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学位論文名	Study on Nonlinear Effects in Optical Fiber Communication Systems with Phase Modulated Formats （位相変調フォーマットを用いた光ファイバ通信システムにおける非線形効果の影響に関する研究）
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論文内容の要旨

This thesis presents a theoretical study on effects of fiber nonlinearity in single channel and multi-channel dispersion-managed (DM) fiber-optic transmission systems for phase modulation schemes and their mitigation techniques. The content of the dissertation is based on the research which was carried out during my doctoral course at the Department of Electrical, Electronic and Information Engineering, Graduate School of Engineering, Osaka University. The dissertation is organized as follows:

Chapter 1 is a general introduction which gives the background, the purpose of the study and overview of the dissertation. It briefly states the researches on advanced modulation format particularly phase modulation formats that are promising for high speed long-haul lightwave communications. Then nonlinear effects are asserted and DM transmission systems have been discussed for soliton and quasi-linear pulse.

Chapter 2 presents the basics of optical fiber communications along with a brief discussion on the modulation formats for ultra-high speed long-haul transmission systems. Phase modulated formats have been discussed addressing the background of this study. Next the basic theories for the analyses employed in this thesis for DM transmission is presented after making a brief discussion on fiber nonlinearities.

Chapter 3 describes the phase jitter mechanism followed by theoretical study of phase jitter in constant dispersion soliton, DM soliton and quasi-linear pulse transmission systems. After introducing ASE noise by periodically located optical amplifiers into the system, the ordinary differential equations derived in chapter 2 are linearized. The dynamics of noise-perturbed pulse parameters have been derived. Therefore, the

variances and cross-correlations of these parameters have been evaluated. The phase jitter effect in DM soliton and quasi-linear systems is examined with physical interpretation. Various DM models have been assumed and the impact of dispersion management on phase jitter has been investigated. The results obtained for DM models are compared to that of a constant dispersion soliton system. The variational results are verified by numerically solving the NLS equation using split-step Fourier method and carrying out Monte Carlo simulations.

Chapter 4 explains the fundamental mechanism of collision-induced phase fluctuations in a periodically dispersion compensated two-channel WDM transmission system. Dynamical equations for pulse propagation in WDM system has been deduced using variational analysis assuming XPM as a perturbation source. Phases shift due to XPM has been estimated for 50 GHz channel spacing. Impact of initial pulse spacing between inter-channel pulses, channel spacing and residual dispersion on phase shift is investigated for different dispersion models.

Chapter 5 concludes the thesis by summarizing the results stating the significance of this study concerning the high speed long-haul fiber-optic transmission systems.

論文審査の結果の要旨

This dissertation presents a theoretical study on effects of fiber nonlinearity in single-channel and multi-channel dispersion-managed (DM) optical fiber transmission systems for phase modulated formats and discusses their mitigation techniques. It also proposes upgraded models to achieve long transmission lines. Analytical results are obtained by variational method and are validated by solving the nonlinear Schrödinger equation numerically using split-step Fourier algorithm. The main results obtained in this dissertation are summarized as follows:

The next generation lightwave transmission systems should provide this high capacity and at the same time, at a lower cost. This shifts the research trend from OOK-based system to the phase modulation formats such as DPSK and multilevel PSK/DPSK to enhance the per-fiber transmission capacity. That's why, in recent years, phase modulation schemes draw huge research attention and are becoming the promising transmission formats for next generation spectrally efficient high speed long-haul optical transmission networks.

The phase noise due to interaction of fiber nonlinearity and amplifier's ASE noise has been examined for various DM maps. Therefore, upgraded DM maps are proposed to obtain phase modulated long transmission line with lower phase noise. It is found that weaker DM map is suitable for DM soliton transmission whereas stronger DM map is preferable for quasi-linear transmission systems regarding phase noise.

The fundamental mechanism of collision-induced phase shift in a DM WDM system has also been investigated. Phase fluctuations due to XPM are calculated for different DM maps and for different bit-rate systems considering RZ pulse. Furthermore, impact of initial pulse spacing, channel spacing and residual dispersion on phase shift has been explored. XPM-induced phase fluctuations could be considerably mitigated by properly choosing channel spacing and residual dispersion.

From all the obtained results, it is concluded that, phase fluctuations due to fiber nonlinearity might be a major limiting factor in the way to realize long-haul high speed phase modulated transmission systems. However, these impairments could be mitigated by properly designing DM transmission systems along with consideration of other design factors like amplifier spacing, channel spacing, and residual dispersion.

The judging committee admits that the thesis is worth the doctoral dissertation.