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SCIENTIFIC AND PRACTICAL IMPLEMENTATION OF METHODS FOR IMPROVING THE QUALITY OF COMPUTER-INTEGRATED INFORMATION SYSTEMS

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The practical realization of potential opportunities of computer-integrated information systems (CIIS) that are currently considerably higher than their real approachable technical characteristics is one of the main tasks of modern theory and practice of information systems. The following are some specific technical suggestions and methods for the physical implementation of a scientifically based adaptive nonlinear distortion compensation (ACNLD) algorithm. The insertion of artificial main and supportive entrances into the scheme of non-linear adaptive compensators allowed using the general theory of adaptive systems for their synthesis. The practical usage of synthesized following such a principle ACNLD according to the created recommendations allows to significantly increase the indices of quality of CIIS in the real conditions of their functioning, comparing with the already known ones. An additional advantage of proposed adaptive method of expansion of linear dynamic diapason (LDD) is an improvement of all-weather of CIIS and increasing of probability of identification of radio local maps of locality captured in different weather conditions without any additional changeovers. Except for this, a flexible reserve for the noise immunity of CIIS is being fulfilled that allows taking into consideration the possible improvements of means of radio electronic struggle. Synthesized ACNLD are considerably free from many drawbacks of linear determined means of expansion of dynamic diapason of radio receiving devices (RRD) and also they have simpler apparatus realization. Except, in a process of projection of ACNLD a considerably less volume of a priori information about the parameters of LDD is needed for the calculation of already known schemes of depression of non-linear distortions. The transferring functions of adaptive filters of ACNLD are quite quickly gather at the non-linear transferring function of radio device (RD) provided that an effective convergence can be seen only with the presence of the inner noises at least unless they exceed the non-linear distortions by the level.

Introduction

The possibilities of practical implementation of potential characteristics of computer-integrated information systems (CIIS) are significantly limited by a number of internal (instability of the parameters of the systems themselves, limited dynamic range of receiving devices) and external factors (non-stationary in time conditions for radio signal propagation, interference at the CIIS input).

A significant factor that substantially affects the quality of CIIS functioning in terms of both active and passive electronic countermeasures is the the limited dynamic range of trransmitting devices (TD) due to the nonlinearity of their amplitude characteristics (AC).

Nonlinear processes in real TDs are little studied and are one of the most difficult to use. In this regard, one of the most important current tasks aimed at improving the quality indicators of CIIS is the expansion of the dynamic range of their TD. Nonlinearity of AC real radio-electronic devices is the main obstacle to the practical creation of invariant automatic control systems (ACS).

There are known methods for extending the linear dynamic range TD based on nonlinear matching of the dynamic range of input effects with a relatively narrow dynamic range of output signals, so their application is accompanied by irreversible loss of information, a decrease in the range of CIIS and significant amplitude and phase nonlinear distortions. This leads to a substantial decline in the quality of information and telecommunication systems (y some cases, their accuracy is much lower accuracy CIIS TD linear due to the nonlinearity AC), a significant degradation of noise immunity.

Optimal, in principle, known linear methods of expanding the dynamic range belong to strict (that is, permanently enabled) protection measures, since deterministic filters with a priori defined and constant y-time parameters are used. In this regard, these methods are very sensitive to unavoidable debugging errors, hardware implementation, and temporary non-stationary parameters of real devices. As a result, the known linear methods have insufficient accuracy in suppressing nonlinear distortions and function satisfactorily only in a relatively narrow dynamic range of input effects, outside of which they are ineffective and can introduce additional distortions.

Until now, studies have usually been conducted under the conditions of introducing fairly serious assumptions about simplification and have not sufficiently taken into account the specific features of the passage of a mixture of radio signals and interference of complex multi-stage TD.

Therefore, it is very relevant at present to develop adaptive ways to extend the linear dynamic range of CIIS, which would be free from the above-mentioned disadvantages of known deterministic linear methods. At the same time, from a practical point of view, the most appropriate and promising is the synthesis of adaptive schemes for compensation of nonlinear distortions. This is due to the fact that these schemes are the simplest, have the highest potential accuracy characteristics and do not reduce the reliability of CIIS, since failure of the compensating filter does not lead to TD failure, in contrast to the known adaptive interference compensators y linear TD, which in this context are only conditionally called linear.

1. Synthesis of an adaptive algorithm for compensation of nonlinear distortions in radio devices of computer-integrated information systems (CIIS)

Known linear adaptive compensators are characterized by the presence of the main and reference inputs, which receive a mixture of the useful signal and interference, respectively [1]. In this case, the interference in the reference input is correlated only with the interference signal from the main input and is statistically related (or less correlated) with the useful signal. To be able to directly use the mathematical apparatus of adaptive systems theory [1] and to formalize the problem of adaptive compensation of nonlinear distortions, we will conditionally represent the output i input of a one-dimensional RD as the main and reference inputs of a nonlinear adaptive compensator, respectively. These inputs will be referred to as adaptive compensators of non-linear distortions (ACNLD) [1]. Then the General block diagram of a one-dimensional ACNLD (fig. 1) is equivalent to a classical linear adaptive compensator [2].

