ON THE QUESTION OF CHOOSING A METHOD FOR ANALYZING TRANSIENT PROCESSES FOR DEVELOPING THE THEORY OF RESOLUTION TIME. RETROSPECTIVE ANALYTICAL REVIEW

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One of the fundamental and central problems of radio engineering and communication theory was and remains the scientific problem of finding ways to potentially reduce the frequency band occupied by the signal, as well as reducing the power of transmitting devices, which provide the necessary speed and reliability of information transfer, that is, the problem of increasing the specific bandwidth. One of the key forms of solving this problem is the transition to the reception of information messages in conditions of strong intersymbol interference. Sufficiently encouraging results in this direction are shown by the theory of resolution time presented in the papers [1-5] for APSK-N- and PSK-n- signals. At the same time, as a mathematical apparatus in these works, it is used as a mathematical apparatus in the field of optimization and analysis of transient processes. At the same time, as shown in these papers, the correct choice of the mathematical apparatus for the analysis of transient processes is of paramount importance. At present, due to the constant growth of the volume of transmitted information, more and more attention is paid to the issues of the possibility of increasing the transmission speed due to the use of the transmission mode "above the Nyquist rate". According to the theory of resolution time, which has been developing quite rapidly recently, it is required to analyze the transient processes in linear selective systems (LSS). In this case, LSS makes it possible to implement frequency selective properties of real communication channels in the channel model. At the same time, the question of choosing a method for analyzing the transient process is quite acute, since it primarily determines the complexity of estimating capacity procedure. This paper presents a retrospective, analytical review of methods for analyzing transient processes in LSS and substantiates the need to apply the method of slowly varying amplitudes S.I. Evtyanov and its developing. On its basis, the simplest and most convenient method for analyzing transient processes was chosen as applied to phase radio engineering systems for transmitting information.

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Criteria for a communication channel model based a theory of resolution time.

Before carrying out such a review, let us formulate the requirements that the method used must satisfy analyzing main provisions which were used in the construction of a communication channel model based on the use of the resolution time theory [1-5]:

1) The real channel with ISI is "composite" [6-8], that is, it includes both the propagation medium and the transmitting and receiving channel-forming equipment. ISI are caused both by multipath propagation (in the general case, without the possibility of beam separation) and by uneven frequency response of a real channel [6-8], which, in the general case, can be represented as an equivalent bandpass filter with variable parameters in time. In this case, we will assume that the duration of the information message does not exceed the period with which the channel parameters change, and, therefore, in the process of transmission, the real channel can be represented as an equivalent linear selective system with a constant complex frequency response (CFR) [8].

2) The presence, in the general case, during the transmission session of the informational message of a constant offset of the receiving frequency relative to the frequency at which it is formed by the transmitter, which is, firstly, a consequence of the instability of the frequency generated by the transmitter, which manifests itself in the form of its inaccurate value, constant within information message [7,8], and secondly, the Doppler frequency shift due to the movement of the propagation medium, the value of which is invariable both in sign and magnitude within one information message, as an example of information transmission in HF- channels [7,8]. So it is advisable to represent it as a transmission from a transmitter to a receiver of a modulated radio signal at a frequency that has a frequency offset relative to the center frequency of an equivalent bandpass filter that determines the frequency-selective properties of a “composite channel”, since, according to [7], developers always strive to select the center frequency channel. Besides this is true because due to the fact that in modern radio engineering data transmission systems (ReDTS), before the transmission of the information message, the preamble is transmitted to the settings of the receiver parameters, it can be assumed that the receiver compensates for the constant phase shift introduced by the “composite channel” and the compensate of the transmission coefficient value at the reception frequency.

3) The level of ISI and measurement errors caused by the inaccuracy of the channel impulse response estimate is more significant compared to the additive white Gaussian noise. Therefore, it is advisable to neglect the latter [8,9].

