American Journal of Circuits, Systems and Signal Processing
Vol. 1, No. 3, 2015, pp. 120-124
http://www.aiscience.org/journal/ajcssp

Method of Reducing the Noise Influence on Phase-Shift Keying Signals

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Abstract

In this paper the method of improvement noise immunity of signals with quadrature phase shift keying is given. In particular, offset quadrature phase-shift keying (OQPSK) signals are considered. The method lies in modification of existing demodulators with application of additional specific narrowband filters in signal phase detector. The simulation model of modified phase detector was realized and the results of its research are given. The results of simulation show that application of modified detector significantly improves noise immunity of OQPSK signals revealing new opportunities of modernization of existing cellular networks.

Keywords

OQPSK, PLL, BER, SNR, Shannon's Limit, Cellular Network, Noise Immunity, Phase Detector

Received: July 10, 2015 / Accepted: August 2, 2015 / Published online: August 11, 2015

1. Introduction

With the development of cellular communications the different problems of rational use of radio spectrum to provide a high quality service for large number of mobile users appeared. For the last years the development of wireless communications became a large scale, inducing developers of radiotechnic devices to find new solutions to the problem of rational use of the allocated frequency spectrum. As a result, the new types of spectral-efficient modulation of radio signals and new protocols that enable efficient distribution of network traffic appeared [1, 2]. One of the key parameters that are used for channel efficiency estimation is signal to noise ratio (SNR): the smaller this value, the better, but on condition of maintaining appropriate connection quality and bit-error rate (BER). Dependence between BER and SNR is the key characteristic of the communication channel and optimization of this characteristic is an important task for modern science [2, 3].

This paper shows the possibility of reducing the SNR during maintaining the required BER using modified phase detector. Also the optimization of filter parameters in this detector was held and its optimum parameters for offset quadrature phase-shift keying (OQPSK) signals were given.

2. Method of Improvement Signal Noise Immunity

In the theory of communications the classic criteria of communication system quality is its position relatively to The Shannon Curve – the ideal limit, reaching which one can get maximum spectral efficiency of the system at given SNR value (Fig. 1). Getting closer to Shannon's Limit results in increasing of signal transmission speed. There are two ways of reaching this aim: increasing signal spectrum resource, which is quite expensive and sometimes impossible, and increasing noise immunity of the transmitted signal. The second way is considered further in this paper.

The phase locked loop device (PLL) is widely used in modern demodulators of phase modulated signals [4]. The resistance of phase locked loop to noise without changing its dynamic properties can be increased by applying the

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modification described in [5].

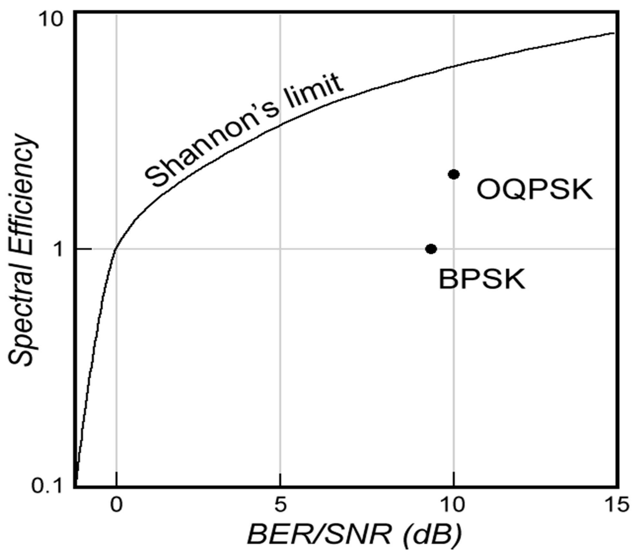

Figure 1. Quadrature modulated signals and Shannon's Limit.

In modified device, the narrowband filter reduces the difference between phases of signal at the input of the phase detector (PD). After the signal passes PD within the working area of detector characteristics, its level is restored using active high-pass filter. So the scheme of modified PLL device differs from its classical analogue by the specific narrowband filters in quadrature phase channels of PD, and corrective high-pass filter after it [6].

Filters parameters must satisfy the followings requirements:

1) The resonance frequency coincides with the frequency of supporting generator.

2) The band of signal passing is much narrower than the band of input devices (in particular, narrower than the spectral band of input signal).

3) The coefficient of transmission on frequencies distant from resonance frequency, is not equal to zero.

Providing the implementation of these requirements at the moments of commutation of input signal's phase, on the output of narrowband filter there is the diminished jump of phase with next slow growth. Diminished noise component does not move the phase of signal outside one quadrant. After the same rule (small jump and slow growth) the voltage changes on the output of PD.

