Compensation of chromatic and polarization mode dispersion in fiber-optic communication lines in microwave signals transmittion.

A N Ermolaev, G P Krishpents, V V Davydov, M G Vysoczkiy

Department of Quantum Electronics,Peter the Great Saint – Petersburg
Polytechnic University, Saint Petersburg 195251, Russia

Abstract. Methods of dispersion compensation in fiber-optic communication lines. A new proposed method of electronic dispersion compensation in the transmission of microwave signals through fiber-optic lines . Represents is proposed the results of experimental studies of this method.

1. Introduction

In fiber-optic communication lines (FOCL) with a single-mode optical fiber there are a number of factors that limit the speed of its transmission are considered. Attenuation, chromatic and polarization mode dispersion and nonlinear effects are among them. These phenomena give rise to the inter symbol interference (ISI) because adjacent pulses begin to overlap are their broadening. This leads to errors during information processing.

By increasing the speed of information transmission impulses (figure 1) start to "deliquesce" in time due to intersymbol interference (figure 2). This leads to overlap of adjacent pulses on one another. In this regard, it is increasing the probability of incorrect signal detection. And at speeds of 10 Gbit/s pulse distortion is not as critical as at speeds of 40 Gbit/s or 100 Gbit/s, which pass all the modern company.

To compensate the chromatic dispersion (CD) and polarization mode dispersion (PMD) different methods are used to-day [1]. In optical data transmission systems optical methods are traditionally used to compensate the chromatic dispersion and polarization mode dispersion. But in the transmission of microwave signals in the range from 10 GHz to 33GHz, the use of optical compensation techniques becomes unacceptable[2, 3].Therefore methods of the electronic compensation of dispersion were developed [1-5], which allow to make the signal processing in digital form in the receiving device.

Nowadays there are a large number of algorithms for compensation of chromatic and polarization mode dispersion. But these algorithms have several drawbacks that in case of a wrong choice of parameters don't allow to decipher the transmitted message without errors.An most cases it leads to the loss of information.

2. Proposed method of compensation of dispertion

To exclude errors in the decoding of the received signals associated with chromatic and polarization mode dispersion, we developed a new algorithm of compensation of these electronic dispersions and the method of determining values according to characteristics of transmitted signals.

For experimental verification of our proposed new method compensation chromatic and polarization mode dispersion was designed and assembled experimental setup (figure 3).
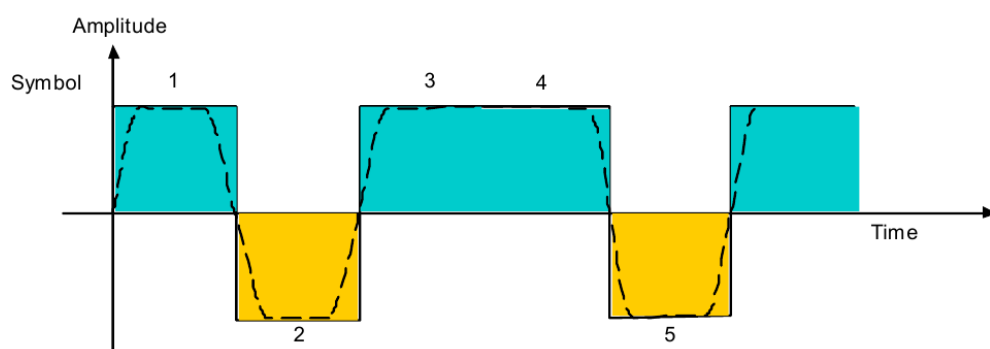
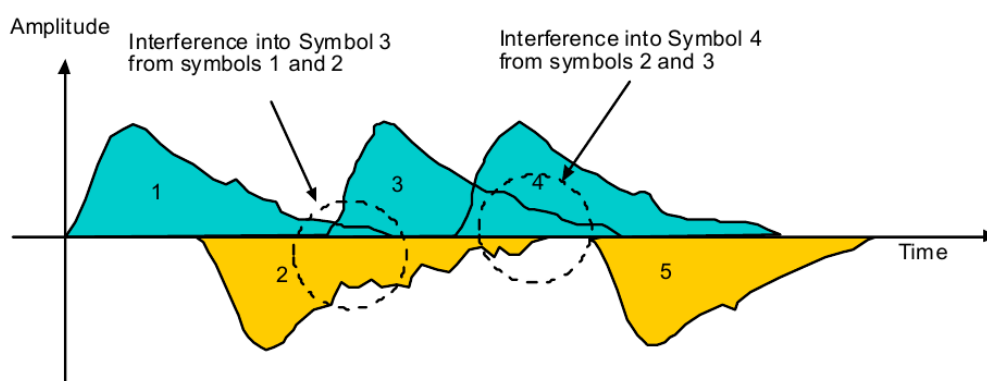**Figure 1.** The signal without the intersymbol interference.

