

Optics Letters

Photonic analog-to-digital conversion with equivalent analog prefiltering by shaping sampling pulses

FEIRAN SU, GUILING WU,* AND JIANPING CHEN

State Key Laboratory of Advanced Optical Communication Systems and Networks, Department of Electronic Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

*Corresponding author: wuguilin@sjtu.edu.cn

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We propose a photonic scheme to digitize RF signals with a programmable equivalent analog prefilter, where the filter impulse response is directly proportional to the time-reversed temporal shape of the sampling pulse and hence can be adjusted by shaping sampling pulses. The model of the proposed scheme is presented to prove its principle and derive its operation conditions. A four-channel scheme with program-controlled pre-filters is demonstrated experimentally, where bandpass filters with the phase shifts of 0° , 90° , 180° , and 270° are synthesized, respectively, by changing temporal shape of the sampling pulses. The experimental results agree well with the theoretical analysis, indicating the validity of the proposed scheme. © 2016 Optical Society of America

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Photonic analog-to-digital converters (ADCs), benefiting from the merit advantages of photonics, have the potential to break the bottlenecks of electronic ADCs in bandwidth and aperture jitter to directly digitize RF signal, and may find important applications in communications, modern radars, and instrumentation, etc. [1]. During the past decades, several schemes have been proposed [2–4] to improve the performance of photonic ADCs in terms of sampling rate, input bandwidth, and effective number of bits (ENOB). In many applications an analog prefilter prior to ADC is often required for various purposes, such as anti-aliasing, suppressing interference, and shifting phase. Conventionally, electronic analog filters are used to fulfill the purposes. However, electronic analog filters have several limitations in bandwidth, loss and tunability [5]. Microwave photonic filters (MPFs) have been proposed to overcome these limitations [5]. Using a MPF as the prefilter of photonic ADCs seems to be a compatible choice. However, the direct cascade of a MPF and a photonic ADC needs multistages electro-optic and optic-electric conversion, which will result in significant loss and distortion.

In this Letter, we propose a photonic scheme to digitize RF signals with a programmable equivalent analog prefilter by shaping photonic sampling pulses. The proposed scheme has a similar structure to time-interleaved photonic ADCs (TIPADCs) where each sampling channel can be modeled as an analog filter along with a sampler [6]. The analog filter can be considered as the equivalent prefilter whose response is the same as the channel response of TIPADCs. Based on the fact that the channel impulse response of TIPADCs is proportional to the product of the time-reversed temporal shape of the sampling pulse train and the photodetection impulse response [6], we reveal that the prefilter impulse response can be directly proportional to the time-reversed temporal shape of the sampling pulse under certain conditions. In the case, by shaping the sampling pulse, the impulse response of the equivalent prefilter can be directly controlled. When multiple channels are interleaved together to increase the total sampling rate, all the pre-filters in channels are combined to form a global equivalent prefilter accordingly. Compared to traditional MPFs, the equivalent prefilter has the same advantages, such as wideband, flexibility, and reconfigurability. However, the proposed scheme directly obtains the filtered and digitized result while it does not output any filtered analog result. Moreover, the bandwidth of the photodetection in the proposed scheme can be much lower than the frequency of the RF input while it must be not less than the frequency of the RF input in existing MPFs. A four-channel scheme based on the principle is demonstrated. By shaping the sampling pulse, bandpass pre-filters are synthesized, and the phase shifting ability is also illustrated to validate the flexibility and reconfigurability of the scheme.

Figure 1 shows the schematic of the proposed scheme. A shape-controlled photonic sampling pulse train generated by a pulse source is modulated by an input RF signal via an intensity modulator. The modulated photonic pulses are demultiplexed into N channels to be photodetected and digitized in parallel by electronic ADCs. The filtering is underlying in the whole process and the samples in each channel are the result of filtering and digitizing the RF input, which can be combined to reconstruct the prefiltered RF signal.

