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"The role of optical link in fiber transmission."

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ABSTRACT; To fulfill the increasing demand of bandwidth and capacity in networks, optical fibertransmission becomes the favorable mode of communication. This review addresses various cost-effective solutions to enhance the data carrying capacity or the transmission distance of the optical system. For the same, 40 Gbps and 100 Gbps data rate per channel was the main focus of the designed optical links. At higher data rates i.e. 40Gbps and 100Gbps nonlinearities plays more crucial role, thus require proper spectral management techniques and strategies to achieve the desired optical link performance. The aim of the present work is to explore the various spectral management techniques to enhance the performance of the pulse propagating through the optical fiber in single and multichannel optical systems. The performance characteristics have been measured in terms of BER-equivalent Q factor. Apparently, there are various methods to increase the overall capacity of lightwave transmission link. The present chapter summarizes the major findings of the thesis and also discusses the future scope of the work.

key notes - BER - equivalent,

I. INTRODUCTION:

Only first-order PMD was considered, neglecting chromatic dispersion and second-order PMD. These factors should be considered echo cancellers were used. To incorporate nonlinear effects, such as those caused by high transmitter laser power, nonlinear filters should be used. These filters would allow further improvements in bit rate, bit error rate, or fiber length.

With the development of Si/SiGe epitaxial transistors, and other high-speed circuits, experiments to verify the simulation results could be performed. These experiments require optical transmission and reception equipment, a PMD emulator and an integrated circuit design to adapt the tap weights of the adaptive filters. Only such a prototype would allow one to identify all of the complex issues associated with an implementation.

2.Techonology:

Fiber nonlinearity has been found to be one of the limiting factors for optical fiber communication systems as channel capacity requirement continues to grow. This dissertation contributes to understanding the effect of fiber nonlinearity on the performance of optical fiber communication systems. For this purpose, we have studied the following different nonlinear effects in detail:

- NLS equation and its analytical solutions;
- XPM- and FWM-induced intensity fluctuations in WDM systems;
- Application of multiuser detection in nonlinearity-limited WDM systems for better performance;
- Nonlinear interaction between signal and optical amplifier noise during co-propagation through fibers;
- Interaction between dispersion and nonlinearity for 40Gb/s systems and the optimization of dispersion compensation.

II. FUNCTION :

To efficiently study optical fiber communication systems, the fiber channel model based on the NLS equation must be correctly and efficiently solved. However, the complicated interaction between fiber dispersion and fiber nonlinearity make it a challenging task to solve the NLS equation. Despite the fact that the SSF method is the most widely-used tool in present studies on optical fiber systems, an analytical solution to the NLS equation is preferable when stochastic nature of the system is taken into account. To take advantage of the analytical nature of the truncated third-order VSTF method and keeping its computation efficiency while reducing its energy divergence, the modified VSTF method is proposed and used to study the signal propagation. Compared with the truncated third-order VSTF method, the modified VSTF method significantly reduces the energy divergence and thus extends the application range of such analytical tools.

WDM has been an efficient way to increase the system capacity with channels being more and more tightly packed. In such systems, XPM- and FWM-induced intensity fluctuation are known to be two limiting degradation sources. In this dissertation, we have applied the VSTF method to study thoroughly these two nonlinear effects, taking advantage of its efficiency on modeling stochastic system parameters including random information bits and random channel phases. Our work also extends previous theoretical works on XPM and FWM effects significantly. It leads to a better model for the study of the two nonlinear effects under which the two nonlinear effects can be correctly compared. The other important extension is in the analysis of the effects of XPM and FWM on complex optical networks where both networks with and without synchronization can be studied by the variance of the intensity fluctuations. Several methods to reduce the intensity fluctuation are also discussed and validated in this dissertation.

As XPM and FWM effects introduce interference from channel to channel, the correlation between the channels also allows the possibility of achieving better error performance by using multiuser detection. Consequently, we propose the use of multiuser detection in WDM systems where the error performance of such systems is studied using a validated Gaussian approximation with lower- and upper-bounds. Significant differences are found between our proposed multiuser detector for optical WDM system and a conventional linear detector due to the presence of the photodetector which is a nonlinear device with square-law operation on the signal. Asymptotic behavior of the multiuser square-law detector is also carefully studied and compared with the linear detector case. Multiuser square-law detection is also applied to a practical WDM system with very narrow channel spacing and the multiuser detector shows promising performance that is impossible for a single-user detector with such narrow channel spacing.

