ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2010. No. 9(105)
ELEKTRONIKA IR ELEKTROTECHNIKA

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SIGNALŲ TECHNOLOGIJA

Comparative Analysis and Ways of Improvement of Noise Immunity of Demodulation of OQPSK Signals

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Introduction

Modern growth of demand on the radio channels induces the use of spectral effective methods of modulation, intended for diminishing of spectral overload of communication systems.

Signals with multi-phase shift keying (MPSK) are widely used in modern wireless communication systems, such as CDMA, EDGE and trunking networks (TETRA).

For detecting the MPSK signals in modern digital receivers, device of phase automatic frequency control (PLL) are widely used. PLL determines the quality of reception and performance of the receiver. However, correct detection of signals is possible only for high signal to noise ratio (SNR) at the entrance to the receiver. Reducing of the required minimum signal-to-noise ratio increases capacity of the system.

Methods of reducing the required minimum SNR while preserving satisfactory quality signal reception is an important scientific and technical challenge. Scientific works with nonlinear analysis device PLL [1,2] and construction of demodulator on its base show the relevance of this area of research for modern requirements to connection with moving objects and reducing of the power of radio signals.

This article explores the way of satisfactory quality of offset quadrature phase shift keyed (OQPSK) signal transmission even at unacceptable small SNR for conventional systems.

Forming a task

Feature of a mixture of harmonic signal with noise is that the probability distribution density of phase of such compound for large values of SNR is close to normal, and with decreasing value close to uniform.

This leads to the anomalous phase jumps in the moments of switching in the receivers (Fig. 1). During the jump phase of the signal value of $\Delta\varphi$, instant value jump phase mixtures in various implementations can take arbitrary values, such as smaller ($\Delta\varphi1$), or even oppositely directed ($\Delta\varphi2$). Such anomalous phase jumps in the time of switching cannot be removed by any filtering after the phase detector (PD), which is one of the issues receiving PSK signals at low SNR.

The main source of noise immunity threshold limit is the limited working area of detector characteristics of PD. Failure of synchronous mode, which prevents detection, occurs because the total synchronization error (static, dynamic and noise) goes beyond the working area ($\pm \pi / 2$). In a classical PLL device is causing the need to find a compromise between the robustness (statistical component of error) and dynamic properties of the device (dynamic component).

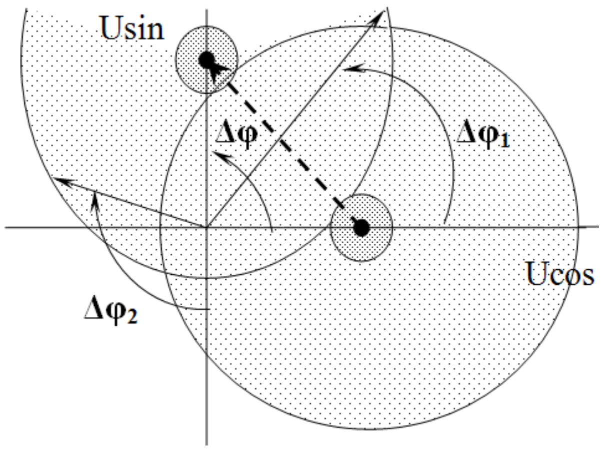

Fig. 1. Change of quadrature components of OQPSK signal on input of narrowband filter during the switching at a low SNR

Modified PLL device

Increasing the noise and deterministic interference resistance of PLL without changing the dynamic properties can be realized with the modified device described in [3] (Fig. 2). In this device, narrowband filter (NBF) reduces the phase difference fluctuations on inputs of phase detector (PD). After passing the signal through the PD in the working area detector characteristics, his is level restored by an active high-pass filter (HPF). The proposed scheme of a modified PLL device differs from the classical analogue of the fact that before the phase detector a narrow-band filter is located, and after PD – the high-pass filter.

