ANALYSIS OF POSSIBLE UTILIZATION OF PHASE SHIFT KEYING MODULATIONS FOR LONG-HAUL OPTICAL TRANSMISSION SYSTEMS

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Abstract This contribution deals with the 8PSK and QPSK modulation techniques and their resistance to nonlinear effects at the signal transmission in the optical transmission media. The paper presents a design and simulation of optical modulators used for optical signals when passing through the optical transmission medium with negative influences degrading the signal transmission.

1. . Introduction

Nowadays, an interest in the information signal transmission through optical fibers rapidly increased due to quality of the transmission and bandwidth. Optical transmission systems are mainly used for the signal transmission over the backbone network while the optical technology gradually penetrates into the access network. The increasing demand for very high-speed data rates by optical transmission systems is not workable by baseband modulation techniques. A deployment of new hardware devices would be either technically unfeasible or costs will be disadvantageously. Therefore, it is began to think about the utilization of several possible modulations to obtain a resistance to influences that mostly degrade the optical signal level and to meet demands placed upon it.

In this paper, principles of PSK modulations are introduced. Also, simulations for passing optical signals through the optical transmission system are introduced and constellation diagrams of QPSK and 8PSK are presented.

2. Principles of the Phase Shift Keying

The Phase Shift Keying PSK technique belongs to group of modulations with carrier wave modulation [1-4]. The PSK appears to be very resistant against nonlinear effects because the signal envelope is constant. For information transmission, a phase modification of carrier signal is used. The carrier signal phase is shifted depending on transmitted information. The phase shift must be also known to demodulator. The simplest PSK modulation shifts carrier signal phase by π for logical 1 and for logical 0 does not shift the carrier signal phase. In practice, we can meet more often with its equivalents [1, 3-11]:

- Multi-level MPSK (where M is number of levels),
- Differential Phase Shift Keying DPSK,
- Differential Binary Phase Shift Keying DBPSK,
- Differential Quadrature Phase Shift Keying DQPSK.

The fundamental difference between PSK (resp. MPSK) and DPSK (resp. DMPSK) is based in a constellation diagram layout. The Differential PSK does not have determined symbols in the constellation diagram as in the common PSK, but it has a table of phase shifts (in degrees or radians) where each phase shift is represented with a symbol. Very advantageous format isthe Multi-level PSK because one phase shift is represented with 2 or more bits (it is depended from number of modulation levels). Other most known techniques are QPSK and 8PSK [1-5].

3. The environment of optical single-mode fibers

Each optical fiber represents a transmission system, which is frequency dependent. Pulse propagation inside this transmission system can be described by the nonlinear Schrödinger equation NLSE, which is derivate from Maxwell equations. From this equation we can expresses effects arising in the environment of optical fibers that can be classified as:

a) linear effects, which are wavelength depended,
b) nonlinear effects, which are intensity (power) depended.

More detailed analysis of linear and nonlinear effects are published in [12-18].

4. Simulations for PSK Modulations

Simulations are performed in the MATLAB Simulink 2014 and consist from implementation of modulation formats into a model of the optical transmission path [12-18]. It is assumed that the fiber length is 80 [km], the total attenuation is a_{total} = 16,8 [dB] (i.e. $\alpha_{specific}$ = 0,21 [dB/km]), values of the PMD 10 [ps/(nm.√km)] and the CD 10 [ps/km]. To simulations of the signal transmission, QPSK and 8PSKmodulation techniques are chosen. At 8-level PSK modulation, three bits are transmitted through a transmission medium at once, since $2^3 = 8$, and two bits, since $2^2 = 4$, are transmitted at the QPSK. Individual symbols are possible to express as complex numbers, thus, as a combination of imaginary and real parts or with combination of magnitude and phase towards to zero. Symbols are located with the π/4 phase shift between them at 8PSK and with the π/2 phase shift at the QPSK. A benefit of the 8PSK is higher transmission rate, since one phase shift is represented by three bits entering the modulator. Disadvantage of the multi-level PSK is a smaller phase distance between symbols, which can lead to higher bit error rates by comparison with modulation techniques with less modulation levels. A complete model of the 8PSK is displayed on Fig.1.

