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ANALYSIS AND INVESTIGATION OF CHARACTERISTICS OF QUADRATIVE PHASE MODULATION AFFECTING INTERFERENCE-RESISTANT RECEPTION

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ABSTRACT

The article investigates the main regularities of noise-immune formation of quadrature phase modulation. Mathematical models, diagrams of the QPSK signal and the results of a theoretical study of the dependence of the bit error probability on E_b / N_0, to ensure noise-immune reception of digital television signals.

Keywords: noise immunity, encoder, quadrature phase modulation, in-phase and quadrature components, bit error probabilities.

The 4-position PM-4 phase modulation according to the signal conditioning method is also called QPSK (Quadrature PSK). QPSK is a compromise between transmission rate and noise immunity and therefore it has been widely used [1].

Analysis and research shows that for the formation of a four-position phase modulation, two parallel digital streams are needed, which form four different states, and the duration of the modulating symbol becomes twice as long. In this case, the clock frequency of the modulating signal is reduced by 2 times. Accordingly, the bandwidth of the modulating signal is halved [1].

For multi-position modulation, the in-phase (I and Q) quadrature components of the modulating signal are used.

The shaping device (I(t) and Q(t) encoder), taking into account the QPSK constellation, is shown in Figure 1.

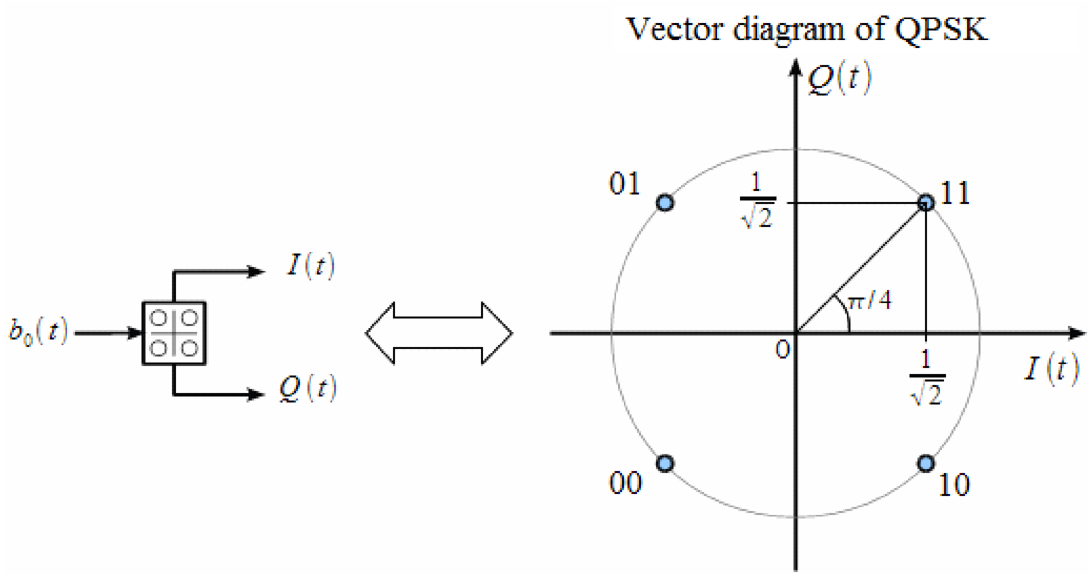

Fig.1. In-phase and quadrature (I(t) and Q(t)) shaping device components of QPSK.

The mathematical model of the QPSK signal is as follows:

$$S_{QPSK}(t) = I(t)\cdot\cos(\omega_0\cdot t+\Phi_0) - Q(t)\cdot\sin(\omega_0\cdot t+\Phi_0) \qquad (1)$$

where: I(t) and Q(t) are the in-phase and quadrature components of the QPSK signal.

The paper presents the investigated block diagram of QPSK (Fig. 2).