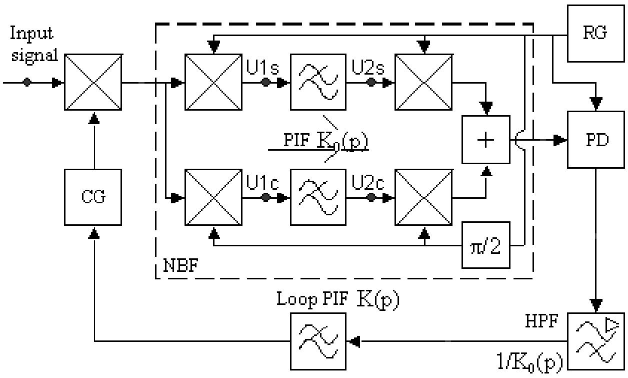

Fig. 2. The block diagram of modified synchronous phase detector

NBF must meet the following conditions:

1) Resonance frequency coincides with the frequency of reference generator (RG);
2) Bandwidth is much narrower than band of input devices (such is narrower than spectral band of input signal);
3) Transfer coefficient is not equal to zero at frequencies far from resonance;

With these conditions at the moment of switching of phase of input signal, at the output of NBF the reduced jump of phase followed by a slow continued rise is observed (Fig. 3). Reduced by narrow band of NBF, the noise does not display the phase signal beyond one quadrant. According to the same law the voltage is changing at the output of PD.

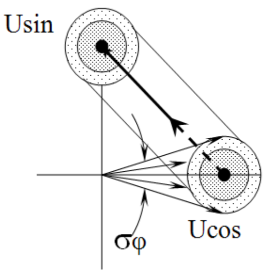

Fig. 3. The change of quadrature components of OQPSK signal at output of narrowband filter at the moment of switching

This NBF realized as synchronously-phase filter in Quadrature channels of which the same proportional-integrating filters (RRC filter) are used. RRC filter have such complex frequency characteristics (CFC)

$$K_0(j\omega) = \frac{1 + j\omega m_0 T_0}{1 + j\omega T_0} \quad (1)$$

and, respectively, with transition characteristics

$$g_0(t) = 1 - (1 - m_0)e^{-\alpha_0 t}, \quad (2)$$

where $\alpha_0 = 1/T_0$ – pass band of RRC filter; m_0 – proportional coefficient of RRC filter.

CFC module (1) is close to 1 in the frequency range between 0 and α_0 and close to m_0 at frequencies higher than α_0/m_0. The frequency α_0 elected several times less than the frequency manipulation phase.

An important feature of the incoming mixture is that its quadrature components have a normal distribution even for large values of noise intensity and therefore voltage at points 1c and 1s in Fig. 2 also distributed by the Gauss law.

Transmitting characteristics of the corrective HPF is inverse to the filter characteristics in quadrature channels NPF. Consequently, the output voltage almost exactly reproduces the phase-change of input signal even for small signal-to-noise ratio.

Simulation

Simulation is conducted for the cases of modeling OQPSK signals. The simulation results are shown in Fig. 4 and 5. The results show that the normality of changes of signal phase at the input of PD as a small jump and slow growth (dark line) remains unchanged even with such high levels of noise, for which realization that correspond to different phases of the value of the input signal is almost impossible to discern.

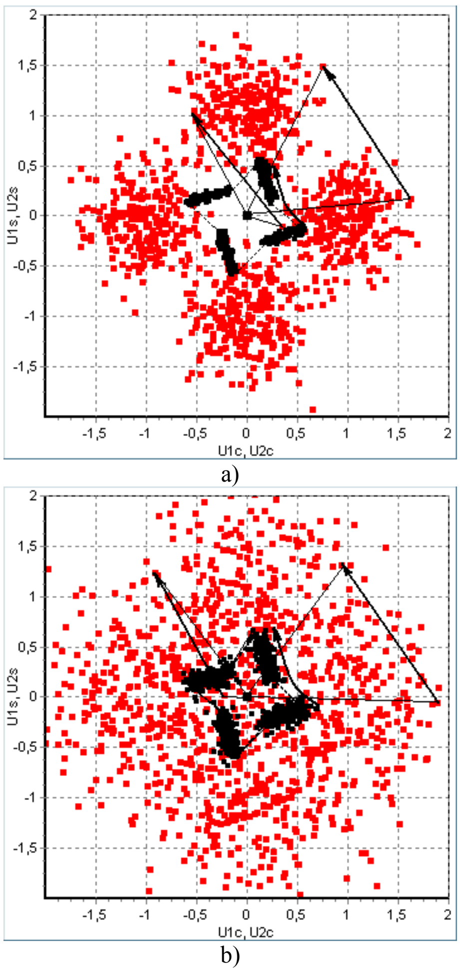

Fig. 4. The phase portraits of input (light) and output (dark) NBF signal at high (a) and low (b) SNR

