Advance Program

Advanced Digital Signal Processing in Next Generation Fiber

Monday, 23 July 2007

ALL SESSIONS WILL BE HELD IN FIRESIDE

9:00 AM - 10:00 AM

Session MA1: ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING
Session Chair: Nikola Alic, *University of California - San Diego, La Jolla, CA, USA*

MA1.1 9:00 AM - 9:30 AM (Invited)

Myths and Truths about Optical OFDM, S. Randel, *Nokia Siemens Networks Portugal S.A., Munich, Germany*, M. Schuster, *Technical University Berlin, Berlin, Germany*, J. Lee, *Eindhoven University of Technology, Eindhoven, The Netherlands* and F. Breyer, *Technical University of Munich, Munich, Germany*

Orthogonal Frequency Division Multiplex (OFDM) is currently discussed as an attractive format to overcome physical impairments in optical communication links such as modal dispersion, chromatic dispersion and polarization mode dispersion. This paper reviews recent progress in the field.

MA1.2 9:30 AM - 10:00 AM (Invited)

RF-Pilot Tone Phase Noise Compensation for Coherent OFDM Transmission Systems, S. L. Jansen, I. Morita, N. Takeda and H. Tanaka, *KDDI R&D Laboratories, Fujimino, Saitama, Japan*

In this paper, we show that by inserting a RF-Pilot tone in the middle of the OFDM spectrum, the local oscillator offset and phase-noise can effectively be compensated for in coherent-OFDM systems.

10:00 AM – 10:30 AM **COFFEE BREAK**

10:30 AM - 12:15 PM

Session MA2: JOINT SESSION ON ADSP & HIGH SPEED: 100 GB ETHERNET
Session Chair: Maurice O'Sullivan, *Nortel Networks, Nepean, ON, Canada*

MA2.1 10:30 AM - 11:00 AM (Invited)

Ethernet Evolution: The Path to 100 Gigabit Ethernet, J. F. D'Ambrosia, *force10networks, Harrisburg, PA, USA*

At the July 2006 IEEE Plenary, the Higher Speed Study Group was formed. This group has adopted a MAC rate objective of 100 Gb/s. This session will provide an update on the state of the group's efforts.

MA2.2 11:00 AM - 11:30 AM (Invited)

100G Ethernet – A Review of Serial Transport Options, P. J. Winzer and G. Raybon, *Alcatel-Lucent, Holmdel, NJ, USA*

We review recently demonstrated options for serial transport technologies at 100 Gb/s, including binary, multi-level, and coherently detected polarization-multiplexed formats.

MA2.3 11:30 AM - 12:00 PM (Invited)

Electronic Dispersion Compensation beyond 10 Gb/s, K. Roberts, *Nortel Networks, Ottawa, ON, Canada*

Electronic dispersion compensation is displacing optical compensation at 10Gb/s. How can this be achieved at 40 Gb/s or 100 Gb/s?

MA2.4 12:00 PM - 12:15 PM

Coherent Equalization versus Direct Detection for 111-Gb/s Ethernet Transport, D. van den Borne, *Eindhoven University of Technology, Eindhoven, The Netherlands*, T. Duthel, C. R. S. Fludger, *CoreOptics GmbH, Nuremberg, Germany*, E.-D. Schmidt, T. Wuth, *Siemens Networks GmbH & Co. KG, Munich, Germany*, C. Schulien, *CoreOptics GmbH, Nuremberg, Germany*, E. Gottwald, *Siemens Networks GmbH & Co. KG, Munich, Germany*, G. Khoe and H. de Waardt, *Eindhoven University of Technology, Eindhoven, The Netherlands*

We discuss coherent equalization to realize robust 111-Gb/s transmission. For 111-Gb/s POLMUX-RZ-DQPSK we experimentally show the advantage of coherent equalization over direction detection for compensation of both chromatic dispersion and differential group delay.

12:15 PM – 1:30 PM **LUNCH BREAK**

1:30 PM - 3:00 PM

Session MA3: QPSK AND DIGITAL SIGNAL PROCESSING
Session Chair: Robert I. Killey, *University College London, London, UK*

MA3.1 1:30 PM - 2:00 PM (Invited)

Ultra Long-Haul QPSK Transmission using a Digital Coherent Receiver, S. J. Savory, G. Gavioli, V. Mikhailov, R. I. Killey and P. Bayvel, *University College London, London, UK*

Digital coherent receivers have enabled ultra-long haul transmission of QPSK data. We outline the principles behind such receivers which have allowed 42.8Gbit/s data to be transmitted over 6400km of standard fibre without optical dispersion compensation.

