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THE USE OF TEST SIGNAL FOR MINIMIZATION OF PULSE AND WIDE BAND AMPLIFIERS MULTIPLICATION ERROR

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Abstract - Pulse amplifiers are widely used in radio engineering. The first requirement to these amplifiers is to provide minimal distortion of rectangular pulse shape. The second is provision minimal multiplica0tion error, which is important for measurements. The standard method, grounded on the usage of negative feedback, may be used for wide band periodical signals and unacceptable for amplification pulse signals due to a signal delete in the forward and backward branches. It is proposed to use for this problem solution, borrowed from cybernetic engineering, the adaptive method with small test signal for calibration. The paper illustrates the mechanism of acting, dynamic and static analysis, based on proposed the Method of Linearization by the Describing Functions.

Keywords - pulse amplifier, adaptive systems, multiplication error.

1. INTRODUCTION

Broad band amplifiers are widely used in many applications of radio engineering, automatic control, communication, measurement and instrumentation. Homogeneous, uniform amplitude-frequency locus we obtain by the usage: small collector's resistance as a load of stages, overall and internal negative feedback, low frequency compensation and high frequency picking.

The first way permits to minimize negative influence of small bypassed montage capacitance and inductance, but cause reducing of a stage gain. No more than three stages may be comprised by the overall negative feedback from the standpoint of system's stability. An internal negative feedback by current or voltage or both are effective, but cause reducing of stage's gain. The low frequency compensation and high frequency picking improve a homogeneous amplitude-frequency locus in small area of frequency band, because the low frequency variation of capacitive and inductive impedance's are differ. It is not necessary to oppose these three methods ; moreover, their combine usage gives the best result. It is difficult sometime to provide high frequency bandwidth with high gain, high accuracy and low gain drift or, on the other words, homogeneous and stable configuration of an amplitude-frequency locus for a high power gain.

Unfortunately it is impossible to use the negative feedback for extension a frequency band, linearization of transmit function and minimization a multiplicative error in the case of pulse signals. If a pulse has a sharp rise edge the forward and backward branch inertia cause delete of a normal response and, therefore, during the rise time an input signal without compensation cause a saturation of a first stage. Homogeneous, uniform amplitude-frequency curve we obtain by the usage a small resistance of collector as a load of stages and galvanic coupling between them. This way permits to minimize negative influence of small bypassed montage capacitance and inductance, but cause reducing of a stage gain. Only small local negative feedback may be used for linearization of transmit function.

It is proposed to use for calibration a small test (pilot) sine form signal with input signal. The test signal causes an additive error. If this error unacceptable, we may reduce it by subtraction of a test signal from output, or interrupt the process of pulses transmission on a short time for calibration. To avoid the information losses two channels structural block diagram may be used. We consider stability analysis for the test signal loop only, because a network for pulses transmission is open-loop. As a closed loop system for test signal is described by non-linear differential equations, it may be used proposed the Generalized Method of Linearization by the Describing Function. It is necessary to take into account that variations of an input signal's amplitude are small and we may consider an amplitude of input test signal as a constant. Static analysis may be carried out as for systems with variable parameters.

2. MECHANISM OF ACTION, CONVERCION OF BLOCK DIAGRAM

Let's consider adaptive broad band pass amplifier with frequency selection of measuring and test signals. An angular frequency of a test signal may be beyond a frequency band and within this band.

If the frequency of a test signal is many times beyond the highest frequency of frequency range, the interval between these frequencies is non-operative. This is the drawback of the method with the frequency selection. Figuratively say, we hold an amplitude-frequency locus by the tail. In the area of high frequency we have a slope of an amplitude-frequency locus, caused by linkage distributed inductance's and capacitance's, which instability cause an error, if we use the calibration by help of the test signal. We must, therefore, provide a homogeneous amplitude-frequency locus, or, what is more difficult, to realize, stability of an amplitude-frequency locus configuration. This type of adaptive amplifiers may be used for amplification periodical signals with wide frequency band.

