Two-Page Summary Preparation for QTS. Important: Do Not Use Symbols, Special Characters, or Math in the title

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It is well-known in the communication theory that an information-bearing signal can be considered as a random process, in which signal characteristics, such as power and phase, experience statistical variations that are linked to modulation formats and coding of data [1]. Such statistical variations can lead to rare events of occurrence of signal with properties very different to standard signal characteristics. Combined with nonlinear properties of fibre channel these statistical fluctuations of signal parameters can result in rather unusual observations. Here we examine statistics of conventional wavelength-division multiplexing (WDM) return-to-zero (RZ) carrier pulses from the view point of their propagation in the nonlinear fibre channel and show that soliton content can be inherent part of a standard (linear) signal.

At low signal power fibre channel is almost linear. Spectral components of a low power optical signal evolve in a trivial way and do not interact with each other during propagation in dispersive (linear) fibre channel. In this sense spectral components of any signal play the role of a natural basis for linear dispersive fibre channel. Evolution of any signal in the basis of spectral harmonics can be described in a simple way. In the nonlinear communication channels signal spectral components start to interact with each other and their propagation is not trivial. In some particular nonlinear channels, however, it is still possible to find similar natural basis with non-interacting components with rather simple evolution (see e.g. [2]).

Nonlinear Schrödinger equation (NLSE) is often used as a master path-average model describing (under certain conditions and within certain limits) signal propagation down the optical fiber (see for detail e.g. [3]). The normalized NLSE can be written in the generic form as:

$$i\frac{\partial q}{\partial z} + \frac{1}{2}\frac{\partial^2 q}{\partial t^2} + |q|^2 q = 0.$$

In general, in the case of anomalous dispersion, NLSE describes the co-existence of dispersive waves and localised coherent structures that are called solitons [3]. Propagation of signal in such a nonlinear channel is conceptually different from linear communication channels. In particular, at high enough power (this will be studied in detail below) any input signal will have a soliton components statistically created by the random process corresponding to the information content. We will demonstrate that soliton content might occur in conventional telecom signals that normally are not associated with soliton transmission. We determine the power threshold for transition between rare occurrences of solitons in conventional RZ WDM signal and regime where probability of having solitons in the WDM carrier pulse is close to unity.

Figure 1 shows how the probability of the soliton occurrence in a WDM signal, depending on the average signal power P_{ave} per channel. Eleven WDM channels are considered in this numerical experiment.

The process of transition from the low probability of discrete eigenvalues (solitons) in the signal to the regime when all the symbols contain a discrete eigenvalues (soliton component) occurs in the power interval of about $3-4$ dBm for 16-QAM, 64-QAM, and 1024-QAM.

Transmission in a non-linear fibre-optic channel reveals new features for the conventional signals developed for classical linear communications channels. We have shown that for the NLSE-based channel model, standard return-to-zero WDM symbols statistically contain a discrete eigenvalue (soliton) component. Through massive statistical modelling we have determined power threshold for transition from low probability of having discrete eigenvalues in the symbol to almost certain presence of soliton component in the signal. Transition zone depends on signal parameters, in particular on the modulation format.

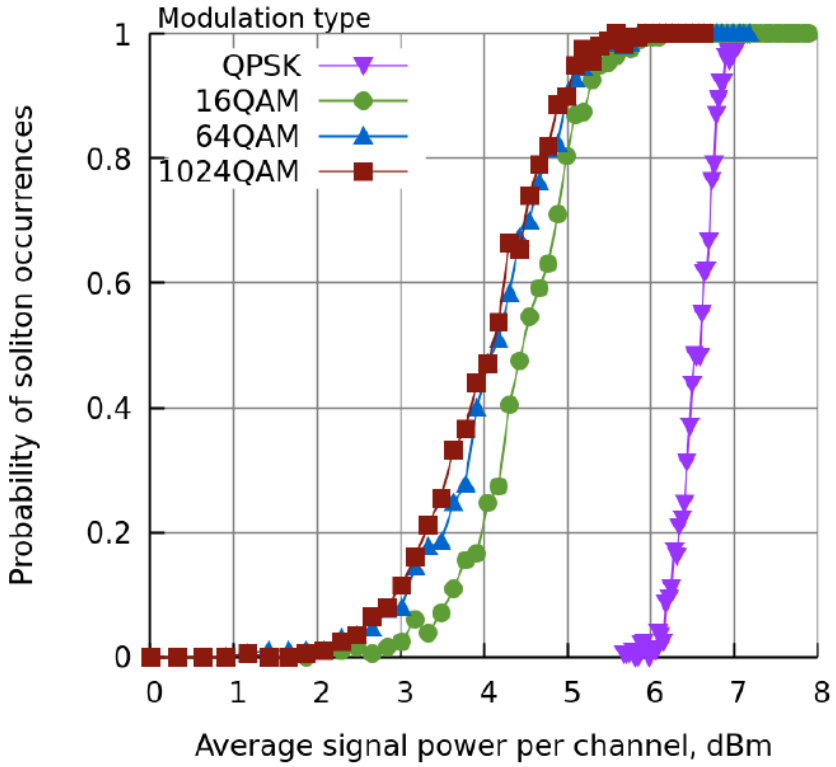

Figure 1: Average number of discrete eigenvalues (solitons) embedded into conventional WDM symbol with 11 channels and QPSK, 16-QAM, 64-QAM and 1024-QAM modulations versus channel average signal power.

References

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