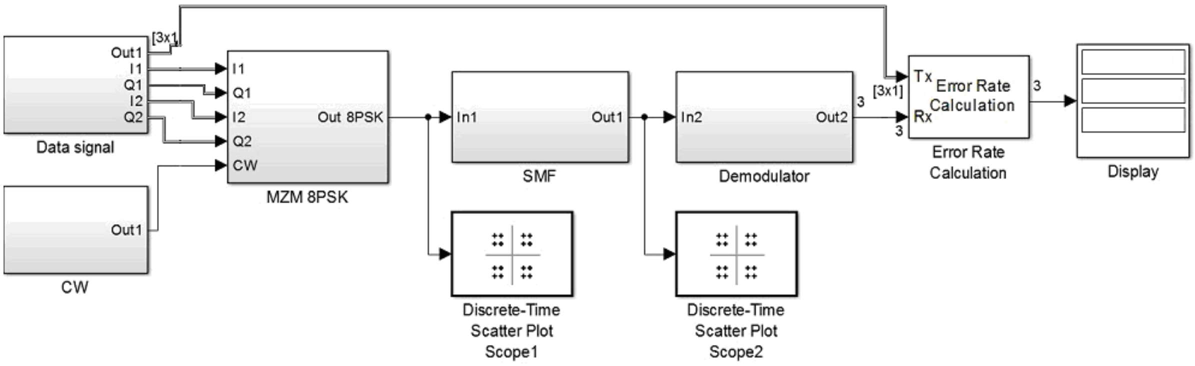

Fig.1:*The optical transmission path utilizing the 8PSK modulation.*

A model consists of next fundamental parts:

- Source of the data signal and the optical signal (CW)
- 8PSK Modulator
- Model of the optical transmission path (SMF)
- 8PSK Demodulator
- Block for the BER calculating

On next figure (Fig.2), constellation diagrams for the 8PSK are shown before passing through a model of the optical transmission path (IN) and after passing through the model (OUT). The signal after passing is attenuated (following the attenuation) and phase shifted (following the dispersion). The received phase shift is approaching decision levels of the 8PSK demodulator (0 to π, -π/2 to π/2, π/4 to 3*π/4 and -3*π/4 to -π/4), overshooting of these levels causes increasing of the bit error rate.