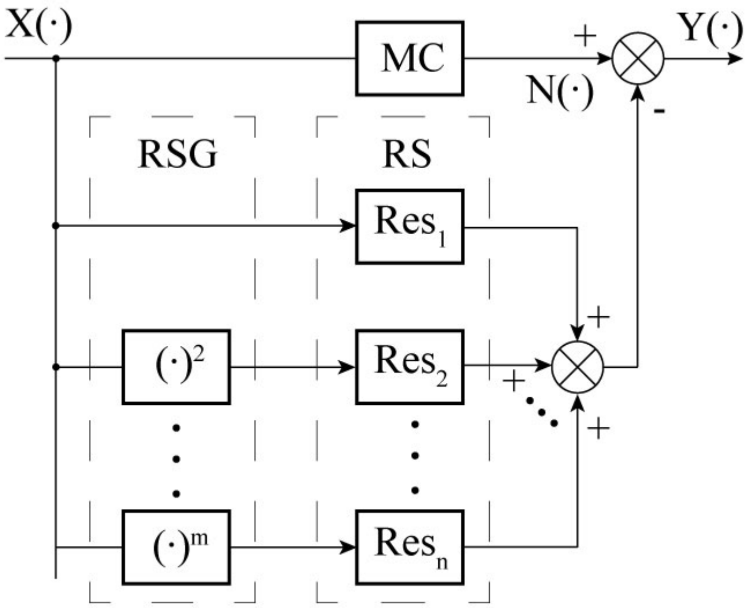

Fig. 1. General block diagram of a one-dimensional ACNLD: MC-main chanel; SG-reference signal generator; RS-reference schema; Res-receiver of the signal

Indeed, the input signal X is only statistically related to the output signal Y and is not correlated with the internal noise N of the given RD.

It is obvious that the ACNLD structure is completely uniquely determined by the method of describing nonlinear processes RD [2, 3] and the algorithm for solving the problem of adaptive compensation of nonlinear distortions [4].

The output signal of a one-dimensional nonlinear RD as truncated by the first m members of the Volterra series according to [5, 6] can be represented as

$$Y(f_1,..., f_m) = Y_c(f_1,..., f_m) + N(f) = \sum_{k=1}^{m} H_k(f_1,..., f_k)\prod_{i=1}^{k} X(f_i) + N(f). \quad (1)$$

Then, according to the modified CMC method [7], it follows from the method of "nonlinear input signals" that for one-dimensional RD, the General reference input ACNLD is separated into the reference signal generators at m reference inputs, each of which is affected by a separate reference signal of the form [7]

$$X_k = X_k(f_1,..., f_k) \doteq \prod_{j=1}^{k} X(f_j), \text{ k=1, 2, … m.} \quad (2)$$

It can be shown that the reference signal X(·) is quite strongly correlated only with the k-th order component of the output signal RD, that is $Y_k(f_1,..., f_m) = H_k(f_1,..., f_k)\prod_{i=1}^{k} X(f_i)$, and it is significantly interconnected, in a statistical sense, with other components of the output signal Y(·) (k≠j) [8]. Therefore, at the ACNLD input, the signal component of the output signal Y (·) is completely suppressed (up to the error of truncation of the Volterra cores by the first m members), while the internal noise N (·) passes without changes [9].

It should be noted that the requirement for complete statistical independence of signals is too strict and unjustified [10]. Adaptive compensators work well enough under the condition of strong correlated signals in the main i reference inputs.

If the useful response is an n-th order component of the output signal, then removing the adaptive filter from the ACNLD, which is affected by the reference signal Xn (·), at the output of the ACNLD, in addition to the internal noise RD N (·), we will also have the signal Yn (·) [11]. Physically, this means the suppression (compensation) of nonlinear distortions of y-RD [12]. The ACNLD structure can be significantly simplified if all adaptive filters are removed, except for the one that receives the reference signal X_l (·), where *l* is the order of the most dangerous nonlinear distortions for this RD [9].

The optimal solution to the adaptive compensation problem is usually physically impossible to implement, since it involves instantaneous measurements and time averaging of a significant number of autocorrelation coefficients of input effects, their mutual correlation with error signals (reference signals), as well as high-order matrix inversions, which is very difficult [11].

