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Advances in Adaptive Filtering for Coherent Dual-Polarization Optical Communication Systems and Their Integration in Dynamic Optical Networks

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***Abstract* - A thorough examination of current developments in adaptive filtering for coherent dual-polarization optical communication systems is provided in this work. The emphasis is on high-capacity networks made possible by dual-polarization, coherent detection, variable bit-rate transceivers. The review explores the effectiveness of different adaptive algorithms in coherent receivers, the importance of dual polarization, and the function of adaptive filters in reducing channel impairments. The research also sheds light on the trade-offs and difficulties related to flexible bitrate optical transceivers. The paper comprises an extensive assessment of dynamic optical networks, categorized by network granularity and generation, in addition to the study of adaptive filtering. A comprehensive understanding of the developments in dynamic optical networking technologies is provided by the discussion of the evolution and traits of each generation. The poll also covers optical access networks, emphasizing the acceptance and advantages of optical access protocols as IEEE EPON and ITU-T GPON. The study also examines how digital filtering might be used to manage transmission constraints, highlighting the significance of segmenting digital filtering into distinct blocks. An overview of the types and applications of optical filters utilized in optical communication systems is included in the discussion. The study wraps up with a review of the literature that summarizes current research on optical communication systems, such as studies on adaptive algorithms' convergence properties, coherent dual-polarization receivers, and machine learning's use in optical fiber communication. The contributions of this paper include a thorough analysis of adaptive algorithm performance, a comparative study of dynamic optical networks, and a comprehensive overview of recent research in optical communication systems.**

Keywords: Adaptive Filtering, Dynamic Optical Networks, Optical Access Networks, Digital Filtering, Optical Filters, Fiber Optic Receivers.

I. INTRODUCTION

Modern optical telecommunications systems are required to manage higher data rates and the increasing number of internet-connected devices as the cloud computing era progresses. This survey explores the advances in this area with a particular emphasis on high-capacity networks enabled by variable bit-rate transceivers with dual polarization and coherent detection [1].

Dual polarization, which was first introduced in [2], is crucial since it practically doubles the data rate when compared to single polarization methods. The adaptive filter, which is essential for equalization to rectify time-varying states of polarization (SOP) and other linear channel impairments, is the cornerstone of dual-polarization communication systems. Comprehending the convergence and tracking efficacy of these adaptive filters is crucial to grasping the constraints of the system [3].

The types of impairments seen in optical channels are a combination of stochastic and deterministic [4]. For example, chromatic dispersion (CD) is a stochastic impairment, whereas polarization mode dispersion (PMD), polarization-dependent loss (PDL), and SOP are deterministic ones. A dual-polarization optical signal is a rotational copy of the optical signal that was delivered, carrying amplitude and phase information in two orthogonal polarizations (X and Y) [5].

In order to separate the two polarizations from the received rotated optical signal, linear adaptive filters can be used, provided that the rotation caused by the channel is either static or gradually varying. The impacts of channel rotation have been lessened by the use of algorithms like constant modulus algorithm (CMA) [6], normalized least mean squares (NLMS), and classical least mean squares (LMS) [7].

The performance of recursive least squares (RLS), constant modulus algorithm (MMA), LMS, and NLMS adaptive filters in coherent receivers for dual-polarization optical signals is examined in this survey. The study takes into account the existence of optical filters, PDL, and SOP

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transients and offers insightful information about how these factors affect system performance [8].

Furthermore, the assessment examines related research on adaptive filtering in coherent receivers and provides a summary of the primary causes of SOP transients in optical communications. In the context of developing programmable optical networks, it presents the idea of adjustable bitrate transponders [4].

A theoretical overview of adaptive filtering and coherent receivers is provided in the following sections, which are followed by information about the simulation environment. A comparative analysis of adaptive algorithms in terms of convergence speed and signal-to-noise ratio (SNR) penalty for various SOP transient speeds is presented in the survey's conclusion, along with simulation results that highlight the impact of SOP rate of change on relative signal-to-noise ratio (RSNR) penalty and the trade-off between back-to-back link configuration and PDL penalty versus SOP tracking capabilities.

The main contributions of this survey are as follows: it provides a thorough analysis and simulation of adaptive algorithm performance in the presence of colored noise and SOP transients; it illustrates the tradeoff between equalizing static and fast variant channels; and it thoroughly studies SOP tracking in the context of flexible bit rate optical transceivers with realistic hardware limitations.

II. INTRODUCTION TO DYNAMIC OPTICAL NETWORKS

Table (1) below provides an overview of dynamic optical networks, categorized by their respective generations and network granularities. Each generation introduces new features and technologies, addressing challenges present in the previous ones. The network granularities, namely Optical Circuit Switching (WRONs), Optical Packet Switching (OPS), and Optical Burst Switching (OBS), exhibit distinct characteristics with associated advantages and disadvantages. This comprehensive classification aids in understanding the evolution and key attributes of dynamic optical networking technologies [9].

