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Signal processing with frequency and phase shift keying modulation in telecommunications

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Abstract
In this paper represents research improving effectiveness of signal processing in telecommunication devices especially for its part, which relates to providing its noise resistance in conditions of noise and interference. This objective has been achieved through development of methods and means for optimization of filtering devices and semigraphical interpretation of clock synchronization systems in telecommunications with frequency shift keying on the base of stochastic models what determines relevance of the subject. Separately, in an article considered the urgent task is using of modified synchronization methods based on the interference influence of adjacent symbols on the phase criterion tract, in particular the use of the modified synchronization scheme, in order to get a formalized outlook representation of the synchronization schemas based on the polyphase structures with using a bank of filters, that allows to improve the characteristics of digital telecommunication channels. This work is devoted to the examination and modeling of these ways. The proposed ideas and results for the construction of synchronization systems can be used in modern means of telecommunication.

Keywords: *dispersion error, interpolation, modulation, synchronization*

1. Introduction

Progress in modern telecommunication systems is connected with using complicated signal and code structures to form information signals [1-5]. Thus both phase locked loop (PLL), which recovers signal carrier frequency and clock synchronization devices (CSD) are needed to be included to the receiving part. Analysis of works [6-8] showed that the basic accent at the decision the task of synchronization charts construction is put on the usage of synchronization devices which are built on the PLL systems. This paper presents the recent problems of the analytical description of synchronization systems that form on the receiving side of radio-frequency line supporting jitter when included some noise that impairs the accepted signal, and also the description of the accident state of a signal. Having of distortions that influence on the quality ofsynchronization systems requires guiding of synthesis of the synchronization systems with minimum influence of destabilizing factors on their quality indexes. The decision of these problems is conducted in the article. The paper presents the analytical description of working and optimizations of transceivers parameters of shift keying modulation signal in the conditions of the real complex, the influence of hindrances is set on quality of treatment of the modulated signals by the evaluation of closeness change of error distribution in the system of synchronization, the analysis of middle sentinel and dispersible dependences is conducted for the synchronization system of on the basis of stochastic models.

The proposed solution and investigational method of synchronization signals systems construction without the classic circles of PLL [9-11] that are unzoomed, that requires research of the dynamic phase systems in order to find the area them resisting work. In of most studies the focus has been on using information and control synchronization devices based on the systems of PLL, and the theory and practice of the use of modified synchronization schemes, the signal processing units on the interpolation information and control schemes with oversampling is imperfect and requires the separate research. The new modified constructions of polyphase interpolators of Farrow are offered for the systems of synchronization of the multiposition modulated signals. The worked out imitation chart of transceiver of

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the multiposition modulated signals is offered. There was experimentally conducted estimation of efficiency of the offered transceiver chart of multiposition signals by the evaluation of its quality work on the basis of determination is suggested in this paper. The article shows the conducted evaluation of signals distortions by the eyediagram, constellation diagram, evaluation of phase and symbol error in the hindrance influences conditions.

2. Research Method

Model of synchronization [12-16] system is described by stochastic equations in according to Figure 1 where the following symbols are used: $\xi = \xi(t)$ –input influence, $\hat{\xi} = \hat{\xi}(t)$ –influence assessment, $\gamma = \gamma(t) = (\xi(t) - \hat{\xi}(t)) / T$ –normalized synchronization error, $\rho(\gamma)$ –discriminatory characteristics, $h(\gamma)$ –fluctuation characteristics, $n(t)$ –Gaussian white noise, $f(\varepsilon)$ –transient pulse function of the linear dynamic element, which describes the effect of processing output signal and adjustment of the clock generator frequency Figure 1. The pulse sequences to identify synchronization error are represented in Figure 2.

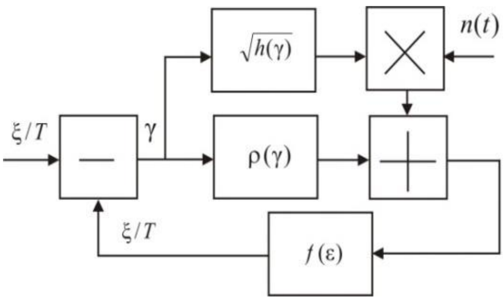


Figure 1. The research clock synchronization scheme

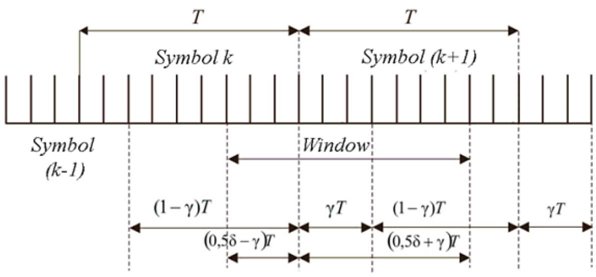


Figure 2. Pulse sequences in synchronozation system

Following assumptions have been made: the influence is a slow process, stable due to large amount of symbol intervals; assessment of the target influence is a slow process normalizing random processes and fluctuation of discriminator's output signal is the condition to be used; spectral density $G(\omega,\gamma)$ is assumed to be stable in the tract transmission frequency band $G(0,\gamma)$ and the fluctuation component is model by white Gaussian noise. The synchronization system is described in terms of the automatic control system. The input influence is represented as $r(t) = U(t) + n(t)$. where signal part is defined as follows: $U(t) = U_0 \sum_i S_i h(t - iT - \xi)$, $h(t) = 1$, $0 \le t \le T$, $h(t) = 0$, $t \in (0,T)$. Thus, the pulses sequence is given U_0 - having rectangular form $h(t)$, which represents binary character data stream $S_i \in \{+1,-1\}$, $n(t)$ –Gaussian white noise. The study is performed in order to identify discriminatory and fluctuational characteristics. The synchronization error is specified by as $\gamma = (\xi - \hat{\xi}) / T$.