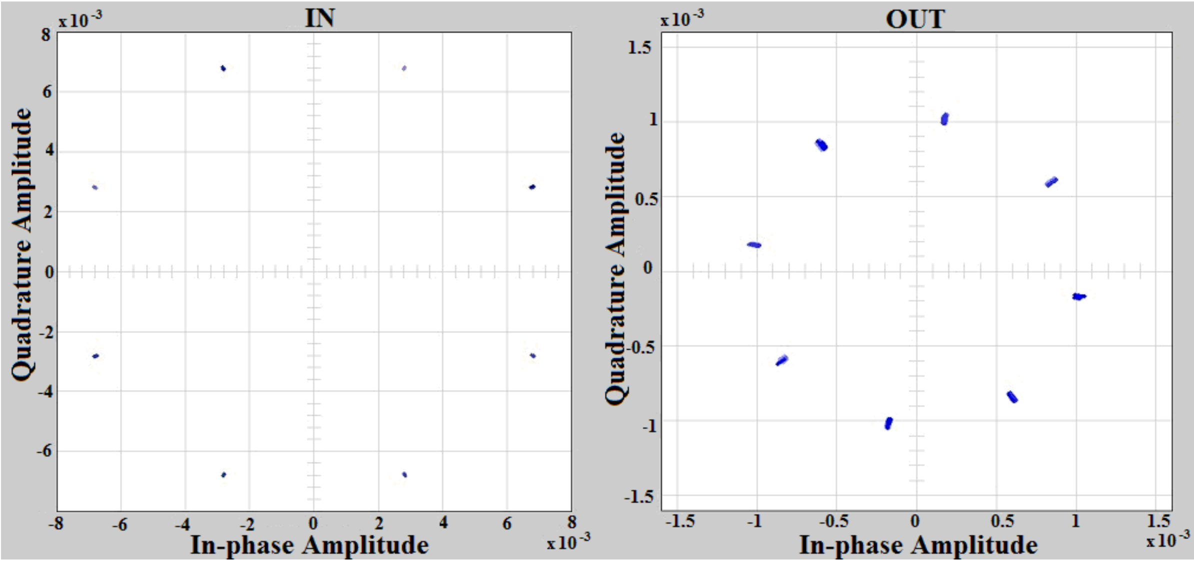

Fig.2: *Constellation diagrams forthe 8PSK*

For comparison, constellation diagrams for the QPSK are included. Constellation diagrams for the QPSK before passing through a model of the optical transmission path (IN) and after passing through the model (OUT) are shown on Fig.3. In the same manner as for the 8PSK,influences of effects at the signal transmission are visible. As can be seen on Fig.3, the QPSK modulation can be used for longer distances as the 8PSK, since the phase distance between individual symbols is greater (decision levels of the QPSK demodulator are from 0 to π for the first bit and from -π/2 to π/2 for the second bit).

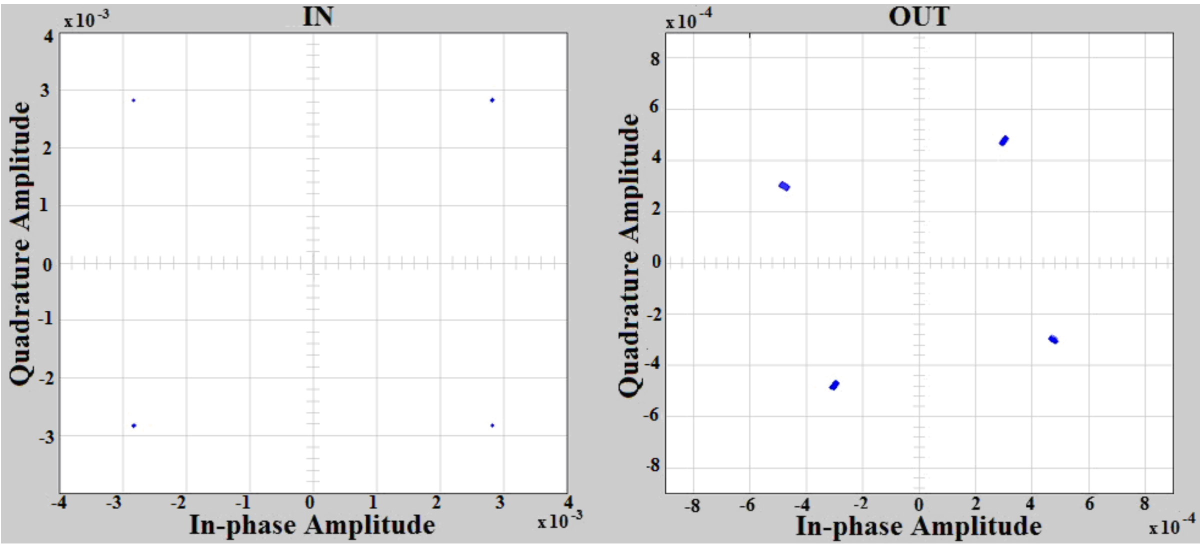

Fig.3: *Constellation diagrams forthe QPSK*

On Fig.4, waterfall curves for the BPSK, QPSK and 8PSK are shown. BPSK (blue) and QPSK (green) curves are overlapped. The 8PSK curve is shown with a red dashed line. As can be seen, the BPSK and the QPSK needs less E_b/N_0 then the 8PSK for a successful payload signal transmission with lower BER (e.g. at BER = 10^{-6}, the difference between QPSK and 8PSK isapproximately 3,5 dB E_b/N_0).

