Method of Improvement of Quality Indexes of Detecting in Cellular Communication Systems

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***Abstract*—The results of imitational simulation of detection OQPSK and 8PSK signals in wireless channel with low signal-to-noise ratio are given in this paper. The simulation was maintained using Matlab program. The main goal of experiment is to confirm the efficiency of modified phase detector, in which specific combination of narrowband filters was used. The results of comparing quality indexes of modified detector and classical detector were illustrated on BER-to-SNR diagrams.**

***Index Terms*—Cellular networks, signal to noise ratio, phase detector, narrowband.**

I. INTRODUCTION

In modern cellular communications one of the most actual problems is rational use of expensive frequency spectrum, because of the increasing of requirements for communication quality and data rates. This led to research in improving quality and capacity of radio channels without increasing the width of the frequency range. Thus the spectral-efficient modulation types QPSK, OQPSK and 8PSK, which are widely used in modern cellular communication systems such as cdma2000 and TETRA emerged. Efficiency of such systems is limited by interference between the users and channel fluctuations arising in the same communication channel. So, the noise immunity is one of the key factors, which limits such quality indexes of cellular systems as channel capacity and data rate.

The method of improving noise immunity for modern types of phase shift keying is described in this paper.

II. FORMING A TASK

In specialized literature [1] the concept of required threshold signal-to-noise ratio (Eb/I_0 or SNR) is mentioned. According to this concept, the incidence of errors in the received signal (BER) should be less or equal to the required value of allowable threshold SNR (7-10 dB in existing communication systems). Equation (1) shows that the capacity M (users-per-cell) of cellular communication system is inversely proportional to SNR (E_b/I_0). Reducing this value, an increase of system's capacity, data rates or noise immunity can be reached. The less required threshold SNR for one receiver, the more receivers can correctly work simultaneously in current cell

$$M = \frac{\gamma G_A G_V G_p}{(E_b / I_0) H_0}, \tag{1}$$

where M – channel capacity, G_A – cell dividing coefficient, G_V – voice activity factor, H_0 – interference from external cells, γ – asynchronous interference, G_p – spectrum-spreading coefficient.

There are scientific publications [2] where the potential reduction of phase detector error emergence caused by frequency unadjustment during synchronization stage is given. This method lies in the use of narrow-band filters that reduce the tremors in signal phase at high values of noise influence without changing the dynamic properties of the detector.

This work is the result of program simulation of modified phase detector mentioned above. This detector was applied to detection of quadrature phase shifted radio signals. Simulation results show the effectiveness of the modified detector, and the resulting diagrams of SNR to BER ratio demonstrate their adequacy.

III. SIMULATION MODEL

To carry out the simulation, in Simulink program the communication radio channel was implemented (Fig. 1). The channel model consists of the signal source, the radio channel, the phase detector and the bit errors counting block. As a signal source to the channel input the phase-modulated signal sequences such as QPSK, OQPSK, and 8PSK were sent. The communication channel is implemented as an AWGN channel, in which the in-phase and quadrature components of the signal are distorted with a noise of certain power.

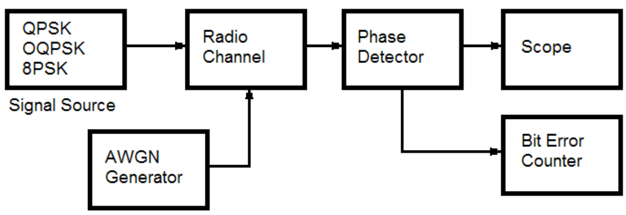

Fig. 1. Structure of wireless communication channel imitational model.

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After addition of the noise, the signal was received and demodulated by phase detector. Phase detectors of modern receivers of digital signals are made using phase locked loop (PLL), whose effective frequency band is agreed with a width of signal spectrum band. Phase detector (Fig. 2) consists of low-pass loop filter, VCO and arctangent-function demodulator, which converts image and real components of received complex signal into stream of informational bits. The modified detector differs from classical detector by the system of narrowband low-pass proportional-integral filters (PIF), established before demodulator, and correction high-pass filter (HPF) established after demodulator.

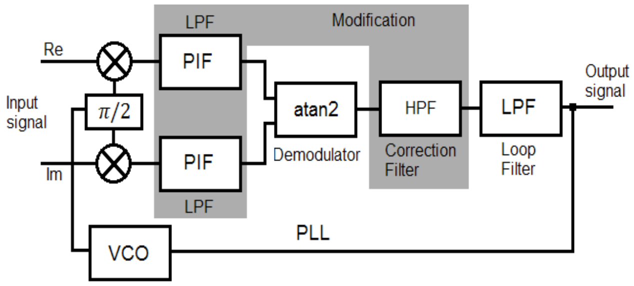

Fig. 2. Modified phase detector imitational model.