The second way is grounded on the usage of a broad pass amplifier for transmission in order an input and calibrating signals: in all odds time intervals the forward branch, that consists of a broad band pass amplifier with a controlled element, conducts an input signal. In all evens time intervals the forward branch conducts a calibrating signal. Input automatically controlled switch of the backward branch permits to compare a sine voltage generator signal with output calibrating signal of the forward branch. Amplitude of envelope of an automatically controlled switch of a backward branch is proportional to the error. The drawback of the second way is information losses during the time of calibration.

2.1 *Broad Band Pass Adaptive Amplifiers with Frequency Selection of a Measuring and Test Signals.*

A block diagram of a broad band pass adaptive amplifier with the frequency selection is shown in Fig. 1.

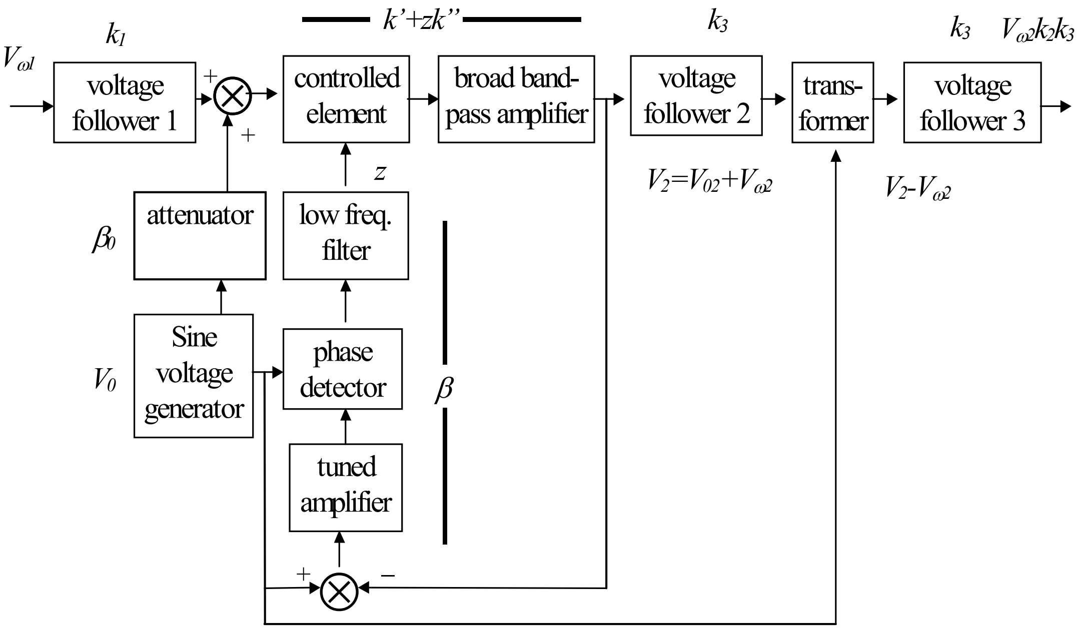

Fig. 1. Broad band pass adaptive amplifier with the frequency selection

A block diagram consists of the forward branch and the backward branch. The forward branch consists of an adder, a controlled element, a broad band pass amplifier. Three voltage followers (unit gain buffers) are used for sequence of impedance's of stages: output and input. Unite gain buffers and a transformer (as subtractor) are used for amplification of a pulse signals very seldom. The backward branch consists of a subtractor as a comparator, a tuned amplifier that is tuned on a sine voltage generator's frequency, a phase detector, which is controlled by this generator, a low frequency filter. The attenuation factor of attenuator equals to the forward branch gain in initial conditions. If the forward branch gain is normal, an output signal of a tuned amplifier equals to zero. Otherwise, an output signal is proportional to a multiplication error, and is used after the backward branch's conversion for restoration the forward branch gain. We shall consider static equations with respect to a calibrating generator's voltage V_0, taking into account that input signal is stopped by a tuned amplifier.