In this regard, the scientific and practical interest is the definition of a quasi-optimal solution, which, together with comparable simplicity, is implemented physically, has a fast convergence y time to the optimal solution [1, 12]. For this purpose, we present the output signal of an adaptive device, which is a fundamentally nonlinear system with non-stationary parameters in time [13], as truncated by the first m members of the Volterra parametric series [6, 15]

$$\sum_{k=1}^{m} W_k(f_1,..., f_k)\prod_{j=1}^{k} X(f_j) \doteq \sum_{k=1}^{m} W_k(t)X_k, \tag{3}$$

where Wk(·) is a k-order parametric NTF (transfer function of the k-th adaptive filter).

The output of the ACNLD generates an error signal ε(·), which, assuming the relative smallness of noise N(·), is equal to [1]

$$\varepsilon(t, f_1, f_2,...) \doteq \varepsilon(t) = Y - \sum_{k=1}^{m} W_k(t)X_k \cong Y_c - \sum_{k=1}^{m} W_k(t)X_k. \tag{4}$$

In the process of regulating the transfer function of the k-th (k=1,2,...,m) active filter in the complex differential form of the record has the form [1, 12, 15]

$$\frac{dW_k(t, f_1, f_2,..., f_k)}{dt} \doteq \frac{dW_k(t)}{dt} = 2e_k \mu\varepsilon(t)X_k^{\otimes}, \tag{5}$$

where μ is a positive constant (the transmission coefficient of the OS chain), which determines the stability and speed of ACNLD rearrangement; εk – the proportionality coefficient, numerically equal to one; the sign ⊗ - denotes a complex conjugate value.

Generalizing the algorithm obtained above to the case of a multidimensional ACNLD, we can state that its structure and the structure of the reference signal generator are uniquely determined by the method of nonlinear input signals.

Similarly we can find a discrete version of the quasi optimal mean square method of ACNLD construction error [1, 12,15].

$$W_k(j+1, z_1,..., z_k) = W_k(j, z_1,..., z_k) + 2e_k \mu\varepsilon(t)X_k^{\otimes}, \tag{6}$$

where j – discrete time; z_i (i=1,2,...) – arguments for a multidimensional z-transform.

Taking into account the advantages of analog ACNLD, which allow suppressing nonlinear distortion directly in TD y real-time, and not in the process of further processing [16], it is advisable to focus on analog ACNLD.

Let's define the error of ACNLD compensation in the following form

$$V_k(t, f_1,..., f_k) \doteq V_k(t) = H_k(t, f_1,..., f_k) - W_k(t, f_1,..., f_k). \quad (7)$$

Repeating the arguments similar to those given in [95] and omitting the intermediate calculations, it is not difficult to see that $\lim_{t\to\infty} V_k(t) = 0, \quad \forall k \in [1,...,m]$. In turn, this means that $\lim_{t\to\infty} W_k(t, f_1,..., f_k) = H_k(f_1,..., f_k), \quad \forall k \in [1,...,m]$.

Consequently, the transfer functions of adaptive ACNLD filters converge in time to NTF RD. It is found that effective convergence is observed as long as the internal noise of the ACNLD does not exceed in magnitude the nonlinear distortions that are compensated.

Synthesized ACNLD can be used to improve the quality characteristics of a wide class of CIIS I ACS, in particular, to improve the spectral characteristics of radio transmitting devices, frequency multipliers i synthesizers, to increase the stability of AC TD I repeaters for various purposes, and to optimize ACS by non-linearity criteria [17]. In addition, it is advisable to develop ACNLD-based adaptive measuring devices of a fundamentally new type designed for direct measurements of nonlinear distortions, as well as identification in the broad and narrow sense of nonlinear dynamic systems [17].

As a result of the conducted synthesis, the principal confirmation of the possibility of adaptive solution of the problem of y RD distortion compensation was obtained [1, 12]. In order to develop a scientifically based design methodology for ACNLD it is necessary to conduct a study of their qualitative characteristics.

2. Method for evaluating the dynamic characteristics and accuracy of ACNLD taking into account internal noise and imperfect parameters of elements of computer-integrated information systems (CIIS)

Dynamic properties of adaptive compensators are usually characterized by a constant time of adaptation (adjustment) of adaptive filters τ [18]. Usually, the realignment occurs exponentially, and the ACNLD adaptation time is determined by the following expression

$$\tau_{ACNLD} = \frac{k_\tau m}{4\mu P_n}, \tag{8}$$

where P_n is a nonlinear distortion compensation power; k_τ – coefficient of proportionality.

The accuracy of adaptation is limited by errors in the gradient estimation ω_1, as well as compensation errors due to delayed adjustment of adaptive filters ω_2 [19]. For ACNLD the specified errors are defined as follows [18]:

$$\omega_1 = k_{\omega_1} \mu P_n, \qquad \omega_2 = \frac{1}{\mu} \frac{k_{\omega 2} \sigma_n^2}{4\sigma_{\min}}, \tag{9}$$

where σ_n, σ_{min} – accordingly, the standard error of nonlinear distortions and the minimum standard error of adaptation; $k_{\omega 1}$, $k_{\omega 2}$ – coefficients of proportionality.

