Cancellation of Non-linear Interference in Optical Fiber Communication (Ramot)

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Objectives

The theoretical research has led to the understanding that the effects of the nonlinear interference (NLIN) between the various channels in wavelength division multiplexed (WDM) environment can be described as time-varying inter-symbol interference (ISI) between the samples of the desired signal. The ISI coefficients depend on the interfering signals and, as our analysis showed, due to the differences in the group velocities, the coefficient are slowly time-varying – at the order of tens and even hundreds samples. This phenomenon gives rise to the capability to track the ISI coefficients and cancel the NLIN. The main goal of this research is to develop methods to perform the cancelation and as a result enable higher communication rates, or higher reach in fiber optic channels. Specifically, the main objective can be divided into several tasks - specification of the principal algorithms and schemes that can track the ISI coefficients and perform cancellation based on that estimate, complexity optimization and fixed-point implementation of the specified algorithm, designing coded modulation schemes to fit the channel after NLIN cancellation, and finally incorporate the developed algorithms in a full end-to-end modem simulation.

Background

New cloud services and abundant video communication over the network leads to a steady exponential increase, at a rate of over 60% per year, in the demand for transmitted data over the network backbone composed of optical fibers. Such growth-rates imply doubling of the demand for transmitted data every year and a half. Unfortunately, the communication rate per fiber is limited, and one of the main factors for this limitation is fiber non-linearity. In WDM systems, the non-linear physical phenomena in the fiber induce non-linear interactions between the different channels, generating complicated distortions of the transmitted optical signals. These distortions essentially diminish the system capability to decode the transmitted data and impose fundamental limits on the achievable communication rates. So far the non-linear distortions were considered as non-cancellable “noise” and were treated as additive white Gaussian noise, independent of the data of interest. This approach limits the achievable communication rates and essentially ignores the fact that the dynamics of the non-linear effects are slow, so non-linear noise mitigation can be applied to obtain higher throughput rates.

Status of the project

The theoretical research that has led to the new model for the NLIN is mostly complete. It was well established that the non-linear effects are rigorously equivalent to a time varying ISI, where the ISI coefficients depend on the data that is transmitted through the neighboring WDM channels. Because of the chromatic dispersion phenomena in the optical fiber, the ISI coefficients were shown to exhibit very long temporal correlations, at the order of tens and even hundreds of samples. The theoretical model has recently corroborated by simulation, validating the theoretical model and the long temporal correlations. The gain in reducing the residual noise after NLIN cancelation was also established theoretically and through simulations. The gain was shown to be substantial – more than an order of magnitude in the noise level by cancelling only two ISI coefficients.

Patent status

US Patent pending

Commercial potential

The market for fiber-optic transceiver modules is estimated at several millions of units per year. The need for better performance in communication rate and distance/reliability can make solutions based the proposed technology to become the leading solutions. Currently the transceiver modules

at relevant (100 Gb/s) rates are sold for ~$25 K per unit, with the price expected to reduce by an order of magnitude when unit becomes a commodity. The estimated cost of the DSP chip is estimated as 50% of the total unit cost. World market, based on current numbers, is estimated at several billions of dollars ($A*10^3*10^6). While the cost per unit is expected to reduce, the exponential growth of the telecomm market at a rate of 60% per year, predicts overall market growth in dollars. The results of development can be used as a basis for the formation of a company that will produce ASIC solutions, or an entire transceiver module. An alternative commercialization path can be based on licensing of technology based on successful simulation results and off-line processing of recorded data.

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