$$V_{02}=(k'+zk'')V_0\beta_0 \qquad (1)$$

$$V_z=(V_0-V_{02})\beta. \qquad (2)$$

From the last equation we obtain

$$V_{02}=V_0\beta_0k' + V_0\beta_0k''\,\beta(V_0-V_{02}), \qquad (3)$$

or

$$V_{02}=V_0\beta_0(k'+V_0\beta k'')-\beta\,\beta_0V_0V_{02}k'', \qquad (4)$$

and finally we obtain the static equation

$$V_{02}=\frac{k'+k''\beta V_0}{1+k'\beta\beta_0V_0}V_0\beta_0. \qquad (5)$$

The forward branch gain equals to

$$k=V_{02}/V_0\beta_0=\frac{k'+k''\beta V_0}{1+k'\beta\beta_0V_0}, \qquad (6)$$

a measuring output signal and a static error equal to

$$V_{\omega 2}=V_{\omega 1}k_1k_2k_3k, \qquad (7)$$

$$\gamma=\frac{\Delta k_1}{k_1}+\frac{\Delta k_2}{k_2}+\frac{\Delta k_3}{k_3}+\frac{\frac{\Delta k}{k}}{1+k''\beta\beta_0V_0}. \qquad (8)$$

If β→∞, the last term→0, and accuracy is determined by errors of voltage followers only (if they present).

Practically, a sine voltage generator's frequency must be higher than highest frequency of an operating frequency band minimum in 3÷5 times.

Technical data of made broad band pass amplifier, that was used in high accuracy Hall-effect gauss-meter for measurement alternating magnetic induction and magnetic field strength, are the following:

amplification factor	100000
operating frequency band	20Hz÷100mHz
multiplication error	0.05%
frequency of calibrating generator	30 mHz

branch conducts, for example, an input signal in all odds time intervals, and a calibrating signal in all evens time intervals. An automatically controlled switch in the backward branch conducts an output signal of the forward branch in all evens time intervals of a calibrating generator's frequency. In all odds time intervals the backward branch conducts an output signal of a sine voltage generator. We have an information loss during the time of calibration: all odds time intervals of commutation.

A frequency of a switching generator signal must be less in 3÷5 times than lowest frequency of a frequency range of the forward branch. It is possible to minimize the information losses for pulse signal amplification by reducing time of calibration: time of calibration may by in thousands times less than time of a pulse signal's conducting. The second way lays