Table 1: Evaluation and Characteristics of Dynamic Optical Networks

Dynamic Network Generation	Characteristics and Technologies	Advantages	Disadvantages
Zero Generation [10]	• Point-to-point networks with one wavelength channel per fiber. • O/E/O converters on every node. • SDH/SONET with ATM virtual circuits.	• Simple design and operation. • No intrinsic delay. • Continuous-mode transmission.	• Requires a priori traffic matrix. • Limited adaptability to changing traffic. • Global optimization may be slow. • Network reconfiguration disruption. • Lightpath granularity.
First Generation [11]	• Emerged in the late 1990s. • WDM deployment in point-to-point links. • O/E/O converters at every node. • Increased use of optics. • SDH protocol with ring topologies. • Introduction of ADM and OXC. • OADMs added flexibility.	• Higher transmission capacity. • Network flexibility with OADMs. • Ring topologies.	• Limited configurability. • OADMs configuration challenges.
Second Generation [12]	• Focus on optical reconfigurability in the optical domain. • Introduction of lightpaths, ROADMs, and WXCs. • Amplifier gain equalization and optical signal monitoring. • Space switching technologies.	• Mitigation of optical signal impairments. • Faster reconfiguration. • Introduction of lightpaths.	• Requires planning tools for circuit changes. • Challenges in core node requirements.
Third Generation [13]	• Integration of data networking entirely into the optical layer. • Fast optical layer switching. • Direct mapping of IP packets into the optical domain. • Introduction of OPS and optical label swapping.	• Increased overall speed and transport capacity. • OPS for store-and-forward routing.	• OPS switching requirements challenges. • Developmental issues in all-optical header processing.
Network Granularity[14][15]	• Optical Circuit Switching (WRONs)	• Simple design and operation.	• Requires a priori traffic matrix.

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		• Offline RWA problem resolution. • No intrinsic delay. • Continuous-mode transmission.	• Limited adaptability to changing traffic. • Global optimization may be slow. • Network reconfiguration disruption. • Lightpath granularity.
	• Optical Packet Switching (OPS)	• Finer granularity for better network utilization. • Reduced power and size footprint. • Maximizes resource utilization. • Optical transparency for heterogeneous tributaries.	• Contention and packet loss in core switches. • Challenging core node requirements. • Enormous optical complexity and cost. • Lack of proper optical technology. • All-optical header processing challenges.
	• Optical Burst Switching (OBS)	• Sub-wavelength granularity. • Relaxed core node switch requirements. • Better network utilization compared to WRONs.	• Contention and burst loss at the edge. • Packet loss within the network core. • Dependencies on wavelength conversion and network connectivity.

III. OPTICAL ACCESS NETWORKS

In the last ten years, optical access networks have become more and more popular, offering a strong substitute for established copper-based broadband technologies such as Asymmetric Digital Subscriber Line (ADSL) [16]. The two main optical access standards, IEEE EPON and ITU-T GPON, provide the foundation for passive optical networks, or PONs, which are optically passive and do not need optical switching or amplification [17].

As seen in Figure 1, a passive optical network functions similarly to older copper-based local area networks (LANs) in that it distributes the optical medium among several users. A passive optical splitter, albeit one with significant insertion losses, facilitates the downstream transmission from the central office to customer residences. All subscribers use the optical medium collectively in the upstream direction, though. An efficient Media Access Control (MAC) protocol, such TDMA, is required to manage this shared resource. In addition, the data is divided into brief packets to reduce network latency. Consequently, dynamic core optical networks and passive optical access networks share a number of physical layer problems, particularly with regard to burst-mode receiver design [18].

IV. FUNCTIONALITY OF THE DIGITAL FILTERING

In order to handle transmission limitations, it is more beneficial to split the digital filtering functionality into two separate blocks, as Figure 1 illustrates. While the second block is devoted to reducing polarization-dependent effects, such as polarization rotations and polarization mode dispersion (PMD), the first block compensates for polarization-independent impairments like chromatic dispersion [19]. Because of their deliberate division, the two blocks can adapt at separate rates. For example, chromatic dispersion may be seen as generally consistent across millisecond duration, although polarization may show change. Furthermore, this method allows for the compensation of large amounts of chromatic dispersion without frequently requiring tap weight adjustments, offering important implementation benefits for the digital signal processing (DSP) framework [20].

Remarkably, this work only discusses linear digital filtering; nonlinear impairments like self-phase modulation or nonlinear phase noise are neither discussed or taken into account when compensating for them. Further nonlinear filtering would be required if it were essential to solve these nonlinear limitations [21].

Nonetheless, this paper's scope is still limited to linear digital filtering, which may be accomplished well with the architecture shown in Figure 3. This architecture works especially well for mitigating linear transmission deficiencies caused from PMD and chromatic dispersion. Another advantage is that the filters can be implemented directly in the time domain or via rapid convolution techniques in the frequency domain, which helps to reduce the DSP system's overall complexity [22].

