Features of the fiber-optics data system using optical solitons

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Abstract. The analysis of the parameters of a high-speed information data system using dispersion-managed solitons is carried out. It is shown that the quality of information transmission can be increased by choosing the input-output point of the symbol sequence on the dispersion map.

1. Introduction

Soliton information transmission systems are distinguished by high reliability of information transmission [1-8]. However, in real fibers, it is possible to realize the soliton regime at certain approximations. Various variants of the soliton-like regime are used depending on the specific problem. The classical regime of the fundamental soliton provides a high speed in the transmission channel but requires a relatively high peak power of symbol pulses. The use of wavelength division multiplexing is hindered by the effect of the interaction of solitons. Pass-average solitons suitable for long hop systems but has symbol width limitations. For high-speed WDM systems, it is advisable to use the dispersion-managed soliton mode. The distinguishing feature of this mode is the low threshold level forming soliton in an optical fiber, which ensures a low level of inter-channel interference. The soliton is formed as averaged over a long nonlinearity manifestation. To implement this mode, the topology of a dispersion map (Figure 1) with alternating segments with a dispersion $\beta_2$ of opposite signs is used. Along the segment length, the parameters of the soliton pulse, such as the pulse duration $T(z)$, the frequency chirp $C(z)$, experience periodic changes, keeping their values $T_0$ and $C_0$ at the segment boundary (Figure 2).

![Figure 1. Typical dispersion management map.](image-url)

Dispersion scheme (Figure 1) consist of the two fibers with the anomalous (negative) dispersion $\beta_{2a}$ and length $l_a$ and positive dispersion $\beta_{2p}$ and length $l_p$ [4]:
where $L_{\text{map}}$ is the period of the dispersion map.

The input pulse width $T_\text{o}$ is determined depending on the initial chirping $C_\text{o}$ and the parameter $T_{\text{map}}$ – dispersion map parameter [4]:

$$T_\text{o} = T_{\text{map}} \sqrt{\frac{1+C_\text{o}^2}{|C_\text{o}|}},$$

where $T_\text{o}$ – pulse width and $C_\text{o}$ - pulse chirp between the segments with different dispersion, and

$$T_{\text{map}} = \sqrt{\frac{|k_2| l_n l_\alpha}{\beta_2}},$$

The dispersion map parameters largely determine the bit rate. However, with the given parameters of the dispersion map, it is possible to select the parameters of the symbol pulse (Figure 2), providing a higher bit rate and higher SN-ratio in the system. For this, a differential dispersion map is used, which makes it possible to input / output data at the midpoint of the segment, the so-called point of zero chirp, where the pulse width takes on a minimum value.

The fiber-optic system with a period $l_a = l_n = 48$ km and 12 km was modeled in OptiSystem. In first configuration input soliton pulse width, corresponding to $T_\text{o} = 12$ ps and $C_\text{o} = 1$, so that the $T_{\text{map}} = 8.5$ ps realized bit rate of 10 Gbit/s. Second configuration referred to as the dense dispersion management: $T_\text{o} = 6$ ps and $C_\text{o} = 1$, so that the $T_{\text{map}} = 4.2$ ps (Figure 2 – 4). In this configuration bit rate of 20 Gbit/s can be realized.

Figure 2. Spatial dynamics of changes in the pulse width $T(z)$ (1 - 2) of the soliton pulse and a chirp $C(z)$ (3 - 4) at $C_\text{o} = 3$ (1, 3) and $C_\text{o} = 1$ (2, 4) (a) on the period of the dispersion map $l_a = l_n = 48$ km, $|\beta_2| \cong 3$ ps$^2$/km (a), $l_a = l_n = 12$ km, $|\beta_2| \cong 3$ ps$^2$/km (b).

On the long-distance propagation solitons can be formed if the nonlinear effects are balanced by the path-average dispersion:

$$\overline{\beta_2} = \frac{\beta_{2a} l_n + \beta_{2a} l_\alpha}{l_n + l_\alpha},$$

As a result, solitons can be formed in an average sense, but the width and power of such solitons oscillate periodically on the dispersion management map.
Figure 3. Dependence of the pulse width $T_o$ at the boundary of segments with different dispersion (1) and width $T_{min}$ (2) in the middle of the segment on the initial energy $E_o$ of the soliton pulse (dispersion map parameters are presented in Figure 2).

Figure 4. Dependence of the pulse power $P_o$ at the boundary of segments with different dispersion (1) and width $P_{m}$ (2) in the middle of the segment on the chirp $C_o$ of the soliton pulse (dispersion map parameters are presented in Figure 2).

As shown by computer simulation with the OptiSystem-program, with an initial value of $C_o = 1$ and entering the middle of a segment with anomalous dispersion, the value of the Q-parameter increases by 3 times (Figure 5).

Figure 5. Q-parameter at the output of the system $Q_m$ when entering the middle of a segment with anomalous dispersion (at the point of zero chirp) depending on the value of the $C_o$ chirp at the boundary of segments with variance of different signs, normalized to the value of $Q_o$ - the value of the Q-parameter at $C_o = 1$ and data input at segment boundaries.

An increase in the initial energy $E_o$ of the pulse and, accordingly, an increase in $C_o = 3$ additionally increases the Q-parameter up to 5.6 times (Figure 5). However, a further increase in these values $C_o$ already leads to a decrease in the value of the Q-parameter since the pulse width at the segment boundary and the interaction of solitons significantly increase.
2. Conclusion

The computer simulation of the fiber-optic data transmission system using optical solitons has been carried out. It is shown that when constructing the system with a dispersion map, which assumes input-output of spectrally limited pulses, the quality of data transmission increases. The optimal parameters of such a system can be chosen.

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