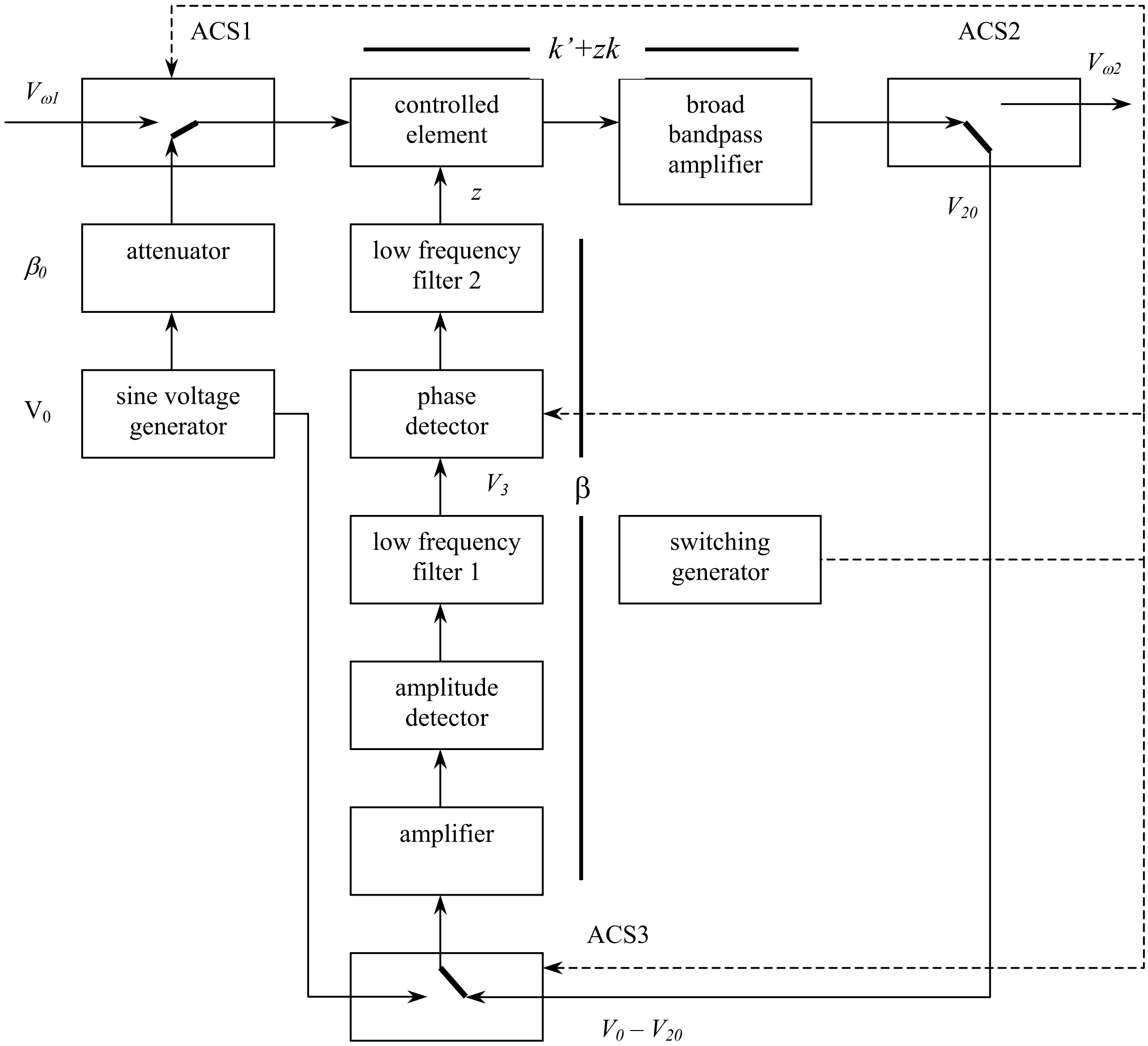

Fig. 2 Block diagram of a broad band pass amplifier with the time selection

2.2. Broad Band Pass Adaptive Amplifier with Time Selection.

A block diagram of a broad band pass amplifier with the time selection is shown in Fig. 2. The forward branch consists of two automatically controlled switches, which in term conduct input and calibrating signals. The forward

in the usage of two channels structural block diagram: we have two similar forward branches and two similar backward branches. The forward branch and the first backward branch we use for transmission input and calibrating signals respectively in evens time intervals. The second forward branch and the second backward branch in these time intervals

respectively are used for transmission of a calibrating and a pulse signal. In all odds time intervals vice verse: channels are changed. Superposition of two channels' output signals permit to expel an information losses.
The drawback is an electronic network elements surplus. The second drawback is in error, caused by commutation. Broad band pass amplifiers are characterized by the same static equation and multiplication error

$$k=\frac{k'+k''\beta V_0}{1+k'\beta\beta_0 V_0}\,, \qquad (9)$$

$$\gamma=\frac{\dfrac{\Delta k_1}{k_1}}{1+k''\beta\beta_0 V_0}\,. \qquad (10)$$

An operating frequency band of a broad band amplifier with the time selection is in 3÷5 times higher than in the case of the frequency selection. We have the limitation in the area of low frequency, because of a switching frequency must correspond to an operating frequency.

3. THE GENERALIZED METHOD OF LINEARIZATION BY THE DESCRIBING FUNCTION FOR DYNAMIC ANALYSIS

Dynamics analysis of a close loop system in the both cases it is reasonable to carry out by the Generalized Method of Linearization by the Describing Function [1]. Consideration signals' envelopes permit to avoid the problem with commutation of voltages. No reason to use proportional + integral modification, because of an amplitude of a test signal vary within small limits.

