THE INFLUENCE OF THE TIME-SHIFTED INTERFERENCE ON THE BIT ERROR PROBABILITY IN A SYSTEM WITH A NONLINEAR-DISPERSIVE OPTICAL FIBER

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In this paper, Gaussian pulse propagating along a dispersive and a nonlinear-dispersive fiber in presence of the time-shifted interference signal is considered. A comparison between the cases when the interference is absent and when it appears at input the fiber is also presented. Specifically, we have observed the cases when anomalous – dispersion regime dominates in the fiber. We have calculated the bit error probability of the digital transmission system versus signal-to-noise ratio (SNR), with dominant dispersion effects and with balanced dispersive and nonlinear effects along the optical fiber, respectively. Also, we considered the system performances for different values of time-shift of interference.

Keywords: time-shifted interference, anomalous-dispersion regime, Gaussian pulse, the bit error probability

1. INTRODUCTION

In nonlinear-dispersive optical fiber both dispersive and nonlinear effects have influence on shape and spectrum of the pulse propagating through the fiber. In such a fiber, self-phase modulation (SPM) give rise to the components with the new frequencies, that is shifting the leading edge of the pulse to a red region and the trailing edge to a blue region.

In normal-dispersion regime red components are propagating faster than the blue ones causing significant signal distortion. In anomalous-dispersion regime, in the beginning, the combined effects of SPM and GVD cancel each other. Therefore, the pulse broadening is not so high as in normal-dispersion regime. In this paper we have presented only the results of the analysis for the anomalous dispersion regime.

The basic equation of propagation of the optical pulses of width greater than 0, 1 ps is:

$$\frac{\partial A}{\partial z}+\beta_1\frac{\partial A}{\partial t}+\frac{i}{2}\beta_2\frac{\partial^2 A}{\partial t^2}+\frac{\alpha}{2}A=i\gamma\left|A\right|^2 A \tag{1}$$

In case of $\alpha = 0$, this propagation equation is called nonlinear Schrödinger equation. In this paper symmetrical split-step Fourier method is used to solve this equation [1] .

2. DIFFERENT PROPAGATION REGIMES

Solving the basic propagation equation can provide us an analysis of the combined effects of group-velocity dispersion (GVD) and self-phase modulation (SPM) on the optical pulses propagation in the single mode fibers.

It is known that refraction index depends on intensity of the pulse propagation along the fiber. If signal has a certain power, Kerr's nonlinearities are inevitable.

However, in anomalous dispersive regime (dispersion coefficient $\beta_2 < 0$), these effects can decrease the influence of GVD. Moreover, the interplay of GVD and SPM can lead to the pulse compression in normal dispersion regime. In anomalous dispersion regime, the fiber can support solitons. [2].

Another unavoidable problem is interchannel crosstalk. It is caused by several factors. We refer to one of them – the reflections on the connections at different points along the fiber. In overall analysis we have considered the linear and nonlinear fibers.

3. INFLUENCE OF INTERFERENCE

In optical telecommunications useful signal frequently has a Gaussian form:

$$A(0,\tau) = a\exp(-\tau^2/2) \tag{2}$$

Parameter a depends on transmitted information ("1" or "0"). At the fiber input useful signal is:

$$s(0,\tau) = A(0,\tau)\cos\omega_r\tau \tag{3}$$

$\omega_r = \omega T_0$ is normalized frequency, T_0 is pulse width. We consider a case of Gaussian pulse propagating along the nonlinear-dispersive fiber, in a dominant anomalous dispersion regime.

If the interference is absent, signal at the distance z from the nonlinear dispersive fiber input, has the form presented in the Fig.1:

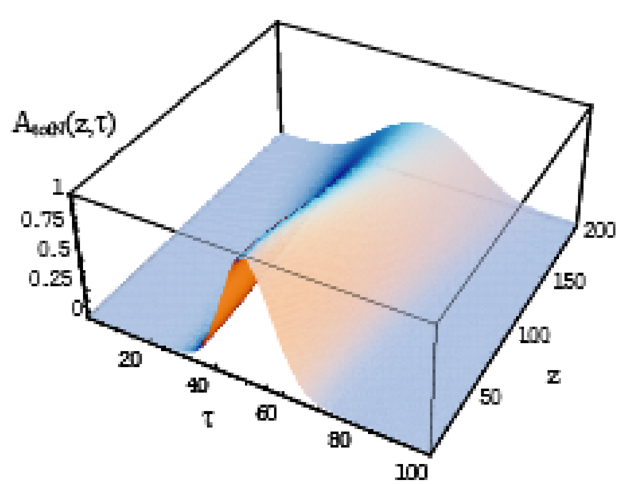

Fig. 1. Normalized propagation of the Gaussian pulse in a nonlinear-dispersive fiber (the interference is absent)

Now, we consider the case when interference signal is time-shifted to useful signal, i.e. it arises at input of the fiber [3]:

$$s_i(z_i,\tau) = A_i(z_i,\tau)\cos\omega_r\tau$$
$$A_i(z_i,\tau) = a_i \exp(-(\tau-b)^2/2) \tag{4}$$

where b – time shift, z_i - the place of arising of interference along the considered optical fiber. Parameter a_i depends on magnitude of crosstalk.

Fig. 2. illustrates the case of Gaussian pulse propagation along the nonlinear-dispersive optical fiber in presence of the time-shifted interference at input of the fiber. Interference signal has Gaussian envelope, too. As expected, mutually canceling effects of GVD and SPM cause that interference has significantly lower influence, because the useful optical signal has not been highly distorted until it reach the point of interference appearing.