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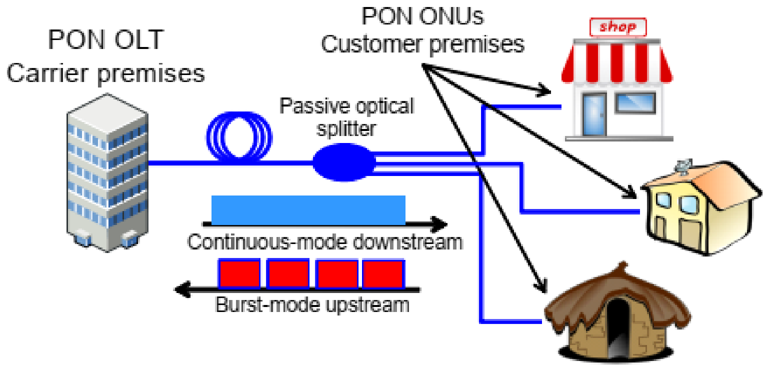

Figure 1: A diagram of a typical passive optical network

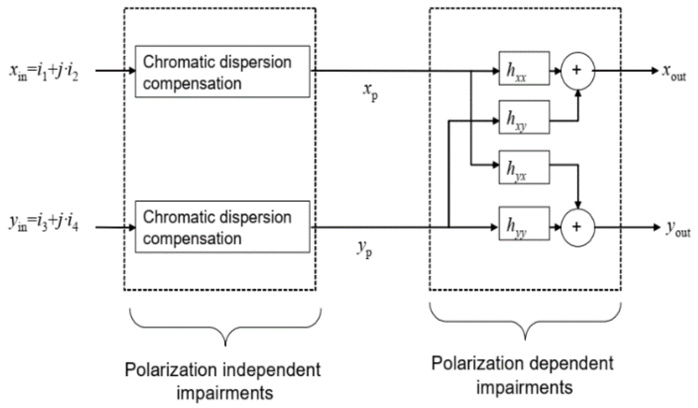

Figure 2: Illustrates the operational aspects of the digital filtering stage. In the context of linear filtering, it is important to note that the order of the two sub blocks can be reversed as needed

V. SUBMISSION OPTICAL FILTERS IN OPTICAL COMMUNICATION SYSTEMS

An overview of the several filters used in optical communication in Table (2). In order to shape, improve, and optimize optical signals for dependable data transfer, these filters are essential. Every filter type has a distinct function in handling issues including interference, dispersion, and polarization effects, from wavelength selection to digital signal processing [23].

Table II: Optical Filters in Optical Communication Systems [23][24][25]

Filter Type	Realistic Application
Color Imaging Filter	Controls spectral properties of light for color imaging
Blue Band Pass Filter	Improves contrast in low contrast scenarios
Infrared Band Pass Filter	Removes interference in barcode backgrounds
Short Pass Filter	Blocks infrared emitted heat in production processes
Band Pass Filter	Eliminates noise in fluorescence microscopes, eye protection from laser radiation, sunglasses
Thin-Film Optical Filters	Improves transmission, blocking, and wavefront properties for bright, high-contrast images
Multispectral Optical Filter Assembly	Used in linear and planar-array CMOS detectors, medical instrumentation, commercial, government, and aerospace applications
Long Wave Infrared (LWIR) Optical Filters	Ideal for gas sensing and thermal imaging

5.1 Digital filters in optical receivers

In the field of fiber optic receivers, digital filters (Table 3) are essential for improving the overall efficiency of optical communication networks. A receiver's main job in fiber optic communication is to translate incoming optical signals into electrical signals so that they can be processed further. An integral part of this signal processing chain is digital filters. They play a major role in minimizing different kinds of impairments and enhancing the quality of the received signal [26].

Equalization is a crucial area in which digital filters are used in fiber optic receivers. Signal quality might deteriorate

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as a result of distortions and attenuations introduced by fiber optic lines. Digital filters are highly skilled in mitigating these distortions, guaranteeing that the received signal accurately replicates the original data that was transmitted. Digital filters have the ability to efficiently mitigate the effects of dispersion and other channel impairments through the utilization of advanced algorithms and adaptive filtering techniques [27].

Additionally, the signal-to-noise ratio of the entire system and the sensitivity of the receiver are enhanced by digital filters. They are essential for suppressing noise because they separate the signal from other interference and background noise. This is especially important in high-speed optical communication systems since data integrity during transmission is crucial [28].

VI. MATCH FILTER IN OPTICAL RECEIVERS

Match filters are frequently employed in optical communication systems to enhance transmitted signal detection. By matching the received signal with a known reference waveform, a signal processing method called matched filtering maximizes the signal-to-noise ratio (SNR). The possibility of accurately recognizing the transmitted information is increased thanks to this technique. let's delve into the mathematical aspects of matched filtering in optical receivers [36].

