency of 400MHz. Additionally, the max. Q factor is 32.97 with CPFSK/OQPSK of 16 bits/symbol and 32.675 with CPFSK/OQPSK of 32 bits/symbol at a modulation frequency of 500MHz. The max. Q factor is 10.14 with CPFSK/OQPSK of 16 bits/symbol and 20.15 with CPFSK/OQPSK of 32 bits/symbol at a modulation frequency of 600MHz.

Table 1. Variables used in this work

Variables	Values/Units
Laser Source Specifications	
Frequency	193.1 THz
Power	10 mW
Extinction ratio	10 dB
Bit rate	10 Gb/s
Threshold current	20 mA
Electrical Modulators Specifications	
Modulation frequency	300 GHz-600 GHz
Bits/symbol	8, 16, 32
Frequency separation	1 MHz
Fiber Specifications	
Loss	0.2 dB/km
Length	30 km
Wavelength	1550 nm
Dispersion	16.75 ps/nm.km
Differential group delay	0.2 ps/km
Receiver Specifications	
APD photodetector	
Ionization ratio	0.9
Responsivity	1 A/W

Figure 3 depicts the max. Q factor variations based on hybrid modulation techniques for CPFSK/OQPSK of 8, 16, and 32 bits/symbol with a modulation frequency 300GHz through fiber length variations. The max. Q factor is 13 with CPFSK/OQPSK of 8 bits/symbol, 24 with CPFSK/OQPSK of 16 bits/symbol, and 40 with CPFSK/OQPSK of 32 bits/symbol at a distance of 5km. The max. Q factor is 12.32 with CPFSK/OQPSK of 8 bits/symbol, 21 with CPFSK/OQPSK of 16 bits/symbol, and 30 with CPFSK/OQPSK of 32 bits/symbol at a distance of 20km. The max. Q factor is 11.79 with CPFSK/OQPSK of 8 bits/symbol, 18 with CPFSK/OQPSK of 16 bits/symbol, and 24.74 with CPFSK/OQPSK of 32 bits/symbol at a distance of 30km. The graph shows that the max. Q factor degrades with an increase in distance.

Figure 4 indicates the optical power variations based on hybrid modulation techniques for CPFSK/OQPSK of 8, 16, and 32 bits/symbol with a modulation frequency of 300GHz through fiber length variations. The optical power is 0.668mW with CPFSK/OQPSK of 8 bits/symbol, 0.6mW with CPFSK/OQPSK of 16 bits/symbol, and 0.56mW with CPFSK/OQPSK of 32 bits/symbol at a distance of 5km. The optical power is 0.342mW with CPFSK/OQPSK of 8 bits/symbol, 0.312mW with CPFSK/OQPSK of 16 bits/symbol, and 0.3mW with CPFSK/OQPSK of 32 bits/symbol at a distance of 20km. The optical power is 0.1986mW with CPFSK/OQPSK of 8 bits/symbol, 0.19mW with CPFSK/OQPSK of 16 bits/symbol, and 0.18mW with CPFSK/OQPSK of 32 bits/symbol at a distance of 30km. The graph confirms that the optical power degrades with an increase in distance.

Figure 5 demonstrates the received electrical power variations based on hybrid modulation techniques for CPFSK/OQPSK of 8, 16, and 32 bits/symbol with a modulation frequency of 300GHz through fiber length variations. The electrical power is 10 μ W with CPFSK/OQPSK of 8 bits/symbol, 9.23 μ W with CPFSK/OQPSK of 16 bits/symbol, and 8.65 μ W with CPFSK/OQPSK of 32 bits/symbol at a distance of 5 km. The electrical power is 5.54 μ W with CPFSK/OQPSK of 8 bits/symbol, 4 μ W with CPFSK/OQPSK of 16 bits/symbol, and 3 μ W with CPFSK/OQPSK of 32 bits/symbol at a distance of 20 km. The electrical power is 0.633 μ W with CPFSK/OQPSK of 8 bits/symbol, 0.6 μ W with CPFSK/OQPSK of 16 bits/symbol, and 0.5 μ W with CPFSK/OQPSK of 32 bits/symbol at a distance of 30km. The graph shows that the electrical power degrades with an increase in distance.