As a rule, loop filter is put into quadrature channels before phase detector (atan2), but its band is agreed with signal band. The essence of modification lays in application of LPF whose frequency band is much narrower than signal band. This approach reduces high-frequency noise components and lowers the chance of abnormal phase jumps and abnormal emissions on phase detector's output. But it also distorts the informational signal and worsens dynamical properties of detector. To correct dynamical properties, an active HPF is putted after detector. Frequency response of HPF is inverse to frequency response of PIF. The imitation simulation showed that without noise influence, dynamical properties of classical and modified filters are the same.

In received signal the number of errors that occurred during its passage through the channel was estimated by error counter. Based on its statistical data the SNR-to-BER ratio for different noise levels was obtained. This data was compared with actual diagrams taken from the literature [3].

IV. Demodulation of OQPSK Signal

OQPSK – type of signal modulation, which is used in modern wireless systems such as cdma2000.

To form OQPSK signal in simulation program, it was established the source, generating a random bit sequence of bits. Then, the sequence was divided into serial pairs of bits (dibits) which formed in-phase and quadrature components of the signal shifted by T/2 time delay. In result the complex quadrature offset phase shifted signal was obtained.

The generated signal (Fig. 3) was sent to the input of imitational model.

Gradually increasing the noise level in channel a number of occurred errors was obtained using classical phase detector and modified phase detector. Based on the complexity and variety of implementations of modern detectors it was decided to estimate number of errors by comparison output signal at certain noise level with output signal without noise in communication channel. An error was detected when signal exceeded certain threshold value (error threshold line). Changing threshold value in terms between 0,8-2 radians had weak influence on final results.

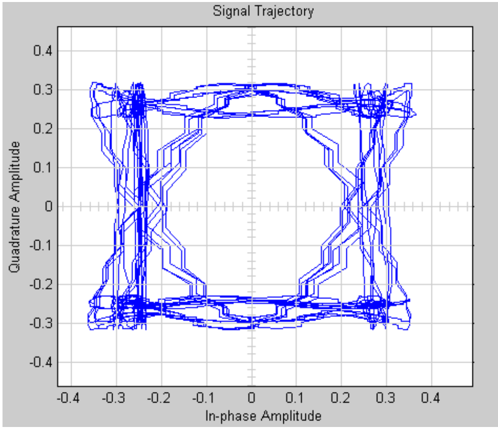

Fig. 3. OQPSK signal plot.

Obtained plots (Fig. 4) demonstrated greater efficiency of modified detector for high-level noise. When anomalous jumps in the classical phase detector prevent the correct determination of changes in signal phase (Fig.4, b), modified detector continues to operate effectively (Fig.4, c).

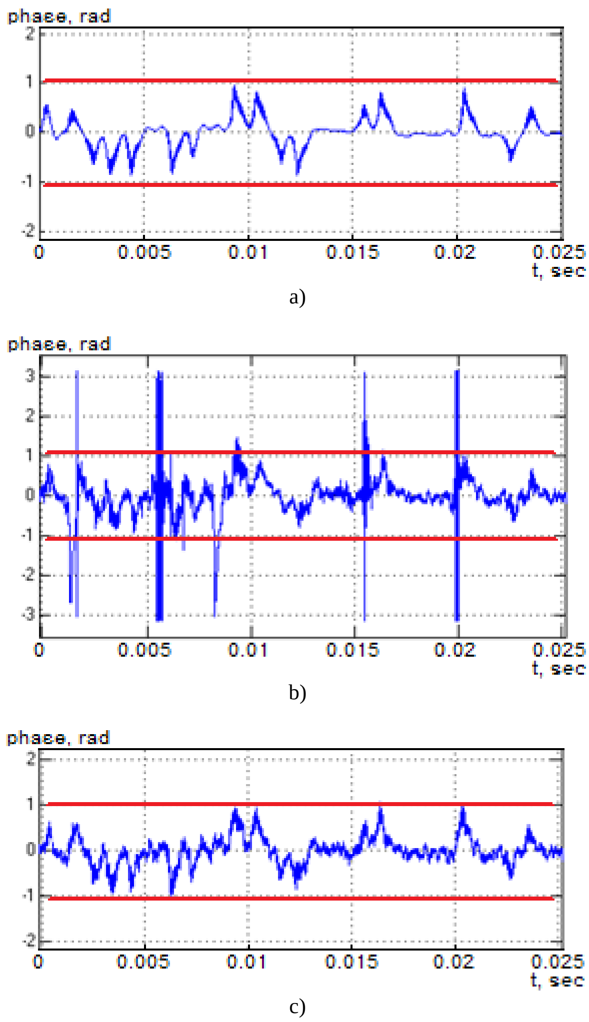

Fig. 4. Fragment of input OQPSK signal (a), output OQPSK signal using classical (b) and modified (c) detectors at low SNR.