Mathematical Representation of Matched Filter: Let s(t) be the transmitted signal and h(t) be the impulse response of the matched filter. The output, y(t), is obtained by convolving the received signal, r(t), with the matched filter impulse response [37]:

$$y(t) = \int_{-\infty}^{\infty} r(t)h(t-\tau)d\tau \quad (1)$$

Correlation Function: The matched filter operation involves correlating the received signal with the reference signal. The correlation function R(τ) is given by:

$$R(\tau) = \int_{-\infty}^{\infty} r(t)s^*(t-\tau)dt \quad (2)$$

Here, $s^*(t)$ is the complex conjugate of the transmitted signal.

Signal Detection and Thresholding: The decision criterion involves comparing the output y(t) with a threshold η:

$$Decision = \begin{cases} 1, & if\, y(t) > \eta \\ 0, & otherwise \end{cases} \quad (3)$$

Optimal Matched Filter Design: The impulse response of the matched filter h(t) is designed to be the time-reversed and conjugate of the transmitted signal s(t):

$$h(t) = s^*(-t) \quad (4)$$

Table III: Digital Filters in optical communication

Digital Filter Type	Application	Characteristics	Description
FIR (Finite Impulse Response) Filter [29]	Signal Equalization, Noise Reduction	No feedback, linear phase characteristics.	Manipulates digital signals with a finite response to impulses. Used for tasks like equalization and noise reduction.
IIR (Infinite Impulse Response) Filter [29]	Signal Processing, Equalization	Feedback loop, more computationally efficient.	Utilizes feedback in its operation, more computationally efficient for certain applications. Used for equalization and processing tasks.
Adaptive Filters [30][31]	Dynamic Signal Processing	Adjusts filter characteristics based on input changes.	Adapts its parameters based on changing signal conditions. Used for dynamic equalization and interference cancellation.
Matched Filter [32]	Signal Detection	Maximizes the signal-to-noise ratio for specific signals.	Optimally matches the filter to the expected signal waveform. Commonly used in signal detection and recognition applications.
Digital Phase-locked Loop (PLL) [33][1]	Clock Recovery, Timing Adjustment	Synchronizes receiver clock with the incoming signal.	Maintains phase and frequency coherence between the receiver and transmitted signal. Used for clock recovery and timing adjustment.
Decision Feedback Equalizer (DFE) [34]	Signal Equalization	Uses feedback from past decisions to mitigate inter symbol interference.	Helps counteract distortions in the received signal caused by symbol interference.
CMA (Constant Modulus Algorithm) [35]	Modulation Format Conversion	Adapts to the constant modulus characteristic of certain signals.	Used for converting signals to a desired modulation format.

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VII. LITERATURE SURVEY

The table provides a comprehensive overview of recent research endeavors in the field of optical communication systems. Researchers have addressed various challenges and explored innovative solutions to enhance system performance and reliability. Each study delves into distinct aspects, ranging from signal tracking and convergence properties to the application of machine learning and advanced modulation techniques. This diversity of research reflects the dynamic nature of optical communication and the constant quest for improved technologies.

In the pursuit of optimizing coherent dual-polarization receivers with QPSK modulation, one study [39]stands out for its focus on tracking State of Polarization (SOP) transients in the presence of Polarization-Dependent Loss (PDL). The achieved SOP tracking, albeit with a slight signal-to-noise ratio penalty, showcases the success of the FPGA implementation and adaptive filter employed.

A comparative study [40]evaluates the convergence properties of Least Mean Squares (LMS) and Recursive Least Squares (RLS) algorithms in Spatial Division Multiplexing (SDM) systems. The findings highlight the superior convergence properties of the RLS algorithm, contributing valuable insights into algorithm effectiveness, particularly in the context of SDM.

Investigating the impact of error feedback delay in coherent receivers [41], the study utilizes the Constant Modulus Algorithm (CMA) with error feedback delay to address Chromatic Dispersion (CD) effects. While successful in addressing CD effects, the study acknowledges limitations, primarily being specific to CMA and potential gaps in covering all impairments.

Efforts to reduce delay in LMS tap weight updates [42], through pipelining and efficient implementation within the adaptive filter's feedback loop demonstrate an 18% reduction in error signal delay. This research highlights the importance of addressing delay concerns for improved tap weight update speed in adaptive filters.

Kalman filtering's application for SOP tracking with PDL and frequency offset [43], explores a sophisticated approach. The study, however, reveals challenges related to power consumption and fiber model considerations, emphasizing the need for further developments in processing complexity and energy efficiency.

The table also captures research on unique topics, such as the study of CAZAC sequences in long-haul transmission systems [44] and the utilization of Fractional Delay Elements (FDE) for SOP transients tracking in long-haul transmission [45]. These investigations provide specialized insights into the impacts and potential applications of CAZAC sequences and FDE in optical communication systems.

