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**Advanced Digital Signal
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Advanced Digital Signal Processing In Coherent Optical Systems

**Darli Augusto de Arruda Mello, Fabio
Aparecido Barbosa**



Advanced Digital Signal Processing In Coherent Optical Systems:

Advanced Digital Signal Processing for Next-generation Coherent Optical Communication Systems Meng Qiu, 2017

Coherent detection combined with digital signal processing DSP has been widely adopted in modern fiber optic transport for long haul and medium reach applications Compared with direct detection systems coherent communication systems can significantly improve the receiver sensitivity and increase the transmission capacity The ever increasing demand for greater transport network capacity necessitates continuous upgrade of future fiber transmission systems In such context novel advanced DSP schemes are necessary to satisfy the requirements of next generation coherent optical communication systems In this thesis we present several advanced DSP techniques to cope with both linear and nonlinear impairments in coherent optical communication systems with data rates of 100 Gb/s and beyond First two effective low complexity algorithms for carrier recovery in single carrier coherent systems are presented Specifically we describe a frequency offset FO tracking algorithm that can dynamically compensate the FO in intradyne coherent systems to avoid potential performance degradation caused by stochastic frequency drift of lasers In addition we demonstrate a format transparent carrier phase recovery CPR algorithm based on interleaved superscalar parallelization which can be economically implemented in practice because it can minimize the required pilot symbol overhead and buffer size in the superscalar parallelization structure Second we explore the digital subcarrier multiplexing SCM technique and discuss its benefits Specifically we employ SCM signals in a long haul transmission scenario to demonstrate the improved tolerance to both fiber nonlinearity and laser linewidth when the number of subcarriers is optimized Furthermore we explore the enhanced flexibility of the DSP design in SCM systems and propose a novel joint CPR algorithm for the correction of cycle slips CS Finally we conduct studies on a low cost solution for medium reach transmission namely the Stokes vector direct detection SV DD systems We demonstrate that the laser linewidth tolerance of SV DD systems is limited by equalization enhanced phase noise EEPN and verify that the EEPN induced performance degradation can be mitigated by a simple maximum likelihood ML phase recovery stage All the aforementioned DSP techniques have been demonstrated by simulations and experiments based on our leading edge coherent optical transmission testbed

Digital Coherent Optical Systems Darli Augusto de Arruda Mello, Fabio

Aparecido Barbosa, 2021-03-08 This textbook details the architecture of a digital coherent optical system and describes its main digital signal processing DSP algorithms The authors first show how the combination of advanced modulation techniques DSP and coherent detection has led to significant gains in capacity and ease of operation The authors follow the path of the information from its generation in the transmitter to propagation through the fiber and processing by the DSP algorithms in the receiver The work summarizes academic results and presents them in a didactic way to students and practitioners working on the area of optical communications A full suite of classroom materials is included for easy integration into a curriculum containing theoretic and simulation problems and off the shelf Matlab Octave functions

Digital Signal Processing For High-speed Optical Communication Jianjun Yu,Xinying Li,Junwen Zhang,2018-03-09

There is an increasing tendency to integrate optical communication with wireless communication to satisfy continuously emerging new data communication demands Thus optical wireless integrated access networks and transmission systems as well as LED based visible light communication are attracting ever increasing research interest Digital signal processing DSP is one new technology for optical transmission As such this book is designed to pave the way to the better understanding of the deployment of DSP in optical fiber communication systems Digital Signal Processing for High Speed Optical Communication covers a wide area of DSP topics in optical communications and describes state of the art digital signal processing techniques for high speed optical communication In this book numerous advanced digital signal processing techniques aiming at the promotion of the capacity increase and performance improvement of optical or optical wireless communication systems and networks are presented and explained Coverage includes new technologies optical filter with MLSE and new pre coding and pre equalization applicable to single carrier and multi carrier direct detection and coherent detection optical commutation systems and networks