Figure 6 depicts the max. Q factor and min. BER values based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency of 500GHz through a fiber length of 30km. The max. Q factor is 32.675 with a min. bit error rate of 1.74×10^{-234} . Figure 7 illustrates the max. signal power and min. noise power variations with wavelength variations based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency of 500 GHz through a fiber length of 30km. The max. signal power is -6.798dBm, and the max. noise power is -104.438dBm. Figure 8 indicates the max. signal power and min. noise power variations with time variations based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency 500GHz through a fiber length of 30km. The max. signal power is 0.0010494, and the min. noise power is -4.977×10^{-5} .

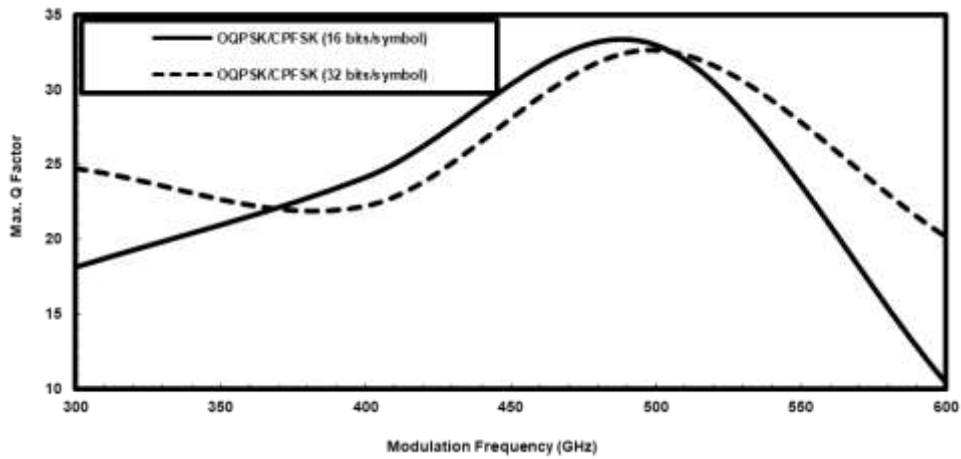


Figure 2. Max. Q Factor variations based hybrid modulation techniques CPFSK/OQPSK (16, 32 bits/symbol) with modulation frequency variations through fiber length (30km)

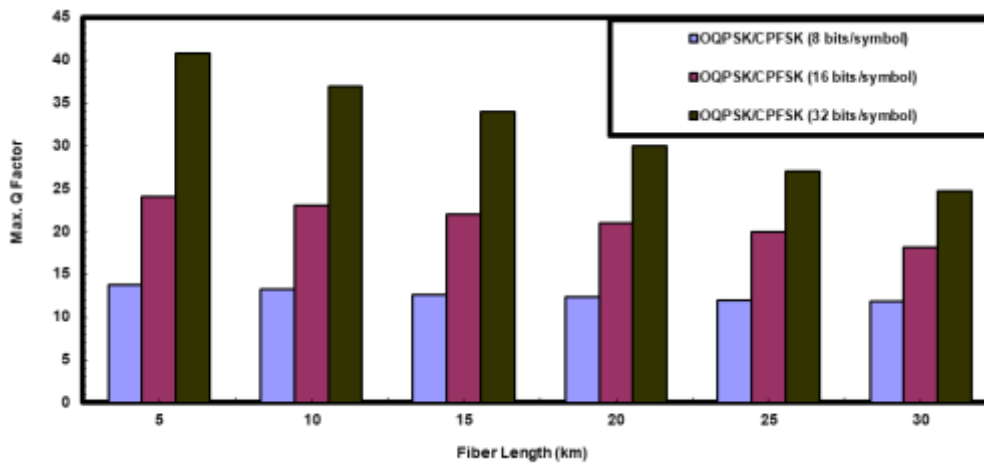


Figure 3. Max. Q Factor variations based hybrid modulation techniques CPFSK/OQPSK (8, 16, 32 bits/symbol) with modulation frequency (300GHz) through fiber length variations