3. Simulation Model of Modified OQPSK Detector

In this paper, the object of research is the signal detection process in modern cellular communication systems that use complex signals with phase shift keying.

In particular, the computer simulation of offset quadrature phase shift keying (OQPSK) signals detection was made. OQPSK signals are widely used in modern cellular communication networks such as cdma2000. The simulation was carried out using Matlab Simulink software. For this purpose, the simulation model was created (Fig. 2) [7]. The model consists of the signal source, the signal transmitter, the radio channel and the phase detector. The simulation model of PD was realized using narrowband filters described in [5].

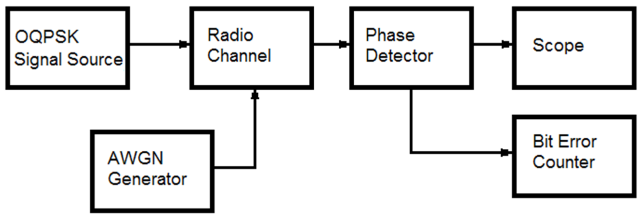

Figure 2. Structure of wireless communication channel simulation model.

The research was carried out for both cases: using classic PD and modified PD. The aim of research was to determine the relation between BER and SNR. The obtained BER-to-SNR values for the classical detector were compared with similar ratios given in the open sources (literature etc.). This made possible to confirm the adequacy level of the created simulation model. A comparison between these ratios and BER-to-SNR ratios, obtained by the use of the modified phase detector, made it possible to confirm the effectiveness of the last one.

4. Simulation Results

OQPSK signals are widely used in modern cellular communication systems, built on CDMA technology. An example of its application is the American wireless third generation communication standard IMT, in which the radio interface cdma2000 is used [8, 9, 10].

In this section the effectiveness of a modified phase detector of OQPSK signals was investigated and its adequacy was verified.

The feature of this type of modulation is that the quadrature phase and in phase components are spaced in time on a half of period. This means that in phase and quadrature phase components of the signal never change simultaneously. Another important feature of this type of modulation is that the trajectory of the signal phase change never becomes zero, which is one of the conditions for the correct functioning of the modified detector.

During simulation, OQPSK signal was generated using long random binary sequences imitating information signal which forms the in phase and quadrature phase components of the future signal. This method is useful for statistical analyzing of received signal on PD during relatively long period of time. Also, to carry out a visual analysis and to obtain qualitative changes in the received signal at different SNR values were created deterministic bit sequences fully duplicated for each experiment.

The polar diagram of received OQPSK signal on the output of simulation model is shown on Fig. 3.

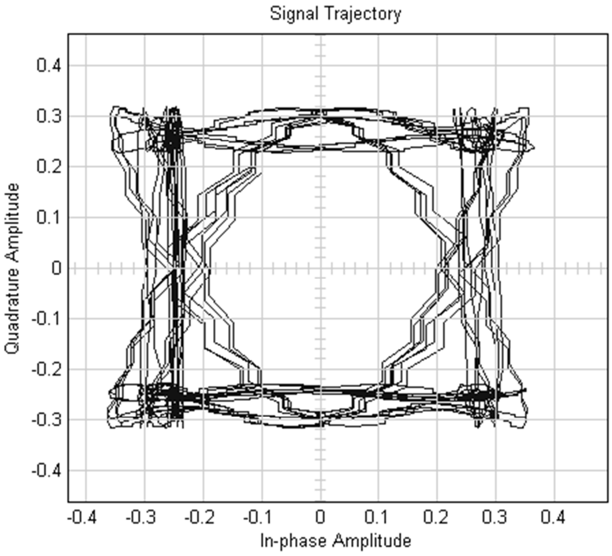

Figure 3. Polar diagram of OQPSK signal.

On the diagram we can see that the signal's phase may acquire one of four possible positions spaced on 90 degrees from each other.