4) The model should be built on the basis of the characteristics of the behavior of the informative parameters of the radio signal caused by the course of transient processes in linear electoral systems and ensure the efficiency and generalization of calculations. And when using a PSK-n-signal for information transmission, it is necessary to take into account the influence of the signal amplitude on the operation of the solver.

Methods of analyzing transient processes in linear systems with lumped-parameter

Based on the previous section we shall analyze methods that are used for estimation of the transient process that occurs in an equivalent filter, whose impulse response describes the communication channel.

The history of the modern theory of transient processes in linear selective systems is based on the application of the Fourier and Laplace transforms and is developed on the basis of operational calculus. The basic ideas of operational calculus were first presented by M.E Vashchenko – Zakharchenko at monography [10] that was published in 1862. In work [10], the symbolic calculus and its application to the solution of linear differential equations with constant and variable coefficients, as well as to the solution of partial differential equations, are presented in detail.

The application of operational calculus to solving electrical engineering problems was presented by O. Haviside [11] in 1892 – 1 93, thanks to which the use of operational calculus became widely known. In his studies, the method of drawing up and solving some differential equations which describe the processes in electrical circuits is considered. O. Heaviside used the same ideas as M.E. Vaschenko - Zakharchenko [10], but they were also not supported by mathematical proofs.

Further development and substantiation of operational calculus belongs to T.J. Bromwich [12-14], B. Van der Pol [15-17], D.R. Carson [18]. Since, D. Carson considered in study [18] the application of operational calculus to problems of electrical engineering and the propagation of telegraph signals through long lines.

In the work of A.M. Efros and A.M. Danilevskii [19], a rigorous proof of the Heaviside operator method is given using Melin-Riemann contour integrals in the domain of a complex variable. The use of the method of contour integrals made it possible to avoid those errors that could arise when interpreting an operator solution using the Heaviside decomposition theorem. A number of new relations and rules of operational calculus, and also proposes a generalized Borel theorem for determination images of functions have been established in this study. A number of examples of operational solutions for the analysis of transient processes caused by switching on a constant voltage and a radio stepwise at the input of a bandpass, a high and low pass filter, and in artificial delay lines are demonstrated.

Among the studies of that period, one can note the papers scientists M.Yu. Yuriev [20], K.A. Kruga [21], M.I. Kontorovich [22], in which the application of the operator method to the solution of problems in electric quadripole network and circuits with distributed constant parameters was developed.

Further development of the theory of transient processes in radio engineering is associated with the peculiarity of selective oscillatory circuits and the nature of high-frequency signals with "slowly" changing envelopes. This made it possible to apply to the study of transient processes in linear systems the method of slowly varying amplitudes, which was applied by B. Van der Pol [23] to consider processes in nonlinear systems.

B. Van der Pol proposed to replace the original differential equation for the analysis of the transient processes by a system of differential equations for slowly varying amplitude and phase. This method was later theoretically substantiated and developed by L.I. Mandelstam and N.D. Papaleksi [24]. They gave a rigorous substantiation of this method for transient processes and, according to their terminology, differential equations for slowly varying amplitudes are called truncated. The order of the truncated equation turns out to be lower than the order of the original equation, and therefore it is easier to find its solution.

D.V. Ageev and Yu.B. Kobzarev [25] were the first to show the possibility of applying the method of B. van der Pol to the study of transient processes in a resonant amplifier.

The study of A.N. Shchukin [26], in which a simple approximate method of analyzing transient processes in resonant and band-pass amplifiers was presented. According to S.I. Evtyanov [27], the simplifications made in [26] follow from the method of B. Van der Pol.

S.I. Evtyanov [27] in his foundational work presents a comprehensive development of the method of slowly varying amplitudes, based on the use of approximate symbolic equations. In the work general rules for drawing up these equations are formulated and a special mathematical apparatus for calculating the transient processes in selective quadripoles is proposed.