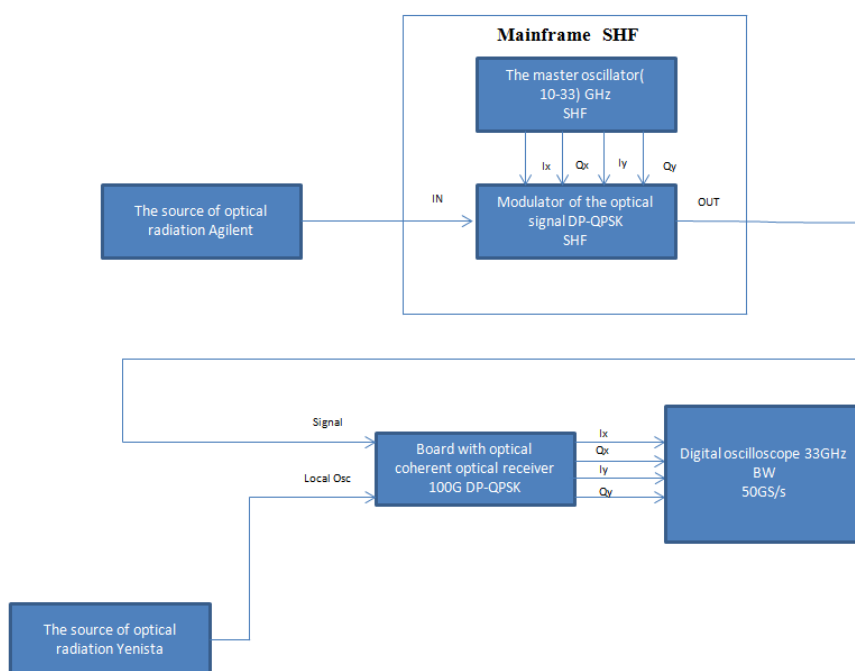**Figure 2.** The signal with the intersymbol interference.

Figure 3. The scheme of experimental installation.

For researches using optical signal (λ = 1510 nm) DP-QPSK format (figure 4) (modulation frequency 25 GHz) is transmitted at a rate of 100 Gbit/s. The structure of the signal in the DP-QPSK format is illustrated in figure 4. The signal includes two information components for formatted QPSK orthogonal polarizations - which means that spectral multiplexing is carried out. In turn, each of the two orthogonally polarized signals in the QPSK format can be represented as the union of two binary phase signals BPSK, phase-shifted by π/2. Each QPSK signal symbol can be one of the four phase values: 0, π/2, π, 3π/4. Consequently, each signal QPSK symbol carries 2 bits of information. Each symbol of DP QPSK signal comprises two symbols of QPSK signal, hence it carries 4 bits of information.

In the experimental setup reference radiation with a wavelength of 1550 nm is modulated by the optical modulator, with the frequency of modulation 25 GHz/s. The radiation is directed to a single mode fiber. The fiber length is 20 m. The optical dispersion compensator is built on the basis of the Bragg grating. Dispersion values are compensated by this device lie in the range from -1200 to 1200 ps/nm. Since at such a considerable distance chromatic dispersion does not have time "to express itself" - we artificially distort using of an optical compensator. With a step of 100 ps/nm, we have changed the setting of the optical dispersion compensator. The optical signal was fed to the optical coherent receiver [4], the output signals of which are phase and quadrature components of each of the two polarizations. In figure 2 shows the block diagram of our proposed method for dispersion compensation. Numbers 1 – 6 marked charts of a signal in a phase plane at different compensation stages of the dispersion. In figure 2 shows the block diagram of our proposed method for dispersion compensation. Numbers 1 – 6 marked charts of a signal in a phase plane at different compensation stages of the dispersion.
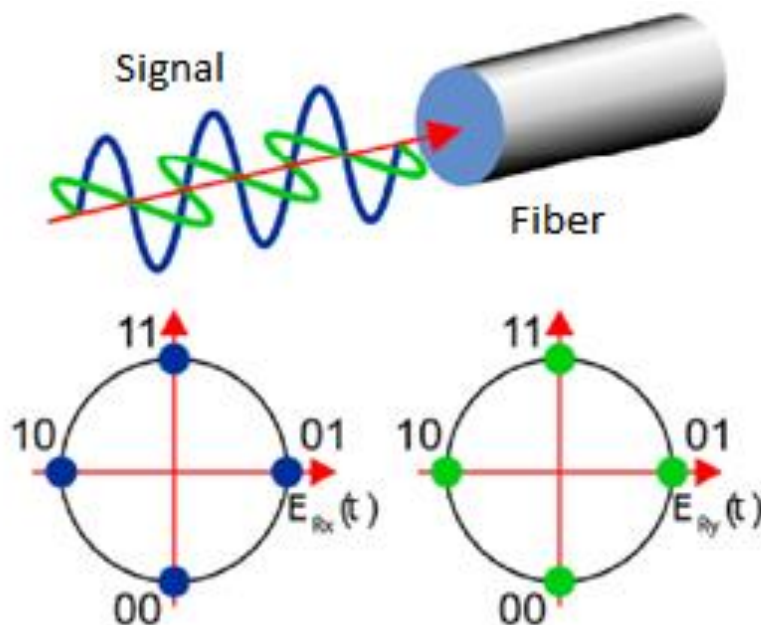