MA3.2 2:00 PM - 2:30 PM (Invited)

Realtime Optical Synchronous QPSK Transmission with DFB Lasers, T. Pfau, O. Adamczyk, V. Herath, R. Peveling, S. Hoffmann, M. Porrmann and R. Noé, *University of Paderborn, Paderborn, Germany*

This paper focuses on the design of the components required to realize a 10 Gbaud synchronous optical quadrature phase shift keying (QPSK) transmission system. These are a 5 bit 10 Gsamples/s analog-to-digital converter and a digital signal processing unit for carrier and data recovery.

MA3.3 2:30 PM - 2:45 PM

PDL-Tolerant Real-time Polarization-Multiplexed QPSK Transmission with Digital Coherent Polarization Diversity Receiver, T. Pfau, R. Peveling, S. Hoffmann, S. Bhandare, S. K. Ibrahim, D. Sandel, O. Adamczyk, M. Porrmann, R. Noé, *University of Paderborn, Paderborn, Germany*, Y. Achiam, D. Schlieder, A. Koslovsky, Y. Benarush, *CeLight, Doar Na Arava, Israel*, J. Hauden, N. Grossard, and H. Porte, *Photline Technologies, Besancon, France*

This paper presents the implementation of a real-time electronic polarization tracking algorithm which enables robust optical polarization-multiplexed synchronous quadrature phase shift keying transmission with DFB lasers. The achieved BER at a data rate of 2.8 Gbit/s is well below the FEC threshold.

MA3.4 2:45 PM - 3:00 PM

Compensation of Coherent DQPSK Receiver Imperfections, I. Roudas, *University of Patras, Somerset, NJ, USA*, M. Sauer, J. Hurley, Y. Mauro and S. Raghavan, *Corning, Inc., Corning, NY, USA*

We experimentally demonstrate that optical hybrid imperfections and intermediate frequency offsets can seriously degrade the performance of coherent synchronous phase-diversity DQPSK receivers but can be compensated using digital signal processing.

3:00 PM - 3:30 PM COFFEE BREAK

3:30 PM - 5:00 PM

Session MA4: IMPLEMENTATION ASPECTS OF DIGITAL SIGNAL PROCESSING
Session Chair: Madeleine Glick, *Intel Corporation, Pittsburgh, PA, USA*

MA4.1 3:30 PM - 4:00 PM (Invited)

40G-OTN FEC Framer LSI Enabling Coding for Advanced Modulation Formats and 4 x 10GbE Transparent Multiplexing, M. Tomizawa and Y. Miyamoto, *NTT Corporation, Yokosuka, Kanagawa, Japan*

OTN functions-integrated LSI offers several functions to support 40G-DWDM systems: 2 kinds of 40G FECs, OTN/SDH/10GE-LAN processing, and coding for advanced modulation formats. 4 x 10GE-LAN transparently multiplexed DQPSK transmission is successfully conducted.

MA4.2 4:00 PM - 4:30 PM (Invited)

Practical Challenges for Electronic Dispersion Compensation in CMOS, T. ChanCarusone, *University of Toronto, Toronto, ON, Canada*

Compared to fractional tap-spacing, baud-rate EDC offers simpler tap-weight adaptation while suffering little performance penalty. Unfortunately, the popular CMOS traveling-wave filter provides insufficient bandwidth for baud-rate tap-spacing.

MA4.3 4:30 PM - 5:00 PM (Invited)

Implementation Aspects of High-Speed DSP for Transmitter and Receiver Signal Processing, J. Sitch, *Nortel Networks, Ottawa, ON, Canada*

Today's electronic processing capability means that it is now possible to perform extensive signal processing on signals at the highest data rates. In this presentation we discuss the design choices available to the DSP designer.

6:30 PM – 8:00 PM WELCOME RECEPTION - QUEEN MARIE BALLROOM

Tuesday, 24 July 2007

9:00 AM - 10:00 AM

Session TuA1: MLSE I
Session Chair: Srikanth Raghavan, *Corning, Inc., Corning, NY, USA*

TuA1.1 9:00 AM - 9:30 AM (Invited)

Review of Recent Progress in MLSE Receiver Technologies, J. Whiteaway, C. R. S. Fludger, S. Langenbach and T. Kupfer, *CoreOptics GmbH, Nuremberg, Germany*

MLSE offers adaptive non-linear equalization at the receiver with acquisition without training. New areas of application considered are directly modulated DFB laser, D(B/Q)PSK, and coherent transmission systems. Reduced complexity algorithms are a new research area.