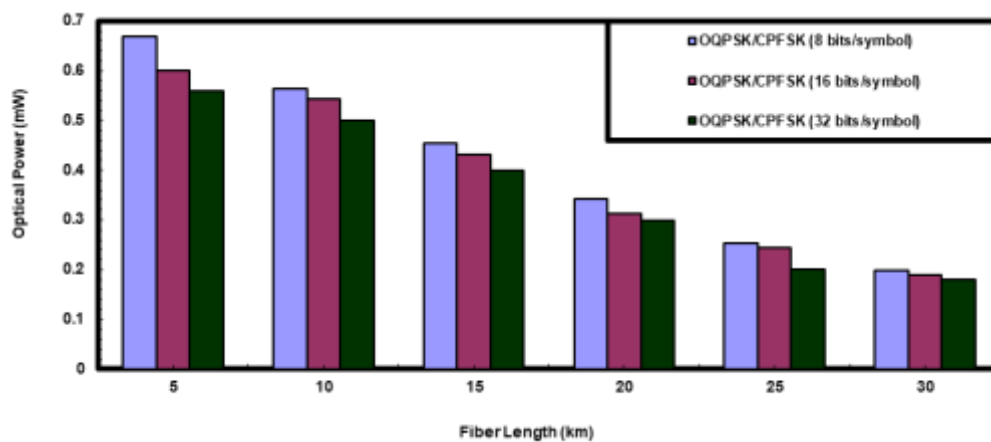


Figure 4. Optical power variations based hybrid modulation techniques CPFSK/OQPSK (8, 16, 32 bits/symbol) with modulation frequency (300GHz) through fiber length variations

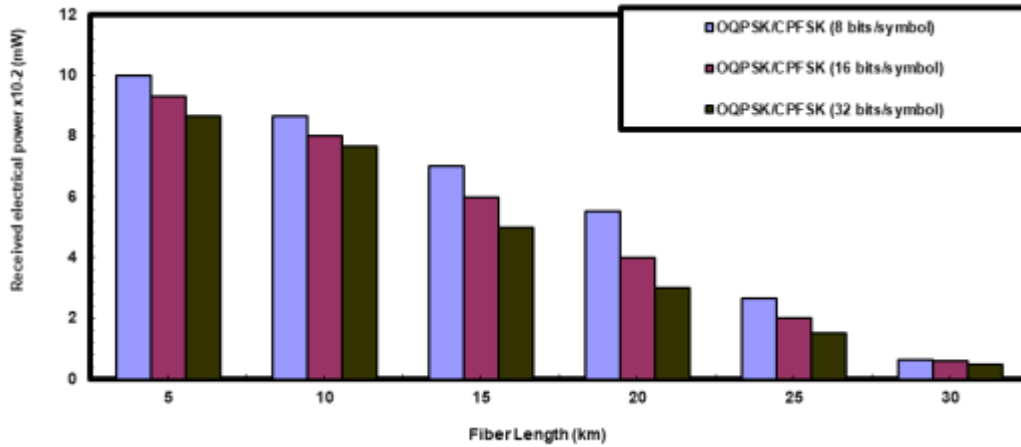


Figure 5. Received electrical power variations based hybrid modulation techniques CPFSK/OQPSK (8, 16, 32 bits/symbol) with modulation frequency (300GHz) through fiber length variations