Photonic Analogtodigital Conversion

Bhushan Shanti Asuri



Photonic Analog-to-Digital Conversion:

Photonic Analog-to-Digital Conversion Barry L. Shoop, 2012-11-02 Photonic based A/D conversion has received and continues to receive considerable attention as an alternative approach to providing enhanced resolution and speed in high performance applications. Some of the potential advantages of using photonic technologies are high speed clocking, broadband sampling, reduced mutual interference of signals, and compatibility with existing photonic based systems. This book provides a comprehensive look at the application of photonic approaches to the problem of analog to digital conversion. It shows progress made, discusses present research, and gives a glimpse of potential future technologies. Photonic Analog-to-Digital Conversion Using a Robust Symmetrical Number System, 2005. A photonic analog to digital converter ADC based on a robust symmetrical number system RSNS was constructed and tested. The analog signal to be converted is used to amplitude modulate an optical pulse from a laser using three Mach Zehnder interferometers (MZI). The Mach Zehnder interferometers fold the input analog signal for a three channel RSNS encoding. The folding waveforms are then detected and amplitude analyzed by three separate comparator banks; the outputs of which are used to determine a digital representation of the analog signal. This design uses the RSNS preprocessing to encode the signal with the fewest number of comparators for any selected bit resolution. In addition to the efficiency of its use of comparators, the RSNS encoding has inherent Gray code properties, making it particularly attractive for eliminating any possible encoding errors. The RSNS encoding is combined with an optical infrastructure that offers high bandwidth and low insertion loss characteristics. A full implementation was constructed and tested. The lack of a high speed data acquisition device limited the results to examining the preprocessing and digital processing separately. With the system integration of a data acquisition device, a wideband direct digital antenna architecture can be demonstrated. *Richtlinien zum Kösemer Studium generale*, 1963.

Integrated Photonic Analog-to-digital Converters Anatol M. Khilo, Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science, 2011. Accurate conversion of wideband multi GHz analog signals into the digital domain has long been a target of analog to digital converter ADC developers driven by applications in radar systems, software radio, medical imaging, and communication systems. Aperture jitter has been a major bottleneck on the way towards higher speeds and better accuracy. Photonic ADCs which perform sampling using ultra stable optical pulse trains generated by mode locked lasers have been investigated as a promising approach to overcome the jitter problem and bring ADC performance to new levels. This work demonstrates that the photonic approach can deliver on its promise by digitizing a 41 GHz signal with 7.0 effective bits and 52 dBc spur free dynamic range (SFDR) using a discrete component photonic ADC. This corresponds to 15 fs jitter, a 4.5 times improvement over the jitter of the best electronic ADCs, and an order of magnitude improvement over the jitter of electronic ADCs operating above 10 GHz. The feasibility of a practical photonic ADC is demonstrated by creating an integrated ADC with a modulator, filters, and photodetectors fabricated on a single silicon chip.

and using it to sample a 10 GHz signal with 3.5 effective bits and 39 dBc SFDR. In both experiments a sample rate of 2.1 GSa/s was obtained by interleaving two 1.05 GSa/s channels; higher sample rates can be achieved by increasing the channel count. A key component of a multi-channel ADC, a dual multi-channel high-performance filter bank, is successfully implemented. A concept for broadband linearization of the silicon modulator, which is another critical component of the photonic ADC, is proposed. Nonlinear phenomena in silicon microring filters and their impact on ADC performance are analyzed, and methods to reduce this impact are proposed. The results presented in the thesis suggest that a practical integrated photonic ADC, which successfully overcomes the electronic jitter bottleneck, is possible today.