The necessary speed and accuracy of ACNLD adaptation can be provided by an appropriate choice of the transmission coefficient μ of the feedback circuit [12, 17, 18]. However, expressions (9) impose contradictory requirements for the value μ. Therefore, the highest quality of adaptation can be provided by choosing the optimal value μ, which is found by equating the right parts of expressions (9) and is determined by the formula

$$\mu_{opt} = \sqrt{\frac{k_{\omega 2} \sigma_н^2}{4 k_{\omega 1} \sigma_{\min} P_н}}. \tag{10}$$

The real achievable values of the adaptation time constant τ ACNLD are usually in the range of ones and tens of NS to ones of ISS. Therefore the main focus of the ACNLD development process should be on ensuring that the specified ACNLD accuracy requirements are met [12].

For ACNLD, the integration error in the k-th channel leads to a compensation error defined as [12, 18]:

$$\lim_{t \to \infty} W_k(t) = H_k + \Delta H_k, \tag{11}$$

where ΔH_k is an error proportional to the error of integration.

In the process of studying the effectiveness of adaptive compensators, the influence of only the external non-correlated influence of a non-ideal optimal adaptive filter is usually taken into account [20]. However, all real radio elements are "noisy" [11], which makes it relevant to analyze the influence of internal ACNLD noise on its efficiency.

The efficiency of linear adaptive compensators, provided that their inputs are affected by external uncorrelated signals [2, 43, 95] can be written as follows

$$\Theta = \frac{\left[\nu_{mainin} + 1\right]\left[\nu_{refin} + 1\right]}{\nu_{mainin} + \nu_{mainin}\nu_{refin} + \nu_{refin}}. \tag{12}$$

Expression (12) allows us to evaluate the impact of internal ACNLD noise on its efficiency, this allows us to make an important practical conclusion that internal ACNLD noise does not lead to a decrease in the quality of functioning of RD [21].

In cases where the internal noise of the ACNLD exceeds the level of non-linear distortion is suppressed, the value Θ=1, which is physically equivalent to the automatic shutdown of the ACNLD and, accordingly, the autonomous mode of RD.

The unavoidable nonlinear properties of real elements have a significant impact on the quality characteristics of adaptive compensators [11]. This is particularly important for ACNLDS that are directly designed to suppress nonlinear y RD distortions.

Given the insufficient degree of study of these issues in the known literature, it is necessary to analyze the influence of non-linearity of AX real ACNLD elements on the qualitative characteristics [22]. Imagine the output signals of real devices reduced to the k-th power, the feedback circuit amplifier i multipliers adaptive filters y as Volterra series [6]

$$(x_k)^+ = \beta_1 x + \beta_2 x^2 + \ldots + \beta_k x^k + \ldots, \tag{13}$$

$$(\mu\varepsilon)^+ = \mu_1 \varepsilon + \mu_2 \varepsilon^2 + \ldots, \tag{14}$$

$$(Z_k)^+ = a_{10}(x_k)^+ + a_{10}(\mu\varepsilon)^+ + a_{20}\left[(x_k)^+\right]^2 + a_{11}(x_k)^+(\mu\varepsilon)^+ + a_{02}\left[(\mu\varepsilon)^+\right]^2 + \ldots \tag{15}$$

$$(Z_k)^+ = b_{10}\left[\frac{1}{S}(y_1)^+\right] + b_{01}(x_k)^+ + b_{20}\left[\frac{1}{S}(y_1)^+\right]^2 + b_{11}\left[\frac{1}{S}(y_1)^+\right](x_k)^+ + b_{02}\left[(x_k)^+\right]^2 + \ldots \tag{16}$$

where $(x_k)^+, (\mu\varepsilon)^+, (y_1)^+, (y_2)^+, (Z_k)^+$ – the output signals of real devices of raising to the k-y degree, the feedback circuit amplifier, the first multiplier of the K-th adaptive filter, the second multiplier of the k-th adaptive filter (k-th adaptive filter), respectively; $\beta_i, \mu_j, a_{ij}, b_{ij}$ – NTF of the specified ACNLD elements respectively.

As follows (14), the non-linearity of the AX amplifier of the ZZ circuit leads to a restriction of the upper limit of the dynamic range for the output ACNLD ε_{max} [6, 23]. The acceptable level of non-linear distortion y amplifiers circle ZZ can be determined from the specified upper level of the dynamic range behind the output ACNLD $\varepsilon_{max\ spec}$, for narrow-band and wide-band amplifier, respectively, we have

$$|\mu_3| \le \frac{1}{|\varepsilon_{\max spec}|^2}, \quad \left. \begin{aligned} |\mu_2| &\le \frac{1}{k_\mu |\varepsilon_{\max spec}|} \\ |\mu_3| &\le \frac{1}{(1-k_\mu)|\varepsilon_{\max spec}|^2} \end{aligned} \right\}, \tag{17}$$

where k_μ – the coefficient that determines the ratio between the permissible levels of nonlinear distortion of the second and third orders ($0 \le k_\mu \le 1$) and depends on the bandwidth of the amplifier circuit ZZ.