The main features of this apparatus are as follows [27, p.19]:

– co plex slowly varying amplitudes are introduced, which simplifies the calculation, since determination of the complex amplitude immediately resolves the question of the law of variation of the amplitude and phase. The term "envelope" refers to a complex amplitude;

– The runcated envelope equations are constructed in symbolic form from the original symbolic equations. In this case, the original equations in differential form do not need to be written;

– uhamel's theorem for envelopes is formulated;

– to solve symbolic truncated equations, the mathematical apparatus of operational calculus is used.

Besides of mentioned above S.I. Evtyanov has presented a large number of solutions for transient processes in selective systems in his monography [27]. The issues of settling the envelope response are considered when a Heaviside step function, a radio stepwise and a linearly increasing voltage are applied to the input of a narrow-band linear system[1] (NBLS). The author also paid attention to the analysis of the properties of the envelope response at the output of NBLS on a radio stepwise in the presence of a frequency detuning. As narrowband linear systems S.I. Evtyanov uses an n-stage resonant amplifier, a band-pass filter, the stages of which are k-type filters, a filter built on stages of two coupled circuits with different implementations, and a three-circuit filter with two coupled circuits. Additionally the analyses of distortions of the envelope of radio pulses with rectangular and triangular shapes caused by transient process were determined in study [27] when such signals pass through NBLS. The author considered the possibility of using the method developed by him for the analysis of transient processes caused by a phase jump in the absence of frequency detuning and with a jump in the frequency of a harmonic oscillation.

The subsequent development of operational calculus was based on the use of contour integrals. So, in the work of F.V. Lukin [31] proposed the application of contour integrals to the study of transient processes in linear elements of radio engineering devices and considered the settling of the signal amplitude under impulse action.

Among spectral methods for analyzing transient processes existing at that time, it is necessary to note the methods proposed by P.K. Akulshin [32] and V.V. Solodovnikov [33,34].

Method of P.K. Akulshin [32] was developed to analyze the establishment of the envelope in linear systems under the action of bursts of radio pulses and is based on replacing the Fourier integral with its series. The author also gives recommendations on the application of this method for radio pulses with other forms of envelopes. As a limitation on the possibility of its application, the following condition can be called: when exposed to a periodic sequence of rectangular radio pulses, the distance between them should be such that the current value has time to grow to the steady state value (90-95%) and decrease almost to zero (10-5%).

Method of V.V. Solodovnikov [33,34] was originally developed for the analysis of automatic control systems and consists in a piecewise linear approximation of the exact (calculated) real frequency characteristic of a closed system, and in the representation of the area bounded by this obtained characteristic, the sum of the areas of a finite sum of elementary rectangular trapezoids. The disadvantage of this method is the large number of calculations, the use of special tables and the dependence of its accuracy on the number of trapezoids into which the area bounded by the real frequency response curve is divided.

In the foreign scientific literature of that period, it is necessary to note the work of M.F. Gardner and J. Burns [35] for linear systems with lumped parameters. The paper contains a systematic presentation of the Laplace transform method, which is the basis of the operator method, and the practical rules of its use as applied to a wide class of problems from the field of mechanics, control theory, and electrical engineering.

The results on the analysis of transient processes in linear systems of this period were summarized by I.I. Teumin in the form of a specialized handbook [36]. The handbook provides a brief material on the application of classical and spectral methods to the problems of transient analysis in linear circuits with lumped parameters, as well as extensive material on the application of operational calculus to the problems of transient analysis in linear circuits. The author paid attention to the S.I. Evtyanov`s [27] method of slowly varying amplitudes and presented the new results of the study of transient processes, which were obtained with its application, in the form of envelopes of responses of NBLS to a radio jump. The handbook also covers:

– transient process for linear systems with lumped constants when video pulses and radio jumps are acting on their input;

– transient pro ess in systems with distributed parameters.

It should be noted that in all these cases, only issues related to the settling of the envelope are considered.

Similar problems were considered by S.G. Ginzburg [37], V.A. Kotelnikov and A.M. Nikolaev [38].