Advanced DSP Techniques for High-Capacity and Energy-Efficient Optical Fiber Communications Zhongqi Pan,Yang Yue,2019-12-03 The rapid proliferation of the Internet has been driving communication networks closer and closer to their limits while available bandwidth is disappearing due to an ever increasing network load Over the past decade optical fiber communication technology has increased per fiber data rate from 10 Tb/s to exceeding 10 Pb/s The major explosion came after the maturity of coherent detection and advanced digital signal processing DSP DSP has played a critical role in accommodating channel impairments mitigation enabling advanced modulation formats for spectral efficiency transmission and realizing flexible bandwidth This book aims to explore novel advanced DSP techniques to enable multi Tb/s channel optical transmission to address pressing bandwidth and power efficiency demands It provides state of the art advances and future perspectives of DSP as well

Advanced Digital Signal Processing for Next-generation Flexible Optical Networks Xiang Lin,2020 To keep pace with the rapid expansion in data exchange traffic around the world optical networks are anticipated to provide flexibility to maximize utilization of the deployed optical fiber resources On the other hand digital signal processing DSP has been employed in coherent optical systems to enable 100G and beyond optical fiber networks The goal of the thesis is to develop advanced DSP techniques for the flexible optical networks With the reconfigured modulation formats in the systems modulation classification MC is essential in the DSP to facilitate the sequential compensation modules which are modulation format dependent Based on the cumulative distribution function CDF of received signal's amplitude an MC algorithm for M-ary quadrature amplitude modulation M-QAM formats with M=4,8,16,32 and 64 is proposed Results show that the proposed algorithm achieves accurate classification at optical signal to noise ratio OSNR of interest and is robust to frequency offset and laser phase noise Relying on the CDF of received signal's amplitude a non data aided NDA OSNR estimation algorithm is

developed for coherent optical systems employing multilevel constellations. It outperforms the state of the art NDA algorithm in terms of performance and complexity. Furthermore, a joint OSNR estimation and MC algorithm enabled by support vector machine is designed. Compared to deep neural network based joint estimation approach, the proposed algorithm achieves better performance with comparable complexity. In addition, a low complexity two stage carrier phase estimation algorithm is proposed for coherent optical systems with 16 QAM format. The proposed algorithm exploits the second power operation instead of the conventional fourth power to remove the modulation phase, which is enabled by constellation partition and rotation. Optical back to back experiments and numerical simulations are carried out to evaluate the performance of the algorithm. Results show that compared with the conventional fourth power based CPE algorithm, the proposed algorithm provides comparable tolerance to the carrier phase noise with reduced complexity. Lastly, a novel transmission scheme is investigated for the open and disaggregated metro coherent optical networks, which impose the requirements for multiple user connectivities on the limited orthogonal frequency resources. Thus, it is desirable to provide connections simultaneously to various users in a non orthogonal way. A transmission scheme based on the non orthogonal sparse code multiple access in a digital subcarrier multiplexing is proposed. Compared to power domain based counterpart, the proposed scheme supports more than 2 users without user pairing and clustering. The feasibility of the proposed scheme is verified through numerical simulations. Three scenarios with 2, 4 and 6 users over 1, 2 and 4 subcarriers respectively are considered. Performance evaluations show that in all scenarios, the proposed scheme attains bit error ratio lower than the forward error correction limits with the transmission ranges of interest in metro applications.

Advanced Digital Optical Communications

Le Nguyen Binh, 2017-11-22. This second edition of Digital Optical Communications provides a comprehensive treatment of the modern aspects of coherent homodyne and self coherent reception techniques using algorithms incorporated in digital signal processing DSP systems and DSP based transmitters to overcome several linear and nonlinear transmission impairments and frequency mismatching between the local oscillator and the carrier as well as clock recovery and cycle slips. These modern transmission systems have emerged as the core technology for Tera bits per second bps and Peta bps optical Internet for the near future. Featuring extensive updates to all existing chapters, Advanced Digital Optical Communications Second Edition contains new chapters on optical fiber structures and propagation, optical coherent receivers, DSP equalizer algorithms and high order spectral DSP receivers. Examines theoretical foundations, practical case studies and MATLAB and Simulink models for simulation transmissions. Includes new end of chapter practice problems and useful appendices to supplement technical information. Downloadable content available with qualifying course adoption. Advanced Digital Optical Communications Second Edition supplies a fundamental understanding of digital communication applications in optical communication technologies, emphasizing operation principles versus heavy mathematical analysis. It is an ideal text for aspiring engineers and a valuable professional reference for those involved in optics, telecommunications, electronics, photonics and digital signal