Nonlinear properties of the reduction in k-th degree lead to distortion of the output signal of the k-th adaptive filter [12]. It follows from formula (13) that

$$(W_k(t))^+ = W_k(t) + \Delta W_k(t) \cong W_k(t) + \sum_{\substack{i=1 \\ i \ne k}}^{\infty} [\beta_i W_k(t)], \tag{18}$$

where $[\beta_i W_k(\cdot)]$ – has a meaningful sense of a t-order NTF and defines the dynamic range limit of the ACNLD on its input.

Component $\beta_j W_k(\cdot)$ causes distortion of the output signal of the j-th (neighboring) channel ACNLD; component $\beta n W k(\cdot)$ leads to the distortion of the useful component of the output signal RD, the components of βiWk(·) (i≠k, k+2,n,j) increases internal noisy of ACNLD [24].

To estimate the distortion of the signal component of the output signal RD, we determine the signal-to-noise ratio in the reference input $\rho_{ref\,in}$ of the ACNLD as follows

$$\rho_{refin} = \left| \frac{\sum_{\substack{l=1 \\ l\neq n}}^{m} \beta_{l_n} W_l(t) X_l}{\sum_{\substack{l=1 \\ l\neq n}}^{m} \beta_{l_l} W_l(t) X_l} \right|, \tag{19}$$

Then the signal-to-noise ratio at the output is equal [1]

$$\rho_{out} = \frac{1}{\rho_{refin}}. \tag{20}$$

Accordingly, the distortion of the signal component of the RD output signal at the ACNLD output can be defined as

$$\varepsilon = \frac{\rho_{refin}}{\rho_{mainin}}, \tag{21}$$

where ρ_{mainin} – the signal-to-noise ratio at the RD output, which is determined, in this case, according to such a formula

$$\rho_{mainin} = \left| \frac{H_n X_n}{\sum_{\substack{k=1 \\ k\neq n}}^{m} H_k X_k} \right|. \tag{22}$$

The signaling component in the ACNLD reference input also causes changes in the spectrum of nonlinear creatures that are compensated, and [1]

$$\{S_Y\}_{out} = \{S_Y\}_{mainin}\, \rho_{mainin} \rho_{refin}, \tag{23}$$

where $\{S_Y\}_{out}, \{S_Y\}_{mainin}$ – the range of nonlinear creators that are compensated at the output of ACNLD and at the output of RD, respectively.

Requirements for the level of nonlinear derivatives of the n-th order can be determined from the maximum allowable value $\rho_{refinal}$, as at [1]

$$\left|\beta_n\right| \le \rho_{refinal} . \tag{24}$$

The results obtained above can be used not only for ACNLD, but also for the analysis of qualitative characteristics of a wide class of adaptive and self-adjusting systems, taking into account internal noise and nonlinear properties of their elements [25].

In order to expand the linear dynamic range of the CIIS, we use the results of the study of the characteristics of accuracy characteristics and dynamic characteristics. Let the linear dynamic range RD be equal to

$$D_1 = D_{1in} = 20\lg\left|\frac{X'_{max}}{X'_{min}}\right| \cong D_{1out} = 20\lg\left|\frac{Y'_{max}}{Y'_{min}}\right| , \tag{25}$$

where $\left|X'_{min}\right|, \left|Y'_{min}\right| \left(\left|X'_{max}\right|, \left|Y'_{max}\right|\right)$ – lower (upper) limit of the dynamic range RD to the input and output, respectively.

Suppose that it is necessary to extend the dynamic range RD to the value D> D_1, where

$$D = D_{in} = 20\lg\left|\frac{X_{max}}{X'_{min}}\right| \cong D_{out} = 20\lg\left|\frac{Y_{max}}{Y'_{min}}\right| , \qquad \left|\frac{X_{max}}{X'_{min}}\right| \cong \left|\frac{Y_{max}}{Y'_{min}}\right| > 1 . \tag{26}$$

ACNLD design should start with the choice of simulator (subtraction device), the dynamic range of which D_Σ should be not less than D, that is

$$D_\Sigma \ge D \text{, at } \left|\varepsilon_{\Sigma\ min}\right| \le \left|Y'_{min}\right| ; \left|\varepsilon_{\Sigma\ max}\right| \ge \left|Y_{max}\right| . \tag{27}$$

where $\left|\varepsilon_{\Sigma\ min}\right| \left(\left|\varepsilon_{\Sigma\ max}\right|\right)$ – lower (upper) limit of the simulator range (subtraction device).

