CHAPTER 50

TECHNOLOGY
ELECTRONICS & COMMUNICATION
ENGINEERING

Doctoral Theses

01. BAJPAI (Rochak)
Some Studies on Mixed Line Rate (MLR) Optical Network.
Supervisor: Dr. Shree Prakash Singh
Th 25775

Abstract

With the advent of more and more internet-based application leads to the tremendous increase in amount of data transmitted in backbone network. This ever-increasing traffic demand paves the way for up-gradation of legacy optical network infrastructure based on 10 Gbps OOK transmission scheme. The mixed line rate - WDM network is proposed as a cost effective solution for this up-gradation problem in which parallel transmission of multiple data rate (i.e. 10/40/100) with different modulation formats such as 10 Gbps with OOK, 40 Gbps with DPSK/Duo-Binary and 100 Gbps with DP-QPSK takes place. In wake of supporting more and more number of users with their heterogeneous demands, in the network, spectral efficient transmission with the help of advanced modulation format becomes inevitable, which require close packing of the channels to support more number of users. The close placement of channels increases the physical layer impairment(PLI) among them and severely affects the performance of the network.In the presented work, we evaluated the quality of transmission of the optical signal through Quality-factor (Q-factor) which is computed by means of mathematical model, developed during this thesis, that accounts for the simultaneous impact of four dominant PLIs namely, stimulated Raman scattering (SRS), four wave mixing (FWM), cross phase modulation (XPM) and amplified spontaneous emission (ASE) noise.At 40 Gbps transmission scheme DPSK modulation scheme is widely explored in the literature. We find the Duo-Binary modulation scheme asmore suitable candidate for 40 Gbps transmission in terms of resilience to physical layer impairments and its spectral efficient performance in comparison to 40 Gbps DPSK transmission scheme. We validate the better performance of Duo-Binary scheme at 40 Gbps by means of mathematical perusal as well as simulation with Synopsis OPTSIM (R) software. Multiple channel transmission at different data rates through the fiber require better understanding of channel placement as their performance is severely affected by physical layer impairments. The presented thesis explored this horizon with placement of 10 Gbps OOK, 40 Gbps DPSK/Duo-Binary, and 100 Gbps DP-QPSK modulation schemes, exhaustively with simulations and better channel placement plans has been suggested to network design engineers for optimum performance of network. In the pursuit of better understanding of optical fibers, numerous fibers have been proposed in the field deployment. We address the issue of better fiber selection for mixed line rate-WDM network with the help of exhaustive simulation, validated by proper reasoning. This analysis will help the network design engineer to choose the better fiber in real time deployment. In view of increasing carbon footprint

of the network, it is necessary to establish power efficiency in the network, at the same time, in order to support more and more number of users' spectral efficient network transmission is inevitable. This work addresses the issue of power efficiency and spectral efficiency, with available modulation formats, required resources (i.e. transponders and regenerators) and their power consumption. The results presented in this thesis are supported by five journal papers and four conference papers.

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1. Introduction 2. Duo-Binary modulation scheme at 40 gbps 3. Performance evaluation of OOK, DPSK and Duo- binary modulation formats at 40 gbps, in presence of physical layer impairments 4. Performance evaluation of OOK, DPSK and due-binary modulation formats at 40 gbps, in presence of physical layer impairments and amplified spontaneous emission noise 5. Performance evaluation of MLR network for ITU-T conforming fibers 6. Comparison of power efficient and spectral efficient MLR optical WDM networks 7. Conclusion and future scope and Bibliography.

02. PRAGHA SHILPI
Design and Analysis of Resonant Devices for Microwave Communication Systems.
Supervisors:Prof. Harish Parthasarathy and Prof. D.K. Upadhyay
Th 25771

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1. Introduction 2. Cavity resonator with anisotropic and inhomogeneous permittivity medium 3. Design of resonant antennas 4. Wave equation in plasma filled cavity resonator 5. Oscillation in plasma filled cavity resonator 6. Conclusions and suggestions for future work. Appendices and Bibliography.