Quite interesting is monography of I.S. Gonorovsky [39], in which the method of A.I. Lurie [40] is used for finding solutions of differential equations with periodic right-hand side. This method was applied to the analysis of transient processes caused by the action of a periodic sequence of signals on the input of linear system. There were also considered transients caused by the passage of a sawtooth and rectangular sequence of video pulses through an aperiodic amplifier. Also I.S. Gonorovskiy shows the application of this method for solving problems of analysis of transient processes during frequency multiplication and for studying the operation of an auto-generator. In addition, in [40], an “analytical

[1] Taking into account the results given in [27–30], we can conclude that the NBLS should be understood as systems in which the ratio of the mean frequency to the bandwidth is at least 15. Thus, according to I.S. Gonorovsky [29, p. 72-74, p. 184], they can be applied to the processing of wide-band signals, which can be considered as a narrow-band process, since the frequency band occupied by them is also small compared to the its carrier frequency.

continuation method" is presented, based on the decomposition of the transmission coefficient of a circuit of detuning degrees, to study the passage of frequency-modulated oscillations through linear systems. I.S. Gonorovskiy also pays his attention to the development of the method of slowly varying amplitudes. The academician Yu.B. Kobzyrev noted that in the work of I.S. Gonorovsky "an original interpretation of the method of slowly varying amplitudes is being developed, which is distinguished by harmony and completeness" [40, p.3-4].

The development of the application of the operational method in selective circuits was reflected in the work of M.I. Kontorovich [41]. The work considers the application of the operational method for the analysis of transient processes on the examples of an oscillatory circuit and two coupled RL circuits with a single step action and a radio jump.

The work of E. Weber [42] is devoted to the same questions, in which the method of analysis of transient processes by means of operational calculus is presented for similar problems.

In the periodical literature of that period (50-60 years of the XX century), considerable attention was paid to the passage of video pulses of various shapes through the RL and RLC circuits. In the work of E.I. Baranchuk [43] considered the passage of rectangular pulses through an RL-circuit, and in the works of R.A. Voronov [44] and I.G. Jakaba [45] examined the effect of a sawtooth voltage on an RLC circuit. In the works of S.I. Kurenkova [46], I.S. Gonorovsky [47] considered the effect of a sequence of sinusoidal pulses on an RLC circuit. This issue is most fully described in the book by I.G. Atabekov [48].

The development of the spectral method for the analysis of transient processes is devoted to the works of G.V. Dobrovolsky [49], K. Cherry [50], A.M. Zaezdny [51]. In papers [49,50] the spectral method was applied together with the method of orthogonal components, which was developed by G. Nyquist and K. Peleger [52] in relation to signals with single-sideband modulation, and later this method was described in the monograph by G. Cartianu [53].

In his monograph G.V. Dobrovolsky [49] proposed a method for analyzing transient processes in linear systems using the secondary parameters of a quadrupole (attenuation and phase shift). The drawback of the method presented in [49] is that the amplitude-frequency and phase-frequency responses of the communication channel are approximated by a piecewise-linear method, which doesn't allow its use for phase systems [54]. In [49], the author investigated the influence of the shape of the amplitude-frequency and phase-frequency responses of communication channels, and distortions (transient processes) caused by them that most often encountered in practice caused when DC and AC pulses are utilized. The author also considered the distortions caused by asymmetric limitation of the spectrum of the transmitted radio signal and the interaction of amplitude-shift keyed signals passing through the communication channel.

In monograph [54] by K. Cherry, a broad discussion of asymmetric sideband channels and their transient process acting in them is presented using examples of single-tone amplitude-modulated oscillation and signal with pulse amplitude modulation. Also in [54], a method for analyzing transient processes based on reflection phenomena in circuits using the frequency response of the steady state is presented. The method can be applied both to circuits with lumped and distributed constants. Taken not in a basic sense, the phenomenon of electrical reflection for transient process analysis is a means of estimation of signal distortion caused by transient process from the appearance of frequency response. The disadvantages of this method, according to the author's remarks, can be attributed to the fact that the method provides the more accurate results, the better the condition of linearity of the phase characteristic is satisfied.