Define the requirements for the accuracy of Δint integration. Since nonlinear distortions of the k-th order are practically and expediently suppressed only to the nonlinear distortions of higher (in the first place (k +2)-th) orders [4], for CIIS cascades [18]

$$\Delta_{\text{int }1} \le \Delta H_{3\,spec} \le \left|H_5\right| , \tag{28}$$

and for coherent detectors and frequency converters

$$\Delta_{int\,2} \le \Delta H_{31\,spec} \le |H_{51}|. \tag{29}$$

In a number of cases the optimum value $u_{opt} \equiv \mu_{1opt}$ lies in the range from 0,1 to 10, and for cascades $\mu_{1opt} \le 1$, and for final and convertible cascades $\mu_{1opt} \ge 1$ [18].

The required dynamic range ACNLD D_2 can be determined from the following inequality [12]

$$D_2 \ge D - D_1. \tag{30}$$

This leads to an important practical conclusion that to construct ACNLD relative to the problem of extending the linear dynamic range of CIIS, you do not need silent elements with ideal parameters and those that are not physically possible to implement.

However, the final and reliable conclusion about the practical implementation and performance of ACNLD, as well as their real qualitative characteristics and capabilities can be made on the basis of experimental confirmation of the main results of theoretical analysis of the accuracy characteristics and dynamic characteristics of nonlinear adaptive compensators. In this regard, it is necessary to conduct experimental tests of the ACNLD.

3. Experimental study of the ACNLD model (CIIS)

This experiment should be carried out on the example of expanding the linear dynamic range of a narrow-band amplifier, since RD of this type make the main contribution to nonlinear distortion in CIIS [25]. Given that the dynamic range of narrowband amplifiers is limited mainly by third-order nonlinear distortions [18], the choice of the specified RD allows simplifying the ACNLD structure (when $l=3$) and obtaining experimental results that will have a clear physical interpretation and concrete practical significance.

Having took into consideration the mentioned more precise definitions, a development of ACNLD of the third row were carried out. A coefficient of transferring of the narrow-band magnifier that was constructed on the basis of the micro scheme TL071 is equal to 10 (on the central frequency of the passing strip – 100 kHz) [26, 27]. Multipliers were built on the integral micro schemes MC1496 [26, 27]. The necessity of using of auto compensation of the constant component constructed on the basis of an integral micro scheme LM118, is conditioned by the presence in the outgoing signal of the micro scheme MC1496 a considerable (up to 5 V) constant component that can break the normal work of the next cascades [26, 27]. Besides, for the improvement of conditions of coordination of cascades to the exit of micro schemes LM118 connected emitting repeaters that are constructed on the transistors NTE101 [26, 27]. A magnifier of the circle of reverse connection ACNLD, integrator and counter (a device of subtraction) are built with the help of micro schemes LM118 of emitted repeaters collected on the basis of transistors NTE101 [26, 27].

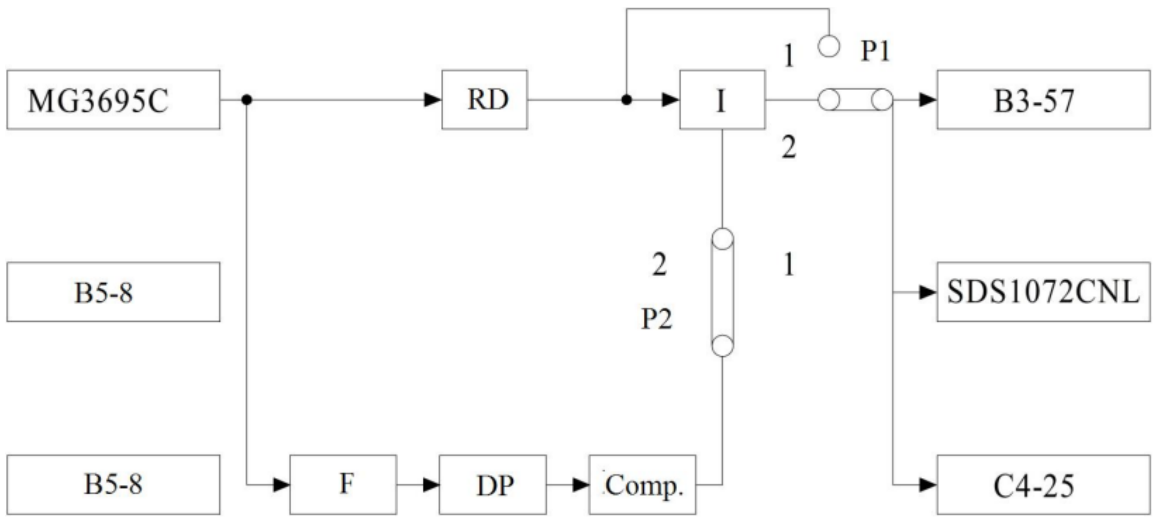

Fig. 2. Functional scheme of experimental installation

Taking into consideration given the need to measure the dynamic range of the narrowband amplifier, it is advisable to use the standard methodic to experimentally determine the dynamic range of electronic amplifiers with a decrease in sensitivity [10]. This methodic is based on measuring the amplitude characteristics of the amplifier. At the same time, the upper limit of its dynamic diapason is considered to be the value of the input (output) signal, which corresponds to the point of the graph of the amplitude characteristic of the amplifier, which defines on the axis of the ordinate from the ideal linear input-output dependence at a distance that corresponds to the sensitivity of the measuring RD [26, 27].