Machine learning's role in optical fiber communication [46] is explored for phase noise recovery and nonlinear noise reduction. This study introduces innovative approaches using principal component-based phase estimation and the K-means algorithm. However, the study acknowledges limitations, emphasizing the need for broader applicability and further verification.

The research findings also extend to visible light communication (reference [33]), where probability-shaping bit loading is employed to increase spectral efficiency and enhance system performance. This study demonstrates improved spectral efficiency under Signal-to-Noise Ratio (SNR) and modulation bandwidth constraints, emphasizing its application in visible light communication scenarios.

Lastly, the investigation into phase noise reduction using optical feedback in mode-locked lasers for coherent Dense Wavelength Division Multiplexing (DWDM) communication [47] showcases the potential of optical feedback. The study narrows the ray width of Mode-Locked Laser (MLL) longitudinal modes and effectively processes single interference signals, indicating the promising use of optical feedback for phase noise reduction in coherent DWDM systems.

Table IV: Research Findings in Optical Communication Systems

Researcher	Problem	Objectives	Method	Results	Strength Points	Limitations
[39]	Coherent dual-polarization receiver with QPSK modulation	Track SOP transients of 5 kHz in the presence of 3 dB PDL	FPGA implementation, adaptive filter	Achieved SOP tracking with 0.5 dB RSNR penalty	FPGA implementation, successful SOP tracking	Limited to QPSK modulation, 2.8 Gb/s data rate
[40]	Comparison of LMS and RLS algorithms in SDM system	Evaluate convergence properties of LMS and RLS algorithms	LMS and RLS algorithms in SDM system with multiple modes	RLS demonstrated superior convergence properties	RLS algorithm effectiveness	Specific to SDM, may not generalize to other systems

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[41]	Effects of error feedback delay using CMA in coherent receiver	Investigate impact of error feedback delay in the presence of CD	CMA with error feedback delay	Explored CD effects, utilized CMA	Addressed CD effects	Limited to CMA, may not cover all impairments
[42]	Pipelining and efficient implementation in adaptive filter feedback loop	Reduce delay in LMS tap weight updates	Pipelining and efficient implementation in the adaptive filter's feedback loop	18% reduction in error signal delay	Improved LMS tap weight update speed	Specific to adaptive filter, may not apply universally
[43]	Kalman filtering for SOP tracking with PDL and frequency offset	Investigate Kalman filtering for SOP tracking	Kalman filtering with PDL and frequency offset	Kalman filtering explored, but challenges with power consumption and fiber model	Explored Kalman filtering	High processing complexity, challenges in power consumption
[44]	CAZAC sequence in long-haul transmission system	Study impact of CAZAC in long-haul transmission system	Analysis of CAZAC sequence as chirp signals	Detailed study on CAZAC's impact in long-haul transmission	Insightful study on CAZAC	Limited to CAZAC sequence, chirp signals
[45]	FDE to track SOP transients in long-haul transmission	Use FDE for SOP transients tracking with QPSK modulation	FDE for SOP tracking in long-haul transmission	Examined SOP tracking with FDE	Focused on FDE for SOP tracking	Ignored other impairments like PDL and optical filtering
[48][49]	SOP transients tracking using FDE with QPSK modulation	Evaluate SOP tracking with different levels of channel estimate averaging	FDE for SOP transients tracking with QPSK modulation	Explored tradeoff between averaging and SOP transients tracking	Analyzed channel estimate averaging tradeoff	Limited to QPSK modulation, back-to-back penalty
[46]	Machine learning-assisted denoising in optical fiber communication	Phase noise recovery and nonlinear noise reduction	Principal component-based phase estimation, K-means algorithm	Improved phase noise recovery and reduced nonlinear noise	Utilization of machine learning for demising	Limited to specific algorithms, may need broader applicability
[50]	Probability-shaping bit loading for visible light communication	Increase spectral efficiency and system performance	Bitloaded discrete multi-tone modulation, advanced modulation format	Higher entropy achieved under SNR and modulation bandwidth constraints	Improved spectral efficiency in visible light communication	Specific to visible light communication, applicability to other systems uncertain
[47]	Mode-locked laser phase noise reduction in coherent DWDM communication	Investigate phase noise reduction using optical feedback	Mode-locked laser with optical feedback	Narrowed ray width of MLL longitudinal modes, effective processing of single interference signals	Utilization of optical feedback for phase noise reduction	Further verification needed for mixed interference signals processing, specific to coherent DWDM communication

VIII. CONCLUSIONS

This research offers a thorough analysis of adaptive filtering in dynamic optical networks and coherent dual-polarization optical communication systems. A more thorough grasp of the changing optical communications environment is made possible by the examination of dynamic optical networks, the study of adaptive algorithms, and the investigation of optical access networks. The intricacy and importance of signal processing in optical networks are highlighted by the division of digital filtering functionality, the function of optical filters, and the significance of digital filters in optical receivers. The review of the literature highlights current research findings and presents a variety of strategies for resolving issues and improving system performance. For those working in the subject of optical communications, including researchers, engineers, and practitioners, this publication is an invaluable resource.