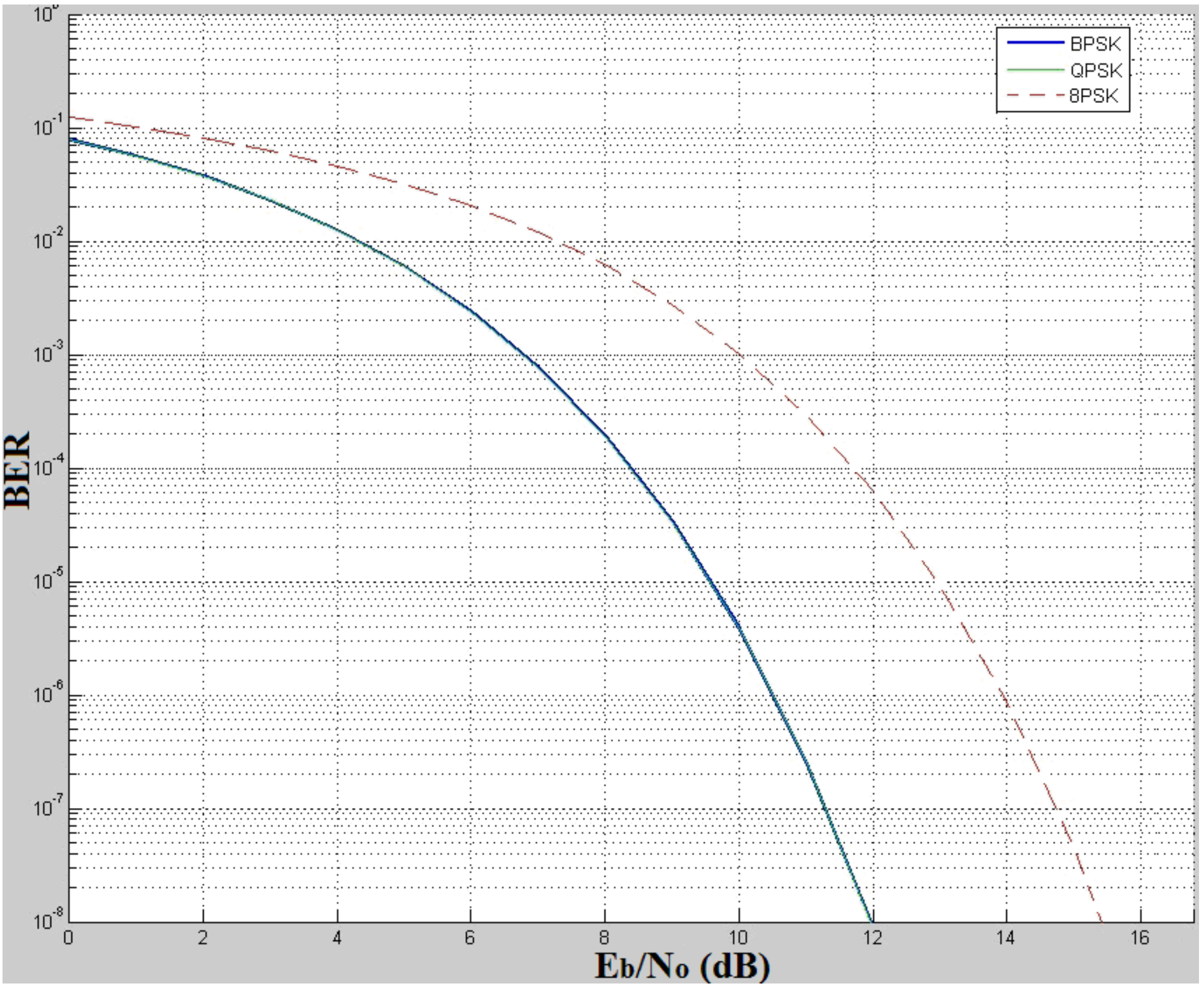

Fig.4: *The BER vs. E_b/N_0 forBPSK,QPSK and 8PSK modulations*

5. Conclusion

Analysis of possible utilization PSK modulations by means of simulation models for QPSK and 8PSK techniques created in the MATLAB Simulink 2014 programming environment is presented. From constellation diagrams, it is possible to compare influences of the optical transmission environment on QPSK and 8PSK transmitted signals. We can see that the signal phase are shifted due dispersion and can influence the final demodulated signal. From simulation results, the QPSK is more resistant against negative influences degrading the signal transmission then at 8PSK, but there are only 2 bits transmitted with one phase shift. On the other hand, at 8PSK are transmitted 3 bits with one phase shift, which means higher possible transmission rates. In future, it is possible to expand the 8PSK simulation model into the 16PSK in the same manner as from the QPSK to the 8PSK.

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