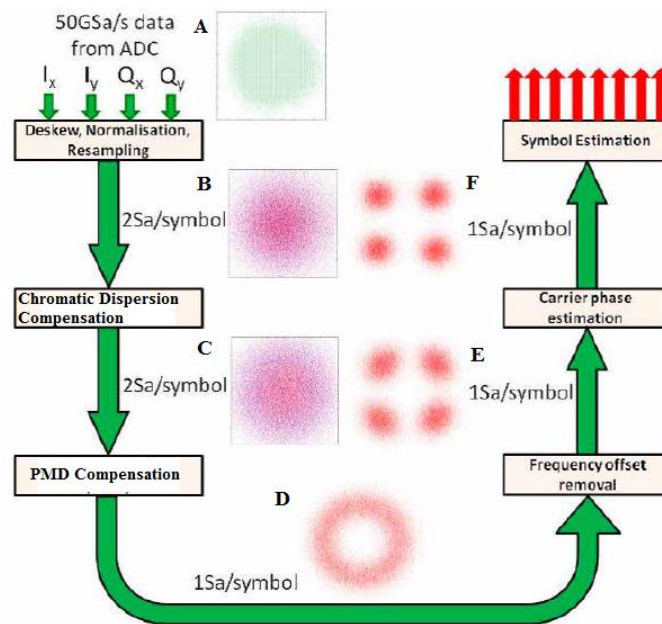**Figure 4.** The structure of DP-QPSK signal.

Figure 5. The algorithm of digital signal processing.

To compensate for chromatic dispersion, we use a digital filter with a transfer function like this:

$$CD = \exp(jf^2\pi\frac{\lambda^2}{c}CD),$$

where f is the clock frequency, λ the signal wavelength, c the speed of light and *CD* the value of CD.

The chromatic dispersion compensation unit executes static compensation of chromatic dispersion independently for two polarizations (chart C), and then to the two polarizations simultaneously apply rapid adaptive distortion compensation methods. The next step DP QPSK signal processing is used constant value signal module search algorithm (CMA - constant modulus algorithm). This algorithm minimizes the signal amplitude deviations from a desired mean value (chart D).The next step is estimated and eliminates the difference frequency between the reference laser and the optical carrier of the received signal, which is determined by the laser transmitter (chart E).The calculated value of the difference frequency is used to eliminate the rotation of the graph in phase plane. In the following steps is estimated and compensated for phase noise (chart F), then determine the values of received symbols.

3. Conclusion

Based on the obtained results we can conclude that if we use the signal chart F (figure 5) after CD and PMD in the signal processing system, bit error rate becomes less than 10^{-12}. This confirms that our proposed method allows us to use of CD and PMD in long communication lines (up to 500 km) without using of optics and other dispersion compensators.

References

[1] Friman R K 2012 *Fiber-optic communication systems* 496

[2] Gurkin N, Nanii O, Novikov A, Plaksin S, Treshchikov V,Ubaydullaev R 2013 *Quantum Electronics* **43** 550

[3] Poggiolini P 2012 *J. Lightw. Technol.* **30** 3857

[4] Le Nguyen B 2014 *Digital Processing. Optical Transmission and Coherent Receiving Techniques* 510

[5] Rice M 2009 *Digital communications: A Discrete - Time Approach* 796