Application of the Generalized Method of Linearization by the Describing Function GMLDF is grounded on the following assumptions.

1. We consider envelopes of signals instead real signals in a close loop system

$$A(t)\sin(\omega t+\varphi)\leftrightarrow A(t) \qquad (11)$$

This assumption permits to regard such essentially non-linear elements as amplitude and phase detectors or rectifier, as linear units. Moreover, that fact permits to reduce in two times the order of resonance network's differential equation by the usage the concept of shorten transfer function.A Controlled Element CE with variable parameters and a transfer function $y=(k'+zk'')x$ we substitute by cascade connected an adder ADD and non-linear element NE (Fig.3.), that may be, for example, described by the 2nd power polynomial:

$$y=k(x+z+a)^2\approx 2kax+2kzx,\ \text{if}\ k'=2ka,\ k''=2k \qquad (12)$$

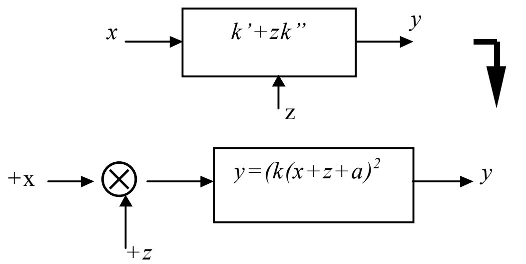

Fig. 3. Controlled element conversion

3. An automatically controlled switch we substitute by an ordinary subtractor (Fig. 4).

The usage of the Generalized Method of Linearization by the Describing Function is based on approximation of differential equation of a closed-loop feedback control system's solution

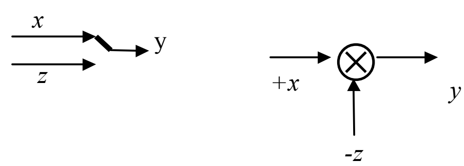

Fig. 4. Conversion of subtractors

by a Fourier series, which we eliminate by first two terms. The

first term is Direct Component that corresponds to the steady state: $s=0,\ f_0\neq 0$. DC $y_0(f_0)$ and fundamental harmonic **x** amplitude of non-linear element with known configuration of the function $F(x)$ we determine by formulas, that are similar to formulas for determination of the 1st and 2d terms of a Fourier series.

An adaptive BBP amplifier's block diagram after transformation Fig.1 has the following configuration (Fig. 5). An attenuator we move backward and it appears twice: in the forward branch after the adder with the same transfer function β_0 and also before the adder with the inverse transfer function $1/\beta_0$. We combine β_0 with a non-inertial element $F(x)$. Taking in account 2d assumption and combining two adders, we obtain the following block diagram Fig. 5.

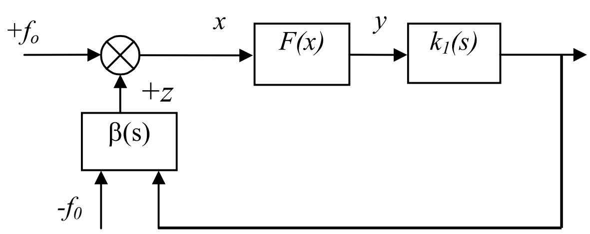

Fig. 5. Simplified block diagram

An input signal equals to $y=A_m \sin\omega t$. Suppose, that a non-linear element's transfer function is not symmetrical with respect to the origin of coordinate
$y=F(x)$, or, for example, may be approximated by the function

$$y-b=(x+a)^2k, \quad (13)$$

and an input signal $x\neq0$. Signals in a close-loop system have Direct Components DC. We confine on consideration DC and 1st harmonic component only. Output components of a non-linear element equal:

$$y_0=\frac{1}{2\pi}\int_0^{2\pi}F(x_0+A\sin\psi\sin =kx_0^2+ka^2+2kax_0+\frac{kA^2}{2}+b, \quad (14)$$

$$q=\frac{1}{\pi A}\int_0^{2\pi}F(x_0+A\sin\psi\sin\psi)d\psi=2k(x+a)\,. \quad (15)$$