The initial sequence of binary symbols b0(t) of duration T is fed to the input of the investigated QPSK modulator (Fig. 3a), then the initial sequence of binary symbols is divided into even (x) and odd (y) pulses using a shift register, after which I(t) and Q(t) pulses (Fig. 3b, c) are fed to two DAC channels for digital-to-analog conversion with simultaneous formation of their spectrum in a digital filter (DF). The output smoothed signals I'(t) and Q'(t) of the DAC are fed to the electronic key, that is, to the electronic switch, which is controlled with a clock generator (Fig. 3d), after which the output generated signals I_k and Q_k are fed (Fig. 3 e, f), on the filter-forming interpolator h(t), for the further formation of manipulating pulses, after processing at the output of the LPF shapers, bipolar pulses I(t) and Q(t) are formed, then the formed bipolar pulses I(t) and Q (t) are fed to the first inputs of the multipliers, and quadrature signals are applied to the second inputs of the multipliers: sine Us and cosine U_c. The generated two-phase signals at the output of the multipliers are fed to the adder for summation, then the modulated signal is passed through a band-pass filter to limit out-of-band radiation, and a QPSK signal is formed at the filter output (Fig. 3g).

This QPSK block diagram under study (Fig. 2) can be used practically for noise-immune transmission of digital television signals of the DVB-T2 standard.

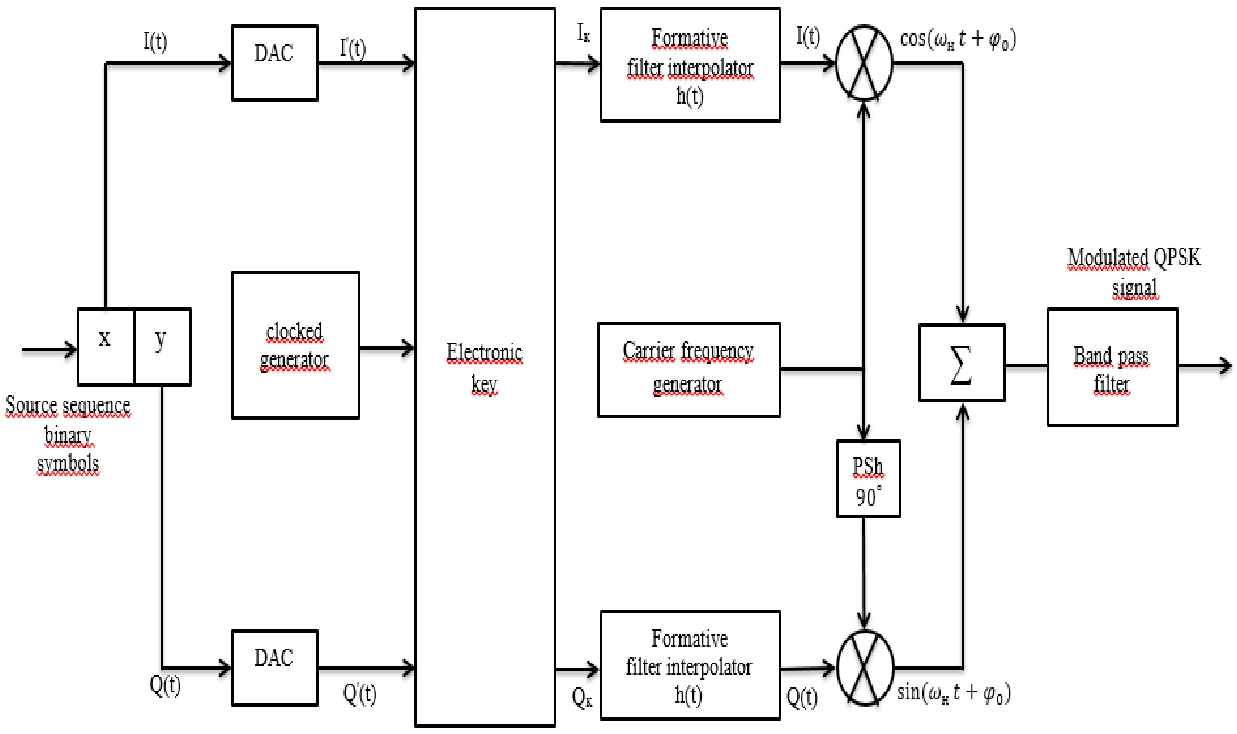

Fig.2. Investigated block diagram of QPSK.