processing **Advanced Digital Signal Processing in Coherent Fiber Optic Communication Systems** Mahdi Malekiha, 2017 To satisfy the explosive growth in global Internet traffic the development of transmission links that not only have high capacity but are also flexible reconfigurable and adaptive is imperative The advents of high speed digital to analog and analog to digital converters and recent progress in complementary metal oxide semiconductor CMOS technology has facilitated the development of optical transceivers relying on coherent detection and digital signal processing DSP for the compensation of fiber impairments Next generation coherent optical networks are anticipated to further approach the Shannon limit and deliver 400 Gb/s or 1 Tb/s data rates per channel while providing flexibility and agility to maximize the utilization of the network resources This thesis explores novel system architectures and advanced DSP algorithms to fulfill these design targets Currently chromatic dispersion CD compensation and forward error correction FEC decoders are the major power consuming more than 50% blocks of a conventional transceiver application specific integrated circuit ASIC This thesis presents the concepts and architectures of multi sub band MSB signaling for mitigation of CD and eliminating the need for a CD compensating equalizer in reduced guard interval RGI orthogonal frequency division multiplexing OFDM and single carrier systems The performance of the proposed techniques are experimentally evaluated using a leading edge optical long haul transmission test bed It is shown that the MSB technique in addition to the evidently lower computational complexity allows for a highly efficient adaptive rate smart transceiver implementation with lower system overhead and simplified parallelism while attaining the same or better transmission reach and performance as the conventional transceiver This is due to its higher tolerance to fiber nonlinearity With coherent technology and advanced FEC it is known that the capacity of current fiber optic transmission systems is fundamentally limited by fiber nonlinearities We have optimized the perturbation based nonlinearity compensation PB NLC equalization scheme and proposed a novel adaptive nonlinear equalizer The performances of the aforementioned DSP equalization schemes are numerically and experimentally studied It is found that the optimized technique demonstrates lower computational complexity over conventional PB NLC In addition the proposed adaptive nonlinear equalizer does not require prior calculations of perturbation coefficients and detailed knowledge of the transmission link parameters It achieves comparable performance to the PB NLC Unlike previously studied adaptive nonlinear equalization techniques our algorithm takes advantage of common symmetries avoids replication of operations and only uses a few adaptive nonlinear coefficients Finally its computational complexity is smaller than previously proposed adaptive nonlinear equalization schemes which meets the requirements of next generation optical networks *Digital Signal Processing In High-Speed Optical Fiber Communication Principle and Application* Jianjun Yu, Nan Chi, 2020-07-06 This book presents the principles and applications of optical fiber communication based on digital signal processing DSP for both single and multi carrier modulation signals In the context of single carrier modulation it describes DSP for linear and nonlinear optical fiber communication systems discussing all optical Nyquist modulation signal generation and processing

and how to use probabilistic and geometrical shaping to improve the transmission performance For multi carrier modulation it examines DSP based OFDM signal generation and detection and presents 4D and high order modulation formats Lastly it demonstrates how to use artificial intelligence in optical fiber communication As such it is a useful resource for students researches and engineers in the field of optical fiber communication

