A simplified optical receiver using the Hilbert transform (Ramot)

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Coherent optical transceivers are widely deployed in metropolitan, long-haul and ultra long-haul fiber optic networks. Their performance in terms of sensitivity and data-rate is unparalleled, but their cost is high, in large part because they rely on an expensive optical front end in the receiver. The fron-end consists of integrated optical elements manufactured with interferometric accuracy and using 8 photo-diodes for signal detection. The Kramers Kronig (KK) receiver has performance that is close to that of the coherent receiver, but it does not require a complex optical fron-end. Instead the received signal is simply detected with two photodiodes (one per polarization). The idea is to add an optical carrier aligned with the edge of the transmitted spectrum. This turns the received signal into a minimum phase signal, in which case the phase can be recovered from the intensity and a complex QAM constellation can be reproduced.

The goal of designing a receiver that is based on direct single-diode detection is been motivating many study groups around the world an a host of solutions that are based on single diode detection has been proposed in the past several years. The KK receiver, which has been published for the first time only in Nov. 2016, has already attracted massive attention, and initial studies confirmed its advantage over all alternative schemes (see comperative experimental study conducted by a group from UC London in Ref. [4] below). The KK-receiver is better than its competitives in spectral efficiency, power efficiency, required electrical bandwidth, and in terms of its being compatible with digital compensation for chromatic dispersion.

The following is a list of features in which KK was compared with competing technologies as was tested numerically in [1] and experimentally in [4]

1) Required OSNR at BER=3.8E-3 in an exemplary system [4]: KK-receiver 23dB, raw detection 33dB. SSB with single stage linearization 28dB, with iterative linearization 26dB. – The KK has measured 3dB B2B OSNR advantage over the best alternative using same bandwidth and spectral efficiency!

2) BER vs. distance in KK receiver was measured to be 10E-5 at 80km, 10E-4 at 160km and 5X10E-4 at 240km. The numbers with best alternative scheme tested in [4] were 2X10E-5, 4X10E-4, and 2X10E-3, respectively. KK used all digital dispersion compensation.

3) Uncomparably best performance when testing CD tolerance with respect to other schemes (perfect digital compensation is possible).

4) Half the optical bandwidth compared to all PAM schemes!

5) Half the optical bandwidth and half electrical bandwidth compared to self heterodyne scheme by Lauery et al.

THE NEED

Communications between data-centers is currently one of the fastest growing markets. The growth was caused by the entry of major players into the communications market. These companies wish to interconnect their growing number of data centers with self owned fiber-optic infrastructure. The enormous volumes of data emphasize the need for spectrally efficient communication technology, but the costs and prices of coherent communications solutions are considered unacceptable for these volumes.

POTENTIAL APPLICATION

This technology is intended for transceivers serving the inter-data-center market.

STAGE OF DEVELOPMENT

The structure of the KK receiver has been established, and its performance has been tested numerically and experimentally. While further tests may be required for specific scenarios, it is now perfectly clear that the KK-receiver works and displays clear advantages over alternative methods.

PATENTS

A provisional patent has been filed

SUPPORTING PUBLICATIONS

Original idea:

[1] A. Mecozzi, C. Antonelli, and M. Shtaif, “Kramers Kronig coherent receiver,” Optica 3, 1220-1227,

2016
Extension of idea:
[2] C. Antonelli, M. Shtaif, A. Mecozzi, “Kramers Kronig PAM Transceiver,” Optical Fiber Comm. Conference (OFC), Los Angeles, 2017, Paper TU3I.5
Experimental verification:
[3] X. Chen, C. Antonelli, S. Chandrasekhar, G. Raybon, J. Sinsky, A. Mecozzi, M. Shtaif, P. Winzer “218-Gb/s Single-Wavelength, Single-Polarization, Single- Photodiode Transmission Over 125-km of Standard Singlemode Fiber Using Kramers-Kronig Detection,” Optical Fiber Comm. Conference (OFC), Los Angeles, 2017, PD paper Th5B.6
Paper by UCL group conducting comparison between KK receiver and competing technologies:
[4] Z. Li, et al., “SSBI Mitigation and the Kramers-Kronig Scheme in Single-Sideband Direct-Detection Transmission with Receiver-based Electronic Dispersion Compensation,” IEEE J. of Lightwave Technol., 2017

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