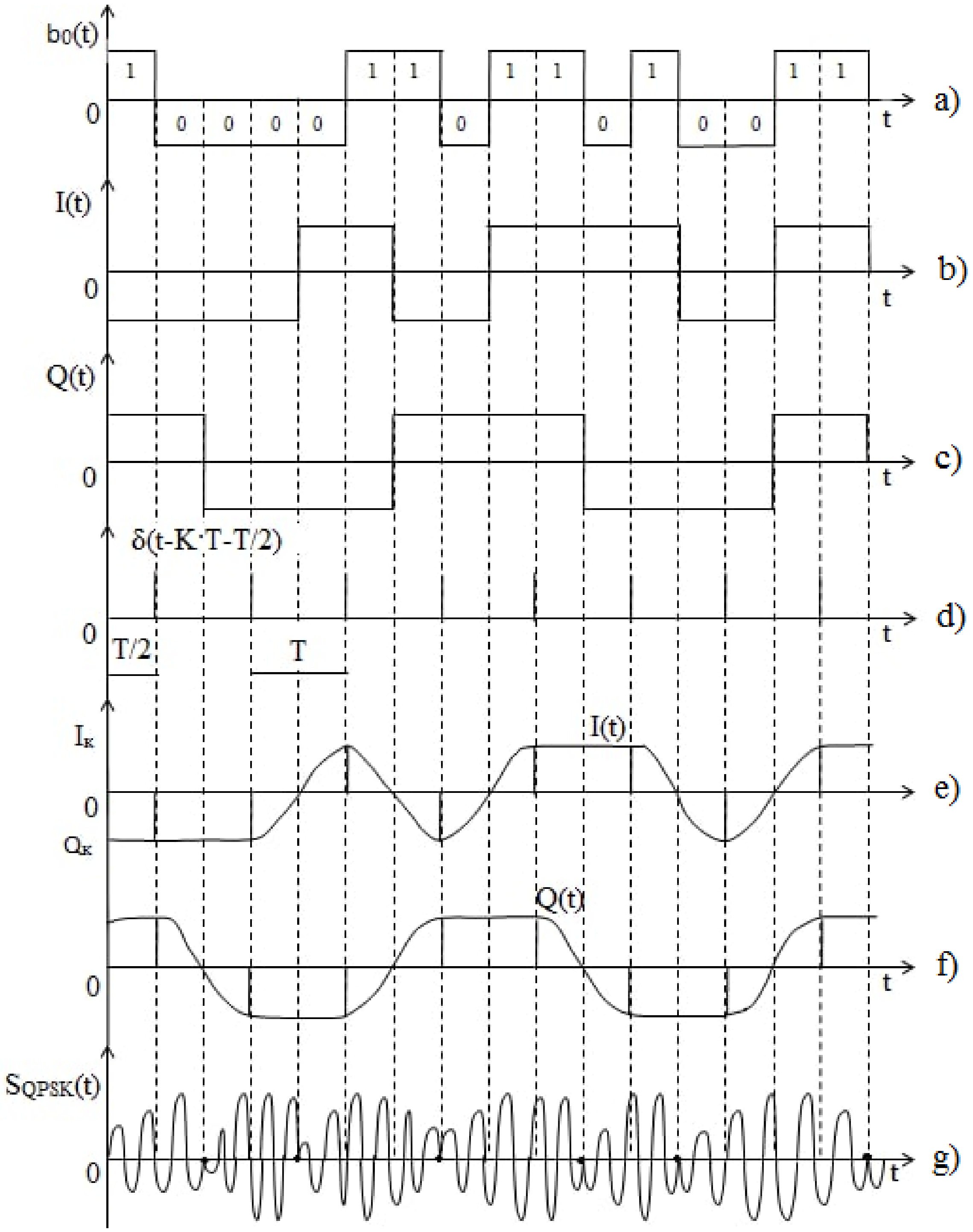

Fig.3. Signal generation QPSK: a - sequence of binary symbols $b_0(t)$ with duration T; b, c — bipolar pulses I(t) and Q(t) at the DAC input; d - signal at the output of the clock generator; e, f - output generated signals I_k and Q_k at the output of the switch; g is the quadrature phase modulated QPSK signal.