III. CONCLUSION :

Error performance of optical fiber communication systems has been studied since the advent of these systems with significant improvement made throughout these years. But most of the theoretical analyses on the error performance are based on the omission of the nonlinear interaction between the ASE noise and the modulated signal during their co-propagation through the fiber. In this dissertation, we have used perturbation theory to study this nonlinear interaction between the ASE noise and the signal. Unlike for previous studies which use the assumption of a CW signal, the output noise in our study is signal-dependent and non-stationary. In this case, we have found the noise frequency correlation functions using perturbation theory, keeping up to the second order in nonlinearity for computation simplicity. Our results are shown to be accurate wherever the perturbative approach is applicable to solve the NLS equation. With the noise characteristics in hand, the detector statistics can be obtained by the Monte Carlo simulation. The results show PDF's that resemble χ^2 distribution, suggesting that the noise is near Gaussian before the photodetector.

As an alternative to more and more channels being used in WDM systems, we see significant improvement on the transmission capacity of a single channel with the optical fiber communication systems evolving from 10Gb/s to 40Gb/s and above per channel. At a bit rate as high as 40Gb/s, the effects from both fiber dispersion and fiber nonlinearity are pronounced due to the high power Fnd large signal bandwidth used. As a result, the complicated interaction between the fiber dispersion and fiber nonlinearity must be carefully studied and the nonlinear interaction between pulses is found to be the limiting system degradation source. To study this nonlinear effect, previous studies have assumed different system and device parameters. We focus on the robustness of system performance and dispersion compensation optimization with respect to different device parameters in Chapter 4 The different devices we consider include transmitters with different pulse shapes; receivers with different optical filter and electrical filter bandwidth., receivers with optical filters of different orders; fibers with different second-order dispersion; fibers with different uncompensated third-order dispersion; and dispersion compensators with and without non-linearity. First, we find that significant system performance can be achieved by optimizing the bi-end DC. Second, a significant difference is found for both system error performance and optimal dispersion compensation for different device parameters in most cases. The results indicate that the dispersion compensation must be carefully optimized using device parameters as close to the practical systems as possible.

With these separate studies on several different nonlinear effects, this dissertation has identified and studied the most important nonlinear effects for modern long-haul optical fiber communication systems. The goal of this dissertation is to find accurate and efficient tools for the system performance study instead of studying a specific system. The proposed analytical tools have all been carefully validated and numerous applications to specific systems have also been given as examples.

IV. FUTURE WORK :

Approximations have been used throughout the works in this dissertation to simplify the problems. For example, in the study of XPM- and FWM-induced intensity fluctuations, we have used a CW probe channel reduce the computational complexity which assumes that the probe channel stays at its peak power. Even though the VSTF method can be applied to the case when a modulated probe channel is needed, it is impractical for the computation of the fluctuation variance due to the multiple-dimension integration in the frequency domain. A computationally efficient way to do the frequency-domain integration is the key to solve this problem.

The Gaussian approximation is popular in research, but its accuracy has been questioned and more accurate techniques are always preferred. Recently, an extension of the K-L expansion with colored noise has been used to find the BER performance for optical fiber communication systems. To move forward, the colored, but still stationary noise should be replaced by the more realistic signal-dependent noise.

As optical fiber communication systems shift from point-to-point long-haul transmission to more intelligent transport networks, many new problems need to be studied and answered. One especially important one is how to design an optical network efficiently.

The present most widely-used network design criteria is based on the worst-case scenario where the worst-case path is identified first and then designed to meet the specification requirement. However, this method is clearly inefficient if this path is only a very small portion of the whole network. To achieve better use of the scarce sources we have, better design criteria should be used while meeting the performance requirement for every channel. For this purpose, something similar to the channel capacity could be defined for the network as the network capacity, then we try to achieve this network capacity by allocating the channel wavelength and channel power etc. Other than the static network, adaptive network is another option which can usually make better use of the network sources than the static network. In this case, to find the worst-case path might itself be a challenging task.