For the metrological support of this measurement methodic, it is necessary to use an input signals' generator and an output voltage meter, in the process of measurement it is also recommended to control the shape of the output signal and its spectral characteristics [2, 11].

According to this, a set of measuring instruments with the technical characteristics of developed ACNLD model is needed to carry out this experiment. A set must include: the high-frequency signal generator MG3695C; micro voltmeter B3-57; oscilloscope SDS1072CNL and spectrum analyzer C4-25. Following that the MC1496 and LM118 micro schemes require a constant voltage of ±9 V and for TL071 micro schemes ±9 V it is advisable to use two power sources B5-8.

Based on the above clarifications, an experimental installation was developed, the functional scheme of which is presented in fig. 1 [3, 27]. During the checking the performance of the ACNLD model, the switch P1 was set to position 2, and the switch P2 was moved from position 1 to position 2 and back. To provide a visual representation of the effect of inhibition of nonlinear distortions using ACNLD, as RD, at this stage of the program's implementation of the experiment, a transistor frequency multiplier on 3, constructed on transistors NTE101, was used. In this case, the frequency of the input monochromatic signal was 100 kHz, and its amplitude was 0.5 V. The spectrographs of the signal at the output of the subtracting device when (P2-2) is disconnected and (P2-1) connected to the ACNLD taken from the screen of the spectrum analyzer C4-25. Here, the first harmonic of the output signal of the frequency multiplier for the convenience of observation is combined with the beginning of the reference. The obtained experimental results can be physically interpreted as the suppression of large nonlinear distortions on the background of a weak useful signal without distorting it. Following this, the first, second, fourth, fifth, etc. harmonics of the output signal of the frequency multiplier can be considered as a useful signal [27]. The comparison of spectrographs also confirms the theoretical conclusions that the potential accuracy of inhibition of nonlinear distortions of the third order is limited by nonlinear distortions of higher (first of all - fifth) orders.

To study the effect of the internal noise of the ACNLD model on the quality of its operation, the switches P1 and P2 were locked in position 2. As the RP, a narrowband amplifier was used [26, 27]. It should be noted that the output voltage of the generator MG3695C was set at the level of sensitivity of the narrowband amplifier (~ 1 μV) at a frequency of 100 kHz. In order to increase the accuracy and reliability of the results at this stage of the program implementation of the experiment a low-noise adder, constructed on the TL071 micro scheme was used as a subtraction device. This adder has a level of internal noise ≈ (0.6-0.8) μV in the frequency band (2.0-2.5) kHz, which is more than 20 dB lower than the amplitude of the minimum output signal of the amplifier equal to (8-10) μV in the same band of frequencies relative to the central frequency of 100 kHz [26, 27]. With the help of microvoltmeter B3-57, the signal voltage was measured at the output of the ACNLD model. It was about 10 μV.

Then the switch P1 was transferred from position 2 to position 1, the 2nd position of the switch P2. Having convinced by the indicators of the device B3-57 that the internal noise of the subtraction device did not practically affect the output of the narrowband amplifier, the switch P1 was locked into position 2, and the switch P2 moved from the 2nd position to the 1st. In this case, the voltage of the output signal, controlled by the microvoltmeter B3-57, did not change and was 10 μV.

Results of measurements of AC of the narrowband amplifier, performed according to the standard method of experimental determination of the dynamic range of the amplifier to reduce their sensitivity [28, 29], are presented in fig. 3