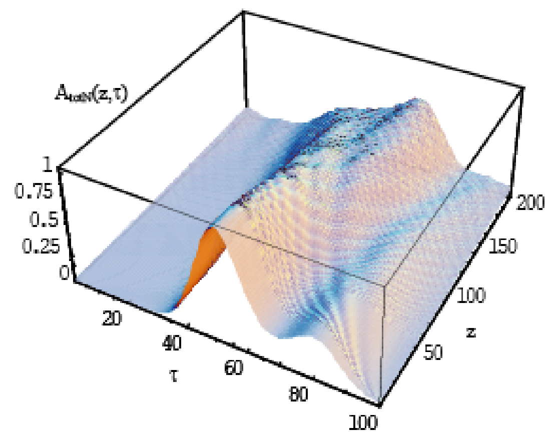

Fig.2. Normalized propagation of the Gaussian pulse along a nonlinear-dispersive fiber (time - shifted interference).

In this calculation the following parameters are used: λ=1550 *nm*, $T_0=1ps$, $A_{eff}=80\mu m^2$, $D=1ps/(km\ nm)$, $n_2 = 2.24 \times 10^{-20}\ m^2/W^2$, $P_0=1W$, $\beta_2= -\lambda^2 D/(2\pi c)$. These parameters qualitatively describe the equal influences of dispersive and nonlinear effects in the fiber.

4. THE BIT ERROR PROBABILITY

$P_{e/\tau,b}$ iz determined using *Gaussian* aproximation. The decision is made with respect to the signal:

$$z = k\,n + y \tag{5}$$

where n represents the number of electrons emitted from a diode, and y represents *Gaussian* noise appearing at the resistances and the amplifier inside the receiver. For $P(H_0) = P(H_1) = 1/2$, P_e is obtained as [4] :

$$P_{e/\tau} = \frac{1}{2}\left[\int_{V_p}^{+\infty} p_0(z/\tau)\,dz + \int_{-\infty}^{V_p} p_1(z/\tau)\,dz\right] \tag{6}$$

where $p_0(z/\tau)$ and $p_1(z/\tau)$ denote conditional probability density functions, and V_p is decision treshold. P_e is obtained for the worst case when *p(τ)* is uniform probability distribution.

$$P_e = \int_{-\infty}^{\infty} P_{e/\tau,b}\; p\,(\tau)\,d\tau \tag{7}$$

5. SIMULATION RESULTS

Fig. 3. shows the influence of time-shift of interference on the bit error probability versus signal-to-noise ratio (SNR), in the case of the anomalous dispersion regime and a propagation with dominant dispersive effects. Parameter *N* describes a propagation regime in the optical fiber. If $N^2 << 1$, the dispersion effects dominates, and for $N^2 \approx 1$ dispersive and nonlinear effects are balanced. In first case, it can be seen that the best performances (the nearest to the case when the interference is absent) are obtained when the interference time-shift is the smallest (*b*=0).

In second case, fig. 4, for the transmission system with the nonlinear and dispersive fiber the results are similar and significantly better for the smaller time-shift, but the results are slightly better for bigger time-shifts (*b*=1 and *b*=2.5).

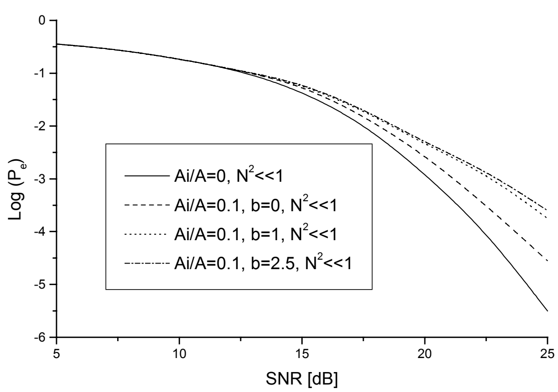

Fig. 3. The bit error probability versus SNR in the presence of time shift of interference in case when the dispersion dominates along the fiber

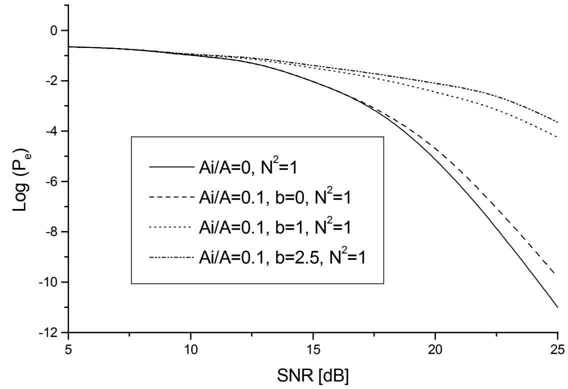

Fig. 4. The bit error probability versus SNR in the presence of time shift of interference in case when dispersive and nonlinear effects are balanced along the fiber

6. CONCLUSIONS

In this paper, the effect of time-shift of interference signal on the bit error probability of the system is considered. The results, in case of the linear-dispersive fiber and the fiber with balanced nonlinear and dispersive effects for dominant anomalous dispersive regime, are presented. Generally, the balanced dispersive and nonlinear effects provide better system performances for different values of time-shift of interference. For the biggest values of the time shifts, the balanced nonlinear and dispersive effects along the optical fiber provides slightly better characteristics, because the large time shifts of intefererence disturbed enough a pulse shape for whole values of *N*.

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