TuA1.2 9:30 AM - 9:45 AM

Chromatic Dispersion Compensation Effectiveness of an MLSE-EDC Receiver for Three Variants of Duobinary, J. D. Downie and J. Hurley, *Corning, Inc., Corning, NY, USA*

Experimental data is obtained on the compensation effectiveness of MLSE-EDC against chromatic dispersion for three variants of the duobinary modulation format. The MLSE technology offers the greatest dispersion tolerance advantage for the optical duobinary format.

TuA1.3 9:45 AM - 10:00 AM

Metastable States of MLSE Receiver Induced by Extreme PMD Conditions, M. D. Feuer, M. Brodsky, *AT&T Labs - Research, Middletown, NJ, USA*, K. E. Cornick, *University of Melbourne, Parkville, VIC, Australia*, T. Kupfer, *CoreOptics GmbH, Nuremberg, Germany*, S. Aramideh, *CoreOptics Inc., Manchester, NH, USA*, P. Noutsios, *CoreOptics GmbH, Nuremberg, Germany* and M. Birk, *AT&T, Middletown, NJ, USA*

We have measured the performance of a 10Gb/s receiver incorporating maximum-likelihood sequence estimation (MLSE) under conditions of severe polarization-mode dispersion (PMD). We find that certain trajectories of PMD evolution can lead to metastable states of receiver operation.

10:00 AM – 10:30 AM COFFEE BREAK

10:30 AM - 12:15 PM

Session TuA2: Coding Techniques
Session Chair: Alexei N. Pilipetskii, *Tyco Telecommunications Laboratories, Eatontown, NJ, USA*

TuA2.1 10:30 AM - 11:00 AM (Invited)

Performance Optimization of Soft-Decision FEC Receivers, K. Onohara, and T. Mizuochi, *Mitsubishi Electric Corporation, Kamakura, Japan*

We present threshold tracking of a soft-decision based forward error correction system as an application of digital signal processing for optical communications. The 3-bit soft-decision thresholds are closely controlled to obtain the best possible error-correction performance.

TuA2.2 11:00 AM - 11:30 AM (Invited)

Modulation Coding for Optical Channels, Z. Taghavi, N. Alic and G. C. Papen, *University of California - San Diego, La Jolla, CA, USA*

The effect of a modulation code generated by a 'forbidden list' of input sequences on the performance of an optical receiver that uses a fixed state Viterbi algorithm is analyzed.

TuA2.3 11:30 AM - 11:45 AM

Chromatic Dispersion Compensation using LDPC-Coded Turbo Equalization, H. G. Batshon, I. B. Djordjevic and L. Minkov, *University of Arizona, Tucson, AZ, USA*

We present an iterative equalization scheme suitable for compensation of chromatic-dispersion. This scheme is able to compensate for chromatic-dispersion over 800km of standard SMF in an NRZ optical-transmission system without optical dispersion-compensation operating at 10Gb/s for only 128-states in corresponding trellis description of the channel.

TuA2.4 11:45 AM - 12:15 PM (Invited)

Iterative Decodable Block-Codes for High-Speed Optical Transmission, I. B. Djordjevic, *University of Arizona, Tucson, AZ, USA*

In this invited paper, we compare performance of three classes of iterative decodable codes suitable for use in high-speed optical transmission systems: (i) turbo product codes (TPCs), (ii) low-density parity-check (LDPC) codes, and (iii) generalized LDPC (GLDPC) codes with Hamming, BCH or Reed-Muller component codes.

12:15 PM – 1:30 PM LUNCH BREAK

1:30 PM - 3:00 PM

Session TuA3: Fiber Transmission
Session Chair: Takashi Mizuochi, *Mitsubishi Electric Corporation, Kamakura, Japan*

TuA3.1 1:30 PM - 2:00 PM (Invited)

Coherent Detection in Submarine Systems, Y. Cai*, Tyco Telecommunications Laboratories, Eatontown, NJ, USA*

We discuss potential advantages of coherent detection in reducing required OSNR or increasing spectral efficiency of current submarine optical systems. We investigate the impact of carrier-phase-estimation schemes and fiber nonlinearity on coherent-detection performance.

TuA3.2 2:00 PM - 2:30 PM (Invited)

QPSK with Coherent Detection over Ultra-Long Distance Improved by Nonlinearity Mitigation, G. Charlet*, Alcatel-Lucent, Nozay, France*

Coherent detection is very promising for improving the capacity and reach of transmission systems. Assuming QPSK format, its performance is compared at 40Gbit/s and after 3,060km with differential detection, and improved by mitigating nonlinearities digitally.

TuA3.3 2:30 PM - 3:00 PM (Invited)

Fiber Nonlinearity Mitigation by Electronic and Optical Techniques, R.-J. Essiambre*, Alcatel-Lucent, Holmdel, NJ, USA*

We discuss various electronic and optical techniques to reduce the impact of fiber nonlinearity and improve other system performance aspects in the context of optically-routed networks. Main differences between optical and electronic techniques are highlighted.