Fig. 4 shows the results of simulation in the absence of filtering inphase and quadrature signal components. Similar results for the case of filters such as "raised cosine" are shown in Fig. 5. This filter is used to limit the spectrum modulated signal. It should be noticed that such a bandpass filter is agreed with birs time transfer.

Time constants of filter channels in the modified PLL (Fig. 2) are much larger than bit transfer time, therefore the phenomenas depicted in Fig. 1 and 3 appear. Fig. 4 shows that even at the great level of interference using a modified PLL makes it possible to get rid of abnormal hopping phase and consequently reduce the noise threshold of the phase detector.

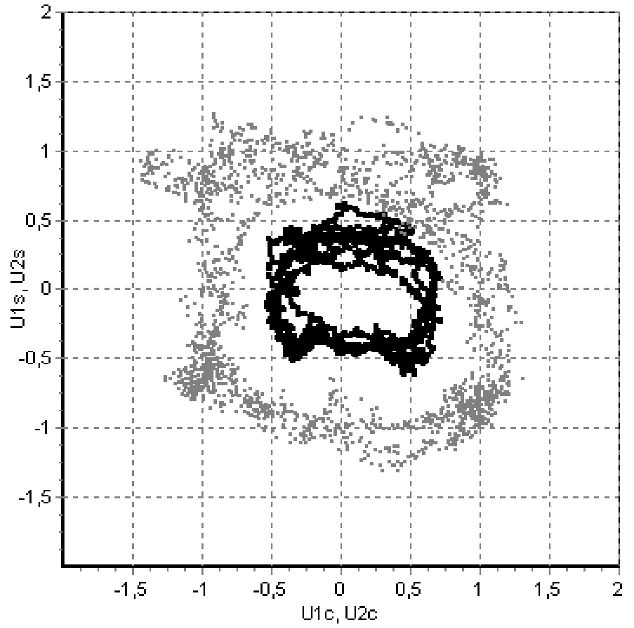

Fig. 5. The phase plot of input (gray) and output (black) signals of NBF at low SNR

Test results of the locked circles of classical and modified PLL devices are shown in Fig. 6 as ostsylohram.

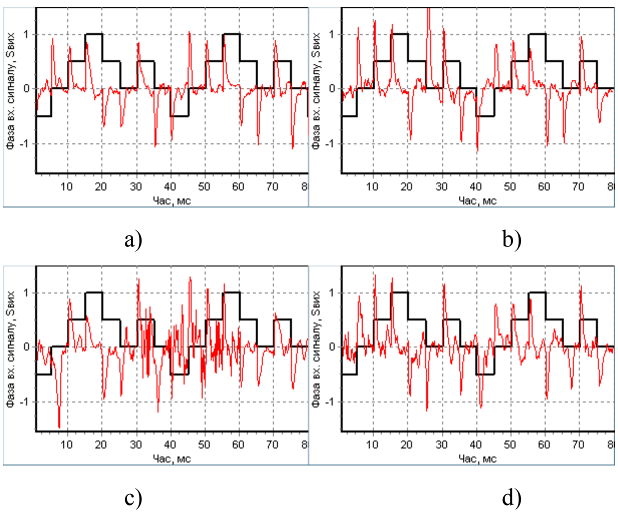

Fig. 6. Output signals of classic (a, c) and modified (b, d) PLL in overtreshold (a, b) and undertreshold(c, d) areas using the QPSK signal

Testing showed that the positive jumps of phase of input signal (counterclockwise in Fig. 1 and 3) correspond to positive changes of voltage at the input of controlled generator, a the negative (clockwise) - negative. With increasing intensity of the input noise (decreasing SNR) to some threshold mean, the noise component of output signal in both classical and modified PLL increases proportional to the intensity of the input noise, as shown on Fig. 6 a, b for SNR equal 1.4. With further increase of noise level in the modified PLL this proportion is kept (Fig. 6 d) and place in the classical anomalous phase jumps (Fig. 6 c) - detection becomes impossible. Dependence shown in Fig. 6 c and d obtained at SNR value equal 0.8, and demonstrate the ability of the modified PLL to OQPSK detection signal even when signal strength is less than the power of obstacles.