In synchronization scheme, the input process $U(t)$ is treated by in-phase and secondary phase integrators, in the form of coherent filters, during symbol interval T see Figure 3. In the in-phase tract the comparator identifies symbol polarity, and detector defines transitions in accordance to the algorithm: if $a_k = a_{k-1}$, then $I_k = 0$; if $a_k = -1$, $a_{k-1} = +1$, then $I_k = +1$; if $a_k = +1$, $a_{k-1} = -1$, then $I_k = -1$, defining the sign of synchronization error. In the secondary phase circuit the synchronization error value is assessed, here $\delta_0 T$ –processing interval. The coherence of circuits is provided by delay link $(1-\delta_0/2)\cdot T$ so that these signals coincide. Synchronization system accuracy is assessed by dispersion of GMSK, as in Figure 4, bit sequence reflecting the synchronization in the circuit [5-13].

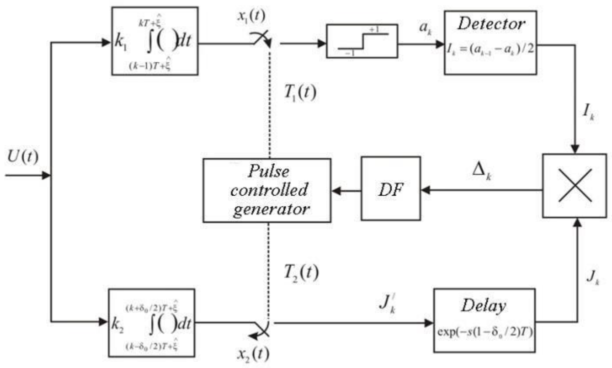


Figure 3. The block diagram of synchronization system in case of fixing scan and reset moments

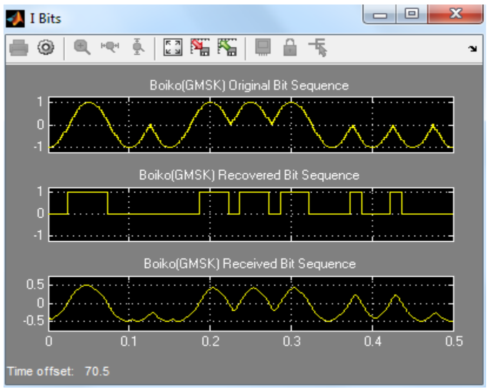


Figure 4. Bit sequence in the synchronization system for GMSK

The circuit components system together with multiplier forms measuring component–synchronization system discriminator. The output signal Δ_k should be filtered and furthermore is used for frequency control in pulse generator and integrators in order to remove a synchronization error.

$$\Delta_k = \frac{(U_{2k}+n_{2k})\text{sign}(U_{1k}+n_{1k}) - \text{sign}(U_{1k+1}+n_{1k+1})}{2}, \qquad (1)$$

where $k = 0, \pm 1, \pm 2, \ldots$; $U_{1k} = k_1 U_0 \sum_i S_i \int_{(k-1)T}^{kT} h(t - iT - \gamma T)dt = k_1 U_0 T\{(1-\gamma)S_k + \gamma S_{k+1}\}$;

$$U_{2k} = k_1 U_0 \sum_i S_i \int_{(k-\delta_0/2)T}^{(k+\delta_0/2)T} h(t - iT - \gamma T)dt = k_2 U_0 T\{(\gamma+\delta_0/2)S_{k+1} - (\gamma-\delta_0/2)S_k\},$$

where U_0 –pulse amplitude; k_1, k_2 –integrators transmission coefficients. The random process in the output of discriminator is defined from formula in (1). Its statistical characteristics are used to define discriminatory and fluctuational characteristics $\alpha(\gamma) = M(\Delta_k/\gamma)$, where $M(\Delta_k/\gamma)$– conditional mathematical expectation at noise samples and symbols. The dispersion of fluctuational error in synchronization system should be defined using the equation from Markov's random processes theory where the probability density distribution $P = P(\gamma, t)$ is expressed by Fokker-Planck-Kolmogorov equation [17-20]:

$$\frac{\partial P}{\partial t} = -\frac{\partial}{\partial \gamma}(A(\gamma)P) + \frac{1}{2}\frac{\partial^2}{\partial \gamma^2}(Z(\gamma)P), \qquad (2)$$
$$P(\gamma, 0) = P_0(\gamma),$$

where $P_0(\gamma)$–initial density distribution of synchronization error; $Z(\gamma) = k^2 S(0,\gamma)$. The solution of (2) at synchronization system stationary mode (for $\frac{\partial P}{\partial t} = 0$) is found as:

$$P(\gamma) = c^{-1} \exp\left(-\int_0^{\gamma} \frac{2h_0^2 \chi_0 \alpha_n(U) + dh(U)/dU}{h(U)} dU \right), \quad (3)$$

$$|\gamma| \le 1/2,$$

where $\chi_0 = \dfrac{4}{U_0 kT}$ –parameter opposite to normalized noise band of the synchronization system linear model; $c = 2\int_0^{1/2} \exp\left(-\int_0^{\gamma} \frac{2h_0^2 \chi_0 \alpha_n(U) + dh(U)/dU}{h(U)} dU \right) d\gamma$ –normalizing constant.

In the diagram, Figure 5 uses blocks forming signals (forming circuit), directly sync with the circle containing PLL voltage controlled oscillator (VCO) and filtering system (Digital Filter Design) [8, 14]. The results of the measured using measuring tools. The mathematical modeling will be performed and error dispersion influence will be assessed in dependence on signal to noise ratio for some values of χ_0 parameter. The study has indicated that in case of narrowing synchronization system band the dispersion of fluctuational error is reduced. In Figure 6, solid curves 1 and 2 demonstrate that the window width minimizes synchronization error dispersion for each value of SNR, however curves 3 and 4 demonstrate constant width of the window. Figure 5 shows a simulation model of synchronization with uniform sampling.