On diagrams (Fig. 4) the error thresholds are shown. Error occurs every time the signal phase crosses the error threshold line. Counting frequency of errors at different noise levels for modified and classical detector, it is possible to receive the statistical BER value, which is one of noise-immunity criteria of device.

The BER-to-SNR ratio for OQPSK signal received by classical and modified detectors are shown on diagram (Fig. 5). It is evident that modified phase detector (curve #1) is more efficient than classical detector (curve #2).

Real BER-to-SNR (marked by "*" chars) were taken from literature and compared with values, received during simulation (curve #2), to prove adequacy of imitational model.

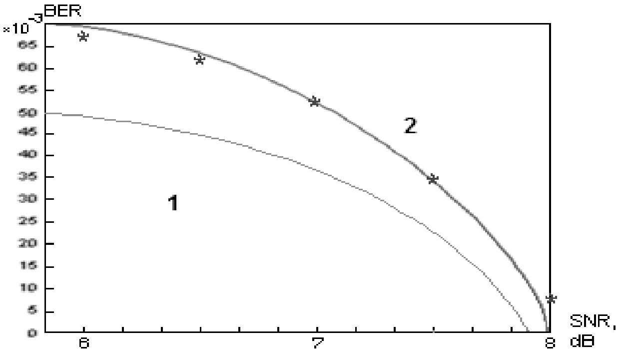

Fig. 5. Diagram of dependence between BER and SNR for OQPSK signal using modified (1) and classic (2) phase detectors.

The power advantage, received after using modified detector, can be used to increase the number of orthogonal channels in cdma2000, or to reduce power expenses in wireless network at the same working conditions as with the use of classical detector.

V. Demodulation of 8PSK signal

8PSK signal is the offset phase-shifted signal, which uses eight possible phase positions in its code. This signal is faster but less noise immune than other quadrature signals. This modulation is used in modern wireless communications such as TETRA.

In imitational model 8PSK signal was generated similar as OQPSK in previous experiment, but using three serial bits to form the in-phase and quadrature signal channels. This allows us to realize eight different possible positions of signal phase.

The generated signal (Fig. 6) was sent to the input of imitational model.

After detection, the signal with additive noise was demodulated. Number of bit errors at high noise levels was counted for classical detector (Fig.7, b) and modified detector (Fig.7, c). Similar to case with OQPSK, less number of errors was received using modified detector.

In result of processing the statistical data, BER for both of simulated detectors was formed. Anomalous phase jumps crossed sensitivity thresholds of error detector more often in simulation with use of classical detector imitation model at high levels of noise fluctuations. This process is illustrated on according BER-to-SNR diagram (Fig. 8).

In this case we receive enough power advantage, to show the high efficiency of modified phase detector.

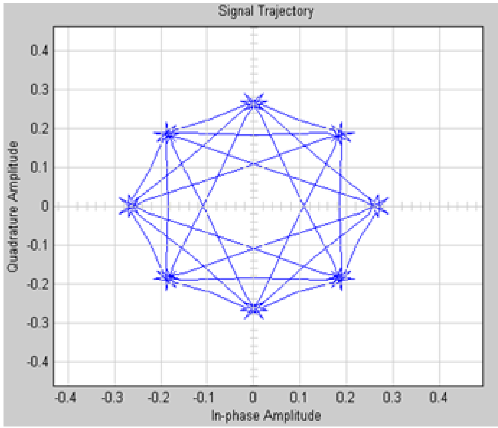

Fig. 6. 8PSK signal plot.

According to Fig. 5, "stars" ("*") show the values of BER-to-SNR taken from open literature and illustrate adequacy of values, received in result of simulation (curve #2).