Applications of Modern RF Photonics

Preetpaul Singh Devgan, 2018-01-31. This unique new resource presents applications of modern RF photonic systems that use RF photonic components for commonly used signal processing systems. This book provides insight into how a variety of systems work together, including RF down conversion, analog-to-digital conversion, RF oscillators, and frequency identification. A comparison of analog versus digital systems is presented. Readers find in-depth coverage of analog delay lines using RF photonics, various system architectures, and details about RF photonic component performance. Signal processing utilizing RF photonics and the need for down conversion is discussed. The many advancements in analog delay line performance are explained, including those in photodetectors, optical fibers, and optical and amplifier modulators. The book highlights the advantages of using oscillators utilizing RF photonics and explores the elements of phase noise, timing jitter, and optoelectronic oscillators. The benefits of signal identification, isolation, and separation of RF photonics are identified. Professionals are brought up to speed on RF frequency identification using optical injection locking. The book provides discussions on the fundamentals and advancements in integrated RF photonics and explains how to design an RF photonic downconverter. It covers additional applications of integrated photonic circuits and gives an explanation of why to use different modulation formats for different applications.

Microwave Photonics Jianping Yao, José Capmany, Ming

Li, 2024-03-08. Overview of techniques in the field of microwave photonics, including recent developments in quantum microwave photonics and integrated microwave photonics. *Microwave Photonics* offers a comprehensive overview of the microwave photonic techniques developed in the last 30 years, covering topics such as photonics generation of microwave signals, photonics processing of microwave signals, photonics distribution of microwave signals, photonic generation and distribution of UWB signals, photonics generation and processing of arbitrary microwave waveforms, photonic true time delay, beamforming for phased array antennas, photonics-assisted instantaneous microwave frequency measurement, quantum microwave photonics, analog-to-digital conversion, and more. The text is supported by a companion website for instructors, including learning objectives and questions/problems to further enhance student learning. Written by key researchers in the field, *Microwave Photonics* includes information on group velocity dispersion and nonlinear effects in fibers, light coherence in light sources, phase and intensity modulators, photodetectors, and fiber Bragg gratings, injection locking, phase-locked loops,

external modulation opto electronic oscillators and array waveguide gratings Photonic microwave delay line filters with negative and complex coefficients and non uniformly spaced photonic microwave delay line filters Double and single sideband modulation radio over fiber networks and microwave photonics to coherent communication systems UWB generation coding and distribution over fiber and instantaneous microwave frequency measurement via power monitoring True time delay beamforming Exploring the subject in depth with expansive coverage of techniques developed in the last 30 years Microwave Photonics is an essential reference for graduate students and researchers to learn microwave photonic technologies Lithium Niobate Photonics James E. Toney, 2015-07-01 This new resource presents the concepts technologies and design techniques for devices based on the electro optic effect in lithium niobate It bridges from the theory of photonics and electro optics to the practice of electro optic device design and application There is an emphasis on practical analysis using modern modeling tools The book explains the fundamental physics of the electro optic effect classes of electro optic materials electro optic properties of lithium niobate and the physics and uses of ferroelectric domain inversion Readers are also provided with the principles of operation performance measures and design considerations for the most common types of electro optic devices beam deflectors intensity and phase modulators including quasi phased matched devices Application of Wavelength Division Sampling in Photonic Analog-to-digital Conversion Bhushan Shanti Asuri, 1998

Neuromorphic Photonic Devices and Applications Min Gu, Elena Goi, Yangyundou Wang, Zhengfen Wan, Yibo Dong, Yuchao Zhang, Haoyi Yu, 2023-12-01 Neuromorphic Photonic Devices and Applications synthesizes the most critical advances in photonic neuromorphic models photonic material platforms and accelerators for neuromorphic computing The book discusses fields and applications that can leverage these new platforms A brief review of the historical development of the field is followed by a discussion of the emerging 2D photonic materials platforms and recent work in implementing neuromorphic models and 3D neuromorphic systems The application of artificial intelligence AI such as neuromorphic models to inverse design neuromorphic materials and devices and predict performance challenges is discussed throughout Finally a comprehensive overview of the applications of neuromorphic photonic technologies and the challenges opportunities and future prospects is discussed making the book suitable for researchers and practitioners in academia and R D in the multidisciplinary field of photonics Includes overview of primary scientific concepts for the research topic of neuromorphic photonics such as neurons as computational units artificial intelligence machine learning and neuromorphic models Reviews the latest advances in photonic materials device platforms and enabling technology drivers of neuromorphic photonics Discusses potential applications in computing and optical communications Broadband Optical Modulators Antao Chen, Edmond Murphy, 2016-04-19 provides the full exciting story of optical modulators a comprehensive review from the fundamental science to the material and processing technology to the optimized device design to the multitude of applications for which broadband optical modulators bring great value Especially valuable in my view is that the authors are

internationally **Enabling Photonics Technologies for Defense, Security, and Aerospace Applications** ,2005