Exact and approximate methods of harmonic synthesis as applied to the problems of radio engineering are presented in the work of A.M. Zaezdny [51]. In [51], these methods were applied to one of the problems of radio engineering - to the analysis of transient processes in linear systems and were demonstrated by a significant number of examples, which included both aperiodic and oscillatory systems. As signals, we selected sequences of video pulses of various shapes with a duty cycle, radio pulses with a rectangular envelope with a duty cycle, modulated either in amplitude, or in phase, or in frequency. Besides A.M. Zaezdny developed the method of S.I. Evtyanov [27], which consisted in reducing the NBLS to two aperiodic systems.

A peculiar approximate method for analyzing transient processes in linear circuits, based on operator calculus, is presented in the work of A. D. Artym [55]. The method was demonstrated by the example of transient processes caused by the supply of a δ-pulse to determine the impulse response and when a radio stepwise jump is applied to the input of a filter of two symmetrically detuned oscillatory circuits in the absence of a frequency detuning. As a result, relations were obtained that describe the behavior of the envelope and slowly changing phase. However, the application of this method for generalized analysis of transient processes is difficult.

One of the fundamental works on the application of operational calculus using Laplace transforms to the theory of transient processes in linear systems is the monograph by A.S. Rosenfeld and B.I. Yakhinson [56]. The paper presents a rigorous theory of the application of Laplace transforms to the problems of analysis of transient processes in linear systems for various purposes with lumped parameters. The authors of this work presented a rigorous method of applying generalized functions and Laplace transform with an extended lower limit to the problems of analyzing transient processes in selective systems, when the initial conditions that determine the stored energy in their elements are nonzero. Also, the technique was applied to study linear circuits in the mode of multiple switching caused both by the peculiarities of changing the parameters of consumers and directly by the energy sources supplying the circuit, as well as by changes in the structure of the circuit itself. In addition, the monography considers the features of the application of Laplace transform to the analysis of transient processes in circuits with sources of discrete influences.

A contribution to the study of transient processes in linear systems was also made by scientists using methods other than operator, spectral and classical. The method of moments considered by N. Akhiezer and M. Kerin [57], I.G. Mamonkin [58]. In 1948, the method of moments was used by W. Elmore [60] to analyze the parameters of transient processes in multi-stage broadband amplifiers. Later, the method of moments was developed in the works of L.A. Meerovich and G.P. Tartakovsky [61,62]. In the works of S.Ya. Shchats [63] and B.N. Fayzulaeva [64] applied, although from different positions, but close approximate methods of analysis of transient processes. A number of methods for analyzing transient processes in linear systems are described in the works of G.K. Gavrilov [65] and O.B. Lurie [66].

Each of the above methods, according to Ya.S. Itskhoki [67] (except for the method of moments, which is, in principle, universal), is intended for solving problems of a certain narrow type. So, for example, the approximate method is applicable to the analysis of processes containing one sharply distinguished "slow" and a number of "fast" components of the process. On the contrary, the method of “reference functions” [65] is effective when the roots of the characteristic equation of the system are close. However, all of the above methods are used to analyze only monotonic changing processes. Although, in the work of L.A. Meerovich [62] showed that when a non-monotonic process is represented by a sum of exponential functions, it is possible to extend the application of the method of moments. However, according to [67], this method is practically inapplicable for the analysis of essentially oscillatory processes. Significant methodological difficulties in the analysis of oscillatory processes arise when using the method described in [66].

The elimination of these shortcomings in the above approximate methods for studying transient processes was carried out in the work of Ya.S. Itskhoki [67], in which the author proposed a method developed by him for estimation the transient response of a linear selective system. However, the use of this method for the analysis of transient processes under the influence of pulsed radio signals in the NBLS was not provided.