Signal processing in digital communication systems [21] is certainly associated with their transformation into a sequence of count referring to specific moments in time, i.e. with the spending of sampling signals in time. To obtain values of sampled signals are mainly used analog-to-digital converters of normalized synchronization error shown in Figure 6:

$$\sigma_\gamma^2 = 2\int_0^{1/2} \gamma^2 P(\gamma) d\gamma \cdot \quad (4)$$

Figure 7 represents graphs, which describe process of setting on stationary mode at error probability $p_0 = 10^{-3}$, in case of GMSK digital modulation. However, when solving problems of construction of modified signal processing schemes, there is the possibility of using algorithms of non-uniform sampling signals [22, 23].

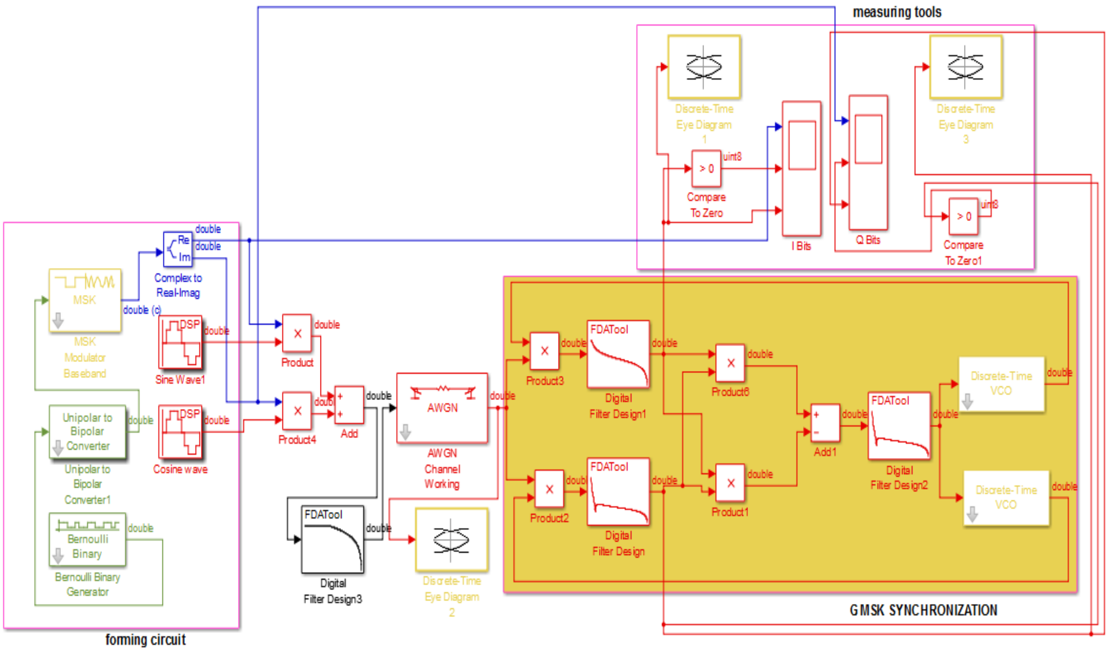


Figure 5. Simulation synchronization scheme for GMSK

3. Results and Discussion

Usually, it is assumed that the sampling is considered deterministic and periodic. The conversion of the sampling frequency F=1/T represents the change of the sampling frequency of a discrete signal. When the new sampling frequency is above the valid one so that $F^{/}> F$ and $T^{/}<T$, then in general this process is called interpolation, the essence of which is to add zeros by the number ($F^{/}/F$)-1 between two adjacent counts. The result is a new sequence with a sampling frequency of $F^{/}$ which the interpolation filter is applied for. To improve the efficiency of synchronization, the method of the sampling frequency conversion using polyphase filters is proposed. Polyphase filter is a set of small filters operating in parallel, each of them processes only a subset of counts signal. This process forms a new sequence and does not run extra computation because it is necessary to calculate the output signal of only one of these filters for each reading. Now, for the recovering of signals with uneven counting are being explored the various methods of converting the sampling frequency, which are designed for minor fluctuations in the deviations of the sampling interval [24, 25].

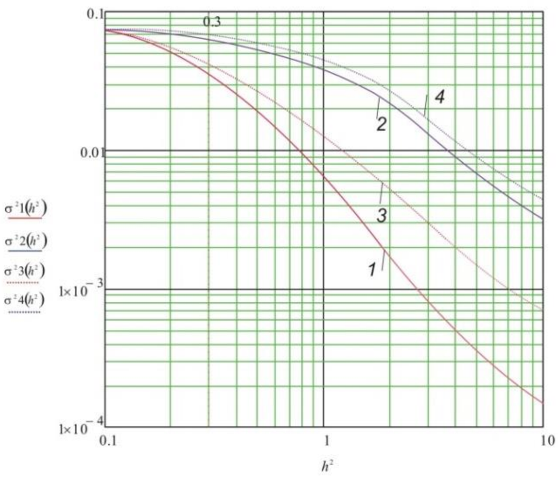


Figure 6. Graphs of dispersion error σ_{γ}^{2} dependence on signal to noise ratio h_0^2: 1–$\chi_0 = 100$, $\delta_0 \to opt$, 2–$\chi_0 = 25$, $\delta_0 \to opt$; 3–$\chi_0 = 100$, $\delta_0 = 1$; 4–$\chi_0 = 25$, $\delta_0 = 1$

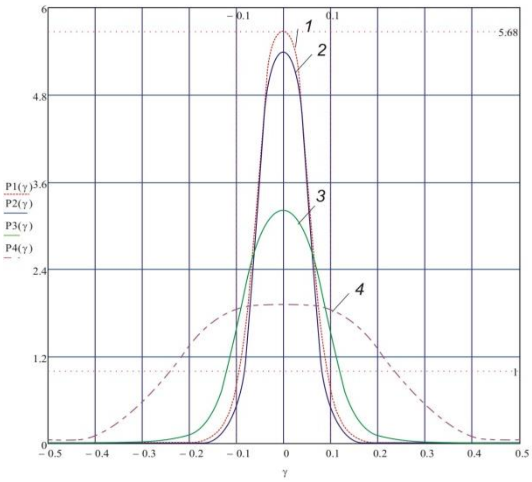


Figure 7. Graphs of probability density distribution at different values of normalized time $t_н$ ($p_0 = 10^{-3}$, $\varpi t = 5 \cdot 10^{-2}$): 1–stationary state; 2–$t_н = 2$; 3–$t_н = 1$; 4 –$t_н = 0.5$