Photonic Time-stretched Analog-to-digital Conversion Yan Han,2004 *System Demonstration of an Optically-sampled, Wavelength-demultiplexed Photonic Analog-to-digital Converter* Michael Yung Peng,Massachusetts Institute of Technology. Department of Electrical Engineering and Computer Science,2011 The performance of electronic analog to digital converters ADCs at high sampling rates is fundamentally limited by the timing jitter of electronic clocks To circumvent this limitation one method is to exploit the orders of magnitude lower timing jitter of mode locked lasers and implement optical sampling as a front end for electronic ADCs The optical sampling wavelength demultiplexing approach to A D conversion which is explored in this thesis offers key benefits such as ease of scalability to higher aggregate sampling rates via passive wavelength division demultiplexing WDM filters and potential for full integration via silicon photonics platform for chip scale signal processing applications This thesis will first cover the design issues for each stage in the optically sampled wavelength demultiplexed photonic ADC architecture followed by experimental results from two system demonstrations Digitization of a 41 GHz signal with 7 0 effective bits at a sampling rate of 2 GSa s was demonstrated with a discrete component photonic ADC which corresponds to 15 fs of jitter a 4 5 times improvement over state of the art electronic ADCs On the way towards an integrated photonic ADC a silicon chip with core photonic components was fabricated and used to digitize a 10 GHz signal with 3 5 effective bits Drop port transmission measurements of an integrated 20 channel WDM filter bank are included to show potential for high sampling rate operation with 10 effective bits **Implementing Software**

Defined Radio Eugene Grayver,2012-07-20 Software Defined Radio makes wireless communications easier more efficient and more reliable This book bridges the gap between academic research and practical implementation When beginning a project practicing engineers technical managers and graduate students can save countless hours by considering the concepts presented in these pages The author covers the myriad options and trade offs available when selecting an appropriate hardware architecture As demonstrated here the choice between hardware and software centric architecture can mean the difference between meeting an aggressive schedule and bogging down in endless design iterations Because of the author s experience overseeing dozens of failed and successful developments he is able to present many real life examples Some of the key concepts covered are Choosing the right architecture for the market laboratory military or commercial Hardware platforms FPGAs GPPs specialized and hybrid devices Standardization efforts to ensure interoperability and portability State of the art components for radio frequency mixed signal and baseband processing The text requires only minimal knowledge of wireless communications whenever possible qualitative arguments are used instead of equations An appendix provides a quick overview of wireless communications and introduces most of the concepts the readers will need to take advantage of the material An essential introduction to SDR this book is sure to be an invaluable addition to any technical bookshelf Enabling Photonic Technologies for Aerospace Applications ,2000 *Microwave Photonics* Chi H.

Lee,2017-12-19 Microwave photonics continues to see rapid growth The integration of optical fiber and wireless networks has become a commercial reality and is becoming increasingly pervasive Such hybrid technology will lead to many innovative applications including backhaul solutions for mobile networks and ultrabroadband wireless networks that can provide users with very high bandwidth services Microwave Photonics Second Edition systematically introduces important technologies and applications in this emerging field It also reviews recent advances in micro and millimeter wavelength and terahertz frequency systems The book features contributions by leading international researchers many of whom are pioneers in the field They examine wave generation measurement detection control and propagation in detail as well as the devices and components that enable ultrawide band and ultrafast transmission switching and signal processing These devices and components include optical controlled microwave devices optical transmitters receivers switching devices detectors and modulators The book explores the theory techniques and technologies that are fueling applications such as radio over fiber injection locked semiconductor lasers and terahertz photonics Throughout the contributors share insights on overcoming current limitations and on potential developments What s New in This Edition Two new chapters on fiber Bragg gratings for microwave photonics applications and ultrawide band sub THz photonic wireless links Updates throughout reflecting advances in the field New illustrations in each chapter Fully illustrated with more than 300 figures and tables this book offers a detailed wide ranging overview of the current state and future directions of this burgeoning technology **Photonics In Space: Advanced Photonic Devices And Systems** Caterina Ciminelli,Mario Nicola Armenise,Francesco