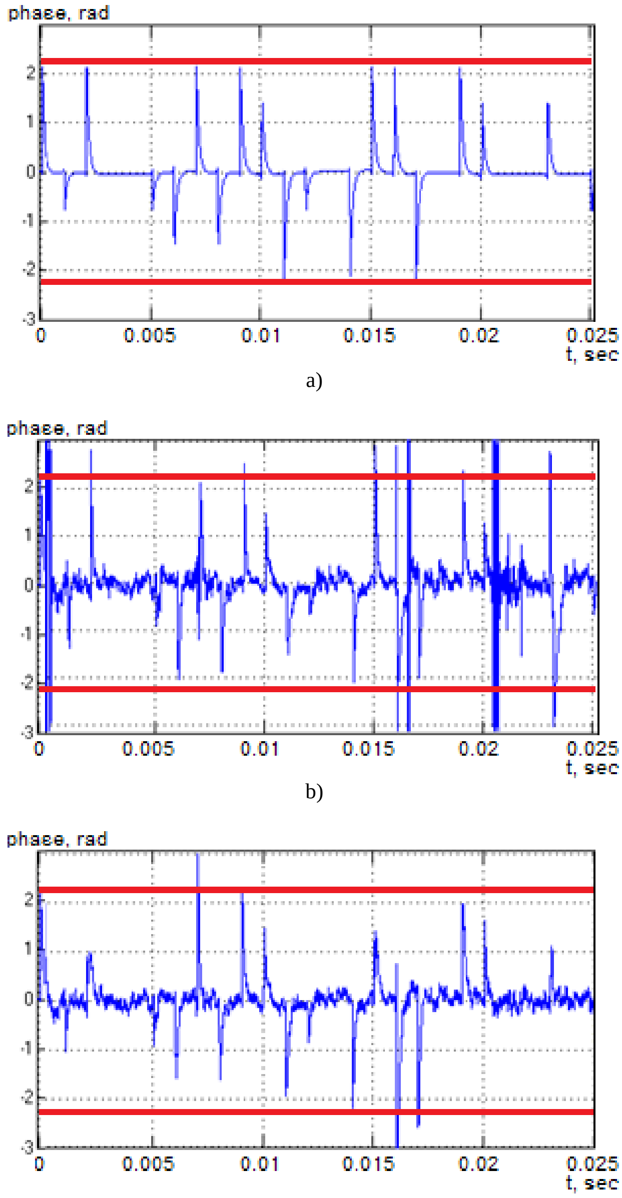

Fig. 7. Fragment of input 8PSK signal (a), output 8PSK signal using classical (b) and modified (c) detectors at low SNR.

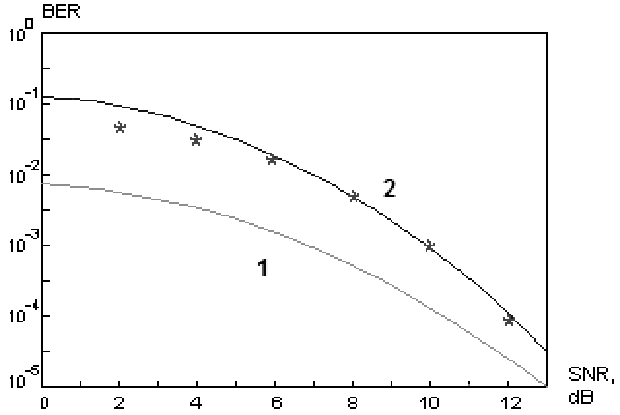

Fig. 8. Diagram of dependence between BER and SNR in TETRA communication channel using modified (1) and classic (2) phase detectors.

Theoretically, the providing of modified detectors can improve radio networks with 8PSK. For example, the higher noise immunity can reduce the number of base stations, needed to provide the necessary SNR in the system. This will result in making the network implementation cheaper.

VI. Practical results and further research

This article shows the possibility of engineering the detecting OQPSK and 8PSK signals at low SNR.

The results of simulation of modified synchronous phase detector showed the possibility of an increase of noise immunity of receiving signals with phase shift keying and the ability of the modified detector to detect OQPSK and 8PSK signals even when signal strength is less than the capacity of obstacles.

As seen from the diagrams (Fig. 5 and Fig. 8), with increasing of noise level, the likelihood of errors in the classical detector increases dramatically, while as in the modified detector quality deteriorates much more slowly. It is important that curve #2 in both diagrams is adequate to BER-to-SNR curve in real systems [3]. This confirms the adequacy of imitational model of phase detector to its real analogues.

This fact allows us to make further work in direction of implementation the simulated device into real equipment. Maintaining experiments on such equipment will show the real practical value of considered modification.

VII. Conclusions

In this paper, adequate imitational models of CDMA cellular channel and TETRA radio channel were created and the noise immunity of OQPSK and 8PSK signals was investigated. During this work, it was determined the relationship between BER and SNR for classical phase detector and detector, modified by the system of narrowband proportional-integrated filters (PIF). The results of simulation are illustrated on appropriate diagrams.

The detection quality of modified detector is higher than in classical detector. Modified phase detector has better noise immunity and in theory can improve existing wireless communications networks.

References

[1] J. Viterby, “The Orthogonal-Random Waveform Dichotomy for Digital Mobile Personal Communication”, *IEEE Personal Communications*, pp. 18–24, 1994.

[2] A. Bondariev, I. Maksymiv, “Comperative Analysis and Ways of Improvement of Noise Immunity of Demodulation of OQPSK Signals”, *Elektronika ir Elektrotechnika (Electronics and Electrical Engineering)*, no. 9, pp. 81–84, 2010.

[3] К. Веселовский, *Системы подвижной радиосвязи (Пер. с польск).* М.: Горячая линия–Телеком, 2006.