3.1. Synthesis of Modified Information and Control Blocks of Synchronization Systems

The reconstruction of such a signal is possible only with the help of digital signal processing, including fluctuations in pitch (detonation) as the non-uniform counting of the signal in time. In this regard, it is very important to find a problem solution to design the synchronization device of the modified type and the possibility of using the Farrow structure for continuous adjustment of sampling frequency conversion, to restore the non-uniform counting of the digitized signal, and its further application in digital signal processing in information and control blocks of telecommunications for the enhancement of noise immunity [22, 23]. The basic equation of interpolation of discrete signal is written as:

$$y(lT_i) = y[(n_l + \mu_l)T_{in}] = \sum_{i=I_1}^{I_2} \sum_{i=I_1} x[(n_l - i)T_{in}] h_I[(i + \mu_l)T_{in}], \quad (5)$$

where $\{x(n)\}$ is a sequence of signal samples with an interval T_{in}; $h_I(t)$ is the impulse characteristic of the interpolating non-recursive filter; *i*–the index of the filter; n_l –an initial coordinate, defining $I=I_2-I_1+1$ samples of the signal to use *l* by interpolator; μ_l–fractional sampling interval which determines the filter coefficients of the *l* interpolant. The impulse characteristic of the interpolation filter is expressed in each interval using a polynomial of degree *M*:

$$h_I(t) = h_i\left[(i+\mu_l)T_{in}\right] = \sum_{m=0}^{M} c_m(i)\mu_l^m . \tag{6}$$

The number of polynomial coefficients $c_m(i)$ is constant that does not depend on μl, and is only determined by impulse characteristic of the interpolation filter $h_I(t)$. The expression of interpellants can be found using:

$$y(l) = \sum_{i=I_1}^{I_2} x(n_l - i)\sum_{m=0}^{M} c_m(i)\mu_l^m \sum_{i=I_1}^{I_2} c_m(i)x(n_l - i) = \sum_{m=0}^{M} \mu_l^m \nu(m), \tag{7}$$

where $\nu(m)$ are the counting of the signal output from the *M*+1 interpolation non-recursive filters with the corresponding coefficients of the impulse characteristic $c_m(I_1)$, $c_m(I_1+1)$… $c_m(I_2)$. Then, the transfer function of such a non-recursive filter can be written in the form:

$$C_m(z) = \sum_{i=I_1}^{I_2} c_m(i)z^{-i} \cdot \tag{8}$$

consequently, the expression (7) is the polynomial of parameter μ_l^m, which is the only variable. This structure includes *M*+1 of non-recursive filters with constant coefficients, connected in parallel and their results are multiplied by the fractional sampling interval. Use Lagrange polynomials to build the Farrow filter. Perform a continuous signal as a sum of products of samples on the Lagrange polynomial:

$$y_a(t) = \sum_{n=0}^{M-1} y(l)\cdot X_I^{M-1}(\mu_l) , \tag{9}$$

where *M* is the degree of the polynomial, the polynomial is equal to the unity at the time of sampling I counting and is zero at other sampling points. Using the formula (8), the transfer function of the polyphase filter can be represented in the following form:

$$G_I(z) = C_0(z) + C_1(z)\cdot\mu_l + C_2(z)\cdot\mu_l^2 + C_3(z)\cdot\mu_l^3 \tag{10}$$

The following expresions for polynomial coefficients were found (10).

$$\begin{aligned}
&C_0(z) = z^{-2}, C_1(z) = \frac{1}{2}\left(z^{-3} - z^{-1}\right) - C_3(z),\\
&C_2(z) = z^{-3} - z^{-2} - C_1(z) - C_3(z),\\
&C_3(z) = \frac{1}{6}\left(z^{-3} - z^{0}\right) + \frac{1}{2}\left(z^{-1} - z^{-2}\right).
\end{aligned}$$

The modified schemes of Farrow polyphase filters are presented in Figure 8 a, b [18]. Using the analytical expression (6) for the impulse characteristic of the interpolation filter and one more approach to the structure modification of the Farrow interpolator for the synchronization system can be described. Instead of μ_l in (6) use construction ($2\mu_l$-1) for formation of the fractional interval. Supposing the impulse characteristic of the filter as follows:

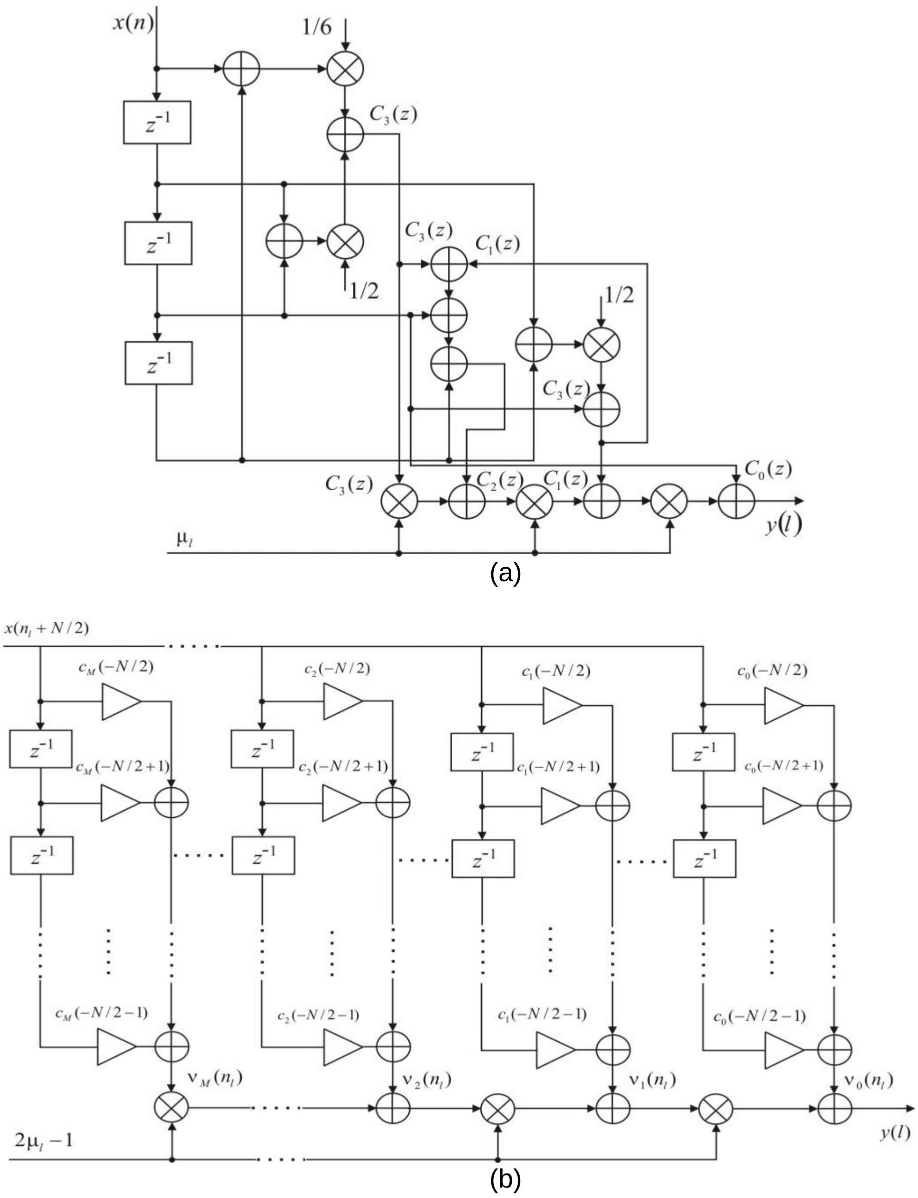
$$h_i\left[(n+\mu_l)T_{in}\right]=\sum_{m=0}^{M}c_m(n)(2\mu_l-1)^m \quad , \tag{11}$$

where is $n=-N/2$, $-N/2+1$, ….., $N/2-1$.

If μ_l is scaled from 0 to 1, then $h_i(t)$ the impulse characteristic will take to each interval $\left[kT_{in},(k+1)T_{in}\right]$ for $k=-N/2,...,N/2-1$ the following construction:

$$h_i(t)=\sum_{m=0}^{M}c_m(k)\left(\frac{2(t-kT_{in})-1}{T_{in}}\right)^m \quad , \tag{12}$$

The symmetry properties $h_i(-t)=h_i(t)$ can provide $c_m(n)=(-1)^m c_m(-n-1)$, for $m=0,1,...,M$ and $n=0,1,...,N/2-1$.



(a)

(b)

Figure 8. The modified schemes of Farrow polyphase filter: (a) - variant 1; (b) - variant 2

The study of the proposed solutions will develop a simulation scheme of the telecommunication of data transmission system. The comparison of the results of the study the proposed solutions in the construction of information and control blocks device synchronization will be carried out on the basis of the multi-phase control system analysis. Principal performance criteria will be an energy gain, minimizing error on constellation diagram, minimization of transient error detector of the information and control system of the synchronization unit [26-29].

The aim of the study is to develop mathematical models and formal description of the process of synthesis of modified information and control blocks of synchronization systems, the development of the multi-phase interpolation unit with the technical expansion interpretation of polyphase matched filters of synchronization devices. It is necessary to carry out the design of a mathematical model by formalizing the solution equation of multi-phase interpolation system, to determine the performance of the estimate of the phase error and the normalized transient error for different values of the fractional interval and the multi-phase construction of matched filters bank in the receivers keyed signals of telecommunication information transmission systems. To achieve this goal it was necessary to solve the following tasks:

a. to investigate experimentally the influence of the values of the fractional interpolation interval of information and control system on the magnitude of error the synchronization device.
b. to carry out the assessment of the error on constellation diagram, to assess jitter to the aperture of eye diagram and changing the noise immunity at a fixed value of probability of bit error using constellation charts, eye diagrams, make a noise immunity curve.

The study of the proposed solutions should carry out the development of simulation schemes of data transmission systems with information and control blocks on the basis of modified polyphase designed scheme presented in Figure 9. Sampling of the received signal is carried out by a fixed sampling clock signal, thus, the selection of samples is not synchronized with the received signal. Figure 10 shows the developed simulation scheme is presented. In this case, it is easy to change the sampling frequency, and sampling frequency must not be a multiple of symbols frequency. In addition, there is no need to use the system of phase automatic frequency retraining (PAFR) [30]. In the circuit shown in Figure 10 the signal is formed in "the scheme of signals formation", which includes the subsystem "modulator". The output signal gets to the Gray coder after the scrambling; then, the differential encoding should be performed, following extrapolation, over-sampling ("Upsample") and the limitation of the signal spectrum of filtering device ("FIR Filter").

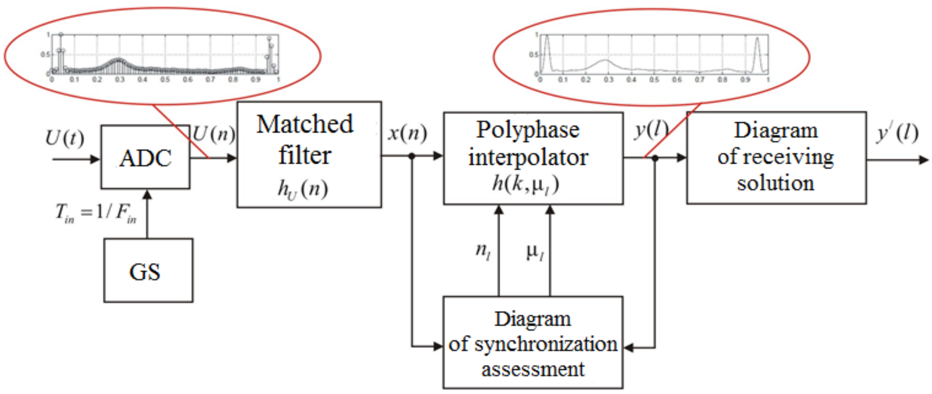


Figure. 9. Diagram of a digital receiver with information and control system based on the polyphase interpolator: GS–is the generator of samples (clock cycles); ADC–analog-digital converter