Dell'olio,2016-07-21 The book focuses on photonic devices and systems for space applications and critically reviews the most promising research advances in the field of photonic technologies which may have a significant impact on the performance of space systems Photonics is emerging as a crucial enabling technology having the potential of enhancing many space systems including the links for on board data handling the high resolution measurement systems and the processing units The book discusses this subject with a special emphasis on the new guided wave devices with high performance low cost and size Most of the scientific content of the book is novel and it is devoted to academic and industrial researchers working on the field

True Linearized Intensity Modulation for Photonic Analog to Digital Conversion Using an Injection-locked Mode-locked Laser Edris Sarailou,2015 Modulating the saturable absorber provides a reduced third order intermodulation tone with respect to modulating the gain This is simply because of the unwanted amplitude modulation created when modulating the gain section current Finally an improved design is proposed and demonstrated to improve the modulator performance This is achieved by introducing a third section to the laser Using the impurity free vacancy disordering technique the photoluminescence peak of this section is blue shifted selectively and therefore there would not be any absorption in that passive section By applying the modulation signal to this passive section rather than applying it to the gain section or saturable absorber section the amplitude and phase modulation could be decoupled The experimental results have presented

here and an almost six fold reduction in V subscript pi and 5 dB improvement in spur free dynamic range have been achieved The proposed and demonstrated configuration as an analog optical link has the potential to increase the performance and resolution of photonic analog to digital converters

Optics, Photonics and Laser Technology 2017 Paulo Ribeiro, David L. Andrews, Maria Raposo, 2019-05-03 This book discusses both the theoretical and practical aspects of optics photonics and lasers presenting new methods technologies advanced prototypes systems tools and techniques as well as a general survey indicating future trends and directions The main fields addressed include nonlinear optical phenomena photonics for energy high field phenomena photonic and optoelectronic sensors and devices optical communications biomedical optics and photonics It also covers a large spectrum of materials ranging from semiconductor based optical materials to optical glasses organic materials photorefractive materials and nanophotonic materials as well as applications such as metrology optometry adaptive optics all optical instrumentation optical communications quantum information lighting technologies energy harvesting and optically based biomedical diagnosis and therapeutics

Microwave Photonics, Second Edition Chi H. Lee, 2013-03-21 Microwave photonics continues to see rapid growth The integration of optical fiber and wireless networks has become a commercial reality and is becoming increasingly pervasive Such hybrid technology will lead to many innovative applications including backhaul solutions for mobile networks and ultrabroadband wireless networks that can provide users with very high bandwidth services Microwave Photonics Second Edition systematically introduces important technologies and applications in this emerging field It also reviews recent advances in micro and millimeter wavelength and terahertz frequency systems The book features contributions by leading international researchers many of whom are pioneers in the field They examine wave generation measurement detection control and propagation in detail as well as the devices and components that enable ultrawide band and ultrafast transmission switching and signal processing These devices and components include optical controlled microwave devices optical transmitters receivers switching devices detectors and modulators The book explores the theory techniques and technologies that are fueling applications such as radio over fiber injection locked semiconductor lasers and terahertz photonics Throughout the contributors share insights on overcoming current limitations and on potential developments What's New in This Edition Two new chapters on fiber Bragg gratings for microwave photonics applications and ultrawide band sub THz photonic wireless links Updates throughout reflecting advances in the field New illustrations in each chapter Fully illustrated with more than 300 figures and tables this book offers a detailed wide ranging overview of the current state and future directions of this burgeoning technology

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