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REFERENCES

[1] W. Shieh and I. Djordjevic, *OFDM for Optical Communications*. 2009. doi: 10.1016/C2009-0-19354-6.

[2] A.V. Lukanenkov, “Experimental Confirmation of the Doubts about Authenticity of Event GW150914,” *J. Appl. Math. Phys.*, vol. 05, no. 02, pp. 538–550, 2017, doi: 10.4236/jamp.2017.52046.

[3] A.A.N. Kolmogorov, W. L. Doyle, and I. Selin, “Interpolation and extrapolation of stationary random sequences.,” 1962. [Online]. Available: https://api.semanticscholar.org/CorpusID:117181677

[4] A. Abdo and C. D’Amours, “Adaptive Filtering in

ISSN (online): 2581-3048
Volume 8, Issue 8, pp 118-127, August-2024
https://doi.org/10.47001/IRJIET/2024.808014

Optical Coherent Flexible Bit-Rate Receivers in the Presence of State-of-Polarization Transients and Colored Noise," *J. Comput. Networks Commun.*, vol. 2019, 2019, doi: 10.1155/2019/2938653.

[5] H. Kogelnik, R. Jopson, and L. Nelson, "Polarization-Mode Dispersion," in *Optical Fiber Telecommunications IVB*, 2002, pp. 725–861. doi: 10.1016/B978-012395173-1/50015-3.

[6] H. Alazki and A. Poznyak, "Robust Model-Free Software Sensors for the HIV/AIDS Infection Process," *Int. J. Mod. Nonlinear Theory Appl.*, vol. 06, no. 02, pp. 39–58, 2017, doi: 10.4236/ijmnta.2017.62004.

[7] S. Bennett, "The emergence of a discipline: Automatic control 1940–1960," *Automatica*, vol. 12, no. 2, pp. 113–121, 1976, doi: https://doi.org/10.1016/0005-1098(76)90075-3.

[8] N. Sireesha, K. Chithra, and T. Sudhakar, "Performance analysis of linear recursive least squares adaptive filter to mitigate multipath effect," *Int. Symp. Ocean Electron. SYMPOL*, vol. 2016-Octob, no. January, 2016, doi: 10.1109/SYMPOL.2015.7581161.

[9] J. M. D. MENDINUETA, "Digital signal processing optical receivers for the mitigation of physical layer impairments in dynamic optical networks," *Thesis*, no. September, p. 163, 2011.

[10] A.A. Salih, M. A. M. Sadeeq, S. R. M. Zeebaree, A. S. Abdulraheem, R. R. Zebari, and O. M. Ahmed, "Evolution of Mobile Wireless Communication to 5G Revolution Artificial Intelligence View project Data Communications and Networking View project Evolution of Mobile Wireless Communication to 5G Revolution," vol. 62, no. June, 2020, [Online]. Available: https://www.researchgate.net/publication/342549960

[11] A.A. Salih, M. A. M. Sadeeq, S. R. M. Zeebaree, A. S. Abdulraheem, R. R. Zebari, and O. M. Ahmed, "Evolution of Mobile Wireless Communication to 5G Revolution Artificial Intelligence View project Data Communications and Networking View project Evolution of Mobile Wireless Communication to 5G Revolution," vol. 62, no. June, 2020.

[12] B. Bhushan, S. Kumar, S. Raghvendra, K. Ishaani, and P. E. 5g, *Springer Tracts in Electrical and Electronics Engineering*. [Online]. Available: https://www.springer.com/us/authors-editors/journal-author/journal-author-hel

[13] H. Hodara and E. Skaljo, "From 1G to 5G," *Fiber Integr. Opt.*, vol. 40, no. 2–3, pp. 85–183, 2021, doi: 10.1080/01468030.2021.1919358.

[14] N. I. Zaidi, M. Hafiz, and M. Yusof, "XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE Data Communication and Networking: Challenges and Solutions".

[15] X. Jing, J. Zhao, Z. Yan, W. Pedrycz, and X. Li, "Granular classifier: Building traffic granules for encrypted traffic classification based on granular computing," *Digit. Commun. Networks*, 2022, doi: 10.1016/j.dcan.2022.12.017.

[16] N. Afraz, F. Slyne, H. Gill, and M. Ruffini, "Evolution of access network sharing and its role in 5G networks," *Appl. Sci.*, vol. 9, no. 21, 2019, doi: 10.3390/app9214566.

[17] K. R. Vemu, S. Bhatnagar, and N. Hemachandra, "Link route pricing for enhanced QoS," *Proc. IEEE Conf. Decis. Control*, vol. 2, no. 2, pp. 1504–1509, 2007, doi: 10.1109/CDC.2007.4434595.