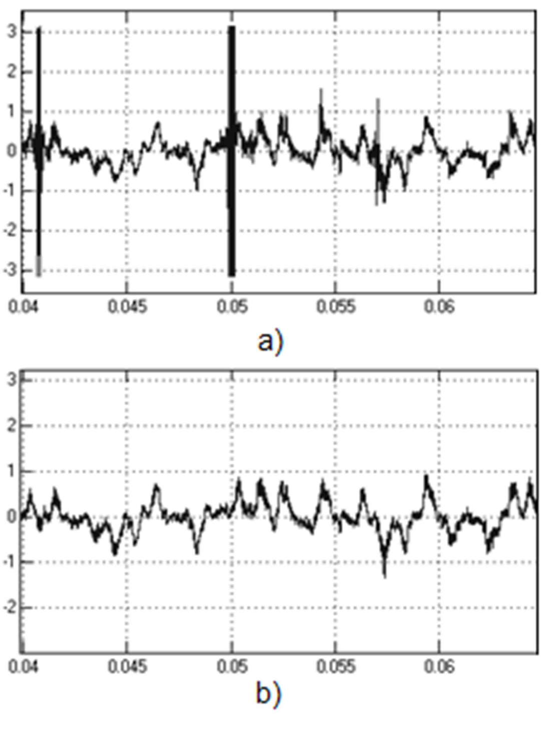

Figure 4. OQPSK signal in the output of ordinary phase detector (a) and modified phase detector (b) under the same low SNR values.

Initially the research was carried out with classical model of PD (without proportional-integrating filters in the phase detector). Gradually increasing the noise level in the communication channel, the threshold effect on the receiver was achieved (Fig. 4 a).

Afterwards the similar experiment was carried out, but with the application of modified PD. The threshold effect in modified PD was achieved at higher noise level comparatively to classical PD, indicating the greater efficiency of the modified detector (Fig. 4 b).

The further research was dedicated to optimization of filter parameters in modified phase detector. Changing such filter parameters as proportional (m_0) and inertia (T_0) coefficients the simulation was carried out at different SNR value in communication channel. As a result, the range of optimum filters parameters was obtained (Fig. 5).

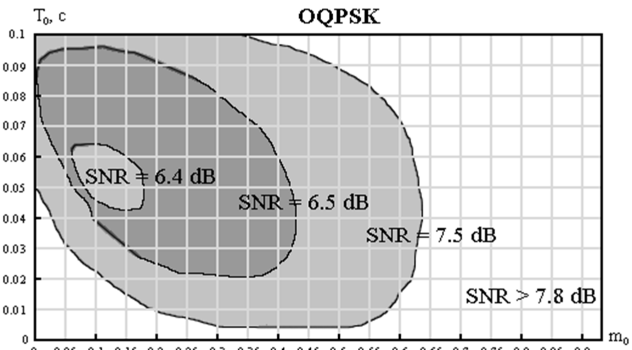

Figure 5. Areas of optimal filter parameters values in modified OQPSK detector at different SNR levels.

On the diagram with different areas which represent different threshold SNR values we can see that the lowest threshold SNR value was achieved at m_0 = 0.1 and T_0 = 0.05 (sec). At these conditions the minimum allowed SNR, at which we can maintain acceptable BER = 10^{-5} is 1.5 (dB) lower than in case of using none modified (classical) phase detector.

The rate of the probability of bit error (BER) to the minimum required signal-to-noise ratio (SNR) is an important criterion, which is used for evaluating the effectiveness of the communication system. In the simulation model the BER-to-SNR ratio was obtained by analyzing the statistical data received on error detector. Error detector estimated the number of errors appeared during the signal transmission through the communication channel at given SNR value. The results of this experiment for OQPSK signal is shown on the diagram (Fig. 6).

The diagram shows that BER-to-SNR curve for the classical detector is almost identical to such diagrams shown in open sources (literature etc.) for real systems. This fact shows the high value of adequacy of the simulation model to real communication systems. A similar ratio obtained using the modified detector with optimal parameters obtained in the previous experiment.

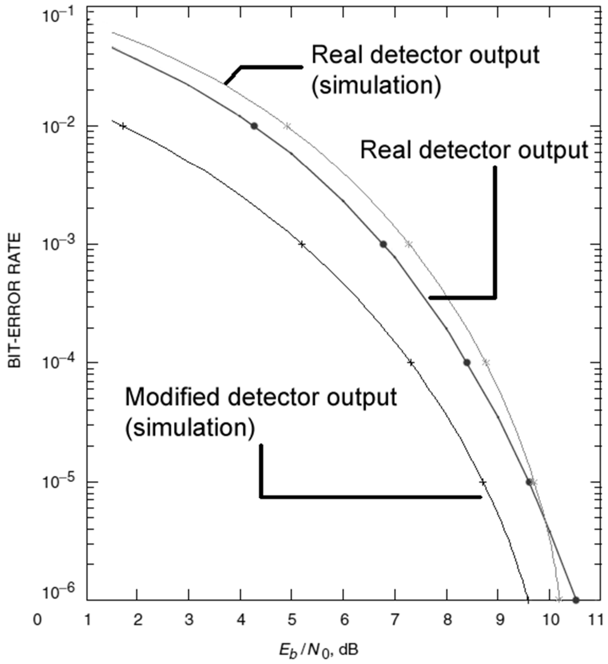

Figure 6. BER-to-SNR values for OQPSK signals acquired during the simulation.