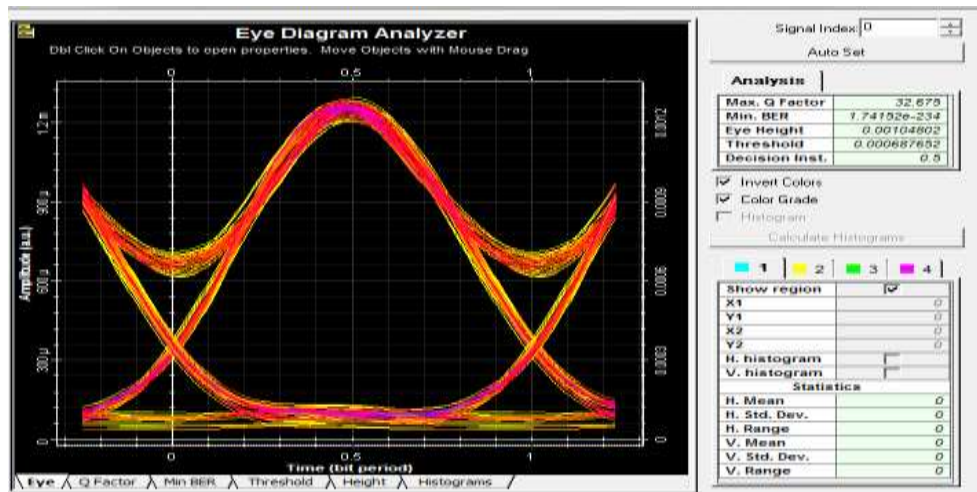


Figure 6. Max. Q Factor and min. BER values based hybrid modulation techniques CPFSK/OQPSK (32 bits/symbol) and modulation frequency (50GHz) through fiber length (3km)

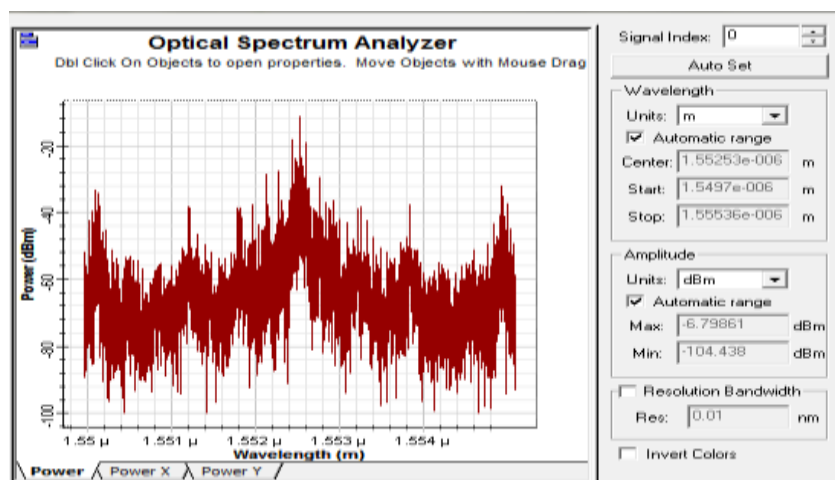


Figure 7. Max. signal power and min. noise power variations with wavelength variations based hybrid modulation techniques CPFSK/OQPSK (32 bits/symbol) and modulation frequency (50GHz) through fiber length (3km)