Later, in the scheme in Figure 9, the output signal enters to the subsystem polyphase interpolator "Polyphase Interpolator", in the information transfer channel. Phase error for the experiment is given by block "Phase Offset". The reception of the transmitted information is performed by the signal processor, which is based on the information and control scheme of synchronization with the polyphase interpolator. In accordance with Figure 8, the circuit includes: matched filter "Matched Filter" (a digital FIR low frequencies filter, raised cosine type, the order is 32, the window type is Boxcar), polyphase interpolator "Polyphase_Farrow_Interpolator", information and control assessment subsystem synchronization, and in accordance with formula (5) are formed: n_l–is initial coordinate, defining I=I_2-I_1+1 samples of the signal to use/interpolator; μ_l–is a fractional sampling interval which determines the filter coefficients of the/interpolant. In the experiment there should be measured the gain in increasing the noise immunity of signal processing, the detection of an error by constellational the chart.

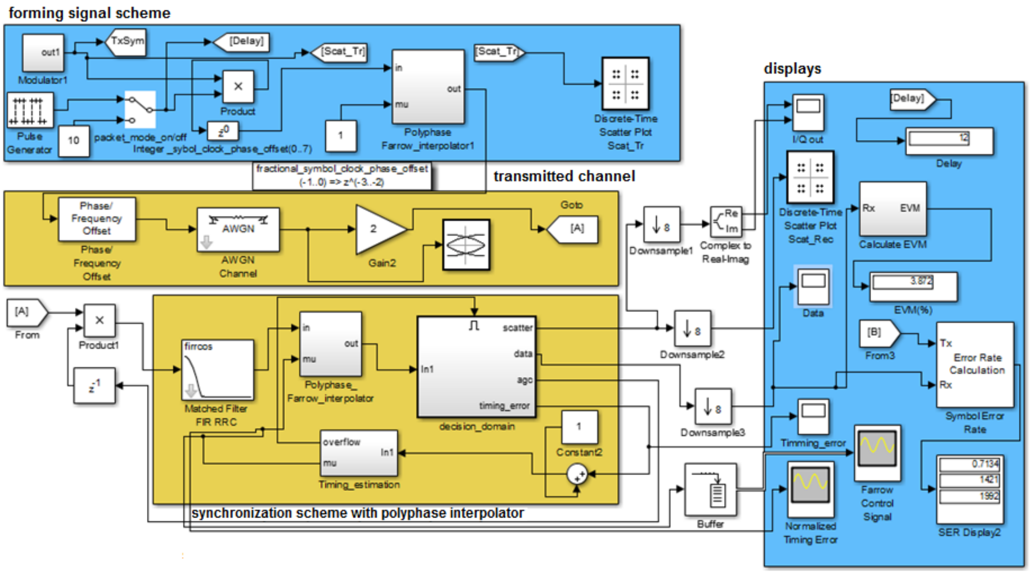


Figure 10. Imitation scheme of data transmitted system for researching of information and control synchronization device with polyphase interpolator

3.2. Research Results

In Figures 11–14, one can see results of study of information and control devices of the synchronization unit with multi-phase filtering system in the form of a display for assessing a transient failure and the signal display of coherent polyphase filter. Figure 15 shows the constellational scheme obtained on the transmitting side channel information transmission–subsystem "The Diagram of the Signal Formation". The studies have been performed for quadrature phase shift keying DQPSK [17]. In Figure 16, the constellation schemes to assess the effectiveness of synchronization systems are shown. The high-quality reproduction of the transmitted signal is observed.

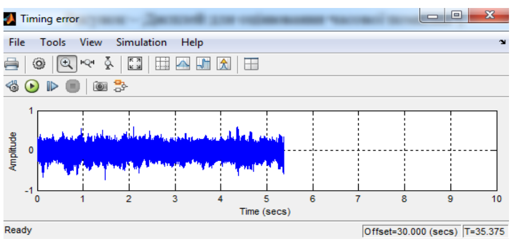


Figure 11. The display for the evaluation of transient failure (temporary failure detector for Figure 10)

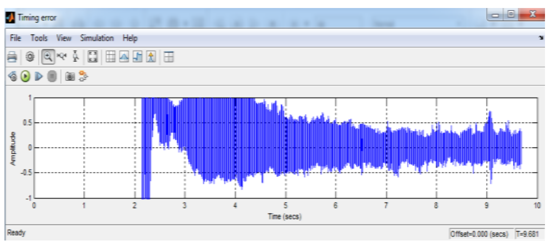


Figure 12. Evaluation of transient failure (for maximum likelihood detector and 32 foreman matched filter)

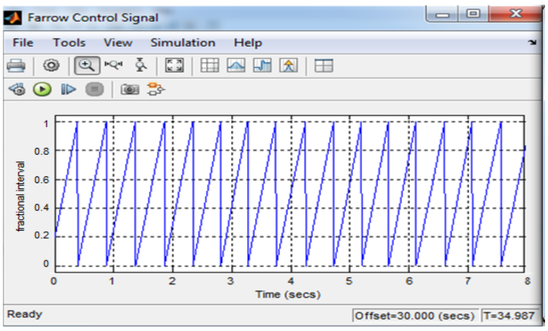


Figure 13. Evaluation of the signal from the interpolator of the Farrow structure (the simulation results: reaction to the jump in phase for the clock synchronization, the loop operates at 2 samples/symbol, the maximum likelihood detector and interpolation Farrow filter (μ = 1))