The obtained results and diagrams show that effectiveness of wireless communication systems with OQPSK signals is raised with reducing the threshold sensitivity of the modified phase detector. Thus, OQPSK signal can be closer to the Shannon's Limit on the axis of the BER-to-SNR values (Fig. 7).

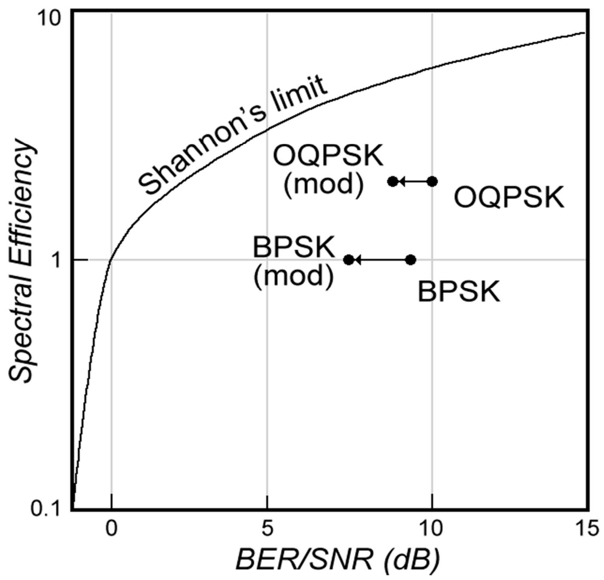

Figure 7. Quadrature modulated signals and Shannon's Limit before and after application of modified phase detector.

Therefore, the implementation of modified detector significantly reduces noise component and reduces abnormal phase jumps during OQPSK signals phase detection. It was discovered that the effectiveness of the modified phase detector depends on parameters such as inertia and proportional coefficients of narrowband filters applied to it.

5. Further Research

The simulation was also maintained, using more complicated signal with eight offset phase conditions (8PSK signal). 8PSK signals are also widely used in modern radio communications such as TETRA standard. The results of the research showed that the effectiveness of 8PSK signals demodulation at low SNR was higher when the modified PD was used. So the implementation of this modified device is fair not only for signals with quadrature phase shift keying, but for more complex signals such as 8PSK.

Further research in this area includes the implementation of the modified phase detector in a real circuit using optimum parameters obtained by the simulation.

6. Conclusions

During the carried out program simulation the noise immunity of modified OQPSK phase detector was investigated. The modification of phase detector lies in application of specific narrowband filters in its in phase and quadrature phase channels. Results showed that the quality of detection improves with increasing values of philters inertia coefficients and with decreasing values of its proportional coefficients. The optimal range of these parameters was determined. Using optimal filters parameters the noise immunity of modified OQPSK detector was significantly improved. The resulting BER-to-SNR diagrams confirm the effectiveness of the modified scheme.

References

[1] D. Tse, P. Viswanath "Fundamentals of Wireless Communication", Cambridge University Press, New York, 2005

[2] Veselovskiy K. "Systems of Mobile Radio Communications", Hot Line, Telecom, Moscow, 2006

[3] Sklar B. "Digital Communications", Williams, Moscow, 2004

[4] F. E. William "Phase-Lock Basics", John Wiley & Sons, 1998

[5] A. Bondariev, I. Maksymiv "Comparative Analysis and Ways of Improvement of Noise Immunity of Demodulation of OQPSK Signals", Electronics and electrical engineering, Kaunas, No.9 (105), pp. 81-84., 2010

[6] Bondariev A.P., Martyniv M.S. "Phase Auto Adjustment Frequency Device", Patent of Ukraine for Invention № 66435, Bulletin №5, 2004

[7] A. Bondariev, I. Maksymiv "Method of improvement of quality indexes of detecting in cellular communication systems", Electronics and electrical engineering, Kaunas, No.10, pp. 85-88., 2012

[8] Yang, Samuel C. "3G CDMA2000 wireless system engineering", Artech House, Inc., 2004

[9] L. Korowajczuk "Designing cdma2000 Systems", John Willey & Sons, Chichester, 2004

[10] Tero Ojanpera, Ramjee Prasad "An Overview of Air Interface Multiple Access for IMT-2000/UMTS", IEEE Communications Magazine, vol. 36, Sept. 1998