[18] A.Pellacani, M. Graziano, and M. Suatoni, "Design , Development , Validation and Verification of GNC technologies," *Eucass2019*, no. July, p. 28760, 2019, doi: 10.13009/EUCASS2019-38.

[19] P. Henry, "Lightwave primer," *IEEE J. Quantum Electron.*, vol. 21, no. 12, pp. 1862–1879, 1985, doi: 10.1109/JQE.1985.1072601.

[20] S. J. Savory, "Digital filters for coherent optical receivers," *Opt. Express*, vol. 16, no. 2, p. 804, 2008, doi: 10.1364/oe.16.000804.

[21] G. Jacobsen, T. Xu, S. Popov, J. Li, A. T. Friberg, and Y. Zhang, "Receiver implemented RF pilot tone phase noise mitigation in coherent optical nPSK and nQAM systems," *Opt. Express*, vol. 19, no. 15, p. 14487, 2011, doi: 10.1364/oe.19.014487.

[22] J. A. Alvarez-Chavez, R. Sanchez-Lara, J. R. Ek-Ek, H. L. Offerhaus, M. May-Alarcon, and V. Golikov, "Optimum Power in a Multi-Span DWDM System Limited by Non-Linear Effects," *Opt. Photonics J.*, vol. 08, no. 12, pp. 337–347, 2018, doi: 10.4236/opj.2018.812029.

[23] G. Li and J. Li, "A Pulse Shaping Based Optical Transmission System of 128QAM for DWDM with N × 904 Gbps," *Applied Sciences*, vol. 9, no. 5. 2019. doi: 10.3390/app9050988.

[24] M. Mabrouk, "BRAGG GRATING AND FABRY-PEROT FILTERS IN DATA TRANSMISSION BY BRAGG GRATING AND FABRY-PEROT FILTERS," no. July 2009, 2019.

[25] V. L. Kalyani and V. Sharma, "Different types of Optical Filters and their Realistic Application," *J. Manag. Eng. Inf. Technol.*, no. July, 2016.

[26] T. Tanimura and T. Hoshida, "Chapter Six - Deep learning techniques for optical monitoring," A. P. T. Lau and F. N. B. T.-M. L. for F. F.-O. C. S. Khan, Eds., Academic Press, 2022, pp. 141–188. doi: https://doi.org/10.1016/B978-0-32-385227-2.00013-9.

[27] F. Solis, B. T. Reyes, D. A. Morero, and M. R. Hueda,

ISSN (online): 2581-3048
Volume 8, Issue 8, pp 118-127, August-2024
https://doi.org/10.47001/IRJIET/2024.808014

"Error-Backpropagation-Based Background Calibration of TI-ADC for Adaptively Equalized Digital Communication Receivers," *IEEE Access*, vol. 10, no. October, pp. 103013–103027, 2022, doi: 10.1109/ACCESS.2022.3208092.

[28] M. H. Hayes, "Schaum's Outline for Digital Signal Processing," *Digit. Signal Process.*, vol. 1, p. 435, 1999, [Online]. Available: https://courses.e-ce.uth.gr/CE446/schaum.pdf

[29] P. J. Gawthrop and L. Wang, *Infinite-impulse and finite-impulse response filters for continuous-time parameter estimation*, vol. 15, no. 1. IFAC, 2002. doi: 10.3182/20020721-6-es-1901.01006.

[30] X. N. Fernando and A. B. Sesay, "Higher order Adaptive filter Characterization of Microwave Fiber Optic link Nonlinearity," *Opt. Pulse Beam Propag. II*, vol. 3927, no. October, pp. 39–49, 2000, doi: 10.1117/12.382081.

[31] T. Weyrauch, M. A. Vorontsov, J. Gowens, and T. G. Bifano, "Fiber coupling with adaptive optics for free-space optical communication," *Free. Laser Commun. Laser Imaging*, vol. 4489, no. May, pp. 177–184, 2002, doi: 10.1117/12.453227.

[32] R. B. T.-H. of G. E. S. E. Unger, "Chapter 4 - Seismic Active Monitoring System Concept," in *Active Geophysical Monitoring*, vol. 40, Pergamon, 2010, pp. 73–90. doi: https://doi.org/10.1016/S0950-1401(10)04009-7.

[33] W. Shieh and I. Djordjevic, "Chapter 3 - Optical Communication Fundamentals," W. Shieh and I. B. T.-O. for O. C. Djordjevic, Eds., Oxford: Academic Press, 2010, pp. 53–118. doi: https://doi.org/10.1016/B978-0-12-374879-9.00003-4.

[34] W. Yafeng, Y. Hao, Y. Dacheng, and W. Xiang, "Iterative decision feedback equalizer with cyclic detection for DFT-S OFDM system," *Comput. Electr. Eng.*, vol. 36, no. 4, pp. 789–801, 2010, doi: https://doi.org/10.1016/j.compeleceng.2008.11.002.