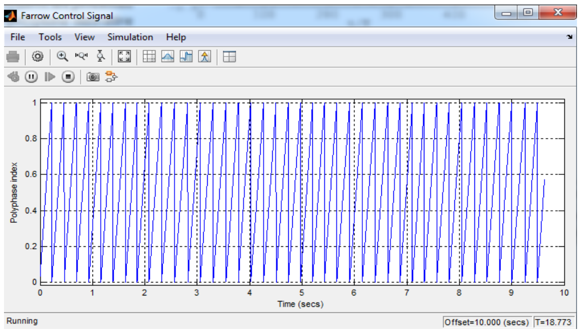


Figure 14. Evaluation of the signal from the interpolator of the Farrow structure (the simulation results: reaction to the jump in phase for the clock synchronization, the cycle works 2 samples/symbol with a maximum likelihood detector and 32 Foreman matched filter)

Formalization of process of such a detector can be described by following equations presented in [30]:

$$\xi(n) = U_I(n) + U_Q(n), \tag{13}$$

$$U_I(n) = [Y_I((n-1)\cdot T + \Psi_{n-1}) - Y_I(nT + \Psi_{n-1})]\cdot Y_I(nT - T/2 + \Psi_{n-1}), \tag{14}$$

$$U_Q(n) = [Y_Q((n-1)\cdot T + \Psi_{n-1}) - Y_Q(nT + \Psi_{n-1})]\cdot Y_Q(nT - T/2 + \Psi_{n-1}). \tag{15}$$

where $\xi(n)$ is a temporary error in the synchronization system for n symbol; Y_I and Y_Q the in phase and quadrature components of the signal; T is the period of symbols following; Ψ_n phase evaluation for the n-th symbol. In Figure 17, it can be see the constellational chart obtained during modeling modeling the receiving side in the system clock synchronization. Figure 18 exposes a diagram obtained for the system of phase synchronization. In Figures 19 and 20, the results of study of the control circuit for the synchronization device are exposed. In Figure 21, the eye diagrams obtained by the method of simulation modeling on the transmitting side are presented. In particular, Figure 19 shows the evaluation of phase error in the phase synchronization unit of the control blocks.

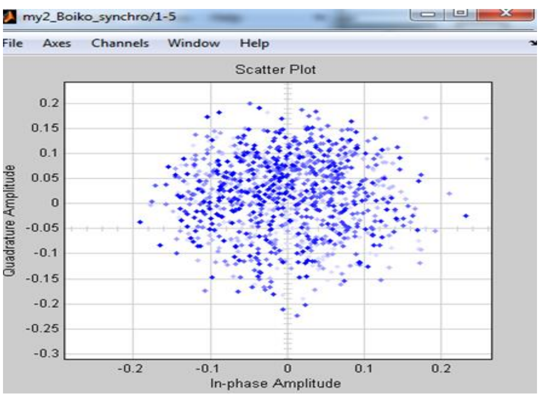


Figure 15. Constellation chart in output of transmission channel

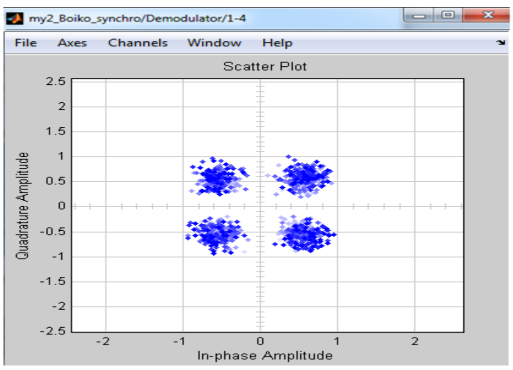


Figure 16. Constellational chart of the recovered signal after synchronization system

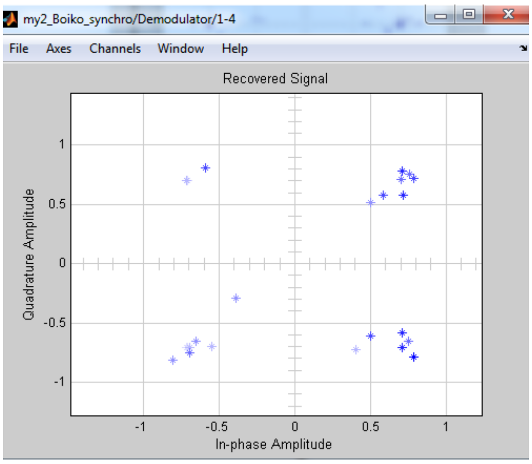


Figure 17. Constellational chart on the receiving side of the communication channel in the system clock

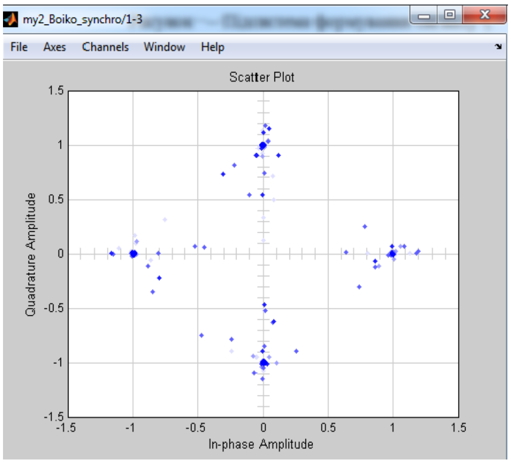


Figure 18. Constellational chart on the receiving side of the communication channel in the system of phase synchronization

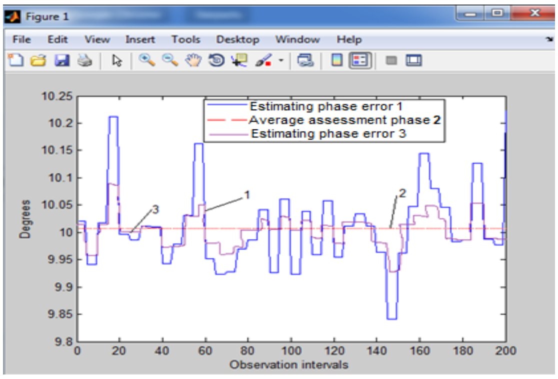


Figure 19. Estimating phase error in the phase synchronization device: 1 and 3–review the resulting modeling; 2–the average value of the carrier phase