One of the methods of complex representation of real radio signals, which is often used in theoretical studies and provides an unambiguous relationship between the amplitude, phase and frequency of a radio signal, is an analytical signal (AS) [54]. As applied to the study of transient processes, this approach was implemented in the form of methods in the works of I.D. Zolotarev [68,69] and I. S Gonorovsky [29].

So in the works of I.D. Zolotarev [68,69] presents a method for analyzing transient processes using the method of simplifying the inverse Laplace transform without assumptions (the method of fast inverse Laplace transform (FILT)), built on the basis of the AS [68, p.8-10; 69, pp. 146-148]. This method was applied by the author to the solution of the following problems:

– to the analysis of transient processes caused by the passage of single radio pulses with different forms of envelopes through a single-stage and *n*-stage resonant amplifier and a selective amplifier on two symmetrically detuned circuits;

– to the analysis of transie t processes caused by switching the amplitude, phase, frequency of the radio signal in the presence and absence of frequency detuning for an *n*-stage resonant amplifier and a filter on two detuned circuits.

Subsequently, the results of these works [68,69] were included in the monograph [54] by I.D Zolotorev and Ya.E. Miller that was published in 2010. The paper [54] presents a method for analyzing the transient process in the selective paths of the radio engineering system, using the method of fast inverse Laplace transform and the method of orthogonal components. This method was applied to analyze the passage of single radio pulses with different envelope shapes through selective systems and to the analysis of transient processes caused by the passage of binary phase-shift keyed signals and frequency-shift keyed signals.

In the paper of I.S Gonorovsky [29], a method is considered that uses AS for the analysis of transient processes in selective linear circuits using spectral and temporal approaches. The application of the method is considered by the example of the passage of a radio pulse with a rectangular envelope through a single oscillatory circuit with a frequency detuning. Also, in the paper for BPSK and FSK signals with a rectangular envelope, transient processes at the output of a tuned single oscillatory circuit (SOC) are considered.

However, in the I.D. Zolotarev and Ya.E. Miller monography [54] was shown that the use of AS has a number of drawbacks. So in the work [54] were "considered the reasons leading to the incorrect determination of the APF (APF - amplitude phase frequency, note. from the author) through the AS, for the first time considered the defect of finding the APF through the AS for an arbitrary type of modulation of the investigated radio signal" [54, p.131]. “In this regard, first of all, it is necessary to abandon the AS and build a new model of the CS (CS is a complex signal, note from the author), which allows to correctly solve the problem. In this case, the adequacy of the found envelopes and the phase of the radio signal to their physical content should be ensured” [54, p. 136].

In conclusion, the above methods for analyzing transient processes in linear circuits are possible, with the exception of specific ones according to the works of M.F. Gardner and J. Burns [35], M.I. Kontorovich [41], I.I. Teumina [36], E. Weber [42], S.G. Ginzburg [37] can be divided into the following categories:

– he classical method, which has been considered in a significant number of papers;

– the method of operational calculus is considered in the works of A.I. Lurie [40], V.A. Ditkin and A.P. Prudnikov [70], M.I. Kontorovich [41], G. Dech [71];

– he Fourier integral method (spectral method) is considered in the works of C. Cherry [50], L.A. Meerovich and L.G. Zelinchenko [72], A.M. Zaezdny [51].

-the method of slowly varying amplitudes is considered in the works of L.I. Mandelstam and N.D. Papaleksi [24], D.V. Ageeva and Yu.B. Kobzareva [25], A.N. Shchukin [26], S.I. Evtyanova [27], I.S. Gonorovsky [39], S.I. Baskakov [28].

According to the comparative analysis carried out in the works of M. F. Gardner and J. Burns [35], , M.I. Kontorovich [41], L.A. Meerovich and L.G. Zelinchenko [72], G. Dech [71], we can give the following assessment to the above methods.