Similar results were obtained for the case of smoothing filter shown on Fig. 7. From the pictures you can see that for small signal-to-noise in the classical detector (Fig. 7. a) becomes impossible to distinguish four different levels of phase, which is typical for OQPSK. At the moments of determining, reference signal at the output of phase detector accepts only three values, two of which are quite close.

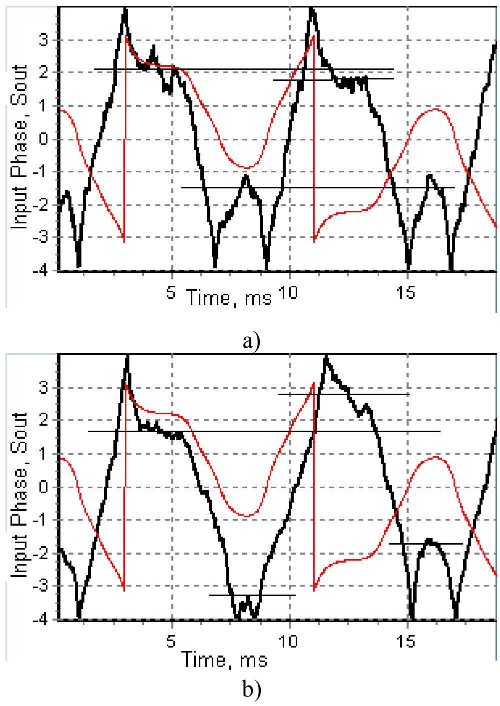

Fig.7. The waveforms of input OQPSK signal phase (light) and output signal (dark) of classic (a) and modified (b) PLL device

For the same low value of signal-to-noise ratio in the modified detector (Fig. 7 b) it can be clearly distinguished all four levels of output voltage, corresponding to a value of four phases, ie dibits of information signal.

The analysis process of detecting a large number of lengthy implementations for the same low SNR at the input of the classical and the modified PLL devices showed that, for OQPS the classic device mistakenly takes about 25% of bits and modified – about 8%.

Conclusions

This article shows the possibility of engineering of detecting OQPSK signals under conditions of 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 PLL for detecting OQPSK signals even when signal strength is less than the capacity of obstacles.

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Received 2010 02 15

A. Bondariev, I. Maksymiv. Comparative Analysis and Ways of Improvement of Noise Immunity of Demodulation of OQPSK Signals // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 9(105). – P. 81–84.

The possibility of engineering implementation of receiving radio signals with multiple shift keying at low signal-to-noise ratio is considered in this paper. Method of improving the detection realized by modifying the PLL device with the system of narrowband filters. Characteristics of filters are selected in such a way as to increase the noise immunity of the detector without changing its dynamic characteristics. The results of simulation showed a higher efficiency of the modified PLL in comparison with classical devices in a low ratio of signal-to-noise ratio. Ill. 7, bibl. 4 (in English; abstracts in English and Lithuanian).

A. Bondariev, I. Maksymiv. Triukšmo įtakos mažinimo lyginamoji analizė OQPSK signalų detekcijoje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 9(105). – P. 81–84.

Apžvelgta inžinerinė galimybė pagerinti gaunamus radijo signalus esant daugialypiam fazės kitimui ir mažam signalo ir triukšmo santykiui. Taikant fazinę kilpą siaurajuosčių filtrų sistemoje patobulintas detektuojamų signalų metodas. Nekeičiant detektoriaus dinaminių charakteristikų, parenkamos filtro charakteristikos, didinančios atsparumą trikdžiams. Modeliavimo metu padidėja efektyvumas palyginti su klasikinėmis sistemomis, esant mažam signalo ir triukšmo santykiui Il. 7, bibl. 4 (anglų kalba; santraukos anglų ir lietuvių k.).