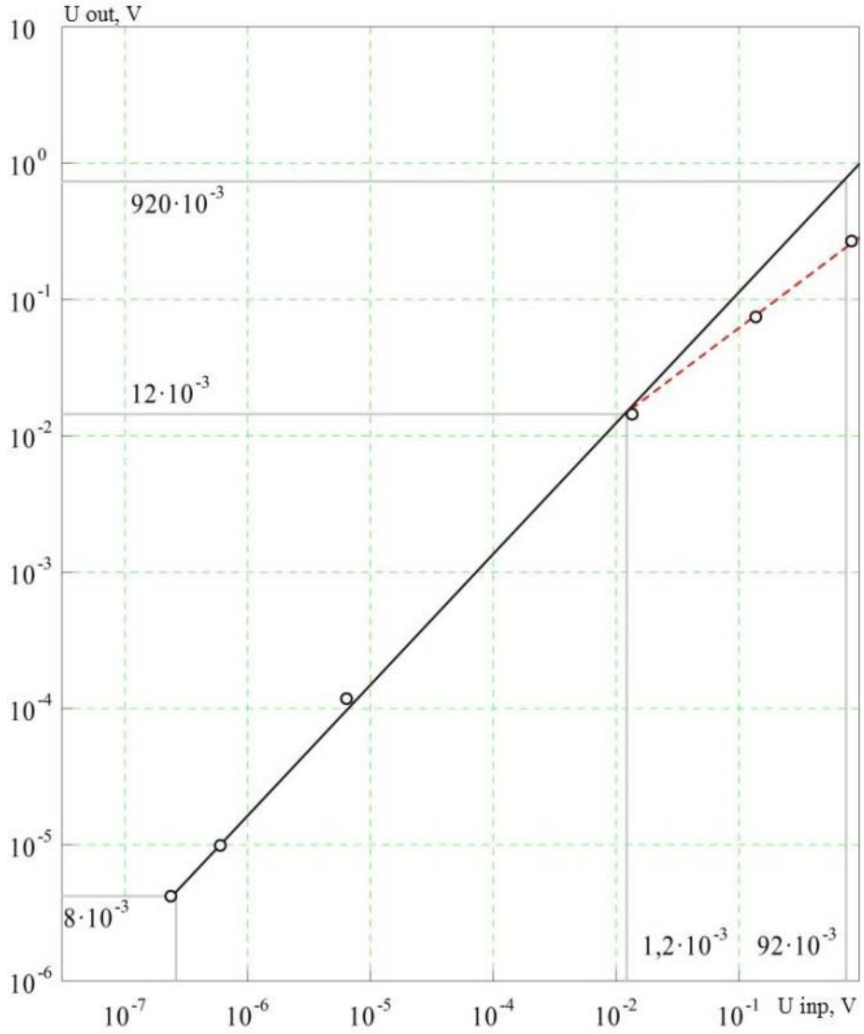

Fig. 3. Measured AC of the narrow-band RD with the compensator of obstacles with the 3rd order: solid line – AC of the narrow-band RD with the compensator; dotted line – AC of the narrow-band RD with the unplugged compensator; (measured meanings are marked with the circles)

To measure the dynamic range of the narrowband amplifier, the switch P1 was set to the 1st position. In this case, the width of the linear dynamic range of this narrowband amplifier was 63.5 dB.

In the process of measuring the dynamic range of the ACNLD layout, the switch P1 was transferred to the 2nd position with the 1st position of the switch P2. In this case, the width of the linear dynamic range of the ACNLD layout was 100.75 dB.

The incomplete gain (the theoretically expected result is 60-67 dB) is explained by the irrational use of the dynamic range of the ACNLD itself (first of all, its multiplier MC1496, whose dynamic range in some cases reaches 70 dB). Indeed, the necessary level of internal noise ACNLD should be 1-1. 2 mV theoretically justified, and in reality it has the order of 40 mV. Therefore, the upper limit of the acnld dynamic range was insufficient, which led to incomplete practical implementation of the potential features of the developed ACNLD layout.

The most important conclusions of the theoretical analysis of the characteristics of accuracy and dynamic characteristics of ACNLD and the main principles were experimentally confirmed. This is a proof of correctness of theoretical researches of qualitative characteristics of ACNLD of computer-integrated information systems.

Conclusions

1. The introduction of the main and reference inputs into the nonlinear adaptive compensator circuit allowed to use a general system for their synthesis. Practical use of synthesized according to this principle of ACNLD and in accordance with the developed recommendations, allows to significantly increase the quality indicators.

2. The application of the proposed practical recommendations does not lead to a decrease in the reliability of CIIS, both in hardware (failure of the ACNLD does not entail a failure of the TD), and in the functional sense (ACNLD are automatically disabled in cases when their application does not improve the signal-to-noise ratio at TD).

3. An additional advantage of the proposed method is improvement of the all-weather CIIS and increasing the probability of identifying radar maps of the area taken under various conditions without additional changeover. At the same time, a flexible margin for CIIS noise immunity is provided, which allows taking into account possible improvements in electronic countermeasures for the expected period of CIIS operation.

4. Synthesized ACNLDS are largely free from many of the disadvantages of linear deterministic ways to extend the dynamic range of TD, and also have a simpler aperture implementation. The ACNLD design process requires significantly less a priori information about TD parameters to calculate nonlinear distortion suppression schemes.

5. The quality characteristics of ACNLD are uniquely determined by the level of internal noise and by the degree of non-ideal parameters of real ACNLD elements. Since the internal noise of the ACNLD does not lead to an additional deterioration in the quality of the TD, compared to its autonomous operation, the maximum achievable dynamic range of the ACNLD is equal to the sum of the dynamic ranges of the RD and of the ACNLD itself.

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