The classical transient analysis method is applicable to relatively simple circuits. Its use is reduced to solving differential equations and determining the integration constants, while the complexity of their determination increases with an increase in the order of the differential equation describing the system, making in some cases the volume of necessary mathematical transformations too large and cumbersome, not allowing to obtain the final results.

The spectral method, although it provides the simplicity of the solution when obtaining the result of the analysis of the transient process, however, its significant drawback is that the form of the obtained solution in some cases is inconvenient, since it has the form of an infinite sum of spectral components. It turns out that the summation analytically is either very difficult or does not lead to known functions.

The operator method is initially the best approach for analyzing transient process as it provides a rational approach to solving differential equations. Its great advantage is the ability in most cases to bypass the difficulties associated with the integration process encountered when using the spectral method.

However, it should be noted, that the use of operational calculus methods for solving specific problems on transient processes in radio engineering systems usually either does not allow immediately obtaining the desired solutions due to the complexity of the initial equations, or the solutions obtained are of little use for technical calculation. This is confirmed by the opinion of Ya.S. Itskhoki, stated in [67, p.5]: "when analyzing transient processes in complex linear circuits, one has to find solutions to high-order differential equations. Regardless of the difficulties in obtaining such a solution, the cumbersome result of rigorous analysis is poorly visible and inconvenient for technical calculations. " The above is especially true for oscillatory circuits or linear selective bandpass systems.

Thus, based on the above, we can conclude that the only method that satisfies the criteria set out in the previous section is the method of slowly varying amplitudes of C.I. Evtyanov [27] and its developing. Additionally, the correctness of this choice is confirmed by:

1) the high accuracy of the approach developed on its basis [30], for the analysis of the transient process at the output of the NBLS, caused by a jump in the phase and amplitude of a harmonic oscillation (elements of PSK-*n*- and APSK-*N*-signals), including and in the presence of a frequency detuning [36]. In this case, the approach obtained, among other things, allows one to formulate the general properties of transient processes for the NBLS.

2) the development of S.I. Evtyanov of this method within the framework of his scientific school for polynomial filters [73], generalized in the form of the "method of truncated operator equations" [74].

3) a gorous justification in the works of I.S. Gonorovsky [39], A.M. Zaezdny [51] the possibility of applying the method of slowly varying amplitudes to the analysis of transient processes in linear selective systems caused by an stepwise change in informative parameters such as amplitude, phase, frequency of harmonic oscillations and justification of the unambiguity of determining the parameters of the complex amplitude that determines the results of the transient process at the output linear selective system.

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К ВОПРОСУ О ВЫБОРЕ МЕТОДА АНАЛИЗА ПЕРЕХОДНЫХ ПРОЦЕССОВ ДЛЯ РАЗВИТИЯ ТЕОРИИ ВРЕМЕННОГО РАЗРЕШЕНИЯ. РЕТРОСПЕКТИВНЫЙ АНАЛИТИЧЕСКИЙ ОБЗОР

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Аннотация

В настоящее в связи с постоянным ростом объема передаваемой информации все большее внимание уделяется вопросам возможности повышения скорости передачи за счёт использования режима передачи "выше скорости Найквиста". Согласно теории разрешающего времени, которая достаточно быстро развивается в последнее время, требуется производить анализ переходных процессов в линейных избирательных системах (ЛИС). В этом случае ЛИС позволяют реализовать в модели канала частотно селективные свойства реальных каналов связи. При этом вопрос выбора метода анализа переходного процесса стоит достаточно остро, так как он прежде всего определяет сложность оценки пропускной способности. В данной работе представлен ретроспективный аналитический обзор по развитию методов анализа переходных процессов в линейных избирательных системах. На его основе выбран наиболее простой и удобный метод анализа переходных процессов применительно для фазовых радиотехнических систем передачи информации.

Ключевые слова: *ретроспективный аналитический обзор, МСИ, разрешающее время разрешения, переходные процессы.*

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