3:00 PM - 3:30 PM COFFEE BREAK

3:30 PM - 5:15 PM

Session TuA4: Coherent Applications
Session Chair: Peter J. Winzer, *Alcatel-Lucent, Holmdel, NJ, USA*

TuA4.1 3:30 PM - 4:00 PM (Invited)

QAM based Coherent Transmission Technologies using DSP, M. Nakazawa*, Tohoku University, Sendai, Miyagi, Japan*

Recent progress on QAM coherent transmission is described. QAM transmission started at 20 Msymbol/s, 64-128 QAM, and recently reached 1 Gsymbol/s, 64 QAM, carrying 12 Gbit/s data in a 2 GHz optical bandwidth.

TuA4.2 4:00 PM - 4:15 PM

Investigation of Electronic Equalization in Coherent Receivers with Complex Modulation Schemes, C. Hebebrand and W. Rosenkranz*, University of Kiel, Kiel, Germany*

We propose a post detection equalizer design for complex multilevel modulation and coherent I/Q-detection and investigate the performance in terms of dispersion tolerance for both linear and nonlinear (Kerr effect) fiber effects.

TuA4.3 4:15 PM - 4:30 PM

Implementation Tolerances for Coherent Analog Links Using I/Q Detection and Digital Demodulation, M. L. Dennis and T. R. Clark*, Johns Hopkins University, Laurel, MD, USA*

We experimentally investigate practical implementation considerations for highly linear analog photonic links based on in-phase and quadrature detection and demodulation using digital signal processing.

TuA4.4 4:30 PM - 4:45 PM

16-QAM Signal Design and Detection in Presence of Nonlinear Phase Noise, A. P. T. Lau and J. M. Kahn*, Stanford University, Stanford, CA, USA*

Constellation design and coherent detection of 16-QAM signals in the presence of nonlinear phase noise are studied. Various decision strategies and phase-noise mitigation techniques are compared in terms of symbol-error rate performance.

TuA4.5 4:45 PM - 5:15 PM (Invited)

Optical Homodyne Receiver Comprising Phase and Polarization Diversities with Digital Signal Processing, K. Kikuchi*, University of Tokyo, Kashiwa, Chiba, Japan*

This paper describes a coherent optical receiver, where drifts of the carrier phase and state of polarization are estimated with digital signal processing. The complex amplitude of the signal is entirely restored with such receiver.

Wednesday, 25 July 2007

9:00 AM - 10:00 AM

Session WA1: MLSE II
Session Chair: Robert I. Killey, *University College London, London, UK*

WA1.1 9:00 AM - 9:30 AM (Invited)

Fundamental Limits on the Performance of Maximum-Likelihood Sequence Estimation in Dispersive Optical Links, P. Poggiolini, *Politecnico di Torino, Torino, Italy*

MLSE experiments supporting 10Gbit/s, 1000km uncompensated G.652 fiber transmission, have been successfully performed. However, a residual 2dB OSNR-penalty, non-linear effects and Viterbi processor complexity may constitute fundamental limitations to actual MLSE exploitation in long-haul links.

WA1.2 9:30 AM - 9:45 AM

Electronic Dispersion Compensation based on Maximum-Likelihood Sequence Estimation for 10 Gb/s Fiber-Optic Communication Systems, X. Zhu*, McMaster University, Hamilton, ON, Canada*, S. Raghavan*, Corning, Inc., Corning, NY, USA* and S. Kumar*, McMaster University, Hamilton, ON, Canada*

We present a two-fold oversampling maximum-likelihood-sequence -estimation receiver for 10Gb/s fiber-optic communication systems. We use the Volterra theory to model the channel nonlinearity, and least mean square algorithm to update the channel characteristics without training sequence.

WA1.3 9:45 AM - 10:00 AM

Simple Method for MLSE Performance Estimation, M. Rubsamen*, Technical University Darmstadt, Darmstadt, Germany*, P. J. Winzer and R.-J. Essiambre*, Alcatel-Lucent, Holmdel, NJ, USA*

We present a novel semi-analytic technique to estimate the performance of MLSE receivers. The technique offers an intuitive explanation for the difference in performance between an MLSE receiver and an ISI-free threshold receiver.

10:00 AM – 10:30 AM COFFEE BREAK

10:30 AM - 12:00 PM

Session WA2: RUMP SESSION: SIGNAL PROCESSING AND HIGH SPEED
Session Chair: Maurice O'Sullivan, *Nortel Networks, Nepean, ON, Canada*

END OF PROGRAM