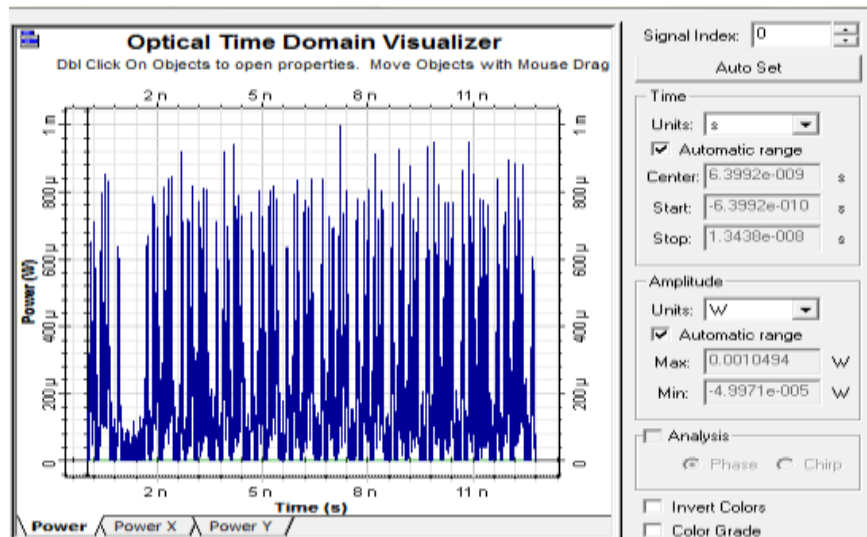


Figure 8. Max. signal power and min. noise power variations with time variations based hybrid modulation techniques CPFSK/OQPSK (32 bits/symbol) and modulation frequency (50GHz) through fiber length (3km)

4. CONCLUSION

This study has demonstrated the positive engagement between the CPFSK/OQPSK modulation transmission techniques for upgrading fiber systems in passive optical networks. The max. signal power, max. Q factor, and min. noise power variations with time/spectral wavelength variations are simulated and estimated based on hybrid modulation techniques for CPFSK/OQPSK of 32 bits/symbol and a modulation frequency of 500GHz through a fiber length of 30km. As well as optical power, received electrical power variations are simulated and studied based on hybrid modulation techniques for CPFSK/OQPSK of 8, 16, and 32 bits/symbol with a modulation frequency of 300GHz through fiber length variations. Max. Q factor variations have been studied and sketched based on hybrid modulation techniques for CPFSK/OQPSK of 16 and 32 bits/symbol with a modulation frequency/fiber length variation at a specified modulation frequency/fiber length. The max. Q factor is enhanced with a modulation frequency of 500MHz and a 32 bits/symbol CPFSK modulation transmission technique.

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BIOGRAPHIES OF AUTHORS



Dr. Aadel Alatwi was born in Tabuk, Saudi Arabia, in 1980. He received the B.S. degree from King Abdul-Aziz University, Jeddah, Saudi Arabia, in 2004, the M.S. and Ph.D degrees from Griffith University, Brisbane, Australia, in 2008 and 2018 respectively, both in communication engineering. He is currently assistant professor in the School of Engineering at Tabuk University, Tabuk, Saudi Arabia. His current research interests include speech coding, speech and speaker recognition, speech enhancement, face recognition, image coding, pattern recognition and artificial neural networks. His email: aadel.alatwi@ut.edu.sa.



Assoc. Prof. Ahmed Nabih Zaki Rashed was born in Menouf city, Menoufia State, Egypt country in 23 July 1976. Received the B.Sc., M.Sc., and Ph.D. scientific degrees in the Electronics and Electrical Communications Engineering Department from Faculty of Electronic Engineering, Menoufia University in 1999, 2005, and 2010 respectively. Currently, his job carrier is a scientific lecturer in Electronics and Electrical Communications Engineering Department, Faculty of Electronic Engineering, Menoufia university, Menouf. Postal Menouf city code: 32951, EGYPT. His scientific master science thesis has focused on polymer fibers in optical access communication systems. Moreover, his scientific Ph. D. thesis has focused on recent applications in linear or nonlinear passive or active in optical networks. His interesting research mainly focuses on transmission capacity, a data rate product and long transmission distances of passive and active optical communication networks, wireless communication, radio over fiber communication systems, and optical network security and management. He has published more than 220 published scientific papers in international journals and conferences. He has published many high scientific research papers in high quality and technical international journals in the field of advanced communication systems, optoelectronic devices, and passive optical access communication networks. His areas of interest and experience in optical communication systems advanced optical communication networks, wireless optical access networks, analog communication systems, optical filters and Sensors. As well as he is editorial board member in high academic scientific International research Journals. Moreover, he is a reviewer member in high impact scientific research international journals in the field of electronics, electrical communication systems, optoelectronics, information technology and advanced optical communication systems and networks. His personal electronic mail ID (E-mail: ahmed_733@yahoo.com). His published paper under the title "High reliability optical interconnections for short range applications in high performance optical communication systems" in Optics and Laser Technology, Elsevier Publisher has achieved most popular download articles in 2013.