03. SHARMA (Abhay)
Design and FPGA Implementation of Signal Processing Systems.
Supervisor: Dr. Tarun Kumar Rawat
Th 25773

Abstract

This thesis is concerned with the designing and efficient implementation of signal processing systems on the field programmable gate array (FPGA). The aim is to present the design and efficient implementation of the three frequently used signal processing systems, namely, the fractional-order differentiator, the fractional-order integrator and the notch filter with the finite precision data representation. The wave digital structure, which is known to be less susceptible to the finite wordlength effects associated with the finite precision data representation, is the basis of the designs presented in this thesis. The wave digital structure emulates the characteristics of a lossless network placed between the resistive termination, so most of the analog reference network properties are retained in its digital counterpart. The low coefficient word-length requirements, excellent stability even under the influence of overflow and round-off errors related to the finite word-length effects, and intrinsically good dynamic range are the attributes of the wave digital structures exploited in deriving efficient implementation architectures. For simplicity in the implementation, a modular wave structure known as lattice wave digital filter is obtained using the symmetric reference analog network in a lattice configuration. The design of the signal processing systems using the lattice wave digital structure

is formulated as an optimization problem. The optimized coefficients of the lattice wave transfer function is obtained by minimizing the error objective function through the natureinspired ant lion optimization algorithm. The frequency response of the designed lattice wave structure approximates the ideal frequency response of the required system with minimum error. The hardware implementation of the designed wave digital signal processing systems can be done through application specific integrated circuit (ASIC), programmable digital signal processor (PDSP) or FPGA. However, the FPGA holds the upper-hand due to its several advantages, for instance, FPGA exploits parallelism which is absent in PDSP, reconfigurability which can not be achieved in both ASIC and PDSP, low non-recurring engineering cost, and fast time to market. The electronic design automation tool provided by Xilinx, namely, system generator for DSP is used in this study to implement the suggested wave digital architecture on the FPGA. The first problem considered in this thesis is the design and efficient implementation of fractional-order digital differentiator. The ant lion optimization algorithm is used to optimize the lattice wave digital structure coefficients. The design improvements are reported in terms of the frequency magnitude response, the absolute magnitude error percentage and the root mean square error. For the Nth order system, the number of multipliers required in the traditional infinite impulse response system realization is 2N +1, whereas, in the case of lattice wave digital structure the number of multipliers required for the implementation is N. Hence, the designed lattice wave fractional order digital differentiator gives the minimum multiplier implementation structure. Additionally, the canonic signed digit encoding and the radix-2r encoding along with the add-shift binary logic is applied to derive the multiplier-less architecture for the efficient FPGA implementation. The next problem is concerned with the design and efficient implementation of digital notch filter. The design of tunable digital notch filter in terms of wave coefficients is explored. The concept of all-pass filters is used to obtain the novel relationships between the digital notch filter parameters and the wave coefficients. Further extension in the form of lattice wave digital notch filter is presented to design the time-varying notch-width system to suppress the transient response and reduce the memory requirement in the FPGA implementation. The last contribution of this thesis is concerned with the design and efficient implementation of fractional-order digital integrator. The ant lion optimization algorithm is used to obtain the optimized infinite impulse response system based fractional-order digital inteiigrator. The transposed direct form II structure of the design is implemented on the FPGA for the fixed-point and the floating-point data representation. A novel floating-point multiplier based on the truncatedWallace tree is proposed to reduce the logic resource utilization of the floating-point architecture. The improvement in the floating-point implementation is reported in terms of the number of LUTs and the maximum combinational path delay. A second design of the fractional order digital integrator is proposed based on the lattice wave digital structure for the fixed-point implementation. The design improvements are reported in terms of the error analysis parameters. The multiplier-less architecture for the efficient FPGA implementation using the add-shift binary logic with the canonic signed digit and the radix-2r encoding scheme is also presented.

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04. SHRIVASTAVA (Shreesh Kumar)

Some Studies on Adaptive Hybrid Free Space Optical/RF Communication System.