[35] P. Johannisson, M. Sjödin, M. Karlsson, H. Wymeersch, E. Agrell, and P. A. Andrekson, "Modified constant modulus algorithm for polarization-switched QPSK," *Opt. Express*, vol. 19, no. 8, p. 7734, 2011, doi: 10.1364/oe.19.007734.

[36] S. Zhang and T. R. Gadekallu, "Digital interference signal filtering on laser interface for optical fiber communication," *EAI Endorsed Trans. Scalable Inf. Syst.*, vol. 10, no. 2, pp. 1–11, 2023, doi: 10.4108/eetsis.v10i1.2589.

[37] L. M. Torres, F. J. Cañete, and L. Díez, "Matched Filtering for MIMO Coherent Optical Communications with Mode-Dependent Loss Channels," *Sensors (Basel).*, vol. 22, no. 3, 2022, doi: 10.3390/s22030798.

[38] V. L. Kalyani and V. Sharma, "Different types of Optical Filters and their Realistic Application," *J. Manag. Eng. Inf. Technol.*, vol. 3, no. 3, pp. 2394–8124, 2016.

[39] T. Pfau *et al.*, "32-Krad/s polarization and 3-dB PDL tracking in a realtime digital coherent polarization-multiplexed QPSK receiver," *LEOS Summer Top. Meet.*, pp. 105–106, 2008, doi: 10.1109/LEOSST.2008.4590511.

[40] A.Noori, A. Amphawan, A. Ghazi, and S. A. Aljunid Ghazi, "Dynamic evolving neural fuzzy inference system equalization scheme in mode division multiplexer for optical fiber transmission," *Bull. Electr. Eng. Informatics*, vol. 8, no. 1, pp. 127–135, 2019, doi: 10.11591/eei.v8i1.1399.

[41] W. Yi *et al.*, "Performance of momentum-based frequency-domain MIMO equalizer in the presence of feedback delay," *Opt. Express*, vol. 28, no. 13, p. 19133, 2020, doi: 10.1364/oe.394304.

[42] P. K. Meher and S. Y. Park, "Low adaptation-delay LMS adaptive filter part-I: Introducing a novel multiplication cell," *Midwest Symp. Circuits Syst.*, no. August 2011, 2011, doi: 10.1109/MWSCAS.2011.6026642.

[43] Y. Feng *et al.*, "Joint tracking and equalization scheme for multi-polarization effects in coherent optical communication systems," *Opt. Express*, vol. 24, no. 22, p. 25491, 2016, doi: 10.1364/oe.24.025491.

[44] D. Chu, "Polyphase codes with good periodic correlation properties (Corresp.)," *IEEE Trans. Inf. Theory*, vol. 18, no. 4, pp. 531–532, 1972, doi: 10.1109/TIT.1972.1054840.

[45] M. Nölle, F. Frey, R. Elschner, C. Schmidt-Langhorst, J. K. Fischer, and C. Schubert, "Investigation of CAZAC Sequences for Data-Aided Channel Estimation Considering Nonlinear Optical Transmission," in *Optical Fiber Communication Conference*, Optica Publishing Group, 2015, p. Th3G.2. doi: 10.1364/OFC.2015.Th3G.2.

[46] X. Pan, X. Wang, B. Tian, C. Wang, H. Zhang, and M. Guizani, "Machine-Learning-Aided Optical Fiber Communication System," *IEEE Netw.*, vol. 35, pp. 136–142, Jul. 2021, doi: 10.1109/MNET.011.2000676.

[47] T. Verolet *et al.*, "Mode Locked Laser Phase Noise Reduction Under Optical Feedback for Coherent DWDM Communication," *J. Light. Technol.*, vol. 38, no. 20, pp. 5708–5715, 2020, doi: 10.1109/JLT.2020.3002653.

[48] C. Zhu, A. V. Tran, C. C. Do, S. Chen, T. Anderson, and E. Skafidas, "Digital signal processing for training-aided coherent optical single-carrier frequency-domain equalization systems," *J. Light. Technol.*, vol. 32, no.

ISSN (online): 2581-3048

Volume 8, Issue 8, pp 118-127, August-2024

https://doi.org/10.47001/IRJIET/2024.808014

24, pp. 4712–4722, 2014, doi: 10.1109/JLT.2014.2364078.

[49] F. Pittalà, I. Slim, A. Mezghani, and J. A. Nossek, “Training-aided frequency-domain channel estimation and equalization for single-carrier coherent optical transmission systems,” *J. Light. Technol.*, vol. 32, no. 24, pp. 4849–4863, 2014, doi: 10.1109/JLT.2014.2358933.

[50] G. Li, F. Hu, P. Zou, C. Wang, G. R. Lin, and N. Chi, “Advanced modulation format of probabilistic shaping bit loading for 450-NM GAN laser diode based visible light communication,” *Sensors (Switzerland)*, vol. 20, no. 21, pp. 1–12, 2020, doi: 10.3390/s20216143.

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