In the following formulas bold designation indicates operations with respect to envelopes. For all signals we have

$$\mathbf{x}=\mathbf{x}_o+\mathbf{A}_m\sin\omega\mathbf{t}, \quad (16)$$
$$\mathbf{y}=\mathbf{y}_o+\mathbf{y}^*, \quad (17)$$
$$\mathbf{z}=\mathbf{z}_o+\mathbf{z}^*. \quad (18)$$

We obtain 2 groups of equations:

with respect to Direct Component;

with respect to 1st harmonic.

With respect to direct component: we take into account that $s=0,\ \mathbf{A}_m\sin\omega t=0,$ (19)
and obtain following variables:

$$\mathbf{f}_o,\ \mathbf{x}_o,\ \mathbf{y}_o,\ \mathbf{z}_o,\ \beta(s)=\beta,\ \mathbf{k}(s)=\mathbf{k}. \quad (20)$$
$$\mathbf{y}_o=\mathbf{F}(\mathbf{x}_o), \quad (21)$$
$$\mathbf{z}_o=[\mathbf{f}_o-\mathbf{k}_1\mathbf{y}_o]\ \beta, \quad (22)$$
$$\mathbf{x}_o=\mathbf{f}_o+\mathbf{z}_o, \quad (23)$$

hence, in result of algebraic equations solution:

$$\mathbf{x}_0=\varphi(\mathbf{f}_0) \quad (24)$$

Equations with respect to the 1st harmonic may be represented in the following form

$$\mathbf{x}=\mathbf{x}^*,\ \mathbf{y}=\mathbf{y}^*,\ \mathbf{z}=\mathbf{z}^*,\ \mathbf{y}^*=\mathbf{q}^*,\ \mathbf{k}(s),\ \beta(s) \quad (25)$$

$$\mathbf{1}+\mathbf{q}\mathbf{k}_1(s)\ \beta(s)=\mathbf{0}, \quad (26)$$

After substitution $\mathbf{x}_o$ from the 1st group of equations, we obtain

$$1+q(\mathbf{A},\mathbf{x}_0,\mathbf{f}_0)\mathbf{k}_1(s)\ \beta(s)=0 \quad (27)$$

Let us substitute s=jω. Last equation may be yield to

$$Re(\mathbf{A},\ \omega,\mathbf{f}_0)=-1, \quad (28)$$
$$Im(\mathbf{A},\ \omega,\mathbf{f}_0)=0,$$

and may be solved with respect to $\mathbf{A},\ \omega$.

If $\mathbf{A}>0$, and linear part doesn't satisfy to the Nyquist test, the system is non-stable, and may be observed stable oscillations.

If $\mathbf{A}<0$, and linear part satisfy to the Nyquist test, the system is stable,

$\mathbf{A}=0$ is a boundary of a field's stability.

If $\omega<0$, we have monotonous convergent process both for stable and usable transient.

If $\omega>0$, we have an oscillation within a transient. If $\omega=0$, be have a critical mode.

The results of this method application were compared with simulation of amplifier by the usage of the Electronic Workbench Programm that confirm a good accuracy.

CONCLUSIONS

The adaptive method permits essentially to reduce a multiplication error, caused by gain in time, gain with temperature instability for pulse amplifiers and broad band pass amplifiers for wide band frequency range. In contradistinction to the classical feedback, this method does not connected with reducing of a gain, provides minimal distortion and does not connected with change to worse a reliability of an amplifier: an amplifier can operate without a loop with test signal.

Stability of non-linear system with variable parameters may be searched by proposed The Generalized Method of Linearization by the Describing Function. This method, which is used for test signal loop, is grounded on assumptions that we consider stability with respect to envelops of signals, a control element is substituted by cascade connected adder and non-linear, non-inertial element, periodical comparison of signals is substituted by uninterrupted comparison.

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