Supervisors: Prof. Sujata Sengar Prof. Shree Prakash Singh

Th 25774

Abstract

With the advent of more and more internet based application leads to the tremendous increase in amount of data transmitted. This ever-increasing traffic demand paves the way for up-gradation of existing wireless communication system. The scarcity of RF spectrum and limitation associated with optical fiber deployment opens a new door for Free Space Optical (FSO) communication system as an alternative for many applications. For high speed data communication applications, FSO systems are the best solution because of its large bandwidth, low implementation cost and high security along with license free spectrum. Despite the many advantages, link availability of quality of SO link has been hampered by path-loss, atmospheric turbulence-induced fading and misalignment error. Employing a RF link in support of FSO provides high reliability besides giving comparable data rates. In this thesis, we analyze and enhance the performance of a hybrid system which is a combination of parallel FSO and RF subsystems. In the context of hybrid FSO/RF systems various switching/ transmission schemes including: hard switching, soft switching and hybrid switching had been presented in the literature. In order to minimize the shortcoming of the existing schemes, we proposed two new switching schemes which conserve optical as well as RF power, improve the error performance and prevent the unnecessary generation of RF interference in the environment. These schemes are modified switching (MS) scheme and improved modified switching (IMS) scheme. The performance of the both schemes are analyzed on in terms of bit error rate (BER) and outage probability and compared with the existing switching schemes. It have been verified from the obtained results that both the proposed switching schemes outperform in comparison to existing schemes. In all the transmission schemes, selection of the link (FSO and/or RF) for data transmission is decided on the basis of optical and RF signal to noise ratio (SNR) threshold levels. Thus, thresholds cannot be chosen arbitrarily, and the proper selection of these threshold levels is necessary. We propose an optimal selection strategy for optical and RF thresholds of the hybrid FSO/RF system with modified switching scheme to achieve minimum BER under the constraint on average system SNR, for a fixed outage probability. In a hybrid FSO/RF system, the actual power consumption comprises contribution from optical as well as RF power. The average system SNR has been defined on the basis of actual power transmission. We propose that the performance of the system should be evaluated with respect to average system SNR, inspite of average optical or RF SNR.Further, an idea of minimum feedback channel information which is referred as channel condition information (CCI), has been proposed for hybrid FSO/RF systems. CCI is a bandwidth efficient form of channel state information (CSI) which is used as a feedback to decide the modes of transmission/operation in accordance with the switching scheme that is used. The impact of incorrect reception of CCI, which may lead to an erroneous switching between transmission modes, on the performance of hybrid system has been evaluated. These errors in the mode of transmission/operation lead to degradation in the link availability and error performance. In addition, a comparative study of different modulation format carried out to find the best suitable modulation format. Results show that the BPSK is a better choice in comparison to other modulation formats under weak to strong turbulence conditions. The results presented in this thesis are supported by four journal papers and two conference papers.

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05. SOYINKA NATH

Some Studies on Hybrid FSO/RF Systems with Shared RF.

Supervisors: Prof. Shree Prakash Singh and Sujata Sengar

Th 25772

Abstract

Free space optical (FSO) communication is the wireless transmission of data via a modulated optical beam directed through free space. Factors which impede the optical signal and deteriorate the FSO link availability include atmospheric turbulence, pointing errors, scattering, rain, fog, snow, haze etc. Use of a dedicated back-up RF link to form a Hybrid FSO/RF system is a common method for improving the FSO's link availability. In hard switched Hybrid FSO/RF system, the back-up RF link is active only when the FSO link is in outage. In other words, the RF link lies idle when the FSO link is suitable for transmission. This reveals the hidden wastage of RF resource in the hard-switched Hybrid FSO/RF system which in turn motivates the presented work. In order to improve the RF utilization in Hybrid FSO/RF system, two novel architectures `Shared RF' and `On-Demand' are proposed. Next, conversion of a standalone FSO link to a `Cognitive Hybrid FSO/RF link' through interweave mode of Cognitive Radio by using spectral holes of a primary RF is suggested. To address the recent interest in Coexisting Radio and Optical Wireless Deployments (CROWD), detailed analysis is performed for a cognitive radio - Hybrid FSO/RF based system by including impact of optical channel impairments and data traffic patterns. The concept of single RF sharing was, further, expanded to accommodate multiple users in the form of design and dimensioning of a Multi Quality of Service system. The Multi-QoS system is able to accommodate three different tiers of link availabilities and more than one system sizes are possible for the same which in turn depend on optical channel conditions.
The use of non-ideal energy detectors in energy sensing mechanism and interweave mode of Cognitive Radio in the above systems cause them to be vulnerable to interference arising due to miss detection of primary RF transmission. In order to provide a holistic understanding, in depth interference analysis for the Cognitive Hybrid FSO/RF link and a Generalized version of Shared RF is undertaken. Further, this analysis shows the possibility of forming multiple back-up RF links by a single Hybrid FSO/RF link. Performance metrics used to study the system performance include link availability or link outage probability, RF utilization factor, bit error rate and ergodic capacity. Closed form expressions are presented for all cases. System parameters such as strength of atmospheric turbulence, pointing error, optical and RF switching thresholds, non-ideal energy detector's probability of false alarm/probability of detection and traffic pattern characteristics have also been considered for system design and analysis. Results show improved RF utilization and system performance for the various proposed systems. Shared RF system reports best RF utilization and ergodic capacity, whereas On-Demand system has the best link reliability. The Cognitive Hybrid FSRO/RF link boosts the utilization of the primary RF and reduces the link outage of the associated FSO link. FSO dependent and traffic dependent temporal holes also play a significant role in

enhancing system performance and RF utilization. In case of the Multi-QoS system, the system dimensions are found to be dictated by strength of atmospheric turbulence and pointing error. Further, study of Cognitive Hybrid FSO/RF link and Generalized Shared RF in the presence of interference gives additional insight into the system performance. Further, the Generalized Shared RF configuration enables multiple solitary FSOs to have their respective back-up RF links, all derived from a single RF resource, thus, highlighting the benefits of RF sharing in Hybrid FSO/RF links even in the presence of interference.

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