In this paper, the dependence of the bit error probability on Eb/N0 is theoretically investigated. The QPSK error probability is examined and calculated using the (2) expression:

$$P_{ER} = Q\sqrt{\frac{2E_b}{N_0}} \qquad (2)$$

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left[-\frac{U^2}{2}\right] du \quad (3)$$

$$x > 0$$

$$P_S = 1 - (1 - P_b)^2 = 1 - 1 + 2P_b - P_b^2 = 2P_b - P_b^2 = 2Q\sqrt{\frac{E_S}{N_0}} - Q^2\left(\sqrt{\frac{E_S}{N_0}}\right)^2 = 2Q\sqrt{\frac{2E_b}{N_0}} - Q^2\left(\sqrt{\frac{2E_b}{N_0}}\right)^2 \quad (4)$$

where: $E_S = 2E_b$
E_b- bit energy
E_S- energy symbol
P_S- probability of symbolic error
P_{er}- bit error probability
N_0- single band noise spectral density
E- energy signal
Q(x)- Gaussian error integral
$P_{ER(PSK)}$ 10^{-1} - bit error probability (BER) E_b/N_0,dB.

A theoretical study of the characteristics affecting the noise immunity of digital signal reception has been carried out.

The bit error probabilities from E_b/N_0 for various 16, 64 and 256-QPSKs are investigated and calculated using expression (4), and the calculated values are summarized in Table 1.

Table 1.

№	$P_{ER(QPSK)}$	E_b/N_0,dB			
		8PSK	16PSK	64PSK	256PSK
1.	0,66	-10	-10	-10	-10
2.	0,33	-4	-3	-2	-1
3.	0,1	-2	1	3	6
4.	0,066	-1	2,7	5	8,7
5.	0,033	0,5	4	6,9	10,7
6.	0,01	1,3	5,2	8,1	12
7.	0,0066	2	6	9	13,4
8.	0,0033	2,5	6,7	10	14,4
9.	0,001	3	7,2	10,7	15,2
10.	0,00066	3,3	8	11,4	16,1
11.	0,00033	3,8	8,5	12	16,8
12.	0,0001	4	8,8	12,5	17,5
13.	0,000066	4,3	9,3	13	18
14.	0,000033	4,7	9,7	13,5	18,6
15.	0,00001	5	10,2	14	19,2
16.	0,0000066	5,2	10,6	14,5	19,8
17.	0,0000033	5,5	10,9	14,9	20,1
18.	0,000001	5,7	11,1	15,1	20,4
19.	0,00000066	5,9	11,3	15,4	20,8
20.	0,00000033	6	11,4	15,6	21,2
21.	0,0000001	6,1	11,6	15,9	21,4
22.	0,000000066	6,3	11,7	16	21,6
23.	0,000000033	6,4	11,8	16,1	21,7
24.	0,00000001	6,5	11,9	16,3	21,8
25.	0,0000000066	6,6	12	16,5	21,9
26.	0,0000000033	6,7	12,1	16,6	22
27.	0,000000001	6,8	12,2	16,7	22,1

Figure 4 shows a plot of bit error probability versus E_b/N_0 on a logarithmic scale.

Fig.4. Plot of bit error probability versus E_b/N_0.

As a result of the study, the following conclusions can be drawn: with an increase in the positioning of the QPSK signal, the probability of a bit error increases and with an increase in E_b / N_0, it will be possible to transmit a large number of symbols, that is, it is possible to provide noise-resistant reception of digital signals.

In [2], the characteristics of quadrature-amplitude modulation affecting noise-immune reception were studied, if we compare QPSK with QAM modulation, we can draw the following conclusions: with an increase in spectral efficiency, the energy efficiency decreases.

The greater the distance between the points in the constellation, the less likely there is an error in determining the neighboring symbol. Thus, for limited bandwidth, where $M \leq 4$, QPSK modulation is the most efficient. If we compare this result with the result obtained by the QPSK method, then the superiority of QAM over QPSK becomes obvious. The ratio of SNR to BER of QAM modulation is much better than that of QPSK [3].

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