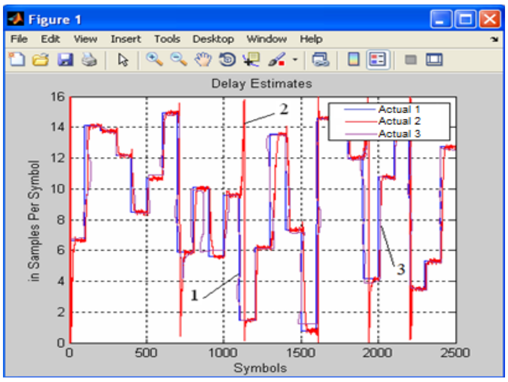


Figure 20. Evalution delayed symbols in unit of clock synchronization: 1–the actual assessment; 2 and 3–review the resulting modeling

The observed fluctuation pattern of change in estimated curve around the mean value of the phase error of the carrier. The using the modified synchronization scheme reduces the phase fluctuations of about 2.02 times. In Figure 20, curve 1 shows the actual delay, and curve 2 is estimated delay for a set of 100 characters in the device clock synchronization. The simulation results show that the application of the proposed method of synchronization method allows the tracking delay, the estimated curve changes its regularity and has a distortion depending on the structure of the device. In general, the provided experiments justify experimental studies show the effectiveness of solutions by using modified timing circuits. Figure 22 presents the results of research of noise immunity of the receiving unit and the signal processing by using the proposed decisions on the use of information and control of the interpolation schemes.

In particular, improving the noise immunity can be determined by definition the energy gain of the use of polyphase interpolators in the control blocks. Analysis of the results in research of noise stability of synchronization schemes that are based on a modified structure and cubic Lagrange interpolator for DQPSK permits to conclude that the energy gain level for BER=10^{-4} (the probability of consumer mistakes) is of about 2.2 dB. For discussion it follows to distinguish innovative scheme-technic improvement of the synchronization system. Remodeling is carried out by forming of connections between the constituents of optimal structure of transceiver at application of the modified charts on the basis of polyphase constructions with the discretisation. The efficiency of digital transceiver construction with polyphase modified interpolators in the devices of transceivers synchronization of the multiposition modulated signals is offered and experimentally has been proved in the article. Due to research results the increase of noise immunity of the modified construction of receiver for different multiposition signals, the winning is got in SNR at the level of 3.4 dB.

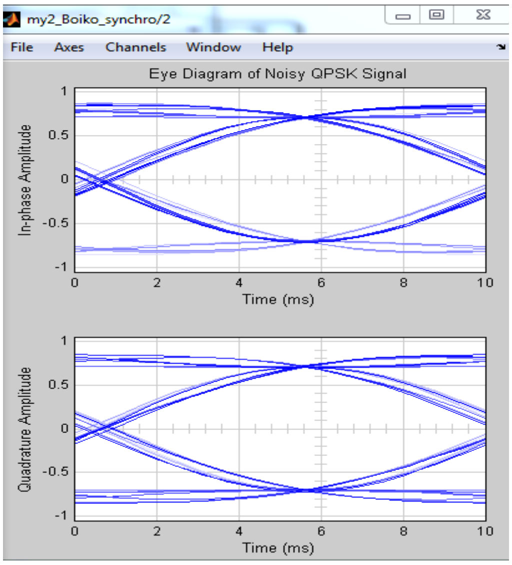


Figure 21. Eye charts to measure distortion signals on the transmitting

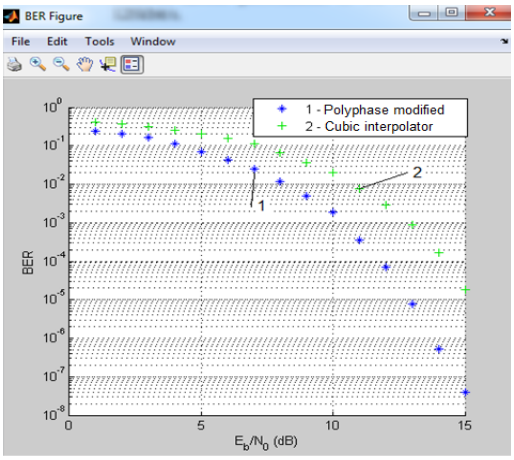


Figure 22. Noise immunity evaluation in the form of bit error (BER) on the ratio E_b / N_0 (signal/noise) to the signal processing unit in the case of DQPSK: 1–polynomial (polyphase interpolator, modified) 2–cubic interpolator on the structure of Lagrange

4. Conclusion

Paper represents obtained analytical and graphical changes of discriminatory characteristics at different values of SNR, and investigates that bonds influence of SNR and accuracy of clock synchronization device on condition of their equal noise bands defined that at the level of $\sigma_\gamma^2 = 10^{-3}$. The benefit of clock synchronization –2.7 dB. The conducted research has indicated that in case of narrowing synchronization system band the dispersion of fluctuational error is decreased. The analysis of the conducted researches is established that the use of the proposed control scheme and signal processing in synchronization systems effectively reduces playback errors of data in the telecommunication channels. Comparative evaluation of the proposed schemes to display EVM, allowed to get the error value on the constellations chart for the case of interpolation using the Farrow structure at the level of 3%. For the case of applying a multiphase design–5.5%. This means that the overall error is reduced by 1.8 times. In addition, note the decrease in amplitude of a transient error as shown in Figure 10 and Figure 11 by 1.8 times.

The repetition frequency of the control signal for the display (Farrow Control Signal) in the experiment differed by 2.5 times. The obtained results allow to confirm the following: the architecture of the synchronization device on the basis of the polyphase filters bank has two advantages compared with devices with sync interpolation device: these devices contain in its structure a separate interpolation filter in addition to the matched filter as shown in Figure 8. In the case of polyphase matched filtering, the control unit synchronization does not require additional interpolation device, reducing the complexity of synchronization. In addition, in the case of using the synchronization device on the basis of the polyphase matched filter bank can implement the agreed design for the detector with a lead-lag. In such circuits, the outputs of the polyphase filters are used directly for formative assessment of phase error.

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