Handbook of Radio and Optical Networks Convergence Tetsuya Kawanishi, 2024-10-02 This handbook provides comprehensive knowledge on device and system technologies for seamlessly integrated networks of various types of transmission media such as optical fibers and millimeter and THz waves to offer super high speed data link service everywhere The seamless integration of the knowledge of radio and optical technologies is needed to construct wired and wireless seamless networks High frequency bands such as millimeter wave and THz wave bands where super wideband spectra are available can offer high speed data transmission and high resolution sensing However the expected coverage is limited due to large wave propagation loss Thus convergence of radio and optical links is indispensable to construct worldwide networks The radio and optical technologies share the same physics and are closely related to each other but have been developed independently Therefore there is a big gap between these two fields Bridging the two fields this handbook is also intended as a common platform to design integrated networks consisting of wireless and wired links Full coverage of wireless and wired convergence fields ranging from basics of device and transmission media to applications allows the reader to efficiently access all the important references in this single handbook Further it also showcases state of the art technology and cases of its use

Advanced Optical and Wireless Communications Systems Ivan B. Djordjevic, 2022-06-21 The new edition of this popular textbook keeps its structure introducing the advanced topics of i wireless communications ii free space optical FSO communications iii indoor optical wireless IR communications and iv fiber optics communications but thoroughly updates the content for new technologies and practical applications The author presents fundamental concepts such as propagation principles modulation formats channel coding diversity principles MIMO signal processing multicarrier modulation equalization adaptive modulation and coding detection principles and software defined transmission first describing them and then following up with a detailed look at each particular system The book is self contained and structured to provide straightforward guidance to readers looking to capture fundamentals and gain theoretical and practical knowledge about wireless communications free space optical communications and fiber optics communications all which can be readily applied in studies research and practical applications The textbook is intended for an upper undergraduate or graduate level courses in fiber optics communication wireless communication and free space optical communication problems an appendix with all background material needed and homework problems In the second edition in addition to the existing chapters being updated and problems being inserted one new chapter has been added related to the physical layer security thus covering both security and reliability issues New material on 5G and 6G technologies has been added in corresponding chapters

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Table of Contents Advanced Digital Signal Processing In Coherent Optical Systems

1. Understanding the eBook Advanced Digital Signal Processing In Coherent Optical Systems
 - The Rise of Digital Reading Advanced Digital Signal Processing In Coherent Optical Systems
 - Advantages of eBooks Over Traditional Books
2. Identifying Advanced Digital Signal Processing In Coherent Optical Systems
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Advanced Digital Signal Processing In Coherent Optical Systems
 - User-Friendly Interface
4. Exploring eBook Recommendations from Advanced Digital Signal Processing In Coherent Optical Systems
 - Personalized Recommendations
 - Advanced Digital Signal Processing In Coherent Optical Systems User Reviews and Ratings
 - Advanced Digital Signal Processing In Coherent Optical Systems and Bestseller Lists
5. Accessing Advanced Digital Signal Processing In Coherent Optical Systems Free and Paid eBooks
 - Advanced Digital Signal Processing In Coherent Optical Systems Public Domain eBooks
 - Advanced Digital Signal Processing In Coherent Optical Systems eBook Subscription Services
 - Advanced Digital Signal Processing In Coherent Optical Systems Budget-Friendly Options
6. Navigating Advanced Digital Signal Processing In Coherent Optical Systems eBook Formats

- ePub, PDF, MOBI, and More
- Advanced Digital Signal Processing In Coherent Optical Systems Compatibility with Devices
- Advanced Digital Signal Processing In Coherent Optical Systems Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Advanced Digital Signal Processing In Coherent Optical Systems
 - Highlighting and Note-Taking Advanced Digital Signal Processing In Coherent Optical Systems
 - Interactive Elements Advanced Digital Signal Processing In Coherent Optical Systems
- 8. Staying Engaged with Advanced Digital Signal Processing In Coherent Optical Systems
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Advanced Digital Signal Processing In Coherent Optical Systems
- 9. Balancing eBooks and Physical Books Advanced Digital Signal Processing In Coherent Optical Systems
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Advanced Digital Signal Processing In Coherent Optical Systems
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Advanced Digital Signal Processing In Coherent Optical Systems
 - Setting Reading Goals Advanced Digital Signal Processing In Coherent Optical Systems
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Advanced Digital Signal Processing In Coherent Optical Systems
 - Fact-Checking eBook Content of Advanced Digital Signal Processing In Coherent Optical Systems
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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